THE BODY AS A SPATIAL SOUND GENERATING INSTRUMENT

Defining the Three Dimensional Data Interpreting Methodology

(3*D*IM)

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Abstract

This practice-led research contributes to the field of interactive dance and spatial sound performance. The document describes a research journey into ways that emphasize the sonic spatiality in dance choreography by creating a range of ChoreoSonic experiments and compositions that succeed from the spatial perspectives of both disciplines.

The project explores an active interrelationship between ambisonic surround sound design and contemporary improvised dance through the technological areas of wireless electronic tracking systems and computer programming. The research process incorporates discussions covering developments in interactive art performances including references from the field of spatial sound composition, dance, interactive technologies and computer mapping.

Alongside these theoretical investigations, an original Three Dimensional Data Interpreting Methodology (3*D*IM) is presented as an artistic spatial mapping strategy in order to achieve an aesthetic conceptualization within the domain of visual and auditory interactive performance. The different parameters of 3*D*IM are sorted into four main categories: raw movement input data from the tracking system, deduced (algorithmic) spatial movement parameters, sonic output and sonic spatiality. Each of these categories consists of the relevant spatial movement or sonic parameters and is accompanied by a graphic of the implementation in the 3*D*IM software.

The 3*D*IM has been designed in the visual programming environment Max/MSP/Jitter, and has been developed and tested in a range of practical interactive 'Sound Skeleton' research experiments and compositions. The resulting interactive ChoreoSonic performance environment enables dance movements in space to be transformed into real time 3D spatial sound composition.

The written thesis also includes video extracts of the 'Sound Skeleton' creations and documentation of the 3*D*IM Max/MSP/Jitter software, with accompanying manual and supporting text.

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Content

Abstract 1

Acknowledgements 2

Content 3

List of Figures 6

List of Tables 8

Chapter 1 Introduction 9

1.1 Background and Motivation 10

1.2 Artistic Viewpoint 12

1.3 Research Aims and Methodology 13

1.4 Research Questions and Aims 15

1.5 Structure of this Document 15

Chapter 2 Interactivity and Gesture Based Sonic Projects 21

2.1 Interactivity: 'Artistic Process' or a 'Tool Exhibition'? 22

2.1.1 Early Movement-Based Sound Projects as Live Interactive Process 24

2.2 Sonic Gesture Measurements 25

2.2.1 The Choice for a Controller Device in a Musical Context 26

2.2.2 Introduction to Mapping 28

2.2.3 Object Location in Space 30

2.2.4 Moving Body Part Tracking 31

2.2.5 Control versus Discontrol 33

2.3 Summary 'Interactivity and Gesture Based Sonic Projects' 34

Chapter 3 Interactive Movement-Based Projects 36

3.1 Data Measurement Methods for Body Motion 37

3.1.1 Full Body Motion and Location Tracking 37

3.1.1.1 Sensitive Dance Floors 38

3.1.1.2 Breaking Beams 40

3.1.1.3 Camera Tracking 42

3.1.2 Body Part Motion Capacity and Personal Space Tracking 47

3.1.2.1 Wired Up 47

3.1.2.2 Motion Capturing the Skeleton 49
3.1.2.3 Gesture Detection accessible for Artists 51
3.1.3 Summary 'Data Measurement Methods for Body Motion' 52
3.2 Choreography in Computer Code 52
3.2.1 Gesture Recognition...53
3.2.2 Motion Analysis Algorithms 54
3.2.3 Choreography as a Composition of Atomic Gestures....................57
3.2.4 Expressive Content 58
3.2.5 Gesture Recognition for Artistic Purposes 60
3.2.6 Summary 'Choreography in Computer Code' 63
3.3 Summary 'Interactive Movement-Based Projects' 64
Chapter 4 Context of the Spatial ChoreoSonic Environment 67
4.1 Music and Sound for Dance 67
4.1.1 Improvisation in Dance and Technology Performance..................69
4.1.2 How does a Dancer perceive the Technology? 70
4.1.2.1 Embodiment and Virtual Disembodiment 72
4.1.2.2 'TranSonic' Perception 75
4.1.3 Summary 'Music and Sound for Dance'.....................................76
4.2 Bodily Space 77
4.2.1 Human Movement in General Space..77
4.2.2 Spatial Bodily Perception of the Dancer 79
4.2.3 The Body in Geometric Space 82
4.2.4 Summary 'Bodily Space' 84
4.3 Auditory Space...85
4.3.1 Spatial Sound: A Moving Sonic Architecture? 86
4.3.2 Ambisonic Surround Sound 87
4.3.3 Spatial Perception of Ambisonic Sound 89
4.3.4 Summary 'Auditory Space'..90
4.4 Audiovisual Spatial Synchronicity, 'Sound as Disembodied Movement' and 'Dance as Embodied Sound' 91
4.4.1 Geometry in Spatial Audiovisual Division and Perception 91
4.4.2 Spatial Body-Sensor Pentagon 93

4.4.3 Geometry in a Cubical Form 95

4.4.4 Summary 'Audiovisual Spatial Synchronicity' 97

4.5 Summary 'Context of the Spatial ChoreoSonic Environment' 98

Chapter 5 Case Study 1: Preliminary Practical Research, 'Cricket' System Development 101

5.1 The Cricket System.. 101

5.1.1 Context of the Cricket System... 103

5.1.2 Technical Operation of the Cricket System 103

5.1.3 Technical Set Up ChoreoSonic Environment 105

5.1.4 Outcome Case Study I: 'Cricket' System Development.............. 106

5.2 System Errors: 'The Ghost of the Machine'.. 108

5.3 A Low Cost Indoor Positioning System (LCIPS) 109

5.4 Summary 'Case Study 1: Preliminary Practical Research'..................... 111

Chapter 6 Three Dimensional Data Interpreting Methodology 112

6.1 Raw Movement Input Data 114

6.1.1 Full Body Motion Data 114

6.1.2 Case Study 2 'Scanning the Space' 116

6.1.3 Kinespheric Movement Data.. 119

6.2 Deduced Spatial Movement Parameters.. 121

6.2.1 Proximity.. 121

6.2.2 Speed 122

6.2.3 Circular Movement, Rotation and 'Wave-ing' 123

6.2.4 Direction 124

6.3 Sonic Output.. 125

6.3.1 Additive Synthesizer 126

6.3.2 Samples and Effects 127

6.3.3 Case Study 3: Showing at the University of Chichester (U.C.), UK (12/01/2007)... 129

6.4 Sonic Spatiality 132

6.4.1 Volume & Panning 133

6.4.2 Frequency 134

6.4.3 Reverb 134

6.4.4 Delay 135
6.5 Interdependent Spatial ChoreoSonic Relationship 136
6.5.1 'Beep-Stop' Model 136
6.5.2 'S-E-N-S-I-O' Model 137
6.5.3 'Vector' Model' 138
6.6 Equipment used 139
6.7 Summary 'Three Dimensional Data Interpreting Methodology' 141
Chapter 7 Conclusions and Future Work 143
7.1 The Theoretical Research 143
7.2 The Preliminary Technical Research 146
7.3 The Final Artistic Outcome 146
7.4 Evaluation and Future Work 148
Appendices 151
1 Documentation 151
2 Publications 152
3 Presentations, Seminars and Workshops 153
4 3DIM Operation Manual 154
5 Software Copyright Clearance 167
Bibliography 168

List of Figures

Figure 1 Picture of Stelarc's robotic construction 'Muscle Machine' (CAD model by John Grimes, UK). 11
Figure 2 Trisha Brown 'Locus' (in Karpinska 2001). 82
Figure 3 The Division of Space through the Moving Body (Laban in Ullmann 1966:143). 91
Figure 4 Head-related System of Coordinates in Auditory Experiments (Blauert 1997a:14). 92
Figure 5 Compiled picture by the author of the Centre of Spatial Movement- and Sound Perception. 92
Figure 6 A flat Pentagonal Pose of the Body (Laban 1966:19). 93
Figure 7 Space Modules of the Arms and Legs I (Kirstein *et al.* 1953:2). 94
Figure 8 Dynamic sensors representation in Max/MSP software. 95
Figure 9 'Geometric Kinesphere' Laban (1966:140). 96

Figure 10 Two cameras viewing the same space intersect to form a box like area representing the common viewing field (Lovell & Mitchell 1995). . 102
Figure 11 Cricket Handheld 1 (2006)..104
Figure 12 Cricket Handheld 2 (2007). 104
Figure 13 Flexible grid of infrastructure of 5 Cricket beacons on the ceiling. 104
Figure 14 Ideal shape of directional flow of 5 Cricket sensors..................105
Figure 15 Two dimensional sensitive floor of 5 Cricket sensors (approximately). 105
Figure 16 The speaker system and Cricket receiver grid. 106
Figure 17 Diagram of the shape of the sensitive space (approximate). 107
Figure 18 Sensor pointing upwards to the ceiling.................................. 109
Figure 19 The four receiving LCIPS sensors attached in the corners of a square grid on the ceiling.. 110
Figure 20 The 5 sensors of the LCIPS.. 110
Figure 21 3*D*IM implementation chart no.1: the four broad parameter categories. 114
Figure 22 3*D*IM implementation chart no.2: raw positioning data of two (Cricket) sensor units. 115
Figure 23 Dancer C. Whitaker from Lila Dance Company with the Cricket handheld 2006. 116
Figure 24 diagram of composition strategy 'Scanning the Space'. 118
Figure 25 Dancer S. Spasic with 5 sensors of the LCIPS in a pentagonal structure. 119
Figure 26 3*D*IM implementation chart no. 3: raw kinespheric input data.... 121
Figure 27 3*D*IM implementation chart no. 4: deduced spatial movement parameters. 125
Figure 28 3*D*IM implementation chart no. 5: additive synthesizer parameters. 127
Figure 29 3*D*IM implementation chart no. 6: samples and effects. 128
Figure 30 The sensitive floor area marked with white tape. From left to right: S. Wijnans, C. Whitaker, G. Adams, S. Rubidge. 130
Figure 31 3*D*IM implementation chart no. 7: Showing at University Chichester. 132
Figure 32 To explain the effect of auditory spaciousness (Blauert 1997b:109). 133
Figure 33 3*D*IM implementation chart no. 8: sonic spatial structure parameters. 136

Figure 34 Technical Set Up 2006-2007. 140
Figure 35 Technical Set Up 2007-2009. 141

List of Tables

Table 1 Overview of the correlation between technology and artistic outcome. 65
Table 2 Mapping layer in the test case by Wanderley *et al.* (2000a). 129
Table 3 3*D*IM for two dancers and additive synthesizer. 129

Chapter 1 Introduction

Spatiality is an important feature in dance performance and choreographic composition, with accompanying sound often seen primarily as a 'time-rhythm' medium, leaving sonic space as an unobserved element of the event. However, experiments with the spatiality of sound have been undertaken by numerous instrumentalists and composers. Historical examples include musicians playing their instruments while walking around the concert hall, spatial positioning of the orchestra (such as Stockhausen's *'Gruppen'* 1955-57, Boulez's *'Répons'* 1981), and the spatial placement of loudspeakers (such as in Cage's *'Williams Mix' 1952,* Henry's *'L'Apocalypse de Jean' 1968,* and Stockhausen's *'Gesang der Jünglinge'* 1955-56). Therefore, the question arises: why has the spatial dimension of sound rarely been incorporated in sound compositions made for dance performance[1]?

This thesis is a research journey into ways to emphasize spatiality in an interactive dance and sound performance such that they succeed from both choreographic and sonic spatial perspectives. The resulting Three Dimensional Data Interpreting Methodology (3*D*IM[2]) developed for this project is presented as a subjective[3] mapping method to achieve an aesthetic conceptualization within the visual and auditory interactive performance domain. In Human Computer Interaction[4] (HCI) the term 'mapping' is used to describe the relationships between the derived input and output data (see Hunt & Kirk 2000a, Hunt *et al.* 2000b, Wanderley 2001, Mandoux & Wohlthat 2004). Computer programmers and electronic engineers continue to search for new

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[1] An exception of the use of the spatial dimension of sound in dance choreography was perhaps the collaboration between David Tudor (with John Cage) and choreographer Merce Cunningham in 'RainForest' (1968). In this choreography live sounds of small resonant objects were spatially mixed as part of the dance performance. Although this electronic sound piece has sometimes been recognized as an infamous spatial installation piece (see: http://www.emf.org/tudor/Works/rainforest.html [accessed 10.06.08]), it is doubtful if the spatial application was really a conscious integration in the choreography of the piece considering the collaborative 'chance' concept of Cunningham and Cage. (From the 1950s onwards, Cage used the mechanism of the Chinese 'I Ching' book to determine a compositional structure based on chance and random numbers).

[2] The italicisation of the character 'D' in 3*D*IM hints at a third dimension.

[3] The term 'subjective' is used here within the context of artistic intuition and sometimes refers to an output from a conscious artistic decision to use a coincidental error or a moment of creative inspiration.

[4] See: http://www.sigchi.org/ [accessed 29.07.08].

mathematical algorithms and solutions to make technical systems (sensors, interfaces, software etc.) more reliable. In this way they aim to improve the logic of the human-machine relationship. However, with some exceptions (Winkler 1995 & 1997, Camurri *et al.* 2004 & 2005, Rovan *et al.* 2001), to my knowledge only a few topical descriptions exist of applied subjective artistic methods and practice of mapping movement parameters to (spatialized) sound. This thesis presents 3*D*IM as an artistic mapping methodology that has been developed and tested during the practical PhD research sessions.

The practical research has been realized with the application of two wireless Radio Frequency (RF)/Ultrasonic (US) Indoor Positioning systems (see Ch.5) to shape the real time ambisonic surround sound environment in using the visual programming environment Max/MSP/Jitter[5]. The project coordinates the trajectory of the whole body through space and the movements of the individual body parts within the mapping strategy. In the thesis, artistic strategies for transcending the conventional perception of musical form in dance performance into a perception of the sonic environment as an interactive 'space-rhythm' dimension will be discussed. Both the individual and collective 'living architecture' (see p.81) of the dance performer(s) is being used as the starting point for a real-time generation of a spatio-temporal musical form. The ideal goal of the project would be to design an innovative method to compose spatial sound.

1.1 Background and Motivation

My collaboration as a sound artist and sensor system developer with robotics performance artist Stelarc in 2002-2003[6] has profoundly stimulated an interest in designing sound by means of real time triggering movements (Wijnans 2004). Stelarc's work 'explores and extends the concept of the body and its relationship with technology through human-machine interfaces incorporating medical imaging, prosthetics, robotics, VR systems and the Internet'[7]. During the Stelarc collaboration, a six legged moving robot 'Muscle Machine' (fig.1) was designed and constructed[8].

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[5] See: http://www.cycling74.com [accessed 06.05.08].
[6] See: http://ahds.ac.uk/performingarts/collections/sci-art/about.htm#wijan [accessed 29.07.08].
[7] From: http://www.stelarc.va.com.au/stelarc1.html [accessed 15.03.2007].
[8] See: http://www.stelarc.va.com.au/musclemachine/index.html [accessed 06.02.2007].

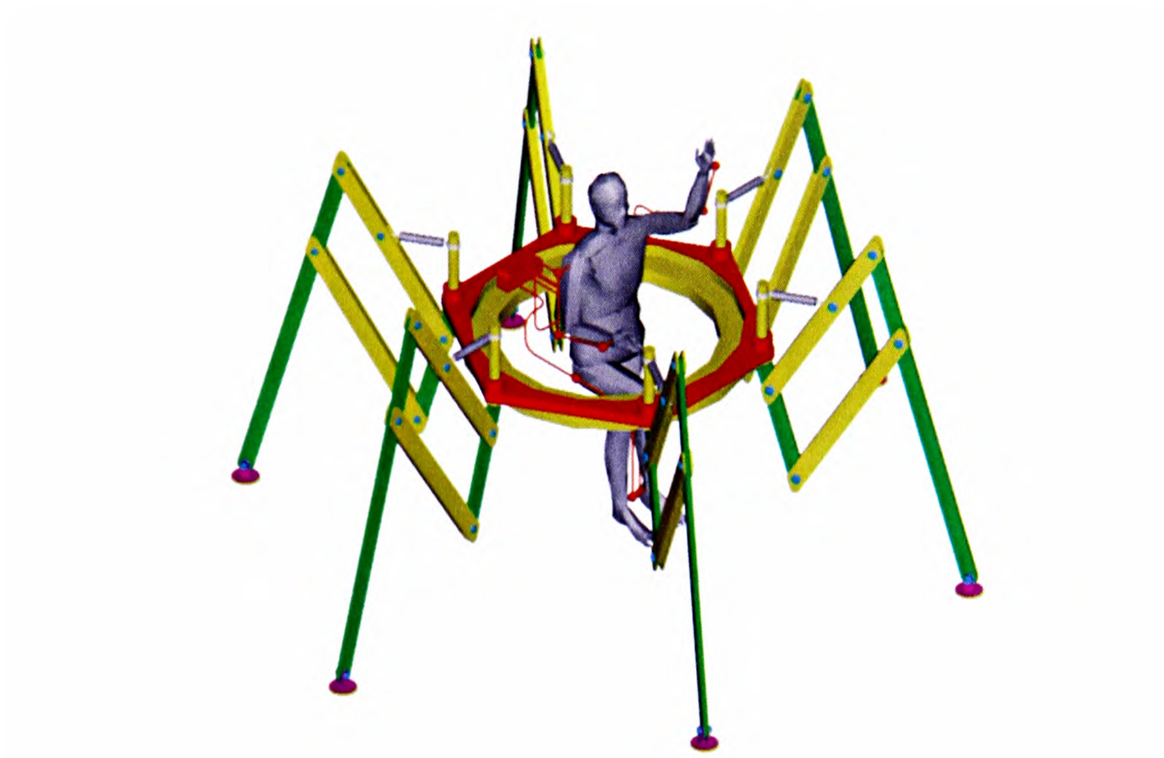

Figure 1 Picture of Stelarc's robotic construction 'Muscle Machine' (CAD model by John Grimes, UK).

The goal was that Stelarc's body, standing in the middle of this hybrid human-machine system, could actuate and direct the movements of the machine with his body movements. The robot's movements were measured by the attached sensor system[9] that communicated the data to a computer.

In general, a robot is able to make mainly mono-linear movements, i.e. moving the segments of a part of the machine construction in only one spatial direction at any one time. A human being is able to make poly-linear movements, i.e. moving several parts of a limb simultaneously in different spatial directions. In addition to this, movement theorist Rudolf Laban (1966:21) points out that 'movements of the body and its limbs do not generally make straight lines, but form curves'. Although technology and robotic design is still progressing rapidly, simulation of the typical human curvilinear motion of the joints with robotic machines has, to my knowledge, not yet been achieved[10]. This experience of working with robotic movements

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[9] The legs of the robot were equipped with pressure-sensors on the feet to receive an 'on/off' signal when the feet 'stepped' on the floor and four pairs of dual-axis micro-accelerometers to track the movement direction and acceleration of two pairs of three legs, and of the two arms. The system was developed in collaboration with V2lab, Rotterdam, NL. See: http://www.v2.nl/section/lab [accessed 09.12.08].

[10] It is another discussion (and beyond the scope of this thesis) whether a robot (like a computer) might have a mind of its own, but there is as yet no evidence of a machine moving with the complex kinematics of a human/animal.

renewed my profound interest in trying to turn the more versatile human movement elements into a real time abstract sound generator.

1.2 Artistic Viewpoint

This research explores the different spatial elements involved in choreography and sound composition and seeks methods to enable me to relate the performed dance movement to the spatial sonic environment. To emphasize the sonic spatiality of interactive movement performance two tracking systems are used in the research. One derives the spatial movement data from the trajectory of the whole body in space, the other also tracks movements of the individual body parts (see Ch. 5). Regarding the possible mapping relationships of a 'sonification of movement' through the interactive movement manipulation of computational systems, Pieter Verstraete remarks:

> A dancer is highly skilled and trained, so the sound designer has to empirically fine-tune the computer system to accurately 'read' the dance idioms and define which sound processing would fit the gestures in a specific situation. (Verstraete 2005:200)

Ben Jezekiel *et al.* (2001) remark that it has been 'established in kinematics that actual three-dimensional human movement can be quite complex, where different body parts move synchronously to achieve a certain intended [or artistic] movement'. On the other side of the mapping process, digital sound can be described as a multiplicity of different layers of flexible or stable sonic parameters (samples, synthesizer and/or instrumental) in a multidimensional environment predefined (primarily) by a sonic artist or composer. Eric Métois describes these sonic parametric layers when he refers to Max Matthew's first generation of his computer synthesis program 'MUSIC'[11]:

> The diversity of sound synthesis techniques allowed a set of parametric descriptions for subsets of this sonic world. Each synthesis algorithm can be seen as a navigational tool that will span a specific subset of timbre space by offering a set of controls which could be interpreted as a language, defining a model for sound. (Métois 1996:17)

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[11] See: http://120years.net/machines/software/index.html [accessed 05.12.08].

It is therefore possible to observe a similarity in dance and sound with respect to the multiplicity and freedom of choice of parameters that lead to the final artistic interactive expression.

We can postulate that a complex development process is involved when creating an interactive dance and sound performance. I list the elements of this process here as follows:

- The choice for a suitable sensor system to obtain body movement data.
- Computer programming.
- Training of performer(s).
- Choreography or dance improvisation.
- Composition.
- Development of a satisfactory mapping process.

The list is not necessarily in chronological order because it consists of interdependent creative elements. As the creator of the particular interactive process discussed in this thesis, I regard myself as an 'artist-technologist' who is the 'audio-movement data translator' in the spatial movement and sound environment. I use this definition to clarify that, as a technologist, I research and/or develop the applied sensor technologies (in collaboration) and/or test the prototypes/beta versions, and program the interactive software in Max/MSP/Jitter to be able to compose the sonic art environment. As an artist, I develop the interactive environment subjectively through the creation of a mapping process that manipulates the derived movement and sound parameters. The interactive experiments and compositions (collectively called the 'Sound Skeleton') that are at the centre of this process exist in the interactive rhythm-time-space domain. The mapping process and the 'Sound Skeleton' creations will be presented in detail in chapter 6.

1.3 Research Aims and Methodology

The aims of the research are:

- The creation of an artistic mapping methodology (3*D*IM) that artists can refer to when creating an interactive stage environment that is closely intertwined with the practical design and (collaborative) testing of new technologies.
- The development of easily configurable and flexible interactive software (in Max/MSP).

- The presentation of interactive ChoreoSonic[12] performance experiments and compositions documented in video format and captured under the name 'Sound Skeleton'.

The results of these investigations have led to a method that will supply a dancer with the freedom (within set computer boundaries) to create authentic real time sonic and choreographic spatial compositions.

Pentti Routio (2004) has observed that nearly all scientific reports produced in the study of art have a purely informative goal, in line with scientific studies of art, i.e. the researcher 'tries to describe the object of study objectively and avoids generating any changes to it'. He argues that the writings maintain an 'impartial nature' and therefore a 'disinterested purpose'. To avoid what he considers to be a weakness of the writing appearing not to originate from the needs of the artist him/herself, Routio proposes the adoption of a 'general normative research' and a practical 'normative case study' by research-artists. A normative approach differs from informative because research-artists are generally not interested in impartial descriptions of works of art, but want to create other and better works that originate from evaluations and reflections of the existing art works.

This normative approach is the chosen methodology of my research, as its intentions align with Routio's list of characteristics summarized below:

- The purpose is to reflect the 'general character of artistic creation which is essentially goal-oriented'.
- Combining some of the procedures of scientific research and artistic creation.
- Producing theory for the benefit of other artists.
- The parallel work of art elucidates, exemplifies or complements the theoretical findings.
- Presenting the results of the artistic study includes elements from both art and science.

Following Routio's proposition, the presentation of this research is divided into two parts. Part I, the 'general normative research', initially entails the evaluation of theoretical design strategies undertaken by artists and scholars in the field. Thereafter, the thesis continues with describing the theoretical concept that determined the context of the created interactive ChoreoSonic movement and sound environment. Part II, the 'normative case study',

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[12] A term coined during a research collaboration between Rubidge and myself in 2006 (see also Rubidge & Wijnans 2008).

presents several case studies from the practical research and describes the development of 3*D*IM that is dynamically[13] designed during the research process. Through this research, the 3*D*IM developments systematically test the written theory during the 'Sound Skeleton' experiments and compositions. This research methodology allows me to fully incorporate the practical knowledge in the artistic debate presented in this thesis.

1.4 Research Questions and Aims

The initial research questions have been formulated as follows:

- Which technical and artistic elements make it possible to create a real time spatial ChoreoSonic performance environment?
- How does one find a satisfactory artistic mapping relationship between the spatiality of dance movement and spatial sound composition in an interactive context?

Due to the nature of these theoretical and practical artistic investigations, research is undertaken in an interdisciplinary context. The research process presents theoretical discussions of artistic developments in the field including references from the subjects of interactive performance technologies, dance movement and spatial sound composition. In addition to these, various ideas of the current research on the mapping process in the computer will be discussed. Specifically it focuses on an analysis of the spatial dancer-technology-sound interaction and refers to other similar interactive dance performances.

The research practice and software have been, and will continue to be, demonstrated to students, artists and practitioners in seminars, workshops and written texts (see appendix 2 and 3).

1.5 Structure of this Document

Part I General Normative Research

Chapter 2 'Interactivity and Gesture Based Sonic Projects' starts the thesis by contextualizing the research. After an introduction to the process of interactivity in Art & Technology projects, the chapter highlights several pioneering digital musical interface designs that have been developed to

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[13] The word 'dynamically' is used in this context to show that the software was developed in an ongoing developmental progress before, during and after the practical experiments.

realize gesturally controlled sonic art projects. The description focuses on artistic, engineering and computer science R&D. The designed technologies are categorized into two data collection methods:

- Object Location in Space.
- Moving Body Part Location Tracking.

It will next be argued that the finger and hand gestures needed to play these new musical interfaces can be regarded as a 'dance of hand and fingers'. The technologies of these projects can be seen as predecessors of the technologies used in later interactive dance performance.

Chapter 3 'Interactive Movement-Based Projects' continues with an extensive review of interactive Dance and Music/Sound Projects. It focuses on an analysis and evaluation of the eventual correlation between, on the one hand, the technology that is applied in interactive performance projects and, on the other hand, on the artistic outcomes in movement and (primarily) sound projects. The chapter focuses on a wide range of movement-based projects, discussing artistic, engineering and computer science research. It presents a discussion of the different mapping concepts that have been developed by movement and sonic artists, and theoretical researchers with the aim of creating a certain movement and sound relationship.

Similar to the former chapter, the invented technologies are categorized into two data collection methods:

- Body Motion and Location Tracking techniques.
- Body Part Motion Capacity and Personal Space Tracking techniques.

It will be shown that these technological methods are related to the two sonic gesture measurement methods mentioned in chapter 2.

The chapter progresses with a discussion of the different software design methods that have been applied in interactive dance choreography. The discussion reviews motion analysis and gesture recognition techniques from the perspective of computer programmers and the artists involved. It is critically questioned if 'choreographing in computer code' by means of using motion analysis and gesture recognition algorithms in the data processing is a useful creative method in an artistic performance context.

Chapter 4 'Context of the Spatial ChoreoSonic Environment' contextualizes the creation of the spatial ChoreoSonic interactive environment in two sections. The aim is to describe how my ideas behind the relationship of dance movement and spatial sound evolved in the creative research process.

The first section of this chapter presents a general discussion of the different concepts that were developed with the aim of creating a certain movement and sound relationship. It is thereafter outlined that performance improvisation in a technological environment is an important feature in the interactive audio-visual-movement environment. The section continues with a focus on interactive performance and presents the viewpoints from movement and sonic artists, and theoretical researchers. The terms 'Embodiment' and 'Virtual Disembodiment' are reviewed, leading to the proposition of the new term 'tranSonic' perception that complements the latter terms.

The second section of the chapter investigates the spatial elements involved in the creation of the ChoreoSonic environment from the various viewpoints of dance and ambisonic surround sound. The discussion focuses specifically on the human perception of the visual, tactical and auditory space in the digitally enhanced performance environment. The end of the chapter proposes a ChoreoSonic relationship between the dancer as a 'living architecture' and ambisonic surround sound as a 'moving sonic architecture'.

Part II Normative Case Study

Chapter 5 'Case Study 1: Preliminary Practical Research, Cricket System Development' presents the development of a prototype wireless Radiofrequency (RF)/ Ultrasonic (US) full body motion tracking system. After the theoretical investigations in the General Normative Research in part I of this thesis, it is concluded that such a system is best suited for measuring the spatiality of dancer's movements in the performance space.

In 2003-2006 I had initiated and researched the technical requirements of a full body motion tracking system. This research culminated in the development of a prototype version of the Cricket system. This system tracks the 3D full body position and trajectories of up to two performers in the sensitive area. The context and technical operation of the Cricket system is described, including preliminary research of the prototype Ambisonic (surround sound) programming in Max/MSP/Jitter. The technical constraints of this prototype RF/US system are identified at the end of this section.

In the second section a more advanced RF/US system, the 'Low Cost Indoor Positioning System' (LCIPS), is described. The LCIPS became available in the second part of my research when the development of the 'Cricket' System came to a pause, due to financial and logistic reasons. The LCIPS was at the time of this research able to track up to 6 RF/US sensors synchronously. The 'Sound Skeleton' creations, that either helped to develop, test or demonstrate the different stages of the 3*D*IM development, utilize either the 'Cricket System' or the 'LCIPS'.

Chapter 6 'Three Dimensional Data Interpreting Methodology (3*D*IM)' presents the development of 3*D*IM in Max/MSP/Jitter as a subjective method to map the spatial movement data derived from the RF/US tracking system to the interactive spatial sound environment. 3*D*IM categorizes a method for mapping the available spatial parameters of both art forms in an interactive ChoreoSonic environment: 'the Body as a Spatial Sound Generating Instrument'.

It is explained that the development of 3*D*IM involves a categorization of the various degrees of dynamic movement freedom, concentrating on the spatial position, rhythm and timing of these elements, and on the sonic parameters that influence the spatialization of the sound. These different elements of the mapping strategy are categorized in four main sections. The first two sections identify the movement input data: the raw movement input data derived from the tracking system (X-Y-Z dimension) and the deduced spatial movement parameters (proximity, speed, rotation and direction). The last two sections of the categorization identify the sonic output categories: the basic sonic result (interactive synthesizer, samples and effects) and the parameters that influence the sonic spatial structure (volume, frequency, reverb and delay). Each of these sections consists of the relevant spatial movement or sonic parameters and is accompanied by a graphic visualization of the implementation in the 3*D*IM software. In order to support the choice of these spatial movement and sound parameters they are underlined by several references from the appropriate field.

It is shown that 3*D*IM was designed before, during and after the practical 'Sound Skeleton' creations that were developed as a result of the theoretical process that was presented in Part I of this thesis. It is outlined how the developments described in this chapter can contribute to the reader's insight into finding a balance between the interdependent technological and artistic elements that are inherent to interactive art performance.

The description of the practical 'Sound Skeleton' creations is accompanied by documentation that includes video extracts compiled in a Power Point presentation (DVD), Max/MSP patches (CDR) and written text.

Chapter 7 'Evaluation and Future Work' evaluates the major outcomes and contributions from this research project and suggests various future developments in the field of interactive dance and technology performance.

Part I

General Normative Research

Chapter 2 Interactivity and Gesture Based Sonic Projects

Introduction

> If it is accepted that the initial intellectual creative process should be 'ideas-led' rather than 'technology-led', then the scope for using the capabilities of software or hardware as a basis for the dramatic or artistic impact of any given piece decreases. That having been said, knowledge of the up-to-date capabilities of systems may lead to a situation where an original idea is enhanced by the possibilities offered by technology, so there is a complex relationship between these two positions. (Grindley 2007)

Neil Grindley outlines the importance of investigating the different types of technological discourses in art environments in which the applied technologies relate to and/or might enhance an intended art creation. In line with Grindley, the point of departure of the next two chapters is the assumption that technology research should not be separated from artistic research when realizing practical research in the interactive Art & Technology field.

Art & Technology have always had a close inter-relationship. The Greek word 'techne' means 'craftmanship', 'craft' or 'art'. 'It is the rational method involved in producing an object or accomplishing a goal or objective. The means of this method is through art'[14]. Raymond Williams (1976:315) points out that 'the term "technology" was used from the seventeenth century onwards to describe a systematic study of the arts or the terminology of a particular art' (*quoted in* Wilson 2001). In the nineteenth century the term switched to being used as a reference to the 'practical arts'. In addition to this, Mick Wilson states that the term 'Art' has been associated with terms such as 'creativity' and 'expression' and was related to affective and subjective aspects of human experience. Relating to recent times, Wilson further notes that 'the emergent modern sense of technology marks the priorities of the common-sense practicality of everyday artisanal life as represented by tools, instruments, or machines within a discourse of progress' (*ibid*).

These notifications bring forward a critical dilemma faced by artists working in the field of interactive technology today. According to Sher Doruff, a media artist working with real time interactive performance technologies, the close

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[14] From: http://www.encyclo.co.uk/define/techne [accessed 10.12.08].

inter-relationship between art and technology is on the one hand a seductive environment that the contemporary artist can easily be overwhelmed by, on the other hand it is an interesting facility provided by the 'sign of our times':

> Even as I race to keep pace with evolving hardware, software, standards, protocols, bandwidths, not to mention information ingestion and correspondence, I find myself longing for a quiet, unmediated breath. The vanishing 'still point.' This is a conundrum - this disparate agitation between the evolution of enabling tools and techniques and a conceptual tentativity towards the 'everything always at once' possibilities these tools engender. Yet, as artists, theoreticians and observers we are of our time and our time is fundamentally facilitated by clever combinations of 1's and 0's - the pigment and piano wire of our compositions. (Doruff 2001)

Mick Wilson (2001) adds to this view the fact that 'The discussion of technological determinism underlines the need to critically treat assumptions that technological innovation is the primary determinant in cultural developments'. These citations illustrate the importance for an artist to try to find a satisfying equilibrium between the applied technology and the resulting art form.

2.1 Interactivity: 'Artistic Process' or a 'Tool Exhibition'?

> **Art** While traditionally art was focused on the appearance of things and their representation, artists now are concerned with processes of transformation, construction and emergence. (Ascott 1996a)

Roy Ascott's 'Glossary', a writing in which he constructs a list of definitions and terms for interactive technologies, introduces us to the modern way in which artists may look at their art creations. This new interpretation is mainly due to the technical inventions that can cause an interaction between the user and the computer interface, the static form of art transformed into a dynamic form of art. However, it should be noted that the shifting attention from a static art product to the process of a real time emerging art piece has been introduced by several performance artists before the advent of computer technology in the arts. Amongst these are artists such as Ulay & Abramovic in their performance 'Imponderabilia'[15] in which the audience participation created the emerging art event or Cage and Cunningham in the project

[15] 'Imponderabilia' by Marina Abramoviç and Ulay (1977), Galleria Communale D'arte Moderna Bologna, video in collection of Montevideo/TBA Amsterdam, the Netherlands.

'Variations V'[16] as one of the first technologically enhanced dance and music performances.

Considering this new form of interaction with the computer in the arts, Söke Dinkla (1994) initially distinguishes 6 implications of interactivity. These different categories can be described and illustrated as:

- 'Power and Play': interaction caused by movements of the audience with sensors in a responsive environment (like a head mounted device).
- 'Participation versus Interaction': the spectator is operating a joystick behind the computer and turns into the director of a changing image of the space.
- 'Proximity and Manipulation': one or more visitors of the interactive environment are able to control image or sound whilst at the same time being manipulated by these effects.
- 'Strategies of Seduction': installations in which desires of the audience are acted and reacted upon with a touch screen as tactile interface.
- 'Nonlinear Narration': an audience member navigates pictures on the screen and in this way direct and edits the auditory storyline.
- 'Remembering, Forgetting, and Reconstructing': a new form of reality arises in a new context. A non-directional, intuitive exploration of images and texts is exploited by manipulating a touchscreen.

From a more technical point of view, Ascott (1996a) defines the static and dynamic forms of interactivity in his 'Glossary' as follows: 'The trivial form is a closed system with a finite data set. The non-trivial form has the open-ended capacity to accommodate new variables'. In other words, in the trivial form the interactive static form is a 'responsive' interactivity, i.e. the computer produces a monologue that a person is able to freely activate in various ways. The non-trivial form of interactivity is defined as a dialogue in which the operator and computer both react to each other. In line with Dinkla, Ascott (1990) had at an earlier time also argued that 'the artist's responsibility was now toward context rather than content, with meaning emerging from the interactions of the viewer and their necessarily unstable relationship'. He puts contemporary artists in a newly defined context: art is no longer a static representation of the artist's creativity, but much more a representation of the dynamic creative processes. However, Ascott (1996b) remarks in another

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[16] A short video of 'Variations V' is available on: http://www.medienkunstnetz.de/works/variations-v/video/1/ [accessed 17.08.08].

writing that, although technology might seem to be inherently seductive acting as an 'instrument of seduction', as noted above by Dinkla, he stresses the reverse is actually true. Artists are in fact seducing the machine to embrace the human way of thinking and feeling.

From an artistic point of view David Rokeby (1998), an interactive installation pioneer, describes interactivity as a 'constructed experience', a dynamic process in which the interface itself is the content that a user can experience by freely choosing the paths that have been prepared in the software. It should be noted here that when the created art project is an interactive performance piece the performer even faces a double task: not only does s/he experience the interactive process as the operator, but s/he also has the task of communicating this experience to an audience in the role of the manipulator of the interactive interface.

2.1.1 Early Movement-Based Sound Projects as Live Interactive Process

One of the first movement based sound performances was the use of the 'Theremin' (1919) instrument[17] by a classical dancer. The 'Theremin' was an electronic musical instrument that used wireless triggers of body movements to create sound in real time. In a review in the Literary Digest in 1927 (Glinsky 2000) the 'Theremin' was described as an instrument with which the performer could not only conduct the music but also make the sound at the same time. Here he was pointing to the necessary movements needed to make sound. The acoustic waves were directly sculpted by wave-ings[18] of the arms that interfered with the surrounding radio frequency antennas.

The 'Terpsitone', also invented by Leon Theremin in 1936, was a dance platform fitted with space-controlling antennae (Mason 2004). Unfortunately this instrument was very hard to control due to the fact that even the smallest bodily movement would output a sound produced by an oscillator. This real time One-to-One effect was a feature that predicted possible difficulties in the future that would arise when working with interactive technologies (see also p.48).

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[17] See: http://www.thereminvox.com/article/articleview/96/1/24/ [accessed 30.06.08].

[18] As suggested by S. Rubidge (personal communication, November 2008), the term wave-ing is used here to make a distinction from 'waving' as the image of the 'hello/goodbye' wave.

A renewed interest in making sound through body movements caught the interest of electronic music composers from the 1960s onwards. An early example of a full scale dance project applying sound in an interactive way was 'Variations V' by Cage and Cunningham in 1965. Whereas the 'Theremin' and the 'Terpsitone' could only cover a very small space with the available technology, John Cage and Merce Cunningham positioned a system of directional photocells on different spots in the stage area to respond to the brightness of the stage lights, and at the same time surrounded the space with several radio antennas to create a responsive environment. The dancers would trigger sounds as soon as they broke the light beams of the stage lights, or if they danced in proximity of the antennas. Proximity measurements would determine the choice of sound and the amount of certain sound parameters (timbre, frequency, duration and amplitude). Johannes Birringer (1998:8) states that Cage's "composition as process" symbolized 'a commitment to the freedom of experimentation'.

The projects cited above are examples of movement based interactive art and technology performances that were able to change the fixity of compositional forms in every event due to the early technological interaction between performer and technology. Performance art emerged as a live interactive process.

2.2 Sonic Gesture Measurements

> If one were to ask for the name of what's left of a trombone when you take away its ability to produce sound you might suspect you were in for a round of language philosophy, but it is precisely that which is missing from the computer as an instrument. (1991:3)

After a more widely spread availability of the computer, it was quickly revealed that the computer, combined with MIDI[19] as the standard communication protocol for digital music, gave musicians and composers a new range of possibilities. In the first instance controller devices available to the artists consisted of a MIDI keyboard, a standard computer mouse, a 2D or 3D joystick, or a graphical Wacom[20] tablet. Originating from the fact that musicians are usually well trained in the coordination of different body parts

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[19] MIDI stands for Musical Instrument Digital Interface, an industry protocol that enables electronic musical instruments, computers and other equipment to communicate with each other.
[20] See: http://www.wacom.com/ourbrand/index.html [accessed 20.05.08].

needed to play their instruments, the artists quickly concluded that the above mentioned tools, available as Human Interfaces (HI) to operate the computer, did not make use of these trained skills. In this context, Sally Jane Norman *et al.* point out:

> Their [artists'] goal is to enhance rather than impoverish gestural skills, by devising tools that are just as responsive and expressive as conventional instruments, but that truly exploit the "meta-control" features of computerized systems, their exponential and algorithmic functions. (Norman *et al.* 1998)

There was a clear need for a lot of different non-contact and contact instruments designed as interfaces for the benefit of musicians and/or sound artists. A number of the designed interfaces that tried to fill the early gap in the lack of digital instruments and controller devices will be outlined below. In particular, the bodily relationship between the used technology that was invented for 'Gestural Control of Music'[21] and the musical, sonic and/or performative outcome is analysed.

2.2.1 The Choice for a Controller Device in a Musical Context

Fernando Lazetta (2000) agrees with Joel Ryan's earlier view that electronic and digital sounds in themselves have no gestural relation to the devices that produce them. This means a loss in the 'symbolic and meaningful dimension that can be present in a musical work' (*ibid*:84). The musical instrument is not only the medium for the musical idea, but also part of this idea. Therefore, the question arose: how best to turn the computer into a sound generating instrument that is responsive to 'blood, sweat and tears', i.e. the well coordinated touch, effort, body dynamics etc. of the musical operator? My research has outlined that there exist three ways[22] to realize this aim in a musical environment:

- An existing controller is used and programmed.

As an example of an artist who used an existing controller to suit his chosen environment, I refer to Joel Chadabe (2000) whose artistic aim was to conduct computer sounds in a conventional manner that was clearly

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[21] The term 'Gestural Control of Music' points to the act of music being produced by the physicality of body movement.
[22] Wanderley described this similarly as 'a three-tier classification of existing controller designs' (2001:19).

perceptual for the audience. He succeeds in both these issues by using two Theremins and wave-ing his hands in the air. He describes his choice of performance device as firstly being dependent on its suitability for a particular musical processing situation, and secondly on the wish that the audience should be able to perceive a meaningful relationship between a performer's gestures and the musical result. Chadabe states that the relationship was clear to the audience in so far that the antennas served as a clear distance reference point for the changes in voices and tempo. He points out that position is easy for an audience to understand as a factor of the interaction.

- The instrument that the musician is accustomed to will be modified with technology (a 'hybrid controller').

Other musicians choose to modify and expand the capabilities of their instruments, or to build an instrument that resembles their original musical instruments and thus fits their skilled coordination. With the help of an engineer or a dedicated organization or institution they are able to add electronic devices (normally sensors[23]) to the instrument. Ryan (1991) refers to several of these artists that developed projects at STEIM[24] (Amsterdam, NL). STEIM is one of the major centers for research & development of instruments & tools for performers in the electronic performance arts and supported artists such as Jon Rose (violin), Michael Barker (contra bass) or Nic Collins (conversion of an antique concertina into a sort of digital trumpet). Ryan states that 'Each composer was interested in the expansion of their instrument through the addition of synthetic or sampled voices, but also in using the computer for the elaboration of the control gestures themselves' (*ibid*).

- A custom built ('alternate') interface controller is designed.

Sound artists could also choose specific sensors and design a completely new custom built Digital Musical Interface (DMI)[25] to fit their particular needs. The MIT lab (USA)[26] and STEIM have been positioned at the forefront of this musical interface design. Bert Bongers (2000) describes how control and

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[23] An overview of several sensor devices can be found at: http://www.cycling74.com/twiki/bin/view/ResourceGuide/SensorDevicesResources [accessed 15.05.08].
[24] See: http://www.steim.org [accessed 22.06.08].
[25] DMI is defined by Marcelo Wanderley as 'used to represent an instrument that contains a separate gestural interface (or gestural controller unit) from a sound generation unit' (Wanderley 2001:16).
[26] See: http://www.media.mit.edu/research/ [accessed 29.07.08].

feedback, as a two way process of interaction between the user and the computer, can be achieved by manipulating the different sensors available at the time. His paper shows us that the choice for a particular sensor or combination of sensors can depend on:

- Ergonomic comfort: e.g. matching artist's (muscular) skills, avoiding limitations or obstructions.
- Technical specifications: e.g. accuracy, update rate, distance reach and resolution.
- Resources: e.g. time scale for the design, availability of engineers and financial resources.

Artists will consequently spend many years training to master a newly designed controller. However, this can also lead to the development of new or unknown dimensions of the musical concept as will be shown in the next sections. There exist multiple writings about DMI design. In order to avoid discussing all nuances of musical interface design, which is not the purpose of this thesis, I refer the reader to Paradiso (1998), Roads (1996:619-658), Bongers (2000) and Jensenius *et al.* (2005:112), R&D centers and institutions such as Ircam[27] or STEIM, or to the New Interfaces for Musical Expression (NIME) Conference Proceedings[28] for further information.

2.2.2 Introduction to Mapping

In all three cases of the choice of a specific DMI design mentioned above, the trajectory of the dataflow requires a specific mapping strategy that will be applied to the dataflow between the chosen or available input controller device and the computer output. Marcelo Wanderley (2001:17) states that 'The mapping layer refers to the liaison strategies between the outputs of the gestural controller and the input controls of the synthesis algorithm' and, later in his writing (*ibid*:66), that 'mapping will be considered as the strategies of correspondence among the output variables of the input device and the available inputs of the sound generating system'. Before a number of interfaces that have been designed for gestural sound composition are identified, it is essential to make a distinction between two main perspectives that exist regarding the mapping of the generated parameters. Wanderley (*ibid*:66) notes that mapping is either a 'specific feature of the composition' or

[27] See: http://www.ircam.fr [accessed 20.05.08].
[28] The archive of the NIME conference proceedings can be found at: http://portal.acm.org/toc.cfm?id=SERIES11275&type=series&coll=GUIDE&dl=GUIDE&CFID=76260934&CFTOKEN=39246692 [accessed 20.05.08].

an 'integral part of the instrument'. He analyses the topic of performer-instrument interaction as follows (*ibid*:66):

> According to the first point of view, the composer decides how best to map input devices' variables to synthesis variables independently in each composition. Mapping is here part of the aesthetic considerations driving the construction of a piece.
>
> The second point of view considers mapping as part of an instrument, independently from the compositional use to be made of it.

He concludes that the study of 'general' compositional mapping strategies is not a major field of research in his writing due to the fact that every composition represents a unique point of view. He therefore continues his chapter about mapping from the second point of view, namely that mapping is an 'integral part of the instrument'[29].

In contrast to Wanderley, the major field of research in this thesis *is* the topic of compositional mapping strategies, although elements from the second point of view (part of the instrument) will be referred to whenever relevant. It will be argued in particular that artistic mapping strategies can be dependent on the chosen interface strategy and specific data communication methods. Thus mapping can be considered from various perspectives because the process has to meet several criteria depending on the interface used, the field of art it relates to and/or the ultimate aesthetic goal it has to meet. Either a similarity between the different elements or a discrepancy between the perspectives of available parameters can exist. In other words, in this writing artistic mapping strategies will be described as emerging from a specific (spatial) data communication.

In the following I will describe some specific pioneering inventions of gestural musical interfaces that are relevant to the subject of this writing. These interfaces have been designed with the goal of measuring sonic gesture and are sometimes referred to as instruments 'conducting the MIDI orchestra' (Boulanger 1990:34). It will be shown in chapter 3 that these interface design inventions have proven to be relevant to the electronic hardware designs and mapping strategies that were later developed in interactive movement-based projects.

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[29] For further reading about mapping as an integral part of the instrument I would like to refer the reader to Wanderley (2001) and several of his (collaborative) papers (*et al.* 1998, *et al.* 2000a, 2000b & 2001).

I propose a classification of these gestural musical interfaces in two data collection categories:

- Object Location in Space.
- Moving Body Part Tracking.

2.2.3 Object Location in Space

'Object Location in Space' is classified here as a method through which position data are derived from an object that is moved in space by the performer's hand. One example of an instrument applying this data measurement is 'Lightning'[30] (1991) created by Don Buchla. It is an optical infrared tracker that measured the horizontal and vertical positions of two wireless handheld wands within a two-dimensional grid. The 'Radio Drum'[31] by Max Mathews (1989) is another DMI that uses radio-frequency waves to derive data from the performer's mallets or sticks. The gesture sensors used measure the location of two batons in three dimensions in relation to a rectangular radio receiver using magnetic capacitance, much in the same way as the 'Theremin' did. The 'Radio Drum' has been further developed into a more precise gesture sensing percussive instrument with a wider sensitive area and less latency[32]. The world-renowned avant-garde multimedia performance artist Laurie Anderson developed 'The Talking Stick' (1999)[33] especially to enhance the visual performative effect. This six foot long baton was played by rubbing one's hand over the shaft and by changing its position in space. The instrument responded to speed of operation and to different positions, movements and postures of the operator. It was capable of manipulating any sound by applying granular synthesis to create new sound textures[34].

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[30] See: http://www.buchla.com/lightning/descript.html [accessed 29.07.08].
[31] See: http://www.fondation-langlois.org/html/e/page.php?NumPage=246 [accessed 29.07.08].
[32] See: http://www.ece.uvic.ca/~peter/radiodrum.html [accessed 29.07.08].
[33] See: http://www.thecityreview.com/laurie.html [accessed 29.07.08].
[34] It should be noted that Anderson had reservations about technology concerning the way in which computers and computer programs, in their current form, limit creativity. See: http://www.jimdavies.org/laurie-anderson/commentary/reviews/performances/mobydick.html [accessed 29.07.08].

2.2.4 Moving Body Part Tracking

The second data collection category 'Moving Body Part Tracking' is classified here as a method to derive data from the fine coordination of hands, fingers, arms and sometimes feet that are commonly needed to play a musical instrument. Michel Waisvisz started to develop 'The Hands' (1984) in the early days of MIDI as a more sensitive and natural musical interface to trigger the computer. 'The Hands' provided a way to play, as it were, little keyboards attached to the hands on stage that could translate hand, arm and finger movements immediately into digital sounds[35]. Waisvisz remarks that he 'wanted to operate, navigate, compose, mold and play sound in a sensible, refined and even sensual and groovy way'[36]. From the mid eighties onwards various commercial hand gloved 'toys' were marketed as interfaces for the computer like the Data Glove[37] (VPL Research, Zimmerman & Lanie 1987), and the Mattel PowerGlove[38] developed for Nintendo (VPL& Abrahms Gentile Entertainment 1989).

Considering the relationship of a musical instrument to the human body, Nick Longo notes that the construction of the piano keyboard is clearly a reflection of the human hand. 'Like fingers, the keys are arranged in a linear side by side manner. Fingers push down in one direction and the keys push back' (Longo 1996). In the case of dance, Wanderley (2001:7) notes that 'these [body] movements are important per se, i.e., the dancer does not usually dance to the interface in order to produce sound, but to the audience'. Following these observations, one might also want to look at the moving fingers as if they are 'dancing' over the piano keyboard. Upon further examination it turns out that just looking at the different possible flexions of the fingers already culminates in a complex movement character.

In line with Longo, 'The Hands' were constructed according to a keyboard model with small touch-tones and keypads. Following Waisvisz, several other sound artists also started to design their own hand glove instruments between

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[35] At an historical occasion Lev Theremin, an inspirator for Waisvisz since he was sixteen, visited Waisvisz at STEIM Amsterdam (1993), NL and they played their instruments (the Theremin and The Hands) together. See: http://crackle.org/Lev%20&%20Michel.htm [accessed 29.07.08].
[36] From: http:// www.crackle.org/TheHands.htm [accessed 02.07.08].
[37] See: http://www.streettech.com/bcp/BCPgraf/StreetTech/VPL.html [accessed 29.07.08].
[38] See: http://www.angelfire.com/ok2/stepinto/PowerGlovePage.html [accessed 07.02.09].

the mid eighties and early nineties. Laetitia Sonami took the development of the hand glove DMI a step further and invented the 'Lady Glove'[39]. This invention embedded additional sensors[40] that were responsive to body posture, measuring the distance between hand and hand, hand and body or hand and feet. The inspiration for this last distance measurement method was sign language, a movement based language in which the distance of the hand from the body affects the meaning of a word or phrase. Sonami emphasizes the importance of gestures: 'Through gestures, the performance aspect of computer music becomes alive, sounds are "embodied", creating a new, seductive approach'. In performance, the effect of the hand motion is fluid and even sensual[41]. She also states that a very obvious relation between what her hand does and the sounds that emanate from the electronics emerged[42].

Another example of a DMI measuring hand movements is constructed by Joseph Rovan, a clarinettist who designed the 'Data Glove'[43] (1997), firstly to accompany his clarinet playing (as a hybrid controller see p.27), but later on as a stand-alone instrument. Two different gloves for the left and the right hand were designed. The right hand was prepared with Force-Sensitive-Resistors (FSRs) on the fingertips, bend sensors, and an accelerometer to sense finger, hand, and arm gesture. The left hand, wearing the second glove with reflective material attached, manipulates an infrared controller. In this way the left hand was able to control the macro level of the sound settings that were fine-tuned by the right hand. In line with Sonami, Rovan also presented the audience with the more noticeable musical gestures that were

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[39] A performance using the Lady Glove entitled 'Mechanization Takes Command' was premiered in 1991 at the Ars Electronica Festival (Linz) with Paul DeMarinis http://www.sonami.net/lady_glove2.htm [accessed 29.06.08].
[40] These electronics consisted of bend sensors on the fingers, magnets on the fingers in combination with hall effect transducers (a device whose output voltage varies according to the applied magnetic field), an acceleromator to measure the speed of motion of the hand and an ultrasound sensor to measure distance.
[41] From: http://www.sonami.net/lady_glove2.htm [accessed 29.06.08].
[42] The data from 'The Hands' and 'The Lady Glove' communicated with the Sensorlab developed by STEIM. The Sensorlab is a device that 'connects the real world of physical phenomena and gestures via Midi to personal computers and to Midi musical and studio devices' (from: http://www.steim.org/steim/sensor.html [accessed 27.06.08]).
[43] See: http://soundidea.org/rovan/projects_glove_01.htm [accessed 29.06.08].

needed to play the instrument. The choreography was determined by the communicating gestures of the sound composition[44].

2.2.5 Control versus Discontrol

As a last example of electronic composers and musicians who have designed gestural interfaces it is useful at this point to mention the Sensor Band[45]. The three members of the Sensor Band, Edwin van der Heide, Zbigniew Karkowski and Atau Tanaka, use a multitude of custom built sensor-based gestural controllers consisting of ultrasound, infrared, and bioelectric sensors measuring data to produce computer music. These instruments fall into both data collection categories mentioned above. However, apart from these DMI designs, they have also brought an additional important issue to the surface. The Sensor Band challenged the term 'Gestural Control of Music' when the members created a live performance musical instrument called 'Soundnet' (1998)[46]. This instrument can be described as a giant web (11X11m) consisting of ropes that the performers had to climb into. By stretching and moving the ropes the sensors that triggered the sounds were actuated. Bongers observed:

> The ropes create a physical network of interdependent connections, so that no single sensor can be moved in a predictable way that is independent of the others. It is a multi-user instrument where each performer is at the mercy of the others' actions. In this way, the conflict of control versus uncontrollability becomes a central conceptual focus of Soundnet. (Bongers 1998:17)

With the 'Soundnet', the Sensor Band showed us that 'gestural control' in electronic music has proven to be a gestural 'discontrol' in certain physical circumstances. We will see later (p.108) that 'discontrol' is a useful creative element in interactive performance.

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[44] Several other devices that measure hand and finger movements have been designed for example 'SoniMime', a system for the sonification of hand motion (Fox *et al.* 2005). Data glove interface developments have also recently been commercially marketed as tools for Virtual Reality applications. See websites such as: http://www.vrlogic.com/html/datagloves.html [accessed 12.07.08] or http://www.vrealities.com/glove.html [accessed 12.07.08].

[45] See: http://www.sensorband.com [accessed 03.07.08].

[46] See: http://www.sensorband.com/soundnet/ [accessed 03.07.08].

2.3 Summary 'Interactivity and Gesture Based Sonic Projects'

Before the technological age, innovations in material design influenced the development of art, such as new materials that could be applied for painting, new tools for sculpture, new musical instruments for sound creation etc. Every instrument and every material in itself created unlimited artistic possibilities. The invention of the computer caused an even bigger cultural shift and opened up an even wider array of artistic possibilities.

This chapter has outlined that Art & Technology projects as 'Art as Process' have an interdependent relationship in which both movement and sound elements influence each other's developments. It was shown that interactive art has been the beginning of a new dialogue between the two ideologically separated sections of Art & Technology. The new way of looking at art creation in the computer age has given rise to a new definition of 'Art as Process'. In this chapter, two different forms of interactivity have been observed regarding 'Interactivity as an Artistic Process' or as a 'Tool Exhibition':

- The dynamic behaviour of interactive computer processes (non-trivial form).
- The static behaviour of the responsive computer processes (trivial form).

Several early types of gestural music (dis)controller interfaces designed by electronic music artists were described because of their relevance to movement based interactive projects and thus relevant to the interactive movement and sound research undertaken in this thesis. In order to study the different technical contexts, I have proposed a categorization of these sonic gesture based devices into two different methods of data measurements:

- Object Location in Space.
- Moving Body Part Tracking.

Within these two categories, it was shown that sonic artists had various reasons to develop new digital musical interfaces:

- The insight that a computer provided new methods for composition.
- The wish to be able to use trained bodily coordination skills.
- The aim of being capable of musical control and/or discontrol.
- The wish to add a visual/choreographic effect to their performance.

The pioneers that invented these new DMIs for 'Sonification and Control' mentioned here, added a visual performative element to the design of electronic musical instruments by measuring the gestures needed to influence the digital sound. Movement, choreography, and physical activity were related to real time interactive sound creation. Waisvisz developed 'The Hands' because 'he wished to be able to "touch sound", freely walk around, move and dance, translating hand, arm and finger movements into sounds'[47]. Sonami choreographs her unique hand-dance creations. Her 'Lady Glove' allowed the performer to move around freely without any spatial reference to the stage and in this way play with her movements that only related to her own personal body space (see also 'Bodily Space' 4.2). Rovan also speaks of a choreography of the motions that were required to initiate and control the sound. Finally the Sensor Band showed us an element of musical 'Gestural Discontrol' in certain physical circumstances[48].

The DMI investigations in this chapter have evidenced the relationship between gesture and music as interdependent to a sonic artist/ musician from a musical as well as a performative and choreographic perspective. This statement of interdependency directs us to the next chapter, where a detailed technical and artistic analysis of 'Interactive Movement-Based Projects' is explored. Here we will see that the technologies of sonic DMI inventions became the predecessors of the technologies later applied in interactive dance performances.

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[47] From: http://www.crackle.org/TheHands.htm [accessed 02.07.08].

[48] Please note that only pioneer inventions are mentioned here. Other gestural interfaces have been designed by for example Marrin & Paradiso (1997) who developed a digital baton that had infra red leds attached to the tip or Sawada *et al.* (1995) who developed sensor gloves and concentrated on exploring different mapping methodologies for mapping hand gestures to musical parameters defined as 'Sonification and Control' methods.

Chapter 3 Interactive Movement-Based Projects

> As Gilpin suggests, we need not wait for digital technology or think of it as a device for body representation but should empower ourselves as informers for technological interface design. (Birringer 1998:120)

In the late 1990s Birringer, a performance and media choreographer, refers to Gilpin who, during a lecture-demonstration at the 'Connecting Bodies' conference (1996 Amsterdam, NL), suggests the need for dance and performance practitioners to start to take control over the computer. This will enable them to express artistic choices in an interaction 'that can actually deal in articulate ways with movement and dynamism of any kind, not just moving bodies' (*ibid*). In line with Birringer, Techla Schiphorst (1997), an interactive media artist, computer designer and choreographer, notes that choreographers need to start writing computer code with the very highest technical knowledge and experience that they already possess of the 'language of embodiment': the anatomy and movement of the body. Sanjoy Roy (2002) also notes the possibility for choreographers, who are skilled in thinking abstractly about processes and composition, to use existing software as a rehearsal tool to investigate a 'creative stimulus in computers'. These remarks point us to a major difference between the interests of sound and dance artists. In the electronic music field, there was an almost immediate affinity with the artistic possibilities that the computer offered.

In the section 'Sonic Gesture Measurements' (2.2) I referred to several musicians and sound artists who measured the musical gestures that were needed to play their instruments. The complexity of the two modes of 'expression' in interactive movement and sound projects are different in such a way that I aim to clarify the technological choices which had to be made to be able to realize the interactive ChoreoSonic 'Sound Skeleton' experiments and compositions. In particular, the following questions will be asked:

- What is the reason behind the choice for specific technologies?
- Can we analyse an Art & Technology correlation?
- What to do with the derived movement data to achieve the goal of (spatial) sound creation by means of interactive dance?

In this chapter, the eventual correlation between the applied technology and the artistic outcomes[49] is analyzed in every movement-based project reviewed, and the final conclusions are later used as a starting point for the conceptualization of the 'Sound Skeleton' creations[50].

3.1 Data Measurement Methods for Body Motion

As noted above, dancers and choreographers did not initially see the creative attraction of the computer due to the fact that their visual output (dance movement) emerged from moving bodies rather than some sort of digital technology. They were used to an immediate movement result and not accustomed to the necessary programming and calibration time required by the computer. However, in the following sections two similar electronic data measurement techniques that ultimately evolved to measure body movements in the dance and technology field will be discussed. I classify these techniques as:

- Full Body Motion and Location Tracking techniques.
- Body Part Motion Capacity and Personal Space Tracking techniques.

Please note that the list of cited electronic systems and performances is by no means meant to be comprehensive[51]. However, it is aimed that a technical and/or artistic context is provided for the practical case studies and 'Sound Skeleton' creations that have originated from these investigations.

3.1.1 Full Body Motion and Location Tracking

Following the outcome of the musical interface design investigation 'Object Location in Space' (2.2.3), this section introduces similar techniques that measure 'Body Motion and Location Tracking' in movement-based projects. These techniques measure the data of the full body movement path and

[49] For the continuation of this writing, the artistic outcomes concentrate on movement based interactive sound and music composition as other art disciplines like video images, animations, sonic compositions, theatre lights and text fall beyond the scope of this publication. However, these art forms will be mentioned whenever it feels appropriate.
[50] Please note that the effort to describe an Art & Technology relation is not claiming to be a complete, objective analysis of a particular work, but observes the main Art & Technology relationships of the piece.
[51] A general overview of systems can be found in the resources 'Controllers and Systems' on the DVD-ROM 'Trends in Gestural Control of Music' (Ircam, 2000), pp. 736-763. Dance and interactive systems overviews can be found in Torre *et al.* (2007).

position of (in this case) the dancers in a predefined sensitive performance area. The techniques[52] discussed are classified as:

- Sensitive Dance Floors.
- Breaking Beams.
- Camera Tracking.

3.1.1.1 Sensitive Dance Floors

Gravity affects the movement of dancing bodies. Jumps for example consist of interdependent movement parameters that can be executed with more or less pressure to the feet, body velocity and force. The arms are used for spins and balance to defy gravity etc. Whereas these are all obvious facts, how has this knowledge been applied in body measurement technology?

Several sensitive floor surfaces have been designed using the transmission of electric signals that provided position coordinates, velocity, and pressure information of a person's feet in the form of standard MIDI messages. Eric Johnstone (1991) developed a small sensitive floor, the 'Podoboard', on which a person had to wear shoes filled with metal contacts to complete an electrical circuit that was sent in MIDI format to the computer. The platform was built as an alternative MIDI instrument that had to be played by moving feet. Johnstone himself was a guitarist who played the floor while sitting on a chair.

In a prototype version of the 'Lifefoot'[53] floor, Russell Pinkston *et al.* (1994 and 1995) attached force-sensing resistors to a plastic sheet covered with polyethylene foam to build a touch sensitive MIDI dance floor. The floor detected contact, impact force, and location of dancers' feet. In this way it was not necessary anymore to wear special shoes. Pinkston *et al.* state that they built this floor to help the dancers to keep 'in time' with the music and to synchronize the stage lights to their performance. It is interesting to note here that the floor was initially designed out of logistic concerns and not to be able to add another element to the artistic concept.

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[52] A Global Positioning System (GPS) is a worldwide radio-navigation system that is also able to measure body position. However, a detailed description of this system is beyond the scope of this thesis because it only functions outdoors due to the fact that the communication with the satellites is usually obstructed when used indoors. For more information about GPS see for example: http://www.trimble.com/gps/whatgps.shtml [accessed 07.02.09].

[53] See: http://www.newscientist.com/article/mg14419540.700-when-the-dance-floor-rocks-and-rolls.html [accessed 29.07.08].

The Magic Carpet is like a playground for the audience, 'a truly "immersive", tetherless musical environment, where any kind of body motion would be directly and immediately converted into expressive sound' (Paradiso *et al.* 1997a). This floor was not initially constructed as a device for dancers but was built for manipulation by the public. It used a pressure-sensing floor (piezoelectric wires running across the carpet) that could accurately distinguish between soft foot motion and hard impacts. It also incorporated a radar system that sent Doppler-shifted reflections from a performer moving within the beam to measure movement direction and upper-body kinematics. Joseph Paradiso *et al.* (*ibid*) state: 'This system has been used in an audio installation, where users launch and modify complex musical sounds and sequences as they wander about the carpet'. The soundscape comprised a low voice triggered by stepping on the carpet, a middle voice (a harmonising fifth) determined by the position of the person and a high voice whose speed, pitch, panning, timbre and structure were controlled by the detected motion. The direction of movement controlled the notes of the chord.

With 'The Magic Carpet' a clear shift from practical needs to the aim of an artistic musical outcome is observed. The cited mapping procedure brings forward a musical concept that is directed by motion, a 'Gestural Control of Music' in a full body movement context. However, the system was not yet really suitable for dancers[54] due to the coarse grid of the wires (every 100mm), the noisiness of the wires (amplified by the radar), and the capability to measure only one foot. The second version of the 'Lifefoot' floor[55] used proximity sensors to track the motion and proximity to the floor of a dancer's foot by locating its contact with the floor. Mikael Fernström & Niall Griffith describe the floor as a musical instrument for a dancer:

> [...] the idea that a dancer's or performer's feet can be used to play a musical instrument in the way that, for example, a pianist's hands are used to play the piano, is relatively new, and largely unexplored. However, the tapping of a dancer's steps can be an important rhythmic component as well as a controlling element in a dance performance. (Fernström & Griffith 1998a:475)

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[54] Dance research experiments with the Magic Carpet have taken place in the MIT Media Lab. See: http://web.media.mit.edu/~joep/SpectrumWeb/captions/Carpet.html [accessed 10.07.08].

[55] See: http://www.ul.ie/%7Epal/litefoot/ [accessed 13.07.08].

A clear reference to the aforementioned 'Moving Body Part Tracking' of the 'Lady's Glove' (p.32) and 'The Data Glove' (p.32) is observed here: instead of measuring movements of the hands and fingers, force sensors were also applied to measure different parameters of the moving feet. In the project described by Fernström & Griffith, the relationship between the movement parameters on the two dimensional coordinate grid and the emerging sound field was defined as follows: the X-direction was mapped to musical scales, the Y-direction to sets of timbres, and the Z-direction (the impact force) to loudness. Considering the relationship of the early artistic interaction between movement and sound, Fernström & Griffith (1998b:3) concluded that a dance teacher was now able to say to a dance student: "do as you hear me doing" as well as "do as you see me doing", and that a dancer can produce their own scores in which even subtle and small movements are being made audible and visible.

Another reference to the section 'Moving Body Part Tracking' is made in the 'Smart Wall' project by Paradiso & Sparacino (1997b) in which scanning laser rangers were initially used to measure hand trajectories. The researchers state that it would also be possible to turn this wall 90 degrees to a floor position to enable measurements of dance movements of the feet.

3.1.1.2 Breaking Beams

An additional variation to the implementation of electronic sensors was discussed when describing the 'Magic Carpet' that used the beams of motion sensing radars to locate the upper body kinematics. Related to this measurement method are several other 'breaking beam' detecting systems that have been designed to measure 'Body Motion and Location Tracking'.

Troika Ranch[56], a leading international dance and technology company founded and directed by composer/media artist Mark Coniglio and dancer/ choreographer Dawn Stoppiello, developed 'The Laserweb'[57] (2000). It detects movements that break the beams of up to eight laser lights[58] which shine over the stage area into light sensitive sensors. The system is able to produce music or, in conjunction with the software program 'Interactor LPT'[59] (also developed by Coniglio) to operate a variety of media devices. On their website

[56] See: http://www.Troika Ranch.org/ [accessed 12.07.08].
[57] See: http://www.Troika Ranch.org/laserweb.html [accessed 12.07.08].
[58] Laser light is defined as coherent light oscillating electromagnetic radiation.
[59] See: http://www.Troika Ranch.org/interactor.html [accessed 12.07.08].

it is stated that the LaserWeb is used in one section of the performance 'The Chemical Wedding of Christian Rosenkreutz'[60] (Troika Ranch 2000) as a cue for the lights to change intensity and for the music to change volume.

The ultrasonic system 'The Soundbeam'[61] (1989) consists of four cone shaped beams that are sensitive for up to six meters. It communicates with an interface box that converts the ultrasonic data into MIDI data. A number of performance groups[62] have developed projects with this system. I premiered an interactive dance and music performance called 'Frozen White'[63] using the Soundbeam system in 2002. In this piece the dancers influenced the acoustic music made by three improvising jazz musicians real time. The dancers' movements in the sensitive path of the Soundbeam added a digital dataflow that influenced the live music in Max/MSP. The dancers were not 'controlling' the sound, but were merely inspiring or even confusing the instrumentalists who had to react instantly to the effects that the movements of the dancers brought on their sounds. The Soundbeam can be regarded as a very long piano keyboard consisting of a sensitive beam that is divided in equal playable parts that the dancer could 'switch on' by breaking the beam: the dancers acted as 'members of the band'.

The systems described above all have a binding sensitive area, either a rectangular matrix form on the dance floors or a triangular cone shaped area 'shining' from the beams. Whereas dancers become very quickly adapted to these reactive geometries, due to their highly developed spatial awareness (for an in depth analysis of this subject see 4.2), this fact also implies that these geometric areas can influence and/or limit the possibilities for the movement choreography.

Whereas the Soundbeam system sends ultrasonic signals into space through sensors that are attached to fixed poles (hence creating an obligatory sensitive area), a dancer might prefer to attach one or several of these sensors to the body to be able to trigger effects in a more spatially free way. Antonio Camurri, founder of 'Infomus lab'[64], describes such a system (Camurri

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[60] See: http://www.troikaranch.org/galleryChem/g-chem.html [accessed 18.01.09].
[61] See: http://www.soundbeam.co.uk/ [accessed 10.12.08].
[62] See: http://www.soundbeam.co.uk/dance/image-gallery.html [accessed 12.07.08].
[63] See: http://www.mudanx.nl/Frozen.WhiteFlash.html [accessed 12.07.08].
[64] See: http://www.infomus.org/ [accessed 12.07.08].

et al. 1995). The 'V-scope' system[65] is an infrared/ultrasound system used in the HARP (Hybrid Action Representation and Planning) application for human movement tracking (see also p.59). It is able to recognize several simple gesture features (like raising or lowering the body, one or both hands, opening and closing of the hands, distance between hands etc.) by acquisition of the position of ultrasonic markers on the body.

Cliff Randell & Henk Muller (2001) discuss dynamic measurements with another RF/US system for precise localization in space. This Low Cost Indoor Positioning System (LCIPS) system was originally designed for mobile and wearable computers for ubiquitous computing[66] and to complement an external positioning system that used GPS. In the art installation 'The Walk in the Wired Woods' (2002)[67] visitors were equipped with headphones and this RF/US wearable device to be able to hear a location-sensitive digital soundscape (Hull *et al.* 2002). This system is used for the practical research project described in this thesis (see Ch.5 and 6) and will be explored practically in the artistic context of this writing[68].

3.1.1.3 Camera Tracking

In the previous sections it was observed that 'Object Location in Space' in Sonic Art performance and 'Body Motion and Location Tracking' in dance performance show elements of the same gesture sensing developments. However, a third completely different method to measure full body motion tracking, called 'Camera Tracking', was developed by several artists and computer engineers around the same time.

In 1982 installation artist David Rokeby started to show an interest in turning the moving body into a sound generating instrument. In an artistic, almost philosophical, writing at the beginning of his interactive career, he (1985:20) stated that he dreamt of a 'composition [that] is transformed into music through physical exploration of the space'. His work consists of a large list of

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[65] See: http://www.infomus.org/Research/Vscope.html [accessed 10.12.08].
[66] A wireless method for PDAs or laptops that a person can carry around in a space to define the position of that person in a building or to activate different elements in a room for example websites or lighting (see writings such as Hightower & Boriello 2001).
[67] See: www.mobilebristol.com/PDF/MobileBristol-2003-03.pdf [accessed 14/10/09].
[68] Many other ultrasonic systems have been (technically) described in the literature such as Auer *et al.* 1996, Flety 2000, McCarthy & Muller 2003.

installations[69] but he is probably most renowned for his interactive environment and installations called 'The Very Nervous System'. The VNS evolved during a period of over a decade from 1982 onwards, using firstly various hardware technologies such as 'video cameras, logic chips for image processing, computers, synthesizers, and a sound system to create a space in which the movements of one's body create sound and/or music'[70]. Rokeby's dream is realized in this version of the VNS when he states:

> With my computers, cameras, and synthesizers, I present a synthetic reality which can be physically explored. The phenomena through which the underlying principles of this 'reality' are articulated are the sound events. The phenomena are instigated by and related to various aspects of the dynamics of the movements of the 'explorer'. (Rokeby 1985/86)

In 1999 he developed the real time motion tracking software 'SoftVNS'[71] as toolbox for Max/MSP to process video in real time using a video camera as the data input device. Like the interactive dance floors mentioned earlier, the SoftVNS software, when used in a dance context, can represent the floor as a square on the computer screen (or, by drawing lines in the software, an irregularly shaped grid), by hanging the camera on the ceiling. The area seen by the camera lens becomes the 'active' area. Or, by putting the camera in front of the stage, a cone shaped horizontal or diagonal sensitive area is formed (see fig. 10 on p.102) much in the same way as the beams discussed earlier. Through changes of light condition, caused by moving body parts, the software analyses the amount and/or presence of motion by splitting these camera areas into different freely assignable regions.

SoftVNS also was not originally developed for dancers. Rokeby (1985/86) notes that the relationship between movement and sound is obscured by the complexity of the system and therefore 'resists absolute analytical comprehension'. He is also of the opinion that it is very hard to repeat a movement in exactly the same way, an observation that could deny the

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[69] See: http://homepage.mac.com/davidrokeby/installations.html [accessed 25.07.08].
[70] From: http://homepage.mac.com/davidrokeby/vns.html [accessed 25.07.08].
[71] See: http://homepage.mac.com/davidrokeby/softVNS.html [accessed 25.07.08]. Note: SoftVNS was originally downloadable as VNS, VNSII and VNSIII. See: http://www3.sympatico.ca/drokeby/vnsIIsoft.html [accessed 03.06.09].

SoftVNS as a choreographic tool. However, Tod Winkler, a composer and multimedia artist, did soon recognize the wide array of possibilities that camera tracking offered for an investigation of how musical material could be shaped and structured by body movement. Whereas Rokeby (1985/86) stated 'I present a synthetic reality which can be physically explored [by the viewer]', Winkler (1997:2) puts this in a performative context as: 'Rather than approach the project with a preconceived notion of a type of music that the dancer would "play," we began with several months of improvisation so that our artistic decisions would naturally evolve out of a spontaneous, physical understanding of the system'.

These citations show evidence of a new research question evolving: how can the interactive relationship between movement and sound become an action that can be understood by an ease of execution, and how do new technologies influence or inspire new collaborative and artistic concepts?

Winkler (1995, 1998a and b) shows us an attempt to analyse the relationship between movement and sound relating to the fact that the technology as well as the body have limitations and constraints in the same way as a musical instrument. In a musical instrument timbral characteristics will not only be formed by specific playing techniques, but also by the applied material, weight, pressure, speed and range. The effort and energy that is needed to play a musical instrument is reflected in the sound. Winkler investigated similarities to this musical hypothesis in an effort to turn the moving body into a musical instrument. He identified physical properties, for example body actions that can be characterized 'by ease of execution, accuracy, repeatability, fatigue, and response' (Winkler 1995:2), and external properties like the limited sensitized stage space that restricts speed and direction of movement (see also 6.2). Winkler identified and categorized a wide range of 'logically' felt possibilities in the mapping of movement to sound and explored many different mapping processes. However he also stated that 'By being aware of these laws [of physics], it is possible to alter them for provocative and intriguing artistic effects, creating models of response unique to the computer' (*ibid*:3).

Early video tracking software such as VNS was generally able to detect the following movement parameters: presence or absence of motion, movement dynamics, body position in the sensitive area and path of travel in 2D. In 'Dark Around the Edges', Winkler, in collaboration with performance artist Walter Ferrero, used 'precise robotic and repetitive movements creating rhythms with machine and percussive sounds and slow, fluid movements producing thick evolving sounds continuously altered by speed' (Winkler 1998a:471). In 'Songs for the Body Electric', a collaboration with choreographer/dancer Gerry Girouard and designer Stephen Rueff, lighting and video cues triggered the SoftVNS software that is very sensitive to light changes (*ibid*).

Richard Povall used the software package 'Big Eye', developed by STEIM (NL)[72], in his work in the mid-1990s. It translated the incoming movement data from the video camera into MIDI for further processing in Max. 'Big Eye' was not only able to track the camera image wholly or partly, but also able to process color tracking. Like softVNS, this software could split the stage into subdivisions. Povall collaborated in a number of movement-based camera tracking projects such as 'The Secret Project'[73] (1999-2001) [74] and 'The Last Garden' (1993)[75] in which real time interactive video images, sound, and texts were created.

In the software package 'Eyecon'[76], developed by the company 'Palindrome'[77], a path of travel in 3D, proximity of multiple dancers to one another (using colour recognition), degree of symmetry in the body on the horizontal plane, and degree of expansion or contraction in the body were added to the detection of the movement parameters. Palindrome was particularly focused on some form of clearly observable interaction between movement and sound for the audience. Frieder Weiß *et al.* (2000) from Palindrome put forward the following statement: 'While too strict a coherence is banal, clearly too subtle a correlation fails to be truly interactive, and the audience is left out of any genuine experience of interactivity'. Here we observe a clear acknowledgement of the effect that the performed interactivity might have on the audience. In Palindrome's 'Seine hohle Form' (2000), a 'musical synthesis

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[72] See: http://www.steim.org/steim/bigeye.html [accessed 26.09.08].
[73] See: http://ahds.ac.uk/ahdscollections/docroot/dpa/callabauthorsdetails.do?project=30&author=42&string=SPovall [accessed 25/0-7/09].
[74] See: http://ahds.ac.uk/ahdscollections/docroot/dpa/callabauthorsdetails.do?project=30&author=42&string=SPovall [accessed 25/0-7/09].
[75] The camera tracking software was developed by Lovell & Mitchell 1995 (see also pp.73 and 96).
[76] See: http://www.frieder-weiss.de/eyecon/equipment.html [accessed 23.07.08].
[77] See: http://www.palindrome.de/pps.htm [accessed 23.07.08].

environment that provides many control parameters, addressing a number of custom-built DSP modules that include granular sampling/synthesis, additive synthesis, spectral filtering, etc.' was built (Rovan *et al.* 2001:47). In this piece several scenes were performed in which spatial extensions of the body triggered appropriate (according to the collaborators) sounds. For example, a wide movement triggered loud, aggressive granular synthesized sounds, or small movements triggered quieter sounds. The height of the dancer was used to control a spectral filter producing a thinner and more continuous musical texture. A clear correlation between the technology used and the choice for the spatial artistic input can be observed. However, relating to the sound output, Palindrome still concluded:

> [...] our current process for gestural mapping could be improved by creating a clearer hierarchy among the parameters that govern relationship between the video-tracking system (EyeCon) and the sound synthesis software (Max/MSP). In particular, we are working to segregate more clearly the tasks that are assigned to each component of the system. (Rovan *et al.* 2001:48)

Several other motion tracking camera systems have been developed, such as 'Cyclops'[78], 'Eyes'[79] (see p.81) or 'Pfinder'[80], offering additional mapping options. For example, in the 'Dance Space Environment[81]' using 'Pfinder' by Paradiso & Sparacino (1997b), the body is transformed into a musician's combo with the hands and feet playing different musical instruments. The height of the body parts was assigned to pitch control, whereas the head was assigned to volume control.

Some of these camera tracking systems are very popular amongst artists because they are cheap and only need a (simple wide angled) camera and a programming environment like Max, Pure Data (Pd)[82], SuperCollider[83], Open Sound World (OSW)[84] or Isadora[85]. Unfortunately camera tracking systems

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[78] See: http://ericsinger.com/cyclopsmax.html [accessed 13.07.08].
[79] See: http://www.squishedeyeball.com/ [accessed 07.07.08].
[80] See: http://www.nbb.cornell.edu/neurobio/land/OldStudentProjects/cs490-95to96/sadahiro/cs490rpt.html#pfinder [accessed 10.12.08].
[81] For more information on the 'Dance Space' environment and 'Pfinder' see http://www.research.ibm.com/journal/sj/393/part1/sparacino.html.
[82] See: http://wwwcrca.ucsd.edu/~msp/software.html [accessed 26.09.08].
[83] See: www.audiosynth.com [accessed 26.09.08].
[84] See: http://osw.sourceforge.net/ [accessed 26.09.08].
[85] Isadora is a realtime media manipulation software package, invented by Coniglio from Troika Ranch, and is an important motion tracking application in

can suffer from occlusion, need special lighting conditions (except when an infrared camera is used) if the tracking is to maintain consistency, require a lot of time to set up, and put severe limits on the size of the data-sensing space that is dependent on the position of the camera.

3.1.2 Body Part Motion Capacity and Personal Space Tracking

Following the outcome of the 'Moving Body Part Tracking' investigation on musical interface design (2.2.4), this section introduces the second parallel line of measurement techniques used in movement based projects: 'Body Part Motion Capacity and Personal Space Tracking'. This technique defines measuring the body movement capacity of different body parts within the personal space of the body, i.e. the space that the body can cover when outreaching the limbs and that is bound to the motion of the whole body in general space (see 4.2.2 for an in depth analysis of the 'personal space').

The discussed techniques are classified as:

- Wired Up
- Motion Capturing the Skeleton
- Gesture Detection accessible for Artists

3.1.2.1 Wired Up

In the early 1990s, several artist collectives developed body part motion sensing systems. Troika Ranch was mentioned earlier (p.40) when discussing 'The Laser Web', a body motion and location tracking system. However, the very first system that the company developed was a wireless device called 'the MidiDancer'[86] (1994). This electrical bodysuit had to be attached to one or more dancer/s and consisted of up to eight plastic fibers that measured the flexion and extension of the major joints on the body. Body shape was analyzed by measuring the angles of arm, leg, and hip joints. The derived data signals were broadcast wirelessly by Radio Frequency signals to a computer and transformed into computer code that controlled theatrical equipment like video cameras or digital sound devices. Troika Ranch stated that they hoped to enrich the dance performance environment by providing

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dance and technology performance. See: http://www.troikatronix.com/isadora.html [accessed 20.07.07].
[86] See: http://www.Troika Ranch.org/mididancer.html [accessed 20.07.08].

the dancer with a real time interactive opportunity to influence computer media.

In the first project using 'the Midi Dancer', called 'In Plane' (1994), the performer controlled 'the generation of music, the recall of video images, the theatrical lighting, and the movements of a robotically controlled video projector'[87]. In this piece the virtual element 'disembodiment' (see also 4.1.2.1) was observed when the dancer was dancing with a real time transformed image of herself on the video screen. Troika Ranch refers to this effect as an emphasis on 'the limitations of both entities: the human performer, bound by time and gravity, and her video dopplegänger, limited by its inability to enter the corporeal world'[88]. In retrospect Stoppiello & Coniglio (2003) concluded that the synchronous 'One-to-One mapping'[89] procedure (they called this technique the 'bleep-blop' method) did not really add to the complexity and subtlety that they had envisaged. They refer to the complexity of the mapping procedure that arose at the early stages of their experimentations, and that still continues to challenge contemporary artists trying to find a satisfying equilibrium between Art & Technology.

A subsequent electronic system, the 'Digital Dance System' developed at DIEM[90] (1999), also communicated wirelessly through Radio Frequency and implemented up to 14 bending sensors that also measured the angles of the dancer's limbs (the distance range of the system is not specified). In 'Movement Study II' (1997-2001) by DIEM, changes in angles of the ankles, knees, elbows and wrists of the dancer influenced the volume and frequency spectrum (brightness) of various tonal and rhythmic sounds produced by the computer. The dancer was also able to determine the speed of a prepared computer composition when a certain number of bends were accomplished. In this piece a clear compositional structure is observed, however, the relational concept between the bending of certain limb and the choice for a certain sound effect is undetermined. Wayne Siegel, director of DIEM, concluded that the dancer possesses 'a certain amount of freedom of movement as well as

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[87] From: http://www.Troika Ranch.org/wrk/inplane.html [accessed 20.07.08].
[88] From: http://www.Troika Ranch.org/wrk/inplane2.html [accessed 20.07.08].
[89] A single control device corresponding to a single musical (synthesis) parameter (Hunt *et al.* 2000b).
[90] See: http://hjem.get2net.dk/diem/products.html [accessed 20.07.08].

expressive control of the music without requiring excessive concentration on instrumental performance'[91].

In the projects directed by Troika Ranch and DIEM the dancer and choreographer were one and the same person because, in the companies' opinion, it transpired that the best artistic results could be achieved by the person who had experienced the movement experimentations him/herself. Siegel states that 'the dancer is placed in an entirely new situation, with the responsibility of interpreting both musical and choreographic ideas and integrating them into a single work'[92]. However, in 'Sisters' (1998), another project by DIEM, the choreography was developed first before a collaborative process started in which sound and choreography developed together.

A later system called 'PAIR and WISEAR' (Topper & Swendsen 2005) is a Linux based sensor system array. In contrast to earlier systems it is focused on tracking the local distance interaction of two or more dancers, measuring touch, proximity and what they call 'focus', i.e. when the dancers are separated by a large distance. They attach force sensing resistors (FSRs), Infrared sensors and accelerometers to hands, body or head. The technical disadvantage of 'PAIR and WISEAR' is that proximity tracking over the distance range for dance performance, mainly the maximum or minimal range of the stage, is not fully solved with the system. Unfortunately I have not been able to find any writings about the artistic use of this system.

By citing these electronic sensor systems I aim to show that in interactive music/sound and dance performance moving body part tracking was initially treated in much the same way: the measurement of the hands and fingers of a musician who plays his/her musical interface or measurements or the activity in the limbs of a dancer to trigger digital sounds in the computer.

3.1.2.2 Motion Capturing the Skeleton

Since the early 1980s[93] Motion Capture (MoCap)[94] systems have been developed primarily to design computer character animations for the film

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[91] From: http://hjem.get2net.dk/diem/notes-mvst.html [accessed 20.07.08].
[92] From: http://hjem.get2net.dk/diem/notes-mvst.html [accessed 20.07.08].
[93] For some history writings about Motion Capture see sites such as aph.org/education/materials/HyperGraph/animation/character_animation/motion_capture/history1.htm and http://www.measurand.com/motion-capture-resources/motion-capture-history.htm [all websites accessed 26.07.08].

industry or bio-mechanic research[95]. MoCap systems can measure the kinetics, acceleration, speed, rotation, and relative displacement of different body parts with high precision and a very fast update rate[96]. However, it is very costly to deviate from the initial intentions of MoCap systems: limited access, the time that's needed for calibration and the extensive software programming can slow down the research progress and consequently raise the costs. Therefore, access to MoCap systems is in general very hard to achieve for artists. Apart from this, the systems suffer from occlusion and need a specialized (expensive) engineer to operate the system, correct the multiple generated errors for which MoCap system are notorious, and interpret the dataflow. A single sensor misreading might cause the computer to believe that the actor's arm was pointed straight up into the air for a fraction of a second, for example, when it was not. On top of this the sensitive range of MoCap is very limited (normally 3X3m) and the system can be highly sensitive to walls and obstructions. Therefore, a broad artistic analysis of the use of Motion Capture systems is missing in the available documentation that widely concentrates on historical and technical facts.

One of the few occasions that artists had access to a MoCap system (the Gypsy[97]) was in a Motion Capture Art-Tech Laboratory called 'Real Time and Networked: Sharing the Body' (2002) in which several dance and animation artists joined with a technical engineering crew. Scott deLahunta (2003) states in the report about this workshop that a clear distinction between artistic and commercial or scientific research exists. This was shown during the laboratory when 'in more than one instance accidental data was being explored through, for example, the conscious occlusion of some of the

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[94] MoCap systems are either magnetic or optical and passive or active. See systems such as Vicon http://www.vicon.com/products/systems.html, Eagle & Hawk http://www.omegasystems.cl/nota_ver.asp?id=79
Reactor http://www.ascension-tech.com/products/reactor.php#specs,
Flock of Birds http://www.evl.uic.edu/core.php?mod=4&type=1&indi=179 or Liberty, Patriot and Fasttrack http://www.polhemus.com [all websites accessed 26.07.08].

[95] The predecessor of Motion Capture was 'Rotoscoping' a movement measurement application used by Walt Disney in the film 'Snow White'. Rotoscoping was invented in 1914 by Max Fleischer. See for example: http://www.lazymovie.com/rotoscoping-saga.html [accessed 12.07.08].

[96] An explanation of MoCap data and suggestive ways to use these systems can be found at Geroch 2004.

[97] See: http://www.metamotion.com/gypsy/gypsy-motion-capture-system.htm [accessed 27.07.08].

reflectors for the optical system and the proposal to use an alternative calibration for the Gypsy' (*ibid*:2). These are not trivial strategies but 'the conditions from which unexpected creative forms are going to emerge [...]' (*ibid*:2)[98]. In a more general Art & Technology context this view is shared by Joke Brouwer *et al.*:

> Artists generally prefer to use technologies of which standardized, commercial versions exist, but they also investigate how these technologies can be used, distorted and shifted in original ways in order to further artistic research. (Brouwer *et al.* 2005:6)

Several artistic projects using MoCap systems will be described later when discussing the software programming involved (3.2).

3.1.2.3 Gesture Detection accessible for Artists

Whereas the previously mentioned camera based systems (3.1.1.3) were applied for full body motion recognition, Camurri *et al.* (1997) developed freely downloadable software for the video capturing camera called 'EyesWeb'[99] (PC only) at the InfoMuslab that resembled the capturing possibilities of Motion Capture system. The 'EyesWeb' platform was developed not only for real time full body motion measurements but also for gesture detection within the personal space of the dancer's body. In EyesWeb a 12-point 2D virtual skeleton is imposed onto the body as seen by the camera. The software is based on a number of stereotypical and coarse posture recognitions that are programmed by different feature extraction algorithms that register the velocity peaks of a gesture. Several of these predefined posture classifications are categorized and sent to a self-organising neural network (see also 'Gesture Recognition' 3.2.1). Neural networks are based on the memory abstraction and processing of human information (Smith 2001). Used in interactive systems the computer is in this way able to adjust and react to the gathered information in the software programming, adding another layer to the human-computer interactivity: the non-trivial form of

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[98] Such errors were used to great extend when the ReActor MoCap system caused hilarious effects during a childrens' workshop tutored by the author at Essex Dance, Chelmsford, UK in 2004. See: http://www.essexdance.co.uk/pages/dtech.htm [accessed 28.07.08].
[99] See: http://www.infomus.org/EywMain.html [accessed 25.07.07] and http://www.audiovisualizers.com/toolshak/vjprgpix/EyesWeb/EyesWeb.htm [accessed 25.07.07].

interactivity as defined by Ascott (see p.23). 'Art as Process' was enhanced with truly interactive computer processes that were easily available to artists.

3.1.3 Summary 'Data Measurement Methods for Body Motion'

In the previous section an overview of interactive technologies and movement-based performance projects has been described from an artistic, engineering, and computer scientific perspective. It was outlined that the use of these technologies had a major impact on the possibilities for artistic development due to the following elements:

- Technical specifications and shortcomings such as the sensitive range and dimension of the system, the data resolution, speed of the data transfer, particular lightning conditions and occlusion.
- Access and availability.
- Financial implications like renting studio space and the needed operational expertise.
- The limited available research time due to set up time, computer programming, testing and calibrating and, last but not least, training of the involved performers.

These body motion measurement methods are related to the two formerly mentioned sonic gesture data measurements. The invented body motion measurement technologies were categorized into two data collection methods:

- Body Motion and Location Tracking techniques.
- Body Part Motion Capacity and Personal Space Tracking techniques.

Apart from the review of these technologies, a wide range of interactive body motion research projects have been described with their accompanying mapping methodologies. It was shown that a multitude of choices have to be made to realize the wide range of possible artistic outcomes. Therefore, in the next section a closer look is taken at a more specific data mapping methodology with the aim of trying to analyse a closer correlation between body movement and sound.

3.2 Choreography in Computer Code

As shown in the previous sections (3.1.1.3, 3.1.2.2 and 3.1.2.3), creating software code for interactive movement purposes gradually became more prominent than the need for the invention of new hardware devices. Computer programmers and electronic engineers try to find new mathematical formulas and technical solutions to improve the technology that is able to digitize human movements. These can be applied in interactive dance and music performance when using a MoCap or a camera based tracking system such as the previously mentioned 'EyesWeb' system. This suggests a certain abstract relationship between interactive movement and digital sound.

The next section observes the developments of a number of engineering and mathematical concepts in the gesture recognition and motion analysis field that can be applied for the creation of new software for the mapping process of dance movements to digital sound. These developments are conceptualized within the artistic context of this thesis by including the views of several artists with regard to how these mathematical ideas can be useful for the development of interactive dance performances.

3.2.1 Gesture Recognition

The research topic of gesture recognition in computer science has the goal of interpreting human gestures via mathematical motion analysis algorithms. In order to discuss the term 'gesture recognition' it is essential to first make clear that the term 'gesture' can have different values and meanings depending on context.

In general terms a gesture can be considered as any time variant change in the state of a part of the body with the intention to emphasize speech[100]. In line with this view, Wilson (2000:10) states that a 'gesture' in human movement is commonly defined as a meaningful 'communicative human movement' such as pointing your finger at somebody, making a peace sign or the typical use in sign language. In a musical context, Wanderley (2001:23-38) classifies gestures as based on either the function that a gesture presents in a certain context or on the physical property of the performed gesture. He states that composers, musicians, conductors and electronic musicians all have different ideas on the term gesture ranging from (figuratively speaking) 'a movement of thought', a functional or ancillary movement to play an instrument or an isolated movement that relates to a specific physical performance to activate different sensors of an interface. In dance a gesture is often considered to be 'an action confined to a part or several parts of the

[100] For a general definition of a gesture see: http://www.allwords.com/word-gesture.html [accessed 13.08.08] or http://www.thefreedictionary.com/gesture [accessed 13.08.08].

body' (Maletic 1987:165). In an interactive movement-based sound environment, Rovan *et al.* (2001) define the term 'choreographic gesture' as a control component for the music composition/performance. In the same way, gesture recognition[101] can be approached from various angles and viewpoints such as artificial intelligence, robotics, music, dance, computer animation, or as commands in a game controller.

The initial aim of research into gesture recognition was to improve the digital representation of human movement in the computer. Badler & Smoliar (1979) present three different early animation models of the human body. I summarize these as follows:

- Stick figures display the body as a network of body segments with the joints articulating the body. This model is a very 'stiff' and primitive abstraction that displays the body with a few longitudinal axis.
- Surface models display a planar composition of the surface of the body. This model visualizes a more accurate abstraction model that makes it possible to display rotations and provide the proper occlusion and depth effects. However, this model has a very high computational cost and is unable to adjust the individual volumes of the moving body parts that move synchronously.
- Volume models decompose the body in several primitive volumes such as cylinders, ellipsoids or spheres. This model represents the body as a 'spherical decomposition' that generally results in a 'bumpy' texture on the edges of the image.

In order to avoid discussing all nuances of the developments of computer animation (which is beyond the scope of this thesis), I will concentrate on the fact that these early models introduce us to several motion analysis models that have been applied for gesture recognition in the interactive dance and music field.

3.2.2 Motion Analysis Algorithms

In the motion analysis field, computer scientists Ming-Yang Wu *et al.* (2004) present algorithms based on the indexing of skeletal segments of full body posture features. These are matched to comparing recorded clips to be able to compile a motion collection in the created 'content-based human motion retrieval system' (*ibid*). The physical constraints of a human being are explored in a sequence of skeleton data that move from one frame to the

[101] For general information on the topic gesture recognition see: http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/COHEN/gesture_overview.html [accessed 20.08.08].

next. The testing uses a MoCap system that de-fragments Tai Chi Chuan movements. They point out the different procedures and choices they incorporate in their computer programming to enable them to test the algorithmic ideas. This 'de-fragmentation' process consists of setting thresholds and boundaries of the data measurement method, decomposing the spaces of the skeleton into smaller parts, and making a choice out of the derived data (color, texture, shape and motion). The researchers state that the results of this investigation can be used in many applications such as visual surveillance, diagnosis and therapy for rehabilitation, athletic training, person identification, and animation generation.

In a musical context, Paul Modler *et al.* (2003:149) describe a gesture recognition process that was developed for the recognition of the expression of hand gestures to control musical parameters in real time. A Time Delay Neural network (TDNN) architecture, that was originally developed to recognize phonemes, learns a set of hand gestures that are captured by a video camera. The motion analysis of the gesture recognition in this artistic context was realized with setting several thresholds and applying filtering to the captured images, much in the same way as in the above mentioned scientific research framework by Wu *et al.* As a result, different audio samples were triggered in jMax[102].

Erin Manning (2006) states that, to be able to realize a mapping process using a motion analysis methodology as described above, most practitioners of dance and technology specify a gesture as having a beginning and an end. In line with this view, Coniglio presented in his talk at the 'Motion Bound' Symposium (Chelmsford, UK, 2005) his view that the body points generated in the 'EyesWeb' software (see p.51) generate a particle system consisting of little 'objects'. These 'objects' create a kind of organic analogy between the body and the computer. He imagines that looking at and memorizing how a point moves in space and how it moves in units in time, defines a point of departure and a point of arrival. This categorical movement form can be used as the starting point for the design of a computer algorithm for gesture analysis. Continuing from these ideas, Wilson describes the use of this concept for gesture recognition by the computer:

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[102] jMAX is a visual programming environment for building interactive real-time music and multimedia applications. See: http://freesoftware.ircam.fr/rubrique.php3?id_rubrique=14 [accessed 02.06.09].

> The condensation algorithm [exploiting particle filtering] is attractive for its simplicity: it requires only a likelihood function which evaluates a point in model parameter space and a propagation method which updates each point to the next iteration. (Wilson 2000:100)

To be able to span the range of human gesture, Benbasat & Paradiso (2002) add to this view a description of a categorization of human movement into 'atomic gestures'. These are gestures 'that cannot be further decomposed, and which can be combined to create larger composite gestures' (*ibid*:88). Atomic gestures are defined by looking at the contained peaks of the movement and 'thereafter, any gesture of interest can be synthesized from its atoms' (*ibid*:88). This analytic approach was taken to make their algorithms efficient in measuring rotation and acceleration within the proposed gesture recognition process. Algorithmic models that can be used are 'direct data stream analysis' that processes the data after the parameters for gesture recognition have been chosen, or a 'Hidden Markov Model' that is defined as a 'framework for the automatic learning of gestures for later recognition and which use a multi-step search using expectation-maximization of gestures' (*ibid*:90).

A similar neural networking learning method was described above (p.55) when referring to Modler's hand recognition research project. However, Benbasat & Paradiso (*ibid*:86) note that several time based limitations are important to observe if the described system is to be used in a dance environment. I recapitulate these as follows:

- The lack of an absolute reference frame to be able to track body orientation relative to a fixed frame for longer than approximately five seconds.
- The system cannot track multi-dimensional gestures, except for those that are separable in space and time.
- Constraints imposed by the algorithms used for body motion analysis and gesture recognition.

Tian-Shu Wang *et al*. (2001) from the Artificial Intelligence and Robotics Lab and Microsoft research centre in China present a similar method for automatically indexing a continuous sequence of gestures. The researchers make two assumptions about the definitions of a gesture. Firstly, they take the position that a gesture can be identified by a categorization of the presented repetitive body movements. They identify these repetitions by using Hidden Markov Models that divide the sequence of movements into 'atomic gestures', i.e. a dynamic segmentation or 'splitting up' process of the recorded gestures. Secondly, they presume that the velocity of a movement changes when the type of gesture is changed, generally in an abrupt fashion. These two features of a gesture are stored and labeled in the computer and compared with new gestures to digitally identify the presented gesture. Finally, the researchers carried out a test on recognizing musical conducting gestures and allocated words to distinct gestures. It was shown that their algorithms could successfully segment and label continuous human gestures. However, they admit to the limitations of the system that is not able to extract a definite lexicon from the sequences of human motion.

3.2.3 Choreography as a Composition of Atomic Gestures

When the gesture recognition models described above (indexing of posture features of skeletal segments, defragmentation, particle division, likelihood function, dynamics categorization and atomic gestures) are transferred to dance performance, Kris Hollands *et al.* (2004:1) state that the kinematics of the movement patterns 'exhibit a great deal of subject- and context-dependent variability that are not easily analysed using conventional event identification techniques'. They describe a kinematic dance research with the Vicon Motion Capture system in which they apply a 'Principal Components Analysis' (PCA) algorithm commonly used for gate analysis to try to identify the kinematics of a contemporary dance movement pattern. PCA categorizes a small number of movement elements in an attempt to sufficiently describe the original variables in a movement pattern. The testing of their motion analysis method involved a dancer who had to choose three reference points in space that were meant to be touched during a self-created dance phrase. This phrase incorporated whole body translations such as rotations and twisting of the body, hands, and arms that were required to reach the three chosen points. As a comparison a second dancer had to repeat this movement phrase. Hollands *et al.* concluded that, to a certain degree, it is possible to reduce dance movements to a small number of components by using the PCA algorithm. However, they also state that the value of reducing the dimensionality of complex movement patterns remains to be seen because dance patterns are not always easy to interpret. In agreement with this view, Manning (2006) also states that: ' "Mapping" gesture risks breaking movement into bits of assimilable data, of replicating the very conformity the computer software is seeking to get beyond'. Manning 'seeks to explore the technogenetic potential of the *wholeness* of movement, including its "unmappable" virtuality' because a body is an interconnected living being, the whole system resonates when one part is moved (*ibid*). She also stresses the importance of including the pre-acceleration of a movement (or the tendency to move) in a gesture[103].

It could be seen that a similarity to this phenomena in sound can be recognized in the act of playing musical instruments, where 'shadow notes' create the flux, timing, or the rhythmic flow of the notes that are truly being played, and also in 'ancillary gestures' of a musician that do not necessarily produce sound (see Wanderley 2001:93-134). However, it would be very complicated to find an interactive artistic relationship between these two shadow issues due to the fact that a very precise tracking system is needed to record these extremely subtle body movements and that the system should be able to communicate these data real time at a very high speed to the digital sound format.

In the following section, it is investigated how to avoid losing the exact flow, timing and rhythm of the artistic expression when dividing dance movements into measurable sequences of gesture for the benefit of the data communication to the computer.

3.2.4 Expressive Content

Don Herbison-Evans (2003) describes the use of the computer in dance as mainly administrative, that is, for dance notation (such as Benesh 1955[104] and Laban 1928[105]) or stage lightning cues. However, he briefly touches upon an interesting artistic question concerning the digitalization of human dance movement:

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[103] This element of a gesture was researched in the Dance and Technology field in 2004 by Armando Menicacci *et al.* They were named 'shadow forms' in a demonstration at the conclusion of the workshop 'Extending Perception TECH LAB' that I visited at the Monaco Dance Forum in 2004. In the preliminary research undertaken in this workshop, dancer Stoppiello from Troika Ranch (see p.39) was wearing sensors attached to her spine on the spots from whence her movements were presumed to be initiated from and which were thought to be necessary to make the intended movement.

[104] More information about Benesh dance notation can be found at the Benesh Institute in London: http://www.benesh.org/BNBNE_Whatisbne.html [accessed 02.087.08].

[105] An impression what the notation looks like and how the notation analyses movement can be found at: http://user.uni-frankfurt.de/~griesbec/LABANE.HTML [accessed 02.08.08].

> There is a long way to go before we understand movement well enough to synthesize computer graphic dancing figures with any aesthetic value. (*ibid*)

Indeed, several questions remain, such as how the system can distinguish between various styles of dance, sense the quality of movement in the computer, define a gesture, how long it is, what the expressive content of a gesture, of movement is etc.

The ongoing research of the developers at InfoMus lab (see p.41 and p.51) concentrates on this analysis of the emotional expressive content in human gestures, as a non-verbal communication method related to feelings, moods, affect and intensity of emotional experience. The research combines 'a scientific perspective (i.e. a deeper understanding of non-verbal communication channels), an engineering perspective (i.e. building enhanced and effective interactive systems for several application domains), and an artistic perspective (i.e. exploiting the means technology provides in order to enrich language and to pioneer novel art forms)'[106]. The main goal is the integration of movement, music, and visual languages in order to design novel paradigms of interaction, mapping strategies, and multimedia interfaces grounded on the real-time multimodal analysis and synthesis of expressive content in music, gesture, and visual languages. The artistic perspective focuses on studies and tests of computational models of expressive gesture[107] mainly in dance and music performance. It is stated that this artistic form in particular uses non-verbal communication mechanisms to convey expressive content.

The lab develops projects like:

- HARP (Hybrid Action Representation and Planning) that introduces the idea of developing Multi Modal Interactive Systems (MISs) in environments in which the user can communicate audiovisual materials interactively to either other people that are participating in the event or to other external spectators. The sensors are chosen according to the type of information that is needed (Camurri *et al.* 1995).
- KANSEI that introduces the idea of involving the Space and Time

[106] From: http://www.infomus.dist.unige.it/EywDefault.html [accessed 01.09.08]. Note: firstly click the link 'Research' and secondly 'Expressive Gesture'.
[107] See: http://www.infomus.org/Research/ExpressiveGesture.html [accessed 02.08.08].

theories of Laban that relate to movement[108] in order to estimate human movement for real time analysis (Camurri *et al.* 1997 & 1999).

- MEGA[109] (Musical Expressive Gesture Applications) that concentrates on gestural control to be able to interact with the sound processing engine that is integrated in EyesWeb (Camurri *et al.* 2004).

InFomus Lab has realized a wide array of (collaborative) artistic ideas in numerous interactive installations, performances, demonstrations, music theatre productions, robot interaction performances, and games using the 'EyesWeb' platform[110]. However, the disadvantages that apply to camera tracking systems (see p.46-47) have unfortunately not yet been solved with the 'EyesWeb' platform.

3.2.5 Gesture Recognition for Artistic Purposes

A Motion Capture system can provide the artists with a significant means to enhance the choreography of performers. It was previously remarked (p.50) that it is unfortunate that a broad cultural analysis of the use of Motion Capture systems has not been carried out, and therefore any descriptions of the artistic practice of gesture recognition algorithms are widely lacking. However, some projects have been realized by artists who did recognize the benefits of choreographing in digital space, such as the possibility to be able to design movement phrases taking place in difficult body positions and from impossible perspectives. These projects involved recording the MoCap data (real time processing was not possible at the time) and processing these data in software packages like 'BIPED'[111] a version of Character Studio[112] (in 'BIPED' by Cunningham 1999) or 'Life Forms'[113] (in 'Trackers' by Cunningham

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108 The movement theories of Laban will be discussed in relationship to spatial sound mapping later in this writing (sections 4.2-4.4).
109 See: http://www.megaproject.org/ [accessed 15.08.08].
110 See: http://www.infomus.dist.unige.it/EywDefault.html [accessed 16.08.08]. Note: click the link 'Events and Activities'.
111 See: http://merce.org/thecompany_r-biped.html [accessed 26.07.08].
112 See: http://www.the3dstudio.com/product_details.aspx?id_product=3637 [accessed 13.08.08].
113 Life Forms 'Studio Animation' and 'DanceForms Choreography' are commercial software packages with tools for editing motion captured data. The first package is able to design 3D character animations and the second to visualize and notate entire dance scores, complete with music integration for choreographers. deLahunta (2002) describes this practice of creating artform with the computer as coding as creative practice.

1990). The MoCap data were used to design the choreography of animated dancing figures that accompanied the performance on a video screen.

Choreographer Myriam Courfink[114] (in collaboration with performing art researcher Rémy Muller) presented her interactive project 'This is my House' during the 'Choreographic Computations' conference[115] (deLahunta & Bevilacqua 2007). The choreography consisted of a predetermined score that was displayed on computer screens above the dancers' heads. The order of this score was interactively determined by using the MoCap data derived by moments of gesture recognition of the dance movements.

It is beyond the scope of this writing to fully describe the choreographic projects that evolved from the use of MoCap data and I therefore refer the reader to several writings of Scott deLahunta (2001, 2002 & 2003). However, one of the few experiments that investigated gestural control of sound using a MoCap[116]system is described in several papers by Frédéric Bevilacqua *et al.* (2001, 2002, 2003 a, b & c) and Christopher Dobrian & Bevilacqua (2003). In their work, Motion Capture data were processed in an early version of MnM[117] (Motion Capture Music), a toolbox for Max/MSP for use with the Vicon MoCap system. MnM uses the previously mentioned PCA algorithm (p.57) to make it possible to map gesture to sound. The software tools are based on vector manipulation in defined matrices and use PCA to reduce the dimensions of the performance space to simplify the mapping procedure (Bevilacqua *et al.* 2005). MnM is dedicated to computer learning methods and more specifically to mapping motion data to any sound parameter in MIDI format[118]. Body data were captured by tracking up to 33 points on the dancer's body (generating 99 parameters in 3D) and used for sound generation. Bevilacqua *et al.* show

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[114] Courfink investigates computer choreography exploring micro-movements and challenging conventional notions of dance. See: http://www.myriam-gourfink.com/ [accessed 13.08.08].

[115] See: http://recherche.ircam.fr/equipes/temps-reel/nime06/workshops.htm [accessed 13.08.08]. Courfink's presentation is documented in audio format on: http://www.du.ahk.nl/nimeworkshop/MyriamRemy.mp3 [accessed 14.08.08].

[116] The project used a Vicon Motion Capture System see: http://www.vicon.com [accessed 25.07.08].

[117] MCMMax is the MnM version developed for the Macintosh. See: http://music.arts.uci.edu/dobrian/motioncapture/mcmmax.htm [accessed 09.08.08].

[118] MnM would have been useful for my research, however, the developments of the toolbox came unfortunately to a halt for reasons unknown to the author and have not been made available to the public.

several example videos[119] in which the distance from different body parts (hands, feet, shoulder) of a dancer to the floor and to each other is captured. These measurements generate changes in pitch, timbre and frequency modulation of synthesis sound, and apply filtering to pre-recorded sounds. The results show the beginning stages of the work, presenting a simple 'One-to-One mapping' layer (see p.48) to demonstrate an evident relationship between gestures and sound. It was decided early on to capture only some of the 33 markers on the body as a first approach. Although Bevilacqua *et al.* recognized the unique power and potential of a MoCap system as being able to devise strategies for mapping many degrees of freedom (DOF)[120] into a meaningful artistic expression, this research also demonstrated the aforementioned difficulties and slow progress of using motion capture data (see p.50).

Another example of sound generation using gesture recognition algorithms is the piece '16 Revolutions' (2006) by Troika Ranch, in which a single video camera on stage is connected to EyesWeb (see p.51) tracking the movement of the torso and the limbs for gesture recognition. EyesWeb was networked using Open Sound Control (OSC)[121] to Isadora. Isadora generates imagery and aspects of the sonic score in real time response to the movement of the freely allocated points of the skeleton[122]. Gesture recognition is applied in subjective terms of 'simple, complex, jittery, angular or less obvious' body gestures. Troika Ranch's latest project at the time of this writing, called 'Loop Diver'[123] (2008), is built around 'interwoven loops of movement, text, music

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[119] See: http://music.arts.uci.edu/dobrian/motioncapture/examples.htm [accessed 29.07.08].
[120] 'Degrees of Freedom' (DOF) is a term meaning a single coordinate used in Kinematics to describe the relative motion between two bodies. Such a coordinate is free only if it can respond without constraint or imposed motion to externally applied forces or torques. A DoF is either a linear coordinate along a single direction (comparable to the six movement planes in Laban movement analysis (see p.80) for translational motion or an angular coordinate for rotational motion.
[121] Open Sound Control (OSC) is a protocol for communication among computers, sound synthesizers, and other multimedia devices that is optimized for modern networking technology. See: http://www.cnmat.berkeley.edu/OpenSoundControl/ [accessed 20.12.2007].
[122] A video section of '16 Revolutions' can be viewed on: http://www.youtube.com/watch?v=Rbv7n0ZgA98&NO.=1 [accessed 14.08.08.07].
[123] See: http://www.Troika Ranch.org/performances.html [accessed 20.07.07].

and interactive visuals'. In this interactive multimedia piece they apply the computer as a 'dictator' that is disturbed by improvisational provocations of the performers. Stoppiello and Coniglio stated during the NIME 2006 conference[124] that the interest of Troika Ranch is not in exactly replicating the input that is sent to the computer, but in having a connection of some kind that can be used artistically. An important interactive element for Troika Ranch is having 'no succession', i.e. the performance will be different every time caused by the movement improvisation (see 4.1.1). This notion takes us back to the beginning of chapter 2 in which interactivity was recognized as 'artistic process' (2.1).

3.2.6 Summary 'Choreography in Computer Code'

In the previous section, various software design methods that can be applied in interactive dance choreography have been described. The discussion reviewed motion analysis and gesture recognition techniques from the perspective of computer programmers and artists involved. Gesture recognition has been approached by either a trajectory-based concept in which curves are considered to be the main recognizable element, or by a dynamic model based concept using Hidden Markov Models. We can conclude that for digital algorithmic purposes the movement of the body is processed as a 'multi sensing' apparatus in the constantly changing environment of separate differences that can be accumulated and added as the total sums of derived numbers. It was shown that a lot of decisions need to be made to be able to test a mathematical concept for motion analysis. Therefore, it is concluded that 'limitation' is a prominent feature of the application of the technology used in interactive art. These limitations were best described in the example of the choices that Bevilacqua *et al.* had to make to simplify the mapping process (see p.62). This example showed that if the artistic context is accompanied by a scientific research context, a lot of mathematical actions have to take place on top of the artistic decisions before it might be possible to map human motion to sound.

However, it was noted earlier (Winkler p.44) that a certain unavoidable limitation is not necessarily counterproductive but opens up other avenues of creative exploration. Rokeby (1998) confirms this view poetically when stating

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[124] Troika Ranch's presentation during NIME 2006 at Ircam can be listened to on: http://www.du.ahk.nl/nimeworkshop/MarkDawn.mp3 [accessed 14.08.08].

that the process of programming (in his own higher-level language) is like creating pathways in a landscape with high mountains and deep valleys:

> The interface defines a sort of landscape, creating valleys into which users tend to gather, like rainwater falling on a watershed. Other areas are separated by forbidding mountain ranges, and are much less traveled'. (*ibid*:8)

Inevitably these pathways would direct his decisions to which interactive elements would be implemented in the software and which would be denied.

Although restrictive or challenging, the results of the investigation 'Choreography in Computer Code' introduced the concept that gesture recognition still has a broad potential for new artistic ideas if the artists are willing to go beyond the software code or the limitations of an 'interactive segmented data body'. However, in line with Hollands and Manning (p.57), I wonder if it may be artistically satisfying to see human (dance) movements in terms of an 'anatomic entity' reduced to 'atomic gestures' for the purpose of computer recognition when undertaking projects of this nature. Considering the fact that I was confronted with the limitations that beset robotic movements (see p.11), I am of the opinion that it is arguable whether it is productive artistically to have to implement a set of reductive mathematical rules to a human body to be able to digitally process the unique expressive qualities of the highly skilled movement artist.

3.3 Summary 'Interactive Movement-Based Projects'

In this chapter, a more or less chronological sequence of the development and strategies for measuring body movement in interactive movement-based projects has been charted. It becomes clear from the reviews and discussions that numerous artistic possibilities arise. The characteristics and limitations of these different technological designs can greatfly vary, and therefore so can the level of interaction between the movement artist and the sonic result.

In chapter 2, I described the early beginnings of the measurement of gestural movement of musical instrumentalists. These artists used similar electronic technologies as those developed for interactive movement-based projects. An analogy was observed between the sonic data measurement methods used in 'Object Location in Space' and 'Moving Body Part Tracking', and the movement data measurement methods in 'Full Body Motion Capacity' and 'Personal Space Tracking techniques'. The invention of above mentioned dance measurement technologies brought forward new possibilities to deepen the artistic relationship between body movement and sound.

Existing technological systems for use in interactive movement-based projects have been analyzed in order to evaluate their strengths and weaknesses. Additionally, a range of projects that emerged from these systems has been reviewed with references to the chosen relationships between movement and sound. The overview in table 1 shows that the correlation between the discussed technology (left) and the artistic outcome (right) is determined by the capabilities of the measuring device, i.e. if the data measurements are versatile and precise more possibilities arise for the mapping relationship.

Flex sensors (MidiDancer, Digital Dance System) • Extension and flexion of joints	*Generation of music, video images, lighting, control of projector, volume, frequency spectrum, various computer sounds*
Metal Contacts (Podoboard) • Position coordinates, velocity	*Foot movements making music*
Pressure / Force Sensing (Magic Carpet, Lifefoot I) • contact, impact force, location, direction	*Pitches of voices, panning, timbre, soundscape*
Radar System (Magic Carpet) • movement direction, upper body kinematics	*Speed, pitch, panning, timbre, soundscape*
Proximity Sensors (Lifefoot II) • Motion, proximity	*Musical scales, timbre, loudness* *Llogistic reasons e.g.* *Dancers keeping in time with the music, synchronize stage lights*
Combination of different sensors (PAIR and WISEAR) • Distance, touch, proximity	*Undefined*
Laser (Laserweb, Smart Wall) • Movement detection	*Music, loudness, light intensity*
UltraSonic Beams (Soundbeam) • proximity	*Manipulating live music*
Wearable UltraSound sensor units (V-scope, LCIPS) • position location, distance	*Soundscape*
Camera Tracking (VNS, Eyes, Big Eye, Eyecon, Cyclops, Pfinder, Eyesweb) • Presence of motion, position, movement dynamics, path of travel, color tracking	*Rhythms, different machine and percussive sounds, lighting and video cues, granular sampling/synthesis, additive synthesis, spectral filtering, loudness, pitch*
Motion Capture (Gypsy, Vicon, Eagle & Hawk, Reactor, Flock of Birds) • kinetics, acceleration, speed, rotation and relative displacement	*Animation, video recordings, pitch, timbre and frequency modulation of synthesis sound, filtering to pre-recorded sounds*

Table 1 Overview of the correlation between technology and artistic outcome.

It was outlined in the introduction to chapter 2 that technical developments are very difficult to keep up with considering the time and effort it takes to incorporate these technologies in the creation of art projects. For the artists, it is important to keep the artistic goal in focus and not 'get lost' in the technology. The technology should only assist in realizing the original idea, not merely serve as a goal in itself.

The investigations in this chapter have clarified the requirements for the technical 3D system to be used in this research. As a result, the development of the 3*D*IM has been realized using the two RF/US systems that will be described in chapter 5. The review of hardware and software design in combination with the artistic outcomes of the described projects in the previous two chapters, provide us with additional ideas for interpretations in the interactive movement based sonic art field. A re-contextualization of this form of performance art leads us to the next chapter in which the creation of the spatial ChoreoSonic performance space is outlined. The aim is to clarify how my ideas behind the relationship of dance movement and spatial sound evolved in the creative research process. It will be shown that this re-contextualization leads to new approaches and methods for the creation of interactive movement-based performance.

Chapter 4 Context of the Spatial ChoreoSonic Environment

Introduction

This chapter describes how my ideas regarding the interactive relationship between the spatiality of dance movement (Choreo) and sound (Sonic) evolved. This exploration ultimately leads to the development of the ChoreoSonic environment and the 3*D*IM software creation.

After an initial review of the relationship between music and dance providing insights into the collaborative experiences of choreographers and music composers, the chapter continues with a deeper exploration of the spatial domain of both movement and sound in the real time interactive performance domain. In the last section, several spatial synchronicities between the two art forms will be observed by combining a number of specific elements that exist in the ChoreoSonic environment.

4.1 Music and Sound for Dance

> Roger Scruton (1993:341) writes that '[m]usic shows us movement without the thing that moves' and I am tempted to suggest that dance shows us music without the thing that sounds [...] and although that may appear rather a circular argument, it is suggestive of the link through metaphor between the two in an important way. (Duerden 2005:31)

Dance researcher Rachel Duerden extends Scruton's view in her article 'Dancing in the Imagined Space of Music' with regard to the relationship between movement and sound. Her thoughts suggest that the relationship between the two art forms does not require explicit articulation: it just naturally exists. Relating to this view, dancer Isadora Duncan tells us about the fact that, as a child, it was the occurrence of sound that encouraged her to move: 'I was born by the sea ... my first idea of movement, of the dance, certainly came from the rhythm of the waves' (Duncan 1927:13). These citations suggest a dynamic relationship between dance and sound, both art forms existing in a time-based domain.

Considering the creative relationship between dance and music, composer Van Stiefel (2002:12) notes that a highly developed sensitivity towards both art forms is necessary: 'It is a matter of negotiating that fine balance between creating music that both *motivates* and *contextualizes* movement successfully'. He later adds to this view the choreographic context: '[...] the composer is either an interpreter of the choreography, or the choreographer is an interpreter of the music' (*ibid*:22). Sketching a certain level of dependency and control regarding music composition for dance, he categorizes the various collaborative relationships between choreographers and composers into music that is either composed before or after the choreography in a recorded, live or improvised version.

All things considered, music commonly functions as a background to dance performance either offering a 'music visualization' opportunity for the dancer[125], or the possibility to regard dance as a means of interpreting music[126]. However, considering the latter, Stiefel remarks that it has been noted that music composed after the creation of the choreography can sound 'forced' or 'too subservient' (*ibid*:18). This, he suggests, is mainly due to the fact that dancers and musicians count time and mark structure differently, in so far as that the dancer counts sequences of movement phrases 'each of which may have a specific, intrinsically physical timing' (*ibid*:6) whereas the musical person counts musical rhythm in bars and beats. Therefore, it is difficult to design musical phrases that adhere to choreographic structure retrospectively. Nevertheless, as noted earlier, the music should motivate and contextualize action. The, at the time, controversial collaboration between Cunningham and Cage (Reynolds 2006, Brown 2007, Copeland 2003), provoked this relationship between dance and music. Cunningham believed that dance only needed to be the same time-length as the music, but that no attempt was needed to relate the two in any other way: both art forms should simply 'co-exist'. In the Cage/Cunningham collaborations, the performative elements dance, music, and lightning would be rehearsed separately and often only come together on the opening night.

In the context of a real time interactive dance and sound performance, the collaborative relationship is challenged in a different (real time) way. In this context the following question arises: how is this relationship created when dance and sound evolve at the same time, when both art forms evolve in a real time interdependent performance creation?

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[125] Music visualization is a dance 'style that called for movement equivalents to the timbres, dynamics, rhythm, and structural shapes of music'. From: http://www.ruhaniat.org/lineage/RSDBio.php [accessed 06.11.08]. It was developed by the early 20th century dancer/choreographer Ruth St. Denis (US).

[126] This concept was initiated around 1920 by dancer/choreographer Martha Graham (US) and Isadora Duncan (US).

4.1.1 Improvisation in Dance and Technology Performance

To answer this question, one important aspect of this interactive relationship can be found in the act of improvisation[127], another example of a real time emerging art process. Adding to the view of Stiefel that the composer is either an interpreter of the choreography or the choreographer is an interpreter of the music, Rovan *et al.* note that in an interactive context:

> There are no musical cues for the dancers, since without their movements the music is either nonexistent, or at other times, missing key elements. This method of working forced not only an inherent degree of improvisation upon the group, but also prompted a sharing of artistic roles in the working process: dancer became musician, composer became choreographer [...]. (Rovan *et al.* 2001:45)

Stiefel noted previously that it is preferable that there should exist a sensitive understanding of the delicate balance between movement and sound. Rovan *et al.* argue that, in an interactive environment, a performer can best achieve this goal by a certain element of improvisation. After a basic learning process, a performer should be able to play the system intuitively[128] without just being a human controller tool that triggers the pre-programmed parameter changes. In line with Rovan *et al.*, Coniglio stresses the importance of implicating performance improvisation in interactive dance performances when he explains his motivation to develop interactive projects:

> [...] I provide interactive control to the performers as a way of imposing the chaos of the organic on to the fixed nature of the electronic, ensuring that the digital materials remain as fluid and alive as the performers themselves. There are two important implications that arise from this approach, namely:
> 1. we must give the performers latitude to improvise if they are to take advantage of such interactivity; and
> 2. the audience must have some understanding of the interaction to complete the loop between audience and performer (Coniglio 2004:7).

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[127] I use the word 'improvisation' in the context of this research as a certain playfulness that allows the dancers to investigate the working of the interactive system. This playfulness can be choreographically structured or free according to the choice of the involved artists.

[128] In accordance with Choi *et al.* (1995:385) the term 'intuitive' in the human-machine interactive context is taken as a process learned by experience, an interactive process that explains the mechanisms of 'the large numbers of states that exist in a complex system' that operate within the participant.

Andy Hunt & Ross Kirk (2000a:385) remark that in an interactive environment 'The control mechanism is a physical and multi-parametric device [that] must be learned by the user until the actions become automatic' and 'Further practice develops an increased control intimacy and thus competence of operation'. They obviously strive for a more 'controlled' musical environment, in line with the earlier mentioned operation of DMI interfaces (see 2.2).

From the viewpoint of the performing artist, Sophia Lycouris explains how artists experiment with improvised hybrid multimedia works that involve mixing elements of movement, sound and choreography:

> There are a number of parameters which inform the decision-making process [in live performance], amongst which one of the most crucial is the performers' assumptions and experiences in relation to models of composition in hybrid improvised work which incorporates the use of technology, the heterogeneity of the participating elements intensifies the role of the unknown (Lycouris 1999).

In other words, the additional use of technology is another factor that inspires the improvisational process of the performers involved. In an earlier paper I added to this viewpoint that: '[...] the aspect of a technology performance improvisation becomes even more important, being able to interact, 'play', freely with a technology that can sometimes distribute an unexpected dataflow' (Wijnans 2004).

4.1.2 How does a Dancer perceive the Technology?

As previously indicated (p.24), in an interactive performance environment the performer faces a double task being the operator of the sensor system and the communicator. In the ChoreoSonic environment the dancer is at same time the active agent (realizing the movement triggers) and the interface (wearing the needed technology on the body). Marc Downie (2005:39) defines this 'embodied' agent from the history of Artificial Intelligence (AI) as '[...] the agent [that] acts upon the world and senses immediately itself acting'. I abbreviate Downie's (2005:40-41) descriptions of the process of the interactive agent in three steps as follows:

- 'The perception system of an agent': the acting of the agent through its systems of perception to be able to transform the world as it finds it.
- 'The motor system of an agent': the coordination of the body's relationship to the world through the agent's motor system.

- 'The action system of an agent': the actions to perform based on the perceptual state and the state of the motor system. The action system articulates these selections to the motor system.

Alluding to Coniglio's earlier statement (p.69), it is interesting to observe how Stoppiello from Troika Ranch, as the interactive agent, perceives Coniglio's 'fixed nature of the electronic' from a dancer's and choreographer's point of view:

> As an artist working with computer technology, my relationship to the world is filtered through a hyper-river of bits performing multiple operations in parallel as they flow madly through computer space/time. This duality has infiltrated my choreographic sensibility. It manifests itself as accumulative phrases that are orderly, repetitive and organized, like a program, but that are interrupted by material that is completely human in its unpredictability and occasional violence. This duality, between what is most human and what is most machine, has become the inspiration for much of my recent work. (Stoppiello & Coniglio 2003:1)

Stoppiello explains that technology has had an inspirational impact on her movement work. Although she remarks that she started to move 'machine like', she realizes that in an improvised environment she has the freedom to let human character prevail at unpredictable moments. In the early dance and technology projects of Troika Ranch, she experienced the controlled technology (sound, video, lights) as other collaborators in the piece that were actually constantly under her control (*ibid*). In line with this view, Diana Theodores points out in her introduction to the 'Connecting Bodies' Symposium (1996)[129] that: 'interactive immersive computer technologies extend and transform the shape of movement and choreography, and if digital media can penetrate the materiality of the body, then our perceptual and ontological notions of embodiment are profoundly affected (*quoted in* Birringer 1998:125).

Considering this issue, Chrissie Parrott refers to the fact that technology can have a positive influence on the dancer's perception. Concerning the use of Motion Capture technology (see 3.1.2.2) and the software Life Forms (see p.60), she observes that: 'The technology redefines the principles of space

[129] At the 'Connecting Bodies Symposium' (1996) Theodores coined the term 'technography' as a way 'to help focus on the mutually informing processes of technology and choreography'. See: http://art.net/~dtz/diana.html [accessed 12.12.08].

and time that we've always looked at as choreographers, and we will continue to look at that, but it helps us redefine them and it helps us redevelop those ideas' (*quoted in* McKechnie & Potter 2005:105). She points out that dancers and choreographers are used to looking at space and time in certain defined ways. For example, the pelvis is considered the centre of gravity and of the personal space of the dancer. However, in the software 'Life Forms' it was impossible to independently move the pelvis of the animated character. This led to the fact that hip swings or pelvic movements were impossible, resulting in quite static movements. As another example Cunningham recognized that 'Life Forms' supplied the choreographer with a 'capacity to slice, cut, separate larger components into smaller ones, and the consequences of then re-ordering the parts' (*quoted in* McKechnie & Potter 2005:96). Therefore, Theodores concludes that technology might be able to help to re-conceptualize the established movement aesthetics. This view is particularly applicable to this research project in which the dancer needs to be aware of the visual and tactical space as well as the auditory space. In section 5.1.4 the experiences of the dancers that collaborated in a 'Sound Skeleton' experiment will be reviewed.

4.1.2.1 Embodiment and Virtual Disembodiment

Theodores pointed us in the former section to the fact that if 'digital media can penetrate the materiality of the body, then our perceptual and ontological notions of embodiment are profoundly affected' (*quoted in* Birringer 1998:125). In a technologically enhanced environment, the term 'embodiment' is frequently used as the bodily relationship of the dancer to the world. The term 'disembodiment' is used in these environments to refer to the 'ideal' relationship of humans to the computer that is one without any physical restraints. The term originated in 'cyberpunk', an anarchistic movement emerging at the onset of the internet in the 1980s. Cyberpunk was directed towards a complete disembodiment and total immersion in visual Cyberspace and Virtual Reality (VR) with the aim of escaping from the limitations of the physical body by creating cyborgs who move 'ever away from the somatic being to the digital spirit, and Nirvana' (Gordon 1999). Cyberpunk promoted the ultimate mind-body split in which logical reason dominates over the illogical nature of life (as proposed by French philosopher Descartes 1596-1650). VR was envisaged to realize physically impossible actions by:

> [...] experiencing an expansion of our physical and sensory powers; getting out of the body and seeing ourselves from the outside; adopting a new identity; apprehending immaterial objects... being able to modify the environment through either verbal commands or physical gestures; seeing creative thoughts instantly realized.[130]

A similar viewpoint is presented by Stelarc when he states that 'The body is obsolete'[131]. Stelarc promotes the idea that 'The body is neither a very efficient nor very durable structure'[132] and can only be enhanced by a human-machine interface. But is the body in fact a 'dis-body[133]'? When we transfer these views back to the dance and technology field, it was noted previously (p.72) that it became possible to abstract and re-choreograph dance movements in the computer. Motion-capture technology and the 'Life Forms' software resulted in a 'disembodiment' of dance in which the body can visually be dissected and manipulated into previously unimaginable shapes and spaces from all sorts of virtual perspectives. Real life dancers interactively manipulate these computer images that consist either of real time recordings of the dancers themselves or of filmic animations that resemble the dancers' movements[134].

However, the term 'disembodied' quickly became contested in the artistic, technological, philosophical, neuro-physiological, and perceptual field. From a dancer's point of view, Carolien Herman (2002) for example questions if: 'New technology has created the ultimate, invisible body: the anti gravitational body, the multi-layered, the vanishing, the inside-out bodies'. In line with Herman, Gloria Mark (1997:221) poses the following question: 'Should we really speak about disembodiment, or rather should we imagine a background-foreground relationship with our bodies where they exist more in the background as we enter a digital environment'? In her writing she argues that '[...] in a virtual world sensory information is restricted, either through a single or very few channels' (*ibid*:223).

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[130] From: http://project.cyberpunk.ru/idb/virtualreality.html [accessed 01.10.08].
[131] From: http://www.stelarc.va.com.au/obsolete/obsolete.html [accessed 01.10.08].
[132] From: http://www.streettech.com/bcp/BCPgraf/CyberCulture/stelarc.htm [accessed 23.02.10].
[133] I coin the term 'dis-body' to name the proposed dis-functioning of the body.
[134] See projects by artists such as Sharir & Gromala (1994), Kaiser *et al.* (1999), Cunningham (1999) and Brown (2005).

Embodiment from a philosophical point of view[135] has been described by Maurice Merleau-Ponty (1962) as the perception by 'a "system" of meanings by which the phenomenological process of recognizing and "sensing" objects takes place, and it is through the medium of the body that we get to "experience" and "perceive" the world' (*quoted in* Ajana 2005:2). Perception is only possible through the body. A similar view was presented earlier (pp.70-71) by Downie in a technological context. Btihaj Ajana (2005:3) approaches the terms 'embodiment' and 'cyberspace' from a phenomenological point of view and goes on to state that conceptual 'disembodiment' is a 'transcendence of body limitations through electronic prosthesis'. The term 'transcendence' means 'exceeding usual limits of ordinary experience' and 'self-transcendence' means 'surpassing the conscious boundaries of oneself'[136].

Herman (2002) relates this notion to the interactive performance '*Telematic Dreaming*' (1994) by Paul Sermon in which performer Suzan Kozel was transformed into a virtual image projected on a bed in another room. A visitor could approach and touch this image. Kozel stated that she felt physically present on the bed and felt physically hurt when people started to elbow her virtual image in the stomach. The virtual image was not disembodied but became a transcendental perception of the physical body. Herman observes that 'The virtual body [of Kozel] is in this case the extension of the real body: in VR the virtual body becomes the scope and active radius of the touch. We think and perceive from the point of view of the virtual body'. Herman concludes:

> [...] embodiment is not a fixed construct but a dynamique [sic], fluid and energetic system. Several independent informational systems are interconnected to take care for an embodied perception. Bodily experiences are multi-layered, non-logical and non-linear. Virtual body extensions, like computer interfaces, create continuity beyond the skin and flesh: the kinesthetic, proprioceptive and sensory informationchannels [sic] of the virtual limbs will lead to complex and organic experiences. A fluid and organic interaction is going on between the virtual body and real body. (Herman 2002)

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[135] A further philosophical discussion is beyond the scope of this writing. For more information on the subject 'disembodiment' I refer the reader to Merleau-Ponty (1962) or Ajana (2005).
[136] From: http://www.britannica.com/EBchecked/topic/602404/transcendence [accessed 01.11.08].

4.1.2.2 'TranSonic' Perception

Following the above discussion of 'disembodiment' and 'transcendence' in technologically enhanced dance environments, in the following section I would like to relate the views cited to movement based interactive spatial sound and introduce the term 'tranSonic' perception.

Mark (1997) favoured above (p.73) a 'disembodiment' as a background-foreground relationship between the performer and the visual imagery. In an interactive sonic environment, Verstraete (2005:6) keeps this relationship closer to the body when he states that 'sound can add an auditory "geography" like a second skin to the dancing body'. Verstraete mentions the interactive dance solo 'Mes Jours et mes Nuits' by sound designer Todor Todoroff and dancer/choreographer Michèle Noiret (2002[137]) and the interactive installation 'Sensuous Geographies' by Sarah Rubidge and Alistair MacDonald (2003[138]) as examples of projects in which sound directly affects the movement creation. Both environments use a multi speaker set up to create interactive spatial sound[139]. In this way the sound acts as an active spatial element that is able to motivate and contextualize (see Stiefel p.67) the movements of either the performer (in 'Mes Jours et mes Nuits') or the audience as performer (in 'Sensuous Geographies'). Duerden interprets this sensation of the dance-sound relationship as follows:

> But suddenly, the music is 'shown' to us and, at the same time, the dance reveals its difference - the difference between the embodied and the disembodied, visual and aural - and we recognise the existence of parallel worlds. (Duerden 2005:28)

Sound becomes an almost tactile and sensual experience for the dancer. Kozel's experience, mentioned above, was similar. In line with Duerden, I would like to introduce the term 'tranSonic' perception[140] to establish this experience: sound is going beyond the prior form of the human auditory

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[137] See: http://www.michele-noiret.be/index.php?page=bios_m [accessed 12.12.08].
[138] See: http://www.sensuousgeographies.co.uk/ [accessed 20.02.10].
[139] Please note that the spatial sound in these environments is applied as a horizontal (2D) moving element with the speakers set up horizontally around the audience.
[140] I originally proposed the term 'TranSoniscendence', but I am grateful to Dr Sher Doruff who advised me to change the name in the simpler term 'tranSonic' perception.

perception. These observations suggest 'sound as a disembodied movement' and 'dance as an embodied sound'.

Verstraete (2005:202) concludes that 'It [interactive choreographic sound] shifts our attention from visual geometric space to acoustic space'. However, there remains a level of sensitive 'discontrol' (see also p.33):

> Though gestural control allows for a new type of intimacy for the dancer and corporeal immediacy between sound and movement for the spectator, the sound environment remains an indefinable presence, an open space for uncontrollability. In an interactive open system, gestural control is about loosing [sic] control enabling a renewed sensibility of choreography and space. (Verstraete 2005:203)

4.1.3 Summary 'Music and Sound for Dance'

In this section the traditional collaboration between choreographers and music/sound composers has been investigated as an introduction to a discussion about the interactive relationship between movement and sound. In this investigation several points of departure in the collaborative relationship between dance and music/sound have been observed:

- The relationship 'naturally exists' (Duerden, Duncan) or it should merely 'coexist' (Cunningham).
- 'Music visualization' that searched for a movement equivalence to musical characteristics (St. Denis).
- The possibility to 'interpret' the music (Graham) with dance movement.

These ways of looking at the relationships between movement and sound have been investigated as an introduction to the different relationship that exists in a real time interactive dance and sound performance. In the interactive domain, this relationship is challenged due to the fact that both art forms cease to exist in a clearly observable time-based domain. This implies that a dancer is, figuratively speaking, moving 'backwards in time' to the sound, i.e. the movement happens not in response to the sound but creates the sound real time. In this case, the dancer is only able to react to a sound that was created at an earlier moment. This mode of creation of the sonic environment eliminates the problems that arise when dancers and musicians count time and mark structure differently (see Stiefel p.68).

This implication has directed us to emphasize the need for play and improvisation as major elements in the creation of an interactive relationship between both art forms. Consequently it has been suggested that in the digitally enhanced environment, computer technologies are, firstly, able to influence the shape of movement and choreography (see Theodores p.71) and, secondly, to redefine the principles of space and time (see Parrot pp.71-72).

The terms 'Embodiment' and 'Disembodiment' have been reviewed as references to the constraints of the physical human body (embodiment) in real life as opposed to the limitless possibilities of the body in virtual life (disembodiment). Ajana (2005) favoured the notion that the self-perception of the body should be considered as a transcendence of body limitations surpassing the usual limits of the conscious bodily boundaries. These observations have led to the introduction of the term 'tranSonic' perception. In line with Verstraete (2005), this ChoreoSonic perception exceeds the usual limits of ordinary experience by moving the movement-sound relationship closer to the body by adding a second (auditory) skin to the dancing body: 'sound as a disembodied movement' and 'dance as an embodied sound'. However, this sensation should not be regarded as a limitation or boundary but as an expansion of the bodily experience into wider space.

In the next two sections, the bodily and auditory spatial elements will be investigated in more detail to explore the creation of a 'tranSonic' perception in the interactive ChoreoSonic environment.

4.2 Bodily Space

Following Parrot's ideas that technology redefines the principles of space and time (pp.71-72) and my observation that the dancer needs to be aware of the visual and tactical space as well as the auditory space in the ChoreoSonic area (p.72), this section investigates space from the various spatial viewpoints of dance in the performance area. The theories focus on issues referring to:

- Human movement in general space.
- Spatial bodily perception of the dancer.
- The body in geometric space.

4.2.1 Human Movement in General Space

> Space is a hidden feature of movement and movement is a visible aspect of space. (Laban 1966:4)

Space as a medium for movement has been conceptualized and articulated by movement theorist Rudolf von Laban in the late 1920s as introduced in his principles of 'Space Harmony' (Laban 1966). His study of movement, Laban

Movement Analysis (LMA), deals with the spatial order of the paths or traceforms that the dancer's limbs make in space, taking into consideration the connection between 'the outer result of movement and the mover's inner attitude' (*ibid*:27). In dance this traceform is constructed out of changing spatial and rhythmic tendencies. 'Newtonian logic' is an important aspect of LMA because Laban observed a parallel geometric spatial structure in human movement and nature. Therefore, before further outlining some relevant concepts of the 'Laban Movement Analysis' (LMA), it is essential to briefly describe how this Newtonian logic is considered as a major scientific concept of geometric space.

General space in a geometrical sense[141] was initially defined by Greek mathematician Euclides (300BC) who described 'plane geometry' to show that three dimensional physical space consists of three plane surfaces[142], in which a plane is defined as a perfectly two dimensional flat surface created of 'a two-dimensional group of points that goes on infinitely in all directions'[143]. In the Cartesian[144] (rectangular) coordinate system two numbers (the X and Y coordinate) determine each spatial point in a plane. The theories of Euclides were still generally accepted during the time that scientist sir Isaac Newton defined the 'three Laws of Motion'[145] in the 17th century:

I. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

II. The rate of change of momentum of a body is proportional to the resultant force acting on the body and is in the same direction. According to Newton, a

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141 I mention some extracts of the theories of Euclides, Newton and Einstein here because they had a particular impact on spatial theories and artists in the movement field. For a deeper investigation of the mathemathical theories about space, I refer the writer to the numerous websites that exist on this subject as it is beyond the scope of this writing.

142 See: http://www.britannica.com/EBchecked/topic/194901/Euclidean-geometry [accessed 15.09.08].

143 From: http://library.thinkquest.org/2647/geometry/glossary.htm#coordplane [accessed 12.12.08].

144 'Cartesian coordinates, also called rectangular coordinates, provide a method of rendering graphs and indicating the positions of points on a two-dimensional (2D) surface or in three-dimensional (3D) space'. From: http://whatis.techtarget.com/definition/0,,sid9_gci824296,00.html [accessed 11.12.08].

145 From: http://csep10.phys.utk.edu/astr161/lect/history/newton3laws.html [accessed 15.09.08].

force causes only a change in velocity (an acceleration); it does not maintain the velocity as Aristotle held.

III. For every action, there is an equal and opposite reaction.

Laban followed this Newtonian logic and stated firstly that 'equilibrium in dance is never a complete stability or a standstill, but the result of two contrasting qualities of movement' (Laban 1966:6) and secondly that 'in movement each reaction has an equal but opposite reaction' (according to Rob Lovell *et al.* 1996).

4.2.2 Spatial Bodily Perception of the Dancer

Throughout his book, Laban (1966) proposes that movement of the body is made up of pathways in which the movement phrase changes the spatial position of the body as well as the combined relationships and connections within the structure of the body. He considers the fact that limbs are only able to move in certain restricted areas of the kinesphere (the so called body 'zones'). The term 'kinesphere' can be defined as:

- The sense of invisible boundaries around an individual body and separating one from others, the encroachment of which may cause anxiety[146].
- The sphere around the body that a dancer can easily reach while standing still and that moves with the person's traceform in space (Laban 1966:10).

Several neuro-physiological sensations are associated with the first definition of the kinesphere. Firstly, the so-called 'sixth sense' that is defined as 'proprioception': the sense of motion and position that 'bind[s] our sense of agency with our embodied selves at an emotional level' (Cole & Montero 2007:1). The term 'kinesthesia' is interrelated with 'proprioception' and is similarly defined as 'the sense that detects bodily position, weight, or movement of the muscles, tendons, and joints'[147]. Secondly, the peri-personal or 'near' space which is defined as the 'close' space that surrounds the body. The conversion of the spatial coordinates of the peri-personal space is 'initially perceived [by the brain] with reference to the sensory organs (e.g. with respect to the retina in vision or with respect to the head in audition) into coordinates that guide the chosen effector, usually the hand, towards those

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[146] From: http://dictionary.reference.com/browse/personal%20space [accessed 15.09.08].

[147] From: http://www.thefreedictionary.com/kinesthesia [accessed 15.09.08].

coordinates'[148]. In post modern dance for example, the peri-personal space is explored in 'contact improvisation' in which points of physical contact start the movement improvisation.

The second definition of the kinesphere is derived from the above mentioned LMA. Within his principles of 'Space Harmony', Laban (1966:10) defined the 'kinesphere' or 'personal space' as 'the sphere around the body whose periphery can be reached by easily extended limbs without stepping away from that place which is the point of support when standing on one foot [...]'. In other words, the kinesphere is defined as the space around a dancer's body limited by the maximum space that the limbs can reach. The centre of the kinesphere is the pelvis, defined as the dividing point of the three possible movement directions: height, breadth and depth (*ibid*:11).

Considering a later geometric space theory, I briefly refer to the General Relativity theory of Einstein's 'laws of gravity'. Here it is stated that '[...] gravity, as well as motion [as a geometrical phenomenon], can affect the intervals of time and of space' and that ' [...] gravity pulling in one direction is completely equivalent to an acceleration in the opposite direction'[149]. Einstein's theory of general relativity proved that Euclidean/Newtonian geometry is a good approximation to the properties of physical space only if the gravitational field is not too strong. Choreographer Cunningham concluded, after having read Einstein, that there are no fixed points in the stage space, the center could be wherever anybody is. In other words, a decentralization of the performance space was created. The choreographer stated:

> And it's all in space, not time. That doesn't sound big, but it's huge. Instead of thinking in time, you're looking visually and putting things in space (*quoted in* Dunning 1991).

Relating to the geometric definitions mentioned above, space in dance can be defined in terms of dimensions, planes (horizontal, median, frontal) and diagonals. If the space is experienced from the perspective of the kinesphere, a multiplicity of directions emerge in relation to these main dimensions with respect to the geometry and boundary of human movement.

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[148] See: http://www.jneurosci.org/cgi/content/full/27/14/3616 [accessed 15.09.08].

[149] From: http://www.pbs.org/wgbh/nova/einstein/relativity/ [accessed 15.09.08].

As an example of this incorporation of the LMA concept in a dance and technology context, Lovell *et al.* (1996) describe the definition, organization and experience of movement space within the developments of the 'Virtual Stage Environment' (VSE). In the VSE a mover is able to control changes in sound, lights, video, and/or graphics within a three dimensional area that is sensitized with two tracking cameras (a picture of the system is shown on p.102) using 'Eyes'[150], a MAX based software package. Within this environment a dancer's movements are interpreted according to Laban's 'Space Harmony' theory. The data measurements involve triggering the pathways of the dancer in space as well as the movements within the personal space of the dancer[151]. A sound composition could for example arise by giving every dimension an individual sound sample or a graphical drawing could be created by following the traceform of the dancer in the performance space. Lovell *et al.* expanded on the ideas of Laban who referred to the dancer's movement as a 'living architecture': 'movement is, so to speak, living architecture- living in the sense of changing emplacements as well as changing cohesion' (Laban 1966:5). The researchers concluded that a design for a 'Virtual Space Harmony' was created in which improvisations of the dancer can be analysed and related to the principles of Laban's Space Harmony theory.

The research described in this thesis also concentrates on these two main spatial and dimensional subjects of the 'Space Harmony' principles[152]:

- The location and the traceforms (pathways) of the movement in general space.
- The localized movement (of the limbs) within the dancer's kinesphere.

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[150] See: http://www.siliconatelier.com/squishedeyeball/index.html [accessed 10.12.08].

[151] Please note that in technological movement research different terms are applied to these two spatial definitions. For example, in Motion Capture technologies, general space is called 'World Space' (measured in a global coordinate system) and personal space is defined as the 'Object Space' (measured in a local coordinate system). See: http://books.google.fr/books?id=pJFowfd5EtkC&pg=PT200&lpg=PT200&dq=motion+capture+worldspace&source=web&ots=M9cE4j6ed-&sig=ezktlaZs9DQl49Pb4Wn9_3zYGDk&hl=fr&sa=X&oi=book_result&resnum=6&ct=result [accessed 06.08.08].

[152] It is beyond the scope of this writing to fully discuss Laban's movement theories. I therefore refer the reader for further information to the numerous publications that discuss Laban's theories.

It is important here to restate that the dancer's body is bound to the kinespere, but the kinesphere is mobile in the context of general space.

4.2.3 The Body in Geometric Space

Several contemporary choreographers have reconfigured the geometric conceptions of Laban. For example, Brown created the choreography 'Locus' (1975) that used her concept of the cube and Laban's concept of the 3 geometric planes of the personal space. In 'Locus' each allocated number on the cube represents a letter of the alphabet (fig. 2).

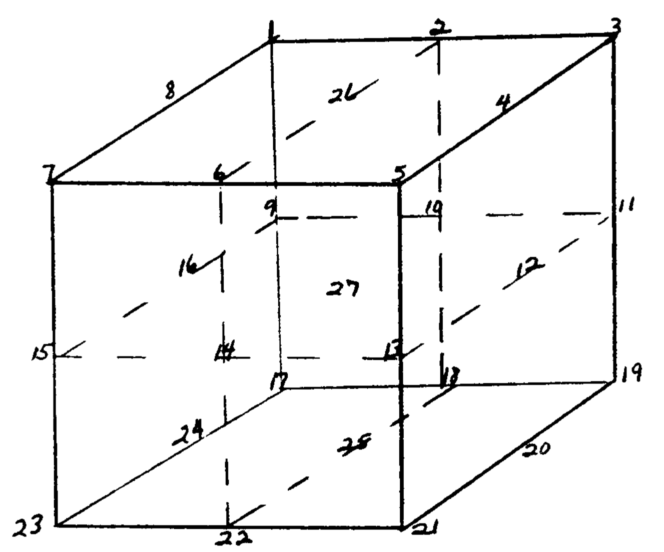

Figure 2 Trisha Brown 'Locus' (in Karpinska 2001).

The choreography of the piece is based on the letters of chosen words, each motivating the movement direction. Downie describes the fundamental compositional technique behind 'Locus' as:

> A *transformation* of the dancer's kinesphere into boxes, the arbitrary representation of these boxes by letters of the alphabet, the manipulation of the temporal sequencing of boxes by the creation of words and messages and the *retransformation* of these messages into movement yields a dance, a complex semaphore often intersecting with the representation's mirror - the spoken word. Downie (2005:22-23)

William Forsythe has extended Laban's view of the dancer as a 'living architecture' and considered the body in space as a 'geometric construct' (in Spier 2005:358) in which the center of movement was not necessarily the center of the body. In this way the impetus for the movement was relocated. From a choreographic point of view, Forsythe has used geometric architectural drawings from the architects Libeskind or Tiepolo as a guideline for improvisational processes for the dancers. In this way time and space were given architectural movement aspects. Regarding the spatiality of movement, Forsythe stated:

> You can establish a line with a gesture . . . I can establish a line by making a crumbling gesture. I can establish a line on the floor with little hops. I can establish it by rubbing it into the floor . . . by making little tiny dots, or between two dots . . .' (*quoted in* Spier 2005:359)

This improvisational technique, based on architectural forms, became one of the building blocks of the highly developed spatial sensibility in Forsythe's choreographies (Forsythe 1999).

In the scientific computing field, Herbert Edelsbrunner & Ernst Mucke (1992) offer a different perspective on the geometry of the movement of a shape in space. The topic of their writing is: 'the definition and computation of the shape of a finite point set in three-dimensional Euclidean space [...]. Intuitively, we think of the set as a cloud of points, and we talk about the shape of this cloud' (*ibid*:44). They conclude that a moving shape in space consists of a 'cloud of points' in space of which the volume and position changes over time. They approach the meaning of the word shape as varying 'with the amount of detail intended' (*ibid*:44).

If we transfer these spatial perspectives to the interactive environment, it can be suggested that space is not an inactive background, but the active director of the dancer through the responsive emergence of spatial sound. Birringer (1998:70-71) observes that several artists actively involve the background as a spatial element to the performance: 'Lucinda Childs and Trisha Brown very consciously use a cinematic approach [...] in the *editing* of their asynchronous movement repetitions onstage, exploiting and disturbing the regular geometries and symmetries perceived within the visual field'. As an example, Brown strapped a working projector, that displayed images of herself dancing, on her back in her piece 'Homemade' (1966). While performing the same dance on stage, the recorded images were wildly moving around, flying as it were, in the performance space[153].

In recent times Sarah Rubidge & Alistair MacDonald describe the term 'choreographic sensibility' towards the environmental space:

> The term choreographic sensibility, used in the context of responsive electronically sensitised environments, refers to a very particular way of interpreting and sensing that environment, and the way the

[153] See: http://www.artsci.washington.edu/news/WinterSpring04/TrishaBrown.htm [accessed 12.12.08].

> environment is shaped by the presence of human bodies. Dancers 'see' not only with their eyes, but also with their bodies. They develop a sensibility which is derived from a finely tuned pro-prioceptive sense, and an equally finely tuned sense of their relative proximity to the perimeters of the space and to objects in the space. (The 'objects' might be invisible objects like sounds, or they might be more tangible objects, such as other people.) (Rubidge & MacDonald 2001)

At the end of the paper it is suggested that 'a choreographer brings to the design [this sensibility] of the architecture of the space of the interactive installation, and in doing so choreographs not only bodies but the space itself' (*ibid*). In their collaborative interactive installation 'Sensuous Geographies' (2003), a performative environment is created in which the viewers are an integral part of the events the performers are generating (see also p.75).

Birringer also adds an environmental factor to the gesture recognition view (see 3.2.1). He addresses interaction as 'a spatial and architectural concept for performance'. This means:

> [...] shifting the emphasis away from the creation of steps, phrases, "combinations" or points on the body that initiate movement, away from the dancer's internal bodily awareness [...] unto her environment, to a not-given space but a shifting relational architecture that influences her and that she shapes or that in turn shapes her. (Birringer 2003:91)

Birringer goes on to suggest that (when working with camera tracking technology) 'the dancers also become "sensors", adopting to a new spatial awareness of a digitally enhanced space or "operating system" which triggers responses and feedback. Dancers appear to be touching invisible partners; they become ghostcatchers' (*ibid*).

4.2.4 Summary 'Bodily Space'

This section of the chapter investigated the perception of space from the performer's point of view. The section started by outlining the spatial movement theories of Laban (1966) in which the Newtonian theory of a space division in three-dimensional planes was defined. Laban applied this theory to both the pathways of the dancer in general space as well as to the movements of the dancer's body within the kinesphere or personal space of the body. It was observed that the kinesphere is bound to the framework of the body but mobile in the context of general space. In this context the body is regarded by Laban as a 'living architecture', it changes position in space as well as the cohesiveness of the body structure. This 'living architecture' moves in the three geometric spatial planes: horizontal plane (left - right), median plane (forwards - backwards) and frontal plane (up - down).

Three neuro-physiological sensations have been noted bearing a relation to the spatial perception of kinespheric movement:

- Proprioception.
- Kinesthesia.
- Peri-personal space.

These three elements assist human beings in the self-perception of the position of the body in general space. It is important to note that these elements are valuable as they suggest the possibility of transcending the conscious body limitations of the dancer and realizing a 'tranSonic' experience. In this case it is desirable to exceed the usual limits of ordinary experience and manipulate the second (auditory) skin as proposed by Verstraete (p.75). Here, the following question (and ambition) is repeated: is it possible to realize 'sound as a disembodied movement' and 'dance as an embodied sound' (p.77) by the emergence of a 'tranSonic' perception? In an attempt to find an answer to this question, the perception of auditory space is explored in the next section.

4.3 Auditory Space

> The results [of aural rendering of events in mediated environments] showed that stereo and six-channel reproduction resulted in significantly stronger changes in emotional reactions than the mono condition. Further, six-channel reproduction received the highest ratings of presence and emotional realism. Taken together, the result suggested that both emotional reactions and ratings of presence increase with spatialized sound. (Västfjäll 2003:181)

Daniel Västfjäll highlights an important impetus for me to use spatial sound in my research by showing that spatial sound increases the emotional perception of sound.

Using space as a compositional element started in the mid 16th century with the placement of various choirs in several places of the church, creating the antiphonal effect. This antiphonal music was later extended to the spatial placements of performers in orchestral and theatrical environments. The spatiality of sound was further challenged with the use of multiple speaker arrangements in sonic performances by composers such as John Cage, Karlheinz Stockhausen, Pierre Henry amongst others (see p.9)[154]. In the contemporary literature about spatial sound[155] several approaches can be found such as binaural spatial sound (over headphones), appliances in industrial engineering fields, arts and entertainment (gaming computer user interfaces), auditory displays for the visually impaired, virtual environments (Naef *et al.* 2002) and NASA space research (Begault 1991).

The following investigation concentrates on three topics involving moving spatial sound that are applicable to the subject of this writing and that will lead to parameter implementation in 3*D*IM:

- Sonic architecture
- Ambisonic (surround) sound
- Psycho-acoustic spatial sound perception

4.3.1 Spatial Sound: A Moving Sonic Architecture?

We have noted previously (p.81) that the moving body has been considered a 'living architecture' in space. Therefore, the following question arises: can moving spatial sound also be considered a 'living sonic architecture' in the ChoreoSonic performance space?

From an acoustic point of view, composer, musical theoretician and architect Iannis Xenakis was often described as 'an architect of music'. Alessandra Capanna sketches his environmental performances called 'Polytòpes':

> [...] the related architectural space was designed to contain loudspeakers and light projectors in determined positions so that they could interact with one another [...]. These were ephemeral architectural installations that were part of experimentation with architectural continuity, carried out through the rigorous application of a mathematical-formative idea. (Capanna 2006)

Using the interplay of lights, sound and the internal walls of the space, Xenakis diffused the architecture of the space, disorienting the audience with a casual disposition in space. In recent times, artist and musician David Cunningham has become interested in a real-time exploration of (spatial)

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[154] For more information on the history of spatial sound see: http://cec.concordia.ca/econtact/Multichannel/spatial_music_short.html [accessed 17.09.08].

[155] See a website such as: http://interface.cipic.uDVDavis.edu/CIL_tutorial/3D_sys1/binaural.htm [accessed 07.08.08].

acoustics. Since 1994 he has presented a series of installations that alter an architectural space to allow its resonant frequencies to become audible and interactive[156]. His installations aim to make the viewer experience the acoustics of space. From an architectural point of view, Lynde Wismer (2004) studied and created musical architecture with layers of sound in space. She concentrates on density, structure and organization, material and emotional interpretation of the individual spaces, in particular noticing the different reverberation levels that are dependent on the size of the space and the pitch of the audible sound.

If sonic space is not created by a building, but with the use of spatial sound software, another sonic architecture emerges. Jan Hofmann (2002) imagines himself as a 'sonic architect' who works on extending his practice through generating single sounds, placing them in a three dimensional X-Y-Z coordinate system in the software. He suggests that ambisonic (surround) sound would make it possible to define sound in terms of its quality, time and 3D space. He goes on to propose the constructive design of a generation of a whole 'environment of sound', much like an architect who creates a building from the elements he works with.

In order to further ground this section's question - can spatial sound be considered a moving sonic architecture? - it is necessary to outline the basic principles of the ambisonic system.

4.3.2 Ambisonic Surround Sound

Ambisonic surround sound[157] can be defined as true 3D sound information, reproducing sound in both vertical, horizontal and depth directions around a centrally positioned listener. The ambisonic method was initially invented to archive a better spatial representation of sounds recorded by microphones. A team of researchers at the Mathematical Institute in Oxford and the Cybernetics department at Reading University developed the 'Soundfield Microphone'[158] which generates a 4-channel signal, called 'B-Format', adding an up-down factor to the left-right and front-back information plus a mono

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[156] See: http://www.stalk.net/piano/asindex.htm [accessed 06.08.08].
[157] Extensive research on Ambisonics is done at the University of York. See: http://www.york.ac.uk/inst/mustech/3d_audio/welcome.html [accessed 07.08.08].
[158] The Soundfield B-format microphone is now manufactured by Soundfield Research, UK. See: http://www.soundfield.com/ [accessed 0.08.08].

reference signal (Elen 2001:2). Ambisonic encodes and decodes sound through the use of several equations and assigns a precise X, Y and Z Cartesian (see p.78) coordinate to every sound.

The speakers used in an ambisonic environment should all be full range and preferably the same brand. The speaker lay out can vary from a conventional stereo spread to hexagonal, octagonal, cubical forms, or any other symmetrical configuration. Michael Gerzon, the inventor in Oxford of the mathematical codes needed for ambisonic sound (early 1970s), refers to ambisonic sound as 'full sphere sound' or 'periphony' (Gerzon 1980). Full sphere sound 'requires speakers to be placed above and below the height of the listeners' ears'[159]. When more speakers are used, the listening area is larger and a more stable sound localization is realized because the 'sweet spot' (the ideal central listening spot in which the ambisonic sound field is reproduced accurately due to the algorithmic decoder process) becomes wider. In this way, listeners that are not positioned in the exact centre will hear more output from more speakers. In a full sphere ambisonic environment the geometry of the (surround) sound can be categorized as a cubiform in which the sound boundaries extend beyond the lines created by the speaker setup depending on certain parameters of the sound, as will be seen later (6.4)[160].

In the research described here, the use of ambisonic ICST tools for Max, developed by the Institute for Computer Music and Sound Technology[161], allow the encoding and decoding in three dimensions of up to third order Ambisonics. Jan Schacher (2006:1) explains that the spatial sound quality of the software is dependent on the Ambisonic order: 'Ambisonic spatialization starts from the premise that the soundwaves any source emits in space, can be modeled using spherical harmonics'. With each higher order an additional layer of this 'spatial harmonic sampling' occurs, making the spatialization more precise and the ideal listening spot wider dependent on size of listening

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159 From Ambisonic Surround Sound FAQ, see: http://members.tripod.com/martin_leese/Ambisonic/faq_latest.html#SECTION5 [accessed 18.09.08].

160 It should be noted here that another surround sound system (5.1) is commercially exploited that processes audio in a horizontal panorama. However, this system cannot be classified as true full sphere sound due to the fact that it supplies an extremely limited audio output in the height direction.

161 See: http://www.icst.net [accessed 07.08.07].

area, room acoustics, speaker specifications etc[162]. However, a precise perception of the dynamic movement of the sound space is still hard to achieve.

4.3.3 Spatial Perception of Ambisonic Sound

Having described the background and the operation of ambisonic sound, I will take a closer look at the perception of full sphere ambisonic audio in the ChoreoSonic environment.

> In effect, the term 'spatial perception' refers to our apprehension of information about relationships between features of our environment [as perceived by the senses] at a level of detail specific to the task(s) in hand [...]. (Lennox *et al.* 1999:4)

Considering the development of 3D audio, Peter Lennox *et al.*, from the Signal Processing Applications Research Group at York University, stress that spatial perception is not an isolated feature but created by an interconnected relationship of all the senses. In line with this view, Jens Blauert (1997a:193) observes: 'The assumption underlying visual theories may be stated as follows: What the subject sees during sound presentation, and where the subject sees it, are factors determining the position of the auditory sound event'. Lennox *et al.* (1999:5) also state: 'Furthermore, perhaps the most significant insight that modern psychoacoustics has to offer the development of audio is the realization that the spatial perception of audio is primarily a time-domain process'. Temporal differences at the ears give rise to good individuation and localization information about sound perception. Therefore, an algorithmic design for audio involves digital filtering according to a head-related transfer function[163] (HRTF). 'An HRTF describes how the shape of the torso, head, pinnae (outer ears), and ear canals affect the properties of the sound wave' (Karpinska 2001). The University of York defines HRTF thus: 'The shape of the head and the external part of the ears results in a frequency dependent response which varies with sound position'[164].

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[162] For a deeper technical analysis of the ICST tools and ambisonic I refer the reader to Schacher (2006). A list of papers about ambisonic sound can be found on http://members.cox.net/surround/uhjdisc/ambipubl.htm [accessed 09/06/09].
[163] See http://www.york.ac.uk/inst/mustech/3d_audio/ambis2.htm [accessed 18.09.08].
[164] From: http://www.york.ac.uk/inst/mustech/3d_audio/gerzono.f.htm [accessed 30.09.08].

As was observed above, spatial audio is an interconnected relationship of all the senses. For this reason, errors in perception of auditory location judgments can also occur under the influence of visual and cognitive cues. Head movements can compensate for this imprecise localization. Where a visual cue for the localization of sound is missing, a number of artists have chosen to blindfold their audience (Rubidge & MacDonald 2004) or darken the exhibition environment (Terry Braun[165]) to help the audience ignore visual distractions and fully focus auditorily on the presented sound transformations and spatialization. However, Lennox *et al.* (1999:1) debate this issue when they state: 'Natural perceptual attempts to improve localisation by head turning and perceiver relocation around or toward a postulated object, always result in a decrease in spatial information apprehended; the opposite of a natural environmental situation'.

All things considered, it should be taken into account that spatiality in a ChoreoSonic environment is experienced differently when observed from the outside as a viewer than when felt from the inside by a dancer, who is actually directing the visible- and audible movements in space (see also 'the inside and outside' point of view p.93). The latter, by moving in the direction of the spatial sound that s/he is guiding, can more easily choose to hear and experience sound from all speakers in the ChoreoSonic environment than the audience. In a live situation only a small minority of the audience may ever be in the most ideal spot to get the full spatial audio effect despite the influence of head movements and visual cues. A sound that is located in one speaker may simply be hard to perceive by a segment of the audience.

4.3.4 Summary 'Auditory Space'

Spatial sound influences the emotional perception of sound and becomes an almost tactile and sensual experience for the dancer in an interactive performance environment. Both the 'full sphere' spatial sound perception and the perception of bodily movement are created by an interconnected relationship of all the senses in the digitally enhanced ChoreoSonic environment.

Ambisonic software, that incorporates the required psycho-acoustic principles, makes it possible to simulate this spatial perception of sound in a 3D

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[165] See: http://www.24hourmuseum.org.uk/nwh_gfx_en/ART20518.html [accessed 15-09-08].

coordinate system based on the same geometric plane theories that determine the bodily space described by Laban (see also p.80). I suggest that the combination of all these factors make it possible to design a 'living sonic architecture'. However, as has been observed, a precise perception of the dynamic movement of the sound space is difficult to achieve. In this research, however, a *precise* perception of the sound is not a major concern.

4.4 Audiovisual Spatial Synchronicity, 'Sound as Disembodied Movement' and 'Dance as Embodied Sound'

This section presents three interdependent spatial ChoreoSonic strategies that have evolved from the spatial concepts described in sections 4.2-4.3 of this chapter. These strategies emphasize the spatial concepts for full body and kinespheric movement, and explain how a 3*D*IM strategy is created:

- Geometry in spatial audio-visual division and perception.
- Spatial body-sensor pentagon.
- Geometry in a cubical form.

4.4.1 Geometry in Spatial Audiovisual Division and Perception

The first spatial synchronicity between body movement and spatial sound perception could be found within the geometric division of space in the median (forwards- backwards), frontal (up and down) and horizontal planes (left-right) of both elements. Laban describes these as six movement directions for the moving body (fig. 3).

DIVISION OF SPACE THROUGH THE MOVING BODY 143

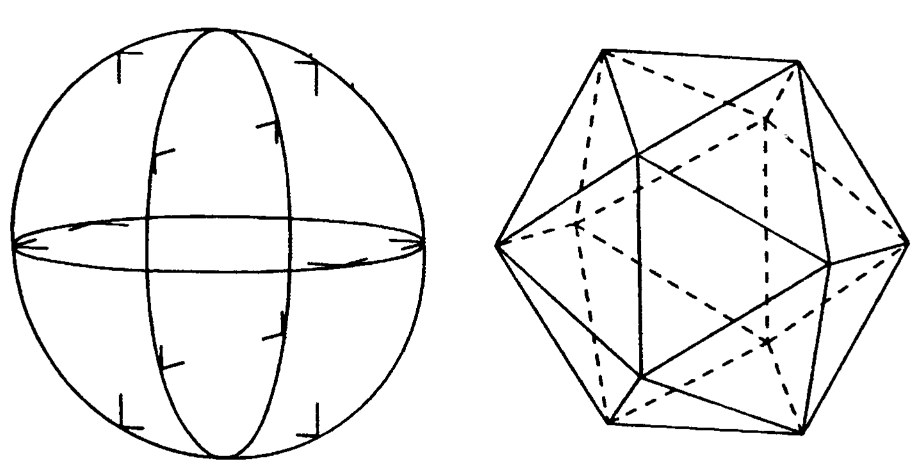

FIG. 58 FIG. 59

Figure 3 The Division of Space through the Moving Body (Laban in Ullmann 1966:143).

Blauert (1997a&b), a psycho-acoustic scientist, observes these movement directions in relationship to the perception of 3D spatial sound (fig. 4).

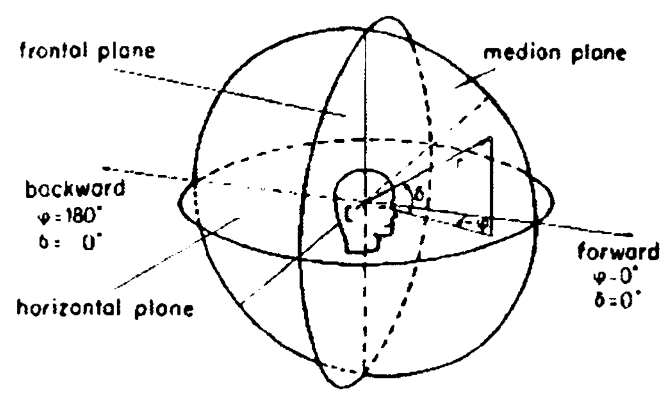

Figure 4 Head-related System of Coordinates in Auditory Experiments (Blauert 1997a:14).

Blauert shows that the quality of directional hearing is dependent on certain parameters of the sound (see 6.4). When we overlay these pictures from Laban and Blauert we more clearly notice their differences in that the centre of the moving body is the pelvis and the centre of spatial hearing is in the middle of the head between both ears (fig. 5).

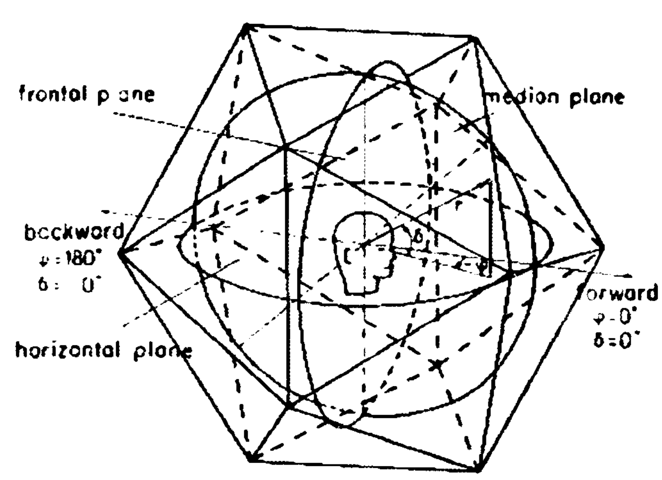

Figure 5 Compiled picture by the author of the Centre of Spatial Movement- and Sound Perception.

However, in the ChoreoSonic environment, this conceptual difference is solved when we take the pelvis of the dancer as the centre of performance and also as the centre for the trigger of the interactive 3D ambisonic sound. Besides this perception, Verstraete points us to two main viewpoints that exist in an interactive dance-sound performance environment:

> While the dancer learns to *utilize* the system as a musical instrument affecting the immediate environment, the spectator *contemplates* from a distance either the technical know-how of the system or the communication through gestures in terms of surfacing meaning or playfulness. (Verstraete 2005:7)

Therefore, to avoid such a division in the experience of the interdependent spatial ChoreoSonic performance relationship, and to integrate the two viewpoints of performer and viewer, I propose the terms 'inside' for the perception of the dancer in the sensitive area and 'outside' for the perception of the centre of performance by the viewer:

- Inside: the pelvis is the centre of performance and is a clearer viewpoint for the dancer who is directing the visible and audible movements as the active agent.
- Outside: the viewer/listener, who is usually more visually focused, sees the dancer as the centre of performance. Thus, the dancer is visually directing the movement of the spatial sound for the audience.

To reach this conceptual aim, the dancer(s) as well as the audience are moving in the performance space (bounded by the eight speakers)[166]. In this way the best spatial perception for both the dancer and the audience can be created within the ChoreoSonic environment[167].

4.4.2 Spatial Body-Sensor Pentagon

A second relationship is derived from Laban's division of the body in a pentagonal structure (fig.6). This flat two-dimensional reconstruction represents the body in a division of the five principle zones of movement: the head, the two arms and the two legs.

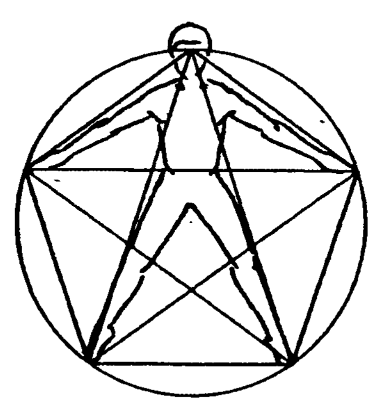

Figure 6 A flat Pentagonal Pose of the Body (Laban 1966:19).

As it was possible to use 5 electronic sensors in the electronic positioning system (see chapter 5) as an experiment (the system originally used just one sensor), a sensor was placed on the head, the two hands and feet according to Laban's pentagonal structure. However, as described previously (p.80), the centre of the kinesphere and thus of full body movement is the pelvis. In this experiment it was impossible to attach the sensor device to the pelvis due to

[166] This performance environment was tested during the sharing at the University of Chichester although the interactive spatial sound was not yet fully operable (see pp.129-132 & DVD 1:22).
[167] The thesis concentrates mainly on the perception of the dancer. An evaluation of audience perception is beyond the scope of the thesis.

its electronic construction (the sensor has to point upwards to the ceiling where four receivers are attached, see p.109). It was possible however, for the sensor on the head to become the trigger for the pelvis with a simple mathematical formula that subtracted the distance between the head and the pelvis of the dancer in the software.

This method would have allowed the measurement of both the movements of the head and the pelvis at the same time, but the decision was taken to allow the movements of the arms and legs to prevail (also according to Laban) in relation to the pelvis. In general, the movements of the limbs together with the movement of the whole body in space are more easily perceived than the movements of the head.

It has been proposed by Lincoln Kirstein *et al.* (1953) that limbs also have their own individual dynamic kinespheres (fig.7). They define the spaces of the two legs and the two arms as the 'space modules' of movement in which the ground of style and technique resides.

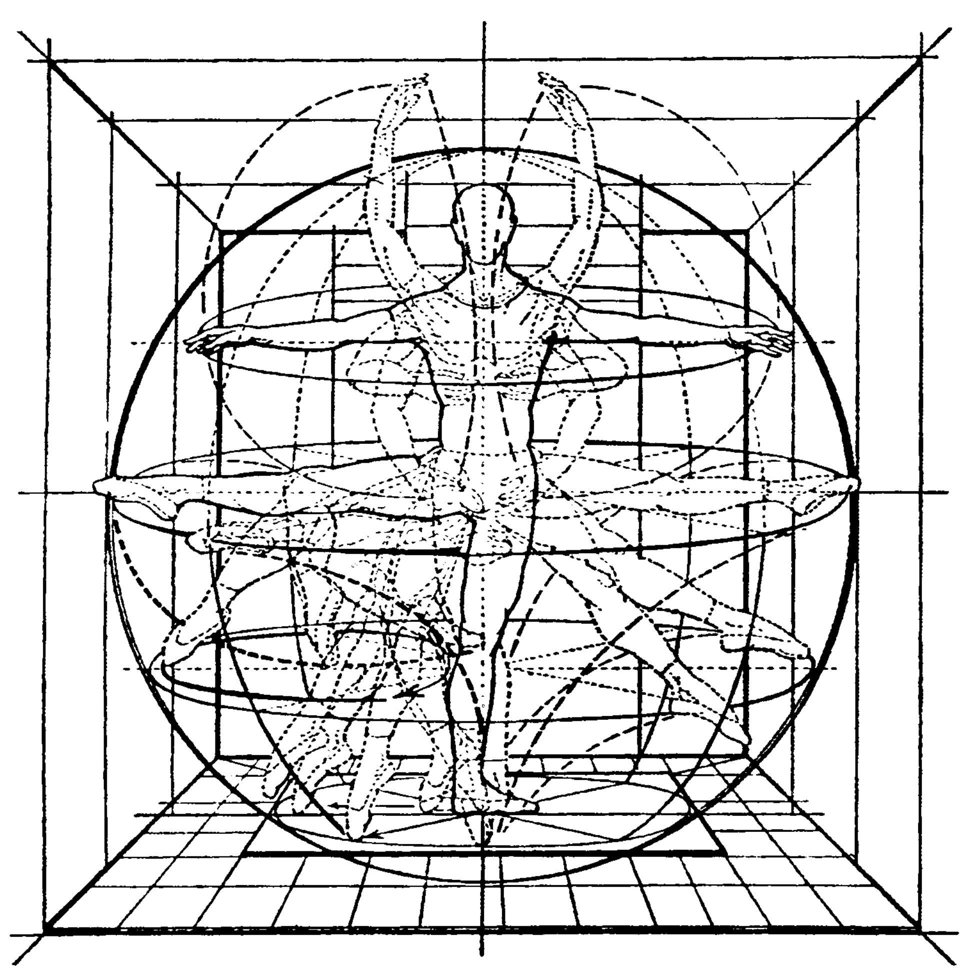

Figure 7 Space Modules of the Arms and Legs I (Kirstein *et al.* 1953:2).

Therefore, in the 'Sound Skeleton' creations each of the four sensors on the limbs determines its own kinesphere and a combination of all 5 sensors determines the kinesphere of the full body. These individual movement spaces were chosen as the trigger space for the spatial sound in the ChoreoSonic environment. Each sensor spatially directs its individually allocated sound. In this way, the body and the limbs direct their allocated sounds to the distance ranges of the surround sound set up.

For a reestablishment of the subjective spatial correlation experienced by the dancer and the viewer (who are both moving in the sensitive area), it can be helpful to visualize a picture of the moving sensors that direct the auditory sensitive space environment outlined above. The real time movement of the five sensors, attached to the body of the dancer, is visualized in the Max/MSP/Jitter software developed for this project (fig.8). In this visualization, the viewer is standing still at the front of the stage.

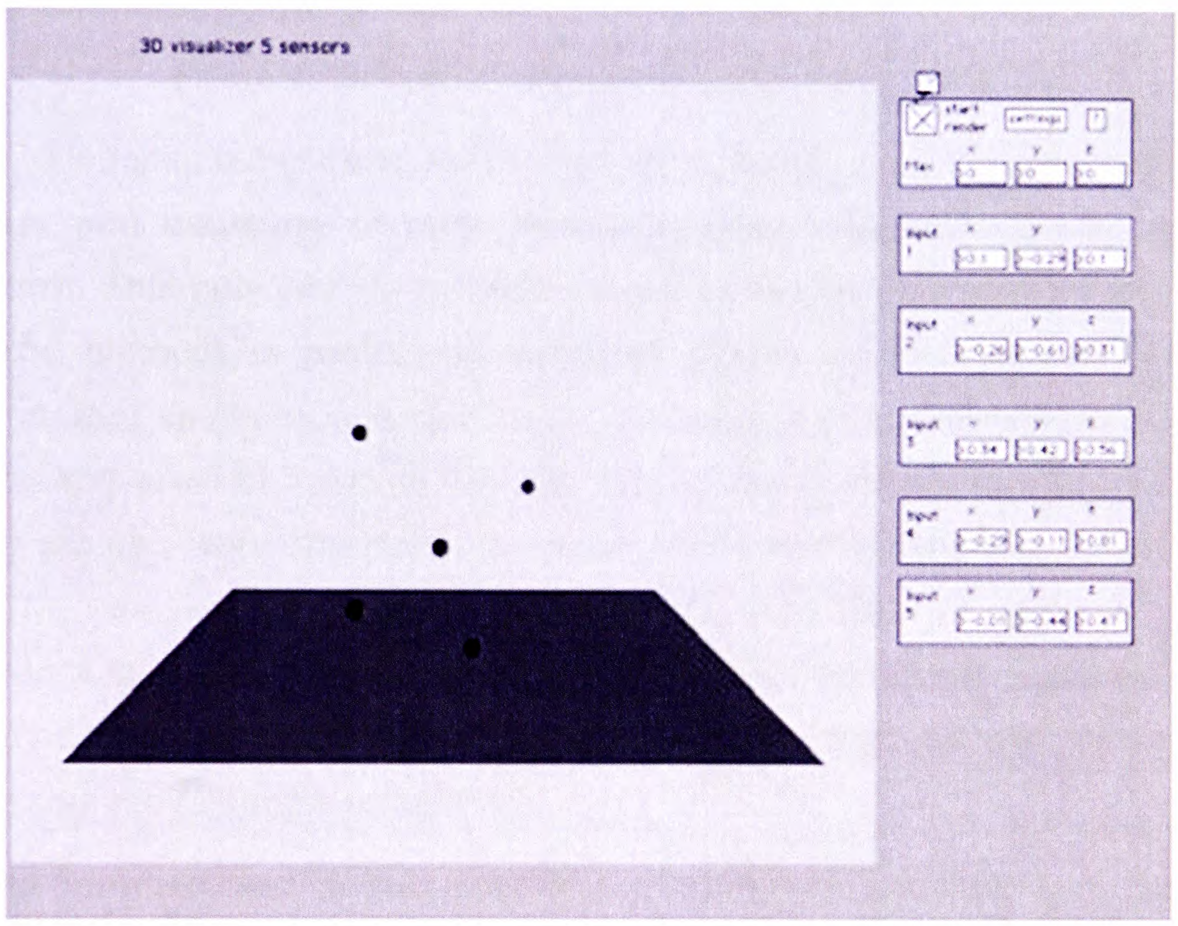

Figure 8 Dynamic sensors representation in Max/MSP software.

This visualization of the moving sensors was shown on a projection screen during a demonstration of several 'Sound Skeleton' experiments in 2007 (see Ch. 6) to emphasize the relationship between the two disciplines. The sensors are represented by dots as is normally also the case with Motion Capture systems.

4.4.3 Geometry in a Cubical Form

As noted above (4.2.2), Laban (1966) defined the space that a dancer can reach (while standing still) as the kinesphere or personal space. A simple geometric form of the kinesphere is the cube (fig. 9).

.O CHOREUTICS

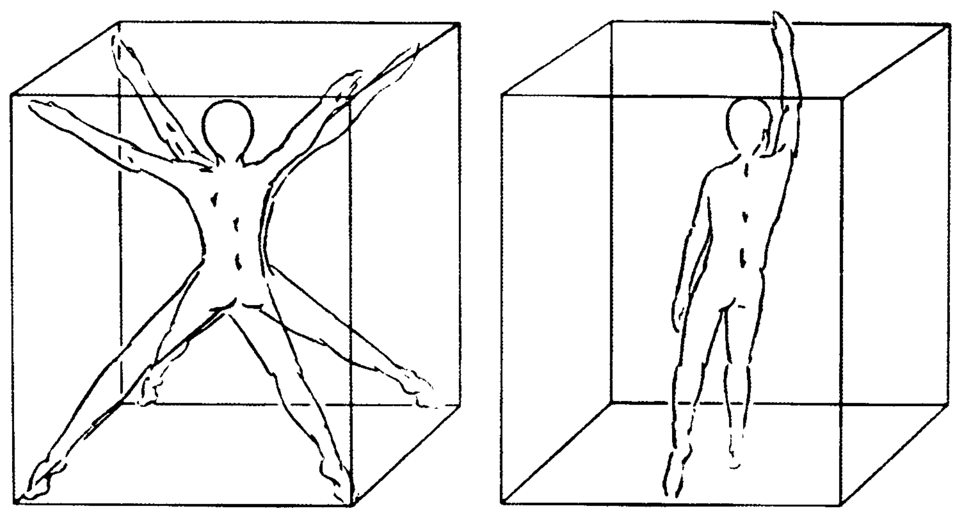

FIG. 53 FIG. 54

Figure 9 'Geometric Kinesphere' Laban (1966:140).

A third relationship between movement and spatial sound arises within the geometry and boundary of both elements, when one concentrates on this cubic form. This cubiform is, as we've seen earlier (p.88), also an important geometric element in ambisonic surround sound. In the 'Sound Skeleton' creations, four speakers are positioned in a square of approximately $25m^2$ on the floor and another four, about two meters above these, forming a cubical speaker set up. Thus, the speaker set up enclosed the sensitive ChoreoSonic area. This speaker placement provides the possibility of making sounds audible in a 3D moving sound space. The triggered ambisonic surround sound can move in all directions in much the same manner as the dancer who triggers this movement interactively.

It should be noted that, strictly speaking, the body does not move in a cubical fashion. Louise Campbell (2005:15) remarks that 'In reality, a kinesphere is the changing area that can be reached with every part of a person's body, clearly not the shape of a box' and 'While some may keep the kinesphere small, intimate, and well inside their possible range of movement, others may extend their kinesphere to the limits of their range of motion'. In much the same way surround sound also does not move in an exact cubical fashion, but rather creates a dynamic sonic environment in which the distance of audible reach and direction is dependent on several characteristics of the sound as will be outlined later (6.4).

To synchronize the spatial movement and sound elements in the 'Sound Skeleton' creations, the kinesphere of the dancer is sonically extended to the cubical sound space of the sensitive interactive area. In this manner, the movement was sonically transferred to the spatial area covered by the surround sound.

As noted previously (p.94), each of the five sensors from the tracking system (see Ch. 5 for a full technical explanation) has its own ChoreoSonic kinesphere: one for the whole body in space (defined by the sensor on the head) and four for the separate limbs. The whole body movement directs the sound localization of its specifically allocated individual sound according to the dancer's position in the ChoreoSonic environment. The limbs spatially position their individually allocated sound according to their localization and proximity to the pelvis (i.e. their own 'space module').

4.4.4 Summary 'Audiovisual Spatial Synchronicity'

The concept of a spatial synchronicity between whole body movement and spatial 3D sound perception was observed within the geometric division of space in the median, frontal and horizontal planes of both elements. Here the pelvis is regarded as the centre of performance according to the concept of the 'inside-outside' relationship (p.93). This concept was defined in relation to the perception of the performer as the centre of performance (from the inside) and the viewer (from the outside) in the ChoreoSonic environment.

It was decided to place a sensor on the head[168], two in the hands and two on the feet according to Laban's pentagonal structure. To optimize the observation of the spatial synchronicity between movement and sound, the movement direction of the spatial sound is bound to the individual spaces of the body: the four kinespheres of the limbs with their individual space modules, as defined by Kirstein (1953), and the dynamic pathways of the full body position of the dancer in the sensitive area, as defined by Laban (1966). In this way, the sounds move spatially in all directions according to the body movement within these five defined spaces.

The dimension of the spatial sound is determined by the size of the cubical set up of the surrounding speakers. As such, the dancer acts as a visual cue that helps the viewers to locate the position of the sound. To reestablish the correlation between the ChoreoSonic spatiality as experienced by the dancer and the viewer a visualization of the moving sensors was created in Max/MSP/Jitter. In this way, the five-sensor configuration is able to intensify

[168] Here the head substitutes the measurement of the spatial movement of the pelvis, being similarly located on the vertical axis of the human body (see p.119).

the perception of the interactive spatial relationship between movement and sound in the created interactive environment.

4.5 Summary 'Context of the Spatial ChoreoSonic Environment'

This chapter looked into numerous writings and artistic practices by researcher-artists that evolved from working within the context of an interactive environment. In these technologically enhanced environments dance and sound are created at the same time, in contrast to traditional dance performance in which music is either created before or after the design of the choreography. This observation directed us to a major performance strategy: after a certain amount of training time, the performer should be able to play the system intuitively and in an improvisational manner. Improvisation in a technological environment, in which the sonic composition is created real time by body movements, can strengthen the interactive ChoreoSonic creation.

It was observed that the use of interactive technology changes the way that choreographers and dancers perceive space and time. A choreography created using animation software enables movement of body parts in independent manners, denying the laws of gravity and physical limitations. This different method for generating a choreography evokes a dynamic representation of the ChoreoSonic environment directed by the well-trained pro-prioception, peri-personal space sensitivity and kinesthetic sense of the dancer. I introduced the term 'tranSonic' perception to identify the perception of ChoreoSonic interactivity in which sound becomes almost tactile and visible: 'sound as a disembodied movement' and 'dance as an embodied sound'.

I listed the two main spatial and dimensional subjects regarding the movements of a dancer as proposed by Laban (1966) as follows:

- The location and the traceforms (pathways) of the movement in general space.
- The localized movement of the limbs within the dancer's kinesphere.

The combination of these two issues directed us to the fact that the dancer's body is bound to the kinespere, but the kinesphere is mobile in the context of general space. In line with these spatial theories, I placed two sensors in the hands and two on the feet to measure the movements of the limbs in their individual space modules, and one on the head to measure full body motion in the sensitive environment. In this way, it is possible to create a dynamic spatial sonic entity that represents the dancer's movements in the ChoreoSonic environment.

In order to accommodate the ambisonic theories described, eight identical full range loudspeakers are placed in a cubiform around the audience and the dancer who both move inside this sensitive area to get maximal spatial sound perception. My research has taken the position that 'space' and 'spatiality' are subjective and time-domain related impressions. Both performer and listener perceive the generated dynamic positioning and timing of movement and spatial sound differently, both elements depending on their position in the sensitive space. For this reason, a visualization of the moving sensors in the ChoreoSonic environment was created in Max/MSP/Jitter.

I list the following artistic decisions, taken from the spatial observations in this chapter, as follows:

- Realization of measurement of the movements of the traceforms (pathways) of the dancer in space by the central sensor on the head (measuring the pelvis).
- Realization of measurement of the movements within the kinesphere of the dancer's body by proximity measurements of the hands and feet to the pelvis.
- The pathway of whole body movement directs the sound localization of its allocated individual sound according to the dancer's position in the ChoreoSonic space.
- Each sensor, that measures the movement of a foot or hand, triggers its allocated individual sound. This sound is spatially directed according to the dimensions of the movement within its own space module.
- The main performance strategy is free body movement improvisation.
- Eight speakers are set up in a cubical form around the sensitive area to enable the perception of the ambisonic sound.
- A visualization of the movements of the sensors attached to the dancer's body is projected on a screen during performance as a guide for the interactive real time ChoreoSonic spatialization process.

These observations are incorporated in the next part of the thesis that describes the practical research: the Normative Case Studies.

Part II

Normative Case Studies

Chapter 5 Case Study 1: Preliminary Practical Research, 'Cricket' System Development

Choreographer: Sarah Rubidge
Dancers: Carrie Whitaker, Guy Adams
Sonic artist, Max/MSP: Stan Wijnans
System engineer: Stan Wijnans
(University of Chichester, UK, 2006-2007)

In chapter 4, I outlined how the tracking system should provide the three dimensional dynamic position (location and traceforms) of the dancer in space and the data measurements of the four space modules of the dancer's limbs.

In collaboration with V2lab[169] (Rotterdam, the Netherlands) and SurroundAV[170] (London, UK) a prototype of such a motion tracking system, the 'Cricket' system, was developed. I initiated, researched and materialized the initial technical developments of this system. The aim was to create a 3D sensitive environment of suitable space dimensions. The work outlined in this chapter resumes the research undertaken in 2006-2007.

5.1 The Cricket System

The Cricket system tracks the 3D (X-Y-Z) position and trajectories of up to two performers as they move through space. The sensitive environment of the system is comparable to the Virtual Stage Environment (VSE). In the VSE, two cameras determine presence, and track the position of a black glove worn by a white costumed dancer. Rob Lovell & John Mitchell (1995) describe the operation of the VSE:

> Two cameras viewing the same space intersect to form a box like area representing the common viewing field. Triggers defined in each camera's image plane form smaller intersections further narrowing the field of view. A three dimensional trigger defined in this manner is sensitive only to events within this box like area. (Lovell & Mitchell 1995)

In figure 10 a picture is shown that displays the basic setup of the VSE.

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169 See: http://www.v2.nl/lab/ [accessed 05.06.09].
170 See: http://www.pgacoustics.org [accessed 15.06.07].

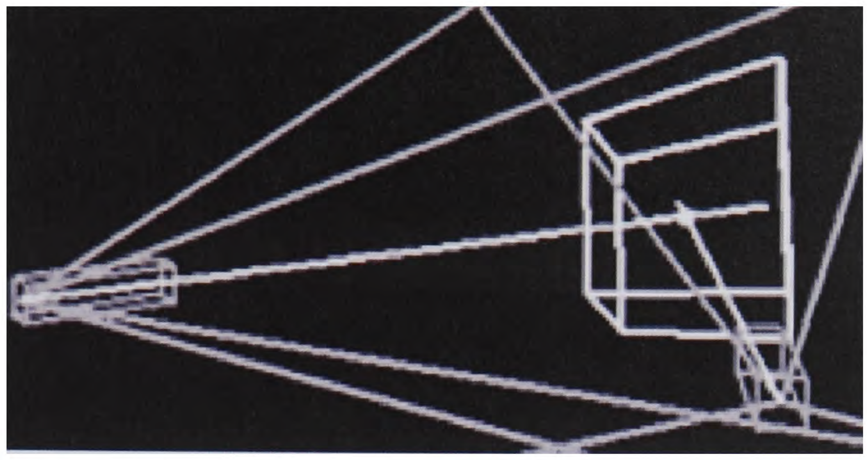

Figure 10 Two cameras viewing the same space intersect to form a box like area representing the common viewing field (Lovell & Mitchell 1995).

However, the RF/US Cricket system was meant to replace optical technologies that suffer from the limitations that beset such camera based systems (see pp.46-47). The ultimate goal of the new development was to design a system that would be easily configurable by artists, with a high data collection precision, that would work indoors over a large space area, be affordable, and easily accessible for artists.

A similar RF/US system has been developed by the Universidade Federal do Paraná in Brazil (Auer *et al.* 1996). However, this system could only track one sender beacon at anyone time. In addition to this, Feldmeier (1996) describes the use of an RF/US system to collect data from the collective activity of groups, summing up the pulses of the sensors worn by 10-1000 participants. In contrast to the development of the Cricket system, here the sensors used had no individual ID. Therefore, the operation of this system can be described as tracking 'one giant person', created by the total amount of the data provided by all active sensors.

The following sections describe the context and technical operation of the Cricket system in an AHRC research project (Small Grants Award 2006) exploring the choreographic potential of the system[171]. The research took place at the University of Chichester (UC), UK, in collaboration with choreographer, digital installation artist, and dance writer Rubidge from the UC and dancers from the Lila Dance Company[172]. It was concluded with a sharing and demonstration session[173] (see also 6.3.3). The testing included preliminary research of prototype ambisonic Max programming by myself in

[171] The writings regularly cite from the AHRC research report written by Rubidge & Wijnans (2008).
[172] See: http://www.liladance.co.uk [accessed 31.08.08].
[173] See: http://alcor.concordia.ca/~kaustin/cecconference/current/9268.html [accessed 31.08.08].

Max/MSP/Jitter (using a beta version of ambisonic externals for Max/MSP programmed by Dave Hunt, UK[174]).

5.1.1 Context of the Cricket System

The first research week took place in May 2006, the second in January 2007, with intermittent choreographic research taking place between them. In both of the research weeks we installed and tested the Cricket tracking system and experimented with the dancers, my interactive composition 'Global Drifts'[175] (see CDR: 'Global Drifts' excerpt sound file and Max patch) and the possibilities of the ambisonic system. The research took place in a studio context in order to gain the most realistic tracking environment for choreographic research, and to explore any issues that might pertain with the ambisonic system.

After the first research week the tracking system was refined for our particular research needs, in collaboration with the engineers at V2, for use in the second research week. During the latter part of the period between research weeks, I developed the real time interactive music composition system further, such that it could be used in the second research week to test the ChoreoSonic potential of both systems. The research methodology was thus reiterative, and combined technological research into the tracking systems, choreographic and sound compositional research *without* the tracking systems, and these research topics *with* the tracking systems. I was responsible for the technological and sonic aspects of the research, Rubidge for the choreographic research. The close dialogue between a choreographer and someone closely involved in the development of the two systems being tested was of considerable benefit in refining the systems for use in a performance context.

5.1.2 Technical Operation of the Cricket System

The Cricket system comprises one, and later two wireless wearable device(s) called the 'Handheld(s)' (fig.11 & fig.12), constituting RF and US technology

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[174] Similar ambisonic objects exist such as 'Spat' (Ircam) and 'VBAP' (by Ville Pulki). However, I offered myself as a beta tester for the 'Ambi-8' Max tools developed by Hunt.
[175] 'Global Drifts' is a Distributed Digital Choreographic Event (2006) by Sarah Rubidge and Hellen Sky, with Seunghye Kim, Hyojung Seo, and Stan Wijnans. See: http://www.sensedigital.co.uk/GD1.htm [accessed 05.07.07].

embodied in Cricket electronic beacons developed by the Massachusetts Institute for Technology (MIT), USA[176].

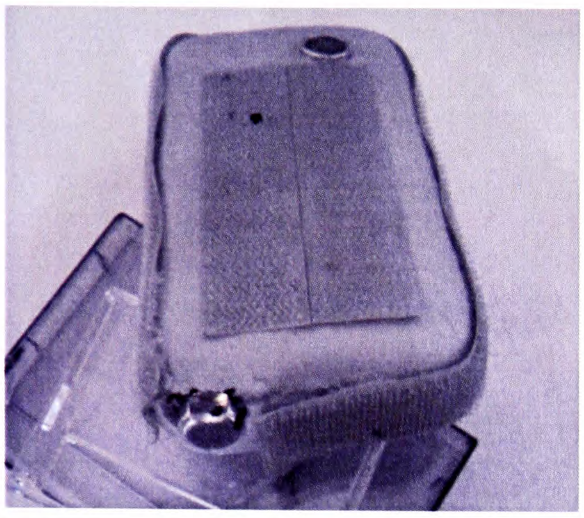

Figure 11 Cricket Handheld 1 (2006).

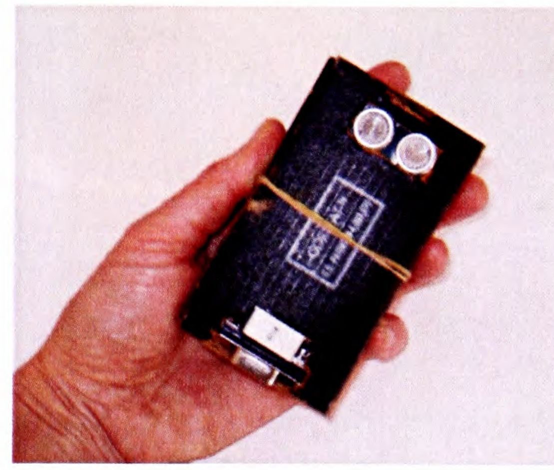

Figure 12 Cricket Handheld 2 (2007).

In the Cricket tracker software, as developed by Marc Boon[177] at V2, NL, the width of the sensitive space area is determined by the position of the 5 receiving Cricket beacons fixed on the ceiling. Four beacons are attached to the edges of a flexible grid that can be shifted in and out to change the length of the holding 'legs', with the fifth beacon placed in the centre of the grid (fig.13). Shifting the width of the 'legs' is required to make the sensitive area as large as possible. The 'handheld' sensor should be pointed upwards to the ceiling to enable communication with this infrastructure by sending out periodic coincident RF and US signals.

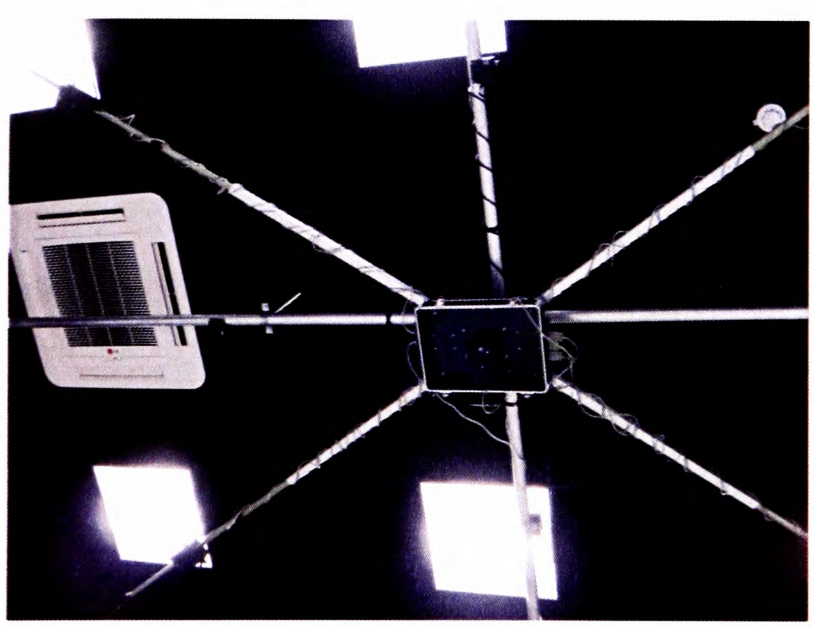

Figure 13 Flexible grid of infrastructure of 5 Cricket beacons on the ceiling.

The 5 Crickets output sensitive cones (fig.14) that realize sensitive circles on the floor (fig.15). The length of the diameter of the sensitive circle is

176 See: http://www.nms.lcs.mit.edu/projects/cricket [accessed 15.06.07].
177 See: http://www.karma-multimedia.nl/ [accessed 03.02.07].

dependent on the height of the grid: the higher the space, the further away the receiving Crickets can be placed from the centre of the grid.

Figure 14 Ideal shape of directional flow of 5 Cricket sensors.

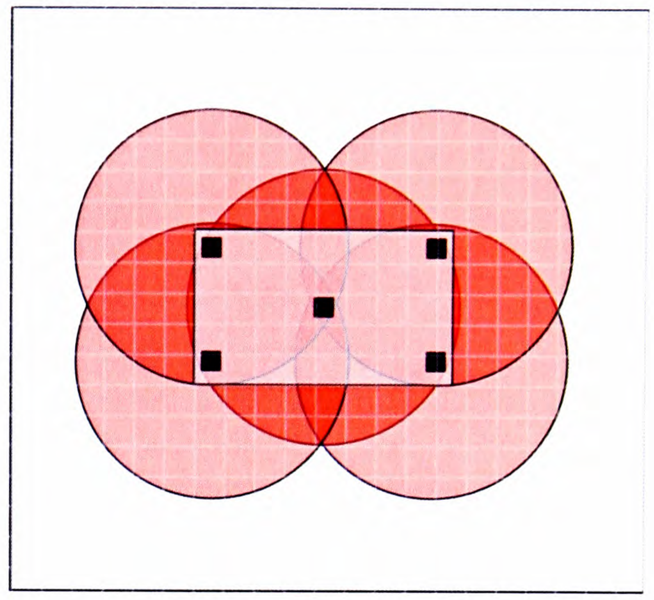

Figure 15 Two dimensional sensitive floor of 5 Cricket sensors (approximately).

According to the Cricket specifications, the perfect height of the grid should be between 4 and 6 meters, wherein the maximum height gives a floor space of between 8 and 10 m^3 with an accuracy of about 2 cm. The dynamic position of the handheld is measured real time in Cartesian X-Y-Z coordinates. The user has to fill in the X-Z (horizontal and depth) distances of the grid in the software, Y (height) being always zero as the software calculates this coordinate automatically, i.e. all receiving Crickets were either on the floor or on the ceiling. The sensitive area displays as an irregular box shape[178] where the 5 cones are overlapping, similar to the box shaped sensitive area that was created in the VSE (see fig.10 p.102). V2 had also developed the required Open Sound Control (OSC) network communication.

5.1.3 Technical Set Up ChoreoSonic Environment

The Cricket system was used in combination with a G4 Mac 1.67 GHz laptop with 1GB RAM that collected the data pulses of the ultrasonic system and controlled the real time changes of the sound. The Cricket software ran on the J2SE Java Runtime Environment version 1.4.2 or higher. The Crickets on the ceiling were connected to the computer with an extended USB connection lead (15m) coming from the ceiling. One of the four Crickets on the ceiling had to be chosen as the centre of the grid with coordinates 0.0, after which the user had to fill in the horizontal and depth measurements of the remaining 3

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[178] The exact ratio of the rectangular overlap of the ultrasonic cones in the sensitive area is unknown to the author.

Cricket sensors. The software communicated over OSC, with Max/MSP to receive the X-Y-Z data package transmitted by the Cricket system[179].

I set up 8 small PC speakers[180] in a cubical form (see p.88), with 4 speakers placed in a square layout at floor levels, and 4 placed above these at slightly higher than head height[181] (fig.16).

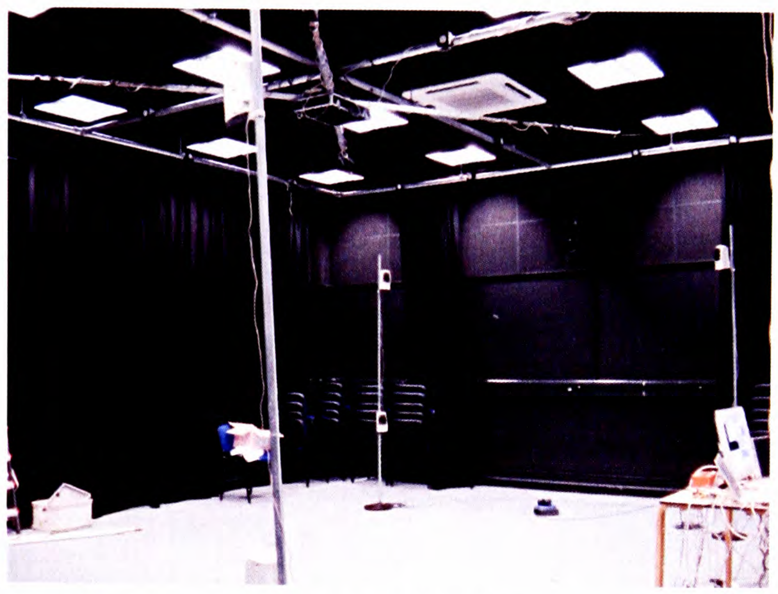

Figure 16 The speaker system and Cricket receiver grid.

5.1.4 Outcome Case Study I: 'Cricket' System Development

During the choreographic research several technical constraints, that influenced the choreographic possibilities, were identified:

- The weight and size of the handheld.
  Although the dancers stated that the weight made it easier to locate the sensor, the physical dimension of the handheld would focus the attention of a viewer too much on the technology.
- Latency[182].
  Due to latency, the sensor did not recognize the same border when moving away from the centre of the sensitive space and towards that centre. In figure 17, the blue lines represent the sensitive area when moving to the outer side, and the green lines represent (approximately) the sensitive (delayed) area when moving to the inner side.

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[179] It should be noted that in line with the ambisonic convention, the X coordinate is assigned to front-back (depth) with positive values to the front, the Y coordinate to left-right with positive values to the left and 0 is the middle of the speaker rig. This is confusing because the ultrasonic system assigns the X to left-right and the Z to front-back and the Y to height.
[180] Ambisonic surround sound needs full range speakers (see p.88), however, our facilities were limited at this stage and investigating the spatial sound was not our first interest.
[181] Thanks to Frank Bulthuis, Amsterdam, NL, for constructing the four poles that held the 8 PC speakers in a cubical set up.
[182] Ultrasonic sensors are notorious for a fairly high latency. See for example: http://www.cs.nps.navy.mil/people/faculty/capps/4473/projects/chang2/Simple.htm [accessed 04.08.08].

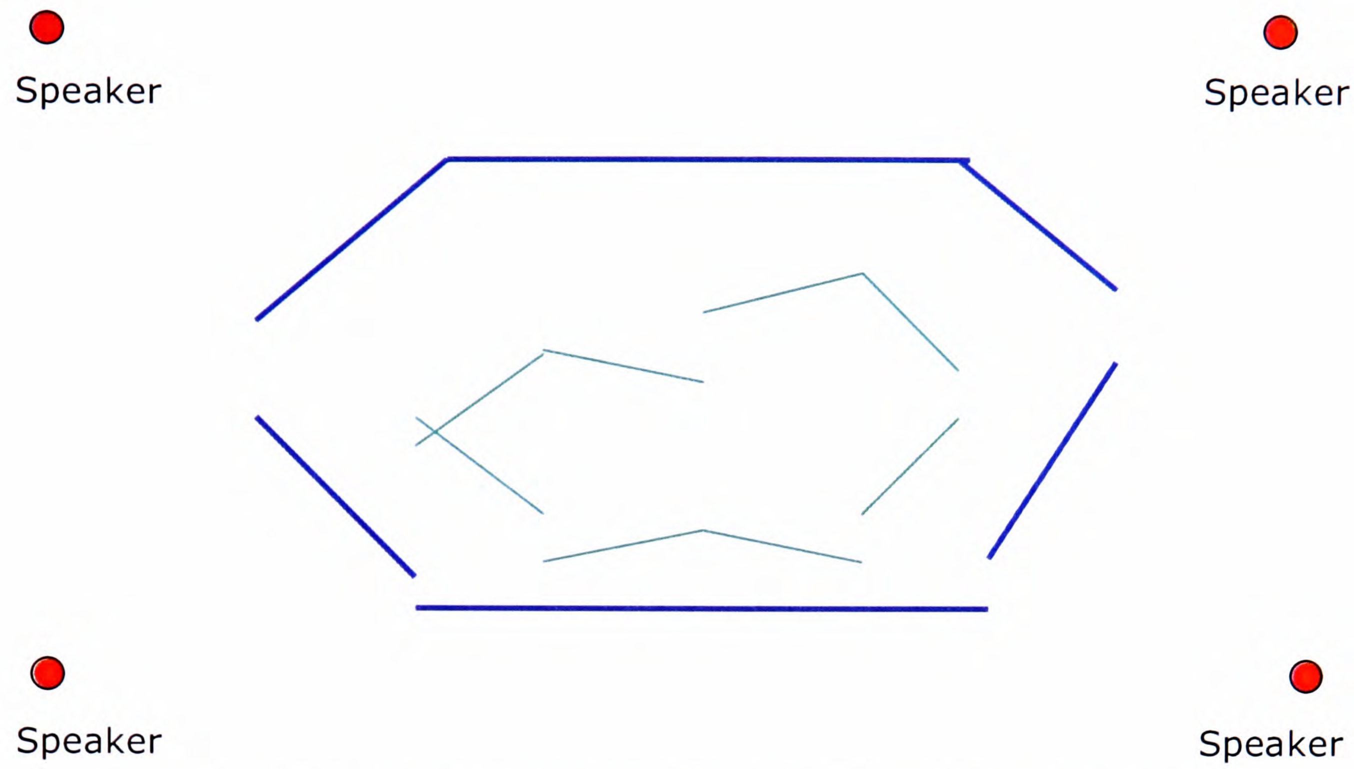

Figure 17 Diagram of the shape of the sensitive space (approximate).

- Slow update rate.
  If the dancers traveled through space too quickly, the sensors found it difficult to 'catch' the motion (also due to the previously mentioned latency problem).
- Occlusion 1.
  The use of rotation as a modulating factor was not a possibility as the sensor was occluded when the dancers rotated their wrists, which meant that the wireless connection between computer and sensor was lost.
- Occlusion 2.
  The dancers' bodies occluded the sensor from time to time if they performed dance movements without paying attention to the position of the handheld.

The choreographic and sonic possibilities that these limitations presented with the dancers (in case they were not resolvable technologically) are further explored in the 'Sound Skeleton' creations that are interwoven in chapter 6 of this writing.

Finally, I list several feedback comments from the dancers regarding the ChoreoSonic interrelationships:

- The dancer has dual responsibilities due to the fact that her movements are surrounded, and therefore overwhelmed, by the 3D sound. However, initial development of a movement vocabulary with choreographer Rubidge gave the dancers a start for the movement improvisation.
- The sounds directed by 2 dancers started to blend at certain positions in the space. This raised questions of the identity and individuality of the dancers, whilst separated in space.
- Because the sound was positioned opposite one of the dancers in the ambisonic Max software, she in particular sometimes was not sure who's sound she was creating. Therefore, she sometimes

decided just to dance until she 'found her sound back'.

- In case there was only one sensor available, the dancer without sensor feels the other one as her sensor. This adds another ChoreoSonic dimension to the dance partner.
- The weight of the sensor unit made it easier for the dancer to trace the movements of this other 'partner'.
- The occlusion of the sensor gave the dancer the power to control the interactive process, i.e. s/he was able to decide if s/he would be dancing 'solo' or with this other 'partner'.

5.2 System Errors: 'The Ghost of the Machine'

After the description of the limitations beset by the 'Cricket' System, let us consider the question: what happens when the technology is limited, stumbles or even fails? The first consideration of an artist is to incorporate any existing technical limitations of the instrument at hand and use them to their benefit. In reference to the DMI design field, Atau Tanaka states:

> With a tool, there is the hope that it will become better at its job, and will perhaps someday do everything. With an instrument, on the other hand, the performer accepts its limitations, and in fact, celebrates them, taking into account the instrument's personality. (*quoted in* Bongers 1998:20)

In line with Tanaka, I consider the computer as a tool and the combination of the sensors used as a musical instrument (in addition to this research I also consider it as a choreographic instrument). The existing imperfections of the technology, created by a jittery and noisy dataflow, can trigger an unintended sound response from the computer. In the research project described in this thesis, the position of any data errors by the tracking system was exploited to create an unexpected sonic atmosphere within the spatial environment. These imperfections necessitate the capacity to improvise from the artists involved (see also 4.1.1). In addition to technological errors, human errors can also add interesting and unexpected mapping relationships between the controller data and the artistic output. In a 'Sound Skeleton' experiment (see DVD: 1, CDR: Max 2007-1 sub-patch synthesizers) during the research at the UC in 2007, a human error existed in the calibration Max subpatch of the ultrasonic sensors. Consequently, a very high 'squeaking' sinusoidal pitch was triggered on one edge of the sensitive area. Remarkably, the dancer was particularly intrigued by this area and purposely returned there frequently to improvise with this sound.

5.3 A Low Cost Indoor Positioning System (LCIPS)

When the development of the Cricket system came to a pause for financial and logistic reasons, a second and more advanced RF/US system, the 'Low Cost Indoor Positioning System' (LCIPS), became available in the second part of my research. The LCIPS has been developed at the Department of Computer Science, University of Bristol, UK and is still in development (Randell & Muller 2001, Randell *et al.* 2002 and 2006). It is at the time of this writing able to track up to 6 RF/US sensors individually and synchronously. As with the Cricket system, the sending sensors have to point upwards (fig. 18) for data communication with the receiving sensors on the ceiling.

Figure 18 Sensor pointing upwards to the ceiling.

The LCIPS was originally designed for mobile and wearable computers for ubiquitous computing, and to complement an external GPS positioning system. The techniques developed for the LCIPS have been extended in a variety of ways, including RF Free versions (McCarthy & Muller 2003), and systems for tracking users (Duff *et al.* 2005). The system uses five transponders which respond sequentially to RF triggers by emitting 40kHz ultrasonic pulses. These pulses are captured by a 2m square grid of receivers mounted above the research/performance space. The receivers are connected to a microcontroller which uses the relative timings of the captured pulses to determine the 3D position of the transponders. The system is designed to achieve a maximum accuracy of 4.3 cm with a full update every 250ms. The host computer filters the data to remove spurious readings, and then converts the measured positions into MIDI signals for convenient interfacing with Max/MSP. The MIDI interface uses 128bit resolution over a distance of 4m.

This translates to a 3.1cm resolution giving a good match to the tracking system parameters[183]. Note that the LCIPS suffers from occlusion like the 'Cricket' system.

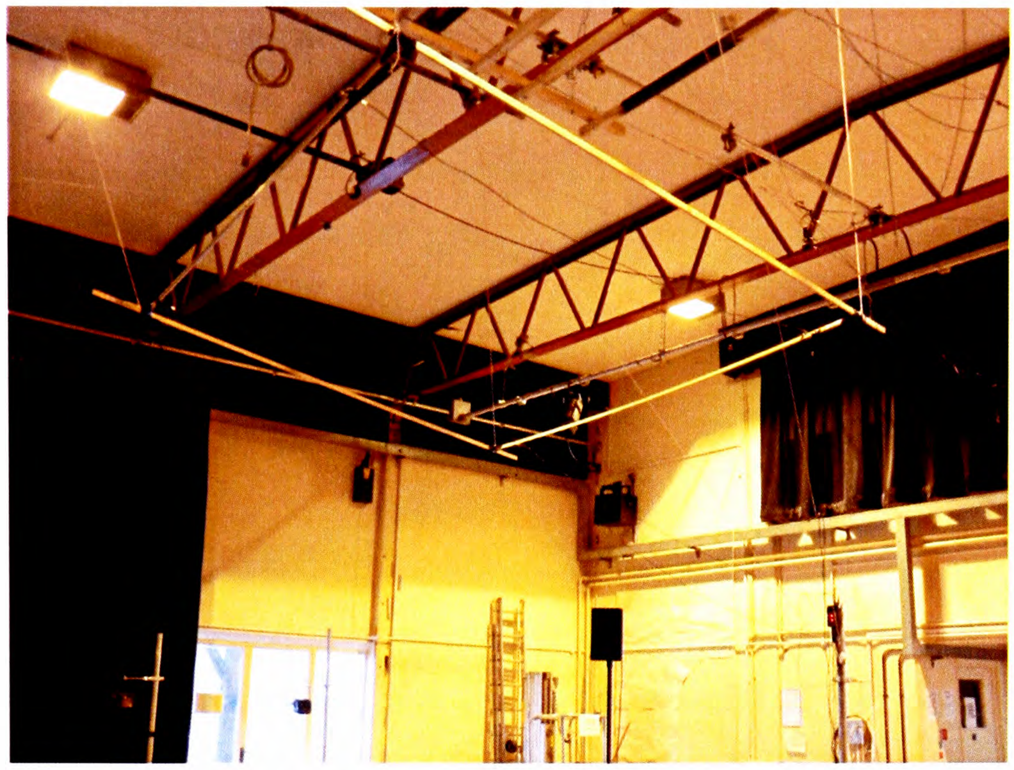

Figure 19 The four receiving LCIPS sensors attached in the corners of a square grid on the ceiling.

In figure 19, the especially constructed wooden hanging grid on the ceiling with four receivers is shown. This grid is very similar to the hanging grid of the Cricket system (see p.104). In the corner of figure 19, one of the high positioned full range speakers is also shown. The mobile wireless sensors (fig. 20) are able to cover an inside area of approximately 25m^2.

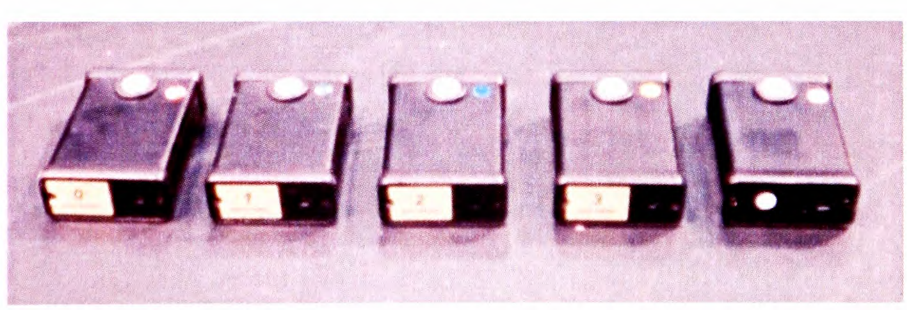

Figure 20 The 5 sensors of the LCIPS.

Calibration of the system only took a couple of minutes in the 3*D*IM software (see DVD: 2, CDR: Max 2006-2008 and 3*D*IM, sub-patch 'calibration').

In chapter 6, the practical 'Sound Skeleton' creations, that utilize either the 'Cricket System' or the 'Low Cost Indoor Positioning System', will be described from an artistic perspective.

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[183] I am much obliged to C. Randell for the text describing the technical specifications of the LCIPS

5.4 Summary 'Case Study 1: Preliminary Practical Research'

In this chapter, two RF/US tracking systems have been described that best fulfill the spatial requirements of this PhD research. Both systems have 3D measurement capabilities, are easy to access and have a fast installation procedure. A prototype of the 'Cricket' system has been tested for its technical and choreographic potential. Several constraints of this RF/US system have been identified such as:

- The dimension of the sensor box.
- Latency.
- Slow update rate.
- Occlusion.

However, it was decided to pursue the research with a similar RF/US system and explore how these limitations can be incorporated in the creative development of the ChoreoSonic environment. This Low Cost Indoor Positioning System (LCIPS) is able to track 6 sensors individually and synchronously.

In the next chapter, the various movement and sonic parameters that influence the perception of the interactive spatial ChoreoSonic experiments will be established practically. The aim is to relate the bodily space (4.2) to the auditory space (4.3) in the practical 'Sound Skeleton' creations undertaken for this project.

Chapter 6 Three Dimensional Data Interpreting Methodology (3*D*IM)

Introduction

Following the contextualization of the spatial ChoreoSonic environment in chapter 4, this chapter describes and analyses the development of the 3DIM software. 3*D*IM proposes a subjective method to map the available movement parameters, as supplied by the RF/US tracking system, to the spatial sound environment. In the introduction (p.9), the term 'subjective' was clarified as meaning: 'an output for a conscious choice, a decision to use a coincidental error or a moment of inspiration'. It is necessary at this point to establish a more precise definition of the words 'subjective mapping' before proceeding with the practical presentations. This definition will restrict the scope of this chapter to a more cohesive artistic proposition.

Downie (2005:30) sketches various departure points of the meaning of the term mapping: '[...] researchers talk of sensor data to musical parameters, of the *mapping* problem, of classes of *mapping*, of good *mappings* and bad *mappings*, of intuitive *mappings* and unsuccessful *mappings*, of tools for *mappings'*. Downie concludes that the published writings on mapping are commonly presented as a 'prescription', 'a vista of possibility', a 'central problem that faces the artist'; 'the solution endlessly deferred as a future work' (*ibid*:32). He stresses the need to create a wider vocabulary with a greater nuance to organize the intellectual field around 'mapping'. He concludes that: 'Mapping should be receding in digital art's rearview mirror, not as a solved or exhausted problem, but as an idea either too small or too broad to really fit [with the tasks and the opportunities at hand]' (*ibid*:36). Guy Garnett & Camille Goudeseune (1999) point us to the complex mapping strategies that might evolve when mapping the performer's geometric 'gesture space' to the listener's 'perceptual space': 'we need a way to define sometimes very complex [geometric gestural] trajectories within the [sound] parameter space' (*ibid*:3-4).

In the context of this research, a creation and classification of the 'parameter' space is necessary to be able to make the choices that support the aesthetic concept of the author. 3*D*IM tries to achieve an interactive conceptualization within the visual (here dance) and auditory spatial domain, defining a classification of the (incoming) spatial movement parameters and those of the (processed) spatial digital audio data. Similar mapping strategies have been developed in research projects such as 'Trans Domain Mapping' (Ng *et al.* 2000a), in which one creative domain (gestures) is mapped onto another (musical events). This strategy uses the 'MvM' (Music via Motion) system consisting of C^{++} software and camera tracking technology (Ng *et al.* 2000b). However, 3*D*IM focuses in particular on the mapping of the *spatiality* of movement parameters into *spatial* sound parameters.

Before describing the development of 3*D*IM, it is important to realize that in interactive dance performances the mapping relations that the technology and applied software offer can limit the aspirations of both the dancer and the audience. Considering this issue, Manning states:

> Yet their "process" [of new technology and dance performances] is limited by the dimensions of the software which tends to call forth a docile body, both in the software-conformist dancer and in the technologically-attentive spectator. Affective transformation depends on evolution in the machinic system such that both bodies and technological systems are altered. Transduction: the process develops according to a dynamic not of interactivity but of relation. (Manning 2006)

This insight determines the dynamic relationship of the mapping process in this research, in which it will be shown that the ChoreoSonic environment is sonically 'choreographed' in tandem with the spatial characteristics of the performers' movements in the sensitive space. The ChoreoSonic environment consists on the one hand of the applied RF/US sensor systems which are able to track the X-Y-Z positional data of up to two (Cricket system) or six (LCIPS system) independent sensor points attached to the body of the dancer. On the other end of this process, the use of Max/MSP/Jitter opens up a wide range of available sound parameters and spatial sound elements that can be generated with the incoming spatial movement data.

The description of the 3*D*IM development is accompanied by various video excerpts (identified in the text as DVD: 'xx') and Max patches (identified as CDR: Max 'year') of the 'Sound Skeleton' creations. These experiments show the developmental process of 3*D*IM as the conceptual ChoreoSonic framework that resulted from a combination of the practical and theoretical processes undertaken in this research. In this documentation it is shown that the artistic outcome is achieved by an interdependent relationship between the two artforms.

In the following sections of this chapter, the development of the 3*D*IM software is described. As a starting point for this description it might be helpful to simplify the mapping possibilities in the ChoreoSonic trajectory. This simplification leads to four broad parameter mapping categories:

1. Raw movement input data of spatial movement events [first derivate].
2. Deduced spatial movement parameters [second (algorithmic) derivate].
3. Sonic output of the first and second movement derivates [first mapping process].
4. Sonic spatial structure [second mapping process].

This starting point for the development of 3*D*IM is displayed in figure 21.

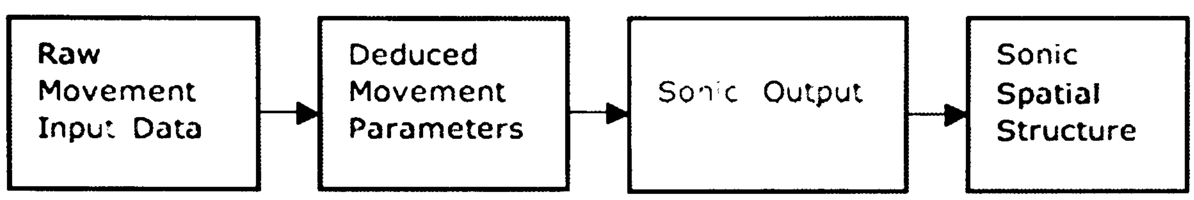

Figure 21 3*D*IM implementation chart no.1: the four broad parameter categories.

In the following, these four categories will be outlined and extended through the development of 3*D*IM - hence this figure is called '3*D*IM implementation chart no. 1'. Three 3*D*IM performance models are then proposed to demonstrate several sonic mapping strategies that emphasize the sonic spatiality of body movement.

6.1 Raw Movement Input Data

Each sensor unit of the ultrasonic dynamic positioning system measures the X (horizontal), Y (height) and Z (depth) position of a moving object/person in the sensitive space in six degrees of freedom: left-right, up-down, front-back (see also p.105). As will be seen, one sensor unit is able to measure full spatial body motion, whereas a combination of five of these units is additionally able to measure the spatial limb movements within the dancer's kinesphere (see 4.2.2).

6.1.1 Full Body Motion Data

In a research project (2006) to test the technicalities of the prototype 'Cricket System' (see chapter 5), the position of the handheld Cricket is taken as the centre of the dancer's movement and not the pelvis as the centre of the dancer's kinesphere (parallelling Forsythe's ideas, see p.82). The handheld can be either moved to another bodily point by holding it against a body part, putting it on the back while crawling (DVD: 3, CDR: Max 2006-1) or by attaching it to a spot on the costume[184]. The 'centre' is thus mobile within the kinesphere of the dancer.

In the research undertaken, this movement centre can also be moved outside the borders of the sensitive area. Aya Karpinska (2001) argues that 'the immersion of composed space within listening space gives rise to superimposed space'. In line with Karpinska, I designated the sensitive area of the Cricket system as the 'composed space' defined by the responsive surround sound system, and the area outside the sensitive area of the Cricket system as the 'superimposed space' in which no new sound manipulations were triggered (Rubidge & Wijnans 2008). This configuration allows the dancers a method to switch sounds on or off or 'leave' the sound in the last position the sensor trigger was placed (DVD: 4, CDR: Max 2007).

The X-Y-Z positioning data derived by the RF/US system are sufficient to allow measurement of the spatial and dynamic positioning of the dancer's body in motion. However, it will be shown in the next section (6.2) that derived movement parameters are needed to trigger the sound parameters that facilitate change in the spatial perception of the sound.

The raw movement input data of the two sensors of the Cricket system for full body motion tracking are implemented in the *3D*IM chart (fig. 22).

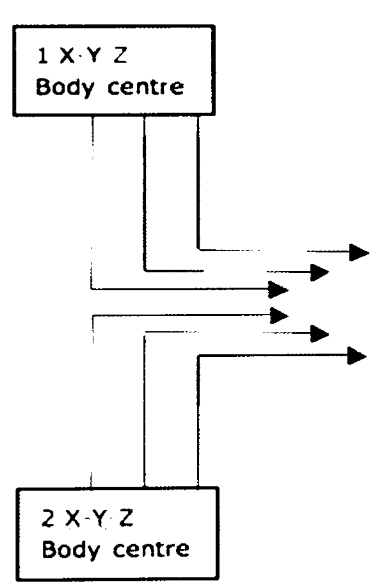

Figure 22 3*D*IM implementation chart no.2: raw positioning data of two (Cricket) sensor units.

[184] The costume of the dancer should be tightly fitted to avoid occlusion of the ultrasonic data stream by flapping clothing fabric.

6.1.2 Case Study 2 'Scanning the Space'

Choreographer: Sarah Rubidge

Dancers: Carrie Whitaker, Abi Mortimer

Sonic artist, Max/MSP: Stan Wijnans

System engineer: Stan Wijnans

(University of Chichester, UK, 2006 and Bath Spa University, UK, 2009)

Using a preliminary 3*D*IM patch in Max (CDR: 2006) and the sole Cricket sensor that worked at the time of the first practical research session (see Rubidge & Wijnans 2008), the X-Y-Z dynamic positioning parameters of the movement of the sensor that was held in the dancer's hand were measured (fig. 23).

Figure 23 Dancer C. Whitaker from Lila Dance Company[185] with the Cricket handheld 2006.

The prototype 3*D*IM Max patch was conceived using the concepts derived from a combination of two similar research projects. The first project was described by Auer *et al.* (1996), who had developed a similar Ultrasound Positioning Acquisition System. Their work presents a design of sensitive geometrical forms in the active space that triggers various MIDI parameters. One of the forms that has been defined in the software was a 'sound volume circle'. As soon as the dancer entered this circle with one attached ultrasonic sender[186] the loudness of the triggered sound would change. In their writing,

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[185] See: http://www.liladance.co.uk [accessed 31.08.08].

[186] In their paper it was not stated where on the dancer's body the ultrasonic sensor was positioned.

the mapping process is of secondary importance to the testing of this scientific ultrasonic design project, which concentrates on accurate determination of a position in space. The second research project was described by Insook Choi *et al.* (1995), in a practical experiment that involved a 'manifold interface' in an interactive space environment. This interface used the 'CHANT' synthesis technique (Rodet *et al.* 1984) that enables a composer to operate a desktop mouse with three degrees of freedom. In this research, vowel sounds were created from formant[187] waveforms (FOF or fonction d'onde formantique) that were defined by seven parameters in a 'CHANT' table. These parameters were localized on various spots in the sensitive space of the software. The composer could create a non-linear path with a mouse in the visual interface supplied to create the vowel sounds composed of the triggered formants.

Combining the concepts presented by these two examples, I designed a preliminary 3*D*IM Max patch that consisted of two different sound environments (CDR:2006, sub-patch 'samples'). The first contained fourteen samples of freely assignable opera vowel sounds[188], the second a set of various freely assignable abstract sounds[189]. These sounds were allocated horizontally to different spots on the floor in the sensitive space. The position configuration and number of the sounds could be changed with a couple of mouse clicks in the Max patch. The nearest trigger spot to the position of the dancer activates the allocated sound. Figure 24 visualizes the compositional strategy of this 'Sound Skeleton' experiment, called 'Scanning the Space'. In this way, the dancer is creating an interactive linear composition either consisting of the basic vocal sample sounds or of the abstract sounds. Thus, the distribution of the sounds over the space defines the geometric ChoreoSonic space.

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[187] Formants are defined as the resonant frequencies of the vocal tract, i.e. the characteristic partials that identify vowels to the listener. See: http://www.britannica.com/EBchecked/topic/213806/formant [accessed 26.02.09].

[188] Note that in this experiment I chose to play with existing voice sounds instead of designing the sounds from their basic formants because it allowed me more time to concentrate on the sound spatialization at a later stage of the practical research.
The vocal samples are from the 'Spectrasonics' sample CDR 'Symphony of Voices' see: http://www.spectrasonics.net/libraries/symphonyvoices.php [accessed 23.02.10].

[189] Freely downloaded from: http://www.freesound.org [accessed 19.12.08].

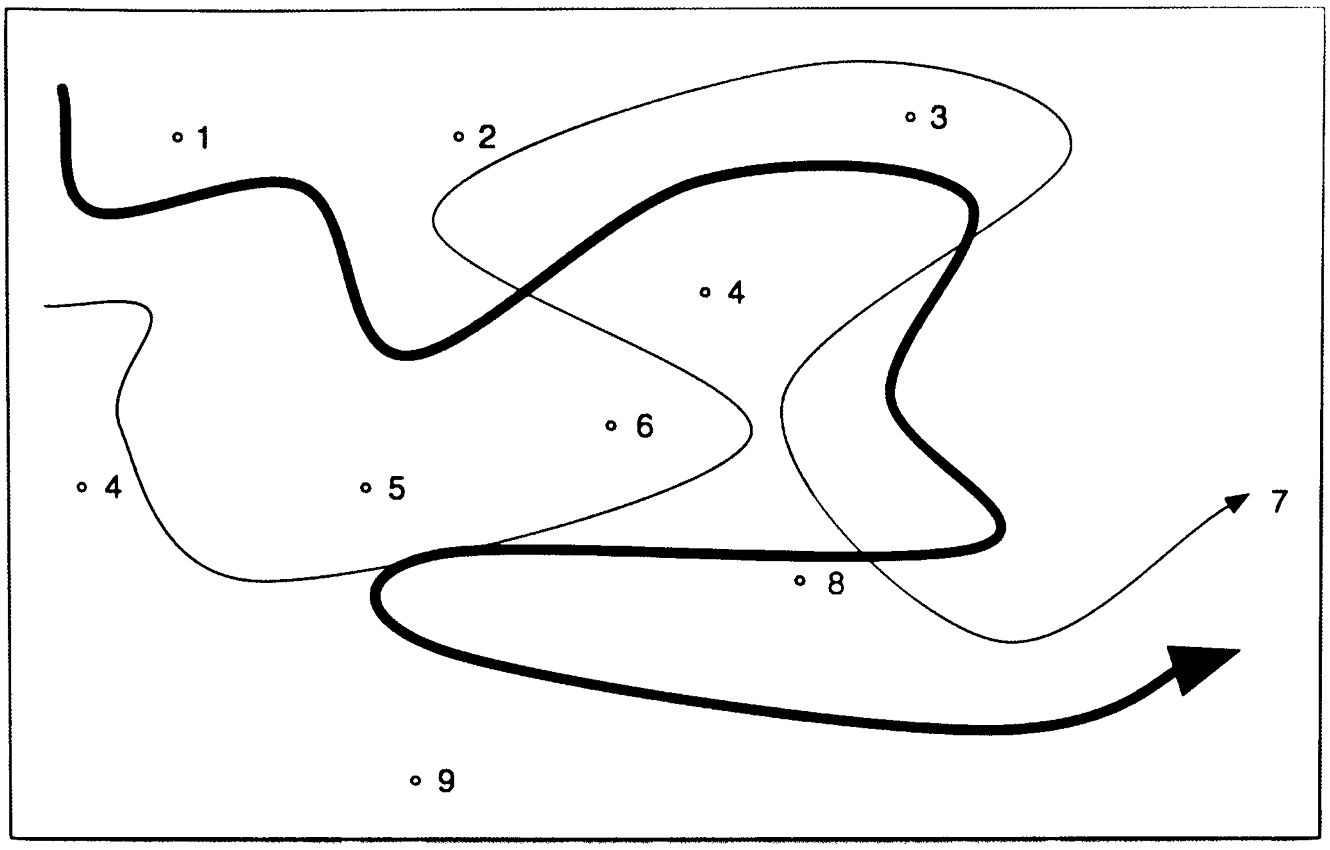

Figure 24 diagram of composition strategy 'Scanning the Space'.

Movement path 1 of the dancer is represented by the thick black line in figure 24. Moving down this pathway the dancer sequentially activates the trigger spots no. 1, 5, 2, 4, 3, 8, 5, 9, 8 and finally 7.

Movement path 2 of the dancer is represented by the thin black line in the diagram. Moving down this pathway the dancer sequentially activates the trigger spots no. 4, 5, 6, 2, 3, 4, 6, 8, 6, 5, 9, 8 and finally 7.

The picture shows that the sound composition depends on the direction and proximity of the dancer's movement path to the sound trigger spots. The irregular geometric distribution of the sounds in space avoids a 'Mickey Mouse' effect[190] in the relationship of the compositional sound response of the computer to the dancer's movements (DVD: 5-6, CDR: Max 2006 & 2009 3*D*IM sub-patches 'Activated spot' & 'Proximity change spots').

From 2007-2009 it was possible to use 5 electronic sensors of the LCIPS positioning system as an experiment (the LCIPS system was originally developed with just one sensor). I therefore started to experiment with triggering sound parameters such as pitch and volume with various numbers and positions of these sensors. These experiments (DVD: 7-8, CDR: Max 2008 sub-patch 'Matrices') show that the ChoreoSonic relationship was unclear due to the undefined mapping process that related the movement of various body

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[190] A term that defines a predictable and therefore unexciting reaction of the interactive system.

parts to randomly chosen sound parameter variations. As we will see in the following sections of this chapter, 3*D*IM was designed as a more specific mapping process in order to create an artistic ChoreoSonic balance.

6.1.3 Kinespheric Movement Data

Using Laban's division of the body as a pentagonal structure with the head, the two extended arms and two extended legs as the points of this pentagon (see p.93), a sensor was placed on the head, two in the hands and two on the feet (fig. 25).

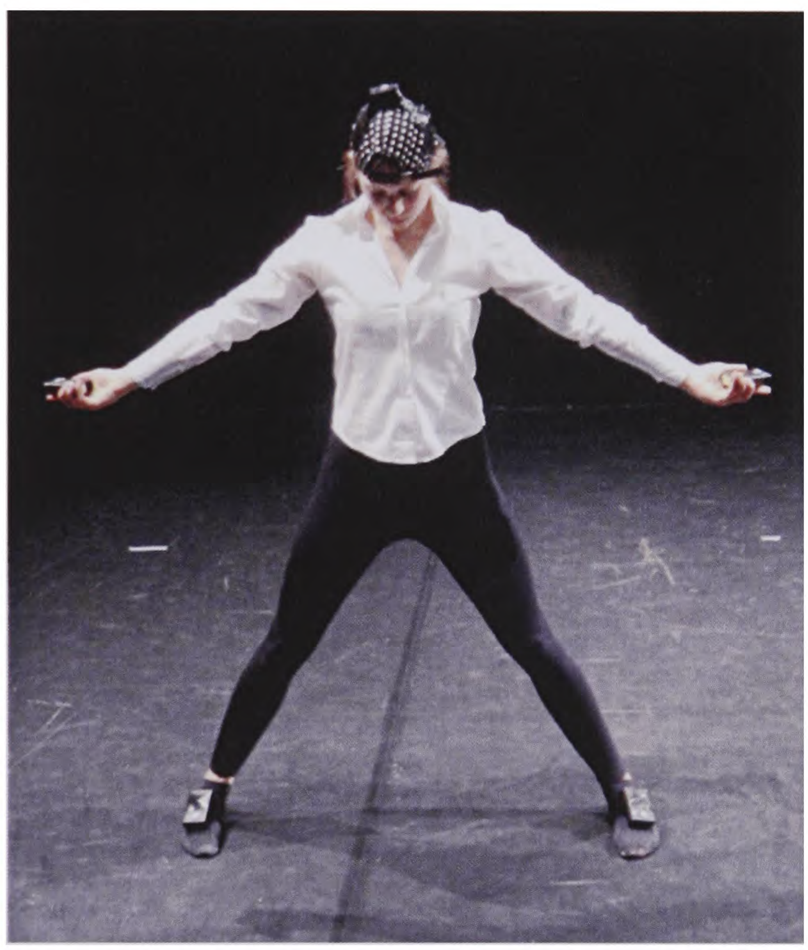

Figure 25 Dancer S. Spasic with 5 sensors of the LCIPS in a pentagonal structure.

This configuration created four 'space modules' (see p.94) for all the limbs and one full body positional space that Max could identify as the basic principle for the spatial mapping strategies in 3*D*IM. As noted earlier (p.80), Laban defined the pelvis as the centre of the kinesphere and thus of the full body movement. It was at this time not possible to attach the sensor unit to the pelvis due to the electronic construction (the sensor has to point upwards to the ceiling where four receivers are attached to avoid obstructing the dataflow). However, it was possible for the sensor on the head to become an approximate trigger for the pelvis by subtracting the distance between head and pelvis from the derived data. It should be noted that occlusion of the RF/US system is still a problem (see p.107).

A similar (six sensor) configuration, consisting of acceleromators[191] and gyroscopes[192], was applied by Torre *et al.* (2007) to measure a dancer's movements. The mapping idea in this project was based on Leonardo Da Vinci's 'Vitruvian Man', 'a nude male figure in two superimposed positions with his arms and legs apart and simultaneously inscribed in a circle and square'[193], taking the male sexual organ as the centre of the body. This configuration is very similar to the previously mentioned 'pentagonal structure' as defined by Laban (p.93). In a Pure Data[194] patch a 'creation of the virtual spherical space around the body of the individual performer' (Torre *et al.* 2007:45) was realized, which the researchers divided in as 'many portions or zones as required' (*ibid*:46). However, an exploration of artistic tasks and possibilities was not implemented in this research project.

The chosen configuration of 5 sensors of the LCIPS in this project is able to measure the movement within the kinesphere, i.e. the individual spatial positions of the limbs in relation to the pelvis, in addition to measuring full body motion in space. In this way, a very simple but innovative Motion Capture system was constructed. As stated earlier (p.110), the kinesphere of the dancer was calibrated in the Max software to be able to adjust the sound parameters to the body size of the performing dancer.

The five separate sets of X-Y-Z coordinate data are added to the 3*D*IM chart (fig. 26).

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191 Acceleromators retrieve the acceleration values along the three dimensional axes X, Y and Z.

192 Gyroscopes measure rotation or angular speed.

193 From: http://www.mlahanas.de/Greeks/LX/VitruviusMan.html [accessed 11/06/09].

194 Pure Data (Pd) is a real time music and multimedia environment similar to Max/MSP. See: http://puredata.info/ [accessed 06.06.09].

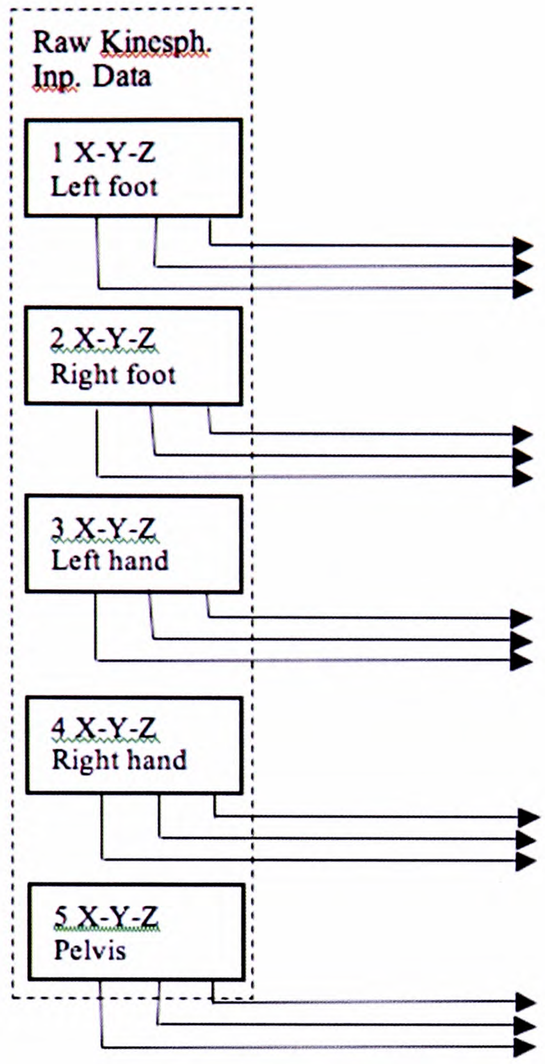

Figure 26 3*D*IM implementation chart no. 3: raw kinespheric input data.

6.2 Deduced Spatial Movement Parameters

Deduced spatial movement parameters are the second (algorithmic) derivatives of the raw X-Y-Z movement input data from each sensor of the RF/US tracking system. In the ChoreoSonic performance area these spatial bodily parameters are classified as:

- Proximity.
- Speed.
- Rotation.
- Direction.

In the following section the basic concepts for the use of these four spatial movement parameters in 3*D*IM are outlined.

6.2.1 Proximity

Proximity, or relative distance in the performance space, is an important spatial movement parameter that influences the energy of the dancer. As Winkler states:

> The stage, room, or space also has its boundaries, limiting speed, direction, and maneuverability. Psychological intensity increases or

> decreases with stage position, as the audience perceives more energy and focus as the performer moves upstage. Apparent gravity pulls the performer downstage with less effort, in a way similar to the very real pull of vertical downward motion. Intensity may also vary with the amount of activity confined to a given space. (Winkler 1995:3)

Similarly, the personal space within any performance can feel smaller when there is something/somebody in proximity of the dancer. Proximity to a wall, an object or another dancer can limit or obstruct the speed and freedom of a dancer's movement.

In a preliminary 'Sound Skeleton' experiment (2007), the proximity of the Cricket sensors in the hands of two dancers was measured to trigger increases and decreases in the additive synthesizer sound volumes (DVD: 9, CDR: Max 2007 sub-patch 'Dancer proximity'). In this experiment the bodies did not always need to be close together to modulate the sound volume. Rather the sensors could be held close to each other using an extended arm, leaving the bodies at some distance from each other. In this way, the distance between the two space modules of the dancers' arms is investigated. On the choreographic implication of this mapping procedure, Rubidge states: 'this gives a quite different emotional nuance to the choreographic forms, and a sense of ambiguity to the interrelationship between sound and movement' (Rubidge & Wijnans 2008).

As stated above, from 2007 onwards this type of spatial movement was measured within the kinesphere of the dancer him/herself by defining the relative distance of the different body parts to the pelvis using 5 sensors of the LCIPS (see p.128).

6.2.2 Speed

Speed defines the tempo and duration of the movement phrases and is a spatial and temporal parameter that has an impact on the spatial bodily perception of a dancer. Laban (1966:87) states: 'It seems that if we direct our attention towards the end of a trace-form or path, we are more easily able to produce a quick movement, than when concentrating on the beginning of a trace-form, which seems to delay the flow'. He suggests that this consideration is evidence of time as a spatial function.

Another significant observation relating to speed was made earlier (p.68) by Stiefel, who remarked that tempo (rhythm) is experienced differently by a dancer than by a musician due to the fact that the two artists count tempo in a different way. Regarding the fact that speed is a time-based parameter, David Topper *et al.* (2002:3) state: 'Variables [of audio spatialization] can also be mapped to trajectory or rate of change, defined by a time-varying function, or generated gesturally in real time'. In line with this citation, the derived speed parameter is used to emphasize sonically this temporal dynamic of the movement path. In several 'Sound Skeleton' creations this dynamic is created by the body as a 'living architecture' (see p.81) in space to generate the moving 'sound architecture' (DVD: 10-13, CDR: Max 2009 3*D*IM sub-patches 'Speedsample', 'Matrix mapping').

6.2.3 Circular Movement, Rotation and 'Wave-ing'

Circular full body motion involves rotation around the body axis and changes the orientation of the dancer in space. Whereas rotation in geometric 360° is possible for full body movement by movements such as rolling on the floor or making a somersault, this is beyond the anatomical capabilities of human limbs. Considering this issue, Longo notes:

> Gestures are wavelike in nature. This is because muscles always operate in pairs. One muscle pulls in one direction, while the other controls the motion by pulling in the opposite direction. (Longo 1996)

This Newtonian phenomenon was earlier observed in the theories of Laban (see p.79). Therefore, the term 'wave-ing'[195] will be used instead of 'rotation' for rotational movement of the limbs within the kinesphere of the dancer.

As previously remarked (p.113), the technology applied to dance movement can limit artistic possibilities. In the research undertaken for this thesis, measuring rotation proved difficult (DVD: 14-15, CDR: Max 2007 & 2006 sub-patch 'Rotation') with the ultrasonic systems due to the fact that the sensors must point upwards to the sensors on the ceiling to be seen by the system (see p.104). Therefore, downward turns of the sensor cannot not be measured. However, in the next section an experiment is shown in which these limited circular and wave-like movements are measured in combination with movement direction.

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[195] The term wave-ing is used here to make a distinction from 'waving' as the image of the 'hello/goodbye' wave.

6.2.4 Direction

Direction of movement path and spatial dimensions are important elements in dance because, firstly, the dancer can only fully 'scan' the spatial 3D environment by changing his/her orientation either in a full body circular movement and/or by including height transitions (jumps), and, secondly, because a *direction* within the kinesphere is limited by certain body constraints. As Winkler stated above, direction towards certain spatial elements such as boundaries of the stage, room, or space can influence the speed or comfort of the dancer's movement. In line with this view, Laban (1966:122) states: `Retardations and accelerations as well as the increase of intensity depend on directional intricacy'. Therefore, direction is an interdependent element that can only be fully incorporated as a spatial movement element when also taking other movement parameters (orientation and speed) into account. A ChoreoSonic effect can develop based on the circular and wave-like movements, combined with the movement direction. It would, for example, be possible to define and change the direction and length of a sonic pathway by using the spatial distance of the movement path in the interactive environment as a parameter (DVD: 16, CDR: Max 2009 3*D*IM Sub- patch 'Direction').

In figure 27 the four deduced spatial movement parameters, proximity, speed, rotation and direction, are added to 3*D*IM.

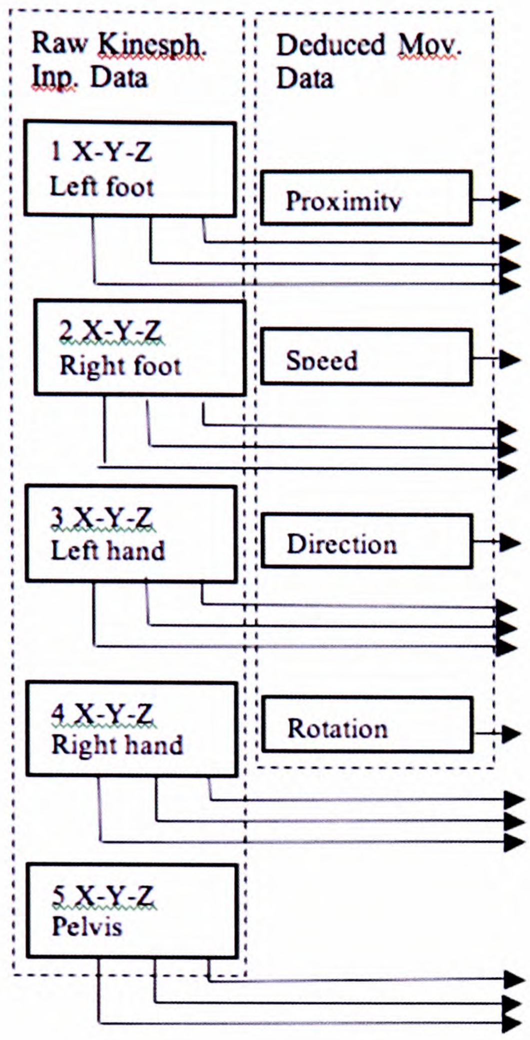

Figure 27 3*D*IM implementation chart no. 4: deduced spatial movement parameters.

6.3 Sonic Output

This section presents a discussion that focuses on sonic compositional mapping strategies that are designed for sonic interpretation of the first and second movement data derivates. The number of possible movement phrases is as numerous as the number of sonic possibilities. This implies that, even if it is possible to define a spatial movement phrase with a limited number of sensors (as is the case in this research), a rich spatial sound composition relating to the varying space of the body might still arise. When referring this issue to the DMI design field, Garnett & Goudeseune remark:

> One might then think that all the instrument builder needs to do is supply as many controls into the synthesis as possible. However, this can lead to a cognitive overload problem; an instrument may have so many controllable sonic parameters that performers cannot attend fully to all of them at once: they need a mental model simpler than brute-force awareness of every detail. (Garnett & Goudeseune 1999:2)

In line with Garnett & Goudeseune, Rovan *et al.* also note, from a choreographic point of view, that:

> The dramatic effectiveness of a dance, however, invariably depends on myriad factors—movement dynamics of body parts and torso, movement in space, location on stage, direction of focus, use of weight, muscle tension, and so on [...] what we perceive in dance is highly filtered and often illusory—the choreographer and dancer work hard for this effect. Indeed, the quality of flow at one moment may dominate our perception of a phrase so much so that individual shapes of the body go unnoticed. (Rovan *et al.* 2001:44)

These quotations point us to the fact that adding a multiple dimension of trigger parameters won't necessarily result in a satisfactory ChoreoSonic composition. For this reason, only two sonic output forms were chosen in the 'Sound Skeleton' creations:

- Additive Synthesizer.
- Samples and Effects.

6.3.1 Additive Synthesizer

I developed an elementary real time interactive additive synthesizer in Max/MSP (2006) to give the dancers freedom to alter the timbres of the sounds with their movements. David Wessel (1979:46) states: 'In the additive model for sound synthesis, a tone is represented by the sum of sinusoidal components, each of which has time-varying amplitude and frequency'. In the preliminary Max patch (CDR: 2007, sub-patch 'synthesizers'), the additive synthesizer consists of eight partials (the sinusoidal components). The additive synthesizer parameters used for the sonification[196] are: frequency of the total timbre, amplitude modulation, modulation depth and duration/tempo. These parameters are added to the 3*D*IM implementation chart no. 5 (fig. 28).

[196] The term 'sonification' is used here in the context of enabling or enhancing a translation of input data into sound in order to find relationships in those data, in this case specifically between movement and sound.

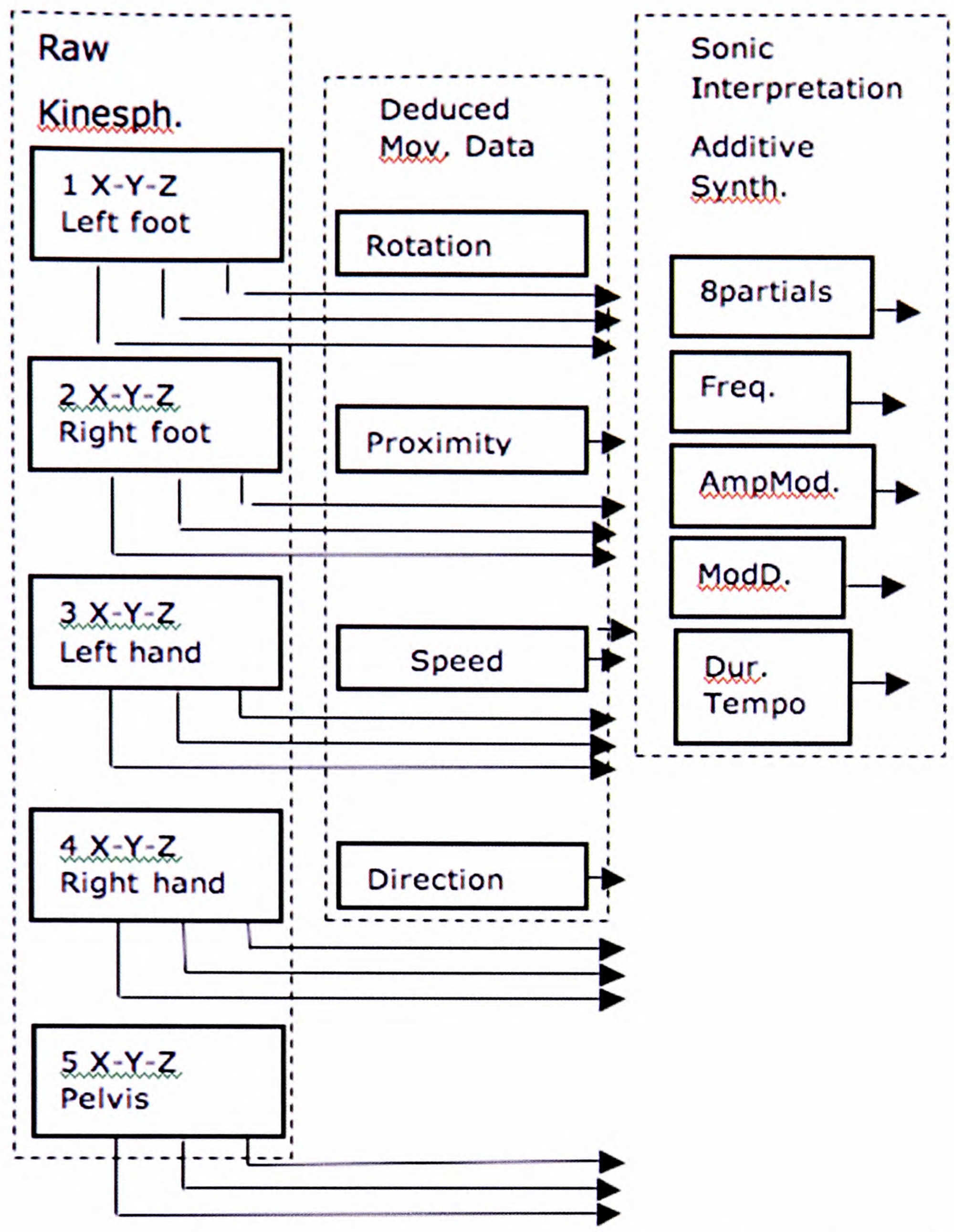

Figure 28 3*D*IM implementation chart no. 5: additive synthesizer parameters.

Several 'Sound Skeleton' experiments (DVD: 17-19, CDR: Max 2007 sub-patch 'synthesizers') using this preliminary Max patch took place during the testing of the prototype Cricket system (University of Chichester 2006-2007). However, I decided to restrict the sonic output to samples after this research due to the unsatisfactory sonic results.

6.3.2 Samples and Effects

A wide range of samples with either an organic character (vocal samples, see p.117) or an abstract character (ranging from machine, gaming, synthesizer, ticking sounds etc.[197]) had been chosen for basic sound generation. Samples were pre-edited in Logic Express[198] to prepare the sounds for looping and further effects processing in Max/MSP. Several of these samples have already been demonstrated in previous video extracts (DVD: 5-8, 10-13 and 16).

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[197] Downloaded from: http://www.freesound.org [accessed 19.12.08].
[198] See: http://www.apple.com/logicexpress/ [accessed 26.09.08].

In two other Sound Skeleton experiments I investigated the ChoreoSonic relationship further. In the first experiment the position of the sensor on the foot (that triggers the sound) is taken as the centre of movement (DVD: 20, CDR: Max 2009 3*D*IM sub-patch 'Bodypart proximity'). In this experiment the dancer's body is more specifically turned into a musical instrument when the proximity of a limb to the pelvis determines the pitch of the sound. In the second experiment, I also asked the dancer to concentrate on the movement of her feet, although the sound was triggered by the sensors in her hands. In this way a certain 'contra' ChoreoSonic relationship is created (DVD: 21, CDR: Max 2009 3*D*IM sub-patch 'Bodypart proximity'). In these examples it is shown that the technology has an influence on the movement choreography and, consequently, on the sonic output.

For reasons of clarity, the parameter changes of the samples that influence the spatial perception of the sound will be listed in the next section. Therefore, in this 3*D*IM implementation chart (fig.29) only the choice of sample (organic or abstract), the possibility to interactively change samples (as demonstrated in Case Study 2, see 6.1.2) and the addition of (vst plug-in) effects are listed.

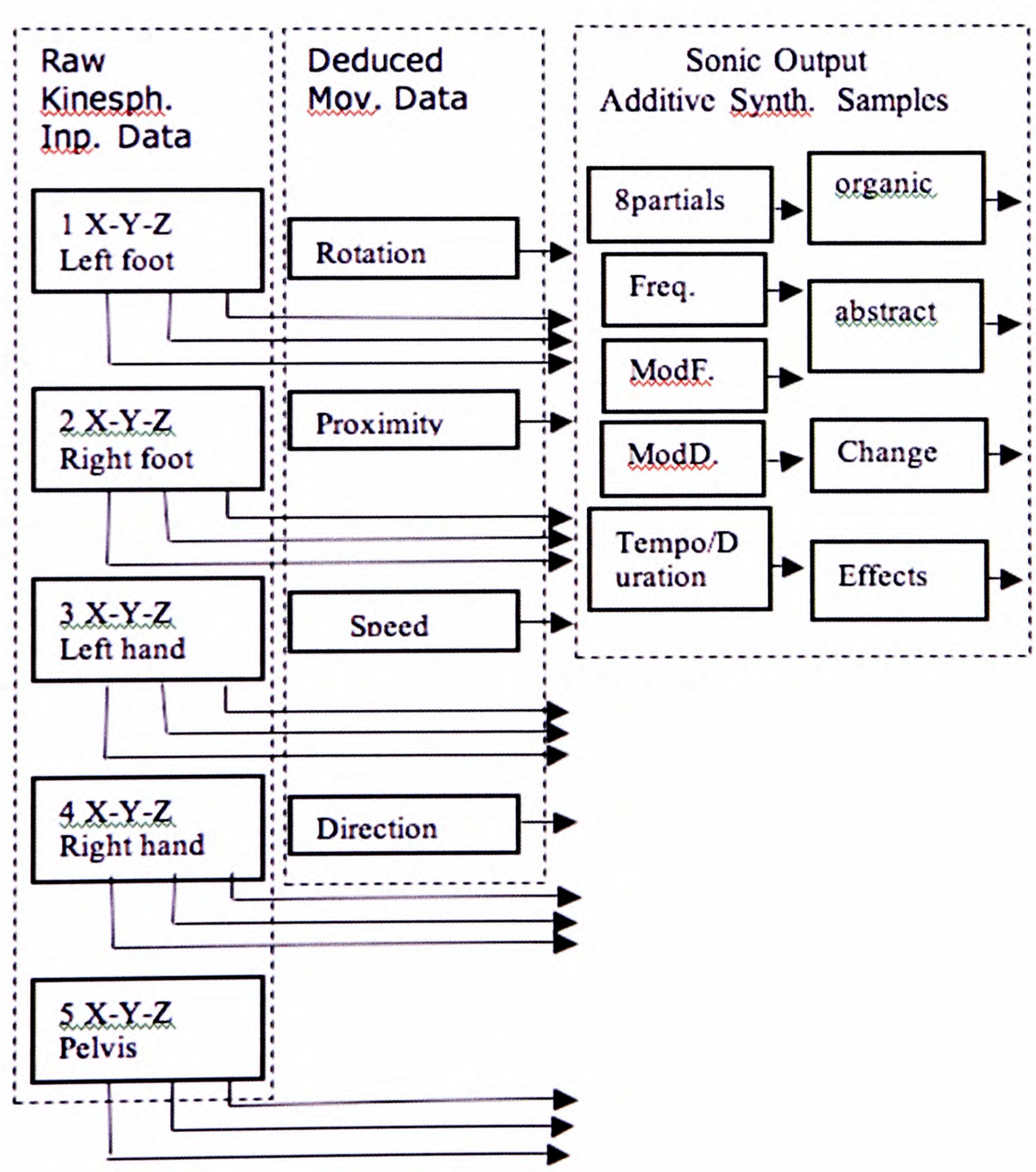

Figure 29 3*D*IM implementation chart no. 6: samples and effects.

6.3.3 Case Study 3: Showing at the University of Chichester (U.C.), UK (12/01/2007).

Choreographer: Sarah Rubidge

Dancers: Carrie Whitaker, Guy Adams

Sonic artist, Max/MSP: Stan Wijnans

System engineer: Stan Wijnans

This case study took place during a showing at the University of Chichester in January 2007. The showing demonstrated the outcome of a collaborative research project undertaken by Rubidge and myself. The mapping concept of this case study is linked to a review of a scientific test that was undertaken by Wanderley *et al.* (2000a) in an engineering R&D project. The research team submitted a theoretical relationship between gestural parameters and musical parameters to a practical test. In that project a Wacom graphic tablet was used as the controller device in combination with force sensors (pressure). One-to-One mapping strategies (see p.48) were applied with participating subjects who had some musical experience, but no experience in using the Wacom graphic tablet. In table no. 2 the mapping layer is shown.

X position	Fundamental frequency
Pressure sensor	Vibrato (modulation)
Pressure of stylus	General amplitude

Table 2 Mapping layer in the test case by Wanderley *et al.* (2000a).

In the 'Sound Skeleton' experiment undertaken for Case Study 3 the aim was to research how two dancers would respond sonically to a similarly simple mapping layout. According to Lovell *et al.* (1996:8), 'Weight-effort is aligned with the vertical dimension, space-effort with the horizontal dimension and time-effort with the saggital dimension'. The X-direction of the dancer in space was therefore chosen to change the fundamental frequency of the resulting combination of the 8 partials in line with Wanderley *et al.* (2000a). Jumps (vertical dimension), that attempt to defeat gravity and weight, were chosen to manipulate modulation depth, and speed to change the volume, in line with Lovell *et al.* (1996). In table no. 3 the mapping layer chosen is shown.

X direction	Frequency
height direction	Modulation
Speed	Loudness

Table 3 3*D*IM for two dancers and additive synthesizer.

In addition to this mapping layer, the position of the full body of one dancer activated 14 spots to trigger opera vowel sounds, as described in Case Study 2 'Scanning the Space' (6.1.2).

Due to limited technical resources - lack of availability of 8 full range speakers - eight small PC speakers were set up in a cubical form to try to achieve full sphere spatial sound (see p.88). A beta version of the ambisonic software developed by D. Hunt in Max/MSP was used for the 3D spatialization of the sound (CDR2:2007-2). During the showing, the viewers were allowed to freely walk around inside the performance space (see p.93) to experiment with Rubidge's notion of creating an installation in which a performance takes place in amongst the visitors to the installation. 'In a non-optical setup such as the Cricket system, such a strategy is possible' (Rubidge & Wijnans 2008). The movement improvisation took place inside and outside the sensitive area of the ChoreoSonic environment. The sensitive area was marked with white tape on the floor (fig. 30).

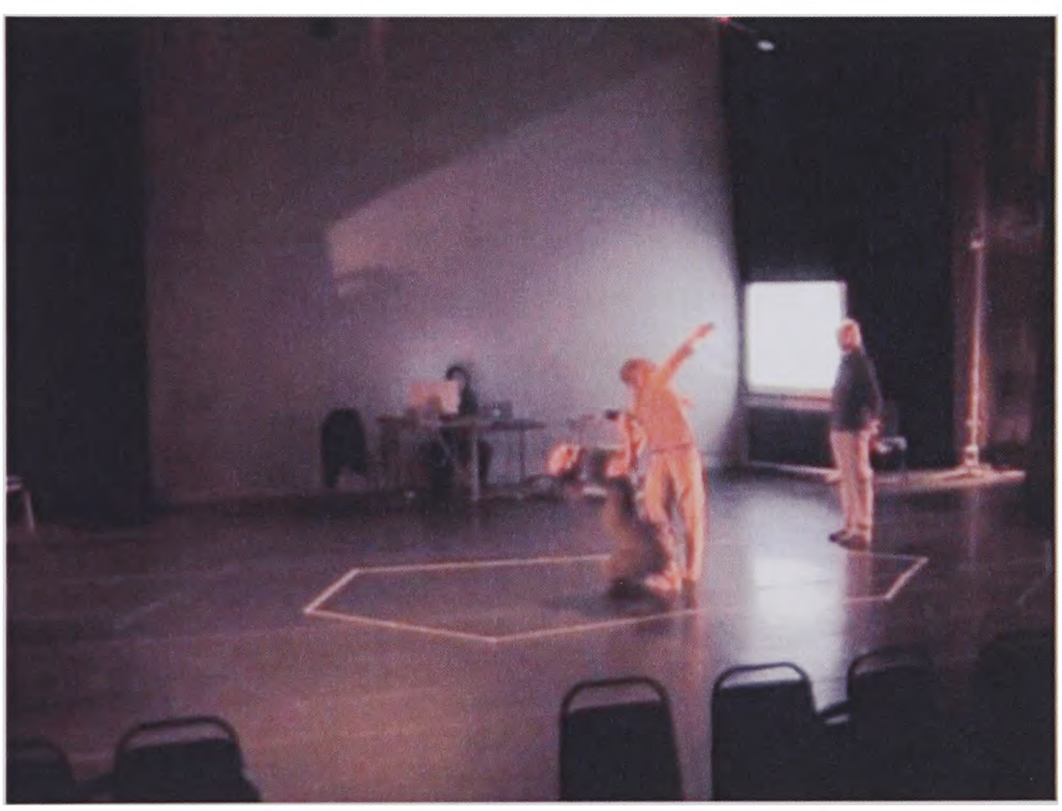

Figure 30 The sensitive floor area marked with white tape. From left to right: S. Wijnans, C. Whitaker, G. Adams, S. Rubidge.

First, the dancers engaged in a ten-minute improvisation, using the micro- and macro- improvisational structures that were developed during the research period. Dancer Whitaker (f) changed the frequency, modulation and loudness of a bell sound that was processed by the interactive additive synthesizer with her movements. The moving 3D sound position was directed to the opposite spatial position of her moving body. Dancer Adams (m) changed the same parameters of a basic sine wave when moving inside the sensitive area. He also triggered a voice sample according to his position in the sensitive area. The position of his allocated sound in space was directed to the same position as his movements. The sounds stayed in their last processed position when the dancers moved outside the sensitive area.

Unfortunately the spatialization of the sound was difficult to perceive accurately by the dancers as well by the attending audience. This was due to the fact that PC speakers are not full range (needed for ambisonics - see p.88) and because I positioned the sounds spatially opposite from Whitaker and close to Adams. Both these decisions made the spatial effect hard to perceive for the dancers, either because the sound was far away and therefore relatively quiet (Whitaker) or the sound was always moving in the same direction (Adams), i.e. very near to him.

Rubidge and I then gave a brief explanation of both the technological and artistic principles underlying the outcomes of the research, using the dancers to demonstrate certain aspects of the system. The dancers then performed a second ten-minute improvisation to allow the audience to view the systems in operation in the light of their new knowledge. At this time, both dancers also triggered an abstract sample when exceeding a set speed threshold. We actively encouraged the audience to move in the active space from time to time to ascertain what such a dialogue between audience and performers would look like (DVD: 22, CDR: Max 2007 main patch button 'demo 1' and 'demo 2') from both the inside and outside point of view (see p.93). Figure 31 shows the 3*D*IM implementation chart used in the showing.

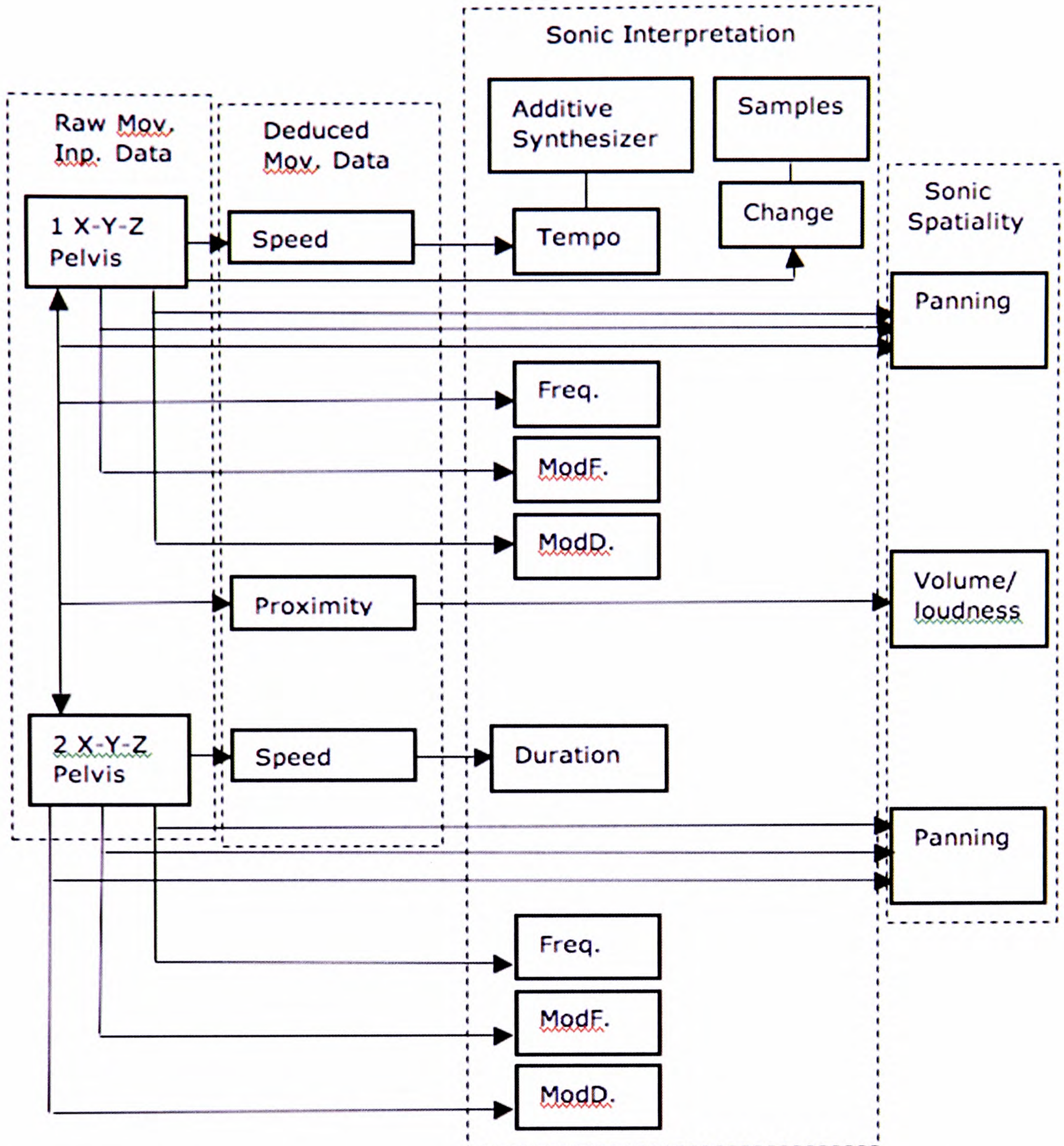

Figure 31 3*D*IM implementation chart no. 7: Showing at University Chichester.

6.4 Sonic Spatiality

In this section, I will categorize the different sound parameters that influence the spatial perception of sound according to generally accepted or scientific premises. The aim of this part of the research is to be able to incorporate the observed spatial sonic elements into the development of the 3*D*IM mapping strategy to allow the modulation of both the texture, direction and sonic reach of the interactive environment. Please note however that, as stated earlier (p.91), a precise and 'naturalistic' fidelity of sound perception is not a major issue in my research. However, it is useful to be aware of the scientific findings in order to be able to alter the spatial sound perception with the movements of the dancer.

The spatial sonic parameters are defined as:

- Volume & Panning.
- Frequency.
- Reverb.
- Delay.

6.4.1 Volume & Panning

Volume and panning are two features that have generally been accepted as having an impact on spatial sound perception. For example, in the MSP manual it is stated that:

> All other factors being equal, we assume that a softer sound is more distant than a louder sound, so the overall loudness effect created by the combined channels will give us an important distance cue ... panning must be concerned not only with the proper balance to suggest direction of the sound source; it must also control the perceived loudness of the combined speakers to suggest distance.[199]

In an acoustic context, Blauert (1997b:108) states: 'Spaciousness increases sharply with increasing sound level'. He outlines that when the volume of an orchestra increases, the sound space is extended accordingly in the median, frontal and horizontal planes (fig. 32).

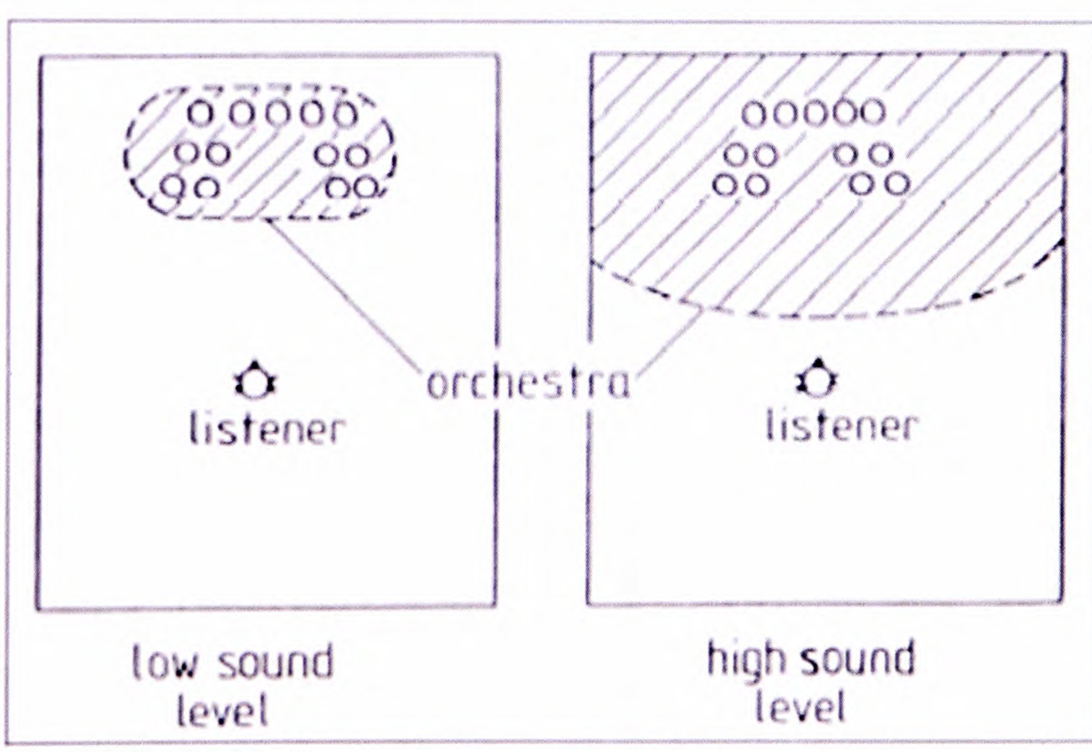

Figure 32 To explain the effect of auditory spaciousness (Blauert 1997b:109).

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[199] From MSP manual Tutorial 22 'Panning for localization and distance effects' online] available from: http://www.cycling74.com/docs/max5/tutorials/msp-tut/mspchapter22.html [accessed 10.08.08].

Therefore, the overall volume created in the spatialization software should give the listener an important distance cue. The applied panning should provide the required volume balance between loudspeakers. For this reason, it is important to level the initial volumes of all loudspeakers in the ChoreoSonic environment.

6.4.2 Frequency

It was shown in several psycho-acoustic experiments by Blauert (1997b) that the frequency spectrum is not only significant for the timbre of the sound, but also for spatial sound perception. In a sound source, that is normally composed of a frequency spectrum of different highs and lows, the various frequencies might be perceived as coming from different spatial locations. For example, Erich Von Hornbostel reported in 1926 that 'the song of a bird constantly changes position, though the bird may not' (*quoted in* Blauert 1997a:43). Low frequency signals are 'perceived as being particularly present and forward oriented', signals in the midrange (centered around 1 kHz) 'sound rather diffuse in space and sometimes even sound as if they are coming from behind the listener' and 'signals with strong components around 8 KHz lead to auditory events above the horizontal plane under a greater or smaller angle of elevation' (Blauert 1997b:106).

It was stated previously (p.89) that the physical characteristics of the listener's head and ears determine a frequency dependent response to sound position. Therefore, a HRTF (head related transfer function) algorithm is applied in ambisonic decoding. Music and sound will consist of a varied and dynamic frequency spectrum. For this reason, it is important to realize that, when frequencies have their own inherent movement (see Von Hornbostel above), an exact controlled direction of the spatial sound is hard to achieve.

6.4.3 Reverb

Although reverberation contributes to the spaciousness, Blauert (1997b:110) notes that 'A too strong and too long reverberation leads to a smearing of the sound signals in time and thus to a loss of sharpness in articulation and clarity'. I tested this statement in several 'Sound Skeleton' compositions (DVD: 23-24, CDR: Max 2009 3*D*IM) to see if, and to what extent, reverb would disturb the perception of the spatial sound. As can be heard in the video excerpt, I concluded that adding reverb emphasizes the perception of the spatiality of the dancer's 'space modules' (p.94). However, the localization of the sounds in space was more difficult to achieve. Therefore, reverb should be applied with caution unless a widening of total space is desirable.

6.4.4 Delay

This parameter is another important element that helps the brain to locate moving spatial sound. Blauert showed that with zero to very short delays (up to 1 ms) 'the percept drifts off to the earlier sounding loudspeaker' but with longer delays (over 80ms), an echo towards the earlier sounding loudspeaker is perceived (1997b:107). It was concluded that 'One factor that contributes to the spatial impression is the characteristic temporal slurring of auditory events that results from late reflections and reverberation' (*ibid* 1997a:348). Delays and echoes originating from reflections from the walls and ceiling can also diffuse the perceived sound signal direction. However, these reflections are not considered in this thesis as this acoustic factor is beyond the scope of this research.

As shown above, volume, panning, frequency of the sound, reverb and delays/echoes have an influence on how we perceive the direction and spatialization of sound. Therefore, I add these four elements as spatial sonic parameters to the 3*D*IM chart (fig.33).

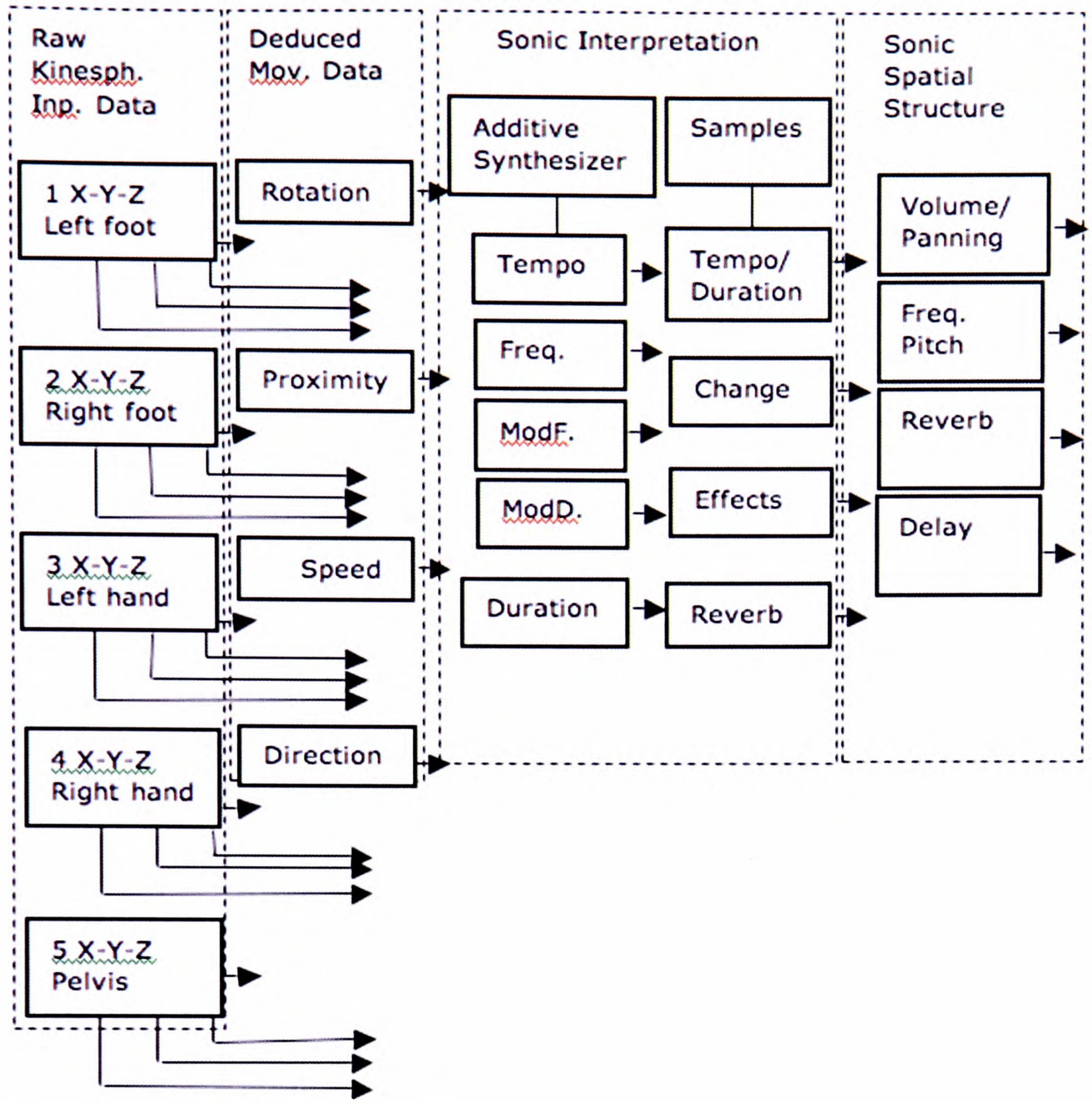

Figure 33 3*D*IM implementation chart no. 8: sonic spatial structure parameters.

6.5 Interdependent Spatial ChoreoSonic Relationship

In this section, three 3*D*IM mapping strategies are proposed that emphasize the influence of sonic spatiality on movement choreography. The aim is to emphasize the 'tranSonic' perception (see 4.1.2.2) of the performative event. The three mapping models are labeled:

- 'Beep-Stop' Model.
- 'S-E-N-S-I-O' Model.
- 'Vector' Model.

A spatial ChoreoSonic relationship can evolve by starting either from a sonic, or a choreographic perspective. In order to support these strategies they are underlined by several references from the appropriate field.

6.5.1 'Beep-Stop' Model

Dance researcher Duerden (2005) remarks in her paper 'Dancing in the Imagined Space of Music':

> Physical movement, perceived visually, is much more sluggish than movement in sound can be; this is a spatial issue, of course – a human body has to get from here to there by passing through all the space between; it cannot simply be 'here' and then be 'there'. (Duerden 2005:29)

She observes that dancers move linearly, but sound can be linear or non-linear. In a philosophical sense, Manning (2006) talks about the 'stop-gap of perception: about a half second'[200]. This space-time perception is inherent to the fact that we perceive events according to a composition of these 'holes of experience' (*ibid*); we perceive the world with a delay. In the following I will propose a way in which a dancer is able to 'beep herself around' (being here and being there) in the created virtual space, emphasized by the interactive spatial sound.

In the ChoreoSonic environment, it is possible for a dancer to break down her/his fluent interactive movement trigger by occluding the sensor with the hand, other body parts or another dancer. Another way to stop the sensor from working (and thus create a 'stop-gap' in the sound composition) is stepping or jumping outside the sensitive range of the system. In the research undertaken, the centre was moved outside the borders of the sensitive area, which gives the dancers a method which allows them to choose to switch sounds on and off, or 'leave' the sound in the last position the sensor was placed (DVD: 4, CDR: Max 2007). The dancer desynchronizes the movement of the body and the spatial sound. In this way, the sound is beeping around spatially by virtue of the quick 'beeping' occlusion of the sensor by the dancer. This creates an interesting choreographic element, especially when this is done at the high speed that is necessary to achieve an obvious spatial and rhythmic sonic effect.

6.5.2 'S-E-N-S-I-O' Model

Previously (pp.83-84), I referred to Rubidge & MacDonald (2001) who used the term 'choreographic sensibility' to indicate that the choreographer in interactive environments brings a certain sensibility to the choreographic

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[200] Bergson (1911) and Whitehead (1922) philosophised about the half-second gap or discontinuity in our experience, before this 'readiness potential' gap of the conscious mind was scientifically proved by Libet (2004) in the late 60's.

design of not only the performers, but also of the architecture of the space itself. To investigate this idea of incorporating the spatial environment, I allocated different trigger parameters to the sensors in the hands of the dancer in order to modulate only one sound. I composed a short compilation of pop music and abstract samples that were switched on or off when the *right* hand movement of dancer Spasic exceeded a certain set speed threshold. This process was marked by another abstract sample to tell the dancer that she had switched on or off the composition. The height of Spasic's *left* hand changed the pitch of the composition. The position of the *whole body* in the sensitive area subtly changes the amount of reverb.

In this way, the architectural space of the body and the spatial environment was sonically choreographed by choosing several spatial parameters in 3*D*IM and by moving from one extreme corner of the Surround Sound space to the opposite corner. Here, the movement space of the dancer is directly linked to the generated sound changes and the spatialization of the sound (DVD: 25, CDR: Max 2009 3*D*IM).

6.5.3 'Vector' Model'

Duerden (2005) further remarks that 'music notes can move much faster than the human body'. This is clearly true, and in an interactive virtual environment this fact is a particularly productive feature to explore as an artist.

When combining the two models described above, we are able to shift the spatial perception purposely and create another spatial possibility. In a ChoreoSonic project, the pathways that the dancer creates can be interrupted, combined or extended by setting various starting points in the ChoreoSonic performance area. To achieve this, a dancer can start from any spot where she has been able to hide, either behind a stage curtain, an object in space, a viewer or another dancer (when more than one dancer is involved in the practice). By influencing the spatial perception of an audience member (who is also moving within the ChoreoSonic environment, see p.93) whilst choosing these different points of view, the pathways of the dancer become vectors that can start from any point in space. In this way the viewer's changing perception of the dancer can trigger different processes of the sonic and spatial elements. This spatial 'playfulness' makes it possible to 'shoot' sounds around according to a sudden 'sensitive displacement' of the dancer in the space.

The purposely chosen 'invisibility' of the dancer by either occluding the sensor ('sonic invisibility'), or by starting to move from different visible positions in space ('movement invisibility') can place, replace and displace the virtual sound body. The perception of the spatialization of the sound is particularly dependent both on the position of the dancer as well as of the position of the listener in the ChoreoSonic performance area. In this context the performative environment is not just an inactive ambience, but is altered by the movements of the interactive agent (here the dancer) through a responsive immersion of the spatial sound. The freely chosen dynamic positioning of the listener can further moderate the perception of the sonic space.

6.6 Equipment used

The initial sound composition in the studio used a Kawai MM-16 16 channel MIDI mixer to imitate the moving sensors on the body.

The preliminary practical research at the University of Chichester (2006-2007) used two networked Apple G4 laptops (OSX 10.4 867 MHz & 1GHz). The first one processed the Cricket data reception and the sounds in Max/MSP 4.5.7. The Cricket data were transferred over a network to the second laptop and the sounds were transferred using a 4-Out Echo Indigo DJ soundcard.

The second laptop spatialized the incoming 4 sound channels from the first laptop in a Max/MSP 4.5.7 patch running the ambisonic tools and a RME Hammerfall Multiface 8In/8Out soundcard. The eight outputs were connected to 8 small Sony PC speakers. Sounds were mixed with a Behringer 1622-FX 8/8 mixing desk. The initial patch uses a beta version of Max 4.5.7 tools for ambisonic sound spatialization (developed by David Hunt, UK).

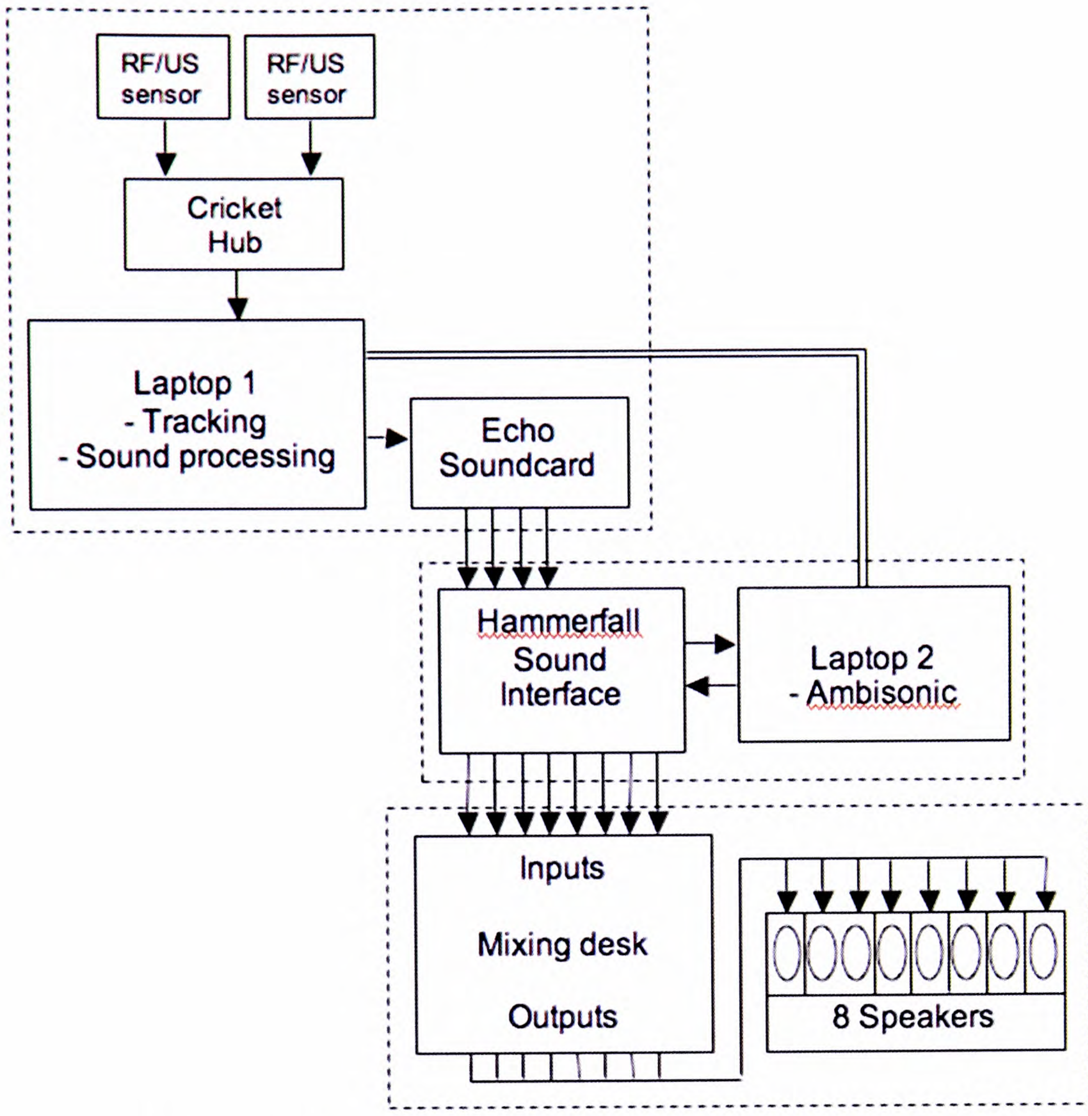

Figure 34 Technical Set Up 2006-2007.

The final version of 3*D*IM was designed and operated using a Mac Pro 3 Ghz Dual-Core Intel computer under OSX 10.4.11 and Max 4.6.3. 3*D*IM is developed to use audio interfaces that have eight analogue audio outputs. In the research a RME Hammerfall Multiface Interface was used as mentioned above. The 8 separate outputs of the Multiface communicated the spatialized sounds that were mixed using a Behringer 1622-FX 8/8 mixing desk, to 8 self-powered Mackie or Peavey speakers.

The final patch uses Max 4.6.3 tools for ambisonic sound spatialization developed by the Institute for Computer Music and Sound Technology in Switzerland (ICST 1.2).

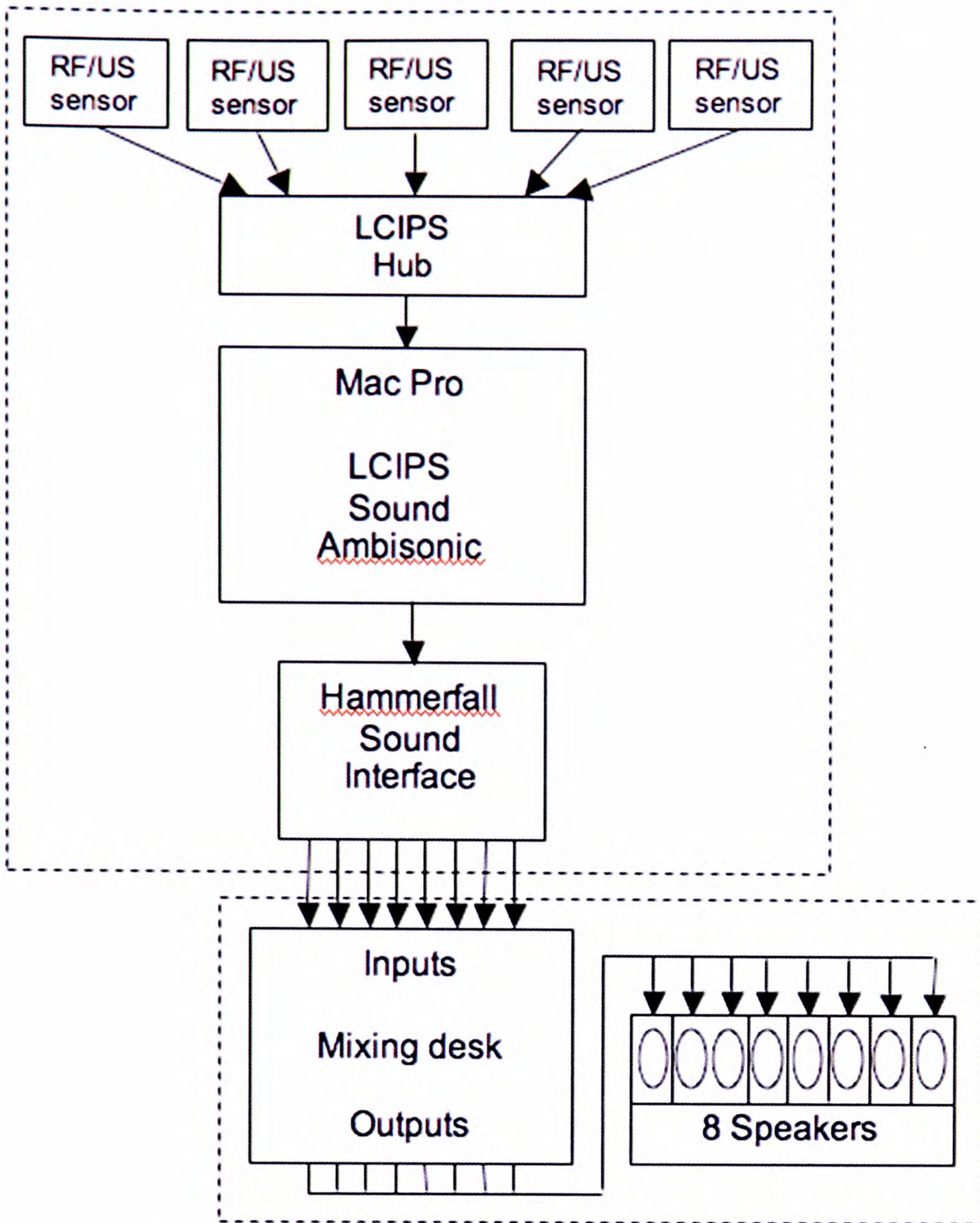

Figure 35 Technical Set Up 2007-2009.

6.7 Summary 'Three Dimensional Data Interpreting Methodology'

In this chapter the development of 3*D*IM has been described. 3*D*IM is a methodology that strives for a greater vocabulary and nuance in the mapping process in the computer as suggested by Downie (2005). It defines a classification of the (incoming) spatial movement parameters and those of the (processed) spatial digital audio data. The following four (spatial) parameter mapping categories have been defined:

1) Raw movement input data.
2) Deduced spatial movement data.
3) Sonic output.
4) Sonic spatial structure.

The description has been accompanied by 3*D*IM implementation charts and video excerpts that showed the results of the undertaken 'Sound Skeleton' creations. These either helped to develop, or tested the strategy of 3*D*IM. A number of creative options for mapping spatial body movement parameters to spatial sound parameters have been described.

Several conclusions can be drawn from the practice undertaken. In the first instance (2006-2008), it showed me that choosing a large selection of movement and sound parameters blurs the perception of the interactive ChoreoSonic relationship. It was also shown that sounds should be clearly defined to be able to achieve a transparent spatial relationship between movement and sound. Apart from these parametrical issues, it also transpired on several occasions that the dancer needed more training time, in particular to adjust to the latency (about half a second) of the RF/US system. It was also concluded that the obvious visibility of the sensors on the dancer's body might obstruct an objective perception of the ChoreoSonic relationship due to the fact that the viewer focuses on the movements of the sensors. As such the sensor becomes a 'remote control' for the sound.

The ChoreoSonic relationship was further investigated by creating a variety of 'Sound Skeleton' experiments and compositions that explored the distances of the four space modules of the body, the kinesphere of the body and the peri-personal space of the dancers. At the final stages of the practical research, the architectural space of the body was sonically choreographed when proposing three theoretical 3*D*IM parametric models that emphasized a 'tranSonic' perception of the performative event: the 'Beep-Stop' Model (creation of a non-linear ChoreoSonic event), 'S-E-N-S-I-O' Model (choreographing sonic space) and 'Vector' Model (shifting the spatial position of movement and sound). In these models, the collaborative work of the dancer and the sonic artist has been presented as an interdependent, rather than a dependent, collaboration in which the spatial sound is able to guide the dance improvisation. These models indicate that interactive spatial surround sound can give rise to new choreographic strategies that emerge using the interactive technology created in this PhD research project.

In this chapter, the elements for artistic development and some of the wide choices of artistic possibilities using the enabling technology and the software development discussed in this thesis have been outlined and demonstrated through a description of a series of artistic experiments and compositions. These show that, in the 'Sound Skeleton' creations, the technology evokes a dynamic sonic representation of the improvised ChoreoSonic environment generated by the well-trained proprioception and spatial awareness of the dancer.

Chapter 7 Conclusions and Future Work

This chapter concludes the research undertaken in this PhD project. In the introduction (Ch.1), it was observed that the spatial dimension of sound has rarely been incorporated in sound compositions made for dance performance. Therefore, in this research project the different spatial elements involved in both disciplines have been explored through a theoretical and practice-led methodology. In order to fully investigate the initial research questions – namely, which technical and artistic elements make it possible to create a real time spatial ChoreoSonic performance environment and what is needed to find a satisfactory artistic mapping relationship between the spatiality of dance movement and spatial sound composition in an interactive context - the thesis was divided into two parts. Part I, the 'general normative research', evaluated theoretical design strategies undertaken by artists and researchers in the field and Part II, the 'normative case study', presented several practical case studies devised to test new design strategies and technologies, and described the final artistic outcome.

PART I General Normative Research

7.1 The Theoretical Research

The thesis began with an investigation of the different types of technological discourses in art environments in which the applied technologies relate to and/or might enhance the intended art creation.

The first chapter (Ch.2) presented a review of a number of gesture based sonic projects describing the technical systems used and the artistic outcome created. Several pioneers (Waisvisz, Sonami, Rovan, the Sensorband) were described. These artists designed new digital musical interfaces for sonification and musical control. The sonic data measurement methods of these DMIs were classified as 'object location in space' and 'moving body part tracking'. These interfaces added movement, choreography and physical activity as a visual element to the sound performance by measuring the gestures needed to create and influence the digital sound creation.

In the next chapter (Ch.3), these sound-based developments were shown to be predecessors to movement-based interactive technologies. An analogy was observed between the sonic data measurement methods used in 'object location in space' and 'moving body part tracking' and the movement data measurement methods used in 'full body motion capacity' and 'personal space tracking techniques'. The review of interactive movement based technologies (sensitive dance floors, breaking beams, camera tracking, electronic body part motion sensing systems and motion capture systems) underlined the need to clearly define the technical capabilities and shortcomings of real time tracking systems. The specifications of these technologies have a major impact on the possibilities for artistic development, i.e. the sensitive geometric range and dimension of the system, and the data resolution and speed of the data transfer. Apart from these factors, it is important to be aware of restrictive issues such as access and availability, financial implications, required operational expertise, and the limited available research time.

Several examples (i.e. Bevilacqua, Camurri, Rokeby, Winkler, Troikaranch) showed that mathematical actions may need to take place on top of the artistic decisions before it's possible to map human motion to sound. It was noted that these unavoidable technical limitations are not necessarily counterproductive, but open up other avenues of creative explorations. At the end of the chapter, motion analysis and gesture recogniton techniques were described as examples of more specific data mapping methodologies. However, it was questioned whether these techniques - digitally processing the unique expressive qualities of the highly skilled movement artist - are artistically productive.

Thus it was outlined that hardware and software technology have, firstly, an influence on the movements that are needed for the artistic result and, secondly, on the final artistic (sonic) outcome. Unfortunately a precise, accessible and affordable system for measuring dancers' movements is still unavailable. Therefore, the decision was taken to pursue the practical research with RF/US systems that offer suitable 3D measurement capabilities, ease of access and a fast installation procedure.

In chapter 4, the digitally enhanced spatial ChoreoSonic environment was discussed in order to contextualize the central artistic methodology in this study. In this last theoretical research chapter it was argued that in such an environment, computer technologies are firstly able to influence the shape of movement and choreography and secondly to redefine the principles of space and time. In the same way, the spatial perception of sound can influence the sense of choreographic spatiality of both the dancer and the audience. The notion of playful improvisation, based on the dancer's knowledge of the capabilities and shortcomings of the applied technical system, is recognized as the main movement strategy in the ChoreoSonic environment.

In line with Laban (1966), the moving body is regarded as a 'living architecture' that changes its pathways (and thus position) in general space as well as the cohesiveness of the body structure. The latter is determined by the personal space (kinesphere) of the body and is bound to the framework of the body, but mobile in the context of general space. This 'living architecture' moves in the three geometric spatial planes: horizontal plane (left - right), median plane (forwards - backwards) and frontal plane (up - down).

It was outlined that three elements assist human beings in the self-perception of the position of the body in general space: proprioception, kinesthesia and the peri-personal space. These elements suggest the possibility of the transcendence of conscious body limitations by the dancer, a perception that surpasses the usual limits of conscious bodily boundaries. In this context, I proposed the term 'tranSonic' perception to identify the perception of a ChoreoSonic interactivity in which sound becomes almost tactile and visible: 'sound as a disembodied movement' and 'dance as an embodied sound'. This ChoreoSonic perception exceeds the usual limits of ordinary experience by moving the movement-sound relationship closer to the body by adding a second (auditory) skin to the dancing body (Verstraete 2005) as a performative transcendence of body limitations. The use of real time ambisonic software, that is able to move sounds around in a three dimensional coordinate system based on the same geometric plane theories that determine the bodily space, makes it possible to design a 'living sonic architecture' that represents the 'living architecture' of the body.

After the contextualization of the ChoreoSonic environment, it was determined that the tracking system should measure the moving body structure and its mobility in general space. Therefore, the decision was taken to place five sensors on the body according to Laban's pentagonal structure (1966). The 3D localization of the sound allocated to the sensor on the head (measuring the position of the pelvis as the centre of full body motion) is directed by the dancer's pathway in the ChoreoSonic environment. The four sensors attached to the limbs spatially direct their individually allocated sounds according to the four space modules of the body (Kirstein 1953). In this way, the sounds move in the three geometric spatial planes according to 'living architecture' of the body.

A visualization in Max/MSP/Jitter of the movements of the sensors attached to the dancer's body is regularly projected on a screen during the 'Sound Skeleton' creations as a guide for the interactive real time ChoreoSonic spatialization process. The perception of the spatial ambisonic sound is realized by using eight full range speakers that are set up in a cubical form at the edges of the sensitive ChoreoSonic environment.

PART II Normative Case Studies

7.2 The Preliminary Technical Research

Chapter 5 described a case study of the development of the prototype 'Cricket' RF/US system. In this practical research period (2006-2007) the technical and choreographic potential of the system was explored using a preliminary surround sound mapping patch in Max/MSP/Jitter, with eight small PC speakers to realize 3D movement of the spatial sound. Several disadvantages of the tracking system were identified such as the physical dimension of the sensor boxes, long latency, occlusion and a slow update rate.

When the development of the Cricket system was postponed, the 'Low Cost Indoor Positioning System' (LCIPS) became available. LCIPS is able to track up to 6 RF/US sensors synchronously. Although this system suffers from similar limitations as the 'Cricket' system, it afforded a significant advantage with its ability to track 5 sensors simultaneously.

After these initial technical investigations, it was concluded that the technology should only assist to the best of its abilities in realizing the original artistic idea, not merely serve as a goal in itself. Therefore, no other systems were further investigated and the choreographic and sonic possibilities, and the limitations of these RF/US systems were fully explored during the 'Sound Skeleton' creations.

7.3 The Final Artistic Outcome

In chapter 6, the theoretical research dimensions described in chapters 2-4 culminated in the development of the Three Dimensional Data Interpreting Methodology (3*D*IM). It is the use of two wireless RF/US systems, the Cricket system and the Low Cost Indoor Positioning system (LCIPS), that has been explored here. The 'data body space' derived from these systems has been defined by introducing the 3*D*IM strategy that is implemented in the specially created Max/MSP/Jitter software.

3*D*IM is a subjective ChoreoSonic mapping matrix that combines and categorizes the time-space-rhythm movement parameters that modulate the parameters of the interactive spatial sound:

- Raw movement input data (full body motion data, kinespheric movement data).

- Deduced spatial movement parameters (proximity, speed, circular movement, rotation and wave-ing, direction).

- Sonic Output (additive synthesizer, samples, effects).

- Sonic spatiality (volume / panning, frequency, reverb, delay).

This process was used as an index and concept for the realization of a range of real time spatial 'Sound Skeleton' experiments and compositions created by the dancer(s). The aim of my research has been to design an open structured system consisting of a flexible software interface that can be adjusted to the tracking system used (as realized in the 3*D*IM 'MIDI' and 'calibration' Max sub-patch, see CDR: 3*D*IM) and the individual artistic needs of the choreographer and sound composer (as realized in the 3*D*IM 'mapping matrix' sub-patch, see CDR: 3*D*IM).

From the reviews and discussions in chapter II-IV, it becomes clear that numerous artistic possibilities arise because complex mapping strategies might evolve when mapping the performer's geometric 'gesture space' to the listener's 'perceptual space'. The level of interaction between the movement artist and the sonic result can vary greatly. In the practical research, the improvising dancer has demonstrated different combinations of the noted spatial movement parameters, the available sonic layers and the parameters that modulated them in 25 concise ChoreoSonic 'Sound Skeleton' creations (see DVD: 1-25). These have tested and demonstrated 3*D*IM, applying the two RF/US tracking systems. The dancer was trained to interact with the elementary sonic layers, concentrating on movement and sonic parameters separately, before beginning to combine the determined ChoreoSonic layers in different mapping configurations. The 'Sound Skeleton' creations showed that computer technologies and spatial digital sound are able to influence the shape of movement and choreography and to redefine the traditional principles of space and time by realizing a 'tranSonic' perception in the interactive ChoreoSonic environment.

7.4 Evaluation and Future Work

The investigations in this thesis have described technological discourses with artistic outcomes, and the spatial movement and sound context from the perspectives of researchers and artists. These theoretical and practical findings have created a meaningful relationship between the dual activities of spatial movement and sound in performance practice within the development of 3*D*IM.

After these investigations, I can articulate the details inherent in the proposed term 'tranSonic' perception by pointing out several contra distinctions in the ChoreoSonic experience that are generated by the sound environment:

- Embodied - Disembodied (a second, auditory skin is added to the body and exposed in the performance space).
- Intimate Space - Open Space (the intimate 'auditory skin' of the dancer changes the perception of the open performance space in which the spatial sound affects the choreographed movement).
- Object - Subject (the objective sound parameters are directed by the subjective experience of the dancer).
- Human - Computer (the duality of what is most human and what is most machine can be an inspiration for the artist(s) involved).

This research project, and the theoretical and practical research it developed, has provided the basis for an artistic mapping methodology that draws upon and offers an overview of technical systems for use by interdisciplinary interactive artist-researchers. Future studies on the development of an interactive ChoreoSonic performance environment and the implementation of new mapping strategies should lead to full performance events accompanied by research writings in the form of papers, book chapters and presentations in conferences and practical workshops. As technology rapidly progresses, it is anticipated that the applied tracking system will be updated or replaced. The 3*D*IM software will be developed and adjusted when new tracking technologies become available. Recently, technologies such as the wireless Wii game controller by Nintendo[201], that features motion sensors with six degrees of freedom[202], or 'Project Nato', for controller free gaming by XBox[203],

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[201] Wi-Fi IEEE 802.11 b/g and Bluetooth 2.0 (EDR).
[202] The wireless signal can be detected within 10 meters of the console. However, the resolution and CPU speed are generally low, see: http://www.whatconsole.co.uk/wii.php [accessed 29.07.08].
[203] See: http://www.xbox.com/en-US/live/projectnatal/ [accessed 23.07.09]. However, at the time of this writing the system has not yet been marketed.

possess cheap and more widespread properties. The data derived from these new technologies can be received in Max/MSP over MIDI or OSC and mapped in the 3*D*IM software for use in an interdisciplinary setting with dancers, composers, technicians and computer scientists.

This research has highlighted the practical artistic methods that are complementary to interactive performance development. It hopes to contribute to Art & Technology research and development methods and interactive performance practice in general. This thesis provides an insight into the concepts of previously applied mapping methodologies and interactive performance methods reflecting on a range of interactive technologies. It provides research subjects for students and professional artists in the field, and can be considered as a reference in interactive performance work. A number of future developments are envisaged, concerning several topics presented in this thesis:

- I suggest further development of the 3*D*IM software and the used Max/MSP tools for direct practical use for those who plan to create interactive performance practices.
- Further research with performers from other artistic fields, such as movement artists and dancers trained in different movement styles (hip-hop, street dance, classical, Asian etc.) or different musical styles (such as jazz, classical, popular) may bring up new findings on the created ChoreoSonic relationship. This can also lead to the creation of new mapping strategies in 3*D*IM.
- Concerning spatial sound, further exploration of the sonic parameters that influence the perception of spatial sound may help the innovative creation of the proposed 'tranSonic' perception of the interactive spatial ChoreoSonic environment. The models proposed at the end of chapter 4 can serve as a basis for these future developments.
- Specifically it would be interesting to see how the availability of new technological inventions, whose tracking mechanisms are more precise, faster and easier to operate, might give rise to new ChoreoSonic models that can augment the spatial interactive relationship of movement and sound.

In all cases, I believe that it is necessary that artists and technologists collaborate closely to create new artistic methods and concepts in the interactive artistic performance domain. I hope that my thesis, and in particular the concept behind the 3*D*IM mapping strategy, can add to a new way of looking at interactive performance development. The thesis has aimed in particular to indicate the need for the development of clear mapping strategies.

This brings me back to the artistic viewpoint described in the beginning of this thesis: as an 'artist-technologist' and 'audio-movement data translator' (p.13), I created 3*D*IM to demonstrate how the interdependent spatial movement and sonic parameters may be used to generate movement-based 3D interactive sonic art: 'the Body as a Spatial Sound Generating Instrument'.

Appendices

1. Documentation
2. Publications
3. Presentations, Seminars & Workshops
4. 3*D*IM Operation Manual
5. Software Copyright Clearance

1 Documentation

1. **CDR** 'Sound Skeleton' Software.
   1) Excerpt preliminary 'Global Drifts' composition (6.28")
      Max patch with sound samples used in the 'Global Drifts' project.
   2) 'Sound Skeleton Experiments'. Max/MSP/Jitter software patches (2006-2008 and 2009 3*D*IM) with 'read me' files, 3*D*IM manual and sound samples.
   3) Install files for patches 2006-2007: Max/MSP 4.5.7, Jitter 1.5.2, Pluggo 3.5.4, Taptools 2.0 and Ambisonic Max tools Hunt
      Install files for patches 2008 and 3DIM: Max 4.6.3, Jitter 1.6.3, Pluggo 3.6.1, & Ambisonic ICST 1.2.
      Read me file, additional Max externals, help files and used VST Pluggo plug-ins.
2. **DVD** 25 'Sound Skeleton' creations accompanied by written text. Total length 27.01".
   1) Error 0.27"
   2) Calibration 0.56"
   3) Sensor Back 0.37"
   4) Border 0.18"
   5) Scanning the Space I 0.35"
   6) Scanning the Space II 0.42"
   7) Overload Parameters I 0.49"
   8) Overload Parameters II 0.42"
   9) Prox-Vol 0.55"

10) Speed Samples 1.10"

11) Speed=Pitch 1.16"

12) ChoreoSonic Rhythm 1.06"

13) ChoreoSonic Rhythm Edit 1.06"

14) Full Body Rotation 0.34"

15) Arm Wave-ing 0.31"

16) Direction 1.40"

17) Hopping 0.14"

18) Additive Synth I 0.16"

19) Additive Synth II 0.33"

20) Foot making Music 1.39"

21) Contra Centre 1.52"

22) Showing University Chichester 3.57"

23) Speed=Reverb 1.44"

24) Kinesphere=Reverb 1.53"

25) S-E-N-S-I-O Model 1.20"

2 Publications

Wijnans, S. (2007) 'Interactive Transformation of Dance Movements into Spatial Sound Creation'. Online Article Publication in Bits, Bytes and the Rhetoric of Practice: New Media Artist Statements, *Journal of the new Media Caucus*, 3(01) [online] available from: http://median.shiftingplanes.org/issues/2007_fall/statements/wijnans_stan/wijnans_stan.html [accessed 05.2008].

Wijnans, S. (2008) 'Sound Skeleton': Interactive transformation of improvised dance movements into a spatial sonic disembodiment'. International Journal of Performance Arts and Digital Media, 4 (1) pp.27-44 [online] available from: http://www.atypon-link.com/INT/doi/abs/10.1386/padm.4.1.27_1?journalCode=padm [accessed 12.09.09].

Rubidge, S. & Wijnans, S. (2008). 'A preliminary Exploration of the Choreographic Potential of new Motion Tracking Technologies in conjunction with Interactive Ambisonic Surround Sound'. Online Report on collaborative AHRC research project with Lila Dance Company funded by AHRC Small Grants [online] available from: http://74.125.77.132/search?q=cache:S7UANHKwFJ4J:www.sensedigital.co.uk/writing/AHRC067Report.pdf+stan+wijnans&hl=nl&ct=clnk&DVD=10&gl=l [accessed 29.11.08].

Wijnans, S. (2009) 'A Choreography of a Spatial Sonic Disembodiment, Development of the Three Dimensional Data Interpreting Methodology'. *Proceedings of Sound, Sight, Space and Play 2009*, pp.1-16. [online available from: http://www.mti.dmu.ac.uk/events-conferences/sssp2009 [accessed 17/10/09].

3 Presentations, Seminars and Workshops

Wijnans S. (2005) The Dancer as Composer; Mapping Movement to Sound. Presentation for *Writing for a Wider Audience Seminar*, University of West England (UWE), Bristol, UK.

Rubidge S. & Wijnans S. (2006) 'Sense and Sensibility'. Presentation interactive surround sound composition for a presentation by Prof. S. Rubidge. Brunel University, UK.

Rubidge S. & Wijnans S. (2006) Exhibition 'Global Drifts'. Non-linear composition for interactive video installation. Dance Studio Shiobhan Davies, London, UK.

Wijnans S. (2007). Workshop tutor 'Tracking Technologies'. Dutch Electronic Art Festival (DEAF 2007). V2, Rotterdam, NL.

Rubidge S. & Wijnans S. (2007) Showing of a preliminary exploration of the choreographic potential of the Cricket tracking system in conjunction with interactive ambisonic surround sound. University of Chichester, UK.

Wijnans S. (2007). 'Sound Skeleton: Interactive Transformation of Dance Movements into Spatial Sound Creation. Paper presentation *(re)Actor2: The Second International Conference on Digital Live Art*. University of Leeds, UK.

Wijnans S. (2009). A practical exploration of the LCIPS and artistic possibilities of 3*D*IM with 3rd year dance students. Workshop/seminar at University of Bath Spa, UK.

Wijnans S. (2009) *Sound, Sight, Space and Play* Conference, keynote talk. deMontfort University, Leicester.

4 3DIM Operation Manual

This manual describes the operation of the Three Dimensional Data Interpreting Methodology (3*D*IM) implemented in Max/MSP/Jitter. The patches have been programmed in Max/MSP 4.6.3 and Jitter 1.6.3. 3*D*IM has not been tested in Max 5.0.

The final version of 3*D*IM was designed and operated using a Macintosh 2X3 Ghz Dual-Core Intel computer under OSX 10.4.11. It is developed to use audio interfaces that have eight analogue audio inputs and outputs. The 8 separate outputs communicate the processed spatial (ambisonic) sound to 8 self-powered speakers.

To achieve a full ambisonic 3-D sound experience:

1. Set up the 8 loudspeakers in a cubical form.
2. Speaker 1 is the left upper speaker 2, 3, and 4 should be set up in clockwise order from speaker nr 1.
3. Speaker 5 is placed below speaker 1. Speaker 6, 7 and 8 are placed in clockwise order on the floor below speaker nrs 2, 3 and 4.

All speakers should preferably be identical with a full-range frequency spectrum and set to the same output level.

In line with standard Ambisonic conventions, X is front-back, Y is left-right, Z= up-down.

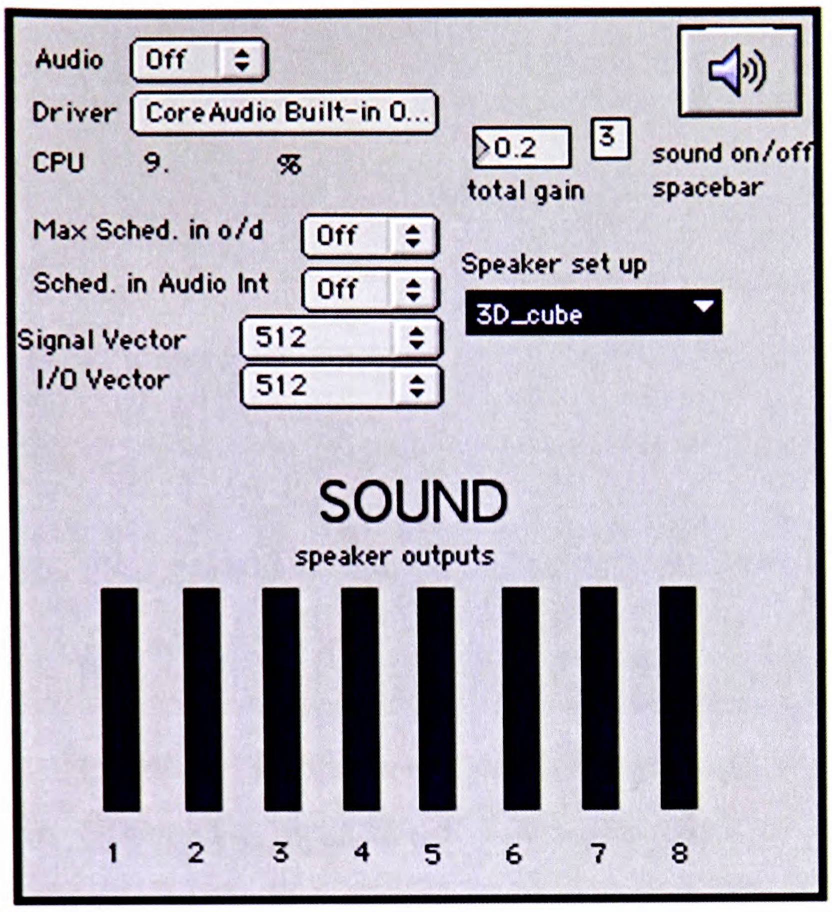
Please note that the applied RF/Ultrasonic tracking system uses the coordinates X for left-right, Y for up-down, Z for front-back. The difference between these coordinate conventions is solved in the 3*D*IM software.

1 The Main Window

The main window of the patch contains the following panels:

1. Sound
2. Mixer
3. Sub Patches
4. Practice Presets Matrix
5. Visualization Help

1.1 Sound

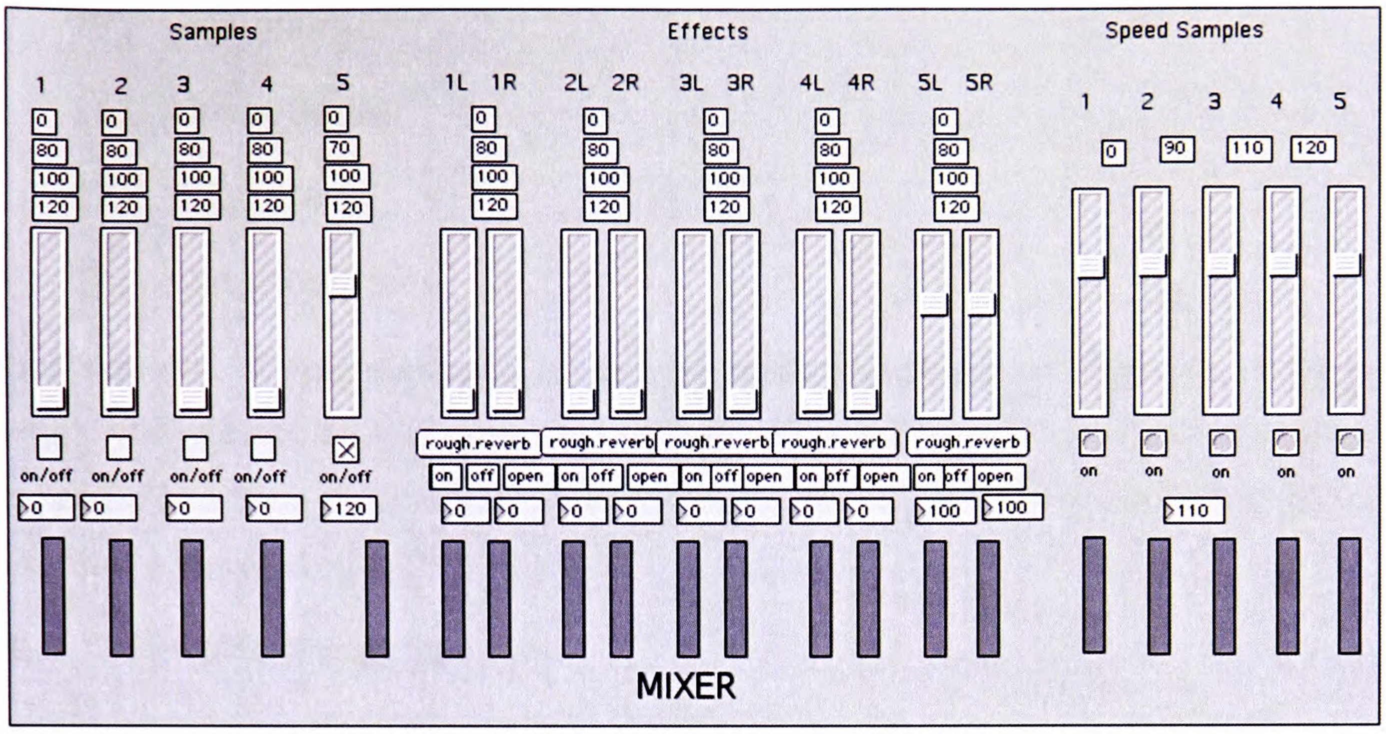


The 'Sound' panel contains first of all the elements from the standard Max/MSP DSP window that are most relevant to be able to access during practical research sessions. Pressing the 'Sound On/Off' button (standard) or spacebar will turn the audio processing on and off.

Secondly, the blue menubar 'Speaker Set Up' on the right chooses different speaker arrangements. In my research the '3D_cube' set up has been used for true full sphere 3-D surround sound. This is automatically filled in when loading the patch.

Thirdly, the meter levels from the 8 speakers are displayed at the lower part of the 'Sound' panel.

1.2 Mixer



In the 'Mixer' panel the 5 output levels of the individually allocated sounds to the 5 sensors and their 5 effects can be easily adjusted during research periods. There is a choice of Pluggo vst effects[204] in the menu bars:

1) rough.reverb
2) SpaceEcho
3) LongStereoDelay
4) Chamberverb
5) fragulator4
6) VibratoCauldron
7) Noyzckippr
8) Comber
9) AudioRatePan
10) FrequencyShift
11) GenericEffect
12) Granular-to-Go
13) MangleFilter

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204 When Pluggo is not authorized, the plug-ins will emit an annoying buzz every minute or so. You need to purchase Pluggo to stop the buzz at cycling74.com and click on Store (see also the 'read me' file on the accompanying documentation CDR).

14) Monstercrunch

15) Pendulum

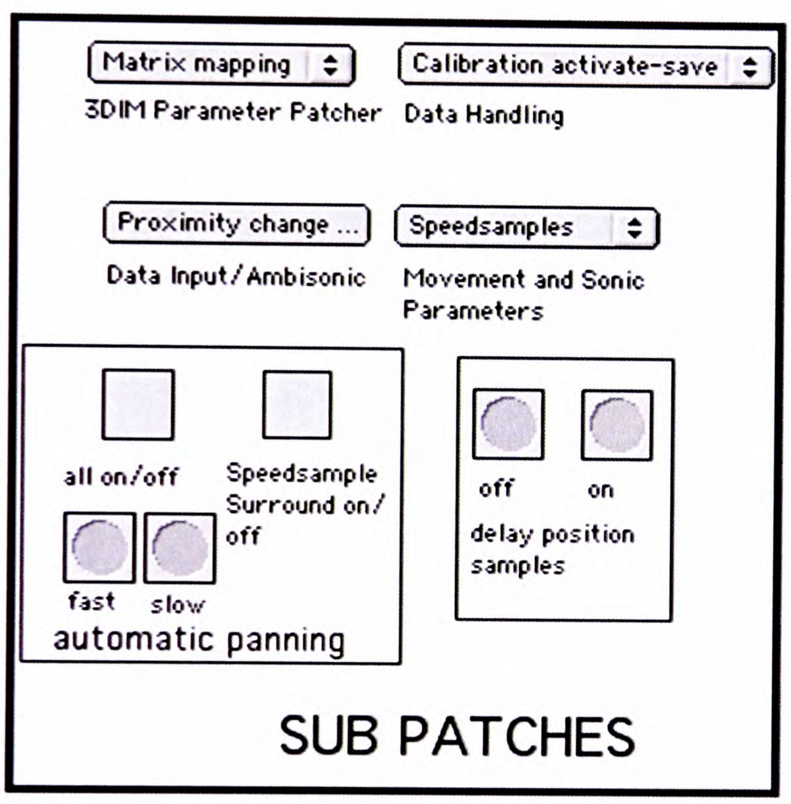
16) SpeedShifter

17) Stutterer

18) RingModulator

The volume of the abstract speed samples (the samples that are triggered when the speed of the dancer's sensor exceeds a set limit (see sub patch 'speed') can also separately be adjusted in the mixer. They can be triggered manually by pressing the button.

1.3 Menubars sub patches

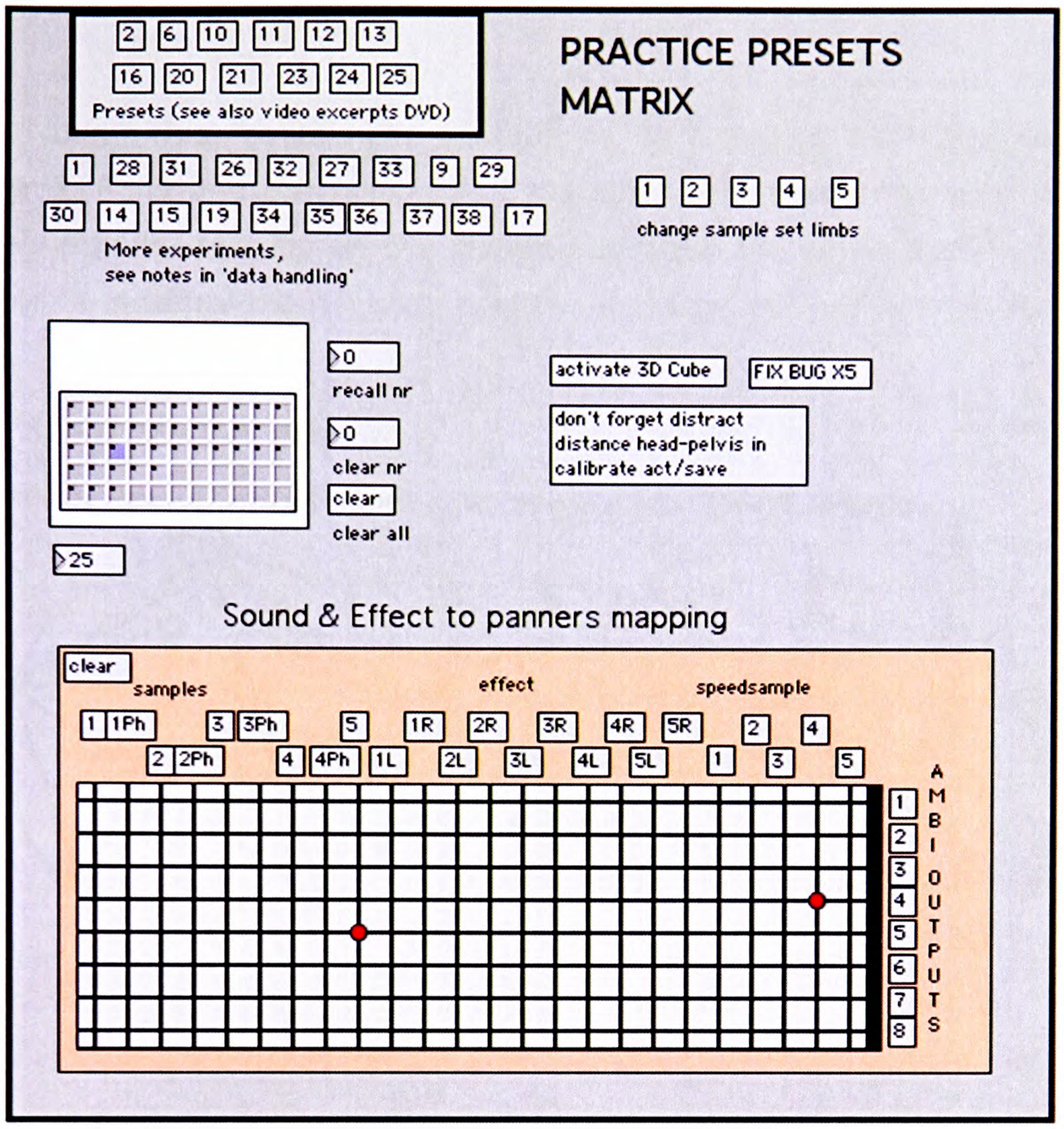


In the 'Sub Patches' panel the operator can access all the sub patches with the menubars (explained fully in section 2 of this manual).

The operator can switch on automatic panning for all the individually triggered sounds and the speed samples that are routed to the 'sounds to ambisonic' sub patch. The panners can be switched on individually in the '8 autopanners' sub patch.

The delay for the position samples can be set to zero (off) or to the times set in the 'position samples' sub patch (on).

1.4 Practice Presets Matrix



In the 'Practice Presets Matrix' panel the operator chooses the outputs for the 5 sounds, 5 effects and 5 speed samples in the parameter mapping matrix (see 2.1 below). The presets of the settings I've used in the practical experiments and compositions that apply 3*D*IM can be chosen by clicking the numbers in the light grey box at the top left of the window (the mapping is fully explained in the sub patch 'notes' in the 'data handling' sub patches). The numbers correspond to the video excerpts.
Several more Max experiments (no video excerpts) are listed below these.

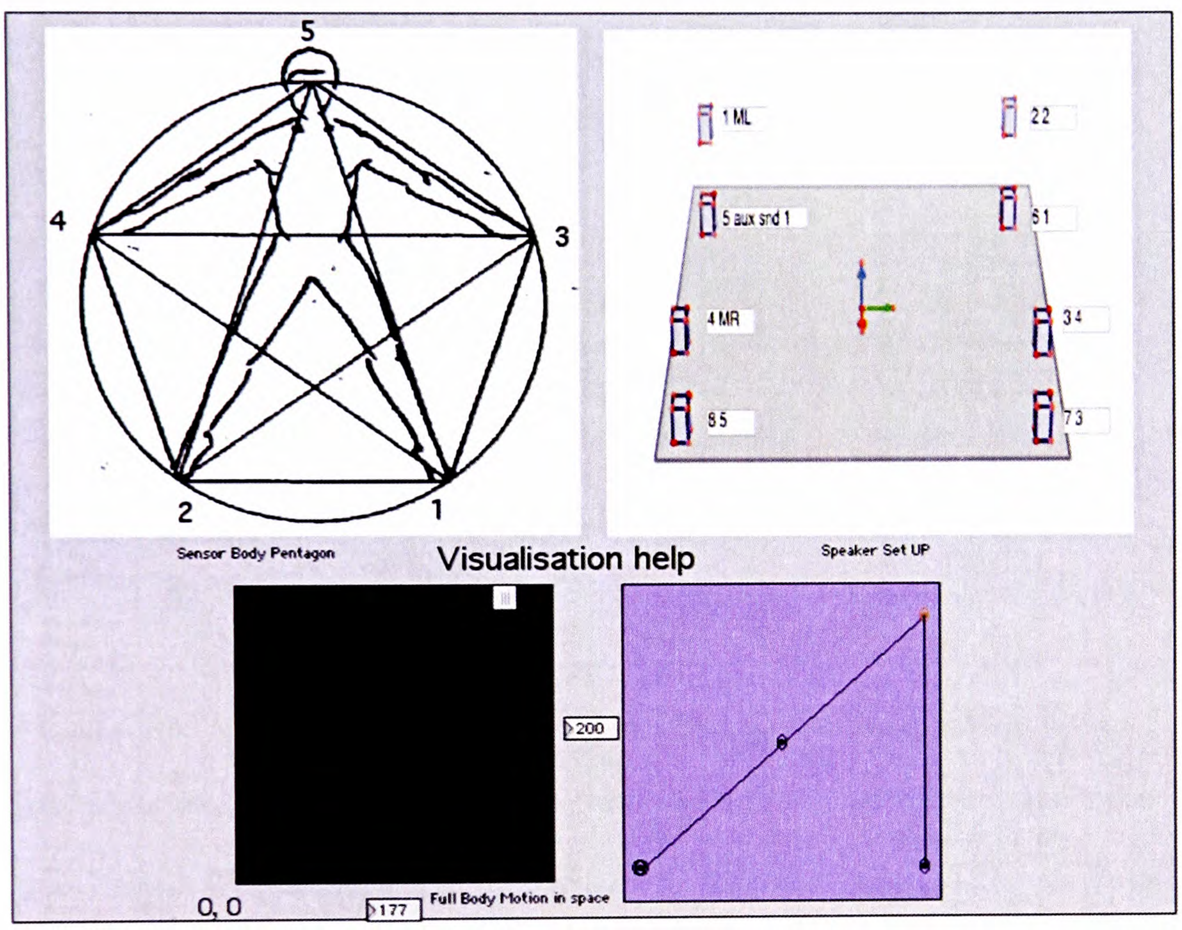
In all experiments undertaken, sound nr. 1 is allocated to output 1 of the ambisonic patch, nr. 2 to 2, nr. 3 to 3, nr. 4 to 4 and nr. 5 to 5. However, the choice should be free due to the fact that an operator might want to set an ambisonic output to react in opposite directions, i.e. the sensor moves to the right and the ambisonic sound moves to the left.

At the top right of the window 5 different sample sets for the 4 sensors of the limbs are pre-programmed to be able to try out different compositions.

'activate 3D cube' sets the speaker set up for full sphere surround sound. This should be loaded automaticly when starting the patch, but sometimes doesn't work.

'fix X5 bug'. This reminds the operator to fix a bug in the 'scale' object of sensor 5. Renewing the numbers of the scale object fixes the bug. There is also a reminder to subtract the distance between the pelvis and the head to be able to measure the full body position of the dancer with the sensor on the head.

1.5 Visualization Help



The 'Visualization Help' panel visualizes the attachment of the sensors to the dancer's body as a reminder for the right configuration. At the right side of the window the lay out for the eight speakers is pictured. At the bottom left of the window the operator can follow the horizontal movement of sensor 5 (the centre of the body) in real time in a picture slider. At the bottom right, the amount of trigger spots for the 'position sample' is reproduced in black dots, the trigger spot turns yellow when activated by the dancer's movement in the performance space.

2 Sub Patches

In the 'Sub Patches' panel 4 different menu bars represent different sub patches which are listed as:

1) 3DIM Parameter Patcher

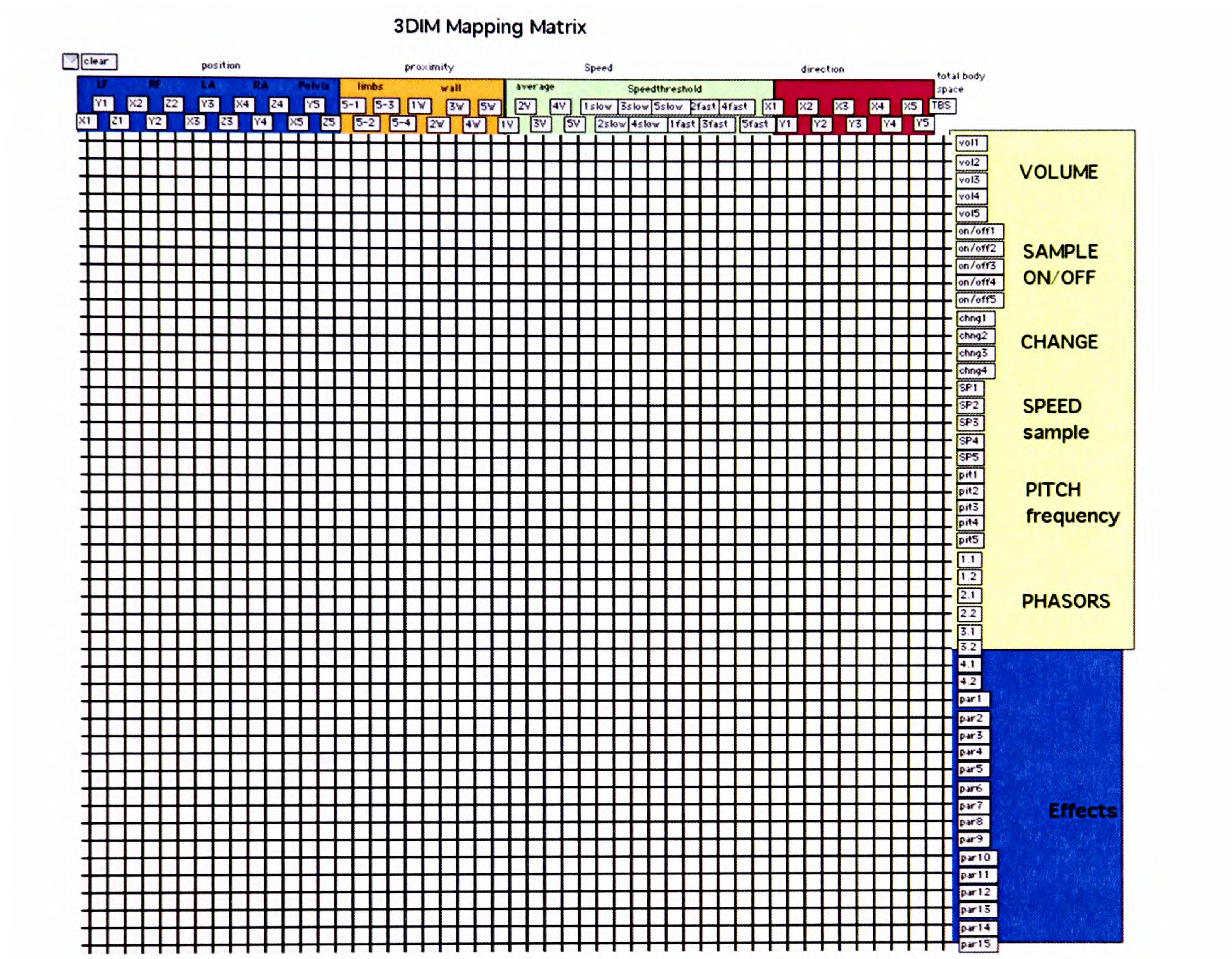
2) Data Handling

3) Data Input/Ambisonic

4) Movement and Sonic Parameters

2.1 3DIM Parameter Patching

'Matrix Mapping'



This is the main 3*D*IM movement to sound mapping matrix. It chooses different mapping configurations that communicate with all the 'Movement and Sonic Parameter' sub patches.

The movement parameters are listed at the upper part of the matrix as follows:

1) X-Y-Z position of the 5 sensors.

2) Proximity of the limbs (sensor 1-4) to the pelvis.

3) Speed and the speed threshold of the 5 sensors.
First of all the average speed of the 5 sensors can be chosen.
Secondly, 'slow' switches on the sound when the sensor moves

above a certain threshold and 'fast' triggers a '1' when above a certain threshold. Both thresholds are set in the 'speed' sub patch in the 'Movement and Sonic Parameters' sub patches.

4) Direction of sensor 1-5 in the sensitive space.

5) Total body space adds the proximity of sensor 1-4 to measure the total body space.

The sound parameters are listed on the right hand side of the matrix as follows:

1) Volume. Changes the volume of samples 1-4 according to the level set in 'Volume Scale' sub patch in the 'Movement and Sonic Parameters' sub patches.

2) Sample on/off. Switch on/off sample 1-4.

3) Change. Change the sound sample of sound 1-4.

4) Speed sample. Switch on the speed sample of sensor 1-5.

5) Pitch/frequency. Change the pitch/frequency of sample 1-4.

6) (Phasors. Redundant).

7) Effects. Control the first three parameters of effect 1-5.

8) PITCH 5 frequency changes the pitch/frequency of sample

2.2 Data handling

'Calibration activate-save'
Switch on the toggles to calibrate (either individually or as a group) one of the following:

- the X-Y-Z position of the 5 sensors in the sensitive space.

- The X-Y-Z space of the dancer's kinesphere.

- Speed.

It's also possible to set the data range to 199 in case the LCIPS is not available.

'View and edit data'
A patch that enables firstly switching on the calibration of the whole performance space or the kinesphere, secondly to quickly change data presets (change set of position samples, set the threshold for the speed parameter,

thirdly fill in the data for the borders of the sensitive space and lastly set low and high volume of the 4 'limb' sensors) during practical research.

'Record and play data'
Records and replays the data of 5 LCIPS sensors (this didn't work as the computer is too slow for all data processing).

'7 Autopanners'
Switch on 7 automatic ambisonic panners for the sound. They can move fast or slow.

'notes'
Notes for the presets in the 'Practice Presets Matrix' that were applied in the research periods in 2009.

2.3 Data Input

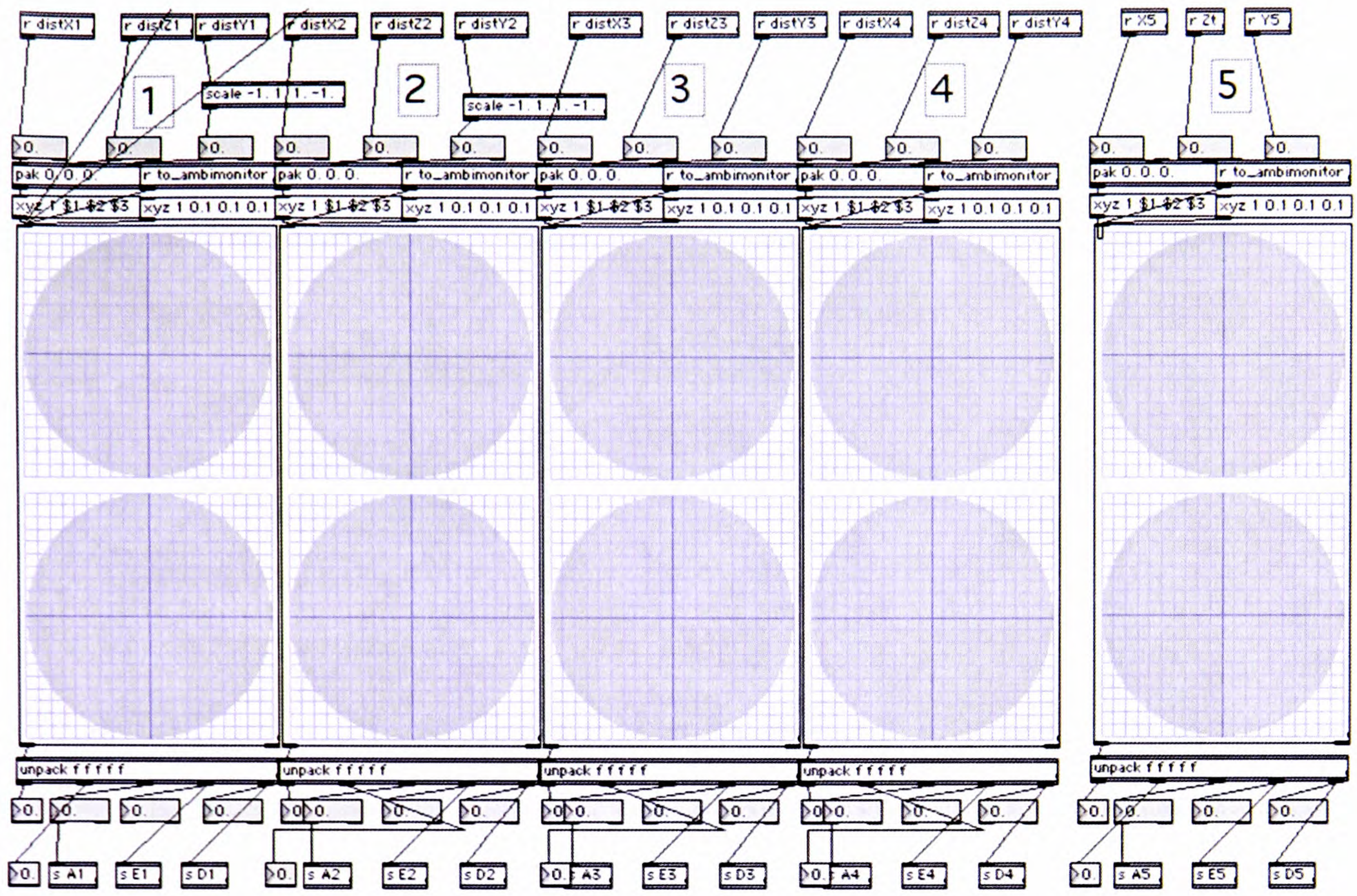
'Midi receive'
Midi data input from the 5 sensors of the 'LCIPS' tracking system. The data are scaled to a range of 0-XX in which the number XX is set in the calibration process. The 'scale' object scales the data back to a range of 0-200. In this way the number range 0-200 can always be used in all the sub patches.
The operator has to fill in the distance between the head and the pelvis of the dancer (marked red) to be able to measure the position of the pelvis by sensor 5.

'Calibration position'
Calibrates the X-Y-Z position data of all 5 sensors.

'Calibration bodyparts'
Calibrates the space of the kinesphere of the dancer and adjusts the software to a specific dancer.

'3D visualizer'
View the 3-D position of the 5 LCIPS sensors in real time (see p.95). The red ball presents sensor 1, the blue ball sensor 2, the yellow ball sensor 3, the green ball sensor 4 and the black ball sensor 5.

'Ambipanners'



View the rotation of the ambisonic panners. The upper circle displays left-right and forward-backward movement, the lower circle displays up-down movement.

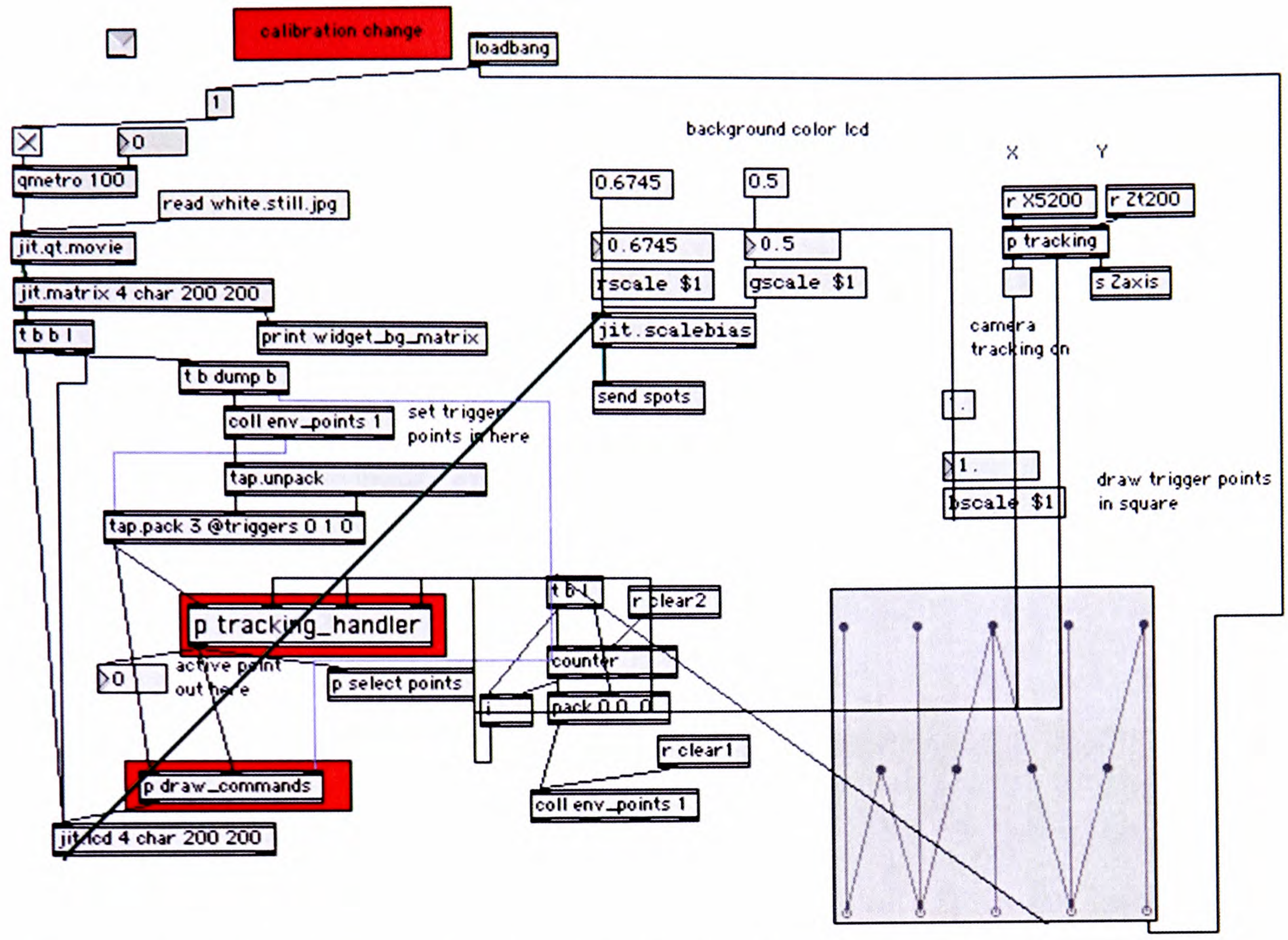
'Matrix datatransfer'

Subpatch that determines the 'Matrix mapping' control panel.

'Sounds to Ambisonic'

The sounds that are mapped in the 'Sound & Effect to panners mapping' control panel are connected to the ICST ambisonic processing.

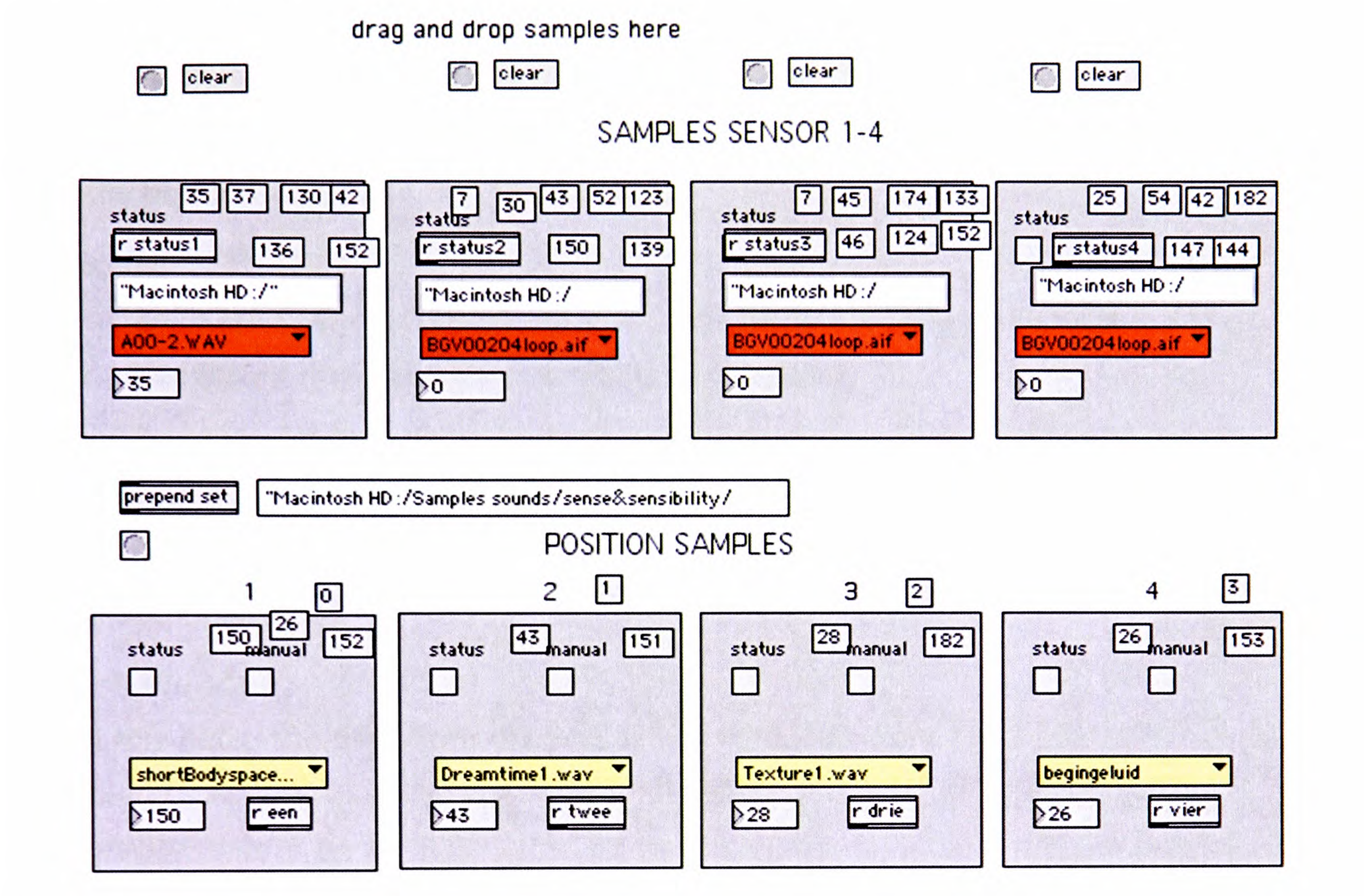
'Proximity change spots'



The full body position of the dancer (the sensor on the head that represents the pelvis) triggers 14 different samples according to the spots set in this sub patch. The placement of the various spots can be changed here.

2.4 Movement and Sonic Parameters

'Load Samples



This sub patch allocates samples in the following way (only 4 samples for the 4 bodysensors and 4 samples for the position samples are displayed in the figure above):

- 4 samples to sensors 1-4 on the limbs.
- 5 samples triggered by the speed of sensor 1-5.
- 14 position samples triggered by sensor 5 (on the head=pelvis measuring full body position).

The patch contains presets chosen by clicking the preset numbers in 'practice preset matrix' on the main page. New samples can be added by 'drag and drop' method.

'Samples playback'

Sample playback patch.

'Position Samples'

Position samples playback patch.

'Speedsamples'

Speed samples playback patch.

'Direction'
Measures if the dancer moves in the left or right direction. This possibility has not been used in a 'Sound Skeleton' experiment.

'Bodypart proximity'

Measures the proximity of the sensors attached to the limbs to the sensor attached to the pelvis.

'Speed'
The software of the LCIPS (C. Randell) measures the speed of sensor 1-5 and communicates these speeds over MIDI to this patch.

'Effsettings1', 'Effsettings2', 'Effsettings3', 'Effsettings4', 'Effsettings5'
In these patches the presets are loaded for the effects. Parameters 1-3 can be changed real time by the allocated sensor (1 for 'effsettings1', 2 for 'effsettings2' etc.)

'volume scale'
In this patch the data from the sensor are scaled down to the preferred volume changes as set in the 'view and edit data' patch ('data handling' menu).

5 Software Copyright Clearance

1. The used Max tools are freely downloadable from:

http://www.maxobjects.com/? [accessed 19.02.10]. The software is released under the terms of the GNU Lesser General Public License (LGPL). For more information regarding this license go to http://www.gnu.org [accessed 19.02.10].

2. Pluggo vst effects:

Pluggo is © 2005 Cycling '74. 'When Pluggo is not authorized, the plug-ins will emit an annoying buzz every minute or so.... Obtaining an authorization will require that you purchase the software at the online store (go to http://www.cycling74.com and click on Store) or visit your favorite retailer of plug-in product' (from Pluggo documentation).

3. Ambisonic tools developed by Dave Hunt:

'Ambi 8' ambisonic tools are used and published with permission of the inventor Dave Hunt.

4. ISCT Ambisonic tools:

Developed by Philippe Kocher and Jan Schacher. 'This software is released under the terms of the GNU Lesser General Public License (LGPL). For more information regarding this license go to www.gnu.org' (from: http://www.icst.net/research/downloads/ambisonics-externals-for-maxmsp/ [accessed 19.02.10]).

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Bevilacqua, F. & Dobrian, C. (2003a) 'Gestural Control of Music Using the Vicon 8 Motion Capture System'. *Proceedings of the New Interfaces for Musical Expression 2003 (NIME-03)* [online] available from: http://music.arts.uci.edu/dobrian/motioncapture/articles.htm [accessed 10.10.09].

Bevilacqua, F., Naugle, L. & Dobrian, C. (2003b) 'Music control from 3D motion capture of dance'. *Conference on New Interfaces for Musical Expression (NIME-03)* [online] available from: http://music.arts.uci.edu/dobrian/motioncapture/articles.htm [accessed 10.10.09].

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