Foundations of Research

in

Creative Computing

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May 2017

To my parents, Wanjun Zhang and Xiuzhi Liu

for their love and support

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Declaration

I declare that the work described in this thesis was originally carried out by me during the period of registration for the degree of Doctor of Philosophy at De Montfort University and Bath Spa University, UK, from October 2012 to March 2016. It is submitted for the degree of Doctor of Philosophy at Bath Spa University. Apart from the degree that this thesis is currently applying for, no other academic degree or award was applied for by me based on this work.

Publication List

[1] Lu Zhang and Hongji Yang, "Definition, Research Scope and Challenges of Creative Computing," *The 19th International Conference on Automation and Computing (ICAC)*, 2013.

[2] Lu Zhang and Hongji Yang, "Conducting Inter-Disciplinary Research for Enhancing Internetware Properties," *The 5th Asia-Pacific Symposium on Internetware*, 2013.

[3] Hongji Yang and Lu Zhang, "Controlling and Being Creative: Software Cybernetics and Creative Computing," *IEEE 38th Computer Software and Applications Conference Workshops (COMPSACW)*, 2014.

[4] Lu Zhang and Hongji Yang, "Knowledge Discovery in Creative Computing for Creative Tasks," *Springer Communications in Computer and Information Science (CCIS)*, Springer, Berlin, 2015.

[5] Lu Zhang and Hongji Yang, "Knowledge Integration in Creative Computing for Creative Rules Generation," *Digital Communications and Networks*, 2015. Submitted.

[6] Hongji Yang and Lu Zhang, "Promoting Creative Computing: Origin, Scope, Research, and Applications," *Digital Communications and Networks*, 2015.

[7] Lu Zhang, Lin Zou, and Hongji Yang, "An Approach to Constructing A General Framework for Creative Computing: Incorporating Semantic Web," *International Symposium on Creative Computing*, 2016.

[8] Hongji Yang, Delin Jing, and Lu Zhang, "Creative Computing: An Approach to Knowledge Combination for Creativity?" *The 10th IEEE SOSE Symposium*, 2016.

Acknowledgements

Firstly, I would like to express my most sincere thanks to my first supervisor Professor Hongji Yang. As a tremendous mentor, you help me to explore myself and find my own way of doing the research. You are always so illuminative, patient, and kind to guide me through various difficulties. As an amiable elder, you can always calm me and encourage me to be happy, confident, and strong. It is you that broaden my horizon and lead me into a new world.

Secondly, I would like to thank my second supervisor Professor Andrew Hugill. I gain a lot of crucial inspirations from you. You can always enlighten me when I encounter problems. You help me from different aspect and offer me various kinds of opportunities to enhance myself.

Thirdly, I would like to thank my third supervisor Dr. Jerry Fishenden. You help me a lot on how to mix the theories with practice. You can always give me valuable suggestions based on your own experience, such as encouraging me to learn by doing.

Fourthly, I would like to thank the Graduate School Office of Bath Spa University for your kind help and good management.

Finally, I would like to thank my dear family for their love and support. My father, Wanjun Zhang, can always give me valuable suggestions on both study and life. My mother, Xiuzhi Liu, always gives me meticulous care and reminds me to take care of myself when they are not around, which always makes me feel warm and happy. Without your love and support, I cannot go so far.

Abstract

Human creativity needs improvement in contemporary society. Because of the fast development and pervasive utilisation, computing has been a loyal servant to support human creativity. It is not only utilised to facilitate creativity research, but also leveraged to assist creative activities in everyday life. However, due to increasingly complicated human life and ever-evolving nature of computing, up to now, people have never stopped exploring the great potentials of computing to facilitate human creativity. As a result, various kinds of new concepts of computing are continuously emerging dedicating to making contributions for human creativity.

Creative Computing is one of the promising ones. Its most important advantage is inspiring a novel approach to facilitating human creativity. By making computing itself become creative, the services supplied by Creative Computing can be more active and better reconcile the contradiction between subjective creativity and objective computing. Instead of imitating or duplicating human creativity, the core idea of Creative Computing is to leverage the uniting power of knowledge to tackle problems in computing field to facilitate human creativity.

My research aims to consolidate Creative Computing as a knowledge discipline to facilitate its development. As Creative Computing is a new field, several important issues are required to be studied. First things first are the fundamental issues. In order to do that, my research devotes to proposing kind of framework of Creative Computing by consolidating it as a knowledge discipline. Various crucial elements of Creative Computing will be studied and described in the thesis. It is hoped that the results of my research can be able to provide valuable suggestions for the following researchers of Creative Computing.

List of Figures

List of Tables

List of Acronyms

IoT   Internet of Things

KM   Knowledge Management

HCI   Human-Computer Interaction

OOP   Object-Oriented Programming

AI   Artificial Intelligence

NLP   Natural Language Processing

SE   Software Engineering

VR   Virtual Reality

AR   Augmented Reality

MR   Mix Reality

DIKW   Data, Information, Knowledge, and Wisdom

MVC   Model-View-Controller

RDF   Resource Description Framework

Table of Contents

Chapter 1.   Introduction

- To elaborate elements of a knowledge discipline

- To articulate research aims and objectives

- To describe research method

- To highlight the original contributions

- To define the criteria for success

- To outline the thesis structure

1.1   Elements of A Knowledge Discipline

To define a discipline is difficult. Firstly, the concept of a discipline could stand for many different things. According to its Latin etymology, the term "discipline" means teaching or instructing [125]. As time goes on, it has been redefined by dictionaries with various kinds of meanings, such as training for obedience, code of behaviours, control and self-control, etc. Nevertheless, the overall goal of a discipline is about controlling or constraining. Even as an academic discipline, it also devotes to telling researchers what to think about and what to leave out [136]. Secondly, as for academic discipline, it is also often confused with the subjects taught in higher education. Not all of subjects could be deemed as disciplines. For example, in Computer Science, a programming language (e.g., Java) could be taught as a subject. However, it is clearly not enough to be a knowledge discipline. Thirdly and most importantly, different disciplines have different contents, features, and requirements, etc. It is extremely difficult to propose a universal definition to suit all of them to the same degree. However, "difficulty" does not mean "impossibility".

Several core elements of a knowledge discipline have been extracted or summarised as follows [83]. Although not all of them are mandatory, to facilitate a good development of Creative Computing as a knowledge discipline, the consolidation

conducted by my research will make the best endeavour to accomplish as many elements as possible.

- *Magnitude of Discipline*

  The magnitude of a knowledge discipline is to do with its ultimate significance of existence. As mentioned before, as an academic discipline, it devotes to providing a starting point of a research to tell researchers what to think about and what to leave out. The first thing to be considered should be the ultimate aim, goal, purpose, or mission of a knowledge discipline (e.g., Creative Computing is promoted with the mission of facilitating human creativity).

- *Concepts and Terminology*

  The concepts and terminology are kind of basic building blocks of a knowledge discipline. As known to us all, language is the most fundamental carrier of knowledge. In order to organise a body of specialist knowledge effectively and efficiently, concise and professional concepts and terminology are necessarily demanded by a knowledge discipline, especially a new discipline like Creative Computing, to facilitate its fast development.

- *Scope of Discipline*

  The scope of an academic discipline devotes to setting the boundary for its specialist knowledge. After all, without "territory", where can researchers of a certain discipline continuously build the corresponding knowledge system? It is particularly crucial to a new discipline like Creative Computing. It is only with a well-defined discipline scope that answers the question of where to study, the following questions (e.g., what to study, how to study, and what to expect from the study) can be able to consider.

- *Parameters of Interest*

  The parameters of interest of a knowledge discipline aim to answer the following question of what to study for potential researchers. After defining the scope of a knowledge discipline, it is time now to consider concrete study points or topics, which might practically be the starting point of a research of a certain discipline.

- *Theoretical Foundations of Discipline*

  The theoretical foundations of a knowledge discipline stand for the fundamental theories that a certain discipline based on (e.g., axioms and lemmas of Mathematics). It is only with the support of those basic theories that the specialist knowledge of an academic discipline can be able to accumulate continually (e.g., theorems and corollaries of Mathematics). Furthermore, nowadays, knowledge generation has no longer been the type of exploration (e.g., Medicine) but combination (e.g., Cognitive Science). Elements from other disciplines are often utilised to form new knowledge discipline (e.g., Creative Computing).

- *Methods of Study*

  In order to better facilitate the development of an academic discipline, only with the support of foundational theories is not enough. Specific methods of study for a knowledge discipline also ought to be considered, which will answer the question of how to study for the following researchers of a certain discipline. Valuable directions or suggestions can be provided by the methods, which will be a solid facilitation for the development of a new discipline, such as Creative Computing.

- *Theories of Discipline*

  The theories of a knowledge discipline refer to the main body of its accumulated specialist knowledge. To form an academic discipline is to help researchers to conduct proper research, which is not about doing research itself, but pushing the boundary of knowledge. Therefore, what a certain study will produce will be finally in the form of the theories of a knowledge discipline (e.g., the theorems and corollaries of Creative Computing).

- *Outcomes of Study*

  The outcomes of a study of a knowledge discipline are to do with the potential application fields and directions of the discipline. All of the studies of a certain discipline are, to some extent, triggered by problems in real life. Therefore, the

outcomes of a certain study (what to expect from a certain study) must contain the corresponding solutions, which will also be applied to real life. Therefore, for a knowledge discipline, the potential application fields and directions should also be discussed to a large extent.

- *Institutional Manifestation*

  It is to do with the corresponding university setting of a knowledge discipline, such as taught subjects, departments, or professional associations (e.g., Centre for Creative Computing of Bath Spa University). It is only through the institutionalisation that a new knowledge discipline (e.g., Creative Computing) is able to reproduce from generation to generation.

1.2   Research Aims

The ultimate aim of my research is to consolidate Creative Computing as a new knowledge discipline. Creative Computing is a relatively new concept/field and developing promisingly. As a knowledge discipline, the fundamental issues of Creative Computing will be studied appropriately, which can provide valuable suggestions and promote its development. Based on the preliminary ideas, the research agenda of Creative Computing will be studied in the research, which will make the best endeavours to make contributions to knowledge.

1.3   Research Objectives

In order to do the consolidation of Creative Computing as a knowledge discipline, there are five objectives to be accomplished:

- *Explaining Magnitude, Concepts, and Terminology of Creative Computing.*

This objective is to study the first and second element of Creative Computing as a knowledge discipline. These two elements are all about explaining Creative Computing. First thing first, the magnitude of Creative Computing will be studied to answer why we need Creative Computing. And then, the study of concepts and terminology will answer what is Creative Computing all about.

- *Defining Scope and Parameters of Interest of Creative Computing.*

This objective is to study the third and fourth element of Creative Computing as a knowledge discipline. These two elements are all about defining the knowledge territory of Creative Computing. Before building up the knowledge system, the boundary of Creative Computing will be set first. And then, interesting topics within the scope of Creative Computing will be discussed.

- *Proposing Theoretical Foundations and Methods of Creative Computing.*

This objective is to study the fifth and sixth element of Creative Computing as a knowledge discipline. These two elements are all about proposing the theoretical and methodological support of Creative Computing. To understand Creative Computing deeply, its foundational theories will be studied in the first place. And then, proper methods of how to do Creative Computing will be studied.

- *Accumulating Theorems and Corollaries of Creative Computing.*

This objective is to study the seventh element of Creative Computing as a knowledge discipline. The element is all about accumulating the theories of Creative Computing. Although Creative Computing aims to compute in creative ways, it is still a scientific field. Hence, inspired by the disciplines like Mathematics, the knowledge of Creative Computing will be studied and organised by theorems and corollaries to instruct Creative Computing.

- *Suggesting Future Application Fields and Directions of Creative Computing.*

This objective is to study the eighth element of Creative Computing as a knowledge discipline. The element is all about suggesting future applications of the outcomes of Creative Computing. After doing a study of Creative Computing, how to apply the results into the real world to make the practical contributions will be studied.

1.4   Research Method

The main method used in my research is secondary research. The most important advantage of this method is its authority or reliability. Based on the various materials like documents or data that have already been collected and analysed, it is better for my study to unite a variety of research efforts together to find something new, surprising, and valuable.

1.5   Original Contributions

- The first contribution of my research is the supply of suggestions for the future research of Creative Computing. As the ultimate aim of my research is to consolidate Creative Computing as a knowledge discipline, basic issues on Creative Computing will be studied as follows.

    o   Why do we need Creative Computing?
    o   What is Creative Computing all about?
    o   What can be studied in the realm of Creative Computing?
    o   How to study Creative Computing?
    o   What are the theories of Creative Computing?
    o   How to test Creative Computing?
    o   Where to apply Creative Computing?

- The second contribution of my research is the proposition of a new approach to studying and facilitating creativity. In order to do Creative Computing, common computing is required to be truly fused with creativity. Differing from imitating human creativity, Creative Computing devotes to utilising the uniting power of knowledge to discover the rules of creativity. By doing so, the services provided by Creative Computing can be more active, which is able to reconcile the contradiction between the subjective creativity and objective computing better. More concrete contributions are as follows.

    o   Theorems of Creative Computing
    o   Corollaries of Creative Computing

- The third contribution of my research is the detecting of a new trend of making the best use of knowledge. That is to combine various kinds of knowledge from diverse kinds of disciplines more intentionally, actively, and even boldly. The development of Creative Computing is particularly based on the combination of novel knowledge to solve problems in computing field. Here are the more concrete contributions.

       o   Unite and Conquer

       o   Novelty of Disciplines

1.6   Criteria for Success

There are generally three criteria to measure the study described in this thesis.

- The first one is to do with the elements of a knowledge discipline. At the very beginning of the thesis, nine core elements of a knowledge discipline have been summarised (see in Table 1).

Table 1. Elements of A Knowledge Discipline

Number	Elements
1	Magnitude of Discipline
2	Concepts and Terminology
3	Scope of Discipline
4	Parameters of Interest
5	Theoretical Foundations of Discipline
6	Methods of Study
7	Theories of Discipline
8	Outcomes of Study
9	Institutional Manifestation

Due to the ultimate aim of the study is to consolidate Creative Computing as a knowledge discipline, how well the corresponding elements can be accomplished will be a crucial criterion.

As the ninth element (i.e., Institutional Manifestation) is beyond the capability, if the rest of the eight elements of Creative Computing (see in Table 2) can be fully studied, the research can be deemed as successful.

Table 2. Elements of Creative Computing

Number	Elements

1	Magnitude of Discipline
2	Concepts and Terminology
3	Scope of Discipline
4	Parameters of Interest
5	Theoretical Foundations of Discipline
6	Methods of Study
7	Theories of Discipline
8	Outcomes of Study

- The second one is to do with the theories of Creative Computing. After building the fundamental framework of Creative Computing, how to prove it or mix the theory with practice should be concerned. Based on the proposed framework, theories of Creative Computing should be studied. Therefore, the knowledge accumulation of Creative Computing should be another important criterion.

If all of the eight elements of Creative Computing, to some extent (see in Table 3), can be reflected, presented, studied, conducted, and proved by developing theories of Creative Computing, the research can be deemed as successful.

Table 3. Demonstration of Elements of Creative Computing

Number	Elements	Descriptions
1	Magnitude of Discipline	The ultimate existing significance of Creative Computing should be reflected.
2	Concepts and Terminology	The utilisation of concepts and terminology of Creative Computing should be presented.
3	Scope of Discipline	The features of the scope of Creative Computing should be reflected.
4	Parameters of Interest	As all of the parameters of interest summarised in the thesis are for the whole field of Creative Computing, in order to exemplify how a certain parameter can be studied, one of the parameters of interest of Creative Computing would be

		studied in the thesis.
5	Theoretical Foundations of Discipline	The ideas of the foundational theories of Creative Computing should be reflected.
6	Methods of Study	The proposed methods of Creative Computing should be proved.
7	Theories of Discipline	The embodiment of theories of Creative Computing should be conducted to some degree. Several theorems and corollaries should be proposed.
8	Outcomes of Study	Various foundations of research in Creative Computing should be proposed.

- The third one is to do with the linking of different knowledge. At the very heart of Creative Computing is the idea of knowledge combination. Hence, the study of issues on combining various kinds of knowledge from diverse kinds of disciplines should also be a vital criterion.

If the general issues (see in Table 4) on knowledge combination of Creative Computing will be fully studied, the research can be deemed as successful.

Table 4. Issues on Knowledge Combination

Number	**Issues**
1	What kind of knowledge can be considered?
2	How to find appropriate knowledge?
3	How to combine prepared knowledge?
4	How to use the combined knowledge to develop Creative Computing?

1.7   Thesis Outline

The structure and contents of the thesis are summarised as follow.

Chapter 1. Introduction introduces the general information about the study described in this thesis. In order to consolidate Creative Computing as a knowledge discipline, at the very beginning, the necessary elements of a knowledge discipline will be summarised and listed in the first place. And then, the research aims, objectives, method, original contributions, and criteria for success will be depicted.

Chapter 2. Background and Related Work describes the background of Creative Computing in the first place, including the societal requirements of creativity and latest evolution of computing for creativity inspiration. And then, various kinds of computing for accelerating creativity will be summarised.

Chapter 3. Magnitude, Concepts, and Terminology of Creative Computing firstly explains the existing significance of Creative Computing. And then, the concepts and terminology of Creative Computing will be articulated to further interpret Creative Computing.

Chapter 4. Scope and Parameters of Interest of Creative Computing defines the research scope of Creative Computing in the first place. And then, the parameters of interest within the scope of Creative Computing will be suggested for the followers of Creative Computing.

Chapter 5. Theoretical Foundations and Methods of Creative Computing proposes various supports for the study of Creative Computing. Firstly, the theoretical foundation will be elaborated to enable a deeper understanding of Creative Computing. Secondly, several methods to do Creative Computing in a more practical way will be raised.

Chapter 6. Theorems of Creative Computing forms several theorems of Creative Computing through combining various kinds of knowledge together. The selected appropriate knowledge will be prepared in the first place. And then, based on the foundation and methods studied above, several theorems of Creative Computing will be developed. This Chapter is also an experimentation of the proposed ideas of Creative Computing (e.g., knowledge combination).

Chapter 7. Prototyping Creative Computing - Deviator reasons one of the theorems of Creative Computing into corollaries. And then, based on the various corollaries, a prototype of Creative Computing named Deviator is developed.

Chapter 8. Prototype Tool for Research Validation develops a prototype tool based on EEG technology to validate the effect of Deviator.

Chapter 9. Future Application Fields of Creative Computing illustrates how the ideas of Creative Computing will work in the real world.

Chapter 10. Conclusions and Future Work summarises the thesis, makes the conclusions, and points out the limitations of the study. Furthermore, the future work of Creative Computing will be discussed to a large extent.

Chapter 2.   Background and Related Work

- To describe background of Creative Computing
- To articulate related work of Creative Computing

2.1   Overview

In this Chapter, the whole background of the advent of Creative Computing will be described in details, including the societal requirements of creativity in modern society and the latest evolution of computing for creativity inspiration. Then it will be followed with the analysis of the related work of Creative Computing, involving research tools, applications in general, virtualising applications, digital art, and computational creativity.

2.2   Societal Requirements of Creativity

Creativity, due to its mysterious power, has been studied for a long time and in various kinds of domains. The early study on creativity might trace back to 19th century [119]. Besides fields of Art, even scientific disciplines, like Mathematics and Physics, also have close relationships with creativity. There have been a variety of conceptions about creativity. It could take form as ability, personality, process, and even just a state of mind. In terms of ability, people always focus on the training or coaching of kind of creative skills. Creative people are often studied to extract personality traits about creativity, such as ambiguity tolerance. Studying creativity through a creative process, researchers have summarised some important stages, such as incubation. Due to the emergence of disciplines like Neuroscience in recent years, the mysterious Aha! Moment can also be studied scientifically. Various brain areas and activities associated with this kind of creative state of mind are discovered. Furthermore, besides individual creativity, researchers also concentrate on studying

how to improve organisational creativity. Issues, like how to make the best use of employees' creativity, how to facilitate and improve employees' creativity, and how to organise a creative environment for employees to be creative, have been the key concerns in organisations across the whole world [32].

Human creativity urgently needs improvement in modern competition. Globally, the market has been in the oversupply status for a long time. The quantity and even the quality of certain products have no longer been the key concerns of enterprises nowadays. People start to pay more and more attention to the satisfaction of the so-called "spiritual requirements". The things, activities, and services are becoming more and more interesting, enjoyable, and playful. The competitions in the modern world have entered into a new era – creativity competition [29]. Furthermore, because of the highly advanced technologies nowadays, the infrastructures and facilities have no longer been the core competitive advantages any more. As the features like uniqueness and novelty have become the secret ingredients of great success, the flash of creative ideas or human creativity as a whole has been the hot pursuit in modern times.

As a result, in order to seize the great opportunity, various companies, organisations, or people all over the world start to provide a variety of services on creativity. Companies like OmniSkills [4, 112] specialise in training, facilitating, consulting on creativity. Organisations like Mycoted [33] and Mind Tools [26] are more like "dictionaries" or "toolkits" of creativity, which include various kinds of tools, techniques, methods, books and other information on creativity. As for people about teaching creativity, one of the most famous is Edward de Bono [41]. His popular ideas of lateral thinking have gained great success all over the world, to help diverse kinds of people to generate creative ideas. Even a cliché "thinking outside the box [47]" has been created to encourage people to change the conventional thinking styles. Besides lateral thinking, there are also many other creative thinking methods, like divergent thinking. Tools like brainstorming, mind mapping and free writing are often used to help people to do divergent thinking [19].

2.3   Latest Evolution of Computing for Creativity Inspiration

Due to rapid development of various computing technologies, there has been no clear boundaries between hardware, software, and web any more. More and more computing technologies tend to be linked together. One typical instance is known as the Internet of Things (IoT). It makes the change to the most basic and indispensable infrastructure − Internet − and tries to connect "everything" in the world together [100]. One of its popular applications is known as Smart House. Through enabling data to exchange among various kinds of devices, facilities and infrastructures, Smart House not only could allow people to control their houses remotely, but also could make certain adjustments dynamically and automatically. As more and more equipment is connected into the Internet, the environment of the Internet is becoming unprecedentedly complicated. In order to deal with the ever-changing situations and conditions over the Internet, new software paradigms, such as Internetware, are continuously emerging, which dedicates to tackling the uncertainties by integrating different technologies together [93]. The well-connected computing technologies nowadays have prepared a multifunctional platform for Creative Computing to facilitate human creativity.

The pervasive utilisation of computing technologies has generated a huge amount of data. There is no doubt that computing, nowadays, has been used almost everywhere, such as Education. Besides facilities, like multimedia and tablets, a variety of educational software has also been widely applied. As the generated enormous number of data might involve valuable information like the learning habits or ability of a student, how to efficiently utilise those kinds of data has been one of the key concerns of researchers in educational field, such as constructing appropriate student models or learning models. One field specialised in doing that is called adaptive learning [104]. Furthermore, various kinds of computing has not been only utilised to facilitate the development of other disciplines, but also leveraged to support people's everyday life. People nowadays are used to using computers to do a lot of things and almost cannot live without them, such as social networking, shopping, learning, working, and entertaining. Diverse kinds of trails and clues left by people have also been leveraged to provide more services for people, such as suggestions of

what you might also like, which actually triggers another crucial professional field named Data Mining (DM). While the old data is being processed, the new data is being created as well, which finally end up with Big Data problems or challenges attracting huge attention across the world. On the one hand, although a great amount of endeavours have been made trying hard to tackle them, it is still believed that novel approaches to processing the huge amount of data are urgently demanded to do kind of surprising discovery, which is just the Creative Computing centres on. On the other hand, such huge amount of data also could be a strong backup for Creative Computing to find something innovative to serve people better.

In order to serve increasingly complicated human life, computing is becoming more and more intelligent. As a result, professionals like Tim Berners-Lee continually come up with new technologies like Semantic Web (also known as Web of Data) [21]. As the inventor of the famous World Wide Web (WWW), Tim is able to foresee the great potential of Semantic Web, which could cross the boundaries between different applications and link various kinds of data together [21]. By doing so, it could enable computer to read and process more data for people, in other words, to share more work for people. Some core components of Semantic Web, such as vocabularies or ontology, RDF data and inference engine, could, to some extent, enable computer to be able to "think", thereby generating more comprehensive, consistent, and precise results for people. Hence, it can be seen that this kind of growth of "computing intelligence" makes it possible and probable to do computing in creative ways – Creative Computing.

2.4   Computing for Accelerating Creativity

2.4.1   Research Tools

Due to the fast development and pervasive utilisation of computing technologies, it also presents its great values in creativity field. In creativity research, various kinds of computing are used to help understand human creativity. Through integrating with technologies of Computer Science, specific disciplines like Cognitive Psychology or Neuroscience are becoming more and more popular. Scientists in these fields can study creativity in a more scientific way. Neuroimaging techniques like fMRI and EEG are often used to study the associated brain structures, areas, and activities

associated with creativity [6, 10, 45]. Except the very explanation of the ultimate nature of creativity still remains a mystery, a lot of valuable results, such as where and when creativity occurs in our brains, have been proposed.

In the meantime, a lot of efforts also have been made to improve human creativity based on those scientific discoveries. For example, the stimulation of unexpected experience to human creativity is one of them. Accordingly, simply breaking the routines can, to some extent, improve human creativity. However, the more efficient way is to experience a new environment. Computing technologies like virtual reality have been the perfect tools to do that, as they could construct a totally new and even absurd environment for people to experience, thereby stimulating their creativity.

2.4.2 Applications in General

Besides various facilitations in creativity research, computing is also widely used to support human creativity in everyday life. Initially, computing is simply used to provide online information about creativity, including the websites of organisations on creativity, toolkits of creativity, and knowledge bases of creativity. As the rapid development of educational technologies, E-Learning systems are becoming more and more popular [58]. Therefore, various kinds of computing are also used to construct online courses or exercises on creativity. For example, The Effective Thinking Online Course is an E-Learning system, which is based on the lateral thinking of Edward de Bono [43]. There are a variety of tools, techniques and exercises about training or coaching creativity. For instance, PMI - Plus, Minus and Interesting is one of the powerful tools to help people think about new ideas [133].

Nowadays, a great number of applications have been specially developed to facilitate human creativity. For example, applications with the function of mind mapping are among the popular ones. They are specialised in facilitating the divergent thinking for people to be creative, such as MindGenius [11]. Moreover, various complicated platforms have also been developed with the aim to generate more comprehensive creative solutions for people to be creative. For example, Goldfire [61] is such a platform dedicating to facilitating professional people to be sustainably or even increasingly productive.

2.4.3   Virtualising Applications

Among the various kinds of applications for facilitating human creativity, there is a particular type of applications that are specialised in virtualising things like materials, contexts and so on. One of the most outstanding advantages of these virtualising applications is able to provide an unlimited platform for people to create without worrying about things like canvas (e.g., Photoshop [105]), musical instruments (e.g., Music Composition of Android [124]), or something like that. Recently, the Guardian selected top 50 apps for creative mind [49]. Magic Piano is one of them, which can allow people to learn how to play music on a virtual piano [49]. Through operating on mobile devices like smartphone or tablet, the Magic Piano can enable people to compose music almost anytime anyplace. By providing a simple and easy interaction, it can allow a musician, student, or even a lover of music to create his or her own piece of music. By doing so, the virtualising applications are able to support human creativity.

2.4.4   Digital Art

In recent years, people in computing field have been paying more and more attention to new ways of facilitating human creativity. There have been various kinds of new trends. One of the most popular is known as Digital Art. A good practitioner is named DevArt (art made with code), which is commissioned by Google dedicating to push the possibilities between creativity and computing. The artists and developers of DevArt have created a lot of creative art installations, which are displayed in the exhibition of Digital Revolution in Barbican, London [8]. Wishing Wall is one of the creative installations that could enable people to turn their wishes into beautiful butterflies. When someone catches a butterfly, the carried wish can also be released immediately. This installation not only utilises the well-connected computing technologies like speech recognition, but also deeply associates different knowledge to form a new approach to represent feelings or emotions.

Some creative installations made by various kinds computing technologies even could cooperate with artists in real time. A digital dance performance called Hidden Fields just leverages the state-of-the-art technologies from Danceroom Spectroscopy [2]. It can interpret dancers into energy fields. The background graphics and soundscapes could be composed interactively according to the fields created by the

dancers' movements. This kind of novel combinations between art and computing mentioned above have become a new trend at the intersections of art and computing fields.

2.4.5   Computational Creativity

As possibilities are pushed forward, computing is even used to generate not simply "work of art", but "creativity" itself to facilitate human creativity. A specific discipline known as computational creativity or artificial creativity is good at doing this. Based on technologies of Artificial Intelligence (AI), computational creativity is able to generate machine creativity through imitating, simulating, or duplicating human creativity [24, 36, 51]. For example, IBM researchers have built a system that can reason about flavours like human does. While the original Watson Deep QA technology showed how a system can learn to reason about the world [54], IBM Research has started to explore the next step of a machine's ability to model human intelligence: generating ideas the world has never been imagined before [114]. There is also a typical example of computational creativity in music. A piece of music composed by a computer program known as EMI (Experiments in Musical Intelligence) can exceed one made by a professional musician. After the performances of three compositions (one is original Bach, one is by a professor of music theory, and one is by EMI), audiences surprisingly selected the one composed by EMI as the original Bach [119]. It can be imagined that computational creativity is able to create some kind of "partner" based on various computing technologies to collaborate with creative people, thereby supporting their creativity [89].

2.5   Summary

To summarise, computing can facilitate human creativity. The latest evolution of computing not only prepares a good physical foundation, but also triggers new type of computing, such as Creative Computing, to emerge. In modern time, various kinds of computing technologies have been applied to support human creativity. The relationship between creativity and computing has been changed over time. For now, computing can even generate machine creativity to accelerate creativity through imitating human creativity. The next step may be adding creative ingredients into computing itself – Creative Computing.

Chapter 3.   Magnitude, Concepts, and Terminology of Creative Computing

- To elaborate the magnitude of Creative Computing
- To articulate the concepts and terminology of Creative Computing

3.1   Overview

In this Chapter, the first and second element of Creative Computing as a knowledge discipline (i.e., magnitude of discipline and concepts and terminology) will be studied. Firstly, the magnitude of Creative Computing will be elaborated through studying its ultimate aim. Secondly, in order to achieve a better understanding, specific concepts and terminology of Creative Computing will be articulated.

3.2   Magnitude of Creative Computing

Everything that Nature makes is means to an end.
—Aristotle, On the Parts of Animals, Book I, Part I [13]

According to the great philosopher Aristotle, in order to explain something, there are four principles could be utilised, also known as four causes. The most important is the final cause that refers to the end, purpose, goal, or aim of something. It is believed that the existence of everything has its ultimate meaning. Therefore, the aim of Creative Computing will be studied to elaborate its magnitude.

Creative Computing aims to facilitate human creativity.
—Hongji Yang and Andrew Hugill,

The Creative Turn: New Challenges for Computing [70]

Human creativity needs improving in modern competition. However, as mentioned before, in computing field, there have been a great many computing technologies dedicating to supporting human creativity. Here comes the crucial question – *why we may benefit from Creative Computing or what makes Creative Computing so special?* To answer this question, three issues will be discussed in details in the following sections.

3.2.1 Human Creativity Needs Inspiration

Human creativity, nowadays, needs more active services like inspiration from computing. According to previous analysis, the facilitations provided by computing for human creativity have been in various kinds of forms, most of which can be classified into two groups: assistance and cooperation (see in Table 5).

Table 5. Forms of Computing on Creativity

Forms	Computing on Creativity
Assistance	Research Tools (EEG [117])
	Applications in General (MindGenius [3])
	Virtualising Applications (Magic Piano [49])
	Digital Art (Wishing Wall [8])
Cooperation	Digital Art (Hidden Fields Performance [2])
	Computational Creativity (Flavour Reason System [114])
Inspiration	Creative Computing (The Imaginary Voyage [69])

In terms of the assistance form, various computing technologies are mainly used as kind of assisting tools to facilitate human creativity. Although great effects can be achieved by these kinds of computing, most of them still passively and heavily rely on people's own creativity. For example, no matter how many shapes, colours, or images have been contained by a mind mapping application (e.g., MindGenius [3]), if a user just cannot come up with an associated idea, there is still no use of the

various kinds of materials. Therefore, human creativity needs more active facilitations.

The cooperation between human and computing can, to some extent, provide more active services for people to be creative. Due to the great computing power, these kinds of computing can "think" something that people cannot, thereby supporting people's creativity. However, just because of it, people's creativity can also be constrained by them. For example, various computing technologies used in Hidden Fields Performance still follow rigorous step-by-step instructions. In order to collaborate with them, dancers sometimes have to compromise with this kind of objectivity, which, to some extent, limits their creativity. As for computational creativity, although the imitation of human creativity can generate surprising results (e.g., a composition by a computer programme can be recognised as an original piece of Bach by audience [119]), there are still many inevitable limitations of machine creativity. For example, due to various difficulties of human creativity (e.g., uncertainties and vagueness), the ultimate nature of creativity still remains a mystery. Although the great computing power has potential to discover something surprising, it is still limited by the proposed theories or rules of creativity. Therefore, a different way of enhancing human creativity more actively should be considered.

Creative Computing devotes to inspiring human creativity (see in Table 5). It dedicates to illuminating people's creativity through continuous stimulations between the input and output of Creative Computing. For example, if somebody is stuck in some place while composing or playing some piece of music, Creative Computing may be able to inspire him or her to try various things out. The possible directions supplied by Creative Computing may be able to lead people toward creativity gradually. Therefore, the advent of Creative Computing is to provide the inspirations for human creativity.

It is important to differentiate the inspirations provided by Creative Computing from the ones of other fields like creative thinking. As mentioned before, there have been many fields dedicating to facilitating human creativity and a lot of results have been achieved. In particular, various kinds of techniques or methods of creative thinking have been proposed to inspire the creative ideas for people, such as random word

games [42] created by Edward de Bono who is a leading authority on lateral thinking [43]. However, the biggest advantage of Creative Computing is the great computing power and Big Data. Based on them, the core ideas of Creative Computing can be able to provide more possibilities to inspire people to be creative. For example, if the idea of randomness is fused into computing, compared with human mind, there can be numerous results generated by the random function of computing to inspire human creativity. Therefore, Creative Computing can serve human creativity better.

3.2.2 Computing Should Be Creative

According to previous analysis, the relationship between creativity and computing has been changed over time. In recent years, as computing has been widely used in creativity field, people have no longer been satisfied with the common use of various computing technologies, such as developing applications for assisting creativity, any more (see in Table 6).

New use of computing to facilitate human creativity has gained more and more attention. Various kinds of computing technologies have been studied to put into new use, like constructing kind of artwork like digital art installations and even duplicating human creativity, in order to push the boundaries between creativity and computing (see in Table 6).

Table 6. Statuses of Computing on Creativity

Statuses	Computing on Creativity
Common Use of Computing	Research Tools (EEG [117])
	Applications in General (MindGenius [3])
	Virtualising Applications (Magic Piano [49])
New Use of Computing	Digital Art (Wishing Wall [8])
	Computational Creativity (Flavour Reason System [114])
New Computing	Creative Computing (The Imaginary Voyage [69])

It is time to consider a new or creative type of computing. It can be seen that both the common use and new use of various computing technologies still focus on the application aspect. It is worth considering that there might be more possibilities for a computing product to inspire human creativity by adding creative ingredients to its own components (e.g., algorithms). Creative Computing is one of the new and promising terms coined to do that. It particularly centres on the interaction between computing technologies and arts or creative industries. Steve Jobs once said, "I like living at the intersections of art and technologies [72]". A typical example is The Imaginary Voyage that is a web application of digital opera used to inspire creative thinking for musicians [69]. It is based on the idea of "syzygy" that is one of the core concepts of Pataphysics, which is kind of philosophy that devotes to supporting people's imagination by deliberately generate exceptions [68]. It has been widely used in many artistic fields like Literature and Music. Through fusing with the pataphysical ingredient like syzygy [64], The Imaginary Voyage can provide users with a variety of creative interactions to stimulate their creative ideas. Therefore, a new or creative type of computing technology should be studied to inspire human creativity, such as Creative Computing (see in Table 6).

3.2.3 Calling for Knowledge Combination

It is to do with the unity of Creative Computing. Nowadays, the term of "Creative Computing" is among the various new concepts in computing field to facilitate human creativity. Most of them concentrate on making contributions to various fields like Computing, Media, and Art. Through utilising newest technologies and encouraging people to do things differently, the term devotes to discovering people's creativity potentials. Locating at kind of intersections among different areas (e.g., Computing and Art), it even can enable a musician to be able to think and do things through a computing perspective, which is very helpful for his or her creativity.

One of the first elaborations of the term "Creative Computing" is in the Editorial of the International Journal of Creative Computing (IJCrC). Accordingly, *to be creative in computing is to unite* [144]. In order to enable computing to be creative, the core idea of Creative Computing is to "Unite and Conquer", which aims to unite various kinds of knowledge from diverse kinds of disciplines together to conquer problems, in other words, knowledge combination. By perceiving the great value and prospect

of the combination between Computing and other fields like Art, the term "Creative Computing" discussed in the study centres on the uniting of all the disciplines and knowledge in the world, which is urgently demanded by contemporary society.

First of all, modern societal requirements demand knowledge to be combined. In terms of the worldwide cooperation, knowledge combination could make it much more efficient, such as the prevention of disasters or diseases. For example, Ebola is one of the most horrible virus diseases in the world. Every year, huge amount of efforts will be made to control its outbreak. However, only medical services are far from enough. Due to its great complexity, humanistic care, community engagement and financial assistances and so on are all vital elements to be considered. If knowledge in those different fields could be, to some extent, combined together, more operations might be able to act automatically, which can make the worldwide cooperation more efficient. In terms of the daily life, the pervasive usage of mobile phone is the most obvious evidence. Mobile phone, especially smartphone, might be the most remarkable invention in modern times. Featured with app store, it has the unlimited potential to do a variety of tasks for people. In order to change complexity into simplicity, people tend to put all of the functions into only one package. In order to do that, various kinds of knowledge needs to be united together.

Knowledge combination has been the popular trend of the utilisation of knowledge. Nowadays, the amount of knowledge is unprecedentedly abundant. While studying and leveraging old knowledge, people are continuously discovering and generating new knowledge. How to make the best use of the various kinds of knowledge has been the key concern all over the world. In computing field, a domain named Knowledge Management (KM) is specialised in using organisational knowledge [35]. Initially, in order to develop more efficiently, each branch of knowledge was divided and progressed independently. As human life is becoming increasingly complicated, more and more knowledge tends to be combined together. Although almost all of the things in the world are made by different knowledge (e.g., even a tablespoon includes knowledge from different disciplines like Physics and Chemistry), more and more intentional combination of knowledge is demanded in contemporary society. As a result, it has triggered different types of combination of knowledge (e.g., multidisciplinary, inter-disciplinary and trans-disciplinary), which has ended up with

new disciplines from the relatively conventional ones like Biochemistry to more recent ones like Cognitive Science.

It is time to combine various kinds of research efforts together. In order to extend the boundary of knowledge, a countless number of studies have been conducted in every domain. Hence, a large number of results have been generated from different research communities. Nowadays, to combine them together is necessary to serve the world better. Commonly, due to the well development of the academic world, one thing can be studied in different areas. For example, robustness can be studied in various domains, such as Computer Science, Economics, and Biology. Software can be studied how to develop it better in Software Engineering. It also can be studied how to facilitate artists' creativity better in fields of Art (e.g., Creative Writing). As more and more intersections emerge, the combination of various research efforts is able to enable people to engage a more comprehensive perspective, which is very helpful to advance people's understanding on something.

Computing, nowadays, can facilitate the combination of knowledge. As mentioned before, various computing technologies have been widely used in different fields to facilitate their development. It makes computing like kind of "glue" that can stick different disciplines together, which enables computing to be the perfect platform to support the combination of various kinds of knowledge from diverse kinds of disciplines (see in Figure 1). For example, a variety of computing technologies have been widely used in Neuroscience (e.g., EEG) to study human brain in a more scientific way. In Education, various educational technologies also have been broadly applied to improve the quality of education. Hence, using computing as kind of platform, the knowledge of Neuroscience has started to be combined with educational knowledge to understand the elements of education (e.g., students) more deeply and improve the quality of education more efficiently. For example, through monitoring a student's brain activities by using EEG, the attention level of the student can be detected and corresponding solutions can be conducted to improve the quality of education.
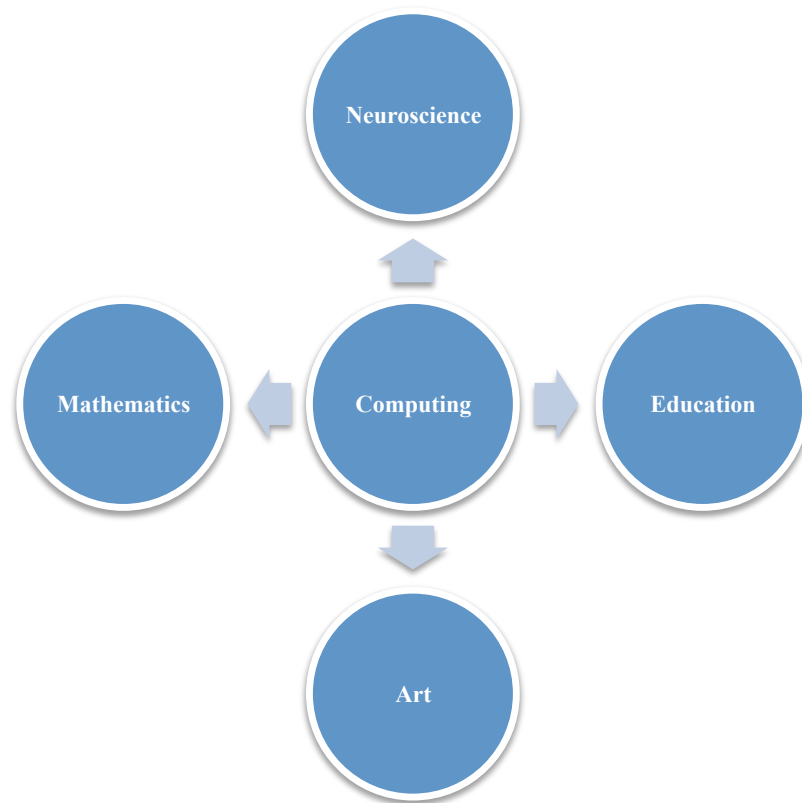
Figure 1. Relationship between Computing and other Fields

Furthermore, according to previous analysis, due to the evolutions of computing, an almost unlimited computing platform has been provided through the integration of various computing technologies together (e.g., Internet of Things). Therefore, the well-developed computing actually not only can support knowledge combination, but also is able to promote the combination of knowledge with great diversity, which is the purpose of the advent of Creative Computing. Based on the well-connected platform, all the work of Creative Computing depends on the combination of knowledge. Therefore, Creative Computing can be deemed as kind of paradigm of uniting, within which a variety of ideas, methods, or technologies will be proposed to support knowledge combination.

3.3 Concepts and Terminology

3.3.1 Creative Computing

To explain what is Creative Computing, there are three perspectives to be considered.

- Functionally, Creative Computing aims to facilitate human creativity.

- Literally, the meaning of "Creative Computing" mainly relies on the significance of the adjective word "creative". However, accordingly, there have been various kinds of conceptions of word "creative". When it is used to describe different things (e.g., product, people, process, and etc.), there would be different meanings. For example, when it is used to describe a product, the word "creative" can stand for "new" and "valuable" [116]. A creative person can be marked as having the ability to create. A creative process (e.g., music composition) is often deemed as containing some particular activities like incubation [92, 116]. Hence, the significance of word "creative" is determined by the meaning of word "computing" of Creative Computing.

Within the term of Creative Computing, the word "computing" means computing product. Accordingly, the term "computing" also can stand for many different things. For example, as a disciplinary concept, computing includes disciplines like computer engineering, software engineering, computer science, information systems, and information technology [59]. As a relatively general concept, computing can be summarised as hardware, software, and web. However, as mentioned before, due to the rapid development of various computing technologies, people nowadays tend to think them as a whole. For example, iPhone, as a type of smartphone, is kind of hardware device. However, it is also featured by excellent software (e.g., iOS) and depends heavily on web. Therefore, in order to cover all of the aspects of computing, the term "computing product" is used in Creative Computing, for a computing product can be a hardware device, software system, or web service.

Hence, according to the above discussions about the meanings of word "creative" (e.g., creative product, process, people, and etc.), the creative computing product studied in the realm of Creative Computing should be featured with being new and valuable. Therefore, Creative Computing aims to facilitate human creativity through designing and developing new and valuable computing product.

However, it is worth mentioning that, although creative computing product is particularly focused on, the design and development of a computing product never can be separated from associated elements like process, people, and

environment. Therefore, within the domain of Creative Computing, in order to produce creative computing product with good quality, other aspects including creative environment and creative developing process also will be studied [70]. More specific descriptions are as follows:

- o Creative computing product centres on the study of designing and developing new and valuable computing product to facilitate human creativity.

- o Computing platform for creativity centres on the study of a special type of Creative Computing. It does not aim to develop creative computing product, but to construct general computing platform, which could enable common computing product to provide creative services for people to facilitate their creativity.

- o Creative development centres on the study of using knowledge and technologies of creativity to improve conventional developing process of computing product, such as software engineering.

- Essentially, to inspire human creativity by designing and developing new and valuable computing product, rules that can trigger creativity will be fused into computing. According to previous analysis, from the common use and new use of computing to new type of computing to facilitate human creativity, the final inspiration of Creative Computing comes from The Imaginary Voyage. Its designing and development is based on the combination with Pataphysics, which is known as the science of imaginary solutions [68]. Through doing knowledge combination, a great many connections between different disciplines have been found related to creativity. Within The Imaginary Voyage, pataphysical concept syzygy is integrated with a concept named panalogy (i.e., parallel analogy), which is coined by a cognitive scientist Marvin Minsky [126] to inspire creativity. The former proposes that the alignment of concepts can trigger people's imagination. The latter provides an idea or direction for describing how to do the alignment to inspire people's creativity. Both of them indicate that to understand something in multiple perspectives is a good way to trigger creativity,

which can be deemed as a kind of rule of creativity. If this kind of creativity rules can be fused into a computing product, based on the great computing power and a large amount of data, numerous surprising results might be produced to inspire human creativity better. Therefore, Creative Computing also can be deemed as kind of new approach to studying creativity. However, it is worth mentioning that the study of Creative Computing about creativity focuses on the rules that can trigger creativity for people by knowledge combination, rather than the ultimate nature of creativity.

It is important to differentiate Creative Computing from computational creativity. Not only they are easy to be linguistically mixed together, but also they are both about creativity and computing. The overlaps between them can trigger crucial confusions. To do the differentiation is to help people to understand Creative Computing more clearly.

Both of them dedicate to supporting human creativity. However the approach is different. Creative Computing requires computing itself to be creative. To be creative in computing is to unite various kinds of knowledge from diverse kinds of disciplines to conquer the difficulties within computing field [144]. By doing knowledge combination, rules triggering creativity can be discovered to fuse into computing to inspire users' creativity. However, computational creativity does not require computing itself to be creative. Its approach to facilitating human creativity is through generating machine creativity by imitating human creativity. The study of computational creativity involves various disciplines like Artificial Intelligence, Cognitive Psychology, Neuroscience and so on [51].

3.3.2   Target Type of User

Creative Computing aims to facilitate people who want to be creative or are required to be creative. According to previous study on creativity, different people might have different characteristics and requirements of creativity, no matter male or female, young or old, expert or outsider, and artist or non-artist. As the ultimate aim of Creative Computing is to support people's creativity, the particular feature of the target user of Creative Computing should be discussed. Here needs to mention that

the feature descriptions below are general ones. If Creative Computing is going to be used in some particular domains, more specific requirements analysis is required.

The most important feature of this category of people is the great desire to be creative. As Creative Computing devotes to facilitating people's creativity through doing computing in creative ways, it is deliberately different from the conventional ones. The results produced by a creative computing product might be unexpected, even strange, absurd, or ridiculous, but meaningful. With the great willingness to think differently, people may be more probable to accept the stimulations supplied by Creative Computing. Based on the great desire to be creative, the unexpected but meaningful results, instead of irritating people, are more probable to trigger the curiosity of people to imagine.

It is worth mentioning that through designing and developing creative computing products, the creativity of the designers or developers also can be enhanced. According to previous analysis, the urgent societal requirements need human creativity to be facilitated. Computing, as a loyal servant, has been widely used to do that. However, just because of this, more and more elements from other fields like Art have been fused into computing field, which also influences the way people doing computing. An increasing number of people are encouraged to do computing in different ways, such as collaborating with artists (e.g., DevArt) and even train an artist (e.g., musician) to do computing. Furthermore, due to the idea of knowledge combination, people of Creative Computing are encouraged to comprehend and learn different knowledge and technologies. By doing so, they are able to understand the world through different perspectives and find something surprisingly valuable.

3.3.3 Human Creativity

In order to support human creativity better, first things first, a foundational theory of human creativity should be selected for the study of Creative Computing. As human creativity has been studied in a variety of domains for a long time, there have been various kinds of conceptions about it. In the realm of Creative Computing, a widely accepted theory of creativity is derived from Professor Margret Boden [105]. As an outstanding expert who is interested in both computing fields (e.g., Artificial

Intelligence and Computer Science) and areas associated with creative mind (e.g., Cognitive Science and Philosophy), her theory of creativity is more comprehensive and appropriate for Creative Computing.

Accordingly, in the field of Creative Computing, human creativity is understood as kind of ability to create. Over time, human creativity has been studied in different forms, such as intelligence, ability, process, personality trait, and even just a state of mind. The relationship between intelligence and creativity has been discussed (e.g., threshold theory [116]). Several stages of a creative process have been extracted (e.g., incubation [98]). Some common features of creative people have been summarised (e.g., ambiguity tolerance [146]). As the rising of Neuroscience, when the creative moment happens, how the brain works has been studied (e.g., mind wandering [37]). In Boden's opinion, creativity should be studied as the ability to create something new, surprising, and valuable [25]. As this kind of creativity ability can underpin people's everyday abilities (e.g., creative thinking), through various facilitations, it might be fostered and reflected in every aspect of life.

3.3.4 Historical Creativity

Creative Computing aims to encourage people to change the world, in other words, to facilitate the historical creativity for people. According to Margret Boden, there are several types of creativity ability. In order to create something new, two degrees of newness should be considered: new to a certain person (P-Creativity) and new to the whole world (H-Creativity) [25]. P-Creativity is, most of the time, studied in child education. After all, it is unnecessary for children to possess a huge amount of knowledge. Therefore, one of the key concerns is to maintain children's original creativity. It also could explain why there are coaching strategies encouraging people to think like a child. However, due to the urgent social requirements of creativity, H-Creativity is more necessary and preferred by contemporary competition. There is almost no doubt that the great success of big digital companies like Apple and Google counts enormously on H-Creativity. Therefore, Creative Computing aims to facilitate people's H-Creativity.

3.3.5 Combinational Creativity

Creative Computing also devotes to facilitating the combinational creativity for people. Like there are two types of creativity (i.e., P-Creativity and H-Creativity) corresponding to the significance of "new", in order to create something surprising, there are also three types of creativity. One is called combinational creativity [25]. Combinational creativity is to do the unfamiliar combinations with familiar things [25]. It has been widely used in modern time. With the utmost abundance of materials nowadays, it has been extremely difficult to create something innovative totally from scratch. Based on the unprecedentedly rich knowledge and technologies, it is believed that there are always possibilities for surprising combinations to emerge, such as Apple Watch and Google Glass. Therefore, Creative Computing encourages people to make the creative use of the existing knowledge, materials, and technologies and think the unthinkable before.

3.3.6 Transformational Creativity

Furthermore, Creative Computing dedicates to supporting people's transformational creativity. Similarly with combinational creativity, another two types of creativity corresponding to the meaning of "surprising" is exploratory and transformational creativity. Exploratory creativity is to do the exploration within only one conceptual space (i.e., structured knowledge system or a thinking style) [25]. On the contrary, transformational creativity is to do the exploration within a new conceptual space that is transformed from an old one [25]. Compared with exploratory creativity, transformational creativity is kind of deep creativity [25], which concerns thoroughly changing the way people seeing the world. This kind of approach has become a new trend, as people's understandings of the world become deeper and deeper. The more we learned about the world, the more unexpected things we discovered, like the quantum entanglement phenomenon of Quantum Mechanics. The more unexpected things we discovered, the more possibilities for us to be creative. IBM once said "the greater the change in beliefs, the more surprising [114]". Furthermore, due to the variations of the concepts, there can be more new relationships, which is very helpful for the generation of innovative combinations (i.e., combinational creativity).

3.3.7   The Aha! Moment

Creative Computing devotes to facilitating human creativity through encouraging the Aha! Moment. It is a state of mind often studied as sudden insight, which is closely associated with people's creativity activity. Accordingly, when a person's creativity is triggered by some means, it is highly possible for him or her to experience the mysterious creative moment [9]. Although it seems sudden and unpredictable, it is actually the result of long time information processing of human brain. Therefore, the development process of the Aha! Moment might be a good choice for a creative computing product to act on. By providing continuous and persistent inspirations and stimulations, people's creativity might be formed gradually by Creative Computing.

Furthermore, the knowledge and technologies of the Aha! Moment also provide a new way to validate Creative Computing. It is associated with the difficulties of the formation of the creativity ability. It would be a long time project. And due to the mysteries of human creativity, people need to practice over and over again. Besides kind of periodical and comprehensive creativity evaluation, it would be better to have a complimentary way to validate Creative Computing. The Aha! Moment is kind of physical reflection when human creativity is stimulated. During each inspiration, the unexpected but meaningful results of Creative Computing may be able to trigger the mysterious moment for people [77]. This kind of "state of mind" might be able to detect by technologies of Neuroscience or Cognitive Psychology (e.g., EEG [9]). Hence, this aspect of human creativity can be leveraged in the demonstration and validation of Creative Computing. Furthermore, the collaboration between Creative Computing and this kind of technologies will be studied in the future to enhance human creativity better.

3.3.8   Creative Interaction

A creative computing product aim to provide creative interactions to encourage the Aha! Moment for people to facilitate their creativity. Accordingly, the advent of sudden insight is because of the unexpected connections between different neurons, which can be triggered by novel associations [20]. Therefore, in order to construct novel associations, even valuable "dissociations [68]" to inspire human creativity, the creative relations between the input and output of a creative computing product will be studied, which is known as creative interactions.

The creative interactions provided by Creative Computing are able to lead people to do the innovative associations, thereby inspiring their creativity. Various theories about human mind or brain have mentioned about this. Accordingly, human mind can be deemed as kind of pattern-making system [43]. It is natural for human mind to create and recognise patterns from the external world, within which creative concepts or relationships might be identified. Furthermore, human brain can also be divided into two systems (i.e., system one and system two) that are associated with unconsciousness and consciousness respectively [75]. No matter which system it is, both of them are able to do novel associations. For example, if a person is provided with a word "thirsty", a word "water" might be automatically associated, which is related to system one. If the person is required to think more, a word "mermaid" might also be proposed through more conscious, complicated, or even intentional thinking, which is related to system two. Therefore, people have the ability to accept the unexpected but meaningful inspirations produced by Creative Computing.

3.4   Summary

To summarise, the facilitations for human creativity provided by various kinds of computing technologies are becoming more and more complicated and active, which has been changed from assistance to cooperation. In order to cope with increasingly urgent societal requirements of creativity, more active services like inspiration have been the new challenges for computing nowadays. Due to the pervasive utilisation of various computing technologies in creativity field, how to use them in new ways has been the hot pursuit. Meanwhile, as various computing technologies have been put into new use, the development of computing itself has also been influenced by the associated novel elements (e.g., artistic/aesthetic ideas), which provides a way to add creative ingredients to computing product itself to enhance human creativity better – Creative Computing.

Chapter 4. Scope and Parameters of Interest of Creative Computing

- To define the scope for Creative Computing
- To propose the parameters of interest of Creative Computing

4.1 Overview

In this Chapter, the third and fourth element of Creative Computing as a knowledge discipline (i.e., scope of discipline and parameters of interest) will be studied. Firstly, the boundary will be set to define the knowledge territory (i.e., scope) for Creative Computing (see in Figure 2). Secondly, parameters of interest (i.e., interesting topics) within the scope of Creative Computing will be proposed to tell potential researchers what could be studied and what to leave out.
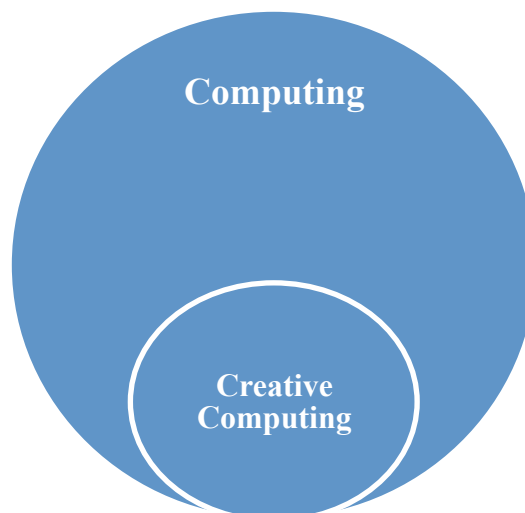
Figure 2. Computing and Creative Computing

4.2 Scope of Creative Computing

Creative Computing, as a new knowledge discipline, covers the intersections of three domains: computing, creativity, and knowledge (see in Figure 3).
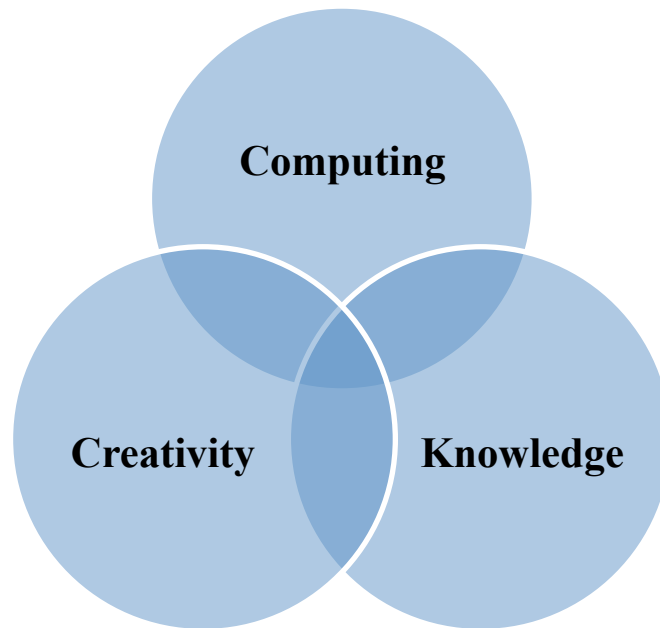
Figure 3. Scope of Creative Computing

Computing Domain. In order to be called Creative Computing, something should be some kind of computing in the first place. Compared with other creativity training or coaching methods, tools, techniques, and so on, the crucial advantages of Creative Computing are its great computing power and strong backup of the huge amount of data. Based on the rules that can trigger creativity, various kinds of stimulations might be produced to inspire human creativity.

Currently, in the realm of Creative Computing, the software aspect of a computing product is particularly focused on. As explained before, the term "computing" stands for computing product, which can be hardware, software, or web. According to previous analysis, various kinds of hardware and web technologies have provided a good platform for software to develop. Hence, due to the great extensibility and flexibility of software, as a new field, Creative Computing pays more attention to the software aspect of a computing product.

Creativity Domain. The aim of Creative Computing is to facilitate human creativity. In order to do that, research results on human creativity within creativity domain will be utilised (e.g., types of creativity). These kinds of knowledge can provide general

suggestions or directions for Creative Computing. For example, the combinational creativity can enable us to be aware of the great significance of relationships among different things to facilitate human creativity.

Knowledge Domain. Accordingly, the core idea of Creative Computing is to combine various kinds of knowledge from diverse kinds of disciplines to address difficulties within computing field [144]. By comprehensively, actively, and boldly leveraging a variety of knowledge, especially the uniting power of knowledge, Creative Computing should be able to find the ideas or rules that can trigger creativity for human creativity facilitation, which, to some extent, also enables Creative Computing to propose a kind of new way to study and utilise human knowledge. Therefore, there is also a crucial intersection between knowledge and Creative Computing.

4.3   Parameters on Creative Computing Product

As mentioned before, Creative Computing particularly centres on the design and development of creative computing product, especially creative software. Several issues that have already been studied in the realm of Creative Computing are described through two aspects: system design and quality control.

4.3.1   Aspect of System Design

In order to make creative software to inspire human creativity, rules that can trigger creativity for people will be found by knowledge combination and fused into software components. Two of them have been particularly focused on: algorithm and architecture. For algorithm, it is one of the core software components. Furthermore, it is possible to embody them into step-by-step algorithms, which might be called creative algorithms. Some parameters that have already been explored in the realm of Creative Computing are as follows.

- *General creative algorithms*

    They are for general purpose and could be directly applied in a variety of domains to facilitate creativity for people, no matter artists or scientific researchers. Besides, due to their abstractness, they also could be embodied further according to specific requirements. Another crucial function of general

creative algorithms is to, to some extent, convert conventional algorithms into creative ones to provide creative services for people to be creative.

- *Creative searching algorithms*

  They are kind of meta-searching algorithms dedicating to creatively reorganising search results that are generated from other search engines. Differing from the conventional searching algorithms like PageRank [30] or even Knowledge Graph of Google [129], the creative searching algorithms, instead of providing people with something they exactly expect, devote to producing something unexpected but useful for people to be creative [109].

- *Creative decision-making algorithms*

  The aim of this kind of algorithms is to facilitate human creativity through assisting people to creatively make decisions or make creative decisions. People need to make decisions almost every single moment, which is one of the main cognitive processes of human life. However, due to the complexity of modern society, the decision-making process is becoming more and more sophisticated. There are too many new challenges needed to consider, such as Big Data. It is time now to consider how to creatively deal with the difficulties of the decision-making process, which will be studied by creative decision-making algorithms.

- *Creativity analysis algorithms*

  As Creative Computing could be deemed as a new kind of creativity study, there should be novel contents about creativity. Through studying creativity from the perspective of computing, creativity studied in Creative Computing is more quantitative or objective, which might be able to form a new type of creativity analysis algorithms.

As for the architecture design, Creative Computing focuses on the construction of the supporting architecture. In order to facilitate the unique features of Creative Computing better, specific architecture should also be studied. Currently, three main parameters being concerned in the domain of Creative Computing are as follows.

- *Combination with Semantic Web*

  Semantic Web is one of the most popular technologies to enable computing to be "intelligent". Based on the core components like ontology, RDF data, and inference engine, a certain computer, to some extent, is able to "think", may be, creatively. Therefore, Semantic Web is believed to be a promising platform for Creative Computing to develop. Depending on the general architecture (framework) of Semantic Web (also known as "layer cake" [5]), a specific architecture for Creative Computing can be constructed. Some particular points might be considered as follows.

  o *Selection of normal web*

    Semantic Web, as a new generation of web technologies, is often deemed as an extension of normal web. Therefore, in order to properly construct a specific architecture for Creative Computing, an appropriate common architecture of web application should also be considered. Accordingly, there have been various kinds of architectures for normal web application, (e.g., MVC and AJAX) and each one has its own contents and features, a proper selection will greatly influence the combination with Semantic Web for Creative Computing.

  o *Composition of creativity ontology*

    As ontology is one of the core components of Semantic Web, it is also very important for Creative Computing to study. Additional semantics could be added into computing through it. Therefore, the creative ideas of Creative Computing can be represented in corresponding ontologies through constructing creative relationships or concepts, which may be called creativity ontology.

  o *Generation of creative data*

    As mentioned before, the output of Creative Computing intends to be unexpected but meaningful to facilitate people to be creative. In order to do that, additional semantics on creativity can be added into common data, which might be called creative data. The RDF data of Semantic Web provides a promising platform for Creative Computing to do that. Through

creatively manipulating the relationships or even the concepts within triples, the creative results might be come up with. For example, if there is a triple "Alice is a dolphin", through adding a new triple "every dolphin is an angel", a creative relationship is constructed between Alice and angel.

- o *Implementation of creative reasoning*

  After the preparation of various resources (e.g., composition of creativity ontologies), inference engine that is the key component to truly realise the functionality of Semantic Web is crucial for Creative Computing to study. Currently, there are three forms of inference engine (i.e., independent, built-in, and self-configured). How to utilise them to reason the RDF data through various ontologies (e.g., creativity ontologies) should be studied in Creative Computing.

- *Creative interactions between end-user and Creative Computing*

  According to previous discussions, Creative Computing aims to inspire human creativity through creative interactions. Here are some potential points to be considered.

  - o *Creative interaction logics*

    As mentioned before, the interactions between user and Creative Computing will be iterative and persistent. Therefore, how to organise the input and output of each interaction to facilitate human creativity should be concerned. For example, various creativity stimulations generated by a creative computing product can be classified into different inspiration degrees. The more unexpected the results will be, the more curiosity might be triggered, the more probable a user's creativity might be inspired.

  - o *Expression of interaction logics*

    In order to maximise the effect of the creative interaction logics, how to better express them to attract people and improve user experience could also be studied in Creative Computing. In computing field, there has been a domain specialised in studying how to enable people to interact with computer in novel ways, which is known as Human-Computer Interaction

(HCI). Various interacting technologies (e.g., touchscreen technology, virtual reality, wearable technology, natural language processing technology) have been playing an increasingly important role in modern society. How to better utilise them for the development of Creative Computing to stimulate human creativity should be studied.

- *Creative interactions between surrounding world and Creative Computing*

  Interactions nowadays have no longer been limited only between human and computer anymore. The external environment also starts to be considered into the interaction design. Accordingly, a playful environment is very helpful for people to be creative [38]. Furthermore, the interactions between a user and a creative computing product must happen in a certain environment. The effect of the creative interactions should be influenced by elements from the environment. An excellent platform to process the information from surrounding environment has been provided by a novel technology known as Internet of Things (IoT). It could support various devices to be able to exchange different types of data, which enables various influencing factors from the circumstance (e.g., colour [141]) to be processed to facilitate human creativity. For example, a typical creative computing product might be able to change the interface colour style according to different situations. Accordingly, colour blue is particularly beneficial for inspiring people's creative performance.

4.3.2   Aspect of Quality Control

Quality control is another promising way to enable a computing product to be creative. Through manipulating the measurement and improvement of software quality towards a creative direction, a computing product can be added more and more creative features. Currently, there are two kinds of quality control studied in the realm of Creative Computing.

- *Control of creative features*

  According to previous analysis, the urgent need of new type of computing is one of the reasons of the advent of Creative Computing. Hence, there are several new or creative features of Creative Computing. In order to do a good quality control,

how to measure and improve the creative aspects of a creative computing product should be studied.

Furthermore, the control of creative features is also demanded by various applications in contemporary society. Due to the oversupply status of modern society, people start to pay more and more attention to the satisfaction of spiritual demands. Software nowadays is becoming increasingly interesting and playful, which has lead to the emergence of new software quality control aspects (e.g., enjoyableness [50]). Therefore, in order to cope with these kind new or even creative features, more and more aspects or elements should be considered in software quality control.

- *Creative quality control*
  It concerns fusing creative contents into both the measurement and improvement of the conventional quality control, such as reliability, security, efficiency, and so on. Due to the fast development of modern society, the elements that can impact conventional software quality are becoming increasingly novel. Taking reliability for an example, conventionally, one of the main influencing factors of software reliability is coding practice. However, various new types of programming keep emerging in modern time. Creative coding is one of them, which, instead of seeking functionality, cares more about the expressiveness of prototype or software. Correspondingly, creative contents are required to be studied to deal with those kinds of novel features.

4.4 Parameters on Computing Platform for Creativity

The overall goal of it is to support common computing products to be able to provide creative services to facilitate human creativity. The so-called creative services stand for the computing services that can stimulate people's creative thinking through providing interesting user experiences. For example, an interesting service provided by a travelling app might be "getting lost in London". As for the meaning of common computing, it both refers to codes (programmes) and software (applications). Due to the diversity and multiple abstraction layers of computing platforms, there are, currently, two main aspects being considered in the domain of Creative Computing: library and middleware.

4.4.1 Aspect of Library

This aspect pays attention to the facilitations for coding or programming to simplify the development of creative services. Currently, two parameters being considered in the realm of Creative Computing are as follows.

- *Creativity models (classes)*

    Their aim is to package creative logics that are essential to Creative Computing into reusable creativity models. By utilising them, the common programmes will be embedded with the "core" of creative ingredients to build creative services in an innovative way to facilitate human creativity. There are a great many programming paradigms to choose. For example, nowadays, Object-Oriented Programming (OOP) has been one of the most popular [108]. As most of the languages of OOP are based on class, the creativity models can be studied as classes of creativity in Creative Computing.

- *Creative data specifications*

    They are to do with the specifications of the potentially new type of data generated from Creative Computing, which may be called creative data. As mentioned before, Creative Computing may be able to change common data into creative data. The manipulations operated on data can be either semantic or formal. Hence, it is necessary to do the specifications of the data related to creativity in Creative Computing.

4.4.2 Aspect of Middleware

The middleware studied in Creative Computing devotes to facilitating more complicated software or applications to be able to provide creative services for people. Due to the crucial feature of middleware (i.e., locating between software applications and operating system), two general parameters being studied in Creative Computing are as follows.

- *Support for individual application for creativity*

    Due to the rapid development, the amount of various computing technologies is extremely huge. While developing new computing products, how to make the best use of the existing ones to facilitate human creativity should be studied.

Middleware, as a kind of computing platform that aims to provide services for the upper level applications, is just a perfect tool to do that. For example, with a same input, a creative output might be generated by a same application through operating on a creative middleware. Therefore, this kind of approach can facilitate human creativity more broadly.

- *Support for application cooperation for creativity*

Various facilitations for human creativity can be either simple or complicated. They can either rely on a single program or count on a collection of applications. As mentioned before, the computing technologies nowadays are unprecedentedly abundant, how to make the fullest utilisation of them has been one of the key concerns. Besides the support of individual application, another crucial feature of middleware is the facilitation for the interoperation between different or disparate applications that might be distributed on different machines. Therefore, creative middleware that can supply a good platform for uniting various applications to facilitate human creativity should be studied.

4.5 Parameters on Creative Development

As mentioned before, the design and development of a creative computing product for human creativity facilitation can never be separated from the associated process. Therefore, influencing factors of the producing process also should be studied in the realm of Creative Computing, such as activity and people.

4.5.1 Aspect of Activity

In terms of the aspect of activity, two issues are particularly considered in the realm of Creative Computing.

- *Research methods for Creative Computing*

  As Creative Computing is a new research field, appropriate research methods might be very helpful to facilitate its development. A huge number of common research methods have been widely used, such as qualitative and quantitative methods. Therefore, how to select the appropriate pre-existing research methods, especially methods on creativity (e.g., creative problem solving methods) for Creative Computing should be considered in the first place. More importantly,

due to the unique features of Creative Computing, such as particular dependence on the combination of novel knowledge, new research methods are still urgently required to be studied in Creative Computing.

- *Available technologies for Creative Computing*

  Technologies nowadays are extremely abundant and diverse. It is unnecessary to construct Creative Computing totally from scratch. Therefore, the selection of appropriate technologies, such as Semantic Web, to develop Creative Computing is necessary. Furthermore, one of the main goals of Creative Computing is to unite various kinds of technologies together. Hence, it is worth mentioning that Creative Computing not only utilises pre-existing technologies, but also aims to create new technologies, which will specialise in facilitating human creativity.

4.5.2   Aspect of People

In order to do Creative Computing, the associated developing people are also required to be creative. Therefore, how to foster the creativity for people like designers and developers also should be concerned. Furthermore, according to the idea of knowledge combination, the collaboration across various disciplines is encouraged in the field of Creative Computing. Hence, a great many elements from different fields might be utilised here. Several parameters currently being studied are as follows.

- *Individual creativity cultivation*

  As a developer of Creative Computing, in order to facilitate other people's creativity, him or her self should be creative in the first place. Therefore, creativity cultivation is extremely necessary for the developers of Creative Computing, especially individual creativity. As Creative Computing pays particular attention to novel knowledge and disciplines, developers of Creative Computing (especially our Centre for Creative Computing) devote to seeking appropriate knowledge from fields like Humanities and Cultural Industries. Due to their features of research, the development of Creative Computing is more like individual project. Furthermore, although different people with different backgrounds or professions could work as a team and conduct a good interdisciplinary research, it is still nowhere near the effect of a versatile

individual that is able to engage different thinking styles. Hence, as a developer and consolidator of Creative Computing, according to my experience, there are some promising perspectives could be used.

o *Perspective of discipline and knowledge*

A developer of Creative Computing is required to be able to absorb and utilise knowledge from other disciplines besides computing. Therefore, to have a comprehensive point of view on academic disciplines and knowledge is necessary. In order to do that, corresponding strategies and methods might be used. For example, the undergraduate courses of Creative Computing in Bath Spa University are combined award, which aims to truly enable students to study various kinds of knowledge from diverse kinds of disciplines and practically engage different styles of thinking.

o *Perspective of coaching materials utilisation*

There have been a huge number of strategies, methods, techniques, and tools to facilitate human creativity, such as creative thinking. Therefore, how to leverage them in Creative Computing to cultivate developers' creativity could be studied. For example, during the stage of knowledge preparation (i.e., seeking appropriate knowledge for Creative Computing), methods of divergent thinking could be utilised. Therefore, a new and specific research process for Creative Computing also might be come up with, through fusing with those coaching materials of creativity.

o *Perspective of habit and hobby*

If a developer of Creative Computing, besides Computer Science, is also interested in other domains, like Writing, it might be just perfect to try to combine them together to create something innovative. For example, there has already been some meaningful collaboration between Creative Computing and Creative Writing in Bath Spa University. Even Steve Jobs once said, "I like living at the intersections of Art and technologies".

• *Collaboration in Creative Computing*

It is worth mentioning that Creative Computing not only centres on individual creativity cultivation, but also focuses on the collaboration between different developers of Creative Computing. There is no doubt that a good collaboration can make the best use of knowledge, which is just one of the unique features of Creative Computing. Furthermore, the developers of Creative Computing can come from different fields. There might be even artists like musicians studied in the realm of Creative Computing. Therefore, how to deeply collaborate with them also should be studied. After all, the knowledge combination in Creative Computing is not only about reading papers, but also talking with creative people.

- *Crowdsourcing in Creative Computing*

  In order to break the limitations and constrains further, Creative Computing also could consider an open call to the crowd, no matter experts or outsiders, for creative ideas. Due to the highly advanced technologies, the space and time could be crossed easily. A creative task could be sent to people all over the world. Therefore, how to utilise the great benefit of crowdsourcing in Creative Computing could be studied.

4.6   Summary

To summarise, Creative Computing, as a new knowledge discipline, generates from the intersections of domains of Computing, Creativity, and Knowledge. Not only knowledge on creativity will be utilised in Creative Computing, the study of Creative Computing will also make valuable contributions for the accumulation of creativity knowledge. By specifically utilising the uniting power of knowledge, Creative Computing will also provide new approaches to leveraging and linking the unprecedentedly enormous knowledge in modern time. As Creative Computing is a relatively new field, it currently pays more attention to the development of software. Inspired by the elements associated with the software aspect of a creative computing product, Creative Computing will be mainly studied within three sub-scopes: creative computing product (software), computing platform for creativity (environment), creative development (process).

Chapter 5. Theoretical Foundations and Methods of Creative Computing

- To elaborate the foundational theories of Creative Computing
- To propose promising methods to study Creative Computing

5.1 Overview

In this Chapter, the fifth and sixth element of Creative Computing as a knowledge discipline (i.e., theoretical foundations of discipline and methods of study) will be studied. Firstly, the theoretical foundation of Creative Computing will be elaborated, which can, to some extent, explain Creative Computing further. Secondly, in order to do a good Creative Computing, appropriate methods are also urgently required to give suggestions for the developers of Creative Computing.

5.2 Theoretical Foundations of Creative Computing

5.2.1 Unity of Knowledge

In order to do a better knowledge combination in Creative Computing, what is knowledge all about should be studied in the first place. According to Epistemology that is specialised in explaining knowledge, also known as the theory of knowledge, a classic definition of knowledge derived from the great philosopher Plato is well accepted. In Plato's opinion, knowledge is the "justified true belief" (see in Figure 5 [55, 97]).
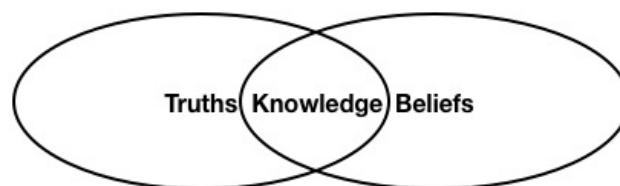
Figure 4. Definition of Knowledge

There are three crucial concepts about knowledge: justification, truth, and belief. As various debates or confusions on justification and belief still remain until nowadays, my research pays more attention to a widely accepted understanding of the truth aspect of knowledge in modern time. It was derived from another great philosopher Marx. According to him, there are two types of truths: relative truths and absolute truths. A good example to explain them is that, for now, all of the knowledge that we human possess belongs to relative truths. An countless number of relative truths will eventually compose the absolute truths, which is the ultimate goal of human knowledge exploration [91].

By studying the truth aspect of knowledge, an important feature of knowledge – unity of knowledge – can be identified. It indicates that, in theory, all of the knowledge in the whole world can be unified together. As multidisciplinary, inter-disciplinary, and even trans-disciplinary idea is playing an increasingly important role in contemporary society, people have found that many theories within different disciplines can have something in common, which might generate new disciplines like Biochemistry, Artificial Intelligence, and Cognitive Psychology.

It is worth mentioning that the unification of knowledge shouldn't be quantitative but logical. Simply putting different knowledge together is not deemed as knowledge combination, which should be kind of deep integration of different knowledge logics. More and more researchers in contemporary society have started to pursue the universal theory that can explain everything in the world. For example, a branch of Theoretical Physics known as String Theory devotes to finding the simplest equation to unify all of the forces together and to eventually explain the ultimate nature of the world.

In the realm of Creative Computing, the unity of knowledge encourages us to pay attention to all of the knowledge in the whole world for knowledge combination. That is the reason why the Centre for Creative Computing is kind of university-wide collaboration [1]. Furthermore, it also indicates that the combination of knowledge in Creative Computing should not be the simple transformation of selected knowledge

to computing programmes. The fusion of ideas of the selected knowledge is important to the development of Creative Computing.

5.2.2 A Paradox of Creativity

The facilitation for creativity is based on a paradox [23, 60]. In creativity domain, although creativity is not about certainty, there are also rules to prevent people from going off the "deep end", such as styles of painting or theories of colours. However, while being the "best friends" of creative people, the rules also can be the "worst enemy" that will constrain their inspirations or even passions. It is very difficult for people to break those limitations to be creative. Some artists or creative people even spend their whole life struggling with guidance or suggestions without being ruled by them. There are even quotations to help people to do that (e.g., have knowledge but forget the knowledge).

In the realm of Creative Computing, as it aims to help people to be creative, in theory, the rules to be creative should be studied very well in the first place. However, according to previous discussions, it is crucial to keep avoiding the irritating constraints of those rules. Furthermore, the meaning of creativity studied in Creative Computing refers to the ability to create something creative while others cannot. There is a critical contradiction that if we know exactly how to be creative, how it can be called "creative".

Hence, the logical solution for the paradox of creativity in Creative Computing is to facilitate human creativity without "knowing" it, but "feeling" it. It refers to the perceptions on creativity of a developer. The facilitation for human creativity provided by Creative Computing can be open-ended. As long as a certain developer of Creative Computing reckon something might work, he or she should just go for it and try it out. In the field of Creative Computing, the formation of this kind of feelings on creativity is particularly based on the comprehension of various kinds of knowledge. It will broaden a developer's horizon and help him or her to see something overlooked and think something unthinkable before, which can be very helpful for people to perceive something surprising about creativity. For example, without extensive learning, how could somebody imagine a special phenomenon in

Astronomy (e.g., the alignment of three celestial bodies) even can be leveraged for stimulating creativity for people?

5.2.3   Novelty of Discipline

Creative Computing pays particular attention to interestingly but unusually used disciplines. In the realm of Creative Computing, the key concern is to reconcile the critical contradiction between objective computing and subjective creativity to facilitate human creativity better. As computing nowadays is facing the great challenges to truly merge with creation process [70], it is time now to add new or even creative ingredients by referring to knowledge from other disciplines. Most of the researchers in computing field are used to doing the explorations only within their own domains. However, since computing could be used to facilitate the development of other fields, what if knowledge in other fields also could help to address problems in computing field? Here needs to mention that "other disciplines" do not mean the conventionally associated fields like Mathematics or Physics, but the areas with totally different features, like Philosophy and Art. It is believed that the more "unthinkable" the disciplines are, the more novel ideas there might be for Creative Computing.

The next crucial issue for Creative Computing is how to define the "novelty" of each discipline. Nowadays, there have been a large number of disciplines in the whole world and each one has its own contents and characteristics. In order to deal with this kind of complexity, a comprehensive study about academic disciplines is conducted. Based on the study, the novelty of a discipline could be counted on three factors: accessibility, dissimilarity, and diversity.

• The accessibility of a discipline stands for if the discipline can be referred. Although each discipline in the whole world might contain creative solutions, not all of them are accessible. It is believed that not all of the disciplines are created equal. Some disciplines are considered as "soft" ones (e.g., Philosophy and Art), which is associated with their generality [121]. On the contrary, some disciplines are deemed as "hard" ones (e.g., Medicine and Astronomy), which is related to their specificity [121]. If a discipline were too specific to be understood by

outsiders, it would be hard for people of Creative Computing to refer. Hence, the first thing to be novel for Creative Computing to use is to be accessible.

- As for the dissimilarity, it is to do with the "distance" between different disciplines. The more dissimilar the disciplines are, the more different their perspectives will be, and the more radical the transformation is able to be. It is believed that there might be more possibilities in the new "world" to create. For example, it seems that Art differs greatly from Science. In common sense, Art is more about inspirations (e.g., Painting) and Science is more about rigid logics (e.g., Mathematics). However, through a mathematical point of view, surprising artwork can be come up with, such as Leonardo da Vinci's Vitruvian Man and M. C. Escher's Relativity.

- In terms of the diversity, it is to do with the various elements involved within each discipline. For example, Art, as the highest abstraction of the natural beauty, encompasses various kinds of elements, from tangible being like Architecture to the intangible like Poetry. Philosophy, as one of the oldest branches of knowledge in the whole world, also contains various kinds of contents, not only include core branches like Epistemology and Metaphysics but also involve part of knowledge of other disciplines like Linguistics and Psychology. As to be creative in computing is to unite, the more elements contained within a promising discipline, the more chances there might be to find the creative solutions for Creative Computing.

5.2.4 Pataphysics

The utilisation of pataphysical theories is a novel and interesting feature of Creative Computing. As a particularly novel and less commonly known discipline, it is considered as one of the main resources for Creative Computing to compute in creative ways. Accordingly, Pataphysics aims to support people's imagination through generating exceptions deliberately [68], which was derived from a French writer named Alfred Jarry. Due to its great value to creativity, it has been widely used in various fields of Art, like Literature and Music. More importantly, there are various kinds of elements from disciplines like Science, Philosophy, and even Art

within Pataphysics, which enables its great diversity for Creative Computing to utilise.

At the very heart of Pataphysics is the idea of deliberately generating "exceptions". However, here is a critical question. Accordingly, as long as something is considered as an exception, it means that there should be no rules to follow. Therefore, how could Pataphysics is able to propose the laws to govern the exceptions? Although it seems like another kind of paradox (the first one is explained in Section 5.2.2), it is possible because the way that pataphysicists see the world is different from ordinary people. It is due to the relationship between Pataphysics, Metaphysics, and Physics. Accordingly, the relationship between Pataphysics and Metaphysics is similar to the one between Metaphysics and Physics [71]. It implies that Pataphysics studies the things beyond Metaphysics and Physics. Without the limitations of physical and metaphysical world, Pataphysics encourages people to imagine proactively, boldly, and even crazily.

It is worth mentioning that pataphysical thinking is totally different from blue-sky thinking. To think proactively, boldly, and even crazily does not mean irrationally. As mentioned above, there is particular relationship between Pataphysics and Metaphysics [68]. Although the approach to understanding the world is different, like the study of Metaphysics cannot be separated from the physical facts, the study of Pataphysics also depends on the comprehension of metaphysical and physical knowledge. By studying various kinds of imaginary phenomena, it is reasonable to believe that there are indeed kind of rules of exceptions existing in the nature, which enables Pataphysics to be able to propose several core concepts to facilitate human creativity. For example, one of the concepts is named Syzygy [63]. It originated from Astronomy and stands for the alignment of celestial bodies, as in an eclipse [64]. Before we human are able to explain an incomprehensible phenomenon like that, what it will trigger is the unexpectedness, curiosity, and, finally, imagination of people, such as the emergence of various kinds of myths and legends. Inspired by Pataphysics, what if an unexpected alignment of concepts is presented in front of people? Hence, in the realm of Creative Computing, by leveraging pataphysical ideas like Syzygy, it is believed that people's creativity might be stimulated.

5.3 Methods of Creative Computing

5.3.1 Unite and Conquer

At the very heart of Creative Computing is the idea of "Unite and Conquer [144]", which is to combine various kinds of knowledge from diverse kinds of disciplines to address difficult problems, in other words, knowledge combination. As mentioned before, due to the rapid development, computing has been pervasively utilised, even in the field of creativity. Nowadays, people almost have no longer been able to live without the support of various computing technologies (e.g., smartphone). Furthermore, due to the more and more complicated human life, computing is increasingly challenged to be more intelligent or even creative [70].

In order to achieve that, what we can rely on is various kinds of related facts, information, skills, and so on, in other words, knowledge, especially the uniting power of knowledge. For example, Artificial Intelligence, as a specific domain to generate machine intelligence, converges various efforts from not only sciences like Computer Science and Mathematics but also professions like Psychology and even Philosophy.

Therefore, it is believed that in order to do Creative Computing to facilitate human creativity, the uniting of knowledge is also or even more necessary. According to previous analysis, in order to enable computing itself to be creative, the creativity is required to be truly fused into computing. The essential relations between creativity and knowledge require different knowledge to be united for Creative Computing [101]. On the one hand, knowledge, to some extent, could be deemed as kind of crystallisation of human creativity. It is also believed that valuable "clues" of human creativity may exist within the diversity of knowledge. On the other hand, accordingly, creativity is based on knowledge. A person cannot be creative without knowing the knowledge in a certain domain. No matter how enormous mathematical gifts an individual may possess, he or she will not be able to contribute to Mathematics without learning its rules [40]. Furthermore, creativity is particularly relied on the uniting power of knowledge. According to Robert Sternberg's Triarchic Theory of Intelligence [130], the creative intelligence depends on the utilisation of pre-existing knowledge to deal with new situations [131, 132]. According to the

previous discussions, the best way to use knowledge nowadays is to integrate them together. Therefore, developers of Creative Computing are demanded to be able to unite various knowledge together to do Creative Computing.

5.3.2 Inter-Disciplinary Knowledge Combination

The knowledge combination in Creative Computing stands for the deep coalescence of knowledge, which refers to inter-disciplinary and trans-disciplinary combination. In order to do a good knowledge combination for Creative Computing to facilitate human creativity, a comprehensive perspective about knowledge should be adopted. As knowledge is macroscopically grouped into different disciplines, in the realm of Creative Computing, "discipline" will be used as the fundamental unit. Accordingly, there are three main types of knowledge combination in academic field: multidisciplinary, inter-disciplinary and trans-disciplinary.

Multidisciplinary combination could be deemed as "Divide and Conquer", which is, most of the time, used for extremely complicated projects like space programme or world health project. There might be collaborations between different knowledge in multidisciplinary combination. However, a crucial shortcoming of this kind of knowledge combination is that the imported different knowledge is still separated by their disciplines. When a certain problem is conquered, those disciplines go back to where they came from [103].

Compared with it, inter-disciplinary combination is kind of crossing-boundaries cooperation. It could fuse different knowledge deeply and finally end up with the extension knowledge of existing disciplines [17, 31]. It even could form new disciplines such as Cognitive Science, which makes it a very promising approach to developing Creative Computing as a new knowledge discipline.

Trans-disciplinary combination is similar with inter-disciplinary combination. The main difference is that trans-disciplinary combination focuses on all the disciplines in the world, which makes it become a more holistic approach than inter-disciplinary combination [142]. Therefore, as Creative Computing is still in its infancy, we start from inter-disciplinary combination. However, the ultimate goal of Creative Computing is trying to combine all of the knowledge in the world to facilitate human

creativity. Hence, the work of our Centre for Creative Computing is university-wide and includes researchers from all the Schools of Bath Spa University.

5.3.3   Abstraction Levels of Creative Computing

In order to truly fuse the deeply combined knowledge into computing, the methods proposed by my research are based on kind of anti-abstraction process. Instead of being bottom-up, the methods of my research are based on kind of top-down process that devote to embodying general rules into concrete examples.

It is to do with the extreme complexity of knowledge. As mentioned before, at the very heart of Creative Computing is the idea of "Unite and Conquer". Therefore, the combined knowledge is the main resource of the ideas to do computing in creative ways. However, there are, in particular, many difficulties within the knowledge utilisation in the field of Creative Computing. First thing first is the subjectivity of the knowledge from novel disciplines, such as Pataphysics. Due to the objectivity of computing, how to reconcile the contradiction between knowledge and computing should be considered.

The solution is associated with the representation of knowledge. Among various formalisms of knowledge representation in computing field (e.g., ontologies), rules are the more general ones, within which an infinite number of possibilities may exist. For example, the aforementioned creative rule instructing an indirect way of utilising problems can be embodied in various ways. Not only because there may be a countless number of problems can be utilised in computing field, but also due to the subjectivities of defining the meaning of the "indirect way" for computing. Furthermore, the enormous number of possibilities of Creative Computing can also be beneficial to enhance the chances of stimulating people to be creative. Therefore, the combined knowledge in Creative Computing will be used to generate the rules of Creative Computing. In order to form the rules and truly fuse them into computing, there would be various transferring levels in different degree of abstraction, which might be called the abstraction levels of Creative Computing (see in Figure 7).
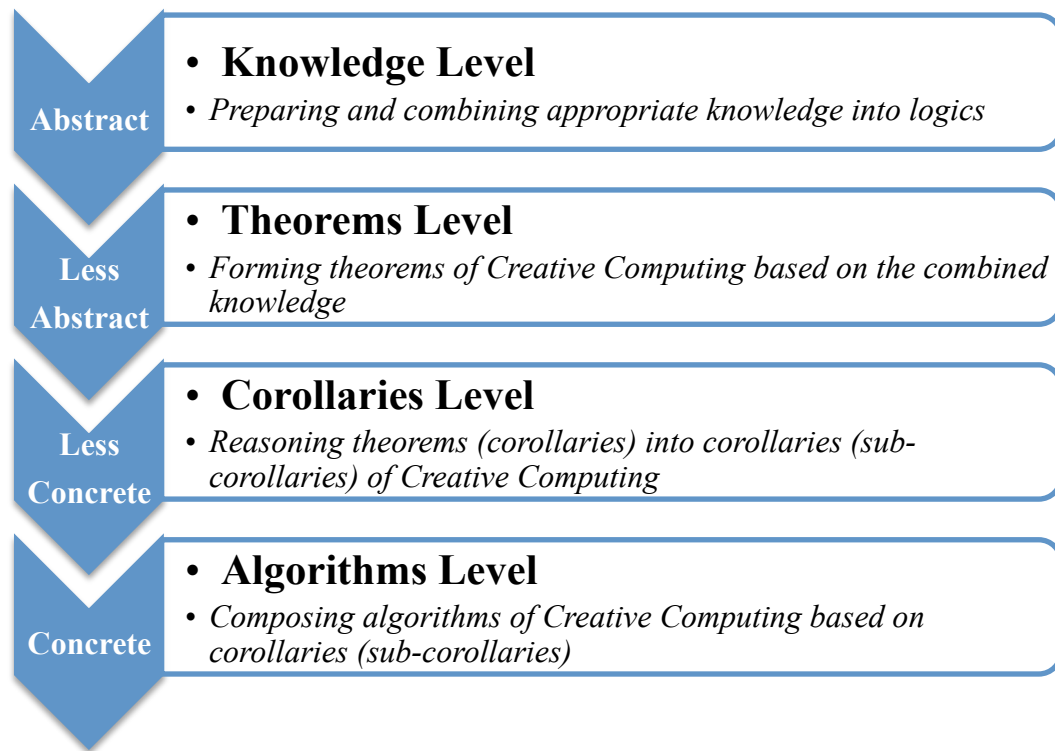
Figure 5. Abstraction Levels of Creative Computing

- **Knowledge Level**

On the knowledge level, appropriate knowledge will be prepared and combined into logics for Creative Computing. As Creative Computing particularly relies on the uniting power of knowledge, due to the complexity of knowledge, there should be a level of knowledge specially concerning the main difficult issues about knowledge, such as knowledge selection and integration.

In order to do that, the methods proposed by my research are fused with ideas of inter-disciplinary research. In order to truly synthesise different knowledge and disciplines, a common inter-disciplinary research often requires researchers from different disciplines with diverse kinds of academic backgrounds to group into teams to work together on a common problem. Its aim is to study a certain problem from a variety of perspectives to advance understanding and form knowledge extension. However, as Creative Computing centres on individual creativity, each developer of Creative Computing is required to learn from various kinds of disciplines to engage different perspectives.

Inspired by the inter-disciplinary ideas, two perspectives will be adopted in Creative Computing: horizontal and vertical perspectives (as shown in Figure 8). In terms of the horizontal perspective, it concerns unifying different knowledge from different disciplines that is associated with the same thing. For example, if " A " stands for an activity of Software Engineering (SE), say system design, " A' " might be the associated knowledge from Art, such as product design. As for the vertical perspective, it focuses on the logical solutions that come from kind of sequential utilisation of knowledge, most of the time, from own professional domain. For instance, in SE, " A " might stand for requirements analysis. "B" may represent system design. "C" might be the following stage - implementation.
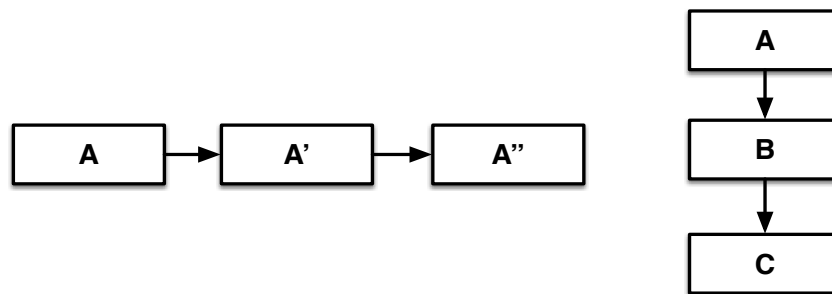
Figure 6. Horizontal (Left) and Vertical (Right) Perspectives

To practically apply the two perspectives in a study of Creative Computing, the vertical perspective can be used to logically list the problems or questions that a certain research needs to address or answer. As for the usage of the horizontal perspective, keeping the problems or questions in mind, a researcher of Creative Computing is required to study various kinds of knowledge from diverse kinds of disciplines, especially the novel ones. It is kind of open-ended process and a verity of things can be tried out. Through comprehensively, boldly, and iteratively studying, appropriate knowledge can be selected and integrated into logics according to the problems or questions. The logically combined knowledge will be used to form the rules of Creative Computing.

- **Theorems Level**

On the theorems level, the rules of Creative Computing will be generated from the combined knowledge and will take the form as theorems of Creative Computing. The theorems will give the core ideas for Creative Computing with the aim to facilitate human creativity. Differing from the common rules for human to be

creative (e.g., taking the riskier path), theorems of Creative Computing will inspire human creativity through doing computing in creative ways (e.g., changing the accuracy into inaccuracy). The features of the theorems of Creative Computing can be summarised as more innovative, illuminating, and powerful.

- o Because of the utilisation of novel disciplines and knowledge (e.g., pataphysical theories), the theorems of Creative Computing can be able to give more innovative instructions for computing to facilitate human creativity. What if somebody inputs a word "frog" and gets the output word "Heqet (Ancient Egyptian frog goddess)" from Creative Computing, rather than an expected word like "toad".

- o Common rules on creativity might only need to tell people, say, "thinking like a child". However, the theorems of Creative Computing need to gradually induce or illuminate people to reckon how to "think like a child". The more concrete instructions make the inspirations of Creative Computing more illuminating.

- o Based on the theorems about creativity, through leveraging the great power of computing and the huge amount of data nowadays, Creative Computing has the great potential to discover something surprising for human creativity facilitation. For example, after inputting a name of a popular bridge of London (e.g., Tower Bridge), a secret spot like Upper Deck Bar that can give travellers a surprisingly magnificent view over the Tower Bridge and River Thames may be outputted by Creative Computing, rather than another bridge recommendation like Waterloo Bridge. The ability to produce this kind of unexpected but meaningful experience enables Creative Computing to be a very powerful tool to facilitate human creativity.

- **Corollaries Level**

On the corollaries level, theorems of Creative Computing will be further embodied into corresponding corollaries (see in Figure 9). Through applying or reasoning over each theorem of Creative Computing from the theorems level, relatively concrete corollaries can be generated. It is worth mentioning that there might be multiple sub-

layers of the corollaries level until they are objective enough to construct concrete instructions for Creative Computing.
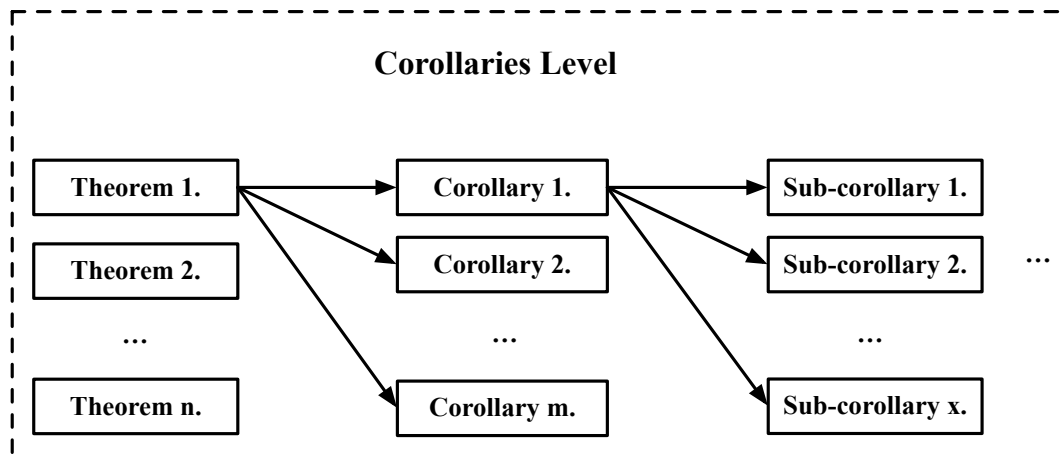
Figure 7. Corollaries Level of Creative Computing

• **Algorithms Level**

On the algorithms level, step-by-step instructions for Creative Computing will be constructed, according to the relatively concrete corollaries (sub-corollaries). As mentioned before, one of the main approaches to truly fusing the creative ideas from the combined knowledge into computing is to form the algorithms on creativity, which might be called creative algorithms. For example, based on the idea of future thinking can be able to stimulate people to be creative, a set of corollaries or sub-corollaries may instruct computer to compute in a fantastical way. Accordingly, future-driven algorithms to inspire the fantasy thinking for people may be composed.

However, the mapping or transformation from the corollaries (sub-corollaries) to algorithms is not straightforward. It also heavily depends on the structure of a certain application. As different application structure may contain different type of data (e.g., RDF data of Semantic Web), it will dramatically change the manipulations of data and influence the composition of corresponding creative algorithms for Creative Computing. That is the reason why a proper structure of Creative Computing also should be studied to facilitate its development.

5.3.4   General Framework of Creative Computing

According to previous discussions, in order to better facilitate the development of Creative Computing, a specific structure should also be studied. Before doing that, pre-existing software structures like general architectures, especially the ones that are widely used, should be studied in the first place. By doing so, fundamental structures might be found for Creative Computing to base on in order to construct its own one.

There are generally two kinds of approaches to describing the specific structure of Creative Computing: framework and architecture. Compared with architecture that is more related to practical implementation of software, a general framework, as kind of large-scale design, is more extensible and will be proposed by my research as part of method support for the development of Creative Computing.

There are two basic structures selected for Creative Computing: Semantic Web and Model-View-Controller (MVC).

- **Semantic Web**

Nowadays, people are requiring computing to do more and more work for people to change the complexity into simplicity. Therefore, computing is becoming more and more "intelligent", which provides a perfect platform for computing to be "creative". One of the most popular is Semantic Web. The aim of Semantic Web is to break boundaries of applications and build relationships between data. By doing so, computer could read and process data, in other words, reason for people [12, 21]. Therefore, through fusing the creative contents into Semantic Web, it might be able to enable computer to "think" creatively, which might make computing to be more active to inspire human creativity.

More importantly, as knowledge combination is the most important idea of Creative Computing, Semantic Web might be a good way to fuse the combined knowledge into computing. That is due to its core components: Ontology, RDF Data, and Inference Engine. In order to organise these vital components, the general architecture of Semantic Web is shown in Figure 10 [5].
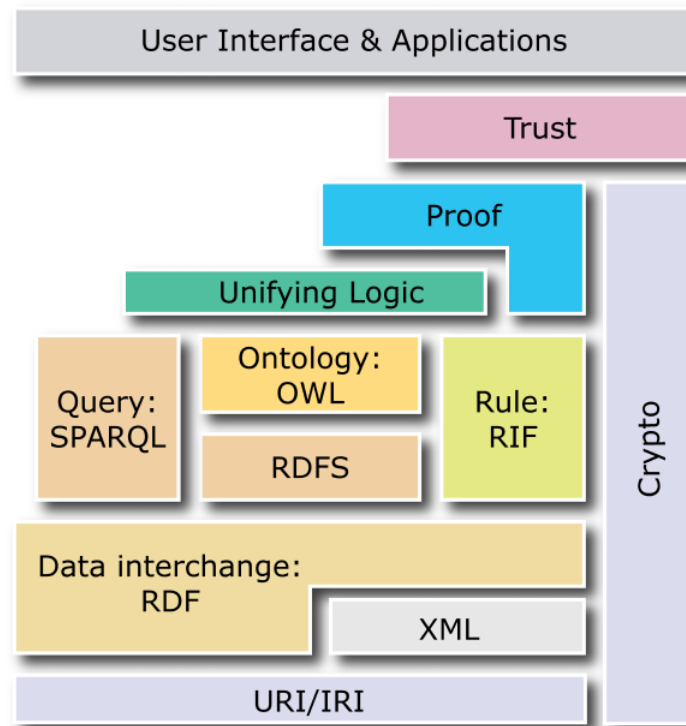
Figure 8. Semantic Web Layer-Cake

o *Ontology (Vocabularies)*. It is an approach to representing knowledge that is generally composed of concepts, interrelationships, and instances. Based on this kind of composition, additional semantics can be added to original RDF data to enable a certain computer to be more intelligent by doing inference. There are many languages to describe ontology, of which OWL (Web Ontology Language) and RDFS (Resource Description Framework Schema) are the widely used ones. However, compared with RDFS, OWL is more complicated and comprehensive. Because of the diversity of the describing languages of ontology, there is a recommendation from W3C (World Wide Web Consortium) named RIF (Rule Interchange Format) that is specialised in exchanging rules between different ontology languages. The so-called "semantics" are added above the normal web just by various kinds of ontology. As the ontology from different instances of Semantic Web could be utilised mutually, that is why data in Semantic Web could be shared across boundaries [48].

o *RDF (Resource Description Framework) Data*. It is kind of meta-data (i.e., data about data). RDF data is composed of triples and each triple has the

format as "subject-predicate-object". Every part of one triple is a URI (Uniform Resource Identifier) that represents an online resource. There are many serialisation formats of RDF data, such as RDF/XML. It is the first standard format for serializing RDF data and is based on XML (Extensible Markup Language) syntax [46]. Although the RDF/XML format is still in use, many RDF users now prefer other RDF serializations like N-Triples, both because they are more human-friendly, and because some RDF graphs are not representable in RDF/XML due to restrictions on the syntax of XML. The specific query language of RDF is called SPARQL. SPARQL to RDF data is like SQL to relational data. It is can be seen that the most important feature of this kind of data is the relationships between different online resources. Depending on the relationships in RDF data, the Semantic Web could allow computing machine to reason over it [48].

o *Inference Engine (Reasoner).* Inference is the final but most necessary step of Semantic Web to infer or reason over ontology and RDF data. With all of the resources (e.g., ontology and RDF data) prepared, there are still no uses of them without actually doing the action of inferring or reasoning. In order to realise it, an inference engine or reasoner is needed [48].

- **Model-View-Controller (MVC)**

As mentioned before, Semantic Web is kind of extension of normal web. Therefore, besides referring to the "Layer-Cake" of Semantic Web, a general structure of normal web is also necessary for Creative Computing to consider. Here comes the Model-View-Controller (MVC) architecture (see in Figure 11).
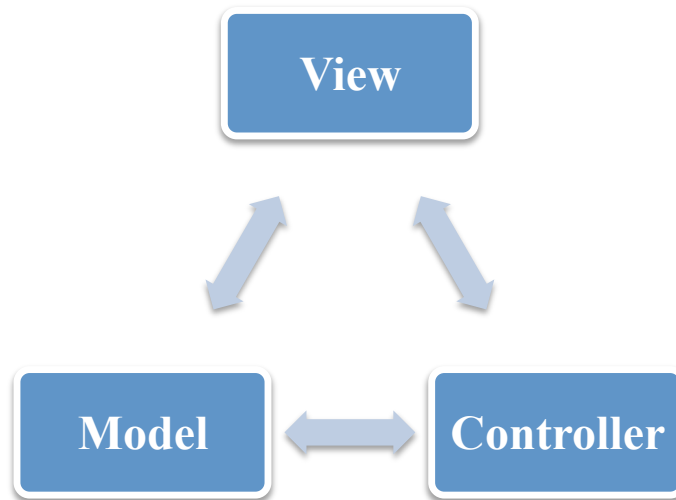
Figure 9. Model-View-Controller Architecture

o *Model* is responsible for performing tasks, such as processing data.

o *View* concerns the interactions between human and computing.

o *Controller* acts as kind of "butler" in charge of allocating tasks and sending results.

There are two reasons why MVC is selected as the basic structure of normal web part to support the development of Creative Computing. Firstly, MVC is always considered as one of the most popular architectural patterns for designing web applications [87]. A lot of well-known frameworks on implementation level, like Struts [67] and Spring [84], are based on it, which makes it the first consideration for Creative Computing to build its framework from a high-level.

Secondly, the most important feature of MVC is the separation of operations between different components. Especially, it separates model from view and controller. For the development of Creative Computing, it enables us to be able to concentrate on the construction of models that will be practically in charge of doing computing in creative ways. The construction of the core models including semantic components can be very complicated. Based on MVC, any variations on the view and controller will not influence the core models of Creative Computing too much.

Finally, as Creative Computing is a relatively new field, MVC could give it a great space to develop in the future. MVC is particularly designed for reuse, especially the

models. As mobile devices are becoming more and more popular (e.g., iPhone, iPad, and iWatch), the constructions of the web applications tend to pay more attention to enable the common web contents to be able to be presented on mobile Internet. As MVC could make the core processing models reusable, the change may not be too much when the view is changed from HTML into Wireless Application Protocol (WAP) that is specifically for using a mobile network.

- **General Framework Construction**

In order to support the development of Creative Computing, a general framework of Creative Computing is proposed in my research, based on the structures of MVC and Semantic Web (see in Figure 12).
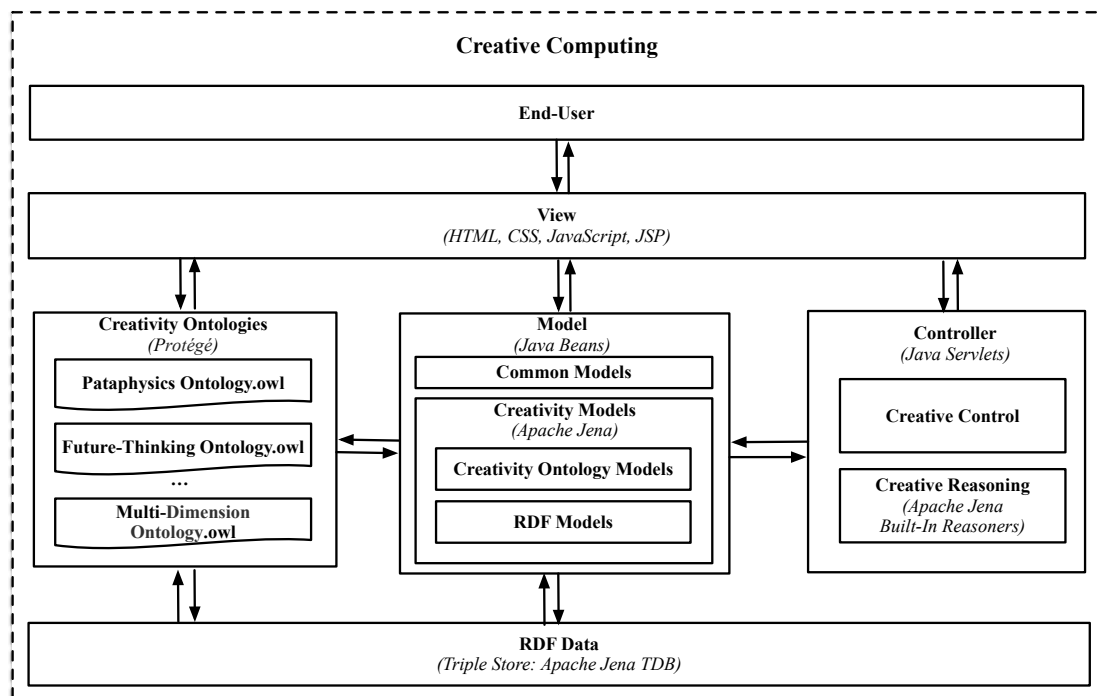

Figure 10. An Overview of the General Framework of Creative Computing

o **Deploying MVC**

The whole framework of Creative Computing is typically based on MVC pattern. The View will get the input from a user and send it to the Controller. The Controller will call corresponding models to process the data and return the output to the View for a user to see.

As for the implementing technologies, the combination of JSP, Java Servlets, and Java Beans are enough for now to develop Creative Computing. Uniting with web technologies like HTML, CSS, JavaScript and so on, JSP is able to construct an excellent dynamic web application interface. Java Servlets provide specific services to get the input from JSP and send it to Java Beans to process. Java Beans, based on pure Java technologies, could enable developers to concentrate on composing the object-oriented processing logics.

o **Creativity Models**

In the framework, creativity models are one of the most important components of Creative Computing. Most of the core tasks will be handled by this category of models, including processing the creativity ontologies and RDF data. Therefore, they should contain two crucial semantic components:

❖ **Creativity Ontology Models** are responsible for processing creativity ontologies, such as reading or uniting different ontology documents for Creative Computing.

❖ **RDF Models** are used to process the RDF data, especially when the amount is huge.

o **Creativity Ontologies**

Based on the platform of Semantic Web, there are generally two ways to support the development of Creative Computing. One of the two is to add the creative semantics into computing through ontology, which might be called creativity ontology. For example, if there is an original RDF data like "Flipper is a dolphin", through adding an additional relationship like "every dolphin is an angel", a more creative result can be generated as "Flipper is an angel", compared with a relatively normal result like "Flipper is a mammal" that can be inferred from "every dolphin is a mammal".

The formation of the creativity ontologies can be based on the theories (i.e., theorems and corollaries) of Creative Computing. Creativity ontologies can be realised through either directly constructing corresponding creativity ontology or

changing pre-existing common ontologies into creative ones (e.g., ontology evolution or versioning). No matter which way is chosen, the generation of the creative relationships or even concepts can be based on the theorems and corollaries of Creative Computing. For example, through manipulating (e.g., changing, adding, or subtracting) the original relationships and concepts, the creativity ontologies might be composed based on the creative theorems and corollaries. In other words, the theorems and corollaries of Creative Computing can be deemed as kind of methods to generate creative relationships or concepts for developing creativity ontologies. By studying various kinds of knowledge, a number of promising creativity ontologies have been studied in the realm of Creative Computing, such as Pataphysics Ontology, Future-Thinking Ontology, and Multi-Dimension Ontology.

Because of the great ontology editing power, Protégé can be considered and utilised in Creative Computing to deal with issues of creativity ontology. It is also a free, open-source ontology editor and framework for building intelligent systems, which is also widely used in the field of Semantic Web. The main language used to describe creativity ontologies in Creative Computing would be OWL (Web Ontology Language).

o **RDF Data**

RDF data is the most fundamental component of Semantic Web applications. The relationships between different data allow intelligent reasoning could be achieved, which makes it also the vital foundation of Creative Computing. Without the data foundation, there would be no use of creativity ontologies.

It is worth mentioning that, in Creative Computing, RDF data, as kind of metadata, might be converted into a new type of data – patadata (meta-metadata). As mentioned before, the utilisation of Pataphysics is one of the unique features of Creative Computing. Based on its pataphysical concepts and theories, the original RDF data might be manipulated in pataphysical ways to achieve unexpected but useful relationships and concepts, which might be called patadata.

○ **Creative Reasoning**

Based on all of the prepared structures, methods, and resources, the creative reasoning will be conducted to truly realise Creative Computing. As mentioned before, there are generally two ways to support Creative Computing based on the platform of Semantic Web. One of the two is through creativity ontology. The other way is through creative reasoning. Due to the fast development of Semantic Web, there have been a great number of common ontologies on the web. Through configuring creative rules for reasoning, creative results also can be generated from Creative Computing to facilitate human creativity.

In order to do that, we need inference engine, also known as reasoner. As mentioned before, three approaches to realising it (i.e., independent reasoner, built-in reasoner, and self-constructed reasoning algorithms) are suggested. Currently, in the realm of Creative Computing, based on the built-in reasoner included in Apache Jena, the construction of creative reasoning algorithms have been studied to realise the theorems and corollaries of Creative Computing.

5.4   Summary

To summarise, based on the unity of knowledge, at the very heart of Creative Computing is the idea of "Unite and Conquer" which devotes to combing various kinds of knowledge from diverse kinds of disciplines together to address critical problems in computing field. Due to the paradox of creativity, the seeking for the rules of creativity to inspire human creativity is particularly based on the exploration of knowledge, especially the knowledge from novel (i.e., interesting and unusually used) disciplines. Accordingly, various disciplines are created with particular features, such as softness, hardness, and even novelty. In order to achieve the "feelings" on creativity without limited by conventional logics, the study of Creative Computing is particularly based on novel knowledge and disciplines like Pataphysics. Being deemed as a science of imaginary solutions and laws governing exceptions, Pataphysics is able to enable us to study the physical and metaphysical world from a new perspective and think the unthinkable before. To further advance understanding and extend knowledge, the inter-disciplinary approach to combing different knowledge will be utilised in Creative Computing. Due to the complexity and subjectivity of knowledge, in order to truly fuse the ideas generated from the

combined knowledge into computing, different abstraction levels of Creative Computing will be crossed. As for the support from the implementation level, the Semantic Web technology that is specialised in enabling computing to be intelligent will be leveraged to build the general framework for Creative Computing.

Chapter 6.   Theorems of Creative Computing

- To prepare appropriate knowledge for Creative Computing
- To develop theorems for Creative Computing

6.1   Overview

In this Chapter, the seventh element of Creative Computing as a knowledge discipline (i.e., theories of discipline) will be studied. After the general study of Creative Computing through Chapter 1 to 5, several elements including magnitude, concept and terminology, scope and parameters of interest, theoretical foundations and methods have been proposed to facilitate the research in Creative Computing. In Chapter 6, in order to prove them to some extent, these elements will be utilised to develop several theorems of Creative Computing.

Firstly, appropriate knowledge will be prepared. According to the idea of knowledge combination, in order to propose the theorems of Creative Computing, what kind of knowledge and disciplines can be used should be studied in the first place. Secondly, by integrating the prepared knowledge, several theorems of Creative Computing with general purpose will be developed.

6.2   Knowledge Preparation

There are two main functions of this part of the study. Firstly, appropriate knowledge selected for the study to develop theorems of Creative Computing will be described briefly. The core contents of the selected knowledge that will be used in the study will be introduced. Secondly, why certain knowledge is selected and what kinds of benefits Creative Computing can get will be discussed.

Here needs to mention that the theorems that will be developed by the study are general ones. Hence, my research will mainly concentrate on knowledge exploration itself for human creativity facilitation, without paying attention to specific domains or requirements.

The appropriate knowledge prepared in my research mainly from four disciplines: Pataphysics, Philosophy, Psychology, and, of course, Computer Science.

6.2.1 Pataphysics and Clinamen

The main difference between the theorems for Creative Computing proposed in the study and the existing conventional ones is due to the utilisation of pataphysical ideas. As mentioned before, Pataphysics provides a novel way for computing to be creative. That is to deliberately generate "exceptions" following the pataphysical laws.

My research pays particular attention to one of the key concepts of Pataphysics: Clinamen [27, 68]. In the beginning, it is used to describe the unpredictable swerve of atoms. The matter of the world might be created by the chain reactions caused by the collisions of atoms, which are triggered by their swerve. Hence, the phenomenon of Clinamen, to some extent, implies "the free will which living things throughout the world have [57]", which surprisingly associates human freedom with the motions of atoms. As leveraged in modern time, it was redefined by Alfred Jarry in Pataphysics, which stands for the action of swerve from a conventional way (see in Figure 13).
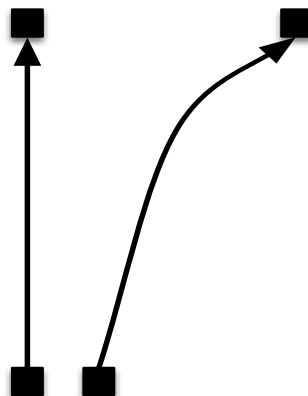

Figure 11. Concept of Clinamen

As mentioned before, the first condition to be creative is to be new. However, without the existence of being old, there is also no significance of being new. Therefore, in order to find the creative way for Creative Computing, the conventional way should be studied in the first place. The operation of Clinamen is a promising approach to doing Creative Computing, through deviating from the conventional way. The key concern is how to deliberately deviate in Creative Computing to improve human creativity. An important part of my research focuses on how to "draw the curve" to enable Creative Computing to facilitate human creativity.

6.2.2   Dialectics and Unity of Opposites

Enlightened by the relationship between Pataphysics and Metaphysics, Philosophy as a promising discipline is considered in my research. As Metaphysics is one of the most traditional branches of Philosophy, there might be more valuable "clues" in the whole domain of Philosophy by using pataphysical perspective. In fact, Philosophy is, indeed, closely related with creativity. Philosophical perspectives, as kinds of vital worldviews, are often used in the study of creativity, such as the synthesis of a pair of opposites - subjective and objective. Accordingly, creativity is the ability to create. This kind of capability can bring something creative from a creator's subjective world (e.g., mind), into existence in the external objective world [116].

This kind of philosophical perspective of creativity inspires a theory of Philosophy for creativity – Dialectics. It is one of the most scientific and fundamental methods to study the nature of the world [135]. In order to encourage people to change the world, the dialectical logics of the nature can be creatively utilised in the study to compose the rules for computing that aim to change the conventional thinking styles of people to facilitate their creativity. One of the central laws of dialectics is the conflict and unity of opposites.

My research focuses on the aspect of the unity of opposites to construct the rules for Creative Computing. Most of the time, people are used to the conflict aspect of the opposites. However, it is rare for people to be aware of the interdependence and mutual containment of the opposites. For example, there is no "good" when there is no "bad". Absolute truths include relative truths and relative truths also contain absolute truths. This kind of "unawareness" can be leveraged by Creative Computing

to inspire people to think in a different but valuable way to facilitate their creativity.

By creatively manipulating the relationships between the two opposites, especially converting one side into the other, the rules formed in the study might be able to turn things around in people's mind and enable them to see things from different angles. Accordingly, the two opposites can be changed into each other under some certain conditions [52]. Although there could be kind of balance between the two opposites, most of the time, one side is always "stronger" than the other side. For example, if something contains both good aspect and bad aspect, people can be used to, tend to, or want to pays more attention to the good aspect. This kind of propensity can be utilised in a reverse way by Creative Computing to facilitate people to see something overlooked and think the unthinkable before. For example, people are very familiar with concrete things like iPhone. What if it is associated with a more abstract concept like smartphone or smart device? It might encourage people to think about technologies like smart home or smart city. Hence, a relationship between IoT and iPhone can be constructed to provide a direction for the development of iPhone.

6.2.3   Taoism and Meanings of Numbers

The unity aspect of opposites is also studied deeply in one ancient school of Chinese Philosophy known as Taoism (Daoism) derived from the great Chinese philosopher Laozi (Lao Tzu). Tao is usually translated as the "way", which is deemed as the ultimate creative principle of the universe in Chinese culture [95]. All things are unified and connected in the Tao. Accordingly, "The Tao produced one; one produced two; two produced three; three produced all things [95]." The meanings of "one", "two", and "three" are also corresponding to the significances of the numbers in Western culture, where "one" stands for the beginning that is the sum of all possibilities. "Two" represents the dual nature of the world. The opposites are the perfect evidences of that. The most important opposites in Taoism are yin and yang. Accordingly, the development of the whole universe is based on the mutual movement between the two forces (yin and yang) [137].

The significance of number "three" might be utilised in the future study of Creative Computing. The reason is because "three" stands for the creating power, which generates the diversity of the world [14]. In Taoism, "three" is the first number

associated with everything. In Western culture, it is the number of the whole, as it contains the past, present, and future. It is even deemed as kind of heavenly number representing soul of people [16], which is the fountain of human creativity. Through penetrating the various meanings, it is found that number three contains particularly close relationship with creativity. It is possible to make Creative Computing through creatively utilising the meanings or relationships provided by number three.

6.2.4 Propositional, Procedural, and Personal Knowledge

As Creative Computing is based on utilising and uniting knowledge, it is necessary for my research to study important issues on knowledge, such as types of knowledge. According to Epistemology, also known as theory of knowledge, there are generally three types of knowledge: propositional, procedural, and personal knowledge [97, 113]. Just as its name implies, propositional knowledge is based on propositions, like 1 + 1 = 2. Therefore, it is also known as "knowledge that", which is the first step to know. Procedural knowledge is about how to do something (i.e., knowledge how), such as how to cook a pancake. It is worth mentioning that procedural knowledge does not only include propositional knowledge, like a pancake is made up of flour. It also contains the real skill to cook in practice. Similarly, within someone's personal knowledge, also known as knowledge by acquaintance [99], there are not only the necessary propositions (e.g., Alice is a girl), but also the true experience, like if Tom says he knows Alice, Tom must actually meet Alice in real life. Hence, personal knowledge is the more unique type of human knowledge.

By studying the types of knowledge, it is realised that the knowledge that we centre on does not only stand for the knowledge that we can learn from materials like books and papers. It also includes intangible things, such as skills or experiences. It also can be seen that propositions are kind of basic knowledge for people. However, in terms of being superior in creativity field, the latters seem more important for people to focus on. Furthermore, with the highly advanced technologies nowadays, there is always someway of accessing propositional knowledge. However, more complicated things like skills and experiences are often unique to a certain person.

6.2.5   Declarative and Non-Declarative Memory

Inspired by the study of knowledge, memory, as a constantly related and confused term, is also studied. Accordingly, there are various kinds of memory systems within human brain, such as short-term memory and long-term memory. As for the latter, it is often studied through another two memory systems: declarative and non-declarative memory. As the name implies, within declarative memory, there are something that could be declared, such as semantic information that we gained from books or papers (e.g., sky is blue) and episodic information (e.g., A passed here just now). Associated with the types of knowledge discussed above, propositional knowledge, due to its expressiveness, is also known as declarative knowledge. On the contrary, the non-declarative memory is all about things that we cannot declare very well, such as some certain skills or expertise that we possess.

6.2.6   Tacit Knowledge and Mental Models

Illuminated by the non-declarative memory, a special type of personal knowledge [107] named tacit knowledge is particularly concerned in the study. Tacit knowledge is type of knowledge that is difficult to articulate to transfer to another person [128], as in the assertion that "we can know more than we can tell [106]." As opposed to it, there is explicit knowledge that is easily transmitted to others [127]. The reason why tacit knowledge is chosen in my research is because human creativity is strongly based on people's tacit knowledge [66, 82, 90, 122, 123, 140]. Due to its great value, it has already been studied in a computing field called Knowledge Management (KM) [102, 111]. It concentrates on the transmission between the tacit and explicit knowledge [22]. However, in Creative Computing, what we try to study is how to facilitate human creativity through stimulating people's tacit knowledge.

One promising influencing factor of tacit knowledge is people's mental models [76]. They are kind of representations of the external world in human mind [85]. However, not only because different people may have different mental models, but also as the mental models of the same individual might change over time, how to use the knowledge "known" to influence the knowledge "unknown" is the key concern in Creative Computing.

6.2.7 Divergent, Lateral, and Aesthetic Thinking – Creative Thinking

As Creative Computing, to some extent, can be deemed as kind of creative "thinking" of a certain computer, there might be some valuable suggestions or inspirations from the study of creative thinking for Creative Computing. Within Cognitive Psychology, there is an analogy between human mind and computer, which enables researchers to be able to study human mind from a computing perspective [78]. For this reason, it is also believed that issues of computing can be studied through a perspective of human mind, especially creative mind.

Divergent thinking, lateral thinking, and aesthetic thinking are three typical types of creative thinking that either can be deemed as kind of thinking style or methods to help people to be creative [74]. As mentioned before, due to great power of creativity, there has already been many training or coaching strategies to stimulate people's creativity. Creative thinking methods are among the most popular.

- The aim of divergent thinking is to get creative ideas through exploring as many possibilities as possible [19]. There are many methods or tools to promote it, like mind map. It is always used together with convergent thinking whose purpose is to provide the correct answer for a particular problem through logic [7]. After divergent thinking, ideas will be organised into solutions through convergent thinking.

- Lateral thinking is one of the most popular creative thinking, which is derived from Edward de Bono who is famous for teaching of thinking [44]. The core idea of lateral thinking is "thinking outside the box [43]". As Creative Computing devotes to promoting human creativity through creatively being different from the conventional ones, it can be regarded as kind of "lateral computing". The main difference is that the lateral thinking methods are used directly on human. However, the rules of Creative Computing will be used specially to change computing, thereby facilitating human creativity.

- Due to the relationship between art and knowledge [99, 145], it is believed that different understandings of the world can be achieved through artistic/aesthetic experience. Works of art always come from life, meanwhile, goes beyond it. Just because of this kind of transcendence, it enables us to be able to see the world in new ways. Furthermore, because of the oversupply status of products nowadays, people tend to pay more attention to spiritual demands. Hence, aesthetic thinking is playing an increasingly important role in modern competition in recent years.

6.2.8   Mind Wandering and Brain Wave

According to previous discussions, one of the functions of Creative Computing is to trigger people's Aha! Moment. Knowledge within the domain of mind wandering may be very helpful for Creative Computing to get some valuable suggestions. In Cognitive Psychology, there is a particular field known as mind wandering that is closely related to creativity [20]. It is one of the main causes that can trigger the mysterious "Aha!" moment [18, 37, 143]. The "randomness" generated from a wandering mind may cause surprising connections of neurons that can trigger the sudden insight. Through study related issues of mind wandering, there might be some valuable ideas, tools, or methods that can be utilised by Creative Computing.

Through studying, the utilisation of various brain waves, especially gamma wave, can be considered by Creative Computing. There have been a lot of brain structures, areas, and activities studied in the domain of mind wandering. Due to the fast development of neuroimaging technologies (e.g., EEG), various brain activities have been detected and represented as different brain waves, some of which are closely related to the state of mind wandering (e.g., alpha and theta wave [28]). However, as what Creative Computing concerns is the state of sudden insight, gamma wave is particularly centred on [77, 86]. Accordingly, it is directly and positively related with the sudden insight. When the "Aha!" moment comes, the gamma wave can increase correspondingly. The combination between Creative Computing and neuroimaging technologies like EEG will be depicted in details in Chapter 8.

6.2.9   Data, Information, Knowledge, and Wisdom

In Computer Science or more precisely Knowledge Management (KM), there is a well-accepted pyramid or hierarchy about data, information, knowledge, and wisdom (as shown in Figure 14) [65]. Through studying the relationships between them, KM

devotes to organising knowledge more efficiently and even achieving "wisdom" by processing data and, more complicated, information [88]. Data refers to raw symbols or signs, like a word "earth", without any context. Information is based on data, which adds meanings to data to enable it to have some purposes (e.g., earth goes around the sun). Knowledge is underpinned by information, which is derived, extracted, and synthesised from various information, such as gravity. On the highest level, there is wisdom, which are kind of principles about how to apply the countless number of knowledge and even generate new knowledge, like General Relativity.
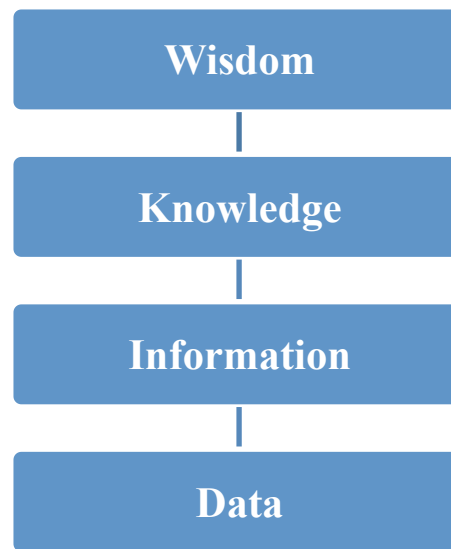
Figure 12. Hierarchy of DIKW

This kind of framework, to some extent, can provide a computing perspective about knowledge, which may give valuable inspirations on the combination of knowledge for Creative Computing. After studying various kinds of knowledge like Pataphysics, Philosophy, and Psychology, as a software engineer, a computing point of view can be very helpful to comprehend and integrate them to form more practical solutions for Creative Computing. It is clear that Creative Computing locates at the knowledge level, as its core idea is knowledge combination. Therefore, it is believed what we can facilitate or even achieve might be the wisdom level. And, what we can depend on may be the infinite number of information and Big Data.

6.3 Theorems Development

6.3.1 Vertical Perspective – Questions Needed to Answer

According to vertical and horizontal perspectives discussed above, the prepared knowledge will be integrated into logics. There are three general questions needed to answer:

- Where to stimulate human creativity through Creative Computing?
- How to creatively stimulate human creativity through Creative Computing?
- How to validate the effects of Creative Computing?

Through answering the general questions above from different perspectives, the prepared knowledge will be integrated into logics for Creative Computing.

6.3.2 Horizontal Perspective – Knowledge Logics Integration

• Where to stimulate human creativity through Creative Computing?

In order to facilitate human creativity, the first thing that my research needs to study is which "areas" of human could be acted on. No matter how creative the computing could be, there are still three core elements to be considered: human, computer, and environment. As Creative Computing is still in its infancy, we mainly focus on the interactions between human and computer. Therefore, in order to promote human creativity through Creative Computing, how to influence people should be studied in the first place. Nowadays, the study of user in computing field has no longer been only within requirements analysis anymore. The more deep concern on human mind has attracted great attention. Hence, in the realm of Creative Computing, first things first are the study of "areas" of human mind.
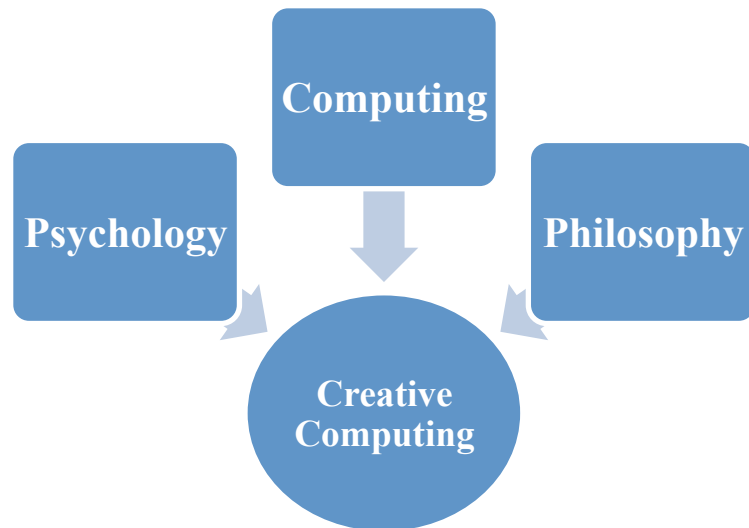
Figure 13. Three Perspectives of Where to Stimulate Human Creativity

To answer this question, three perspectives will be adopted in my research (see in Figure 15): Psychology, Computing, and Philosophy. There is no doubt that the natural resource of creativity is the human brain. In Cognitive Psychology or Neuroscience, human brain is often studied horizontally. For example, it could be divided into different areas, which are responsible for different functions. Furthermore, especially in creativity study, different hemispheres, cortex, or lobes are associated with some particular capabilities, such as logical reasoning and artistic abilities. Inspired by the psychological study of human creativity, in Creative Computing, a vertical or abstractive perspective will be applied to understand human brain and creativity through a computing perspective. Referring to the pyramid framework of data, information, knowledge, and wisdom (DIKW) [65] in computing field, human mind also could be abstracted into different levels: physic level, logic level, knowledge level, and intelligence level (see in Figure 16).
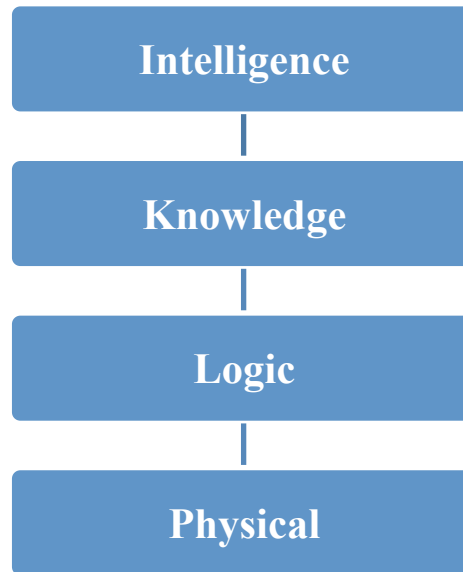
Figure 14. Abstraction Levels of Human Mind

- The physical level includes the brain structures, areas, activities, and, ultimately, neurons. It is the most basic foundation of human brain, which is like the fundamental function of data.

- The logic level is inspired by the composition of information. In Cognitive Psychology, there is an analogy to compare human mind with computer. It regards human mind as kind of information system to receive, process, and output information. From data to information, there should be meanings or semantics to be added on. In order to form the meanings or semantics, there should be logics between different data, such as linguistic or mathematic logics. For example, the basic logic of Semantic Web is the triple that takes form as "subject – predicate – object." Furthermore, logic is responsible for reasoning, which is one of the main ways to associate different ideas to make sense of things. These kinds of associations will physically generate various connections between different neurons. Therefore, there should be a kind of logic level of human mind above the physical level.

- Above the logic level of human mind, there should be a level of knowledge. Corresponding to the knowledge level over the information level, as knowledge will be eventually stored in human mind, there should be an enormous number of

knowledge systems with in human mind. Those knowledge systems can be deemed as kind of maps to link different memories, ideas, and beliefs, etc.

- Similar with the meaning of "wisdom", accordingly, intelligence is about how to acquire and apply various kinds of knowledge. Therefore, there should be an intelligence level above the knowledge level of human mind. One of the main human intelligences is known as creative intelligence (i.e., creativity).

According to Sternberg, creativity can be deemed as kind of human intelligence, which is about how to utilise existing knowledge to deal with new situations [130]. Hence, in the realm of Creative Computing, to support human creativity, the knowledge level of human brain will be particularly focused on.

Through studying types of knowledge (i.e., propositional, procedural, and personal knowledge) according to Epistemology, the knowledge can be further summarised into two general categories: known and unknown. According to previous analysis, there is always some knowledge known clearly to us, such as 1 + 1 = 2 and the capital city of United Kingdom is London. However, there is also always some knowledge known not very clearly or unknown to us at all, such as some particular cooking skills or abilities to deal with new things. We may just come up with some delicious recipes without knowing why or we may not know we can do something. It is also, to some extent, corresponding to people's memory systems: declarative and non-declarative memory. Accordingly, some memories can be declared or described. However, some just cannot be recollected consciously. Hence, according to the previous study, the known and unknown knowledge can be interpreted in another way as explicit and tacit knowledge.

Users' tacit knowledge can be leveraged in Creative Computing. Recent studies have shown that people's creativity is mainly based on their tacit knowledge. With the highly advanced technologies nowadays, it is relatively easy for people to access explicit knowledge, as most of it can be stored in some kind of media, such as papers and books. Due to the uniqueness of tacit knowledge, it is always associated with people's ability to create something while others cannot. However, because of the vagueness of tacit knowledge, even the individual him or her self may do not know it

very clearly, not to mention somebody else. Hence, there is kind of paradox on how to sufficiently utilise the knowledge known to influence the knowledge unknown.

According to the study of tacit knowledge, Creative Computing can facilitate human creativity through stimulating people's mental models, which are one of the main influencing factors of tacit knowledge. As people's mental models could be deemed as kind of representations of the external world, in order to encourage people to "change the world", the virtual models of the world in human mind (i.e., inner world) can be changed in the first place. The variations to this kind of "worldview" may be able to enable people to see something overlooked or think something unthinkable before, where creativity can just exist. However, there is a crucial problem: different individual might have different mental models and even the mental models of one individual will change over time, not to mention we almost cannot know what someone's mental models look like.

The solution considered in my research is the utilisation of common models of the world. Due to the extremely abundant knowledge nowadays, there have been a huge number of common models of the world, such as encyclopaedia like Wikipedia that can be widely accepted. Through manipulating them, people's mental models might be changed. If a user has known the modified contents before, my creative rules may be able to change his or her mental models. If a user does not know the modified contents before, my creative rules may be able to help the user to construct totally new and valuable, in other words, creative mental models.

To facilitate people's combinational and transformational creativity, the common models of the world can be composed of concepts and relationships. Due to the complexity, mental models can be studied in different ways, one of which is regarding mental models as some kind of representations of concepts and relationships. As combinational creativity is to do the unfamiliar combinations with familiar things, it is to do with the relationships between concepts. As long as the relationships between concepts have been changed, users might be able to discover and create more interesting and surprising combinations. As for the transformational creativity, it is to do with the transformation of a conceptual space. Correspondingly, through changing the concepts of users' mental models, it might be also able to

facilitate people's transformational creativity to enable them to see the world in a creative way.

• How to creatively stimulate human creativity through Creative Computing?
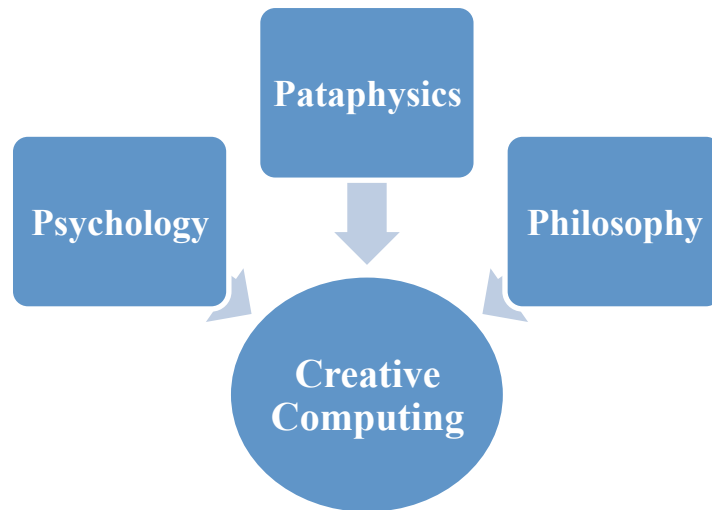

Figure 15. Three Perspectives of Creative Stimulation of Human Creativity

To answer this question, three perspectives are utilised in my research (see in Figure 17): Psychology, Pataphysics, and Philosophy. The first inspirations of my research come from three types of creative thinking (i.e., divergent thinking, lateral thinking, and aesthetic thinking).

• Divergent thinking inspires Creative Computing that the amount of the possible solutions should be huge to enhance the chance of stimulating people's creativity. However, only divergent thinking itself is far from enough. Illuminated by its idea of working in conjunction with convergent thinking, how to organise the diverse kinds of possibilities should also be considered in Creative Computing, such as how to group them into different degrees of creativity stimulation.

• Inspired by lateral thinking, the stimulations of Creative Computing should be more free, flexible, or even provocative. At the very heart of lateral thinking is the idea of breaking old patterns and liberate information for human mind. The main approach to achieving that is to be indirect. Regarding the conventional

way of solving problems (e.g., working step-by-step) as kind of direct approach, the one proposed by lateral thinking aims to tackle problems in a indirect but creative way. There are a countless number of possibilities to be indirect, which can be just utilised by Creative Computing to be stimulating.

- Aesthetic thinking provides a promising direction for Creative Computing to be indirectly stimulating for facilitating human creativity. That is to focus more on knowledge that is closely related to creativity, such as knowledge that is widely used in artistic or aesthetic fields. A work of Art is full of the creator's creativity, which is often appreciated by aesthetic principles. Hence, through computing aesthetically, there might be another way to achieve creativity for Creative Computing to facilitate human creativity.

Therefore, the second inspirations come from Pataphysics, which can be deemed as a branch of Philosophy and is widely used in fields of Art (e.g., Music and Literature). According to previous analysis, in order to find the creative ideas to compute, Creative Computing pays particular attention to novel disciplines and knowledge. Hence, the utilisation of pataphysical knowledge is one of the important features of Creative Computing.

- As laws generating exceptions to stimulate creativity, Pataphysics is specialised in making surprising or even absurd provocations by scientifically studying imaginary phenomena beyond Physics and Metaphysics, rather than provide direct results based on conventional associations. What if you input word "apple" and get a result of word "doctor", rather than a word "iPhone". Through fusing with ideas of Pataphysics, the unexpected but meaningful results might be generated by Creative Computing to inspire human creativity.

- Furthermore, there are a variety of concepts devoting to generating valuable "exceptions" deliberately within Pataphysics. As mentioned before, concept clinamen is particularly focused on, which aims to deliberately deviate from a conventional way of doing things. By combining with this idea, the indirect way

of computing for Creative Computing can be supported to generate unexpected but meaningful results to stimulate human creativity.
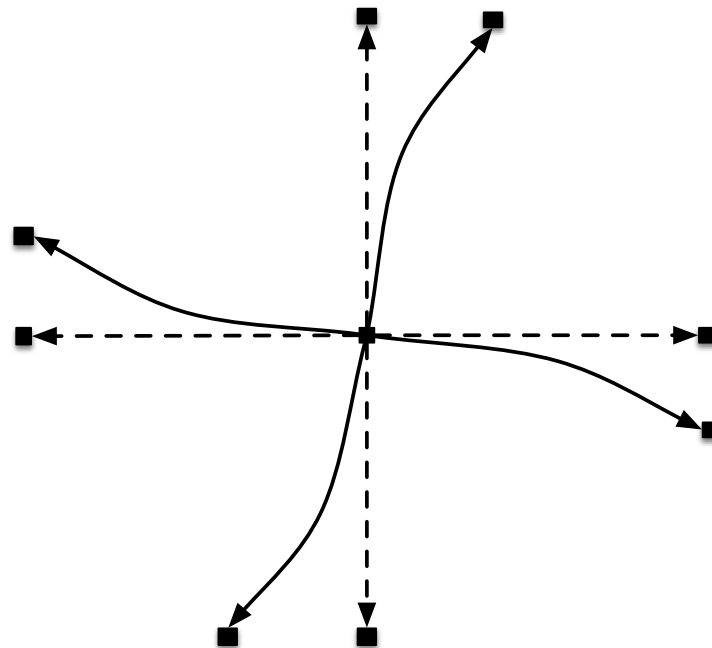

Figure 16. Pataphysical Operation of Creative Computing

Therefore, for now, to synthesise all of the inspirations above, the core idea of the general rules proposed in the study for Creative Computing is shown in Figure 18, which might be called pataphysical operation of Creative Computing. The whole idea of this pataphysical operation is to generate as many creative results for facilitating human creativity as possible, which is inspired by divergent thinking. Through fusing with ideas of lateral thinking, the results tend to be indirectly provocative. Inspired by the emphasis on novel disciplines and knowledge of Creative Computing and the idea of aesthetic thinking, pataphysical theories kind of underpin the ideas of Creative Computing. Based on the pataphysical concept of clinamen, instead of constructing conventional associations, the rules for Creative Computing will try to establish kind of creative associations between different things through the operation of deviation. By doing so, unexpected but meaningful stimulations might be generated by Creative Computing to inspire human creativity.

Through applying the proposed idea of Creative Computing above, the relationships between different concepts and even concepts themselves can be manipulated to

stimulate human creativity. According to the analysis of question one, a solution has been found for facilitating human creativity. That is to stimulate people's tacit knowledge by manipulating the relationships and concepts of common models of the surrounding world, like Wikipedia. In order to support the solution, two issues of the proposed pataphysical operation of Creative Computing are studied in the research.

- The first issue is about how to define the "curve" to support the manipulations of relationships and concepts of common models. In order to do the deviation (i.e., from A to C), two approaches are summarised as follows (see in Figure 19).
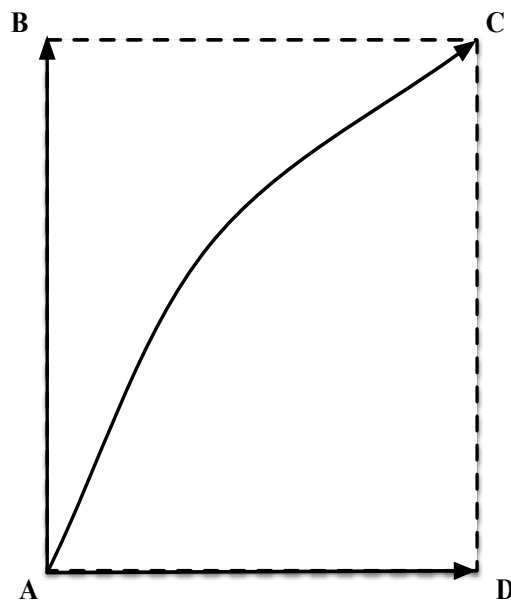

Figure 17. Two Approaches to Deviating

- o The first approach is through deviating a conventional association (i.e., from A to B to C). It is to do with the manipulations of relationships between different concepts.
- A conventional association will be constructed (i.e., from A to B);
- The directly associated B will be deviated to indirectly associated (i.e., dissociated) C.
  - o The second approach is through thoroughly deviating (i.e., from A to D to C). It is to do with the manipulations of concepts themselves.
- The original A will be deviated to D at the beginning;

- A direct association between D and C will be constructed to enable the deviation from A to C.

  For example (as shown in Figure 20), if we enter a word "Toad", we might expect a directly and commonly associated word "Frog". If the word "Frog" can be pataphysically deviated to the word "Heqet" (who is a frog-goddess of Egyptian mythology standing for life and fertility), a surprising relationship can be constructed between word "Toad" and word "Heqet", which might be able to lead a user into a different context, culture, or even world to stimulate their creativity.

  If we enter a word "Bridge", instead of getting an expected result "Waterloo", we might be able to have an unexpected word "Teak", through pataphysically transforming the word "Bridge" into word "Deck". By radically manipulating the concept, surprising relationship between "Bridge" and "Teak" might be able to inspire people of a variety of things, such as U Bein Bridge, wooden bridge, and even Myanmar.
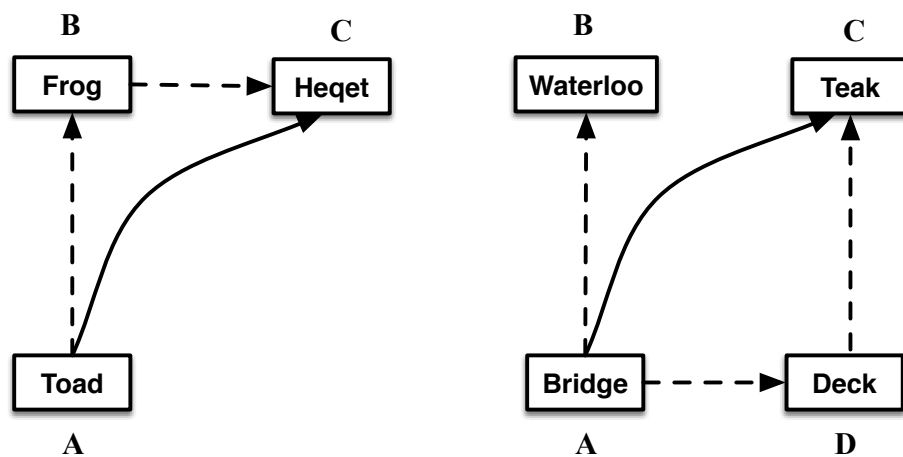
Figure 18. Pataphysical Manipulation of Relationship (Left) and Concept (Right)

- The second issue is about how to meaningfully define the "curve" to support the manipulations of relationships and concepts of common models. The final inspirations of my general rules for Creative Computing come from Philosophy.

Inspired by the relationship between Pataphysics, Metaphysics, and Physics, it is believed that seeing Philosophy as a whole might be more productive for the discovery of promising solutions for the deviation of Creative Computing. Furthermore, Philosophy studies the most fundamental nature of the world and deeply underpins the thinking of people, which makes it have more potential for Creative Computing to stimulate the creative thinking for people.

o A well-known philosophical theory known as unity of opposites is used in my research. Most of the time, people are used to seeing the conflict aspect of opposites. In order to enable Creative Computing, the unity aspect of opposites will be utilised in my research.

o Accordingly, there are three different meanings contained within the unity aspect of opposites. The significance that leveraged in my research is the convertible feature, which means that under certain conditions, the two opposites can be changed into each other.

o In this study, regarding one side of the opposites that is commonly used as the conventional way, in order to deviate from it, the other side of the opposites can be utilised. Through changing or constructing some certain conditions, the common side of the opposites can be converted into the other side. Through this kind of variation (i.e., deviation), the rules for Creative Computing proposed in the study might be able to turn people's mind around to see the world from a new perspective, thereby facilitating human creativity.

o Accordingly, there have already been several widely accepted pairs of opposites, such as finite and infinite, force and matter, positive and negative, and so on. Hence, based on some particular natural and social phenomena, through identifying appropriate opposites, rules for Creative Computing can be proposed in my research to facilitate human creativity.
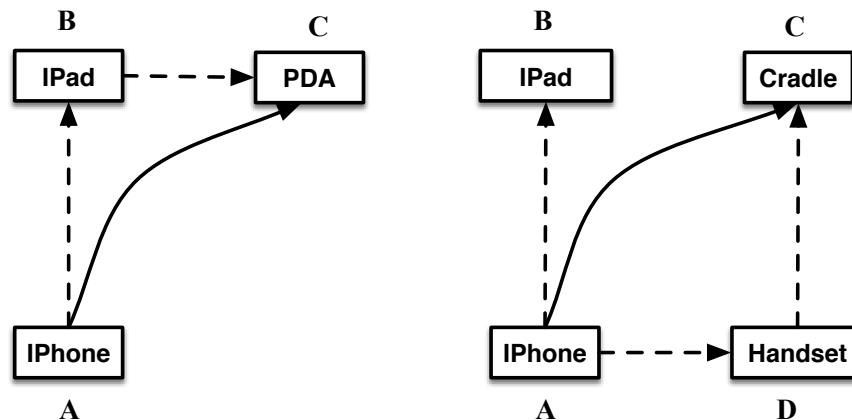
Figure 19. Meaningfully Pataphysical Operation of Creative Computing

For example (see in Figure 21), according to Cognitive Psychology, it is believed that various kinds of concepts are sort of classified into different hierarchies within human mind. For instance, most of the time, people are used to relatively concrete concepts, like iPhone, rather than smartphone. What if we encourage people to pay more attention to abstract concepts (e.g., digital device), as there might be different possibilities within different abstraction levels? This kind of phenomena are actually corresponding to a pair of opposites: concrete and abstract.

If we enter a word "IPhone", word "IPad" may meet our expectations. However, if we change the relatively concrete word "IPad" into a more abstract word "PDA" (Personal Digital Assistant), the relationship constructed between word "IPhone" and word "PDA" might be able to inspire people to "broaden their horizons" (e.g., to see all of the possibilities that a iPhone could act as kind of secretary).

Furthermore, if we change the word "IPhone" at the beginning into, say, word "Handset", to transform it into a more abstract world, surprising possibilities might be discovered. For instance, through thinking an iPhone as kind of handset, we might imagine what if iPhone is "hand-free"? Hence, here comes the word "cradle".

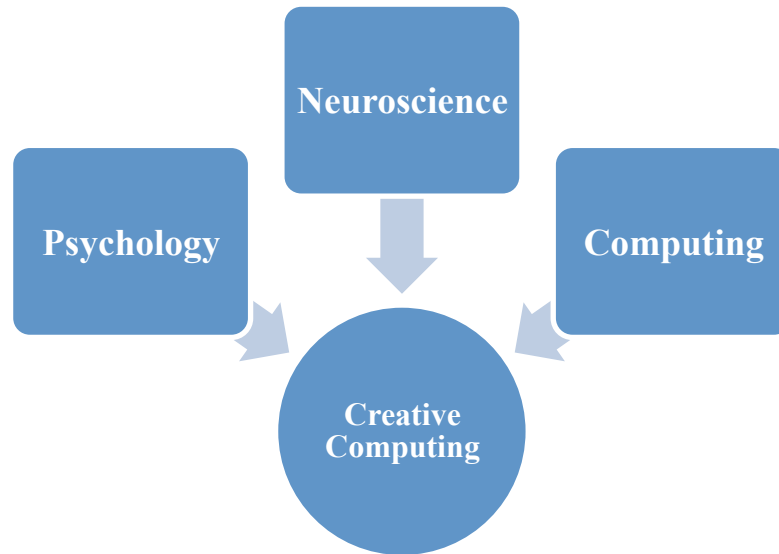*• How to validate the effects of Creative Computing?*

Figure 20. Three Perspectives of Validating Creative Computing

There are three perspectives used in my research to answer this question: Psychology, Neuroscience, and Computing (see in Figure 22). Through studying knowledge about mind wandering, gamma wave detection will be considered as one of the approaches in my research to validating the stimulations of Creative Computing.

As discussed before, Creative Computing aims to facilitate human creativity through continuous stimulations. However, the precondition is that people could recognise and even be amused by the seemingly absurd logics of Creative Computing. When that moment happens, it is very likely that Creative Computing would trigger the mysterious Aha! Moment.

According to Neuroscience, this kind of sudden insight is directly and positively associated with one type of brain wave – gamma wave. Through detecting the movement of a user's gamma wave while he or she is interacting with Creative Computing, the effects of Creative Computing might be able to show visually.

6.3.3   Theorems Formation

Through integrating the prepared knowledge into logics for creativity facilitation, the general theorems of Creative Computing formed by my research are as follows.

Theorem 1. *Changing accuracy into inaccuracy.*

As various kinds of computing technologies developed so far, most of them still concentrate on how to provide the results or services that exactly expected by users, in other words, what they pursue is accuracy. One of them is the famous Semantic Web. Based on it, there have been a variety of knowledge graphs all over the world, such as the knowledge graph from Google dedicating to provide more accurate information or knowledge for people.

However, at the very heart of Creative Computing is the idea of inspiring human creativity through providing unexpected but meaningful results, in other words, what Creative Computing pursues is inaccuracy. Furthermore, one of the most important features of Creative Computing is the utilisation of Pataphysics, which is about generating valuable exceptions. Therefore, what Creative Computing seeks is not the "right" solution, but the "wrong" answer, which should contain great power for stimulating creativity.

Theorem 2. *Changing the objective into subjective.*

Commonly, most of the research results on creativity are generated from Psychology, especially Cognitive Psychology. From a philosophical point of view, the research process adopted in those fields is from subjective to objective, which studies how the ideas formed in the subjective world (i.e., human mind) can be transformed into the objective world (i.e., physical existence). One typical example is Neuroscience that studies human mind through leveraging objective approaches, such as the utilisation of neuroimaging technologies.

As more and more research results on creativity have been proposed, researchers in computing field have started to consider reversely combining them with computing to facilitate human creativity. A new process has emerged to do the study on creativity from objective to subjective. Through utilising the discovered knowledge on creativity, the objective computing is becoming more and more subjective, even like human. One typical example is computational creativity that devotes to imitating

or duplicating human creativity.

However, instead of generating machine creativity like computational creativity, what Creative Computing aims to do is to truly engage creativity to better reconcile the contradiction between subjective creativity and objective computing. One of the representatives of the usage of subjective perspective in Creative Computing is the utilisation of a paradox of creativity. According to previous study, developers are required to do Creative Computing to facilitate human creativity without "knowing" it, but "feeling" it, based on the comprehension of various kinds of knowledge.

Theorem 3. *Changing the macroscopic into microscopic.*

Most of the time, people are used to using the macroscopic perspective. For example, over time, people have never stopped searching the ultimate nature of the world. We humans are always used to looking at the sky and being curious about the universe, from the ancient time, like Copernicus and Galileo, to the modern theories, like general relativity, multidimensional space, and parallel universe. After the theory of the Big Bang, researchers all over the world have started to study what the cosmos was like before it.

However, it is incredibly surprising that the world can be totally different through seeing it from a microscopic perspective. A famous example is the rise of Quantum Mechanics. No one has expected that, in a microscopic field, like quantum world, strange phenomena like quantum entanglement can firmly exist. Therefore, there might be a great many surprising relationships or concepts that can be utilised by Creative Computing to facilitate human creativity.

Theorem 4. *Changing the concrete into the abstract.*

According to Cognitive Psychology, there are hierarchies of concepts in human mind [53]. Most of the time, people are used to the middle or lower level concepts, such as mobile phone or iPhone, in other words, relatively concrete concepts.

However, without the limitations of reality, in abstract world, there can be more possibilities for people to be creative. Taking abstract art as an example, an abstract painting can be only expressed by colours. However, just because of its "simplicity," there can be various kinds of interpretations that can greatly stimulate creativity for people. More importantly, the abstraction process can be diverse. It all depends on the construction of conditions. Principally, there can be an enormous number of possibilities and probabilities to discover something creative for Creative Computing to facilitate human creativity.

Theorem 5. *Changing the negative into the positive.*

It is natural for people to prefer positive things and reject negative ones. For example, most of the time, people will do their best to avoid problems. When encountering a certain problem, we always try to address them, no matter directly or indirectly.

However, what if the problem cannot be thoroughly solved, what if it surprisingly contains great power of creation, and what if we can utilise it in a positive way? A typical example is the unpredictable swerve of atoms that underpins the concept of clinamen. Just because of this kind of "unpredictability", the diversity of natural world is generated. In the realm of Creative Computing, a problem might be utilised as kind of facilitation or stepping-stone. A certain goal might be achieved creatively by discovering and leveraging the positive things that are associated with a certain problem.

6.4   Summary

To summarise, based on the previous study of this thesis, several theorems to instruct Creative Computing have been developed, which, on the other hand, proves the ideas and methods of Creative Computing. The prepared appropriate knowledge in the study is mainly from Pataphysics, Philosophy, Psychology, and Computer Science. It is worth mentioning that the utilisation of pataphysical ideas is the most important difference between the conventional creativity rules for computing and the theorems of Creative Computing developed in this study. Depending on the inter-disciplinary

ideas, the selected knowledge will be integrated into logics to form the theorems of Creative Computing eventually.

Chapter 7.   Prototyping Creative Computing – The Deviator

- To choose one of the theorems of Creative Computing to apply
- To propose corollaries of Creative Computing based on the chosen theorem
- To develop a prototype of Creative Computing based on the corollaries

7.1   Overview

In this Chapter, the seventh element of Creative Computing as a knowledge discipline (i.e., theories of discipline) will be studied continually. One of the theorems of Creative Computing will be studied and applied to propose relatively concrete corollaries for Creative Computing. In order to mix the theory with practice, a prototype of Creative Computing named Deviator will be developed based on the proposed corollaries.

7.2   General Descriptions of Deviator

The prototype aims to prove the idea of deviation of Creative Computing to inspire human creativity. According to the study of the theorems of Creative Computing raised in Chapter 6, the main idea of the theorems is based on the pataphysical concept clinamen, which stands for an operation of deviating from a conventional way of thinking or doing something. Therefore, the prototype is named Deviator and includes nine functions of deviation (as shown in Figure 23):

- ChangeLetterDeviation
- AddLetterDeviation
- SubtractLetterDeviation
- FunctionDeviation
- PolysemyDeviation

- VaguenessDeviation
- CompoundDeviation
- Cross-CultureDeviation
- ClichéDeviation

Currently, the study centres on the exploration of text. Therefore, the input of the prototype begins with a word or phrase. Hence, the various deviation functions of the prototype can be divided into two parts: Word Tail Deviation (see in Section 7.3) and Phrase Pataphysics Deviation (see in Section 7.4).

Figure 21. Home Page of Deviator

As for the implementation, it is mainly based on Java programming techniques, like JSP, Java Servlet and Java Bean. In particular, Apache Jena is leveraged for the development of Deviator, which is a popular free and open source Java library used for building Semantic Web applications. It includes many crucial interfaces, such as Ontology API and RDF API, and so on, which are just the perfect tools to support the general framework of Creative Computing. It is worth mentioning that the huge amount of RDF data that underpins Deviator is supported by a native triple store of Apache Jena named TDB, which can be deemed as a kind of database of semantic data. It has good compatibility to all of the APIs provided by Jena, which enables

Deviator to be able to reason over a huge amount of data and to prove the idea of deviation of Creative Computing to inspire people's creative thinking.

7.3 Word Tail Deviation

As the section title implies, the input of this part of Deviator should be a word. Before the real implementation of the deviation functions that are based on the theorems proposed in Chapter 6, this part of Deviator is a relatively simple attempt of the operation of deviation for inspiring people's creativity.

The functions of this part are inspired by the ideas of wordplay. Although there has been a verity of confusions on wordplay, the term is still commonly considered as one of the representatives of linguistic creativity. Through manipulating a certain word, surprising results might be discovered for facilitating human creativity. One of the most popular is kind of manipulation of meaning, which is known as pun [96]. Through adding multiple meanings to a word or set of words, a variety of effects (e.g., rhetorical or humorous) can be achieved.

Within this part of Deviator, the letter aspect of a word is considered. Besides the aspect of meaning, a word also possesses many other aspects (e.g., pronunciation, prefix/suffix, and even shape) that are less commonly considered for manipulation. As for the manipulation of the letter aspect of a word, according to Linguistics [94], the more similar two or more words are, the more surprising relationships there might be between the words. In the prototype, based on the operation of deviation, in order to maintain part of the conventional composition of a certain word, the last letter will be manipulated by the prototype. Therefore, this part of Deviator is named Word Tail Deviation. It is believed that the generated word(s) or the relationships between them might be possible to inspire people's creative thinking or, at least, to help people to find something surprising.

7.3.1   ChangeLetterDeviation

Function

The last letter of the input word will be changed to deviate to other word(s).

Algorithm

Begin

1. **Input:** a word

2. **While** not at end of alphabet **Do**

3. Change the last letter of the word into each letters of alphabet, except its own last letter

4. **End**

5. **While** there is still one or more words to be examined **Do**

6. **If** the new word is a real word **Then**

7. **Output:** the new word

8. **Else**

9. **Output:** "the word cannot be changed into a new word by changing the last letter."

10. **End**

End

Implementation Example

If inputting a word "big" (as shown in Figure 22), a set of words can be generated through changing the last letter "g" (as shown in Figure 23).

Figure 22. Input of ChangeLetterDeviation: Big

Figure 23. Output of ChangeLetterDeviation: Big

7.3.2 AddLetterDeviation

Function

A new letter will be added to the end of the input word to deviate to other word(s).

Algorithm

    Begin

      1. **Input:** a word

      2. **While** not at end of alphabet **Do**

      3. Add a letter at the end of the word from alphabet

      4. **End**

      5. **While** there is still one or more words to be examined **Do**

      6. **If** the new word is a real word **Then**

      7. **Output:** the new word

      8. **Else**

      9. **Output:** "the word cannot be changed into a new word by adding a last letter."

      10. **End**

    End

Implementation Example

If inputting a word "apple" (see in Figure 24), a new word "applet" can be generated through adding a letter into the word (see in Figure 25).

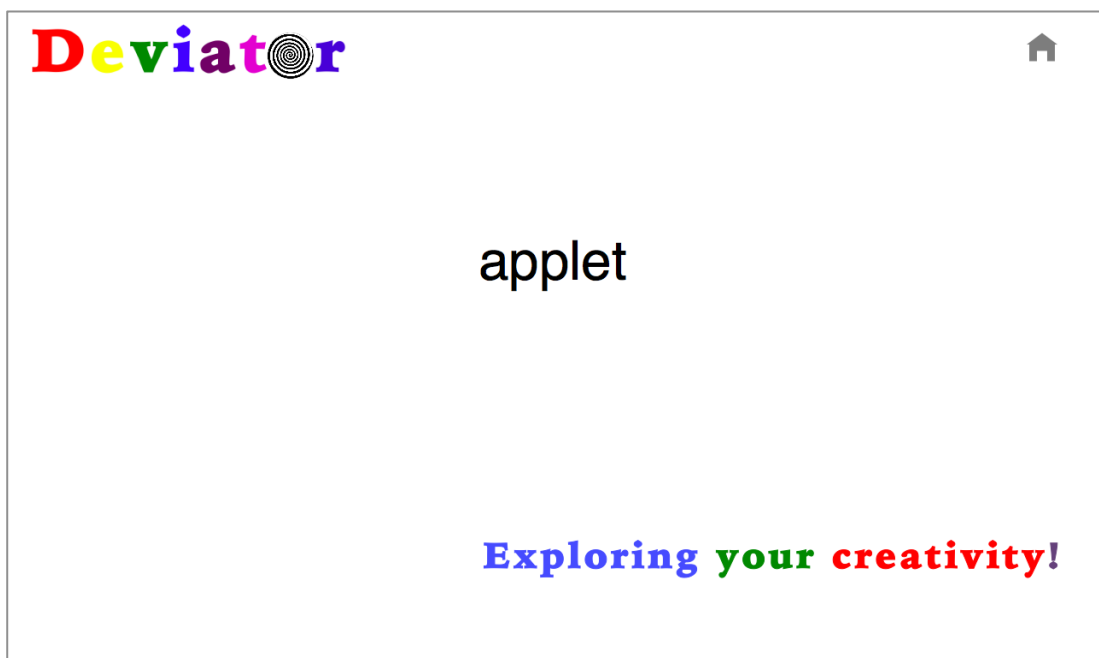Figure 24. Input of AddLetterDeviation: Apple

Figure 25. Output of AddLetterDeviation: Apple

7.3.3   SubtractLetterDeviation

Function

The last letter of the input word will be subtracted to deviate to other word(s).

Algorithm

   Begin

1. **Input:** a word

2. Subtract the last letter of the word

3. **If** the new word is a real word **Then**

4. **Output:** the new word

5. **Else**

6. **Output:** "the word cannot be changed into a new word by subtracting the last letter."

   End

Implementation Example

If inputting a word "orange" (see in Figure 26), a word "orang" can be generated through subtracting the last letter of the word (see in Figure 27).

Figure 26. Input of SubtractLetterDeviation: Orange

Figure 27. Output of SubtractLetterDeviation: Orange

7.4   Phrase Pataphysics Deviation

After trying out relatively simple Word Tail Deviation, this part of Deviator devotes to doing more complicated and meaningful deviation to inspire people's creativity. In order to do that, according to the methods raised in Section 5.3.3, different abstraction levels (i.e., knowledge level, theorems level, and corollaries level) will be crossed gradually to reach the algorithms level where corresponding computing algorithms will be composed to finally realise the pataphysical deviation.

There are five theorems proposed in Chapter 6 and each theorem contains almost a countless number of possibilities. Therefore, within this part of Deviator, one of the five theorems is selected to reason relevant corollaries, in order to exemplify the whole process of making a creative computing product. By doing so, six set of corollaries are generated to underpin the six pataphysical functions of Deviator respectively:

- Corollaries on Function - FunctionDeviation
- Corollaries on Polysemy - PolysemyDeviation
- Corollaries on Vagueness - VaguenessDeviation
- Corollaries on Compound - CompoundDeviation

- Corollaries on Cross-Culture - Cross-CultureDeviation
- Corollaries on Cliché - ClichéDeviation

In order to compose supporting algorithms that underpin the pataphysical functions of Deviator, creative reasoning algorithms will be focused on. As discussed before, there are generally two approaches to mapping the corollaries of Creative Computing to supporting algorithms. One is through composing creativity ontologies. The only thing we should concern is how to utilise the creative concepts or relationships of them. The other is through creative reasoning, which is kind of creative usage of common ontologies (see more in Section 5.3.4). While implementing this prototype, one creative reasoning algorithm of each pataphysical function will be composed based on the corollaries generated from the chosen theorem.

It is worth mentioning that, within this part of Deviator, the common ontology that is used by creative reasoning algorithms is from DBpedia, which is a semantic version of Wikipedia. As mentioned before, in order to facilitate human creativity through stimulating tacit knowledge, people's mental models can be utilised. Although the real mental models of people are hard to know, as we have entered into the era of Big Data, there have existed a great many well-accepted common models of the surrounding world, such as encyclopaedia like Wikipedia. Through "manipulating" those kinds of common models, people may be encouraged to see the world in a creative way.

Furthermore, in order to show how Creative Computing will make contributions in the real world, this part of Deviator is put in a particular context of Digital Heritage, which is one of the potential application fields of Creative Computing. Based on the RDF data provided by DBpedia, hundreds of instances under a class of HistoricPlace are utilised to do the semantic deviation. Through pataphysically deviating from one place to another place a user might never think before, surprising experiences might be provided for people to inspire their creativity. Therefore, the input of this part of Deviator should be a name of a historic place taking form as a phrase, which is the reason why this part of Deviator is named Phrase Pataphysics Deviation.

7.4.1　　　Chosen Theorem Description

According to previous analysis, as each theorem might contain a countless number of possibilities, in order to exemplify how to develop a creative computing product by following the theorems of Creative Computing, one of the six theorems raised in Chapter 6 is selected to generate corresponding corollaries. The corollaries underpin the six pataphysical functions of Deviator are generated from the ***Theorem 5***.

Changing the negative into the positive.

Through reasoning, one of the possibilities of ***Theorem 5*** can be interpreted as "using a negative problem in a positive way". Accordingly, ***Theorem 5*** can be interpreted into a huge amount of possibilities, which is associated with the two adjective words – negative and positive. In common sense, many things can be described as negative, such as an irritating problem. Sometimes, a certain problem even might seem unlikely to be solved. However, most of the time, something can be deemed as including both good and bad aspect. Therefore, what if a difficult problem can be utilised in a positive way by leveraging its good aspect. A typical example of this is mind wandering that is studied in previous section (see in Section 6.2.8). It often refers to lack of attention or negative emotion [79]. However, just because of this kind of distraction, it is possible for remote neurons to be connected. By doing so, sudden insight might be triggered, which is pursued urgently by creative people [20, 115]. Hence, various kinds of methods (e.g., fantasy thinking) have been used to stimulate mind wandering for people to enhance their creative thinking.

According to the theorem interpretation above, the negative problem concerned in my research is ambiguity. Computing is a very rigorous process, which follows step-by-step instructions. What it seeks is a kind of precision to provide something a user exactly demands. Therefore, in computing field, ambiguity is often considered as a crucial problem, as it always prevents computer from understanding human clearly, such as in Artificial Intelligence (AI) or Natural Language Processing (NLP) [62]. It can severely influence the accuracy of the computing results in those fields.

However, ambiguity also has good aspect that is closely associated with creativity. Through studying creative people, a particular personality trait is extracted known as ambiguity tolerance. Studies show that creative people is more probable to accept

various ambiguities than ordinary people [146]. It implies a certain relationship between ambiguity and human creativity, which can be a good support to use ambiguity reversely, in other words, positively. Furthermore, ambiguity is often used in artistic fields like Visual Art and Literature. There are great values of various interpretations of ambiguity images of Visual Art. In Literature like Poetry, creative inspirations might just come from ambiguities (e.g., clichés and puns [134]). Hence, the hypothesis is that ambiguity might be used in a positive way to inspire human creativity.

Initially, my research starts from the exploration of text. Therefore, several core causes of text ambiguity are utilised in the study to help people to do the deviation thinking. Accordingly, ambiguity is the quality of being open to more than one interpretation [125]. The natural relationships between different interpretations are good tools to support people to deviate from a conventional point of view to another angle. Through studying, six causes of text ambiguity are summarised here (i.e., function, polysemy, vagueness, compound, cross-culture, and cliché). Because of them, when encountering a word, people may feel confused what the word really stands for.

- The function cause means that a word might possess several different functions (e.g., noun, verb, adjective, and adverb). With different function, the word may stand for different meanings, which may result in ambiguity. For example, word "book" can mean a reading book as a noun. It also can be a verb that stands for a reservation action, such as "book a table".

- The polysemy cause means that a word not only may possess multiple functions, but also may contain multiple meanings of each function. With different meaning, a word might be understood as different things, which may lead to ambiguity. For example, word "bridge" can stand for several things as a noun, such as architecture, game, deck, and so on.

- The vagueness cause means that a word, especially adjective word, might not have absolute value. This kind of relativity may end up with ambiguity. For

example, there is no certain value of adjective word "tall", whose meaning is based on the thing it describes. If it is used to describe a person, 190cm might be deemed as tall. However, if it were leveraged to depict a building, there would be a different value of being tall.

- Compound word is a kind of word that is composed by two or more independent words (e.g., Sunday). The compound cause means that the meanings of each composing word of a compound word may lead to confusions of the meaning of the compound word itself, which may cause ambiguity. For example, phrase "green house" describes a house whose colour is green. However, actually, word "greenhouse" stands for a glass building for plants.

- The cross-culture cause means that a word might contain different meanings within different cultures, which may give rise to ambiguity. For example, the number word "six" possesses special meaning in Chinese culture, which particularly means success or something goes smoothly.

- Cliché is kind of expression that even loses its original meaning due to overuse. The cliché cause means that a cliché may be able to add more meanings to a word or construct more relationships between different words, which may cause ambiguity. For example, the cliché "compare apple and orange", which means the comparison between two things that are totally different, kind of builds a special relationship between word "apple" and "orange".

By leveraging the six core causes of text ambiguity in a positive way to stimulate users' creativity, corresponding corollaries of Creative Computing are composed. The aim of each set of corollaries is to support each pataphysical function through providing a variety of manipulations of concepts and relationships by utilising one of the causes of text ambiguity. For each set of corollaries, an input word is required. The relevant corollaries will output a sentence or phrase that might contain more information to construct unexpected but meaningful relationships between the input and the output. By doing so, some ideas or methods will be proposed divergently.

And then, through kind of convergent reasoning, an algorithm of each pataphysical function will be composed based on the ideas or methods proposed by the corollaries.

7.4.2   FunctionDeviation

Corollaries on Function

This section uses the function cause of ambiguity to help people to do the deviation, which concerns various functions of a word, such as noun, verb, adjective, and adverb. A word might possess more than one function. For example, word "book" could be deemed as both noun (e.g., a comic book) and verb (e.g., book a table). By utilising different functions of a word, a variety of manipulations to deviate from one function (e.g., intentional function) to another function (e.g., unintentional function) are described as follows:

Firstly, the intentional function of an input word should be recognised.

1) A certain number of words that are semantically associated with the input word should be outputted first;

2) A user is required to do a second input by selecting one of the first output words;

3) The intentional function of the input word could be recognised according to the selection during Step 2.

   Example:
   a) **Search Engine:** WordNet
   b) **Input:** Book
   c) **The Semantically Associated (Main Meaning Depicting) Words:**
      Volume, Record, Script, Ledger, Koran, Bible, Reserve
   d) **The Selection of a User:**
      Reserve
   e) **The Intentional Function:**
      Verb

Secondly,

1) One of the unintentional function(s) of the input word could be selected randomly. Then, a sentence or phrase, which contains the input word with the selected unintentional function, should be outputted.

Example:

a) **Search Engine:** WordNet

b) **The Randomly Selected Unintentional Function:**

Noun

c) **Output:**

His name is in all the record books.

2) One of the unintentional function(s) of the input word could be selected randomly. The semantically associated words or phrases could be obtained. One of the related words should be selected randomly. Then, a sentence or phrase, which contains the selected word, could be outputted.

Example:

a) **Search Engine:** BabelNet

b) **The Randomly Selected Unintentional Function:**

Noun

c) **The Semantically Associated Words:**

Signature, Running Headline, Publication

d) **The Randomly Selected Word:**

Signature

e) **Output:**

The analysis concluded that the signature on the document was 'very similar' to Chen's.

3) The synonym(s) of the input word with the intentional function could be obtained. One of the synonyms could be selected randomly. One of the unintentional function(s) should also be selected randomly. Therefore, a sentence or phrase, which contains the input word with the selected unintentional function, could be selected. Then, the input word in the selected sentence or phrase should be replaced by the randomly selected synonym. Finally, the substituted sentence or phrase should be outputted.

Example:

a) Search Engine: Oxford Dictionary

b) The Synonyms of Input Word with Intentional Function:

Reserve, Prearrange, Order, Charter, Hire

c) The Randomly Selected Synonym:

Order

d) The Randomly Selected Unintentional Function:

Noun

e) The Selected Sentence or Phrase:

After some serious research he wrote a book on the subject, Ancient Mosaics in Bulgaria.

f) Output:

After some serious research he wrote an order on the subject, Ancient Mosaics in Bulgaria.

4) One of the unintentional function(s) could be selected randomly. One synonym of the input word with the randomly selected unintentional function could be obtained. In the meantime, one synonym of the input word with the intentional function could also be obtained. Then, a sentence or phrase, which contains the two selected synonyms, should be outputted.

Example:

a) Search Engine: Oxford Dictionary, Google

b) The Randomly Selected Unintentional Function:

Noun

c) The Synonym of Input Word with Unintentional Function:

Volume

d) The Synonym of Input Word with Intentional Function:

Reserve

e) Output:

As data is written to the volume, more space is automatically allocated (if available), and the volume reserve increases up to a user-defined limit.

5) The total number of the functions of the input word could be calculated. Then, a sentence or phrase, which contains the counted number of input words, should be outputted.

Example:

a) **Search Engine:** Wikipedia

b) **The Total Number of Functions of Input Word:**

   2

c) **Output:**

   Book Book is a rural community in the central east part of the Riverina.

Algorithm

Begin

1. **Input:** a phrase (i.e., a name of a historic place)

2. **If** the input phrase is contained by the database (i.e., DBpedia) **Then**

   /*The input phrase might be associated with one or more phrases in the database, in other words, there might be more than one historic place contained in DBpedia that is associated with the input place*/

3. **While** there is still one or more phrases to be examined **Do**

4. **If** the associated phrase contains one or more words that possess multiple functions (i.e., noun, verb, adjective, and adverb) **Then**

5. **While** there is still one or more words to be examined **Do**

6. Select words representing the multiple functions of the examined word, according to the corollaries on function

7. **While** there is still one or more words to be examined **Do**

8. **If** the representing word is contained by the database (i.e., DBpedia) **Then**

9. **Output:** one or more phrases (i.e., names of deviated historic places) containing the selected word

10. **Else**

11. **If** the word is not the last one to be examined **Then**

12. Continue to examine the next word

13. **Else**

14. **Output:** "There is no result of the input historic place by using FunctionDeviation."

15. **End**

16. **End**

17. **Else**

18. **Output:** "The input historic place does not contain the element for FunctionDeviation."

19. **End**

20. **Else**

21. **Output:** "The input place is not a historic place."

End

Implementation Examples

If inputting a historic place named "Book Site" (see in Figure 28), several other historic places will be listed through FunctionDeviation of Deviator (see in Figure 29), which particularly focuses on deviating from noun to verb. Hence, by deviating noun "book" to verb "book", several results that are associated with verb "book" are generated. It is worth mentioning that each result is linked to a webpage of DBpedia that contains comprehensive information about the place. An example is shown in Figure 30.

Figure 28. Input of FunctionDeviation: Book Site
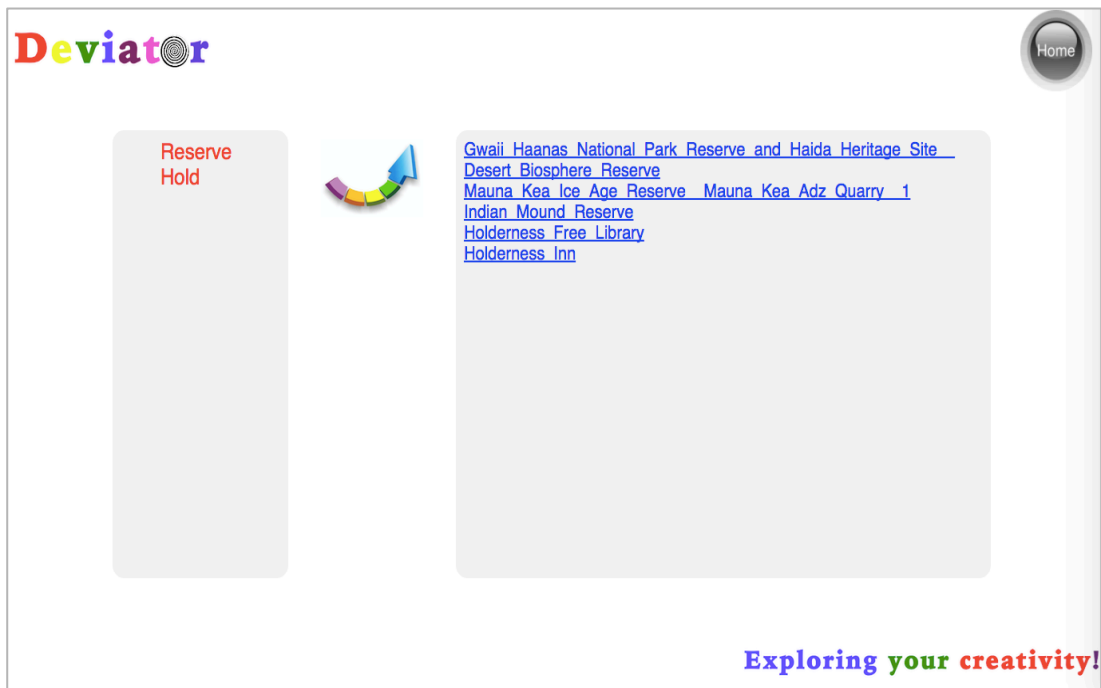
Figure 29. Output of FunctionDeviation: Book Site
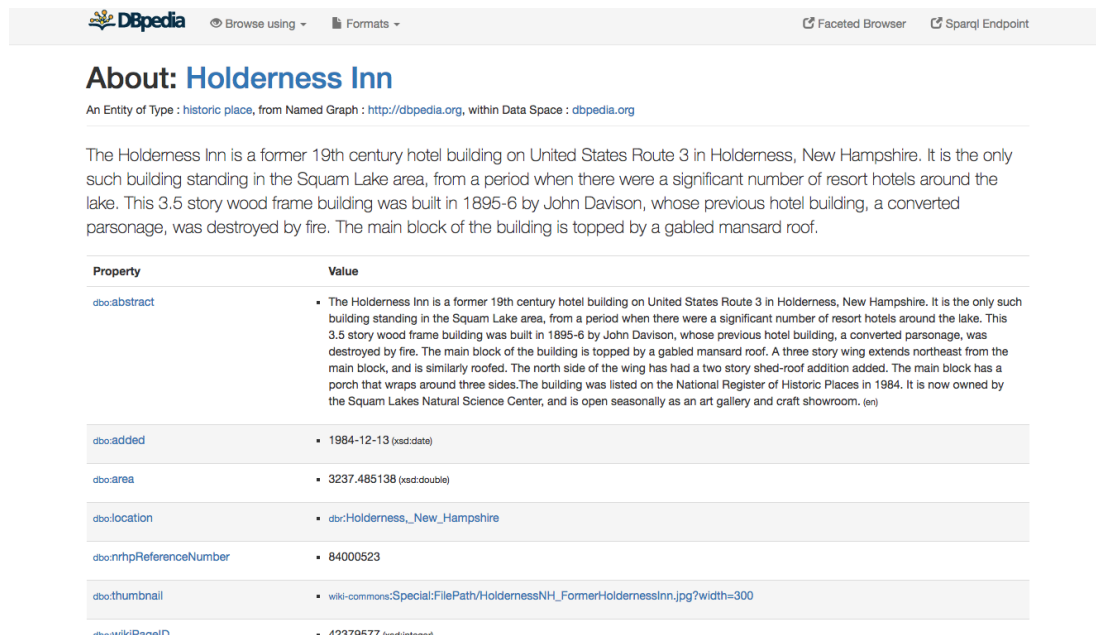
Figure 30. Details in DBpedia: Holderness Inn [GNU General Public License]

Another example of FunctionDeviation is shown below. A place named "Corsham Court" is inputted as shown in Figure 31. A list of deviated places is generated by deviating noun "court" to verb "court" (see in Figure 32). The details of one of the results are shown in Figure 33.

Figure 31. Input of FunctionDeviation: Corsham Court
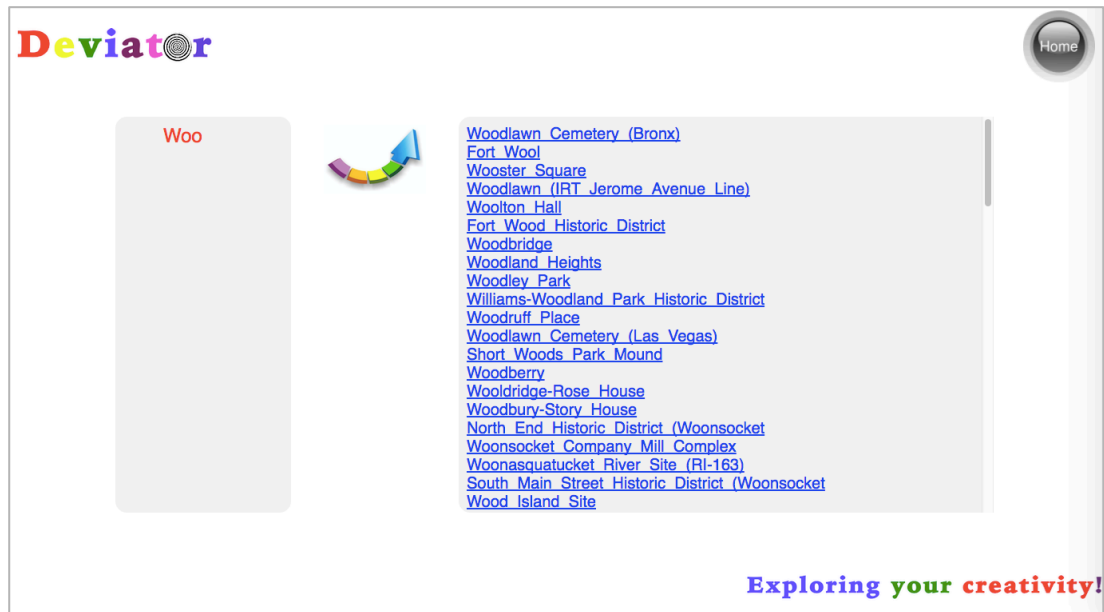
Figure 32. Output of FunctionDeviation: Corsham Court
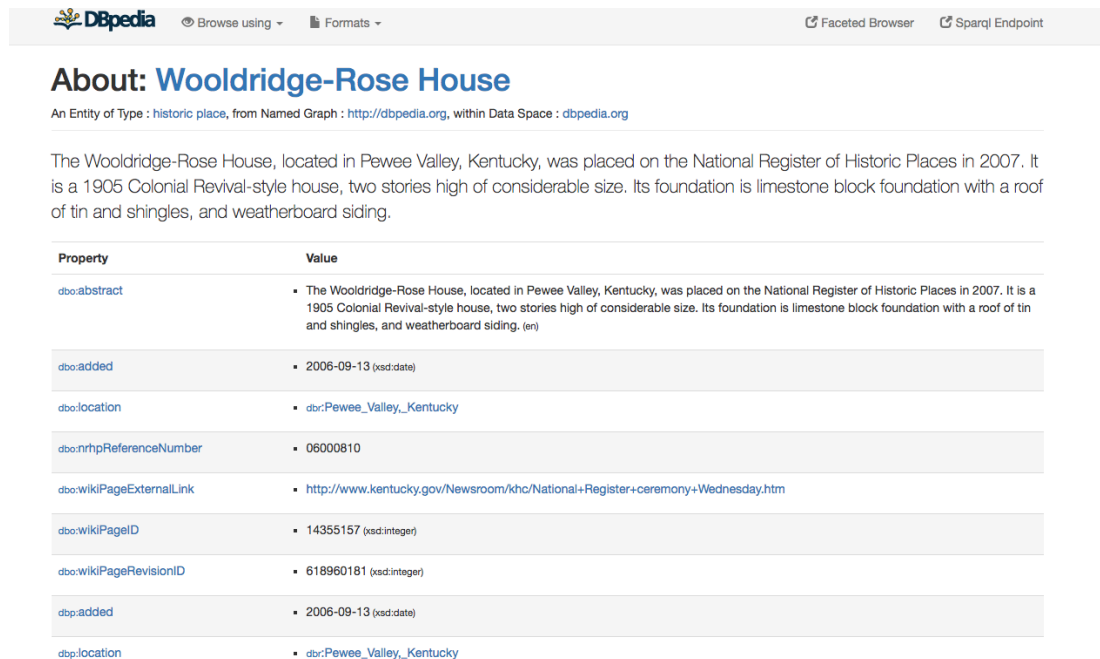
Figure 33. Details in DBpedia: Wooldridge-Rose House [GNU General Public License]

7.4.3   PolysemyDeviation

Corollaries on Polysemy

This section uses the polysemy cause of ambiguity to help people to do the deviation, which concerns the multiple meanings of a word. A word might have more than one meaning of each function, such as noun, verb, adjective, and adverb. For example, word "bridge", as a noun, could stand for various things, like a structure, a game, and even a part of a person's nose. By utilising different meanings of a word, a variety of manipulations to deviate from one meaning (e.g., conventional meaning) to another meaning (e.g., unconventional meaning) are described as follows:

Firstly, the unconventional meaning(s) should be selected, according to the word frequency.

1) Input the word into a search engine with the function of word frequency counts, such as WordNet;

2) Filter the search result(s) with the lowest frequency;

3) Extract the main depicting word(s) from the filtered result(s).

    Example:

    a) **Input:** Bridge

    b) **Search Engine:** WordNet

    c) **Search Results of WordNet Ordered by Frequency Counts:**

        (4) Span (a structure that allows people or vehicles to cross an obstacle such as a river or canal or railway etc.)

        (3) Circuit (a circuit consisting of two branches (4 arms arranged in a diamond configuration) across which a meter is connected)

        (2) (Something resembling a bridge in form or function) "his letters provided a bridge across the centuries"

        (1) (The hard ridge that forms the upper part of the nose) "her glasses left marks on the bridge of her nose"

        (1) (Any of various card games based on whist for four players)

        (A wooden support that holds the strings up)

        Bridgework (a denture anchored to teeth on either side of missing teeth)

        Nosepiece (the link between two lenses; rests on the nose)

        Bridge deck (an upper deck where a ship is steered and the captain stands)

    d) **The Filtered Results with the Lowest (0) Frequency:**

(A wooden support that holds the strings up)

Bridgework (a denture anchored to teeth on either side of missing teeth)

Nosepiece (the link between two lenses; rests on the nose)

Bridge deck (an upper deck where a ship is steered and the captain stands)

e) The Main Depicting Word(s):

Bridgework

Nosepiece

Deck

Secondly,

1) The newest meaning(s) could be selected, according to the time of emergence or the period of intense study. Then, a sentence or phrase, which is associated with each latest meaning, should be outputted.

Example:

a) **Search Engine:** Dictionary.com

b) **Time of Emergence:**

Bridgework: 1880-1885

Nosepiece: 1605-1615

Deck: 1425-1475

c) **The Newest Meaning(s):**

Bridgework

d) **Output:**

It was a striking example of bridgework, very well done, and may now be seen in the Louvre.

2) The most incongruous meaning(s) could be selected, according to the classification (category). Then, a sentence or phrase, which is associated with each incongruous meaning, should be outputted.

Example:

a) **Classification:**

Bridgework: Medicine

Nosepiece: Medicine

Deck: Transportation

b) The Most Incongruous Meaning(s):

Deck

c) Output:

He stood on the deck of his flagship.

3) The meaning(s) that is the closest to human could be selected, according to the preposition location to a person (e.g., in person < on person < person on < person in). Then, a sentence or phrase, which is associated with each closest meaning, should be outputted.

Example:

a) Preposition Location:

Bridgework: in person (We knew who it was because the doctor identified the bridgework in his mouth.)

Nosepiece: on person (With a nosepiece on like that, you couldn't tell who a man was.)

Deck: person on (He stood on the deck of his flagship.)

b) The Closest Meaning:

Bridgework

c) Output:

It was a striking example of bridgework, very well done, and may now be seen in the Louvre.

4) The simplest meaning(s) could be selected, according to the length of each main depicting word. Then, a sentence or phrase, which is associated with each simplest meaning, should be outputted.

Example:

a) Word Length:

Bridgework: 10

Nosepiece: 9

Deck: 4

b) The Simplest Meaning(s):

Deck

c) Output:

He stood on the deck of his flagship

5) The random meaning could be selected. Then, a sentence or phrase, which is associated with the random meaning, should be outputted.

Algorithm

  Begin

1. **Input:** a phrase (i.e., a name of a historic place)

2. **If** the input phrase is contained by the database (i.e., DBpedia) **Then** /*The input phrase might be associated with one or more phrases in the database, in other words, there might be more than one historic place contained in DBpedia that is associated with the input place*/

3. **While** there is still one or more phrases to be examined **Do**

4. **If** the associated phrase contains one or more words that possess multiple meanings of one function (i.e., noun, verb, adjective, and adverb) **Then**

5. **While** there is still one or more words to be examined **Do**

6. Select words representing the multiple meanings of the examined word, according to the corollaries on polysemy

7. **While** there is still one or more words to be examined **Do**

8. **If** the representing word is contained by the database (i.e., DBpedia) **Then**

9. **Output:** one or more phrases (i.e., names of deviated historic places) containing the selected word

10. **Else**

11. **If** the word is not the last one to be examined **Then**

12. Continue to examine the next word

13. **Else**

14. **Output:** "There is no result of the input historic place by using PolysemyDeviation."

15. **End**

16. **End**

17. **Else**

18. **Output:** "The input historic place does not contain the element for PolysemyDeviation."

19. **End**

20. **Else**

21. **Output:** "The input place is not a historic place."

End

Implementation Examples

If inputting a historic place named "Tower of London" (see in Figure 34), several other historic places will be listed through PolysemyDeviation of Deviator (see in Figure 35), which particularly focuses on deviating from one meaning to another meaning of a word as a noun. It is worth mentioning that the associated phrase or place of "Tower of London" is "Tower Bridge", of which the word "bridge" contains multiple meanings as a noun. Hence, by deviating from meaning "bridge" to "deck", several results that are associated with meaning "deck" are generated. An example of DBpedia is shown in Figure 36.

Figure 34. Input of PolysemyDeviation: Tower of London
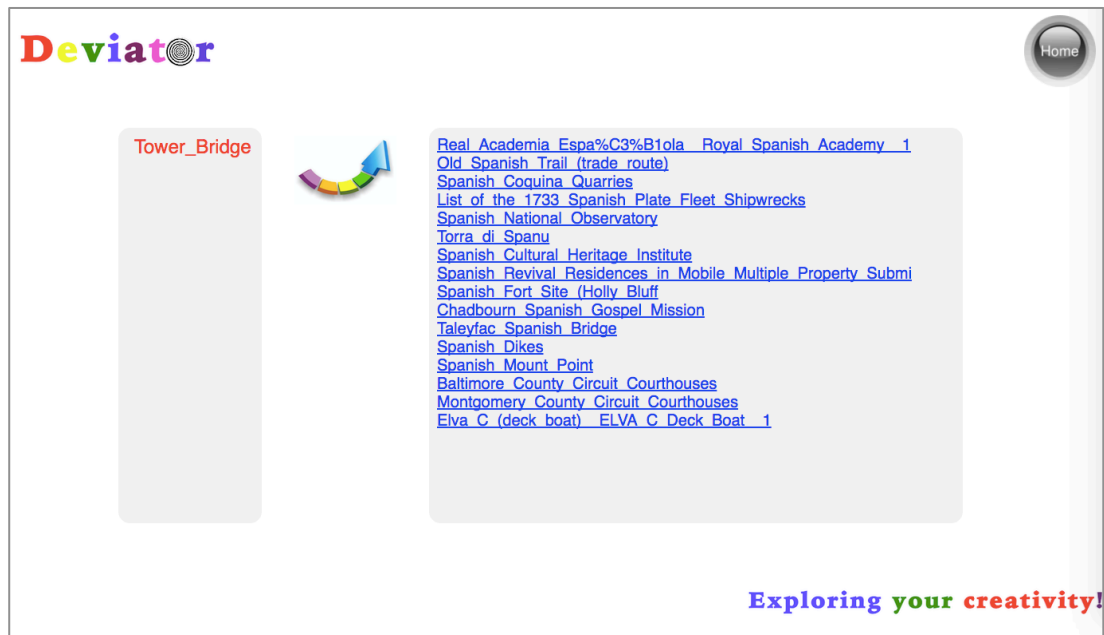
Figure 35. Output of PolysemyDeviation: Tower of London
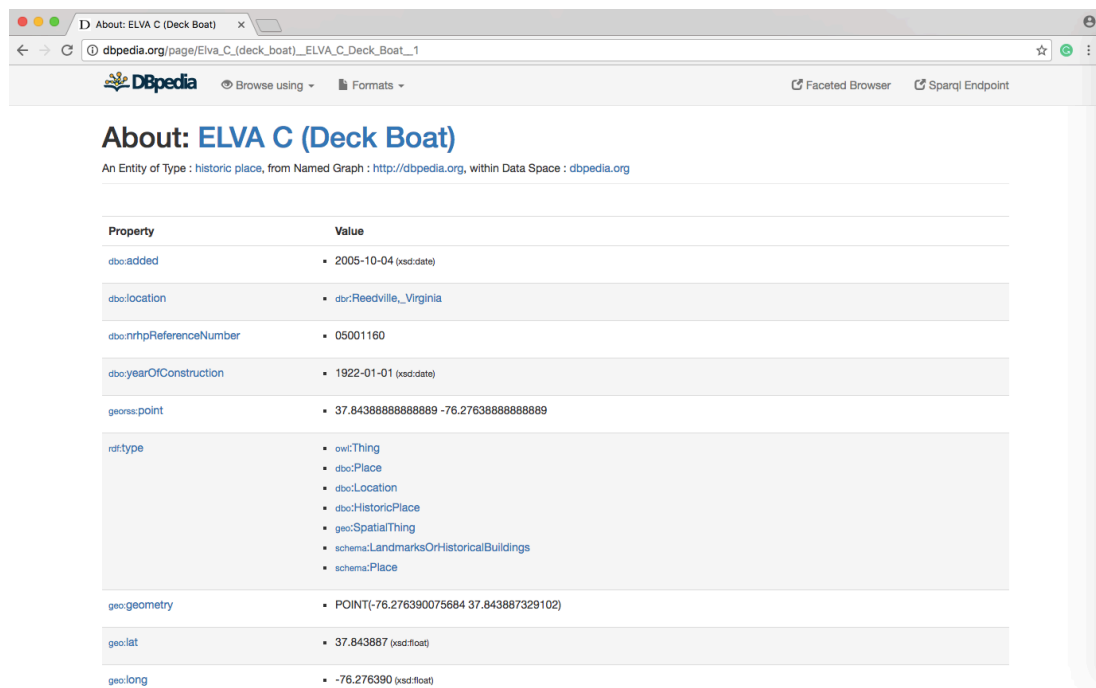
Figure 36. Details in DBpedia: Elva C Deck Boat [GNU General Public License]

Another example of PolysemyDeviation is shown below. A place named "Big Ben" is inputted as shown in Figure 37. A list of deviated places is generated by deviating noun "four" to number "4" (see in Figure 38). The details of one of the results are shown in Figure 39.

Figure 37. Input of PolysemyDeviation: Big Ben

Figure 38. Output of PolysemyDeviation: Big Ben
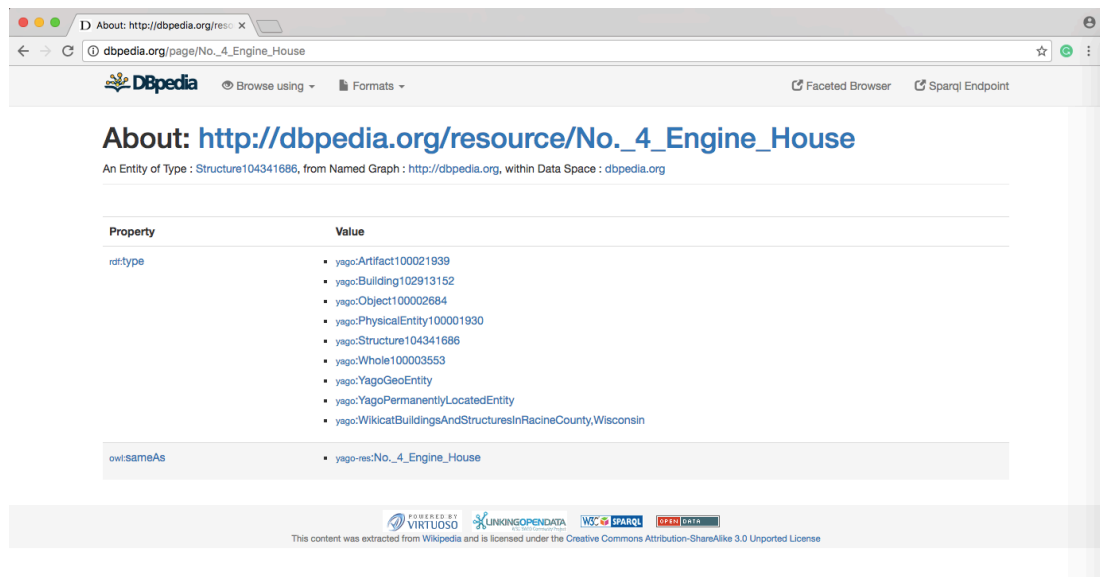
Figure 39. Details in DBpedia: No.4 Engine House [GNU General Public License]

7.4.4 VaguenessDeviation

Corollaries on Vagueness

This section uses the vagueness cause of ambiguity to help people to do deviation, which concerns the uncertain value of a word, especially an adjective word. A word might not have absolute but relative value. For example, word "tall", as an adjective, does not have precise defining value. Somebody cannot say something is tall without referring to a certain standard. By utilising this kind of flexibility of a word, a variety of manipulations to deviate from one degree of value (e.g., original value) to another degree of value (e.g., opposite value) are described as follows:

1) If the input word has opposite word(s), such as antonym(s), a sentence or phrase, which contains each opposite word, could be selected. Next, the opposite word(s) in the sentences or phrases will be replaced by the input word. Then, the substituted sentences or phrases will be outputted.

   Example:
   a) **Search Engine:** Dictionary.com
   b) **Input:** Tall
   c) **The Opposite Word(s):**
   Short

d) Selected Sentence:

Cairo was always there in both my novels before and in the majority of the short stories.

e) Output:

Cairo was always there in both my novels before and in the majority of the tall stories.

2) If the input word shares the same meaning(s) with other word(s), such as synonyms, the most complicated synonymous word should be selected, according to the length of the word. Then, a sentence or phrase, which is associated with the most complicated synonymous word, should be outputted.

Example:

a) **Search Engine:** Oxford Dictionary

b) **Input:** Tall

c) **Synonyms:**

Big, High, Large, Huge, Towering, Colossal, Gigantic, Giant, Monstrous, Giant-Size, Brobdingnagian, Lanky, Rangy, Gangling, Leggy, Long-Legged

d) **The Most Complicated Synonymous Word:**

Brobdingnagian

e) **Output:**

Huge great Brobdingnagian wooden doors open to the King's Cross building site, giving light and air of fair to middling quality.

3) If the input word is associated with "average value" with reference to an object (such as word "tall"), the value will be set manually or randomly. Then, a sentence or phrase, which is associated with the input word and "average value", could be outputted.

Example:

a) **Search Engine:** Wikipedia

b) **Input:** Tall

c) **"Average Value":**

7

d) Output:

The Likir Monastery was first built in the 11th century and was rebuilt in the 18th century, and currently has a 25-foot-tall (7.6 m) gold-covered Buddha statue.

4) If the input word is a class of objects in real world, the concrete instance(s) with the most number of properties should be selected. Then, a sentence or phrase, which is associated with the selected instance(s), should be outputted.

Example:

a) **Search Engine:** DBpedia

b) **Input:** Person

c) **The Concrete Instance(s) (the first three of the result list ordered by alphabet):**

A. B. Swindell

Abu Bakar Bashir

Abu Sabaya

d) **The Number of Properties:**

A. B. Swindell: 42

Abu Bakar Bashir: 31

Abu Sabaya: 42

e) **The Selected Instance(s):**

A. B. Swindell

Abu Sabaya

f) **Output:**

Albin B. Swindell (born October 14, 1945 in Robeson County, North Carolina) was a Democratic member of the North Carolina General Assembly representing the state's eleventh Senate district, including constituents in Nash and Wilson counties.

Abu Sabaya (About this sound pronunction AH-boo sah-bah-YAH July 18, 1962 – June 21, 2002), born Aldam Tilao, was one of the leaders of the Abu Sayyaf in the southern Philippines until he was killed by soldiers of the Philippine Army in 2002.

5) If the input word is a class of objects in real world, a property could be selected randomly. Then, a sentence or phrase, which is associated with the selected property, should be outputted.

Example:

a) **Search Engine:** DBpedia

b) **Input:** Person

c) **Random Property:**
   Allegiance

d) **Output:**
   Loyalty to him became the test of patriotism and social allegiance in general.

Algorithm

Begin

1. **Input:** a phrase (i.e., a name of a historic place)
2. **If** the input phrase is contained by the database (i.e., DBpedia) **Then**
   /*The input phrase might be associated with one or more phrases in the database, in other words, there might be more than one historic place contained in DBpedia that is associated with the input place*/
3. **While** there is still one or more phrases to be examined **Do**
4. **If** the associated phrase contains one or more words that possess uncertain values **Then**
5. **While** there is still one or more words to be examined **Do**
   /*It is believed that the more complicated a word is, the more meanings or values it may contain, which can be utilised to do deviation*/
6. Select synonym(s) that are more complicated (e.g., longer or contain more letters), in other words, possess more values than the examined word, according to the corollaries on vagueness
7. **While** there is still one or more synonyms to be examined **Do**
8. **If** the synonym is contained by the database (i.e., DBpedia) **Then**
9. **Output:** one or more phrases (i.e., names of deviated historic places) containing the synonym
10. **Else**

11. **If** the synonym is not the last one to be examined **Then**

12. Continue to examine the next synonym

13. **Else**

14. **Output:** "There is no result of the input historic place by using VaguenessDeviation."

15. **End**

16. **End**

17. **Else**

18. **Output:** "The input historic place does not contain the element for VaguenessDeviation."

19. **End**

20. **Else**

21. **Output:** "The input place is not a historic place."

End

Implementation Examples

If inputting a historic place named "New River Inn" (see in Figure 40), several other historic places will be listed through VaguenessDeviation of Deviator (see in Figure 41), which particularly focuses on utilising adjective words to deviate from one degree to another degree of value. Hence, by deviating from word "new" to more complicated synonyms like "fresh" or "novel", several results that are associated with various values of being "new" are generated. An example of DBpedia is shown in Figure 42.

Figure 40. Input of VaguenessDeviation: New River Inn
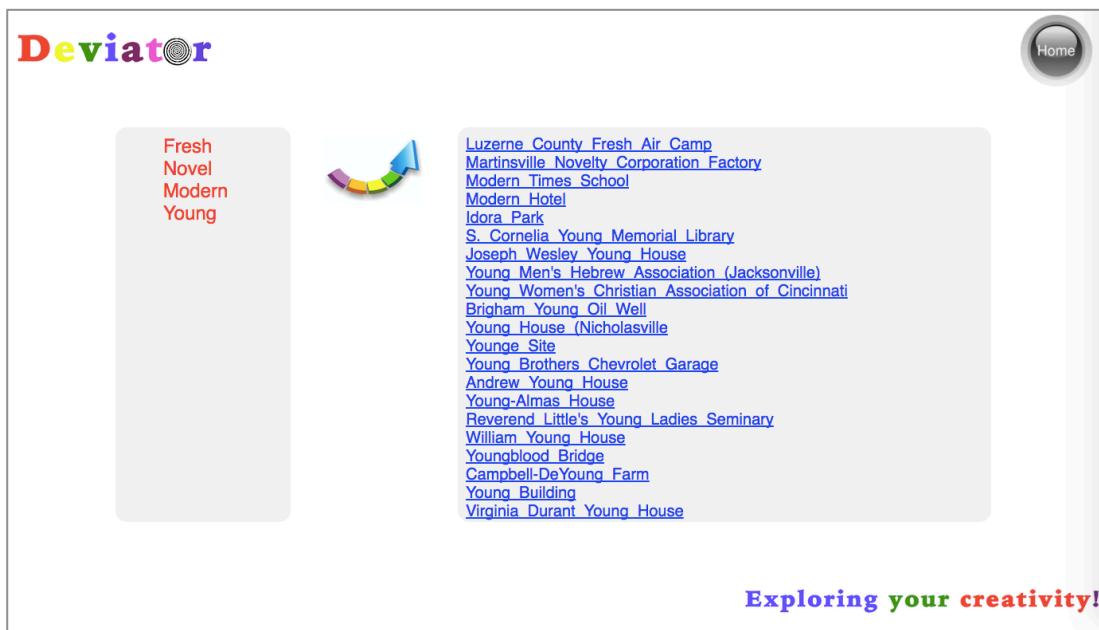
Figure 41. Output of VaguenessDeviation: New River Inn
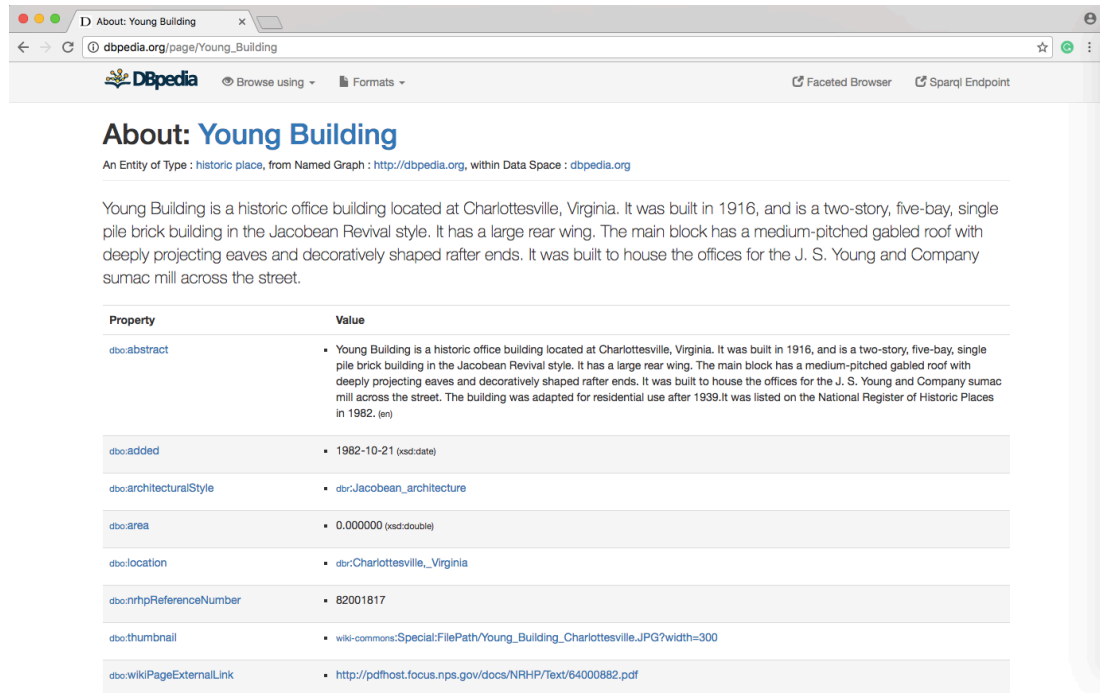
Figure 42. Details in DBpedia: Young Building [GNU General Public License]

Another example of VaguenessDeviation is shown below. A place named "Big Ben" is inputted as shown in Figure 43. A list of deviated places is generated by deviating word "big" to more complicated words "adult" and "great" (see in Figure 44). The details of one of the results are shown in Figure 45.

Figure 43. Input of VaguenessDeviation: Big Ben
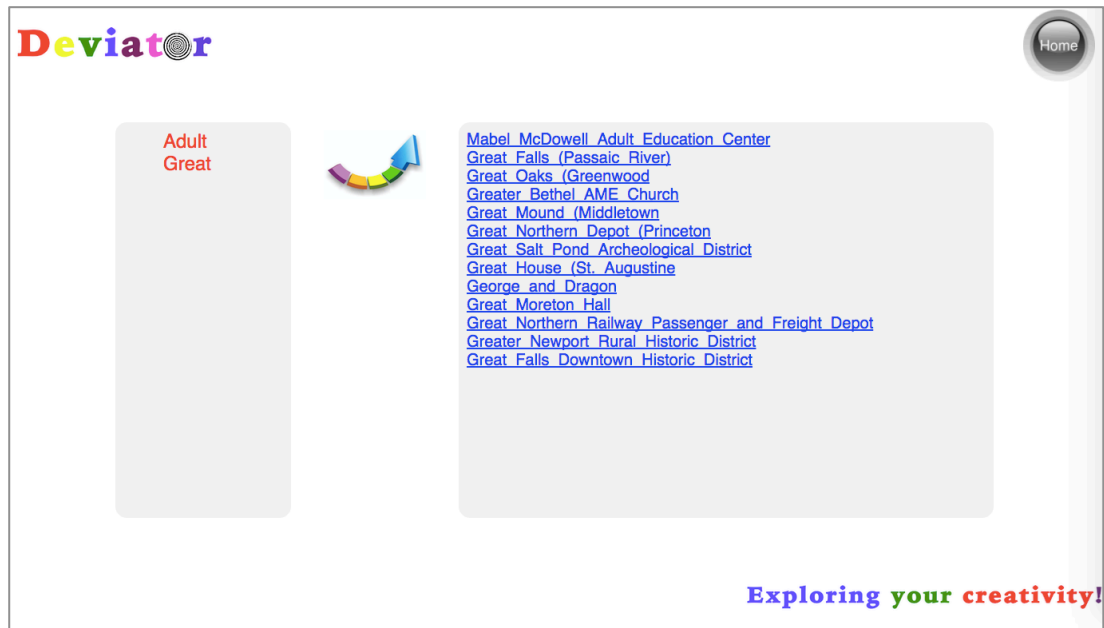
Figure 44. Output of VaguenessDeviation: Big Ben
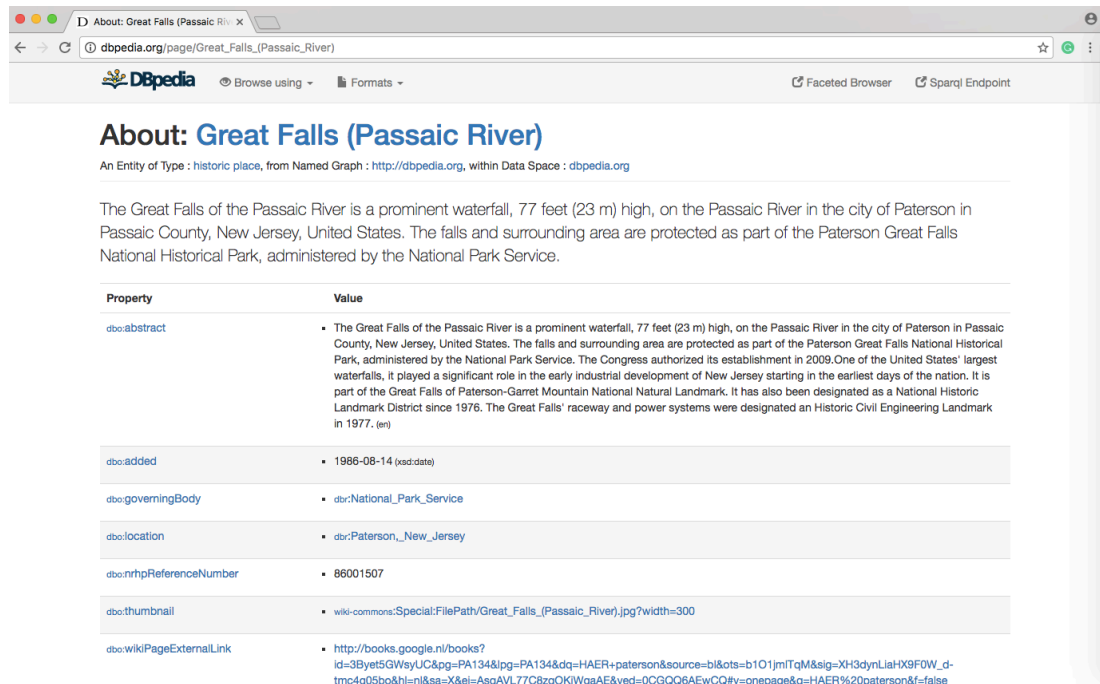
Figure 45. Details in DBpedia: Great Falls [GNU General Public License]

7.4.5 CompoundDeviation

Corollaries on Compound

This section uses the compound cause of ambiguity to help people to do deviation, which concerns the composition of a word. A word might be a compound word that could be divided into two or more independent words by splitting the letters. For example, compound word "greenhouse" is made up of two words "green" and "house". If people are not familiar with the real meaning of word "greenhouse", it is easy for people to understand it as a house with green colour, instead of interpreting it as a glass building for plants. By utilising this kind of ambiguity, a variety of manipulations to deviate from one word to other words that might contain surprising relationships to help people to do kind of creative thinking are described as follows:

Firstly, the input word should be split into independent sub-words.

1) If the input word contains "-" (e.g., after-effect), the sub-words could be obtained by regarding "-" as a separator.

   Example:
   a) **Input:** After-Effect
   b) **Separator:** "-"
   c) **Sub-Words:**
      After, Effect

2) If the input word has a normal shape (e.g., Sunday), the length (number of letters) of the word should be calculated first (using "L" as the symbol). Then, from left to right, the certain number ($>=2$ && $<=L\%2$) of letters will be selected iteratively to check whether it could be a real word. Once the former part has been recognised as a real word, the latter part should also be checked. Only when the two parts are both recognised as real words, the two parts could be regarded as sub-words.

   Example:
   a) **Input:** Sunday
   b) **Length:** 6
   c) **The Number of Letters to be Selected:**
      2, 3 ($>=2$ && $<=6\%2$)
   d) **Sub-Words:**

Sun, Day

Secondly,

1) If the former word is a noun and, in the mean time, the latter word is also a noun (e.g., Sunday), a sentence or phrase, which contains both the former word and the latter word, should be outputted.

   Example:

   a) **Search Engine:** Wikipedia

   b) **Input:** Sunday

   c) **Sub-Words:**

   Sun, Day

   d) **Output:**

   Sun Day (May 3, 1978) was designated by United President Jimmy Carter specifically devoted to advocacy for solar power.

2) If the former word is a verb and, in the mean time, the latter word is a noun (e.g., jumpsuit), a new word, which comes from another compound noun starting with the latter noun of the input word, could be selected. Then, a sentence or phrase, which contains both the former verb of the input word and the selected word, should be outputted.

   Example:

   a) **Search Engine:** Oxford Dictionary

   b) **Input:** Jumpsuit

   c) **Sub-Words:**

   Jump, Suit

   d) **Compound Word Starting with the Latter Part of the Input Word:**

   Suitcase

   e) **The Selected Word:**

   Case

   f) **Output:**

   Jump Case Synonyms

3) If the former word is an adjective word and, in the mean time, the latter word is a noun (e.g., easy-chair), a new compound noun, which also starts with the former adjective word of the input word, should be selected. If the latter part of the new compound word is a noun, the noun should be selected. Then, a sentence or phrase, which both contains the latter noun of the input word and the selected word, should be outputted.

Example:

a) **Search Engine:** Oxford Dictionary, Wikipedia

b) **Input:** Easy-Chair

c) **Sub-Words:**

Easy, Chair

d) **The New Compound Noun:**

Easy-Game

e) **The Selected Word:**

Game

f) **Output:**

The Chair is a game show television program that premiered on ABC in January 2002.

4) If the former word is an adverb word and, in the mean time, the latter word is a verb (e.g., upset), a new compound noun, which contains the former adverb word of the input word as the latter part, should be selected. If the former part of the new compound word is a verb, the verb should be selected. Then, a sentence or phrase, which both contains the latter verb of the input word and the former verb of the new compound word, should be outputted.

Example:

a) **Search Engine:** Oxford Dictionary, Wikipedia

b) **Input:** Upset

c) **Sub-Words:**

Up, Set

d) **The New Compound Word:**

Slip-Up

e) The Selected Word:

Slip

f) Output:

The piece is covered in a reddish clay slip and set out to dry and then this process is repeated.

5) If the former word is an adverb word and, in the mean time, the latter word is a noun (e.g., upgrade), a new compound noun, which also starts with the former adverb word of the input word, should be selected. If the latter part of the new compound word is a verb, the verb will be selected. Then, a sentence or phrase, which contains both the latter noun of the input word and the selected verb, should be outputted.

Example:

a) Search Engine: Oxford Dictionary, Wikipedia

b) Input: Upgrade

c) Sub-Words:

Up, Grade

d) The New Compound Word:

Upset

e) The Selected Word:

Set

f) Output:

Davies, a scrum half, is a member of the age grade set up in the Scarlets region for the past few seasons.

Algorithm

Begin

1. **Input:** a phrase (i.e., a name of a historic place)
2. **If** the input phrase is contained by the database (i.e., DBpedia) **Then**
3. Break the phrase into single words
4. **While** there is still one or more words to be examined **Do**
5. **If** the examined word is able to compose a compound word **Then**

6. The other word of the compound word will be selected, according to the corollaries on compound

7. **If** the selected word is contained by database (i.e., DBpedia) **Then**

8. **Output:** one or more phrases (i.e., names of historic places) containing the selected word

9. **Else**

10. **Output:** "The input place cannot be deviated by CompoundDeviation."

11. **Else**

12. **If** the word is the last one to be examined **Then**

13. **Output:** "The input place does not contain elements for CompoundDeviation."

14. **Else**

15. Continue the examination

16. **End**

17. **Else**

18. **Output:** "The input place is not a historic place."

    End

Implementation Examples

If inputting a historic place named "Sun Bright" (see in Figure 46), several other historic places will be listed through CompoundDeviation of Deviator (see in Figure 47), which particularly focuses on utilising the natural relationship provided by compound word to deviate from one word to another. Hence, by deviating from word "sun" to words that can compose other compound words with word "sun" like "day", "flower", and so on, several results are generated. An example of DBpedia is shown in Figure 48.

Figure 46. Input of CompoundDeviation: Sun Bright

Figure 47. Output of CompoundDeviation: Sun Bright

Figure 48. Details in DBpedia: Dayville Historic District [GNU General Public License]

Another example of CompoundDeviation is shown below. A place named "Book Site" is inputted as shown in Figure 49. A list of deviated places is generated by deviating word "book" to words that can compose other compound words with word "book" like "case", "worm", and so on (see in Figure 50). The details of one of the results are shown in Figure 51.

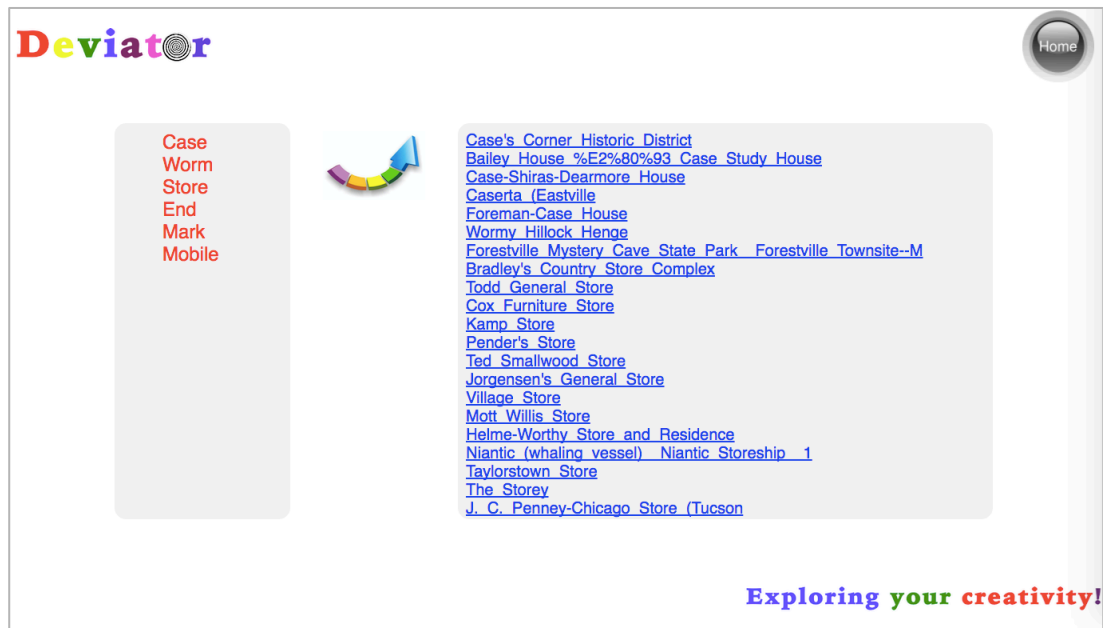Figure 49. Input of CompoundDeviation: Book Site

Figure 50. Output of CompoundDeviation: Book Site

Figure 51. Details in DBpedia: Foreman-Case House [GNU General Public License]

7.4.6 Cross-CultureDeviation

Corollaries on Cross-Culture

This section uses cross-culture cause of ambiguity to help people to do deviation, which concerns there might be various meanings of a word within different culture. A word might have totally different meanings in a different culture. For example, in Chinese culture, word "way", as a noun, includes a special meaning of "Tao" that stands for the laws of nature. If people are not familiar with this kind of interpretation of word "way", it might be easy for people to get confused. By

utilising this kind of ambiguity, the creative thinking of people might be stimulated. A verity of manipulations to help people to think through a different culture perspective is described below:

1) A different culture could be selected. Then, a sentence or phrase, which contains the input word within the selected culture, could be searched. Then, the translated sentence or phrase should be outputted.

   Example:
   a) **The Different Culture:** Chinese
   b) **Search Engine:** Wikipedia in Chinese
   c) **Input:** Way
   d) **Output:**
      "Go my way" is a Japanese musical group of the third generation of J Soul Brothers first six singles.

2) A third party perspective, such as a great ideologist or philosopher, within a different culture could be selected. Then, a sentence or phrase, which both contains the selected third party and the input word, should be outputted.

   Example:
   a) **Search Engine:** Wikipedia
   b) **Input:** Way
   c) **The Selected Third Party (Philosopher) within Chinese:**
      Lao Tzu
   d) **Output:**
      Legend of the Origin of the Book Tao Te Ching on Lao Tzu's Way into Exile

The rest of the algorithms below are all based on the corresponding translations in a different culture. Therefore,

Firstly, translation(s) in different culture of the input word should be obtained.
1) Input the word into a search engine with function of word translation, such as BabelNet;

2) Select a or more different culture(s), such as Chinese;

3) Extract the corresponding word(s) in the selected culture(s).

Example:

a) **Search Engine:** BabelNet

b) **Input:** Way

c) **The Selected Different Culture:**

Chinese

d) **Translation(s):**

Approach, Pattern, Style

Secondly,

3) One of the translations could be selected randomly. Then, utilising the selected translation as a new input to get back its associated English corresponding word(s), a sentence or phrase, which contains a randomly chosen English corresponding word, should be outputted.

Example:

a) **Search Engine:** BabelNet

b) **The Selected Random Translation:**

Pattern

c) **English Translation(s) of the Selected Word:**

Pattern, Figure, Design

d) **The Random English Translation:**

Pattern

e) **Output:**

These aspects then become ornamented with Islamic-inspired decorative patterns and Islamic cultural artefacts.

4) One of the translations could be selected randomly. It could be utilised as a new input to get semantically associated word(s) within the same culture. One of the related words could be selected randomly. Then, a sentence or phrase, which is associated with the selected word, should be outputted.

Example:

a) **Search Engine:** BabelNet, Wikipedia

b) **The Selected Random Translation:**

Pattern

c) **The Semantically Associated Word(s) within Chinese**

Hydrozoa, Ka Esi, Topkapı Palace, Decoration, Alan Turing, Biology

d) **The Random Word:**

Alan Turing

e) **Output:**

Alan Mathison Turing, OBE, FRS was a British pioneering computer scientist, mathematician, logician, cryptanalyst, mathematical biologist, and marathon and ultra distance runner.

5) One of the translations could be selected randomly. A third party perspective, such as a great ideologist or philosopher, within the same culture could be selected. Then, a translated sentence or phrase, which both contains the selected random translation and the third party, could be outputted.

Example:

a) **Search Engine:** Google

b) **The Selected Random Translation:**

Pattern

c) **The Selected Third Party (Philosopher):**

Lao Tzu

d) **Output:**

In Lao Tzu's worldview, all things exist pattern is a dynamic process, including conversion and qualitative aspects.

Algorithm

Begin

1. **Input:** a phrase (i.e., a name of a historic place)
2. **If** the input phrase is contained by the database (i.e., DBpedia) **Then**
3. Break the phrase into single words
4. **While** there is still one or more words to be examined **Do**

/*The instruction below is based on a cross-culture database*/

5. **If** the examined word contains special meanings in Chinese culture **Then**

6. The associated word(s) will be selected, according to the corollaries on cross-culture

7. **While** there is still one or more words to be examined **Do**

8. **If** the selected word is contained by database (i.e., DBpedia) **Then**

9. **Output:** one or more phrases (i.e., names of historic places) containing the selected word

10. **Else**

11. **If** the word is the last one to be examined **Then**

12. **Output:** "There is no result by Cross-CultureDeviation."

13. **Else**

14. Continue the examination

15. **End**

16. **Else**

17. **If** the word is the last one to be examined **Then**

18. **Output:** "The input place does not contain elements for Cross-CultureDeviation."

19. **Else**

20. Continue the examination

21. **End**

22. **Else**

23. **Output:** "The input place is not a historic place."

End

Implementation Examples

If inputting a historic place named "Half Way House" (see in Figure 52), several other historic places will be listed through Cross-CultureDeviation of Deviator (see in Figure 53), which particularly focuses on utilising the special meaning of a word in different culture to deviate from one word to another. Hence, by deviating from word "way" to words that stand for the different meaning like "style" and "Tao", several results are generated. An example of DBpedia is shown in Figure 54.

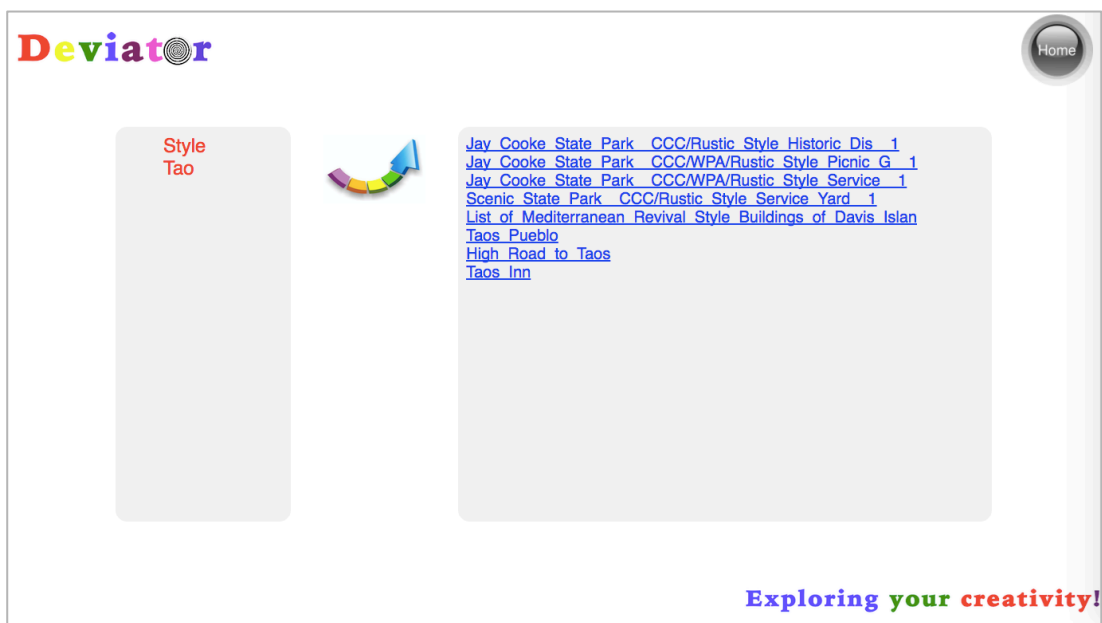Figure 52. Input of Cross-CultureDeviation: Half Way House

Figure 53. Output of Cross-CultureDeviation: Half Way House

About: Taos Inn

An Entity of Type : Ort, from Named Graph : http://dbpedia.org, within Data Space : dbpedia.org

Taos Inn is an historic inn located in Taos, New Mexico. It is made up of several adobe houses dating from the 19th century, one of which was a home of Thomas "Doc" Martin which hosted the formative meeting of the Taos Society of Artists in 1915. After Doc's death, his widow Helen Martin converted the houses into a hotel, which opened on June 7, 1936 as Hotel Martin. The name was changed to "Taos Inn" by subsequent owners.It was added to the New Mexico State Register of Cultural Properties in 1981 and to the National Register of Historic Places in 1982.

Property	Value
dbo:abstract	• Taos Inn is an historic inn located in Taos, New Mexico. It is made up of several adobe houses dating from the 19th century, one of which was a home of Thomas "Doc" Martin which hosted the formative meeting of the Taos Society of Artists in 1915. After Doc's death, his widow Helen Martin converted the houses into a hotel, which opened on June 7, 1936 as Hotel Martin. The name was changed to "Taos Inn" by subsequent owners. It was added to the New Mexico State Register of Cultural Properties in 1981 and to the National Register of Historic Places in 1982. (en)
dbo:architecturalStyle	• dbr:Pueblo_Revival_architecture • dbr:Spanish_Colonial_architecture
dbo:location	• dbr:Taos,_New_Mexico
dbo:nrhpReferenceNumber	• 82003341

Figure 54. Details in DBpedia: Taos Inn [GNU General Public License]

Another example of Cross-CultureDeviation is shown below. A place named "Apple House" is inputted as shown in Figure 55. A list of deviated places is generated by deviating word "apple" to words that represent the special meanings of word "apple" in Chinese culture, like "safe" and "sound" (see in Figure 56). The details of one of the results are shown in Figure 57.

Figure 55. Input of Cross-CultureDeviation: Apple House

144

Figure 56. Output of Cross-CultureDeviation: Apple House

Figure 57. Details in DBpedia: Safety Harbor Site [GNU General Public License]

7.4.7   ClichéDeviation

Corollaries on ClichéDeviation

This section uses the cliché cause of ambiguity to help people to do the deviation, which concerns the utilisation of cliché that can provide natural and special relationships between different words. For example, word "apple" can be associated with word "doctor" by a cliché: an apple a day keeps the doctor away, which means if you behave in a healthy way everyday, you will not get sick. A word, to some

extent, might loose its original meaning and be connected to another word(s) through a cliché. By utilising this kind of ambiguity, a variety of manipulations can be described below:

1) The most complicated (longest) cliché, which contains the input word, should be outputted.

    Example:

    a) Search Engine: ClichéSite.com

    b) Input: Apple

    c) The Cliché(s):

        An apple a day keeps the doctor away

        Apple of my eye

        Compare apple and oranges

        One bad apple spoils the (whole) barrel / bushel / lot / bunch

    d) Output:

        One bad apple spoils the (whole) barrel / bushel / lot / bunch

2) If new word(s) could be obtained by changing the first letter of the input word, the new word(s) will be inputted iteratively into the cliché search engine, to check if there is/are cliché(s) which contain(s) the new words. If so, the most complicated (longest) cliché should be outputted.

    Example:

    a) Search Engine: ClichéSite.com

    b) Input: Haste

    c) The New Word(s) by Changing the First Letter:

        Baste, Caste, Paste, Taste, Waste

    d) The Cliché(s):

        No accounting for taste

        So close, you can taste it

        Taste of your own medicine

        Haste makes waste

    e) Output:

So close, you can taste it

3) If new word(s) could be obtained by changing the first letter of the input word, each new word will be inputted iteratively together with the input word into a cliché search engine, to check if there is/are cliché(s) both including the input word and the new word. If so, the most complicated (longest) cliché should be outputted.

Example:

a) **Search Engine:** ClichéSite.com

b) **Input:** Haste

c) **The New Word(s) by Changing the First Letter:**
Baste, Caste, Paste, Taste, Waste

d) **Output:**
Haste makes waste

Else (the input word does not have associated cliché),

4) If new word(s) could be obtained by changing the first letter of the input word, the new word(s) will be inputted iteratively into the cliché search engine, to check if there is/are cliché(s). If so, the most complicated (longest) cliché should be outputted.

Example:

a) **Search Engine:** ClichéSite.com

b) **Input:** Middle

c) **The New Word(s) by Changing the First Letter:**
Diddle, Fiddle, Piddle, Riddle

d) **The Cliché(s):**
Fit as a fiddle
Play second fiddle

e) **Output:**
Fit as a fiddle

5) The synonym(s) of the input word, within the same part-of-speech, could be obtained to check if there is/are cliché(s). If so, the most complicated (longest) cliché should be outputted.

Example:

a) **Search Engine:** Oxford Dictionary, ClichéSite.com

b) **Input:** Middle

c) **Synonyms:**

Central, Mid, Mean, Medium, Medial, Median, Midway, Halfway, Equidistant, Mesial

d) **The Cliché(s):**

Ends justify the means

e) **Output:**

Ends justify the means

6) The antonym(s) of the input word, within the same part-of-speech, could be obtained to check if there is/are cliché(s). If so, the most complicated (longest) cliché should be outputted.

Example:

a) **Search Engine:** synonym, ClichéSite.com

b) **Input:** Middle

c) **Antonyms:**

End, Beginning

d) **The Cliché(s):**

All's well that ends well

At the end of my rope

At the end of the day

At the end of the pecking order

At wits' end

Burn the candle at both ends

End over end

Ends justify the means

Light at the end of the tunnel

Make ends meet

Pot of gold at the end of the rainbow

Raw end of the deal

Short end of the stick

South end of a north bound horse

Good beginning makes a good ending

e) Output:

Pot of gold at the end of the rainbow

Algorithm

Begin

1. **Input:** a phrase (i.e., a name of a historic place)

2. **If** the input phrase is contained by the database (i.e., DBpedia) **Then**

3. Break the phrase into single words

4. **While** there is still one or more words to be examined **Do**

5. **If** there is at least one word is contained within one or more clichés **Then**

6. Select a associated word within one of the clichés, according to the corollaries on cliché

7. **If** the selected word is also contained by one or more clichés **Then**

8. Select a associated word within one of the clichés, according to the corollaries on cliché

9. **If** the selected word is contained by the database (i.e., DBpedia) **Then**

10. **Output:** one or more phrases (i.e., names of deviated historic places) containing the selected word

11. **Else**

12. **Output:** "There is no result by ClichéDeviation."

13. **Else**

14. **Output:** "There is no element within the input place for ClichéDeviation."

15. **Else**

16. **Output:** "There is no element within the input place for ClichéDeviation."

17. **End**

18. **Else**

19. **Output:** "The input place is not a historic place."

End

Implementation Examples

If inputting a historic place named "Orange Springs" (see in Figure 58), several other historic places will be listed through ClichéDeviation of Deviator (see in Figure 59), which particularly focuses on utilising the special relationship between different words supplied by cliché. Hence, by deviating from word "orange" to words that are associated with it by cliché like "apple" and "doctor", several results are generated. An example of DBpedia is shown in Figure 60.

Figure 58. Input of Cliche'Deviation: Orange Springs

Figure 59. Output of Cliche'Deviation: Orange Springs

Figure 60. Details in DBpedia: Pine Apple Historic District [GNU General Public License]

Another example of ClichéDeviation is shown below. A place named "Half Way House" is inputted as shown in Figure 61. A list of deviated places is generated through finding various associated clichés (see in Figure 62). The details of one of the results are shown in Figure 63.

Figure 61. Input of Cliche'Deviation: Half Way House

Figure 62. Output of Cliche'Deviation: Half Way House

Figure 63. Details in DBpedia: Appleton Farm [GNU General Public License]

7.5 Summary

To summarise, through further reasoning, the theorem 5 (i.e., changing the negative into positive) is interpreted as "using a negative problem in a positive way." Ambiguity, as one of the crucial problems in computing field, is concerned in the study to facilitate human creativity. The most important feature of the study is not to address the phenomena of ambiguity, but to utilise the positive relationship between ambiguity and creativity to inspire human creativity. Based on different factors that can trigger ambiguity, several corollaries of creativity can be composed for Creative Computing. Unexpected but valuable relationships may be discovered through creative manipulations of the corollaries of Creative Computing. In order to mix the theory with practice, a prototype named Deviator has been developed to prove the great value of the theorem and corollaries.

Chapter 8.   Prototype Tool for Research Validation

- To propose a promising approach to validating Creative Computing
- To build a prototype of Creative Computing to validate the research
- To do a simple experiment to truly apply the prototype with the approach to validate Creative Computing

8.1   Overview

In this Chapter, the main goal is to demonstrate and validate Creative Computing. Firstly, a promising approach to validating the results of Creative Computing will be discussed. Secondly, a prototype to validate Creative Computing according to the approach discussed above will be developed. Finally, a simple experiment will be conducted to truly use the prototype by the approach to validate the prototype of Creative Computing named Deviator studied in Chapter 7.

8.2   Consideration of Validation Incorporating Bio-Sensing Technologies

Due to fast development of computing technologies, there have been a great number of bio-sensing technologies used in various fields, especially health and wellbeing. There are generally two types of biosensors: mind and body. As one of the main aims of Creative Computing is to unite new and novel technologies, the validation incorporating bio-sensing technologies will be considered as follows.

8.2.1   Mind Visualising, Measuring, and Controlling

The study of how to facilitate human creativity from a deeper level of human mind tends to be a hot trend in the realm of Creative Computing. As the fast development of Neuroscience and Cognitive Psychology, there have been an enormous number of

research results on human mind. As discussed before, due to the pervasive utilisation of computing technologies in those areas, it is time to combine the accumulated knowledge from disciplines like Neuroscience or Cognitive Psychology to advance the understanding of human mind from a computing perspective, which might be able to enable Creative Computing to facilitate human creativity better.

Furthermore, various kinds of widely used neuroimaging devices enable Creative Computing to facilitate human creativity from a deeper mind. As mentioned before, due to the fast development of human life, nowadays, people have focused on how to enjoy life, instead of just living, which triggers the continuous emergence of new technologies or devices (e.g., wearable and mobile devices). Even seemingly complicated neuroimaging technologies like EEG also have walked out of the research lab and entered into everyday life, such as the EEG biosensors (e.g., brainwave reader) from a digital company named NeuroSky.

The functions of mind visualising, measuring, and controlling provided by those neuroimaging technologies (e.g., brainwave reader) can impact the development of Creative Computing from various levels.

- o Firstly, the cooperation level can be considered. The neuroimaging technologies can cooperate with Creative Computing. According to previous study, creativity is also studied as a state of mind (i.e., sudden insight) in Creative Computing. It is believed that, when Creative Computing comes into effect, the Aha! Moment of human mind can be triggered to some extent, which enables these kinds of technologies can be utilised as kind of complementary approach to validating Creative Computing.

- o Secondly, the transformation level can also be considered. Besides monitoring effect discussed above, mind visualising, measuring, and controlling are also able to influence Creative Computing itself.

    - o The monitoring results can be further utilised by Creative Computing to facilitate human creativity better. For example, the stimulations provided by Creative Computing can be divided into different degrees

of creativity according to the variations of the mind results. By doing so, various kinds of strategies can be generated for Creative Computing to facilitate human creativity better.

o The algorithms of Creative Computing can be changed. The conventional input of Creative Computing can be changed into kind of biological data, such as signals of brain activity. Several EEG biometric algorithms (e.g., attention measurement algorithms) have already been studied. How about composing algorithms for Creative Computing based on the data directly from brain? There might be one day that Creative Computing can be able to communicate directly and creatively with human mind or become truly adaptive to facilitate human creativity.

8.2.2 Eye Tracking and Thinking

The relationship between eye tracking and thinking can provide a new approach to measuring Creative Computing. One main function of eye tracking is to measure eye movement. Accordingly, different eye movement can stand for different mind state [138], which has already been proved its great value to insight studies [81]. As the ultimate aim of Creative Computing is to facilitate human creativity that is often deemed as kind of advanced cognitive process, the improvement of Creative Computing might be achieved through recording and analysing eye movement patterns during the usage of Creative Computing.

8.3 Gamma Wave Detection

The study starts from the attempt of cooperation between Creative Computing and neuroimaging technologies like EEG. There is a validation programme implemented in the study with the function of gamma wave detection. Gamma wave is one type of brain wave, which is a pattern of neural oscillation of human. Accordingly, gamma wave is directly and positively associated with the creative moment (i.e., sudden insight) that is pursued by Creative Computing. When the creative idea suddenly comes into someone's mind and triggers the Aha! Moment, the gamma wave will increase correspondingly. The neuroimaging device used in my research is called MindWave Headset of NeuroSky (see in Figure 64), which is a company specialised

in bio-sensing technologies. By showing the movement of gamma wave, the effect of Creative Computing could be shown visually.

[Image removed for copyright reasons.]

Figure 64. MindWave HeadSet

There are two types of interface of the validation prototype: oscillogram (see in Figure 65) and spectrum (see in Figure 66). The oscillogram interface is able to show people's gamma wave movement in real time, which could show more direct effect of a typical product of Creative Computing.
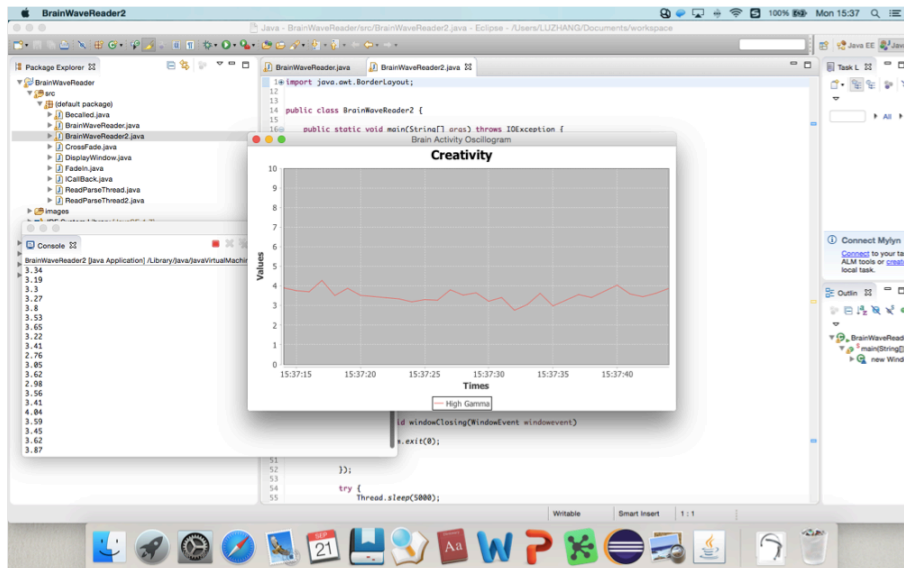
Figure 65. Gamma Wave Oscillogram

In order to create a more artistic and relaxed environment for people, the spectrum interface was developed.
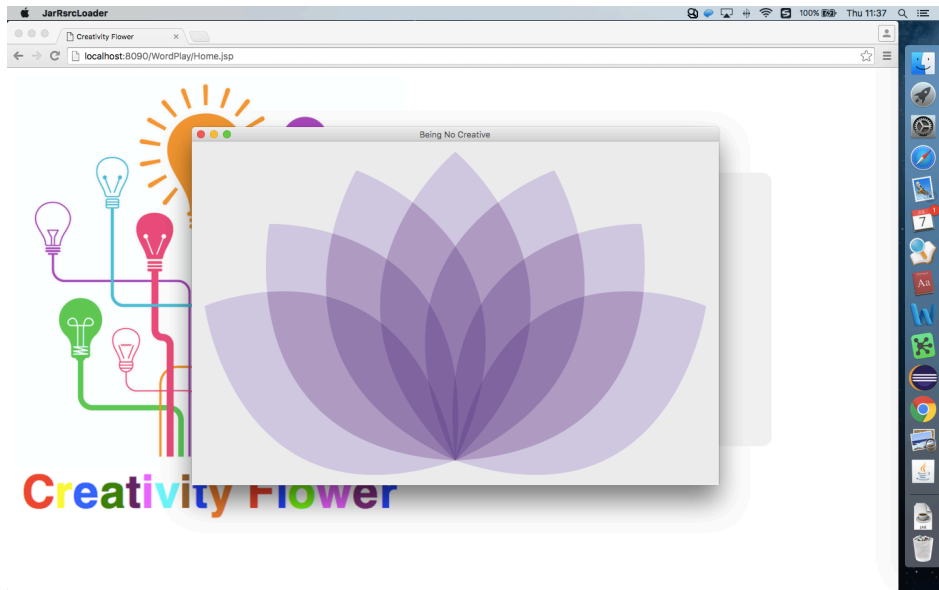
Figure 66. Gamma Wave Spectrum

Based on the interpretation of gamma wave data provided by the device, the creativity sate of people can be divided into different degrees. By using different colours to represent different degree of gamma wave (see in Table 7), it is more interesting and easier for people to see their brain state while doing creative training or tasks.

Table 7. Creativity State

Colour	Creativity State
	Being no creative
	Being less creative
	Being creative

Being highly creative
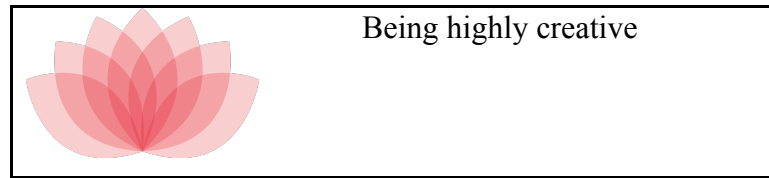
8.4 Cooperation Experiment between Deviator and Gamma Wave Detection

After the consideration of incorporating neuroimaging technologies like EEG and the implementation of the prototype with the function of gamma wave detection, it is time for the real cooperation between Deviator and the two gamma wave detection programmes. By doing kind of simple experiment to let a few people try out some interesting or surprising examples of Deviator and show the creative mind state in real time, the stimulating or enhancing effect of Deviator for creativity might be discussed and validated to some extent.

Aims of Experiment:

The experiment aims to examine:

1. If Deviator can stimulate people's creative thinking to some degree
2. If incorporating technologies of Neuroscience like EEG is beneficial for the validation of Creative Computing

Facilities of Experiment:

A laptop on which programs are running

An extended screen (see in Figure 67 and 68)

A MindWave Headset of NeuroSky
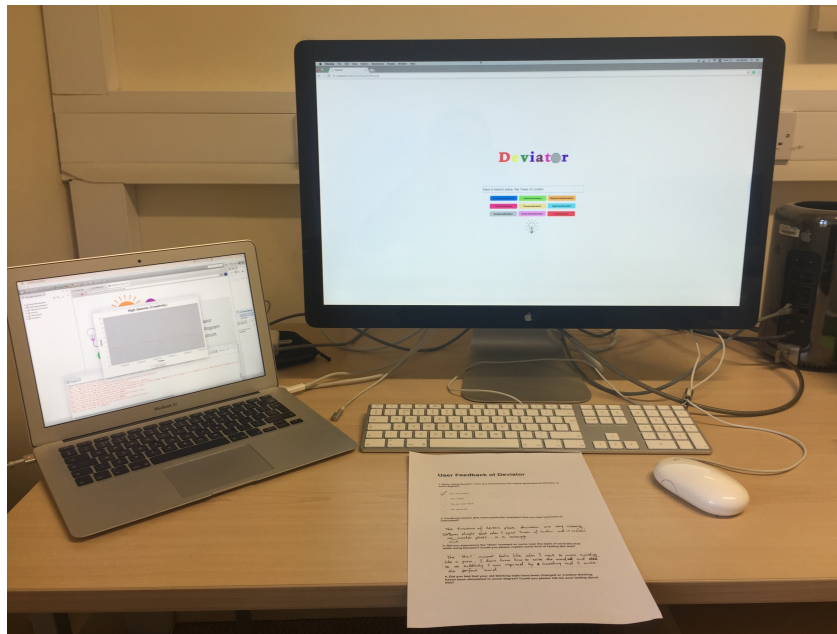
Figure 67. Facilities of Experiment: Oscillogram
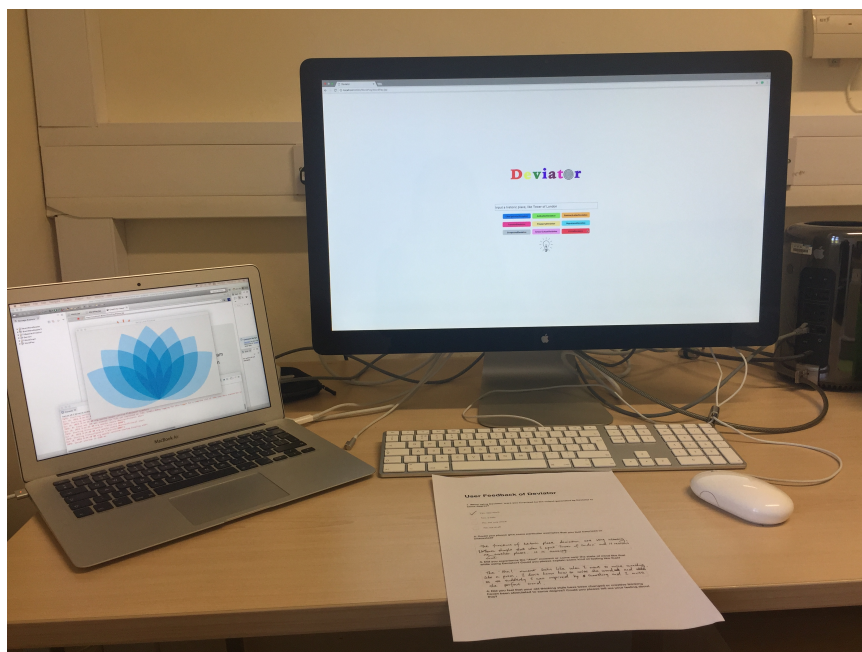
Figure 68. Facilities of Experiment: Spectrum

Steps of Experiment:

1. Recruit six people who are interested in creative things or tasks

2. Describe the experiment to the six people clearly and get consent from them

3. Design a questionnaire to collect the feedbacks from the participants

4. Each person is required to wear the MindWave Headset first

5. Each person is asked to use all of the nine deviation functions of Deviator for 5 minutes while wearing the headset

6. Each person is encouraged to pay attention to interesting examples

7. When each person uses Deviator while wearing the MindWave Headset, two types of brainwave will be recorded in real time

8. After trying out the various functions of Deviator, each person is invited to answer the questionnaire designed in step 3

8.5 User Feedback Discussion

- *In terms of the interesting examples*, when participants used the three functions of Word Tail Deviation, there are some surprising examples:

  o Hell->Help
  o Car->Ca (i.e., an abbreviation that stands for preceding a date or amount)
  o Eat->Ear

  The Word Tail Deviation is indeed able to trigger some kind of creative thinking for people. Some surprising relationships might be revealed, like "Hell" and "Help". The participant have never thought there might be a relationship between "Hell" and "Help". The meanings of the two words are even opposite to some extent. The most interesting thing is that the relationship might trigger some kind of philosophical thinking for people. Some new relationships might be found, like "Car" and "Ca". Before using the Deviator, the participant has never known the word "Ca". Some novel relationships might be found, like "Eat" and "Ear". The most interesting thing is that the two words are so close to us, but we almost never thought to connect them together.

  When people used the six functions of Phrase Pataphysics Deviation, there are some interesting examples:

  o Corsham Court ->   Wooster Square
                    The Yard
  o Half Way House -> Taos Inn
                    Newton Upper Falls

> SoHo
>
> Mother Orange Tree

o   Tower of London -> Old Spanish Trail

> Elva C Deck Boat

According to the feedbacks, the Phrase Pataphysics Deviation is more surprising to trigger creative thinking for people. When inputting a historic place, some places that the participant may never think before might be outputted to stimulate people's creative thinking. When "Corsham Court" is inputted, it can be deviated by two functions: FunctionDeviation and CompoundDeviation. Word "court" possesses a verb meaning of "woo" that can be utilised by FunctionDeviation. It can also be able to compose a compound word "courtyard" with word "yard" that can be leveraged by CompoundDeviation. Another surprising thing is that "Half Way House" is able to have so many outputs. Word "way" has special meanings in Chinese culture. It is interesting to see that it also contains so many potentials for other deviations like FunctionDeviation and even ClichéDeviation. It is also interesting to see famous historic place like "Tower of London" can be deviated to so many unknown places like "Elva C Deck Boat".

- *As for the effect of Deviator on enhancing creativity*, four of the six participants thought that they are surprised by the stimulating effect of Deviator to some degree. Some people thought it could provide some outputs that they have never thought of. Some people felt it could reveal some interesting or surprising relationships between the inputs and the outputs. Among all of the six pataphysical deviation functions, FunctionDeviation and CompoundDeviation are relatively easier to generate good results. Some participants reckoned that the Deviator could broaden their horizon to some extent.

- *In terms of the cooperation effect between the Deviator and Gamma Wave Detection*, through doing the experiment, all of the mind states of the six people was recorded while they were using Deviator. It is positive that the effect of Deviator can be showed through neuroimaging technologies like EEG. By analysing the records, it is found that as a person experienced an interesting

example or creative moment, his or her brainwave movements would change correspondingly. According to the interpretations of the EEG data provided by the headset, the average mind state of people should be around value 3 (see in Figure 69) and in the less creative state (see in Figure 70). When the value is above 4 and almost reaches 5, the mind state should be creative (see in Figure 71).
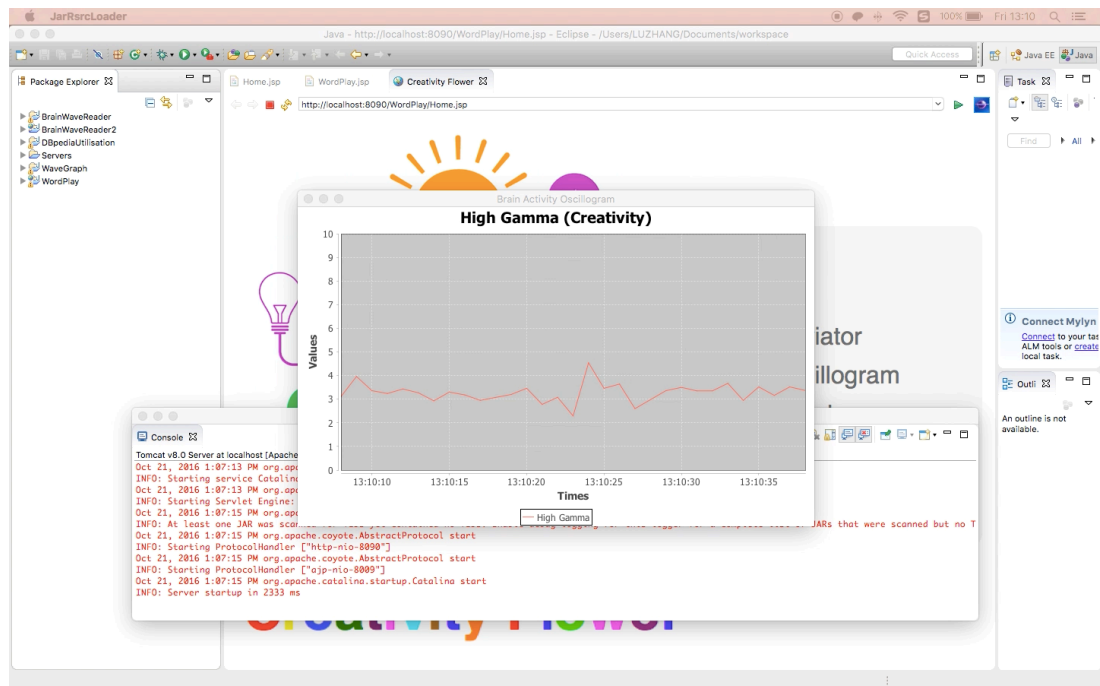
Figure 69. Creativity Oscillogram
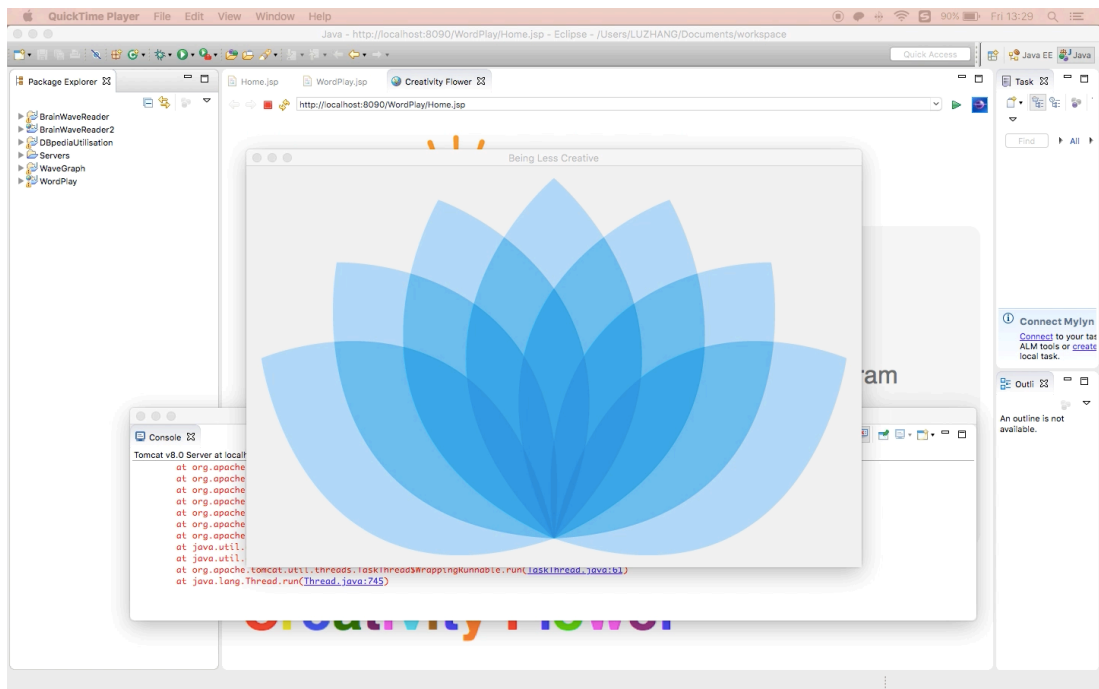
Figure 70. Creativity Spectrum: Being Less Creative
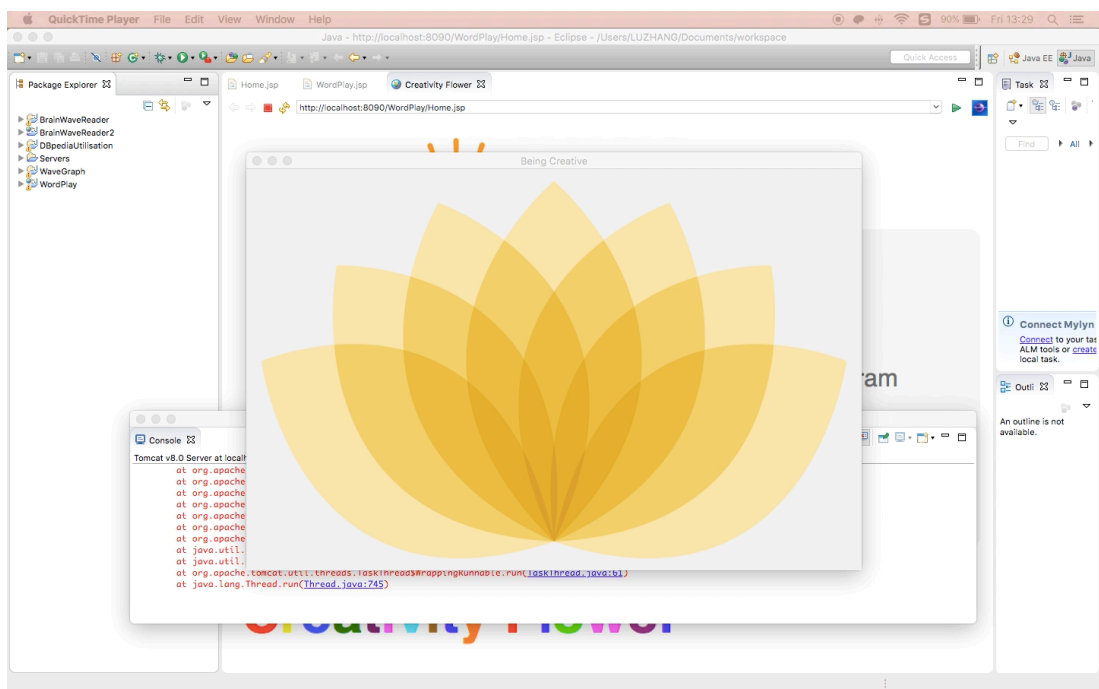
Figure 71. Creativity Spectrum: Being Creative

- *As for the shortcomings of the Deviator*, there are several suggestions provided by the participants:

o The first step to identify if the input place is a historic place is too strict. As a matter of fact, there might be no need to require the input is a historic place or even a place. People should be allowed to enter anything to free their mind.

o If there are too many deviation manipulations within one function, the relationships between the inputs and outputs might be too remote to confuse people. It would be better to classify different kinds of manipulations or stimulations into different degrees on creativity.

o The Deviator should try to spread on some other things and not limited in the historic place or digital heritage.

8.6   Summary

To summarise, due to the creative way of inspiring the creativity for people, Creative Computing also requires new approaches to validating its results. As various disciplines are becoming more and more overlapping, an increasing number of novel technologies from other fields may be able to use in the realm of Creative Computing. Particularly, as creativity is kind of cognitive process, a promising technology (i.e., gamma wave detection) from Cognitive Science is considered in the study. It is believed that the facilitation from disciplines like Cognitive Science can support the development of Creative Computing better.

Chapter 9. Future Application Fields of Creative Computing

- To introduce potential application fields for Creative Computing
- To describe typical examples of Creative Computing

9.1 Overview

In this Chapter, the eighth element of Creative Computing as a knowledge discipline (i.e., outcomes of study) will be studied. The potential application fields of Creative Computing will be introduced, within which typical examples will be described.

9.2 Visual Art, Music, and Literature

The first ought to be considered is the fields of Art, which, in common sense, are deemed as having the closest relationship with creativity. However, there are various kinds of accounts on Art, such as different forms of Art (e.g., Symbolic Art and Modern Art) derived from the historical development of Art [15]. Nevertheless, according to the great philosopher Hegel, there are five individual arts that are necessary to represent Art: Architecture, Sculpture, Painting, Music, and Poetry [73]. Over time, they can be summarised further into three categories: Visual Art, Music, and Literature.

A typical example of Creative Computing used in Art is named The Imaginary Voyage. It is an online opera application (i.e., digital opera), which aims to supply creative stimulations for musicians or people who are fond of opera. The whole organisation of the application is based on a pataphysical novel written by Alfred Jarry who proposed Pataphysics. Depending on pataphysical logics, there are five islands within the application and each island has its own features [69]. For instance, on the island named Land of Lace, there are various kinds of combinations of

materials like music, animation, and even language. Every time when a user enters the island, there can be different contents, which aims to trigger different inspirations for the user.

Here needs to introduce a particular creative technology of Creative Computing named Syzygy Surfer [110, 118], which underpins The Imaginary Voyage. It is based on one of the important concepts of Pataphysics – Syzygy [64]. It originates from a natural phenomenon of the alignment of celestial bodies, as in an eclipse. According to Pataphysics, before the understanding of the phenomenon, it will trigger various imaginary solutions. It is believed that, by leveraging the ideas of Syzygy, unexpected or surprising results can be able to emerge to stimulate or inspire human creativity.

Another example of Creative Computing in fields of Art is a project on poetry generation and analysis. By identifying and organising creative influencing factors, the project is trying to generate or help people to generate creative poetries, as such in poetry analysis. In order to do that, the main thing should be studied is how to quantify creativity into more concrete aspects, factors, or even percentages. For example, according to pataphysical theories, synonym might be deemed as 10% creative. Association is 50% creative. And dissociation is 100% creative [68].

9.3   Digital Heritage

In contemporary society, in creativity field, there is a popular tendency aiming to generate digital creativity, such as digital art. Recent research has shown that we have encountered digital revolution, which also influences and triggers the utilisation of digital technologies in Heritage – Digital Heritage. Nowadays, people have no longer been satisfied with using them for preservation and conservation any more. New use of digital technologies (e.g., 3D virtualisation) and use of new digital technologies (e.g., Syzygy Surfer) has been the key concern in Digital Heritage. That is the reason why Creative Computing might be very helpful in Digital Heritage.

A typical example of Creative Computing developed for Digital Heritage is called London Streets. It is an app for iPhone/iPad and Android devices, which can allow users to access the past through the images of the present, by utilising various multi-

layered navigation techniques [56]. At the very heart of London Streets is the idea of providing novel approaches for people to exploring the stories of the old streets of London, such as "seeing through time" by simply using a virtual lens. By moving a virtual lens over an image of the present, users are able to see what the exact same place might look like in the past. London Streets has also been considering fusing with pataphysical ideas, in order to offer more creative services and experiences for people to enjoy, such as navigating users to a totally unexpected but wonderful place.

9.4 Education

In the field of Education, creativity is always one of the most important concerns [39]. Not only students are encouraged to think creatively (i.e., creative learning and learning creativity), but also educators or related institutions are required to be creative (i.e., creative teaching and teaching creativity) [39]. Various computing technologies have been widely used and dramatically transform the domain of Education [38]. A specific field called Educational Technology (ET) has been formed for a long time dedicating to improving the quality of education, by efficiently leveraging highly advanced technologies like multimedia, electronic white board, electronic schoolbag, or even Virtual Reality (VR), Augmented Reality (AR), and Mix Reality (MR) [34, 58, 139]. In recent years, various computing technologies from ET have also been adopted to support creativity education, such as iPad apps like Educreations, Popplet, and Idea Sketch. As a new type of computing, Creative Computing not only uses pre-existing technologies, but also develops new technologies to facilitate human creativity, which makes it a perfect tool to facilitate creativity in Education.

A typical example of Creative Computing in Education is a project named BERTIE. By uniting various aspects or factors (e.g., religion, emotion, motivation, etc.) from different disciplines, a creative inspiring model is proposed. It can help students to creatively explore their potential ability, which can be very helpful for their future development.

9.5 Health and Wellbeing

The area of Health and Wellbeing considered in Creative Computing pays particular attention to people with terminal or life-restricting conditions, such as chronic illness.

Their life can be very complicated, difficult, and even desperate. It is highly anticipated that creativity is beneficial for people's health and wellbeing [80, 120]. Through exploring the creative potential for people with difficult conditions and enable them to be able to live in creative and meaningful ways, it might be a promising approach to healing the "wounds" and also a good way for personal development. As the advent of Creative Computing is to facilitate human creativity, it might be just an excellent platform to achieve that.

A typical example of Creative Computing in the domain of Health and Wellbeing is a project named Creative Skills for Life (CSL). The project aims to achieve measurable health benefits through acting on users' creative potential by making and sharing creative contents. The "creative problem solving" approach underpinning the project is utilising the creative contents as kind of medium to encourage people with difficult conditions, such as isolating conditions, to find the creative ways to live, such as virtually interacting with others through doing creative tasks together.

9.6 Gaming and Animation

Due to fast development of computing technologies (e.g., Virtual Reality), gaming and animation have always been the hot pursuit. Over time, as more and more complicated devices (e.g., Oculus, HoloLens, and Magic Leap) become widely used, researchers tend to pay more and more attention to new use of gaming and animation, like leveraging game to do scientific research and, of course, facilitate creativity.

A typical example of Creative Computing in the field of Gaming and Animation is a project that tries to design a decision-making game. Its aim is to facilitate human creativity through supporting users to make creative decisions or creatively make decisions by playing the game. In order to do that, new elements have been utilised to do Creative Computing, such as ideas of lateral thinking that are often used in psychological or artistic field.

9.7 Summary

To summarise, the outcomes of the study of Creative Computing can be applied in various domains and make different types of contributions for facilitating human creativity. It is worth mentioning that the promising application fields illustrated here

are the ones being considered in the current realm of Creative Computing. More possibilities can be discovered over time.

Chapter 10.   Conclusions and Future Work

- To summarise the thesis
- To propose the future work of Creative Computing

10.1   Conclusions

10.1.1   Revisit of Criteria for Success

In order to do the conclusions of the thesis, the criteria for success of the study will be revisited.

1) The ultimate aim of the study is to do the consolidation of Creative Computing as a knowledge discipline to facilitate its fast development. The proposed eight elements of Creative Computing have been studied.

2) Five theorems have been studied and proposed for Creative Computing. One of the theorems has been reasoned into six corollaries for Creative Computing. During the study, core ideas of the eight elements of Creative Computing have been reflected, presented, studied, conducted, and proved.

3) During the development of the theorems and corollaries of Creative Computing, the four general issues on knowledge combination have been fully studied.

The core ideas are summarised as follows.

o Urgent societal requirements trigger the advent of Creative Computing. As human life is becoming increasingly complicated, creativity, due to its mysterious power, has been the hot pursuit in recent years. It also draws great attention from computing field and an enormous number of efforts have been made by computing to facilitate human creativity. Due to its great potential, people have never stopped exploring the possibilities of computing to facilitate human creativity in new ways.

o Through doing computing in creative ways, Creative Computing can be able to provide more active services for facilitating human creativity. At the very heart of Creative Computing is the idea of combining various kinds of knowledge from diverse kinds of disciplines, especially novel ones (e.g., Pataphysics). By doing so, the problems in computing field can be studied through various other perspectives (e.g., philosophical perspective), within which novel solutions may be discovered to enable Creative Computing.

o Although Creative Computing imports various elements from other disciplines (e.g., Pataphysics and Philosophy), it is still kind of scientific research. Therefore, the rules of creativity for Creative Computing take forms as theorems, corollaries, and, necessarily, sub-corollaries. To practically apply those theories of Creative Computing, the meaning of "computing" has been studied and described in the thesis.

o Currently, Creative Computing centres on the software aspect of a computing product. A lot of interesting research topics have been summarised in the study. In particular, designing algorithms on creativity for a computing product is one of the most direct ways of realising Creative Computing. Through constructing step-by-step instructions for a computing product to compute in creative ways, a typical example of Creative Computing can be developed with the aim to facilitate human creativity.

o In order to support the composition of creative algorithms of Creative Computing, a proper structure should also be studied. As kind of general

research, the study starts from the design of a higher-level structure –
framework for Creative Computing. Based on Semantic Web that is one of
the most promising technologies to enable computing to be more intelligent
and MVC that is often deemed as the most popular web application
architectural pattern, a general framework has been proposed in the study.

o Due to its great value to creativity, Creative Computing can be applied in
various kinds of fields. Currently, Creative Computing pays attention to
several fields including fields of Art, Digital Heritage, Education, Health and
Wellbeing, and Gaming and Animation. Within potential application fields,
the future directions of Creative Computing can be summarised as follows.

o Creative Computing can be used for creative ideas and, more
importantly, creative interactions, which can be a good assist for
creative people like artists. There are creativity patterns generated
from Creative Computing. When a creator, say a musician, is stuck in
some place while playing or compositing a piece of music, Creative
Computing can be able to provide valuable suggestions to induce him
or her to find the potential directions to achieve creativity.

1) Creative Computing has great potential to supply new contents on
creativity, such as a new method to evaluate creativity. As known
to us all, there are a lot of difficulties within creativity, such as
vagueness, uncertainties, confusions, and so on, which makes it
one of the most subjective things to evaluate [105]. However,
through a perspective of Creative Computing, the results on
creativity can be more objective, which might be able to make
new contributions for the evaluation of creativity, such as
constructing matrixes to quantify creativity.

2) Creative Computing can bring creative services and experiences
for fields like Digital Heritage. Various computing services, in
modern time, tend to be more interesting, enjoyable, and playful
than conventional ones, as such in Digital Heritage. People

nowadays prefer to seek "fantastic voyage", such as deliberately getting "lost" in London, rather than follow the pre-set rules, like sightseeing lines.

3) Creative Computing can be used for creativity cultivation, especially in fields like Education. As the aim of Creative Computing is to eventually help people to form the ability to create, there are various kinds of hidden logics or knowledge (e.g., unity of opposites) behind it. Hence, Creative Computing can be a good mentor on creativity cultivation.

4) Creative Computing can provide an excellent platform for creativity potential exploration, which, in particular, can be very helpful for people with difficult conditions to find creative ways of living. There will be no things that people cannot do, but ideas that people cannot expect within Creative Computing. Through the inspirations of Creative Computing, people may be able to find meaningful things to do in a different way.

5) Creative Computing can impact new use or type of computing, especially in fields like Gaming and Animation. Creative Computing is a typical instance of new type of computing. The ideas of knowledge combination enable Creative Computing to be able to compute in different ways. Due to equally urgent requirements on creativity in Gamming and Animation, the ideas of Creative Computing may be able to bring new perspectives or methods for the transformation of fields like Gamming and Animation. Based on the advanced understanding of creativity and especially the new strategy of "Unite and Conquer", conventional ways of doing gaming and animation can be changed into creative ones by importing and combining various novel elements.

10.1.2   Limitations

Although the core elements of Creative Computing as a knowledge discipline have been studied and described in the thesis, there are still some limitations summarised as follows.

1. The ultimate nature of creativity cannot be answered. Through studying Creative Computing, it is found that in order to enable computing to be creative, the rules of creativity should be studied. The idea of Creative Computing to do that is through combing various kinds of knowledge. Due to the unprecedentedly huge number of knowledge, there should be an infinite number of possibilities for computing to be creative. However, as we cannot know the absolute boundary of knowledge, it is impossible to touch the essence of creativity. Currently, what we can do is only to reconcile the contradiction between subjective creativity and objective computing, instead of thoroughly addressing it.

2. Finding appropriate knowledge is difficult. Creative Computing is based on knowledge combination. However, the exploration of knowledge itself is difficult. Firstly, the amount of knowledge is unprecedentedly huge. While using pre-existing knowledge, people are still creating new knowledge. There is always some knowledge that we can try. Secondly, there are still various confusions on the classification of discipline around the world and the boundaries of disciplines are becoming increasingly obscure. In order to engage a comprehensive point of view, the study uses discipline as unit and tries to get the overview of all the disciplines all over the world. However, even discipline is closely associated with higher education, different institutional manifestation may have different opinions on discipline. Although some features of discipline have been extracted in the study, there is still much vagueness within the study of discipline and knowledge.

3. Evaluation is difficult. As mentioned before, there are various difficulties within creativity, such as vagueness and uncertainties. Therefore, the

evaluation of the research results on creativity is difficult. Although a promising approach to detecting the variation of gamma wave has been discussed in the study, there are also many other influencing factors of the movement of gamma wave that can disturb the evaluation. Other methods (e.g., survey) should be considered as the domain of Creative Computing is becoming increasingly mature.

10.2 Future Work

Due to various constraints, several interesting research topics that may be studied in the future are summarised as follows.

- *Future-Driven Algorithm*

  Accordingly, future thinking is one of the promising approaches to facilitating human creativity. For example, one type of mind wandering is kind of future thinking. By simply imaging the future self may be able to simulate the creative thinking. There are generally two forms of future thinking: expectations and fantasies. Compared with expectations, fantasy thinking may be more possible to stimulate human creativity. For example, the relationship between past, present, and future might be utilised to compose the future-driven algorithm to facilitate human creativity.

- *Multidimensional Algorithm*

  As people's understanding of the world becomes increasingly deeper, more and more new perspectives to study the world are continuously emerging, like the theories of multi-dimension space. Regarding the perceptible physical world as a four-dimensional space, multi-dimensional space might contain totally different contents of the world that may possess surprising relationships for computing to use. For example, five-dimensional space is deemed as kind of time plane that is composed of an infinite number of four-dimensional spaces along with a timeline. Hence, there are, in theory, a countless number of possibilities of almost every single moment within the five-dimensional space. It can be imagined that human mind, to some extent, works in the similar way of five-dimensional space. With various stimuli to break the limitations, the human mind can come up with any possibilities immediately. By utilising this kind of novel idea, another kind of

creative algorithm that might be called multidimensional algorithm might be composed for Creative Computing to facilitate human creativity.

- **Technological Algorithm**

  Although the development of technologies is triggered by societal requirements, to some extent, human life is also pushed forward by the fast development of technologies. For example, due to the advent of various wearable technologies, people are paying more and more attention to healthy lifestyle. According to this kind of idea, due to the continuous emergence of novel computing technologies, through thinking from technological perspective, new ideas might be discovered for Creative Computing to facilitate human creativity. For example, as various bio-sensing technologies become more and more widely used, how they can change the approaches to computing might be considered, which may be able to provide novel facilitations for human creativity.

- **New Type of Creative Computing**

  Due to the fast development of modern society, new computing technologies are continuously emerging. Although one of the missions of Creative Computing is to make the best use of them, when the change is fundamental, they might eventually bring new type of Creative Computing. One of the most promising is quantum computing that is based on phenomena of Quantum Mechanics (e.g., superposition). As quantum computing uses quantum bits, instead of binary bits, to manipulate data, its computing power can be enhanced dramatically, which will impose great influence on Creative Computing. Furthermore, due to the importance of Pataphysics to Creative Computing, the variation of understanding of physical world will impact greatly on the core ideas of Creative Computing.

- **New Understanding of Creativity**

  One of the main features of Creative Computing is studying creativity through an objective perspective of computing. Instead of imitating or duplicating human creativity, the core idea of Creative Computing is to utilise the uniting power of knowledge to discover the mechanisms of creativity. When we human are approaching the "absolute truths," various new understandings of creativity will

continuously emerge and eventually the ultimate answer of creativity might be answered. Furthermore, as more and more new understandings of the world emerged, such as regarding the intelligence as kind of objective existence, new point of view on creativity might also be come up with though the knowledge combination of Creative Computing.

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Appendix A

Selected Code of Prototype

package servlet;

import java.io.IOException;
import javax.servlet.ServletException;
import javax.servlet.annotation.WebServlet;
import javax.servlet.http.HttpServlet;
import javax.servlet.http.HttpServletRequest;
import javax.servlet.http.HttpServletResponse;
import wordJudgement.bean.JudgeIfWord;
import lettersVariation.bean.Changingletters;

/**
 * Servlet implementation class ControlLogic
 */
@WebServlet("/ControlLogic")
public class ControlLogic extends HttpServlet {
        private static final long serialVersionUID = 1L;

  /**
   * @see HttpServlet#HttpServlet()
   */
  public ControlLogic() {
    super();
    // TODO Auto-generated constructor stub
  }

        /**
         * @see HttpServlet#doPost(HttpServletRequest request,
HttpServletResponse response)
         */

        public void doPost(HttpServletRequest request, HttpServletResponse
response) throws ServletException, IOException {
                // TODO Auto-generated method stub

                //get the input word from index.jsp
                String inputword = request.getParameter("InputWord");

                //define a string[] to receive the results
                String[] outputs = new String[26];

```
                //it is used to judge if the input word could be changed into a new
word by changing the last letter
                boolean trueOrflase = false;

                //change the input word
                Changingletters newwords = new Changingletters();
                newwords.setInputword(inputword);
                //String[] changedwords = newwords.changeLastletter();
                String[] changedwords = newwords.changeLastletter();

                //judge if the changed word == input word
                for (int i=0; i<26; i++)
                {
                  if (changedwords[i].equals(inputword))
                  {
                        outputs[i] = null;
                  }
                  else
                  {

                        //judge if the changed word is a real word or not
                        JudgeIfWord wordORnot = new JudgeIfWord();
                        wordORnot.setInputword(changedwords[i]);
                        String result = wordORnot.search();

                        if (result == "y")
                        {
                            outputs[i] = changedwords[i];
                            trueOrflase=true;

                        }
                        else
                        {
                            String output = null;
                            outputs[i] = output;

                        }
                  }
                }

                if (trueOrflase)
                {
                   request.setAttribute( "outputword",outputs);
                   request.setAttribute( "inputword",inputword);

request.getRequestDispatcher( "Display.jsp").forward(request,response);
                }
                else
                {
```

```
                          String[] w = {"The"," word"," cannot"," be"," changed","
into"," a",
                                  " new"," word"," by"," changing"," the","
last"," letter"};
                  request.setAttribute("outputword", w);
                  request.setAttribute("inputword",inputword);

       request.getRequestDispatcher( "Display.jsp").forward(request,response);
              }

       }

}


package lettersVariation.bean;

public class Addingletters {

       // define properties
              private String Inputword;

              // define constructors without parameters
              public Addingletters(){}

              // output value of input word
              public String getInputword() {
                      return Inputword;
              }

              // set value of input word
              public void setInputword(String inputword) {
                      Inputword = inputword;
              }

              // add a letter at the back of the word
              public String[] addaletter()
              {
                      // define the returned changed words
                      String[] a = new String[26];

                      String b;

                      // define a alphabet
                      char[] a_z = {'a','b','c','d','e','f','g','h','i','j','k','l','m'
                              ,'n','o','p','q','r','s','t','u','v','w','x','y','z'};

                      for (int i=0; i<26; i++)
                      {
                              b = String.valueOf(a_z[i]);
```

```
                        a[i] = Inputword + b;
                }

                return a;
        }

}

package lettersVariation.bean;

public class Changingletters {

        // define properties
        private String Inputword;

        // define constructors without parameters
        public Changingletters(){}

        // output value of input word
        public String getInputword() {
                return Inputword;
        }

        // set value of input word
        public void setInputword(String inputword) {
                Inputword = inputword;
        }

        // change the last letter of input word
        public String[] changeLastletter(){

                // define the returned changed words
                String[] c = new String[26];

                // obtain the length of input word
                int letternumber = Inputword.length();

                // obtain former letters before the last letter
                String e = Inputword.substring(0, letternumber-1);

                // define a alphabet
                char[] A_Z = {'a','b','c','d','e','f','g','h','i','j','k','l','m'
                                ,'n','o','p','q','r','s','t','u','v','w','x','y','z'};

                // select a letter from alphabet in order
                for (int i=0; i<26; i++)
                {
                  char h = A_Z[i];
                  String g = String.valueOf(h);
```

```
                    // replace the last letter with the selected letter
                    c[i] = e+g;
                }
                return c;
        }

        // change the first letter of input word
            public String[] changeFirstletter(){

                    // define the returned changed words
                    String[] c = new String[26];

                    // obtain the length of input word
                    int letternumber = Inputword.length();

                    // obtain latter letters after the first letter
                    String e = Inputword.substring(1, letternumber);

                    // define a alphabet
                    char[] A_Z = {'a','b','c','d','e','f','g','h','i','j','k','l','m'
                                ,'n','o','p','q','r','s','t','u','v','w','x','y','z'};

                    // select a letter from alphabet in order
                    for (int i=0; i<26; i++)
                    {
                        char h = A_Z[i];
                        String g = String.valueOf(h);

                        // replace the first letter with the selected letter
                        c[i] = g+e;
                    }
                    return c;
                }


}

package lettersVariation.bean;

public class Subtractingletters {

        // define properties
        private String Inputword;

        // define constructors without parameters
        public Subtractingletters () {}

        // output value of input word
        public String getInputword() {
                return Inputword;
```

```
        }

        // set value of input word
        public void setInputword(String inputword) {
                Inputword = inputword;
        }

        // subtract the last letter of input word
    public String subtractLastletter ()
    {
        // obtain the length of input word
        int letternumber = Inputword.length();

        //subtract the last letter of input word
        String a = Inputword.substring(0, letternumber-1);
        return a;
    }

}


package wordJudgement.bean;

import java.io.File;
import java.io.IOException;
import java.net.URL;

import edu.mit.jwi.Dictionary;
import edu.mit.jwi.IDictionary;
import edu.mit.jwi.item.POS;

public class JudgeIfWord {

        //define properties
        private String inputword;


        //define constructors without parameters
        public JudgeIfWord () {}

        //output input word value
        public String getInputword() {
                return inputword;
        }

        //set input word value
        public void setInputword(String inputword) {
                this.inputword = inputword;
        }
```

```
//judge if the changed word is a word or not
public String search() throws IOException{

//construct URL to WordNet Dictionary directory on the computer
String wordNetDirectory = "/Users/LUZHANG/Documents/WordNet-3.0";
String path = wordNetDirectory + File.separator + "dict";
URL url = new URL("file", null, path);


//construct the Dictionary object and open it
IDictionary dict = new Dictionary(url);
dict.open();

// look up first sense of the input word
if (dict.getIndexWord (inputword, POS.NOUN )==null)
{

    if (dict.getIndexWord (inputword, POS.VERB )==null)
    {

            if(dict.getIndexWord (inputword, POS.ADJECTIVE )==null)
            {

                    if(dict.getIndexWord (inputword, POS.ADVERB )==null)
                    {
                            dict.close();
                            return "n";
                    }
                    else
                    {
                            dict.close();
                            return "y";
                    }
            }
            else
            {
                    dict.close();
                    return "y";
            }
    }
    else
    {
            dict.close();
            return "y";
    }
}
else
{
```

```
        dict.close();
        return "y";
    }


  }
}
```

Appendix B

Code of Gamma Wave Detection

```java
import java.awt.BorderLayout;
import java.awt.event.WindowAdapter;
import java.awt.event.WindowEvent;
import java.io.IOException;
import java.io.InputStream;
import java.io.OutputStream;
import java.net.Socket;
import javax.swing.JFrame;
import net.sf.json.JSONObject;


public class BrainWaveReader2 {

	public static void main(String[] args) throws IOException {
		// TODO Auto-generated method stub

	//open a socket connection to TGC
		@SuppressWarnings("resource")
				Socket socket = new Socket("127.0.0.1", 13854);
		//keep real-time connection
		socket.setKeepAlive(true);

		//configure TGC to output JSON format data
		JSONObject configuration = new JSONObject();
		configuration.put("enableRawOutput", true);
		configuration.put("format", "Json");
		byte[] srtbyte = configuration.toString().getBytes();
		OutputStream out = socket.getOutputStream();
		out.write(srtbyte);
		out.flush();

		//open an input to the socket
		InputStream is = socket.getInputStream();

		JFrame frame = new JFrame("Brain Activity Oscillogram");
		Becalled rtcp=new Becalled(is, "High Gamma", "Creativity", "Values");
			frame.getContentPane().add(rtcp,new BorderLayout().CENTER);
			frame.pack();
		frame.setLocationRelativeTo(null);
			frame.setVisible(true);

		(new Thread(rtcp)).start();
```

```java
            frame.addWindowListener(new WindowAdapter()
            {
              public void windowClosing(WindowEvent windowevent)
              {
                System.exit(0);
              }

            });

            try {
                        Thread.sleep(5000);
                } catch (InterruptedException e) {
                        // TODO Auto-generated catch block
                        e.printStackTrace();
                }

        }

}

import java.io.InputStream;
import java.math.BigDecimal;

import net.sf.json.JSONObject;

import org.jfree.chart.ChartFactory;
import org.jfree.chart.ChartPanel;
import org.jfree.chart.JFreeChart;
import org.jfree.chart.axis.ValueAxis;
import org.jfree.chart.plot.XYPlot;
import org.jfree.data.time.Millisecond;
import org.jfree.data.time.Second;
import org.jfree.data.time.TimeSeries;
import org.jfree.data.time.TimeSeriesCollection;

public class Becalled extends ChartPanel implements Runnable
{
    private static TimeSeries timeSeries;
    InputStream is;

    public Becalled(InputStream is1, String chartContent, String title, String
yaxisName)
    {
        super(createChart(chartContent,title,yaxisName));
        is = is1;
    }

    private static JFreeChart createChart(String chartContent,String title,String
yaxisName)
```

```
    {

        timeSeries = new TimeSeries(chartContent,Second.class);
        TimeSeriesCollection timeseriescollection = new
TimeSeriesCollection(timeSeries);

        JFreeChart jfreechart =
ChartFactory.createTimeSeriesChart(title,"Times",yaxisName,timeseriescollection,tr
ue,true,false);

        XYPlot xyplot = jfreechart.getXYPlot(); //x y

        ValueAxis valueaxis = xyplot.getDomainAxis();  //x
        valueaxis.setAutoRange(true);
        valueaxis.setFixedAutoRange(30000D);

        //valueaxis = xyplot.getRangeAxis(); //y

        ValueAxis axis = xyplot.getRangeAxis(); //y
        axis.setRange(0,10);
        xyplot.setRangeAxis(axis);

        return jfreechart;
    }

        public void run(){

                try {

                    while (true){

                        //convert input stream into string through operating bytes
                        int count = 2048;
                        byte[] b = new byte[count];
                        int readCount = 0;
                        while (readCount < count) {
                        readCount += is.read(b, readCount, count - readCount);
                        }
                        String packetstring = new String(b);

                        //tokenize the stream using the carriage return (\r) delimiter
                        String[] packets = packetstring.split("\r");

                        // iterate over each of the packets, parsing it into JSON
                        for (int p=1; p<packets.length-1; p++)
                        {
                            //filter normal data to ensure it is a object
                            if (packets[p].startsWith("{") && packets[p].endsWith("}"))
                            {
                                    if (packets[p].contains("eegPower"))
```

```
                        {
                    JSONObject
skuObject=JSONObject.fromObject(packets[p]);
                    //String m =
skuObject.getJSONObject("eegPower").getString("lowGamma");
                    String n =
skuObject.getJSONObject("eegPower").getString("highGamma");
                    //String sum = "highGamma " + n;
                    double f = Float.parseFloat(n);

                    if (f > 0)
                    {
                      double a = Math.log10(f);
                      BigDecimal d = new BigDecimal(a);
                      double c = d.setScale(2,
BigDecimal.ROUND_HALF_UP).doubleValue();

                      timeSeries.add(new Second(), c);
                      System.out.println(String.valueOf(c));
                      Thread.sleep(1000);

                    }

                    //System.out.println(x);

                        }
                    }
                }

                }
            } catch (Exception e) {
        e.printStackTrace();
    }
        }

}
```