MODULAR STRUCTURES IN MANUFACTURING AND OBJECT ART

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PRODUCT ARCHITECTURE AND MODULAR THEORY

Modularity is, of course, well established in many forms of product design and manufacture. Anything for which a production line is used will almost inevitably feature some modular components which are then assembled to produce an object or variable range of objects. We are also familiar with modular products where we as consumers have control over the final structure, with the manufacturer simply providing the components and the means to connect them: examples might include IKEA's modular furniture ranges, Portakabin's modular buildings, and Lego.

Ericsson and Erixon go on to present design criteria for modular product architecture in a suitably context-free manner as to be adaptable to modular music. Initially, they suggest a definition of product modularity as:

> …having two characteristics: 1) similarity between the physical and functional architecture of the design, and 2) minimization of the degree of interaction between physical components. Hence, the modular product platform definition of modularisation is "decomposition of a product into building blocks (modules) with specific interfaces, driven by company-specific strategies".[1]

Here they isolate one of the most important concepts in any modular structure: the interface. In any physical system, there needs to be a standardised way of joining modules in order that a variety of products can be constructed with minimal alteration of the basic modules. For example, Lego bricks have a common spacing of knobs and recesses: if these were different for each brick, they could not clip together. This needs to be considered at the planning stage of a modular product, before the products themselves are built. In order to contextualise this as part of the product development process, Ericsson and Erixon construct a hierarchy of different structural levels which should be considered when planning a modular product and production line:

> Product architecture can be treated on three levels: the product range level [the modular system], product level [items constructed from modules], and component level [the modules]. Measures to reduce complexity affect the product range, product, and component levels exponentially […] There is, therefore, a great potential for improvement if the right decisions are made at the higher levels.[2]

This emphasises the need to make the correct decisions on the product range level (particularly with regards to the interface design), as mistakes here multiply to cause significant problems at lower levels.

They go on to outline other key structural concepts in modular product design. Of particular relevance here are the subassembly and carryover, both of which will be shown to have direct relevance to modular music:

> Subassembly. The difference between a module and a subassembly should be noted. A subassembly is often the result of the assembly planning activity. Subassemblies are created because the product design does not permit entire assembly in one flow. The need for many subassemblies may be one of the first indicators of poor product design. A module, however, is chosen for specific, corporate strategic reasons and the interfaces should take the ability to be assembled into account. It is often beneficial to subassemble the modules off-line of the final assembly line. Consequently, a subassembly is not necessarily a module, but a module is often a subassembly.
> Carryover. A carryover is a part or a subsystem of a product that most likely will not be exposed to any design changes during the life of the product platform. The part, therefore, can be carried over from an earlier product generation to a later one.[3]

So a modular system consists of a conceptual rationale for its employment, a pool of modules, and an interface with which to join them. All of these are interdependent. Within this product range architecture however, whether this be in manufacturing or art context, there are two distinct categories of modular structures: open modularity and closed modularity.

Closed Modularity

Closed modular structures have a limited number of possible formations. When dealing with physical objects, there are two principal criteria which indicate that a structure is closed. Firstly, there needs to be a limiting interface which restricts the ways in which modules can be joined within the rules of the system (as defined by the requirements of the product). So to take the example of a flat-pack furniture kit, although each component module is physically separate and independently manufactured, each has a particular place in the assembled product. The interface fixes each module's position in relation to the others, so whilst it might be possible to substitute equivalently shaped modules (for example, in a different colour), most modules have a unique position which cannot be changed and although it might occasionally be physically possible to attach a shelf perpendicularly to a cabinet, the eventual use prevents this. The interface is therefore defined both by its physical connectivity options and the practical constraints of its eventual use.

The other criterion which indicates a structure is closed is that of having a limited number of modules. When combined with a limiting interface, a finite number of modules allows the creation of a finite number of objects (however large this number might be). Importantly, for a modular structure to be closed, both conditions must be satisfied. Having a limiting interface but an unlimited number of modules,[4] or a limited number of modules which can be connected in an unlimited number of ways, clearly results in an unlimited and therefore open modular system. For a closed modular structure to exist, it must have both a limiting interface and a limited number of modules.

In a manufacturing context, one of the case studies Ericsson and Erixon discuss is the Swedish winch manufacturing company Sepson. This is a clear example of closed modularity:

The modularization project generated a new concept for winches, consisting of six modules. Three of the modules were variant modules and the rest were common units.[5] With the new modular design, a typical winch uses seven modules (including two gear-box modules). Through various combinations of the six modules, 28 variants of winches can be created.[6]

There were therefore a limited number of possible modules that could be used, and a limiting interface through which they could be connected. Crucially here the interface makes the product non-extensible, and therefore closed.

A further example can be seen in object artist Carl Andre's work from the 1960s, which utilised readily obtainable building materials to produce modular structures in a variety of arrangements. His *Equivalents I-VIII* (1966) used 120 firebricks in various arrangements to test our understanding of equivalency. All the bricks are the same, and are tessellated in an identical way in each configuration: bricks placed end-to-end to form rows, which are then placed next to each other to form larger structures. This method creates a closed modular system because each construction features a limited number of modules (120) and there is a fixed interface (the bricks could not be spread randomly around the room under these conditions, for example). Although the number of permutations available is very high, it is not infinite as there are closing conditions built into the method. It should also be mentioned that in this case the interface method is driven by artistic and not functional needs: other artistic applications of the same materials with a different interface could also be found, something which is less likely in a manufacturing context.

Open Modularity

Open modular structures have an unlimited number of possible formations. As with closed structures, the nature of the interface and the number of modules has a direct bearing on defining a structure as open. Here, either of these two conditions needs to be delimited. If there is no fixed interface, any method of combination is theoretically possible, immediately creating a theoretically infinite number of structures. For example, if the Carl Andre piece were to remove the particular tessellation method as an interface, it would clearly allow any placement of 120 bricks to become valid within the work's remit. Also, if there is no limit to the number of modules that can be used, then the structure becomes continuously extensible, allowing progressively larger structures with a correspondingly larger number of permutations. Again, with Andre's work, if each configuration was not limited to 120 bricks, the structure could theoretically consist of any combination (allowed by the interface) of all possible bricks at any given moment.

Returning to self-assembly furniture, many of IKEA's storage ranges are modular in an open way as they are also extensible. For example the IVAR shelving range consists of eight side units of differing heights and depths, six shelves of differing widths and depths, and a range of cabinets.[7] These can be used to shelve out a wide variety of spaces as a result of the flexible interface between modules and the possibility of

adding to the configuration at a later date if a new use is required.[8] Whilst the interface is limited (although quite flexible), the system allows users to continually expand their configuration as required making this an open product. In contrast to other ranges (e.g. IKEA's BILLY range), customers buy the modules themselves as opposed to kits with pre-selected combinations designed to build a particular object.[9]

Within object art, Dan Flavin's work provides an example of an open modular system. Flavin's 'proposals' are constructed out of arrangements of neon lights, but whereas in much of Andre's work each unit is identical and tessellated, with Flavin there are often differences between each module (e.g. colour, size, orientation) and, more importantly, no common interface. *'Monument' for V. Tatlin* (1966-9) is perhaps closest to Andre's use of modules as the close, ordered arrangement suggests an interface and focus on the relationship of the modules to each other and the overall structure. We see it as an object, which could exist in any space. Other configurations go beyond this however. Although it clearly uses the same materials, *Greens crossing greens (to Piet Mondrian who lacked green)* (1966) cuts across the space positioning the lights in more than one plane and separating them physically.
So whilst with Andre there is a use of a single basic module which is repeated and tessellated, with Flavin these modules are varied, do not have a standardised way of relating to each other between constructions, and leak out from the object itself into the space in a more tangible way. This is a clear example of open modularity, as the absence of a common interface leads to an infinite number of permutations of even a limited set of modules.

So with closed modularity, there are a limited number of structures that can be made as a result of having a limited number of modules and a limiting interface between them. With open modularity on the other hand there are an unlimited number of possible structures due either to the lack of a limiting interface between modules, or the number of modules theoretically available.

MODULAR STRUCTURES IN TEMPORAL ARTS

Whilst many of the concepts developed in modular product platform theory are transferable to modular structures in art, they do not take into account the temporal nature of music, relating as they do to physical structures. Although there is in one sense a physical placement of objects when dealing with notation and the manipulation of score fragments, sound files, or equivalent units, the experience of music takes place in time. As a result, any interface for a piece of modular music (or literature, film, dance etc.) must regulate the degree of linearity created by resultant sequences of modules. As with object-based modularity, temporal modularity also requires both modules and an interface, but there is perhaps also a greater need for a map of the modular network given the lack of a physical trace: when constructing

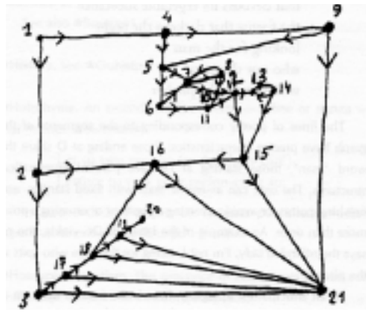
a physical object it is self-evident, whereas a temporal object is not immediately clear and must be experienced in sequence to become intelligible. In some cases, as will be seen, such notation is relatively straightforward, but as systems grow, mapping an increasingly complex set of links becomes very difficult indeed.

With temporal modularity there are also two principal interface methods: linear and simultaneous. Modules might be placed so as to follow each other or to occur at the same time, and combinations of these two methods of placement have the potential to create a rich network of inter-relations. With each, depending on the context, there will be local criteria which define the nature of the connection, but generally a rule system is in operation to determine allowable configurations within the aims of the system. Temporal modularity can also exist in open and closed forms.

Closed Modularity

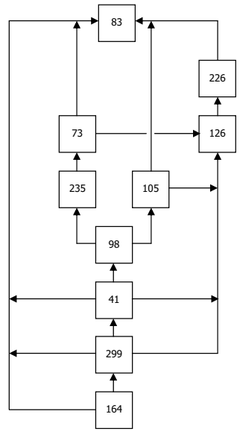
Closed temporal modular structures require both a limited number of modules and an interface which has an end condition in order to produce a limited number of formations. Many such examples exist in literature and the work of the Oulipo[10] writers in particular. Perhaps the two best known examples are by Raymond Queneau. His *Cent mille milliards de poèmes* (100,000,000,000,000 poems) (1961) was originally published as a set of ten sonnets with each line printed on separate strips of paper that could be recombined to produce 10^{11} different poems. Although there are a colossal number of potential poems which result from this method,[11] it is nevertheless closed as a structure. There are only ten lines which can act as the end of the poem and there are no feedback loops within the system. Upon reading the final line of a given version therefore, the poem is complete within the rules of the system. Importantly, whilst the rhyming structure is consistent regardless of the choice of lines made, the links between each line are nonsensical. Any line might follow any other within the structure without fear of reducing the semantic content: indeed, the poem relies on the serendipity of connections made through this approach.

The other Queneau work of note in this respect is his *Un Conte á Votre Façon* (A Story as You Like It) (1967). This brief example defines a genre much developed subsequently, that of multiple-choice narratives, familiar through many adventure stories where readers are able to choose their own route through a narrative. In Queneau's Story, the narrative centres on three peas/beanpoles/bushes and their dreams. It consists of 21 short events (modules), each followed by two choices for the reader as to the next event. Upon moving to the next event, there are again two more choices and so on until the final event (20 or 21) which concludes the story, as shown in Queneau's graphical representation of the structure in Example 1:



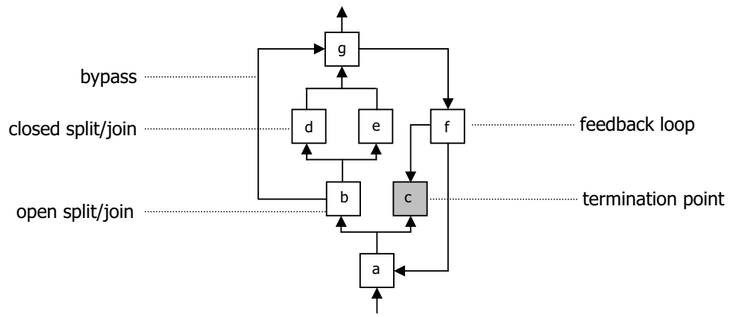
Example 1: Graph of Raymond Queneau's *Un Conte á Votre Façon* (A Story as You Like It) (1967)16

This is a multiply-directed narrative which has one start point and two end points, rendering it closed. This is also true of most of the more ambitious examples of this genre, notably the series of books created by Steve Jackson and Ian Livingstone. In their *Deathtrap Dungeon* (1984), the reader works through a series of 400 events in an effort to guide their avatar through a maze populated by hostile creatures and puzzles. Each paragraph is more substantial than with Queneau, and has between one and six exit routes, creating a relatively complex series of narratives. There are also more frequent termination points which, with the exception of the final successful outcome, result in failure of the task at hand. Jackson and Livingstone develop a range of common structural devices to organise the events in their narrative. Principally these consist of variations on a branching structure where one event opens up the possibility of two, and so on. In order to limit the complexity though, branches regularly converge to produce separate episodes within the narrative. For example, regardless of decisions made by the reader, a route through the first 64 events always ends up at event 37. In Example 2 a smaller episode can be seen:



Example 2: Diagram showing the structure of an episode in Steve Jackson and Ian Livingstone's *Deathtrap Dungeon*.

Here, the entire episode will take readers from event 164 to event 83, regardless of the decisions they make (although crucial information may only be learned depending on the events visited). There are however nine possible ways to move between these two points. Although this is not a particularly efficient example as there are fewer paths than nodes, when taken over the entire story, the number of routes increases exponentially. In such structures, a number of common formations appear:



Example 3: Common formations in printed multivariant narratives

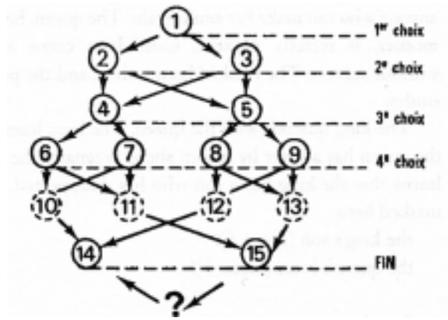
Example 3 clearly shows the function of split/join points. There is an open split at a: this decision point does not have an inevitable outcome as the path may end at c (a termination point), or go to b where it may continue to a further split at d/e or bypass them to conclude at g. The split/join at b is closed however, as regardless of the decision made, the path converges at g. There is also a feedback loop via f which allows a further tracing through the network, with the possibility of being terminated at c. The vast majority of *Deathtrap Dungeon* consists of these formations with varying degrees of complexity. The network of sieves and funnels guides the reader along an inevitable path to one of the termination points (there are 29 in total).

Without such a structure, controlling a multivariant narrative would be virtually impossible: writing out all of the possible paths as separate texts is pointlessly impractical. Within this structure though, the authors still need to manipulate the text so that whichever route is taken, the flow of text from event to event still makes sense. Some events are relatively neutral in their meaning (e.g. a choice of going west or east, leading to a new location which needs no introduction), whilst others, where interaction with other characters or objects takes place, are more loaded (e.g. attempting to elicit responses from another character and following these up without redundant duplication of information). This clearly demonstrates the interdependency of the interface and the design of the individual modules, as with object-based modularity.

The efficiency of this approach can be seen in another Oulipian example, Paul Fournel and Jean-Pierre Énard's multiple-choice theatre described in *The Theatre Tree: a combinatory play*.[13] Here too a split/join network is used. Their aim was to produce a

play with four decision points at which the audience could intervene, but realised that an endlessly branching structure would be practically impossible for actors to realise. By joining the narrative later in the play it became manageable. Fournel says:

> …the audience will be asked to choose four times, which means there will be five scenes in the play. Given that our "tree" contains fifteen scenes (four of which do not lead to choices), sixteen different plays of five scenes each may be engendered. In order to produce these sixteen plays in traditional fashion, one would have to write eighty scenes (16 x 5). We have thus economized sixty-seven scenes.[14]



Example 4: Diagram from Paul Fournel and Jean-Pierre Énard's *The Theatre Tree: a combinatory play*

Closed modular structures also appear in music. A widely used strategy is the use of mobile forms, developed initially by Earle Brown in the 1950s from the work of Alexander Calder.

Calder's mobiles connect finely balanced and brightly coloured shapes with a network of rods and wires which cause the work to move with the slightest air currents, creating a changing relationship between a limited set of parts. These mobiles always renew their shape within predefined boundaries, and are often variable during the experience of the subject (different to modular object art, which is normally fixed prior to viewing). Importantly, the elements are not detachable and cannot be recombined to produce new constructions.

In the preface to his *Folio (1952/3)*, Brown states that a mobile score is

> …subject to physical manipulation of its components, resulting in an unknown number of different, integral, and "valid" realisations.[15]

This creates a clear link to the notion of modularity, and suggests a route to its possible application in music. In practice however for the pieces in this collection, manipulation refers to the orientation of a page (*December 1952*), the placement of clefs against staves (*November 1952 "Synergy"*), the synchronisation of parts (*MM-87 & MM-135 March 1953*) and the application of tempo (*October 1952*). This is not (necessarily) a modular approach, although it shares a similar concern with creating multiple outcomes from a limited set of materials and instructions.

A closer link can be found in Karlheinz Stockhausen's *Klavierstück XI* (1956). Here an array of 19 groups (modules) are spaced on the page with no definitive ordering or implication of sequence. To play the piece, the performer selects a group at random

("the first that catches his eye")[16] and chooses the tempo,[17] dynamic and type of attack. On completion of a group, another is selected and the tempo, dynamic and attack instructions at the end of the previous group should be applied. If a group is arrived at for a second time there are some alternative interpretation instructions (mostly octave transpositions), and when a third occurrence takes place, this is the end of the piece.

Visually, the piece can clearly be seen to be constructed from modules that can be combined according to a defined method via an interface. The fact that most modules end with either a sustained sound or a pause also highlights the structure of the piece aurally, with its use of self-contained moments, perhaps emphasising the modular nature of the music (some groups end with the word binden (join) however, which might lead to a more continuous performance). Stockhausen also specifies that the piece "should if possible be performed twice or more in the course of a programme."[18] Clearly the variable nature of the piece is something that carries a proportion of its meaning and that it is important, as with Andre's *Equivalents I-VIII*, that we experience more than one version in order to understand this. *Klavierstück XI* is apparently an example of a closed modular piece: the number of modules is fixed, and there is a terminating condition in the interface (finish after the third repeat of a group).

Perhaps the best example of a modular work from this period though is Earle Brown's *25 Pages* (1953). In contrast to *Folio*, Brown combines physical manipulation of the score with a modular structure. He explains the method of preparing the score in the introduction:

> The 25 pages may be played in any sequence; each page may be performed either side up; events within each two line system may be read as either treble or bass clef; the total time duration of the piece is between 8 mins. 20 sec. and 25 mins., based on 5 sec. and 15 sec. per 2 line system as probable but not compulsory time extremities. A time structure in terms of seconds per 2 line system may be preset by the performer, obtained from the composer or be arrived at spontaneously during the performance. The indicated note durations are precise relative to each other and to the eventual time value assigned to each line system.....It will be seen that the basic "mobile" elements of the piece; page sequence and inversion, clef disposition and time; admit of a considerable number of different presentations of this material. All of these possibilities are valid within the total concept of the work provided that once a selection from the range of possibilities has been made, it be executed with devotion and accuracy in regards to the time durations, attacks and intensities. The variable factors are to be dealt with to any degree of simplicity or complexity interesting the performer. The piece may be played by any number of pianos up to 25.[19]

So here there are twenty five modules (or fifty if you include both inversions, of which a maximum of twenty five can be performed in any one version). They can be combined in a clearly stated manner (an interface) and he suggests the notion of validity in relation to this approach, implying that ways of using this material outside of the interface are not possible. Brown accepts all possible realisations if the instructions are followed with intent as being legitimate instances of the piece: this too is vital for any modular construction where the end-user has the responsibility of constructing the finished item (whether it be a self-assembly shelving system or a piece of music).

25 Pages is also seemingly an example of a closed modular piece: Brown did not write any further pages, and the interface is clearly defined. There is however a problem, and one that is peculiar to any situation where there is an element of interpretation of the finished structure before its perception. Whilst theoretically there are a limited number of permutations of the pages, orientations, and deployments of clefs, there is not a limited number of versions. Brown's suggestion that interpreters arrive at a duration for each system (and therefore the piece) that does not have a "compulsory time extremity" effectively creates an infinite number of versions. A particular arrangement of the physical material might be interpreted in an infinite number of ways, with each system lasting any fixed duration. Brown's modularity here is physically defined by two elements: page sequence and orientation (how the notation is ordered). This is then modified or customised by an interpretative layer: duration and clef disposition (what the notation means). So whilst the score can be considered a modular construction, the sounding result potentially deletes any trace of this in our experience of the music: it is a conceptual modularity.

Brown recognised this difference in his prefatory note to Folio in relation to mobility and graphic scores, stating

> ...a conceptually "mobile" approach to basically fixed graphical elements; subject to an infinite number of performance realizations through the involvement of the performer's immediate responses to the intentionally ambiguous graphic stimuli relative to the conditions of performance involvement.[20]

So only our knowledge of the score and concept behind the piece reveals this aspect of its construction. This is clearly a different situation from both Andre's and Flavin's work where however much the viewing context mediates our experience, we still see the modules and are aware of the method of construction: indeed, this is one of the principal conveyers of meaning in the work.[21]

Open Modularity

Open temporal modular structures require only the absence of an interface which has an end condition in order to produce an unlimited number of formations. If this is the case, whether there is a finite number of modules or not is irrelevant. In order for this to happen, the interface might allow repetitions and loops, layering of modules, or multiple end points. In his *For a Potential Analysis of Combinatory Literature*, Claude Berge (another Oulipo member) discusses the use of circuits in such systems. In relation to Queneau's *Cent mille milliards de poèmes* he observes that "...it should be noted that the reader advances in a graph without circuits; that is, he can never encounter the same verse twice in a reading...".[22] Essentially, the reader cannot double back and repeat a previously read line. There are however examples of multivariant narratives in which such loops form a central structural role, and produce open forms as a result.

Since the advent of hypertext, many authors have contributed to the development of hypertext fiction, a branch of literature which develops the multivariant narratives of Queneau's story and Jackson and Livingstone's adventure books (not to mention work by Julio Cortázar, Marc Saporta, B.S. Johnson, and implications of the work of Jorge Luis Borges) in computer realisations. Whilst a book is perhaps designed to project linear narratives as a result of its bound format and the progressive turning of numbered pages, blocks of on-screen text can be more easily linked without a need for such linearity. Authors have used the loosening of narrative constraints provided by the medium to produce work which deals with networks rather than trajectories.

In his *Patterns of Hypertext*,[23] author and theorist Mark Bernstein suggests a method for this by presenting a range of structural devices used by authors to control readers' progression through a story. Many of these are familiar from earlier printed examples such as those outlined above. He observes the split/join, the sieve (tree), and the cycle (loop) and in addition defines, amongst others: the contour, in which cycles interface with each other to produce larger cycles; the tangle, where a number of exit links do not give the reader a clear idea as to their direction, creating narrative confusion; and the neighbourhood, where individual episodes display associative tendencies and create stable inter-related areas of a text (perhaps referencing Erixon and Ericcson's sub-assemblies). The expansion of the cycle/loop in particular is central to open modular forms. Theoretically, endless retracings through a network may occur within a single reading. In a good example of such work, these repetitions create new relationships with the narrative as previously assimilated information is reframed in the light of new developments.[24] This feedback clearly increases the number of readings, potentially to the point where termination is a choice of the reader, rather than being enforced by the author.

Marie-Laure Ryan also discusses the properties of digital texts which create open forms in her paper *Multivariant Narratives*.[25] In the course of defining three aspects of such narratives, variable discourse, variable point of view and variable plot, she discusses Stewart Moulthrop's *Victory Garden* (1991), an early and now classic form of the genre, saying:

> The presence of circuits—the formal trademark of a network— means that there may be many different ways to get to the same node. The system designer can control the reader's itinerary on the local level (where to go from a given node) but not on the global level. This feature discourages what I call a "narrative" interpretation of the sequence viewed by the reader: an interpretation that narrowly associates the order of appearance of lexia with a chronological and causal chain of events in the reference world. And later that it:
> …does not tell a different story for every reader, or with every reading session, it rather tells a story in many different ways, varying discourse instead of plot. Approaching the text like a jig-saw puzzle, the reader rearranges lexia mentally, so that a fragment encountered at T1 in the reading sequence may be assigned time slot T22 in the reader's final reconstruction of the plot.

This then suggests that whilst the events of a particular story might be limited,

the navigation structure allows for an unlimited number of readings due to the presence of circuits in the text, and that this may in fact not tell different stories, but the same one in a variety of ways.

This is equally true of Matthias Spahlinger's *128 erfüllte Augenblicke* (128 fulfilled instants) (1975) for voice, clarinet and cello. It isolates three parameters (number of pitches, duration, and a pitch-noise continuum), each of which has four defined discrete possible states.

Spahlinger uses these possibilities to create a three-dimensional grid with sixty-four vertices. Further to this, he also specifies one of two possible changes of state: the tendency to increase or to decrease. This results in 128 separate combinations of these parameters, for each of which one instant (module) was composed. These are mostly very short, ranging from 2 to 37.5 seconds in duration, and a single long instant (.311>) lasting about 4'20". Each instant has a unique number derived from its position on the grid and its tendency to increase or decrease.

In performance, the players decide on the sequence of instants to be played. Spahlinger's preliminary remark clearly outlines the piece's open nature, as he states "the performers are free to choose the order in which they play the instants, as well as the number of times they play them or repeat them".[26] So again the presence of circuits allows an infinite number of realisations of the piece as instants can be repeated: there is no time-limiting condition or possible exhaustion of the material in these terms. The result is an open modular form. Spahlinger also recognises the fact that formally the piece has no fixed structure. Although he provides a diagram representing the relationship of the modules to each other, this gives no indication of the myriad of possible structures that might be presented. This emphasises the fragmentary (and modular) nature of the music, which Spahlinger summarises by saying:

> The fact that the musical development of this three-dimensional form cannot be depicted, separates the instants, as if they wish to exclude each other mutually, but also opens them up for each other at the same time—in a sad freedom.[27]

By creating very precisely notated modules, Spahlinger's approach is made noticeably different from that of both Brown and Stockhausen. Whilst the ordering of each module is variable, the performance of each is essentially fixed. There is no composed transformation layer where the material is modified, leading to a situation whereby modules are generally identifiable. It is possible to recognise each module given sufficient exposure, something which is much harder to do in *25 Pages* or *Klavierstück XI* where the notated material is altered by the methods stated. This emphasises the fact that the modular nature of the music might be audible and carry meaning,[28] even if the listener has no prior knowledge of the ideas behind the piece.

In this piece however, as with all the modular structures examined so far, the question of differences in meaning, if we perceive the work on its own (as a single realisation, and without knowledge of the concept) or as one of many hearings

(or the possibility of multiple hearings) remains. Spahlinger addresses the effect this might have on the listener, saying:

> The fact that the listener knows where he is without knowing where he is formally and temporally (that all, in sum, could occur differently), might contribute to making all the hierarchies …which develop between the text and context [appear] as simply temporary.[29]

So he is suggesting that one outcome of such an approach is to challenge the conventional relationship between the work and its context by disorientating the listener through the subversion of any received sense of linearity in music they might have.

One final example demonstrates a different approach to modularity. Whilst with the examples from Brown, Stockhausen and Spahlinger modularity is apparent in the sequential (re)arrangement of material, with much of John Cage's work simultaneity is also a component of the modular interface. In Cage's work, the possibility of combining sections of individual instrumental parts with themselves, with other instrumental parts in the same piece, or with nominally separate pieces is apparent. On the level of combining complete pieces, there is a selection of indeterminate music from 1957-1970 which may be performed simultaneously. In the preface to his *Song Books* (1970) Cage states this clearly:

> The solos may be sung with or without other indeterminate music e.g. Rozart Mix and Concert for Orchestra.[30]

These pieces include *Concert for Piano and Orchestra* (1957-8), all of its constituent sub-pieces *(Solo for Violin, Solo for Bassoon etc.)*, *Solo for Voice 1* (1958), *Fontana Mix* (1958), *Aria* (1958), *Variations I* (1958), *Solo for Voice 2* (1960), *Variations II* (1961) and *Song Books* (1970). The actual method for combining pieces is not precisely specified, but it is implied by the instructions for creating a performance of *Concert for Piano and Orchestra*:

> The whole is to be taken as a body of material presentable at any point between minimum (nothing played) and maximum (everything played), both horizontally and vertically: a program made within a determined length of time (to be altered by a conductor when there is one) may involve any reading i.e., any sequence of parts or parts thereof.[31] and:
> Given a total performance time-length, the player may make a program that will fill it.[32]

So the interface for these pieces is simply an agreed time-length, which might change in certain situations,[33] and the relatively open instructions for the creation of each part. It is therefore very open, in line with Cage's well-documented views on simultaneity of experience.[34] These pieces demonstrate a higher-level structural modularity, and one where the notion of distinct pieces might be subsumed into the view of a composer's work as a whole and the implication that all music is part of the modularly structured experiences of our daily lives.

His clearest modular piece though is the later *Music for* (1984-7), which consists of seventeen separate parts for voice and instruments and no score. In the subtitle, Cage denotes that there is "no fixed relation"[35] between parts, and in the performance directions that

> Played in its entirety the work will last 30 minutes. If desired, performances of shorter lengths may be given, each player independently of the others choosing an uninterrupted sequence of pieces and interludes[40] the length of which is approximately that of the agreed upon time.[41]

As with his earlier indeterminate work, a common performance duration provides the interface, but within this there is a higher degree of control of material. Each piece must begin within a specified time window lasting either 15, 30, 45 or 60 seconds, and finish within a later window of the same duration. Each interlude starts and ends at a precise time point. So although there is almost no precisely controlled synchronisation of material, within more general terms the kinds of material which might be heard together are to some extent predictable. This is true only for complete performances using all the parts and lasting the maximum duration however: if parts are missing, or if in a shorter performance players do not choose to play uninterrupted sequences of pieces and interludes which correspond to each other in relation to the time structure, then it becomes impossible to predict the result and the piece becomes more open.

This piece, in contrast to sequential modular constructions where modules follow each other and are not superimposed, opens up many more possible arrangements. The fact that modules may be combined both sequentially and simultaneously adds a contrapuntal element to the interface. In Cage's work in particular this raises the possibility of unplanned coincidences and their resonant meaning outside of music, in accordance with his general philosophy.

These examples of modular approaches to structure in manufacturing and object art, as well as literature and music, suggest some of the possibilities such strategies might offer with regards to flexibility and recontextualisation of material. The generative nature of these constructions, where a very large number of potential realisations might be spawned by a single system, gives them an additional structural level and with it an additional layer of meaning. Most of these examples are to some extent, however, limited in their scope as although they may be open and subject to an unlimited number of permutations, they are not necessarily extensible. Upon completion of the system, no new modules are added and they become locked. The possibility, then, of adopting an entirely modular approach where the design of a system is not only open but can also be extended indefinitely is a natural continuation of this work.

NOTES:

1. Anna Ericsson and Gunnar Erixon, *Controlling Design Variants: Modular Product Platforms* (Michigan: ASME, 1999), 19.
2. Ibid., 17.
3. Ibid., 19-20.
4. Although it is practically impossible for an infinite number of modules to exist, the important point is that the structure is extensible.
5. Common unit is a term used by the authors to describe a module which is present in all resultant products.
6. Ibid., 88-90.
7. See http://www.ikea.com
8. I have used IVAR as a storage system in five different locations over the past few years and in each case it has been readily adaptable to the space.
9. Although with BILLY each shelving configuration is more or less fixed upon construction, they can be combined as larger units to produce new structures. This range is therefore an example of Ericsson and Erixon's sub-assembly concept.
10. Oulipo (Ouvroir de Littérature Potentielle or Workshop for Potential Literature) was founded in 1960 by Raymond Queneau and François Le Lionnais and consisted of writers, mathematicians and academics. Their activities focused on researching the 'possibilities of incorporating mathematical structures in literary works', and 'writing which was subjected to severely restrictive methods'. See Ed. Harry Mathews and Alastair Brotchie, *Oulipo Compendium*, 2nd Edn. (London: Atlas Press, 2005) 37-44 and 205.
11. If each of the possible permutations of the poem were read end-to-end lasting a minute each, it would take over 190 million years to complete!
12. Harry Mathews and Alastair Brotchie, 155.

13. Paul Fournel and Jean-Pierre Énard, 'The Theatre Tree: a combinatory play', *OULIPO: A Primer of Potential Literature*, ed. Warren F. Motte Jr., 2nd Edn (Normal: Dalkey Archive Press, 1998) 159-62
14. Ibid., 160
15. Earle Brown, *Folio* (New York: Associated Music Publishers, 1961), Prefatory Note.
16. Karlheinz Stockhausen, *Klavierstück XI* (Wien: Universal Edition, 1957), performing directions.
17. The performer decides on six different tempi from very slow to very fast which should then be related to the six tempo markings in the score as they occur.
18. Ibid.
19. Earle Brown, *25 Pages* (Toronto: Universal Edition, 1975)
20. Earle Brown, Folio, prefatory note.
21. Links might be made with Steve Reich's *Music as Gradual Process* in which he states "I am interested in perceptible processes. I want to be able to hear the process happening throughout the sounding music.....What I'm interested in is a compositional process and a sounding music that are one and the same thing." Steve Reich, 'Music as a Gradual Process', in *Writings on Music 1965-2000*, ed. Paul Hillier (Oxford: Oxford University Press, 2002), 34- 5.
22. Claude Berge, 'For a Potential Analysis of Combinatorial Literature', *OULIPO: A Primer of Potential Literature*, ed. Warren F. Motte Jr., 2nd Edn (Normal: Dalkey Archive Press, 1998) 118
23. Mark Bernstein, 'Patterns of Hypertext', *Proceedings of Hypertext '98*, Frank Shipman, Elli Mylonas and Kaj Groenback, eds, Association for Computer Machinery. (New York, 1998). Text reproduced at http://www.eastgate.com/patterns/Print.html.
24. An experience which may be familiar when rereading a book or seeing a film for a second time where previously unnoticed incidents assume greater significance based on knowledge of their eventual outcome.
25. Marie-Laure Ryan, 'Multivariant Narratives', *A Companion to Digital Humainities*, eds. Susan Schreibman, Ray Siemens and John Unsworth. Oxford: Blackwell Publishing, 2004. 415-430.
26. Mathias Spahlinger, *128 erfüllte Augenblicke* (Wiesbaden: Breitkopf & Härtel, 1975), preliminary remark.
27. Ibid.
28. Again, a clear link can be made here with Reich's views on the audibility of compositional process.
29. Peter Niklas Wilson, 'What a composer can never compose: Notes on Mathias Spahlinger's chamber music', trans. John Tyler Tuttle, *Musica Impura*, *Accords 206222* (1998), 18.
30. John Cage, *Song Books: Volume I* (New York: Peters Edition, 1970) general directions.
31. John Cage, *Concert for Piano and Orchestra* (New York: Henmar Press, 1960), piano performance instructions.
32. John Cage, *Solo for Violin* (New York: Henmar Press, 1960), performance instructions.
33. The conductor in the *Concert for Piano and Orchestra* uses his arms to represent the hands of a clock. He controls the speed of musical time by varying their speed of rotation, thereby altering the players' predefined clock timings.
34. For example, "I would assume that relations would exist between sounds as they would exist between people and that these relationships are more complex than any I would be able to prescribe. So by simply dropping that responsibility of making relationships I don't lose the relationship. I keep the situation in what you might call a natural complexity that can be observed in one way or another." John Cage quoted in Michael Nyman, *Experimental Music*, 29.
35. "Parts for voice and instruments without score (no fixed relation), title to be completed by adding to "Music for" - the number of players performing". John Cage, *Music for* (New York: Henmar Press, 1984), title page.
36. A piece is written on two systems and consists of either a held note or a more gestural passage in proportional notation. An interlude lasts 5, 10 or 15 seconds, and consists of single notes or chords to be played in free rhythm but with the specified articulation.
37. Ibid., performance instructions.