TANGIBLE REPRESENTATIONS AND MODES OF CREATIVE ENGAGEMENT

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ABSTRACT

Tangible interfaces are finding their way into various areas of creative activity, particularly in the creation of music. Tangible representations of musical information, together with their graphical counterparts, play an important role in increasingly complex representational systems. This paper explores the relationships between these representations in the context of various modes of compositional (and by extension, creative) engagement adopted by composers in their working process.

INTRODUCTION

The purpose of this writing is to identify and explore issues surrounding the use of tangible representations in the composition of music. Particularly, it is concerned with the problem of how to scale and manipulate a tangible representation. In the context of computational creativity, our progress toward a more creative partnership with the computer will demand representations that engage in different ways than are possible with current *screen, keyboard and mouse* interfaces. My motivation here is to revisit issues uncovered in the development of the *Music Table*, an augmented reality-based tabletop music-making system(Berry, Makino, Hikawa, Suzuki et al. 2006). The *Music Table* allows players to make short repeating phrases by manipulating and arranging objects on a tabletop while hearing the musical results at the same time. Although the *Music Table* is fun to play, it shares with most, if not all, tangible musical interfaces a resistance to changes in scale and in levels of abstraction.

In a perfect world, we might enjoy the tangible, concrete and embodied aspects that make tangible interfaces attractive, yet still take advantage of the plasticity and flexibility that makes a purely graphical representation so powerful and flexible. It appears however to be an inescapable fact that a physical representation is subject to physical laws. It is almost impossible to copy, paste, stretch or squash a tangible representation in the way that one might expect to do with a purely graphical representation. Although we are talking about music composition, much of what is discussed could well apply to other creative activities where a tangible representation might be desirable.

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It is my belief that a combination of augmented reality techniques, combined with an informed approach to manipulating the various levels of representation in such a system, can allow a composer to attempt composition on a longer time scale than is possible with existing tangible music systems. Making a new tangible music system that could represent music on a larger scale is the ultimate goal of this exploration. To this end, it is necessary to consider existing theory about cognition, representation, composition, embodiment and tangible interfaces and how they might inform the design of tangible interfaces that allow a more flexible type of interaction and representation. To begin with, we will look more closely at the process of musical composition.

ON MUSIC COMPOSITION

There appears to be little empirical research on composition as a process. Sloboda (Sloboda 1985) notes that there are basically four things we can look at to learn more about composition, particularly as a cognitive process, these are: existing examples of scores and working sketches by composers; composers' own writings and remarks about their process; live observation of composers and analysis of 'think aloud' protocols resulting from observed sessions and fourthly, observation and description of improvisatory performance .

INSPIRATION AND EXECUTION

Using terms coined by composer, Roger Sessions, Sloboda identifies two distinct phases as follows: *inspiration* - a phase where the composer first becomes aware of basic thematic ideas, then *execution* – a phase where the most viable basic material is extended and developed. Sloboda also stresses the importance of a history of listening whereby a composer develops the ability to choose which raw materials and subsequent manipulations will be effective. Sloboda notes the central role of notations of various kinds at all stages as an important feature of the composition process. Different composers exhibit different use of scores, particularly in working sketches. Mozart would often write the melody and bass lines almost completely in one sitting then, judging by the change of ink, he would later fill in the middle parts. Beethoven would make endless little sketches of works over periods as long as twenty years, where Stravinsky would build up quite complex vertical structures quite early in the process, and would develop a piece over a relatively short period of time.

Sloboda highlights the importance of exploration on an instrument as a characteristic of the *inspiration* phase and refers to Sudnow's descriptions of learning jazz improvisation and how he learned to 'find' the right notes and patterns with his hands. The importance of physical moves on an instrument in the creative process signals to me the hidden representational role of the instrument, especially in the hands of a composer. The instrument provides affordances and constraints that serve to restrict, but also to map out a small sub-space of the greater space of all musical possibilities for a composer. In its representational role, the traditional instrument used in composition has many connections to a tangible music interface such as the *music table*. First and foremost is the way that it allows for exploration of musical possibilities and provides feedback about the consequences of the player/composer's physical moves about the instrument or representation. The relationship between representation and control is similar in both traditional musical instruments and tangible interfaces. The frets on a guitar fingerboard serve to give visual and tactile clues as to where the fingers should be placed to produce particular notes. However, it is the very presence of a fret at that location that determines the note that will sound. In tangible interfaces, the tangible elements usually serve dual representation and control functions (Ullmer and Ishii 2000). The original *Music Table*'s note blocks represent, by their position on the table, the position of notes on the pitch/time axis but they also send instructions to the computer to tell it when and how to play these notes.

BROWN'S MODES OF COMPOSITIONAL ENGAGEMENT

Dividing composition into two phases could easily be read as sequential stages of a developmental description. However, a composer may in fact regularly move from one phase of operation to the other during the course of a given composition. This hints at *inspiration* and *execution* being better described as *modes* of operation in the composition process, each with their own different style of thinking. Brown tries to make this more explicit by breaking down the composition process into a number of *modes of compositional engagement (Brown 2001)*. While Sloboda is speaking primarily about composition of western European tonal music by traditional methods, much of what he says can also apply to computer-based and other types of composition that make up contemporary practice. The idea of there being fundamental elements to composition, common between contemporary and traditional practitioners, is also explored by Brown through interviews with contemporary composers about their work process in general and the role of the computer in that process.

Brown identifies five kinds of engagement between a composer and his or her compositional medium. The names reflect both the various roles of the composer and the corresponding role of the medium in each case.

Observer – Artefact

> Here the composer stands apart from the composition and tries to observe it as an audience or critic – to see it *as it is* and not in terms of its potential.

Director – Tool

> Here the composer acts to direct and manipulate the compositional medium as a tool. In this mode the *composer as director* is very much in control of the medium. This corresponds closely to the *execution* phase described by Sloboda.

Player - Instrument

> This mode is more improvisatory and intuitive than conscious or deliberate in nature. This is close to the *inspiration* phase described earlier. It does not have to be on a physical instrument, nor does it require realtime feedback from the medium. This mode of engagement, when using a live instrument, can appear a lot like improvised performance. However, the way a composer engages with an instrument in this mode is different to a performer engaged in performance. Here again, I see the instrument itself in a representational role as a map traversed by the composer. Even in the case of computer music practice, Brown quotes Lansky as describing his work on low-level programming at the computer as "…sort of improvising in real-slow time." Lansky's description of his process could easily spill into Brown's fourth mode of engagement, the *Explorer – Model* mode.

Explorer – Model

Here the systems, both technological and theoretical (for example, tonal or microtonal systems of harmony and voice leading, serial techniques and rule-based systems), that form part of one's compositional medium, are treated as a place in which to explore. In Brown's words,

"The medium externalises musical ideas which can then be viewed from many perspectives, reflected upon, and further explored. The medium acts as a cognitive amplifier for the composer in its ability to leverage ideas by building upon the stored knowledge in its symbol systems and existing procedures, and by capturing concepts and freeing up the mind for new thoughts".

Papert uses the term, *microworlds* (Papert 1980) do describe such models for exploration, especially in the context of computer-based learning about mathematics. He likens it to creating a special country where a person can go to learn the language. He describes the computer as a *math-land* where children can go to learn the language of mathematics from its native speaker, the computer. A tangible representation can potentially make such a *microworld* something to be experienced bodily.

Selector - Creator

The fifth mode sees the composer abandoning control to the systems and process in the compositional medium, be it a set of game rules, an algorithm, a chance event etc. The medium takes the role of *creator* and the composer takes a more curatorial role in *selecting* from the output of whatever process has been set in motion.

It would be tempting to more cautiously say 'generator' instead of 'creator' in this case (Brown actually uses 'generator' rather than 'creator' in his PhD thesis), but that might be to labour under the assumption that creativity takes place exclusively inside the heads of human beings. Writers such as Zhang and Norman (Zhang and Norman 1994) and Hutchins (Hutchins 1995) place a part of our cognitive process out in the world where we think with the aid of external, and often shared, representations. The feeling of partnership or one-ness with the compositional medium reported by some of Brown's interviewees could be seen as an instinctive awareness of the distributed nature of cognition.

Brown's modes of engagement are not intended to be exclusive of one another, in fact the composer might behave in ways that suggest more than one mode at a time and rapid transitions from one mode to another and back again.

BROWN'S MODES AND TANGIBLE REPRESENTATIONS

Although Brown's paper is not heavily cited, I see much in his model that rings true from both my own experience as a composer and from my reading. Brown's emphasis on the interplay between the composer and the compositional medium in terms of paired roles points to the kinds of activities that a music composition tool might need to support. Conveniently, the composer's roles yield a set of verbs: *observe, direct, play, explore* and *select*. I believe that these can help frame my research in terms of which of these activities are being supported by physical representations at any moment in the composition process.

Tangible music interfaces like the *Music Table* offer a working process that is deliberate but spontaneous where changes in a musical pattern are experienced as physical moves with an immediate musical result. Such interfaces might then be more suited for some modes of engagement than others. For example, the *Player – Instrument* mode could be well supported by a tangible representation since it is traditionally accomplished with a physical instrument and there are many parallels in terms of the level of physical involvement and the intuitive level of action characteristic of both instruments and tangible interfaces.

A tangible approach to the *explorer – model* mode would depend heavily on how effectively the tangible elements represent the model, or models, being explored by the composer. It will also depend on how well the tangible elements allow control of the model and whether the pathways for control are intuitively coupled to the representation. For example, Iwai Toshio's *Composition on the Table* (Iwai 1999), as well as many of his other works, provide an interaction environment that provides a model for the gallery visitor to explore. The tangible aspect may be no more than a grid of switches but it provides a map of the model in real space and the human body must move in that space in order to manipulate it. The original *Music Table* was a simple representation of pitch and time as a flat tabletop, so it only supports this mode in a limited way. The reacTable* (Jordà 2003), on the other hand, provides a more complex tangible representation of a sound synthesis model that demands significant exploration in order to understand it.

The *director – tool* mode demands a more depth-oriented approach and a mutability of tools that is not well served by tangible interfaces in their current state of development. Current technologies can still be used to support this mode of compositional engagement, but with a degree of compromise depending on whether one prefers the advantages of a purely graphical interface/representational system or those of a purely tangible one. If the latter, the *director – tool* mode might be a very frustrating activity. One could simply go to another tool, such as a commercial desktop music composition program while in this mode, however, it would then be difficult to go back to other modes when the need arises. How to support this particular mode of engagement using tangible representations and interaction promises to be an interesting and potentially very rewarding challenge.

The *observer – artefact* mode is one that is difficult to maintain on a traditional instrument on account of the effort and focus required to play a new piece of music even without also trying to dispassionately reflect upon it and hear how it is working. Traditional instrumental composers had to rely on their skill at an instrument to enter this mode, unless they had the luxury of other musicians to pay the piece back to them. Compared to a traditional instrument, because the *Music Table* does not require trained and refined motor skills to operate, it is easier to step back from one's work and reflect on what is being made (Makino et al. 2005). The ability to appreciate the artefact at different levels of scale – to assess how well it 'works' both as a whole and in specific details is probably only marginally served by a tangible representation although the tangible elements could provide intuitive ways to control one's view. One could also speculate that, when looking critically at a physical representation, a player may, through seeing and touching a physical pattern in space, have a different intuition about the pattern and how it works than by simply hearing it.

In general, Brown's *modes of engagement* potentially offer a lens through which to view the significance of different ways of working, different activities, different cognitive styles and, consequently, different tools associated with different modes of compositional engagement.

DISTRIBUTED COGNITION AND REPRESENTATIONAL SYSTEMS

Many authors mention the importance of representation in tangible interfaces, but often in the context of the technological systems needed to maintain them. Ullmer (Ullmer and Ishii 2000) for instance makes a distinction between physical and digital representations to distinguish between the tangible objects and the graphical images on the screen. These kinds of distinctions are important from an engineering perspective where the functionality of the various subsystems is paramount. However, the groupings of system components may not correspond with how a human interacting with the system perceives and manipulates the representations. From the human perspective, a tangible interactive environment can be seen as one overarching representation.

Zhang and Norman (Zhang and Norman 1994) argue that certain types of tasks require us to process information distributed across a person's internal mind and the external environment. They claim that traditional cognitive science has tried to describe such tasks purely in terms of an internal representation and has diminished the role of external representations as merely aids to cognition rather than as a part of cognition itself. This has led to models of overly complex internal representations where Zhang and Norman would argue that the complexity is really a reflection of complexity in the environment.

They focus on three main problems:

1. The distributed representation of information
2. Interaction between internal and external representations
3. The nature of external representations

An important point is that a task may involve more than one representation and the representations can be internal and external. Together they make up what the authors call a *representational system*. This term is helpful for me because, so far in my readings, I have been irritated by the separation of what I see as one big representation into different representations according to arbitrary and usually technological boundaries (real/virtual, physical/digital, tangible/intangible, graphic/haptic etc.). Although I see the practicality of such divisions when dealing with the logistics of building such environments, I don't think it effectively describes what is actually happening when someone engages with a tangible interactive system. I am also reminded of Dourish's assertion that it is the user who makes the meaning out of the interaction, not the designer (Dourish 2001 p172).

Zhang's use of the term *representational system* helps resolve some of this for me because, by describing it as a system, it keeps in mind the idea that representation is a process not a static monolithic object. As a term, it also signals that, as a representational system, there are likely to be sub-systems of representations or representational components within it. This reconciles the idea of one overarching system of representation with that of multiple representations assuming different roles and linkages within it.

Zhang divides the distributed representational space into internal and external, representational spaces, each containing any number of representations with changing linkages between them. When the internal and external representational spaces are combined into a distributed representational space, they form a representation of the abstract task space. Zhang points out that, in a system of any level of complexity, the person engaged in the activity does not really think about the representation space as representing anything in particular. Instead it is seen as the medium through which the activity gets done. That is why a technology or systems-centred description of representation does not really get at how we actually use representations in our activities.

Another important insight from Zhang and Norman's work is that external representations can be used to render implicit the information that could otherwise only be explicit in an internal representation. For example, physical constraints can enforce a rule in a puzzle that would otherwise have to be remembered and recalled if expressed internally. The user can use the information without even being aware of the fact that they are using it. Related to this, external representations can also anchor and structure cognitive behaviour. By physically constraining the range of possible behaviours only actions relevant to the problem space are possible.

From the system's point of view, by rendering information implicit, external representations make the task easier for the user. However, from the user's perspective, external representations actually change the nature of a task because they do not have to be aware of rules and other information that otherwise they might have to explicitly consider. Finally, external representations are an essential and defining part of distributed cognitive tasks and one cannot really be considered without the other.

Although intended as an approach to the study of cognition, Zhang and Norman also claim that their approach can yield design principles for effective representations, especially where the task is distributed across internal mind and external environment.

I am concerned more with external representations than internal ones, but the relationship between the two is still important, and music is a highly abstract phenomenon in terms of how we listen to it and how we create it. In moving between external representations in the *Music Table*, the role of internal representations must be also considered. In other words, what elements will be explicit and require a decision or management by the player, and which ones will be implicit in the physical layout of the interface? For example, even though the mapping of up-down to pitch and left-right to time is something the player must be aware of and remember, because traditional western notation follows this convention (as does written text for the time dimension at least), it is not something that needs much memorization on behalf of the player. The same is true of mapping rotation to loudness in imitation of volume controls in electronic equipment. Zhang and Norman's study also found that, of all the possible parameters in an external representation, location was the one that was most quickly remembered easily processed by the subjects, giving map the two most significant musical parameters to two locational parameters in the representation. In the case of tonal music, these are pitch and time.

As the kinds of manipulations we use to manage the couplings between the various representational sub-systems will require some learning on the part of the player, it is probably better to try and constrain the complexity of the player's internal representation by constraining the choices in the environment.

EMBODIED REPRESENTATION

The word *representation* can refer to a thing, but it also refers to the process by which such a thing can come about. Dourish (Dourish 2001) echoes phenomenological philosophers in saying that it is our action in the world that gives the world meaning for us. The representations that concern Dourish are those that are in some way embodied in the world. The embodiment itself is not purely physical however, but a function of our being in and participating in the world. The cultural and social settings of our activity are also a part of what Dourish calls embodiment. Embodied representation can be externalised and distributed (in line with Zhang and Norman and Hutchins).

Embodied representations of the world are also participating parts of that world, and embodied computation not only represents the world but participates in and changes the world.

In the *Music Table*, any change to the representation also affects the music being represented as well as played. As an embodied representation of the music, the representation is part of the music itself and will probably have subtle effects on the actual music produced in comparison with that produced by *piano, pen and paper*. In the sense of being a process, the music is not just the sound but the whole process that leads to its production and consumption. The whole purpose of the act of representing is to enact change to that which it represents. In the case of creative music activity, this initial representation may start out as a blank piece of paper or a musical instrument sitting quietly in a corner of the room silently representing a space of musical possibilities.

Even when viewed as a representational system, technologies and materials will necessarily be different for different modes of perception and modes of interaction. This makes multimodal representations hard to integrate with each other in practice. Within the one representation, there may be several sub-representations at work at any time. This makes it important to study the linkages between them.

COUPLING

An important concept for Dourish is the idea of *coupling*, a concept derived from Heidegger's writings about tool use. Coupling is primarily concerned with control and describes how we act on some things through others. A simple example of this would be how a familiar tool, such as a computer keyboard or a hammer, ceases to be something that we *act on* and becomes something we *act through* instead. Coupling is manifest as a process rather than a fixed state, and various functional elements are regularly coupled and decoupled in the course of a particular activity. We are *acting on* the hammer when we take it out of the toolbox and bring it to the job, but we are *acting through* the hammer when we commence banging in the nail. Rather than being seen as a breakdown in transparency, and therefore to be avoided, decoupling and re-coupling is an important part of how we move between different kinds of activities and how we engage and disengage with the tools we employ to carry out those activities. The management of coupling will be an important part of any design where the context and scale of a representational system frequently needs to be reconfigured.

In the *Music Table*, there are a variety of couplings at work. Couplings occur between elements of control and elements of representation, so *coupling* and *mapping* become almost interchangeable. *Mapping* could more generally be seen as *coupling* at a representational level. The most obvious coupling is between the physical objects and the graphical elements that follow them. The augmented reality registration in 3D between real and computer-generated objects strengthens this coupling because the objects are seen on the screen as being literally stuck together from the point of view of the camera. At the same time, the player can see the real objects because they are there in plain view on the tabletop without the graphical augmentations.

It is often enough for us to interact with the physical objects without graphic augmentations. Blocks can represent and control pitch and time without our needing to hear the musical result. However, the blocks also offer control over the loudness of notes by rotating the block in place on the tabletop. Rotation is a method that we are culturally primed to understand as loudness through our use of volume controls on audio devices so it makes sense to map it this way in the *Music Table*. We could say that clockwise rotation and loudness of sound is a coupling that is embodied in our cultural understandings of the action. It also makes sense that, when saved to a phrase object, the same clockwise rotation on a phrase object would increase the overall sound level of the whole phrase. Here, although the object itself has its own absolute rotational state relative to the tabletop, the rotational gesture is coupled with an incrementing and decrementing of the loudness of the actual sound and the state of the graphical elements of the representation. The blocks also offer control of the length of a note event (the time between turning the note on and turning the note off) by tilting the block to the right or left. Here the physical block has almost no representational role, apart from suggesting that one direction is less and the other is more. The state is communicated back to the player by the graphics and the sound of the music. Once again it would serve us to retain this coupling at a coarser level of detail by using the left-right tilting action to change the overall note lengths or articulations for the entire phrase when manipulating a phrase object.

When a group of notes are saved as a phrase, one object takes on the role of several objects manipulated as a larger pattern. At some point, it will be necessary to retrieve the original pattern of notes in a form that allows individual notes to be edited without affecting the others in the grouping. Unless we can magically make the original note objects reappear in the exact positions of the notes, some way must be found to smoothly effect a changing of roles between the various tangible objects available to the player at the tabletop. Here coupling is crucial as it becomes necessary to decouple note objects from notes and to re-couple with them others in order to recover, edit and reconfigure different patterns.

CONCLUSIONS AND THOUGHTS FOR EXPLORATION

The existence of multi-levelled representational systems (levels of scale and levels of abstraction) is one of the key ideas to emerge from the process of this writing, along with the idea that, if our cognition can be distributed across our mind and the environment, our creativity can be also something that partly happens out in the world around us, including the very medium we aim to creatively shape. If the computational process is also interdependent with what is happening in the physical world then computational creativity also becomes hard to pin down as taking place purely inside the computer(Berry, Makino, Hikawa, Inoue et al. 2006). Separating representation from what is represented becomes an equally slippery concept. Managing the movement between levels of representation (including levels of detail and of abstraction) is one of key design challenges and areas for exploration through the development of a new prototype *Music Table*-like system planned to address and explore these issues. The concept of coupling is also be an area for expansion and investigation, not only coupling in the sense of links between representations, but in the Heideggerian sense of whether we act *on* or *through* the representational and control elements of an interface. How the coupling process manifests across different layers and levels of representation, as well as the implications for different functionality for physical behaviours in interaction, will also be a focus for ongoing research.

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