ABSTRACT
This paper summarises the author’s PhD research on the representation and control of time in tangible user interfaces. The aim of the research is to create a theoretical framework that can aid the design of new temporal-media tangible interfaces.

Author Keywords

ACM Classification Keywords
H.5.2 User Interfaces: Theory and Methods

General Terms
Design, Theory

INTRODUCTION
The research question for the thesis arose from the experience of designing new tangible user interfaces (TUIs) for digital musical instruments. In some aspects TUIs provide an ideal method of interaction for music - they can be intuitive, accessible, multi-user and, most importantly, fun. In other aspects TUIs have some severe limitations that prohibit their use in a serious professional music capacity - namely scalability, flexibility and cost. The thesis aims to address these problems by creating a theoretical model of time in TUIs that can be used to aid the designer of new temporal-media TUIs.

BACKGROUND
Four research areas form the background to the thesis: tangible user interfaces, time understood through embodied interaction, interaction design and digital musical instruments. The Tangible User Interface paradigm, and the bringing together of ‘bits and atoms’ [2], forms the core of the research. In brief, tangible interfaces ‘give physical form to digital information, employing physical artifacts both as representations and controls for computational media’ [7]. A number of established theoretical models exist, and given that temporal-media TUIs are a subset of TUIs in general, these existing frameworks and theories provide a good starting point from which to formulate a new theory specifically addressing the design of temporal-media TUIs.

ADAPTING THE MCRIT MODEL
As temporal-media TUIs are a subset of tangible user interfaces in general, it was decided to adapt an existing and proven TUI theoretical model. The Model, Control, Representation (intangible/tangible) (MCRit) [8] theory was chosen, as it logically divides a TUI into distinct components that can then be discussed in relation to temporal-media. Interaction designers tend towards using simpler theoretical models over those that are complex or prescriptive, and the MCRit model provides a level of analysis that encourages its use in practical design situations. The following sections describe the parts of the original MCRit model and how they have been adapted for interaction with temporal media.

Temporal-MCRit: Model
The model in the original MCRit theory is the computing system behind the control and the representation elements. Simply put, the goal of a TUI is to give the user the illusion of physically and directly manipulating the model, without experiencing the mediating layers of representation and control. In order to adapt the MCRit theory to specifically address temporal-TUIs, the question is asked ‘how will a user understand the model?’ The proposed answer is that time is
understood through metaphor, so the most important factor in designing a model for a temporal-TUI is to address the metaphor used in the presentation of the model.

**Temporal-MCRit: Control**
The control element of the original MCRit theory describes the part of the TUI that the users manipulate. One of the aims of TUI research is to make the control element and the tangible representation elements as closely linked as possible, so that the illusion of interacting with a coherent and whole object is maintained. The problem with controlling a temporal system is that the thing needing to be physically controlled (time) is inherently not physical. The proposed method of controlling time is to either encapsulate time within an object (control through containment or embodiment) or to place a handle on time (control through a peripheral object).

**Temporal-MCRit: Representation (intangible/tangible)**
The representation element of the original MCRit model is split into both tangible and intangible elements. In a temporal-TUI it is proposed that the important aspect to consider is that time can only be represented through change. A perhaps obvious observation, but nonetheless important is that a static temporal-TUI would not be able to effectively represent temporal-media. An exception is the possible use of entropy as a means of statically representing times direction, but in general it is maintained that in a temporal-TUI the representation will incorporate some form of change, whether tangible (physical motion, modulation of form etc.), or intangible (motion of light, colour, sound etc.).

**THE BEATBEARING**
The BeatBearing [1] tangible rhythm sequencer (see figure 1) has been used during the development of the adapted MCRit theory as a test-bed for the emerging concepts, and as a spring-board from which concept designs can be developed. The BeatBearing is simple in operation, allowing the user to place ball bearings into holes on a 4x8 grid, constructing a rhythmic score played by a red line sweeping underneath the grid triggering sounds as it strikes the ball bearings. The simplicity of the design encourages the asking of ‘what if...?’ design questions, helping to populate the temporal-TUI design space with many possible design variations of the BeatBearing.

**EVALUATION OF TEMPORAL-MCRIT**
In order to evaluate the use of the temporal-MCRit theory as an aid to design, several variations of the BeatBearing have been developed, simulating possible design choices both with full knowledge and conversely with no knowledge of the temporal-MCRit theory. A user study has recently been completed; early analysis of the data indicates that application of the theory can result in temporal-media TUIs that are easier to understand and use.

**FURTHER WORK & CONCLUSION**
The next step in the PhD research is to use the temporal-MCRit model to generate a series of concept designs exploring the more detailed aspects of the theoretical model. The aim of the concept designs will be to validate the existing theory and to point out ways of both refining and expanding beyond the basic model. Currently, one design path for an advanced temporal-TUI is that of the ‘Hierarchical-TUI’, based upon the premise of nesting tangible elements (and time frames), allowing the construction of complex hierarchical structures. Early work on these concept design indicate that they may shed new light on many common design problems relevant to TUI design in general, including the scalability of data structures, saving/recalling workspaces and actuation of the tangibles.

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**REFERENCES**