DYNAMIC CONCEPTS MAPS FOR MUSIC

Tillman Weyde
Research Department of Music and Media Technology
University of Osnabrück, Germany
tillman.weyde@uos.de

Jens Wissmann
Institute of Cognitive Science
University of Osnabrück, Germany
jens.wissmann@uos.de

Abstract. Concepts maps are used to represent domain knowledge, mostly by attaching word labels to a static graph. For concepts and relations which unfold in time, this representation is not well suited because temporal relations have to be mapped to static ones. This can be useful to understand and memorize structures, but it detaches the representation in the map from its temporal nature. One approach of introducing dynamics into concept maps is the integration of multimedia elements. These elements can display dynamic content like audio and video, but do not affect the map's structure. The temporal aspect of a domain can be represented in a concept map by changing the appearance of nodes or edges over time. A second approach is to change the perspective on the map, e.g. showing a different part of the map, and a third one is to change the structure of the map dynamically. The first and the third approach have been realized by the authors in a prototypical software for mapping musical structures. Music provides an excellent test bed for dynamic concept maps, since is has complex inherent temporal structures (e.g. harmony, rhythm, form). Our software supports dynamic mapping by using dynamic nodes displays, e.g. with a cursor highlighting the song position, and by allowing to change the structure according to music playback, e.g. showing only nodes that are currently played back, or building up a map during playback.

1 Introduction

Mapping-techniques are tools for supporting cognitive representation of complex domain knowledge. There are several different variants in use, like Concept Mapping (e.g. Novak & Gowin, 1984), Mind Mapping (e.g. Buzan & Buzan, 1993) or Knowledge Maps (O'Donnell et al., 2002). All of these use spatial, network-like representations for knowledge construction, organization and presentation. They visualize domain knowledge as graphs with nodes, representing concepts or objects, and edges, representing relations or actions. As Jonassen (1992, p. 21) points out: „concept maps are representations of the cognitive structure, perhaps crude and simplistic, albeit effective in helping learners describe and analyze their knowledge structures".

There has been an ongoing discussion, which concrete map structures are adequate cognitive representations and therefore suitable to use. Concept Mapping approaches have traditionally focused on the use of textual propositions and hierarchical positional structures. In the last decade concept maps have been enriched with multimedia objects. One of the approaches is described by Alpert & Grueneberg (2001), who point out that there are different kinds of mental representations and that it is important to incorporate these to support the learner's with their individual differences (like needs or preferences in expression or learning style) when using concept maps to demonstrate their own knowledge or acquire new knowledge.

There are various arguments to include images in maps. Mental models include both propositions and imagery (e.g. Kosslyn, 1980 & Johnson-Laird, 1983) and are probably separately coded (Baddeley, 1982, p. 212). Furthermore there is evidence that memory for visual imagery is more robust than for purely textual information Shephard (1967) and that information that is encoded both visually and verbally is more memorable (Paivio 1986). An important aspect of mental representation is its temporal dynamic nature (Johnson-Laird, 1983). Most maps are static, even when their content is dynamic in time. This aspect is especially important for instructional visualizations of procedural knowledge, or with acoustic information that is processed and stored in auditory memory (Dowling & Harwood, 1986). Heeren and Kommers (1992) showed that incorporation of temporally dynamic visual and aural elements in a concept map knowledge representation tool enhances its "flexibility of expressiveness", giving users enhanced means of representing their knowledge.

Approaches like that of Alpert & Grueneberg (2001) focus on the integration of temporal dynamic and aural content encapsulated in the nodes of a map. Temporal changes in the overall presentation of the graph have been explored mainly to enhance the layout of graph and or in the context of creating and editing maps, but not in relation to temporal concepts.

While pen and paper offer virtually no means of make map dynamic, this is well possible with computers. Among other benefits, modern computers offer the option to realize dynamic and interactive software for maps.

Maps can automatically be generated from or linked with existing data. Computers can control and layout dynamic maps in playback or user interaction.

2 Mapping Concepts and Relations to Time

Dynamic mapping requires the identification of temporal properties of the content elements and of ways to map them in a dynamic manner. Examples for temporal properties of concepts are begin time, duration, or behavior over time. A concrete example would be the change of phases in a combustion engine. Relations can include succession, synchronicity or exclusion, for instance the fuel flows into the cylinder when the inlet valve is open, the fuel flows out after it has been burnt. If a node represents an object with a complex dynamic behavior, dynamic displays are a useful means of reification, as in the example of a motor's internal parts or the movement of an animal. This has been described by Alpert & Grueneberg (2001) and O'Reill & Samarawickrema (2003), but only as a means of illustration. Nodes and relations may change their appearance according to time, and synchronizing the contents of several multimedia elements can give an enhanced impression of their temporal relations and interactions. E.g. in an illustration of the moving parts inside a motor and the flow of gas and fumes, nodes may be 'camshaft' and 'valve', a relation could be 'opens'. Here a synchronized animation is very helpful to make their relations visible.

A step further in dynamizing maps is to create dynamic views on the map. E.g. a map display could be centered around one or several active nodes, or magnification effects like hyperbolic projection could be used. The size of the nodes or their distance can be changed over time. The last step in is to dynamize the map itself, i.e. its graph structure. When nodes have times of activity, they may be introduced when they are active, or removed when they are inactive, or both to render a cumulative, subtractive, or momentary map. This approach is useful when concepts change over time, like in history, or when a complex temporal development shall be represented.

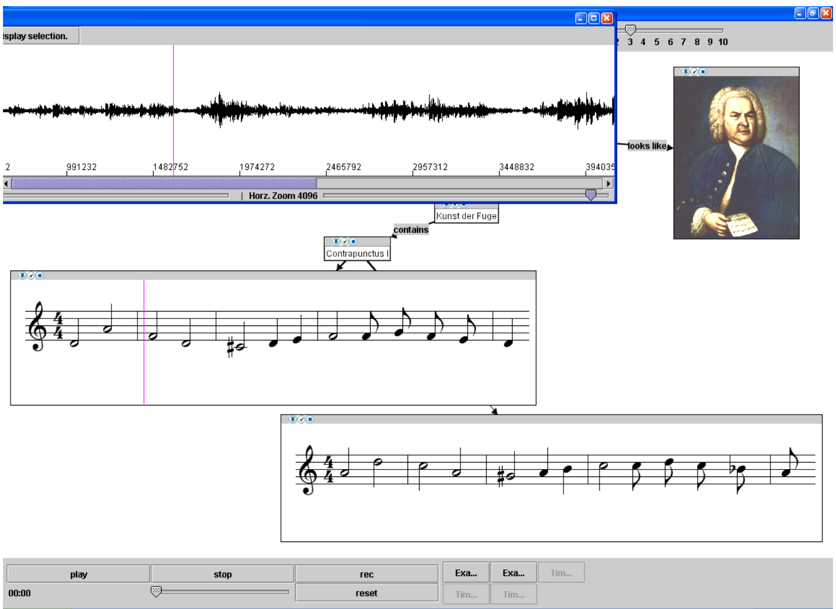


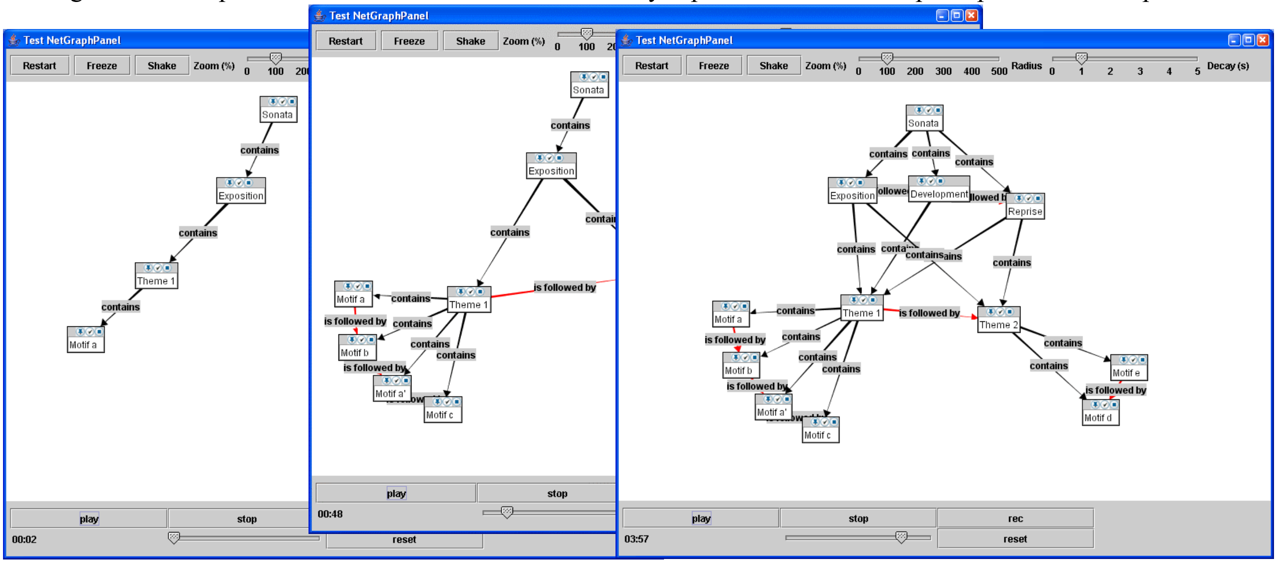
Figure 1. Musical objects are integrated as nodes in a concept map and can synchronize to playback.

3 Dynamic Concept Mapping Applied to Music

We developed a mapping software prototype that changes the overall arrangement of the presentation in time to support knowledge acquisition with a temporal component. For this purpose we focused on the domain of music, which has a complex intrinsic temporal structure. Declarative concepts can be used to describe musical structures (e.g. score, notes, harmony etc.) or relate the music to its context (e.g. composer, performer, historical background). In our application, relevant concepts for a given piece of music are presented in a concept map. When the piece is played back, the information presented in the map is synchronized with the music. The implementation is based on the MUSITECH framework (see Gieseking & Weyde, 2002), which provides an object model for musical contents and structures.

In addition to object representations of musical content, structures and metadata, the MUSITECH framework also contains display components for various musical objects as well as general multimedia elements. These components can be used as nodes in the music map (see Figure 1). Depending on the used display component, a node may not only have viewing but also editing abilities. Many of these components can display the current position synchronously to music playback (e.g. score displays). The length of the edges can automatically be adjusted to represent time relations between the musical events in the map. To relate the music to the objects of the maps, the color of nodes and edges can be changed according to the current playback position. However – this does not affect the map's structure.

Musical structure is normally described with reference to form prototypes, like the Fugue or the Sonata form as general concepts of musical form. These can be easily represented as a concept map. A first example is the



Sonata form shown in Figure 2. The objects in the map have references to the timeline of a piece of music. The music map is dynamically adjusted to current playback position by inserting nodes into the network, when their musical content is being played. So the structure of the Sonata is built up cumulatively while playing. It shows the succession of the motifs in the themes, the themes in the sections and the sections in a movement with succession relations in red and containment in black. The length of the succession edges corresponds to the time between the connected objects. The relation between motifs, themes and sections is apparent through the structure concept maps.

Figure 2. A concept map representing a sonata form is cumulatively build up while the sonata is played

The map can be enhanced by introducing further information, e.g. using nodes that represent the current harmonic context. One can present all structural levels going down to the single musical-note played. But here a question arises on which level of granularity is appropriate for the presented information. In dynamic presentations the level of granularity is more important than in static concept maps in terms of usability, because if the map is too complex and changes too much in a short time it is hard for a user to keep the overview.

Another question is the time window of the events in the map. It might be helpful in some learning scenarios to introduce concepts in the map before they are actually listened to in order to prepare the listeners to pay attention to a certain structure, e.g. an important motif. Further it depends on the learning scenario how long information in the map is presented. In the Sonata example one would probably like to see the structure build up during the complete playback. In a case like presentation of the currently audible notes or text the information has to disappear quickly or be faded out when their context disappears.

4 Conclusions

The relations of music within itself and to its context can easily be represented in concept maps. Like with other abstract matters, the visualization and the interaction help users create and use internal cognitive representations. In music, there is a particular need for this, because music contains complex non-hierarchical structures. The introduction of temporal aspects into the map enhances the abilities of maps to illustrate musical knowledge and relate it to musical listening experience. Therefore dynamic maps are an adequate tool for handling temporal information. However – the behavior of the dynamical presentation must be well coordinated in order to give an impression of the connection of the audible music and the presented concepts. The first experiences with the use of dynamical maps for music encourages further work in the direction of dynamic concept maps.

Further research could explore whether the relation of the temporal structure of music and diagrams can be put on a more formal basis. Inspiration for this research could come from the research on temporal logic that Sowmya and Ramesh (1994) have successfully applied to statecharts, or the visual models of discrete-state transition system introduced by Harel (1987).

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6 References

Alpert, S. R. & Grueneberg, K. (2001). Multimedia in Concept Maps: A Design Rationale and Web-Based Application. In Proceedings of ED-MEDIA 2001, World Conference on Educational

Baddeley, A. (1982). Domains of recollection, Psychological Review, 89, 708-729.

Buzan, T. & Buzan, B. (1993). The Mind Map Book. BBC Books, London.

Dowling, W.L. & Harwood, D.L. (1986). Music Cognition. Academic Press., Orlando FL.

Gieseking, M. & Weyde, T. (2002). Concepts of the MUSITECH infrastructure on for interactive Internet-based musical applications. In: Proceedings of the Second International Conference on Web Delivering of Music, Darmstadt 2002.

Harel, D. (1987). Statecharts: A Visual Formalism for Complex Systems. In: Science of Computer Programming 8, 1987, pp. 231 – 274.

Heeren, E. & Kommers, P.A.M. (1992). Flexibility of expressiveness: A critical factor in the design of concept mapping tools for learning. In P.A.M. Kommers, D.H. Jonassen, and J.T. Mayes (Eds.), Cognitive Technologies for Learning (pp. 85-101). Springer-Verlag, Berlin.

Johnson-Laird, P.N. (1983). Mental Models. Cambridge, UK: Cambridge University Press.

Jonassen, D. (1992). Semantic networking as cognitive tools. In Kommers, P., Jonassen, D., and Kosslyn, S.M. (Eds.). Image and Mind. Cambridge, MA: Harvard University Press.

Kosslyn, S.M. (1980). Image and Mind. Cambridge, MA: Harvard University Press.

Novak, J. & Gowin, D. (1984). Learning how to learn. Cambridge University Press, New York.

O'Donnell, A., Dansereau, D. & Hall, R. (2002). Knowledge maps as scaffolds for cognitive processing. Educational Psychology Review, (14 (1)):71–86.

O'Reilly, J. & Samarawickrema, G. (2003) Using multimedia concept maps to enhance the learner experience in Business Law. In Proceedings of EET 2003

Paivio, A. (1986). Mental Representations: A Dual Coding Approach. New York: Oxford University Press.

Shephard, RN. (1967). Recognition memory for words, sentences, and pictures. Journal of Verbal Learning and Verbal Behaviour, 6, 156-163.

Sowmya, A. and Ramesh, S. (1994). Extending statecharts with temporal logic. Technical report, School of CSE, UNSW, Sydney, 1994.