THE USE OF LOGIC AS A DESIGN TOOL IN COGNITIVE MUSICOLOGY

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Introduction

Musicology as a cognitive science deals with aspects of mental musical information processing. One of its aims is to arrive at a process model of musical activity such as listening, composing and performance.

In this report we concentrate on a process model of musical listening. An account is given of a control structure for knowledge driven perception which relies to some extent on a logical system, called dynamic dialectical logic (developed by Batens, 1986).

Below are summarized some of the central ideas that were presented at the Conference.

Aspects of reasoning

The conception of listening used comprises the idea that the cognitive aspect of listening amounts to the acquisition of musical knowledge. We distinguish three types of reasoning with respect to this acquisition process: categorization, network construction and network use. Categorization concerns the process in which the input information flow is segmented and chunked into musical units figuring in a mental representation. These musical units, called *basic* structural units, are taken as a point of departure to construct a network. Network construction is the process in which relationships are established between structural units and new *derived* structural units are generated. The result is an associative network of structural units and relationships that stand for the musical knowledge contained in the mental states of a listener. Such a network we call a dynamical hierarchical network: DHN (Leman, 1986).

Finally, the third type of reasoning involved uses musical knowledge to process new incoming information. On certain appropriate conditions a DHN will be used as a hypothesis concerning the information flow expected. Confirmation or rejection of the expectations may change the character of the network used. The remainder of this report is entirely concerned with the aspect of default reasoning in music. Logic is used as a design tool for the formal implementation of default reasoning in cognitive driven perception.

Network use

A DHN is conceived as an associative structure which reflects the intramusical knowledge of a listener. Studies in music perception and learning reveal that perception is to some extent cognition driven. When a DHN is taken as a prospective hypothesis concerning the information flow, two situations may occur. Either the new information matches with the default values of the hypothesis or it does not. The first we call confirmation, the second we call rejection. Confirmation means that the new incoming data are consistent with the hypothesis, rejection means that the incoming data are inconsistent with the hypothesis.

The effect of confirmation is that the new information can be very quickly processed and integrated into the existing knowledge structure. The system need not traverse the processing steps all over again and processing time is liberated which may be used for higher level processing of the data available. Confirmation thus can be seen as a kind of perceptual leraning.

The effect of inconsistencies may be that a train of thought is completely interrupted. According to Meyer (1956) this interruption is the principal cause of emotion in music.

However, it may occur that only a small part of the hypothesis is inconsistent with the new data. Consequently, the hypothesis will be adapted and the new data will be incorporated in an updated musical knowledge structure.

Below we describe a formal implementation of this control structure. Its design is partly based on dynamical dialectical logics, henceforth DDLs. DDLs restrict the rules of inference with respect to the statements which behave inconsistently. This makes them particularly interesting for application in expert systems and systems that use default reasoning.

The basic idea behind DDL is that all rules of the standard Propositional Calculus do apply, except in those cases where it turns out that premisses are inconsistent. DDL thus assumes consistency of the set of premisses but when inconsistencies are derived a special instruction is invoked that deletes all steps which turned out to be derived on the basis of this inconsistency.

The application of this idea to the management of knowledge driven perception in the realm of music is straightforward.

Formal implementation

We first introduce a new formalism for the description of network construction. Afterwards this formalism is extended to handle aspects of network use.

The formalism of describing the steps taken during network construction is reminiscent of a proof in the Propositional Calculus. We adopt the following convention: (i) Basic structural units are treated as premisses. (ii) Procedures which detect relationships between structural units and which generate new units are interpreted as inference rules. (iii) relations and structural units derived are conceived as conclusions or derivations. They are arrived at by application of the inference rules to the premisses and/or other units derived. The description obtained is a combined declarative/procedural representation of a DHN. For example:

(1) SU1	PD	CAR	SU1
(2) SU2	PD	CAR	SU2
(3) immsucc (SU2, SU1)	(1), (2)	IMMSUCC	SU1, SU2
(4) almid (SU2, SU1)	(1), (2)	ALMID	SU1, SU2
(5) SU1/2	(4)	CIR	SU1, SU2
(6) instan (SU1, SU1/2)	(4), (5)	INSTAN	SU1, SU2
(7) instan (SU2, SU1/2)	(4), (5)	INSTAN	SU1, SU2
(8) SU3	PD	CAR	SU3
(9) immsucc (SU3, SU2)	(2), (8)	IMMSUCC	SU2, SU3
(10) SU1-2-3	PD, (1), (2), (8)	COR	SU1, SU2, SU3
(11) comp (SU1, SU1-2-3)	(1), (10)	COMP	SU1, SU2, SU3
(12) comp (SU2, SU1-2-3)	(2), (10)	COMP	SU1, SU2, SU3
(13) comp (SU3, SU1-2-3)	(8), (10)	COMP	SU1, SU2, SU3
(14) SU4	PD	CAR	SU4
(15) immsucc (SU4, SU3)	(8), (14)	IMMSUCC	SU3, SU4
(16) instan (SU4, SU1/2)	(14), (5)	INSTAN	SU4, SU1, SU2

Basic structural units (premisses) are written as SUn (n=1,..,i,j,..). Though they contain in fact the information of the musical data structure, these data are not represented here (a more detailed account is presented in Leman (1986)).

Relations discovered between structural units are notated as R(SUi, SUj). Derived structural units are of two kinds in this representation: generalized units, notated as SUi/j and conjunctive units, notated as SU1-2-3. The rules of inference are CAR, IMMSUCC, ALMID, CIR, INSTAN, COR end COMP. CAR is a concept formation rule which reflects the process of categorization. IMMSUCC is a production rule which detects the relationship of immediate successor. ALMID, INSTAN and COMP produce the respective relationship of almost identity, instantiation and component. CIR and COR generate derived units, respectively generalized units and conjunctive units.

The rules may be conceived as independent modules ("demons") that continuously scan the incoming information. The results of their activity are fired on a blackboard structure.

Making abstraction of the fifth column, this representation is very close to an ordinary proof in PC or its predicative counterpart. However, restrictions must be taken into account with respect to the insertion of premisses: these depend upon a time dependent categorization process. The detection of relationships and new units is also dependent on the processing available and the allocation of processing resources.

If a DHN is used as a prospective hypothesis then the basic structural units, i.e. the elements from which all other relations and units of this network are derived, are assumed to behave consistent. In the representation this is achieved by writing down for each line that contains a premiss (as its second element) this premiss as the fifth element. This element is called the consistency condition and its value is assumed to be true in absence of any information to the contrary. Those derivations which rely on lines that contain consistency conditions take over these conditions in their fifth element. For instance: the second element of line (16) is derived from lines (5) and (14). Hence its conditions are those of line (5) which are SU1 and SU2 and line (14) which is SU4.

The control of this prospective hypothesis involves two procedures, called REJECT and CONFIRM.

REJECT is invoked if the default value (i.e. a basic structural unit that is assumed to be true in absence of any information to the contrary) doesn't match with the new incoming data. Then all lines which contains this unit in their fifth element are deleted. Consequently part of a prospective DHN may thus be rejected.

CONFIRM is invoked if the default value matches with the new incoming data. Then this value is deleted in the fifth element of all lines which contain this value in their fifth element.

Below is shown what happens when first SU1 is confirmed, SU2 is rejected and SU3 is confirmed:

(i) Confirmation of default value SU1 causes the deletion of SU1 in the fifth column.

(ii) The occurrence of an inconsistency between the next new data and the default value SU2 causes the deletion of all lines that contain SU2 in their fifth element.

(iii) Confirmation of SU3 causes the deletion of SU3 in the fifth column.

The resulting DHN representation at this moment is shown below:

(1) SU1	PD	CAR	0
(8) SU3	PD	CAR	0
(14) SU4	PD	CAR	SU4
(15) immsucc (SU4, SU3)	(8), (14)	IMMSUCC	0
(17) SU2*	PD	CAR	0

Notice that line (14) still contains a default value. Line (17) is added to the network because of the fact that SU2* was distinguished from SU2.

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