Encoding Scores for Electronic Music

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Abstract

A perspective on the specific issues of music encoding dealing with Electronic Music is presented. In many cases the works to be discussed exist in a fixed media format and hence no prescriptive score is necessary to facilitate a 'valid' performance. While there are a number of descriptive scores for pieces of Electronic Music, these are to be treated differently, as they are purely aimed at analysis and therefore contain a certain information bias. Data that is more comparable to instrumental scores is contained in rare examples of so-called realization scores. It is argued that these realization scores can be identified as the main subject for encoding of Electronic Music works. For this we will discuss an example from one such score by Karlheinz Stockhausen. For his piece *KONTAKTE*, Stockhausen released a realization score that unfolds a very detailed documentation of all steps made within the studio production of that work, including the complex patching of studio devices and the specific transformation processes achieved by the use of tape machines. The paper presents an approach to formalize and encode all these steps within the framework of a semantic database. Using technology like the semantic web standard, Linked Data and the corresponding RDF/OWL framework, an Electronic Music production setup and its usage can be encoded, stored, and analyzed.

1 Introduction

In the field of digital music encoding, there are increasingly different research perspectives, methods, and topics in recent years. Frequently, phenomena related to Common Western Notation [17, 18] or notation systems of the Renaissance and Medieval periods [2, 23] are addressed. However, examples of Electronic Music are not very strongly represented. (Here and in the following, the term *Electronic Music* is intended to refer generally to electronically produced, composed new music and to explicitly include genres such as *musique concrète*). Only a few examples can be found, and most of them are oriented more towards the field of Music Information Retrieval [13, 19] and/or analysis [7, 20]. The main reason for this could be found in the nature of Electronic Music that is – if not realized within a live-electronic setup – predominantly existent within a fixed media format, be it on magnetic tape in the earlier days of the genre or any type of digital data storage today. Instead of having to be realized within a performance situation that implies musicians reading and playing or singing the notes of a score, the 'tape' (we will stick to this term, including all digital variants) is realized within a production situation in a studio for Electronic Music. (This studio may today of course also be realized virtually within a software framework – our examinations and results will be valid for either type of situation.)

The absence of a prescriptive score implies a problem in tracking informational resources for any of these pieces, as basically all there is to be analyzed is the resulting audio material that can, e.g., be dealt with by classic methods of visualization. The well-known examples here would be the amplitude-depiction of a waveform display or the frequency-based sonogram. Both follow the reading logic of a score, offering a time axis to read along and in the case of the sonogram even an equivalent vertical tonal dimension with the analogous assignment of 'low' and 'high'. In addition, a considerable amount of work has been put on methods of transcription to generate scores that enable a listener to follow the piece with a corresponding visual counterpart [4, 28]. Evidently, the status of such a descriptive score differs significantly from that of a prescriptive one: In spite of the various attempts to gain access to an ideally unified language for such transcriptions, the *a posteriori* nature of it will always imply a bias imposed upon the written result by the inevitable pre-assumptions of each transcriptor. This is, of course, an analogy to the margin of interpretation that is at the disposal of each instrumentalist playing the notes of an instrumental score. It is evident that these transcribed scores are therefore not an apt material to be taken into consideration as a database. The question naturally arises whether this inherent lack of *a priori* information in Electronic Music is to be taken for granted, that is, to basically just rely on empirical methods of information retrieval or, if there are ways to do so, on a piece under examination.

2 Scores for Electronic Music

2.1 Background: Early Scores of Stockhausen's Electronic Pieces

The early period of Electronic Music saw a multitude of approaches to this new genre, ranging from the empirical techniques of the *musique concrète* to the more pre-determined approach of the works from the Studio for Electronic Music of the West German Radio (WDR) in Cologne. The latter, among others represented by Karlheinz Stockhausen, provides a few interesting examples that prove the composers' reflections on the relevance of scores for their new creations.

An early example of a full-fledged score for a piece of Electronic Music is Stockhausen's *STUDIE II* from 1954 [25]. This score not only provides enough information to follow the piece by reading, it is also one of the rare cases where enough information is offered to actually re-realize the piece. As the introductory notes of the score suggest, this score was meant to be used to create further versions of the piece. This clearly indicates that the concept of a piece existing solely in one finished version – usually realized by the composer – on fixed media was not quite decided yet within the then context of Electronic Music. Due to this, a variety of new interpretations of the piece exists, for example, as a realtime patch running on the Max/MSP platform [8] or in more hardware-oriented approaches [29]. For this paper, we will focus on a slightly more complex example of a score that opens up many facets of the production process.

2.2 The Score of Karlheinz Stockhausen's *KONTAKTE*

From 1958 to 1960, Stockhausen realized, together with Gottfried Michael Koenig, the Electronic Music for his piece *KONTAKTE*, which turned out to become one of his best known pieces. Within the five years that had passed since *STUDIE II* (which of course incorporated the composition and realization of *GESANG DER JÜNGLINGE*), the working processes in the studio of the WDR had become much more complex: Many more facets of possible usages of all devices as well as the manifold possibilities of manipulation of sound structures by the means of tape had been made accessible [6, 26].

Given this background, Stockhausen decided to fully document the working processes undertaken to realize the material for *KONTAKTE* in a so-called realization score [27]. All the crucial processes of sound generation and processing are written down precisely, as the examples in Figures 1 and 2 illustrate.

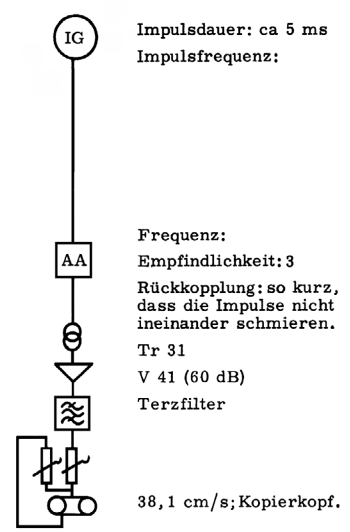

Figure 1: A basic patch for sound generation in *KONTAKTE*: An impulse generator is processed by a band pass filter, which in turn is levelled and processed by a filter bank. The result can be delayed via the feedback fader. © *With kind permission of the Stockhausen Foundation for Music* (http://www.karlheinzstockhausen.org).

The graphic examples display how the single devices in use (whose individual symbols are thoroughly explained in an introductory section) are set up and connected. Specific production dates are identified and thereby indicate individual stages of the production. It should be noted that at this point every aspect of electronic sound generation (with exception of very simple instruments such as electric organs) had to be individually planned and performed. This situation would change within the 1960s that brought along the development of commercial music electronics and the concept of the synthesizer. This process encapsulated a lot of the processes explicitly shown here back into the body of a new type of 'instrument'. *KONTAKTE* exists in two versions: One that only consists of the Electronic Music on four-channel tape, and one that combines this with two soloists on piano and percussion. Interestingly, Stockhausen also created a transcription of the tape as he needed to communicate the Electronic Music to the instrumentalists. The index numbers of patches and processes can be picked up from the timeline, giving the reader the opportunity to switch to a 'second layer' of detailed information. Comparing the graphic part of the performance score with the transcribed graphical representation and the more documentary realization score, it becomes quite clear that the latter will be the more rewarding database for an encoding process that is likely to produce valid and productive results. Evidently, the realization score is a close relative to the classic instrumental score, providing the information necessary to produce the acoustic result intended by the composer. We take this as evidence that those detailed notes should serve as our database. The samples from Stockhausen's realization score give an impression of the type of information offered. For this article, just these very simple instances were chosen, the score of course also offers much more complex settings on its more than 60 pages. The first example shows a typical setup to generate sounds with filtered impulses. In the second, a unique technical idea to realize rotations of sound that could be put down on a four-track tape machine is depicted. On the one hand, the examples show the potential relevance of a semantic interface to electronic processes of sound generation; on the other hand, they illustrate the challenges that can arise when encoding score data of electronic music. In the following chapter, we propose an approach for this based on linked semantic data encoding. For this article, we choose to encode the second example, as the rotation apparatus is probably furthest from a classic understanding of musical or instrumental parameters. This qualifies it as a suitable object to test our encoding concept.

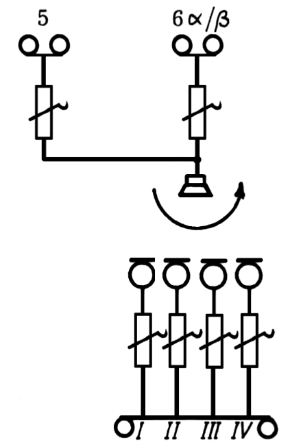

Figure 2: This is a symbolic depiction of the rotation table. It was used to spatialize material from one or two tape machines. © *With kind permission of the Stockhausen Foundation for Music* (http://www.karlheinzstockhausen.org).

3 Encoding the Rotation Table from Karlheinz Stockhausen's *KONTAKTE*

The 'rotation table' presented a simple and convincing possibility to render spatial movements into a fixed form on a multi-channel tape and thus at the same time to integrate them as a new parameter into the process of composition. A mono signal is sent to a directional loudspeaker mounted on a rotating table (Figure 3). Using manual movements, the signal can thus be made to actually rotate in the studio space, and this movement is recorded with four microphones mounted symmetrically at an angle of 90 degrees. By recording their signals on a four-channel tape and reproducing them in an equally symmetrical quadraphonic square of loudspeakers, the effect of the rotation is reproduced quite convincingly.

In the lack of normalized standards and information processing formats, a comprehensive encoding and storage of this realization score resulting from the complex development process is hardly possible. The general lack of an established documentation format for Electronic Music finds a shining example at this point. To close this methodological gap, a data structure is needed that does adequate service to the hybrid of technical and artistic-aesthetic nature of Electronic Music production. In fact, this results in an encoding framework for Electronic Music, which will be described and evaluated in this paper.

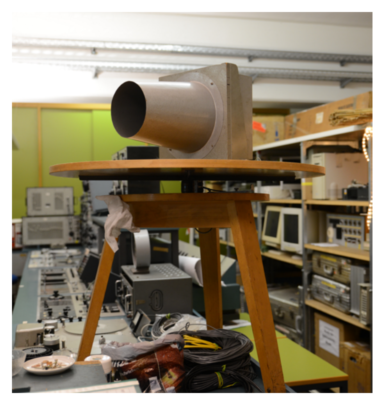

Figure 3: The rotation table at the WDR studio for Electronic music in Cologne (own image), 2020.

3.1 Ontological and Semantic Approach

The networked structure and the connected, interacting technical setup of an Electronic Music production places a high demand on the Linked Data [24] structure. Realization scores for Electronic Music, as shown in the previous chapter, call for a technical orientation of the stock. In addition, a complex and heterogeneous data set must be expected, since there are no standards for scores in the analog context either. These requirements can be met with the help of a semantic database according to the RDF standard[1] based on a specialized ontology. Such a semantic database models the data fed to it as a knowledge graph, as is done, for example, in the music databases of DBtune.org.[2] Semantic databases and ontologies also have a certain legacy in musicology as exemplified by the Music Ontology approach [22] and its extending frameworks.

For the creation of a semantic database, a specific ontology must first be defined as a basic structuring order that describes the nomenclature and data type of the occurring data sets or objects. In the case of Electronic Music scores, fundamental preliminary work is required here, since terminologies are lacking in many areas. The need for systematization has been addressed in various places [3, 9, 12, 16]. A categorization, for example, of the electronic devices in the studio fundus of the time, as comparably made by the Hornbostel-Sachs classification for acoustic instruments [10], does not exist here or is poorly elaborated [15].

However, an ontological framework for the representation of conventional western notation exists in the form of MusicOWL [11]. It extends the basic Music Ontology with data types for musical notation and thus allows semantic storage of musical notation, similar to the MEI format, using XML. Other extending ontologies like the Studio Ontology [5] or the Audio Features Ontology [1] provide capabilities for representing music technology functionalities. Other ontological approaches like the Device Ontology or the Connectivity Ontology offer basic technical functionalities, whereas the Timeline Ontology [21] depicts a time dimension, in real-time historical or in inner-work runtime aspects. An ontological approach to Electronic Music encoding therefore works at the intersection of these technologies (Figure 4). Using these technologies and adding some new functionalities, an Electronic Music production setup can be implemented by means of a replication of the signal paths and devices. Here, the terminology and functionality is chiefly delivered by the Device Ontology and the Connectivity Ontology [5]. In order to avoid a documentation of purely technical structures and to assign musical meaning to the information, a concept of *function*, which assigns an acoustic or music technological task to sections or individual elements of the apparatus, is being delivered by this work. The function concept is multidimensional in order to be able to represent both overall and partial functions of the production devices. This results in a multi-dimensional *ontological structure* of the production setup, which can be functionally documented on all levels. This allows encoding of Electronic Music scores and realization descriptions and can even be linked to various other ontologies.

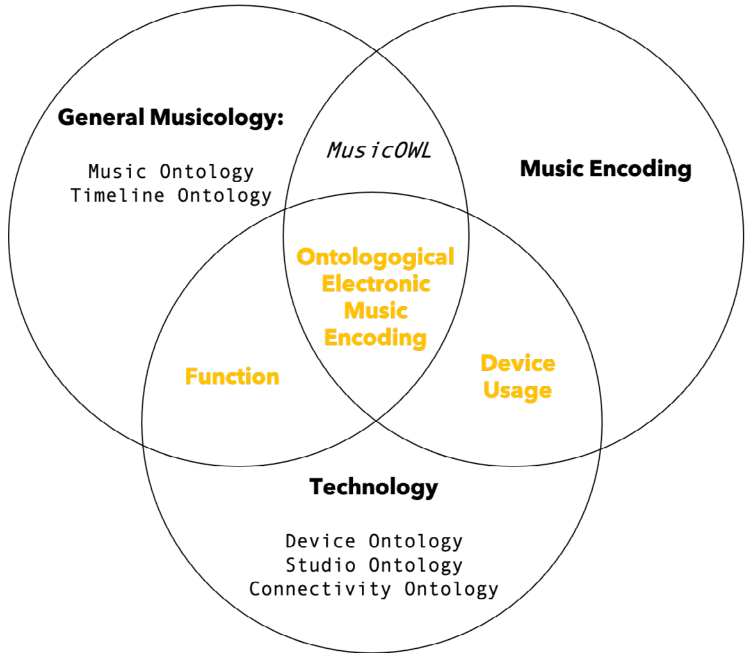

Figure 4: Core elements of the ontology in touch with existing research fields and ontological approaches.

3.2 Encoding

Semantic Encoding of Stockhausen's rotation table is quite straightforward with the help of the Device and Connectivity Ontology. With the exception of the acoustic signal between the loudspeaker and microphones, all signal flows can be traced and the rotation angle of the rotation table can be realized with the help of a status term. But the use of these two existing ontologies involves the problem that no statement about the

1 https://www.w3.org/RDF/ (accessed January 12, 2022).

2 http://dbtune.org (accessed January 12, 2022).

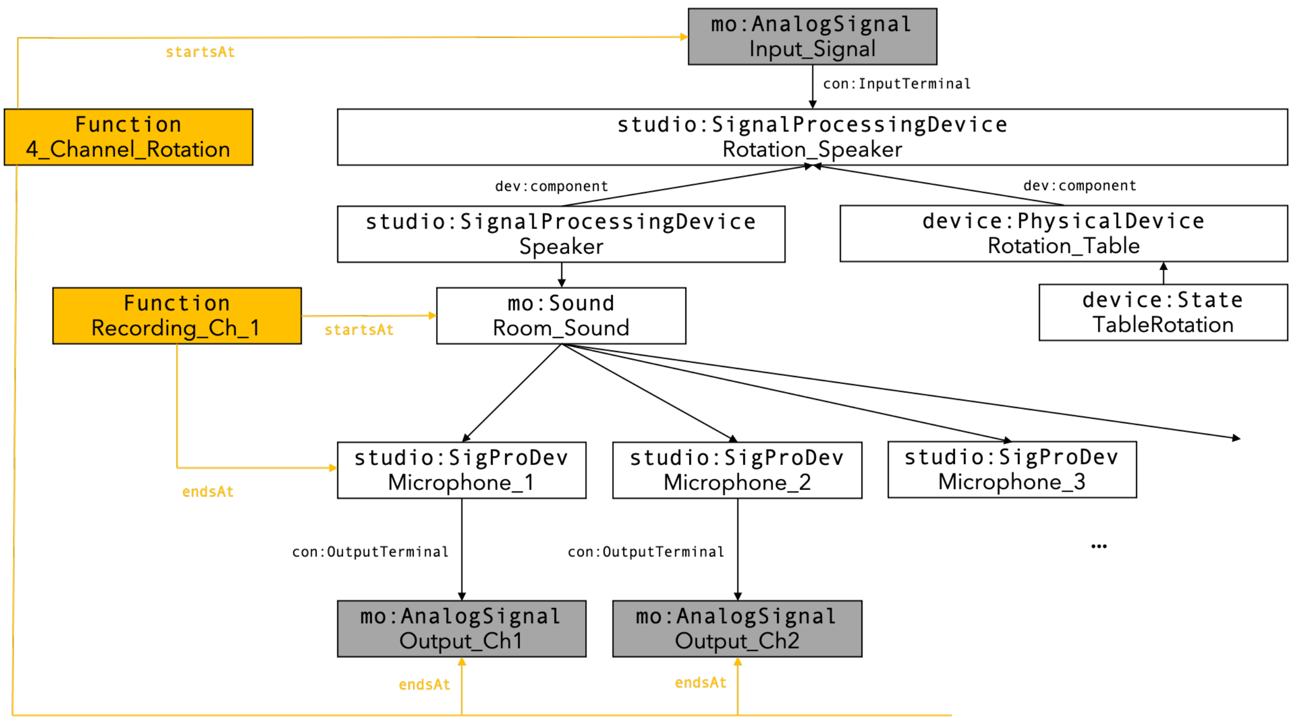

Figure 5: Function descriptions in the ontological model. The functions of individual sections of the circuit are documented using function typing. For the sake of clarity, not all four microphones and channels are shown.

function and use of the apparatus is possible. The physical-acoustic effect of the rotation is also not recognizable from the technical setup, since there is no possibility to locate the microphones to the loudspeaker. This results in a lack of expression for the composer's intentions documented in the score.

By introducing the *function* concept, this missing functionality can be documented. In order to reference the effect of four-channel symmetric rotation, which can be characterized quite unambiguously by acoustic or room acoustic parameters, the above function description concept is used. Defining an input and an output module, the function type "4-channel rotation" is stretched over the whole apparatus. In the overall structure of all devices (e.g., pulse generator, band pass filter), which were used to realize *KONTAKTE*, a specific section can now be found as a rotation element (Figure 5).

In order to realize a multi-dimensional function description that can thus be applied to different levels of detail, the term can be used in an overlapping manner: First, "4-channel rotation" is the function of the overall circuit. Furthermore, the attribution of the function "Recording-Channel-1" for the recording process at one of the four microphones describes the sub-task of a circuit section and thus a sub-function of the overall function of the rotation table. The same procedure can be used with superordinate functions for the definition of the procedure in the production apparatus. The semantic representation of time dimensional data (like changes in device settings within the production process, e.g., the table's rotation angle) can be realized by using the Timeline Ontology. For means of conciseness, this complex semantic encoding is not shown in the given example.

4 Conclusion

Using a semantic data representation provides new possibilities of Electronic Music encoding. Intended functionality and composers' thoughts on the apparatus can be documented, even extending the possibilities of classical music notation. The actual target of Semantic Web and Linked Data technologies, a worldwide and cross-disciplinary connected knowledge graph [24], allows various use cases for the encoded information. As, for example, RDF datasets become readable by AI systems, a great potential beyond the mere encoding of Electronic Music scores can also be expected.

Scores of Electronic Music deserve to be added to the catalogue of encoded musical notation as a valuable expansion. They confront us with new problems as to how to encode specific processes of electronic sound generation. These processes are not only relevant within a limited focus on production processes from a very specific area of music history. Rather, through the vast development of music electronics in the 20th century and within the contexts of digitization of all levels of music production, they have become interwoven with a multitude of aspects within present day music theory and practice. Therefore, the aim of encoding these processes is clearly justified.

The presented approach of semantic encoding by means of an ontology has proven to be a sufficiently powerful tool to deal with the information available. A resulting database on the foundations of this ontology could in a future scenario even provide possibilities for automated remodelling of the device setups shown. This could (as in the example cited in chapter 2.1) for example be realized on a platform like Max/MSP. Sound generation processes that were previously difficult to comprehend could thus be exemplified within the experimental setting itself.

Acknowledgments

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Encoding Scores for Electronic Music

DFG-Projekt PRESET: **PR**inciples of **E**lectronic sound synthesis: **S**ystematization and **E**volution of a **T**erminology

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Background: The Score of Stockhausen's KONTAKTE

In the field of digital music coding, there are increasingly different research perspectives, methods and topics in recent years. However, examples of Electronic Music are not very strongly represented. The main reason for this could lie in the nature of this music that is predominantly existent within a fixed media format. Instead of having to be realized within a performance situation that implies musicians reading and playing or singing the notes of a score, the "tape" is realized within a production situation in a studio for Electronic Music. This absence of prescriptive scores implies a problem in tracking informational resources for any of these pieces, as basically all there is to be analyzed is the resulting audio material. The question naturally arises whether this inherent lack of *a priori* information in Electronic Music is to be taken for granted, that is, to basically just rely on empirical methods of information retrieval or if there are ways to do so on a piece under examination.

The early period of Electronic Music saw a multitude of approaches to the new genre, ranging from the empirical techniques of the musique concrète to more pre-determined approach of the works from the studio for Electronic Music in Cologne. The latter, among others represented by Karlheinz Stockhausen, provides a few interesting examples that prove the composers' reflections on the relevance of scores for their new creations. From 1958 to 1960 Stockhausen, together with Gottfried Michael Koenig, realized the Electronic Music for his piece KONTAKTE. Stockhausen decided to fully document the working processes undertaken to realize the material for KONTAKTE in a so-called realization score (Stockhausen, 1968). All the crucial processes of sound generation and processing are written down precisely. Graphic depictions of device setups illustrate individual stages of the production. Evidently, the realization score is a close relative to the classic instrumental score, providing the information necessary to produce the acoustic result intended by the composer. For this example we choose to encode the rotation apparatus used in KONTAKTE as this is probably most remote from a classic understanding of musical or instrumental parameters.

Fig. 1: The rotation speaker from Stockhausen's KONTAKTE at the WDR Studio for Electronic Music in Cologne, DE

Semantic Encoding of the KONTAKTE Rotation Table

The rotation table presented a simple and convincing possibility to render spatial movements on a multi-channel tape by sending a mono signal to a directional loudspeaker mounted on a rotating table (Figure 1). Using manual movements, the signal is picked up by four microphones and recorded on tape, recreating a rotation effect when played back over a quadraphonic loudspeaker setup (Figure 2).

In the lack of normalized standards for scores of Electronic Music, a linked data (Sakr, 2018) structure is being used for the encoding. These semantic databases, according to the RDF standard and based on a specialized ontology, also have a certain legacy in musicology, as exemplified by the Music Ontology approach (Raimond, 2007) and its extending frameworks e.g. the Studio Ontology or the Device Ontology (Fazekas, 2011). According to this interconnected data representation system, the Electronic Music Ontology (EMON) was developed for our purpose.

Semantic Encoding of Stockhausen's rotation table is quite straightforward with the help of the Device and Connectivity Ontology. Signal flows can be traced and the rotation angle of the rotation table can be realized with the help of a status term. But the use of these two existing ontologies involves the problem that no statement about the function and use of the apparatus is possible. The physical-acoustic effect of the rotation is not recognizable from the technical setup, due to the lack of a possibility to locate the microphones in relation to the loudspeaker. This results in the absence of any means of expression for the composer's intentions documented in the score.

By introducing the **function** concept from EMON, this missing functionality can be documented. In order to reference the effect of 4-channel symmetric rotation, an input and an output module for the functionality are defined and signed with the function type "4-channel rotation". In the overall structure of all devices which were used to realize KONTAKTE, a specific section can now be found as a rotation element (Figure 3).

In order to realize a multi-dimensional function description that can thus be applied to different levels of detail, the term can be used in an overlapping manner: First, "4-channel rotation" is the function of the overall circuit. Furthermore, the attribution of the function "Recording-Channel-1" for the recording process at one of the four microphones describes the sub-task of a circuit section and thus a sub-function. The same procedure can be used with superordinate functions for the definition of the procedure in the production apparatus.

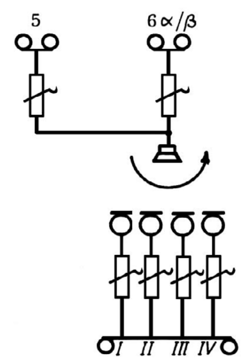

Fig. 2: Realization score of KONTAKTE: Functional sketch of the rotation speaker. © *With kind permission of the Stockhausen Foundation for Music* (http://www.karlheinzstockhausen.org).

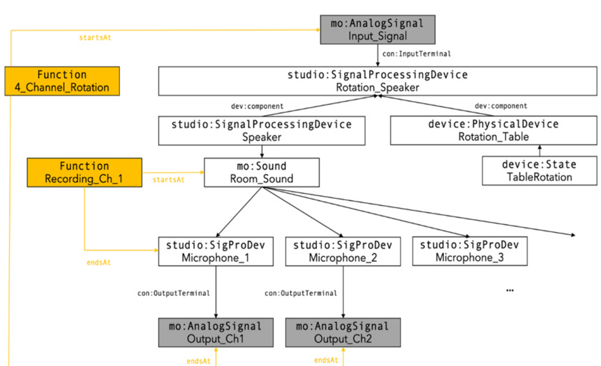

Fig. 3: Partial semantic encoding of the rotation speaker using EMON and related ontologies

Conclusion

Scores of Electronic Music confront us with new problems as to how to encode specific processes of electronic sound generation. These processes are not only relevant within a limited scope on production processes from a very specific area of music history. Through the vast development of music electronics of the 20th century and within the contexts of digitization of all levels of music production, they rather have become interwoven with a multitude of aspects within present day music theory and practice. Therefore, the benefit of encoding these processes using a semantic data representation is straightforward. Intended functionality and composer's thoughts on the apparatus can be documented. The actual target of Semantic Web and Linked Data technologies, a worldwide and cross-disciplinary connected knowledge database (Sakr, 2018), allows various use cases for the encoded information. For example, as RDF datasets become readable by AI systems, it can be expected that they will be used beyond the mere encoding of Electronic Music scores. A resulting database on the foundations of this ontology could in a future scenario even provide possibilities for automated remodelling of device setups, for example on a platform like Max/MSP. Sound generation processes that were previously difficult to comprehend could thus be exemplified within the experimental setting itself.

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