INTEGRATED SYNTACTIC AND SEMANTIC DATA STRUCTURING
An Abstraction of Intelligent Man-machine Communication *

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Abstract: The paper discusses an approach to intelligent man-machine communication which is a fundamental topic of intelligent interface of any software. The approach presented in the paper is based on integration of syntactic and semantic approximations of information structure. In most cases of communication automatic revealing of the structure of information subjected to communication is not possible due to its complexity. Proposed solution of this problem is based on raw, approximated descriptions of information entities and relations between them. This approach reveals parallel syntactic and semantic attempts to so called languages of natural communication. Duality of both attempts automatically exposes structure of information and allows a machine for information maintenance and processing in human-like way. The attempt is reflected in the domain of music information taking music notation as the language of natural communication.

1 INTRODUCTION

For all the time information exchange between human beings has been done in *languages of natural communication*. Natural languages, music notation, gesture language, etc. are examples of languages of natural communication. Languages of natural communication have been created, developed and used prior to their formal codification and - up to now - they have no formal full definition.

Since the beginning of the computing era people have been thinking about computers as their partners or - less radically - intelligent tools that can act in a manner similar to a man's reaction. Computers as partners of a man require exchanging information and understanding communication. Up-to-now a form of man-machine information exchange has been dominated by machines requirements. Due to poor abilities of machines human beings have had to create communication tools which could be recognized by computers. Indeed, *languages of formal communication* have been using almost exclusively in man-machine communication. Not only Pascal, C++, Java, but also all kinds of menus and dialog boxes with all their options and features often hardly guessed and always easily forgettable. This kind of tools have been widely applied and used despite their inadequacy and uncomfortableness. Amazingly, a man's product has dominated him as nothing before - at least in the aspect of communication.

Humans have been always thinking about raising human-like relations with machines, i.e. on his own, human's, conditions. Since communication and mutual understanding are the most important features of such relations, people have been considering machines as human like behaving artefacts with human's features and skills. Such a thinking was a science fiction deliberation rather then nearest future ability. But now it slowly comes to reality. There are two reasons for making the computing equipment more and more user-friendly and acting in a human-like manner. The giant increase of the computing equipment's power/output allows, on the one hand, for the emulation by brute force of a man's simple behavior. On the other hand, advances in research in the fields of artificial intelligence, algorithms and computability and other areas of computer sciences, as well as various social sciences, break barriers in making computers more intelligent, barriers unsurmountable only with respect to increasing power of computing hardware.

In this paper our attention is focused on the aspect of the computing technologies development which employs both information exchange and understanding. We will discuss the problem of information ex-

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change between man and the machine as well as automatic understanding of information by the machine. Importantly, communication understood as an information exchange is being maintained in some type of language which we wish to be more a language of natural communication rather then a language of formal communication. This meaning of communication includes not only a simple exchange of files of information represented in the binary form, as - for instance - the exchange of text files without looking into their meaning. It is also understood as a presentation of *a language text* contained in the file, i.e. a language construction or a sequence of language constructions, with an expectation that its contents will be analyzed and a structured space of data representing knowledge embedded in it will be created and then interactively used. In other words, we expect that such a kind of communication will involve a language in which the given language text was formulated. This language will perhaps be a language of natural communication.

2 APPROXIMATED DATA STRUCTURING

The notion of *understanding* is regarded as the main feature of intelligent communication and an important goal of the present paper. We would like to characterize the meaning in which the word *understanding* is used in the paper. Understanding is an ability to identify objects and sets of objects defined by concepts expressed in a given language. The concept's description in a given language is what the syntax is. A mapping which casts the concepts' description on the real world objects is what the semantics is. Ability to recognize the semantics is the meaning of understanding. We reflect meanings of the above notions in music notation seen as a language of natural communication.

2.1 Syntax

Syntactic approach is a crucial stage and a crucial problem in the wide spectrum of tasks as, for instance, pattern recognition, translation of programming languages, processing of natural languages, music processing, etc. Syntactic approach is generally based on the context-free methods which have been intensively studied. Context-free methods have also been applied in practice for the processing of artificial languages as, for instance, programming languages, in technical drawings, etc. We can even say that application in this field has been successful.

Unfortunately, natural communication between people, e.g. communication in a natural language or using music notation, is too complex to be formalized in a context-free way, though it is clear that such communication is rule-governed, cf. (Bargiela and Homenda, 2002). Even if there is a definite set of rules defining a language of natural communication, the rules are much more complicated than those describing artificial languages of formal communication. And such rules can often be broken with little impact on communication. Thus, a description of such tools as a natural language or music notation must definitely be highly flexible and deeply tolerant to natural anarchy of its subjects. With all that in mind, the proposed approach to describing languages of natural communication will rely on the sensible application of the proposed context-free methods applied locally in the structured space of a language of natural communication. Moreover, it is assumed that the context-free methods will not be applied unfairly to generate incorrect constructions of them. Those assumptions allow for a raw approximation of languages of natural communication as, for instance, natural language or music notation, which are far more complex than a context-free tools utilized for such an approximation. Of course, such assumptions are real shortcomings in accurate description of a language of natural communication and in its processing. These shortcomings must be solved by employing some other methods, perhaps not context-free.

Below, we present an approximated description of a local area of music notation. This description is given in the form of context free grammar. For more details on context free descriptions of music notation see (Homenda, 2006; Homenda, 2007).

<stave> → *<beginning_barline> <bl_stave>*
→ *<bl_stave>*
<bl_stave> → *<key_signature> <ks_stave>*
→ *<ks_stave>*
<ks_stave> → *<time_signature> <ts_stave>*
→ *<ts_stave>*
<ts_stave> → *<measure> <barline> <ts_stave>*
→ *<measure> <barline>*
<measure> → *<change_of_k_sign.> <ks_measure>*
→ *<ks_measure>*
<ks_measure> → *<change_of_t_sign.> <ts_measure>*
→ *<ts_measure>*
<ts_measure> → *<vertical event> <ts_measure>*
→ *<vertical event>*
<vertical event> → *<stem> <vertical event>*
→ *<stem>*
<stem> → *<beams> <note_stem>*
→ *<flags> <note_stem>*
→ *<note_stem>*

$$
\begin{aligned}
<stem> &\rightarrow <beams>\ <rhythm\_group>\ <note\_stem>\\
&\rightarrow <flags>\ <rhythm\_group>\ <note\_stem>\\
&\rightarrow <note\_stem>\ <rhythm\_group>\\
<beams> &\rightarrow left\ beam\ \ <beams>\\
&\rightarrow right\ beam\ \ <beams>\\
&\rightarrow right\ beam\\
<rhythm\_group> &\rightarrow left\ rh\ gr\ \ <rhythm\_group>\\
&\rightarrow right\ rh\ gr\ \ <rhythm\_group>\\
&\rightarrow 3\\
<flags> &\rightarrow flag\ \ <flags>\ \mid flag\\
<note\_stem> &\rightarrow note\ head\ \ <note\_stem>\\
&\rightarrow note\ head\ \ stem
\end{aligned}
$$

2.2 Semantics

As mentioned above, people use different tools for communication: natural languages, programming languages, artificial languages, language of gesture, drawings, photographs, music notation. All those tools could be seen as tools used for describing a matter of communication and as information carriers. We can observe that different tools can be used for encoding the same communication matter description. Immersing our deliberations into music notation we should be aware that among different tools of natural communication, natural languages are most universal. In general, they cover most parts of information spaces spanned by other tools. Therefore, a natural language can alternatively describe constructions of music notation. Interpreting this observation we can notice that, for instance, a given score can also be described in Braille Music (Krolick, 1998), MusicXML (G. Castan and Roland, 2001) or other formats or even, e.g., in the English language. Moreover, all such descriptions carry similar information space.

Likewise, a description of a subject (a thing, a thought, an idea, etc.) may be prepared in different natural languages. Such descriptions approximate the subject bringing its projection onto the language used for description. And such a description could be translated to other natural language without a significant lost of information. This means that the subject being described is a meaning of a description. So, a study on a subject described in a natural language (or even in any language of natural communication) may supplement the study on descriptions themselves. In other words, syntactic analysis of language descriptions may be supplemented by a semantic analysis of description's subject.

In this study music notation, as a language of natural communication, cast onto a space of communication subjects (i.e. onto musical scores, as texts of the language of natural communication) is understood as the semantic approach to music information processing. Formally, assuming that L is a music notation lexicon and M is music notation, the mapping V describes semantics of the music notation description:

$$V : L \rightarrow M$$

The mapping V assigns objects of a given musical score M to items stored in the corresponding lexicon L. The lexicon L is a set of local portions of the derivation tree of the score, c.f. (Homenda, 2006).

3 MAN-MACHINE COMMUNICATION AS AN INTELLIGENT INFORMATION EXCHANGE

As mentioned before, communication is understood as a presentation or an exchange of information between two (or more then two) objects of communication. Essential feature communication is understanding information being exchanged. Understanding requires exact description of relations between information entities, what is done in the form of syntactic and semantic structuring integrated in frames of information granulation paradigm.

3.1 Syntactic Analysis - A Tool Describing Communicated Data

Syntactic analysis is a tool used for data space structuring. As discussed above, syntactic methods cannot be used for full structuring of complex data spaces as, for instance, for structuring music information. Thus, it is used for approximation of data structuring. Such an approximation is often sufficient for revealing structures of data that could be extracted form the data space and possibly subjected to further processing.

Syntactic analysis is a suitable tool for acquiring user's choice of data. Selection tool is usually used to define user's choice. A selection done by user could either be interpreted at the lowest level of data structures, or may be performed to a part of structured data space. In Figure 1 we have two rectangle selections in two upper parts. These selections could be interpreted as numerical data representing raster bitmaps which have nothing common with displayed music notation.

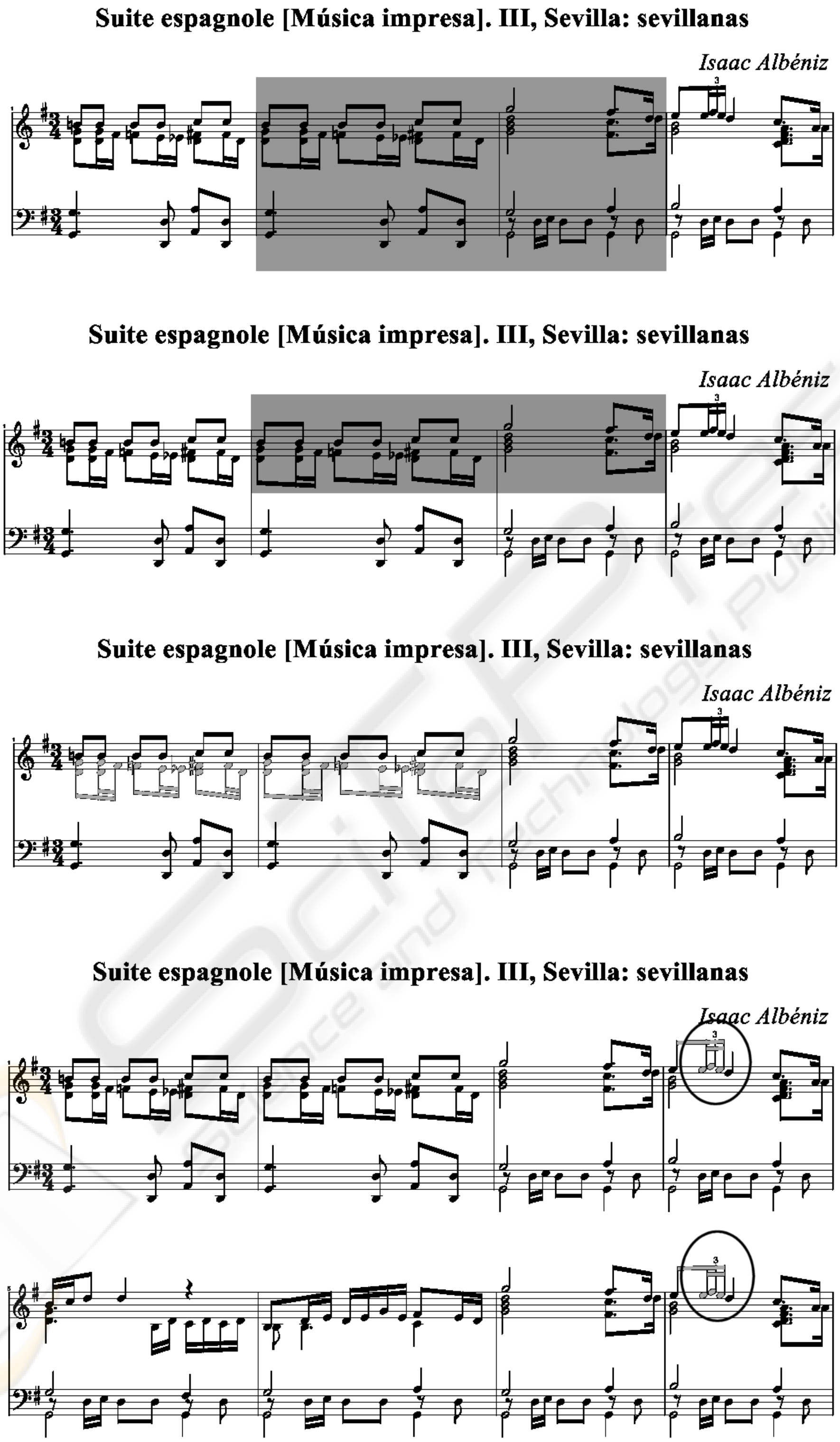

Figure 1: Examples of selections: two measures in a system, two measures in a stave, lower voice line in first two measures, triplets on sixteens.

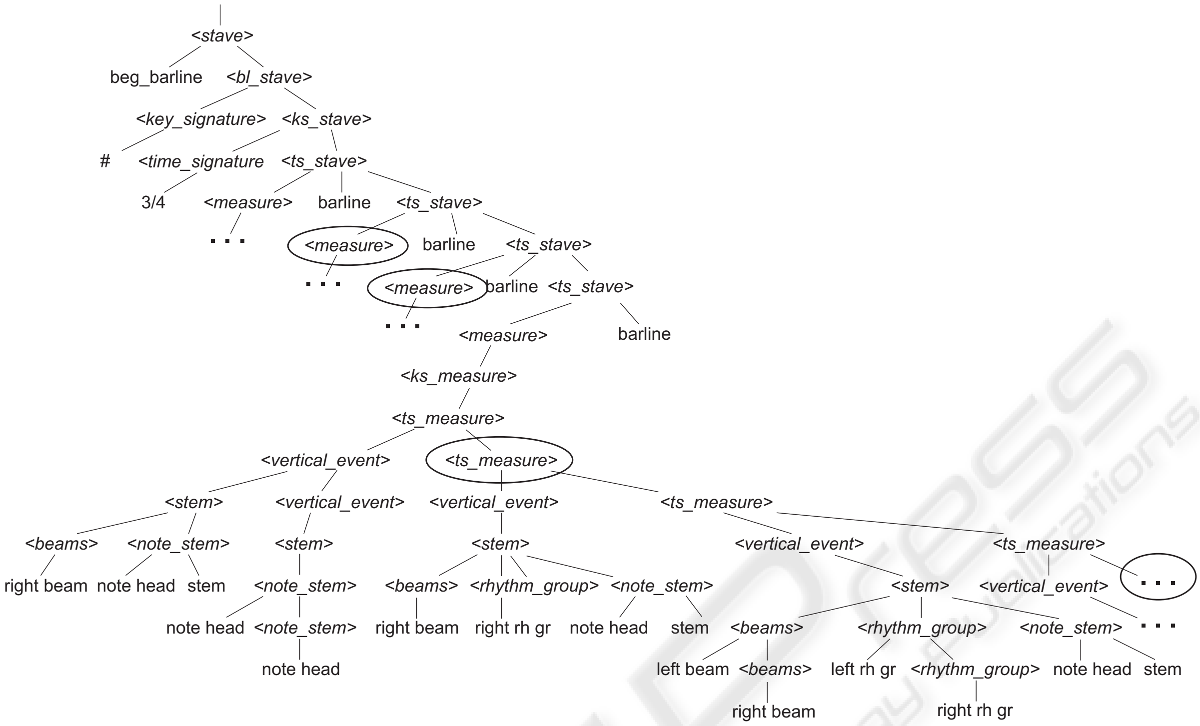

Figure 2: Derivation tree of the first triplet marked in Figure 1.

Figure 3: Examples of transpositions: original score, automatic recognition of the original score, upper voice line moved one octave up and lower voice line moved one octave down, third measure transposed from D to G.

On the other hand these selections could be understood as a part of music notation, namely: two measures in a system and two measures in a stave. In case of lower two parts selections shown as grayed symbols of music notation cannot be interpreted as a raw numerical data. These selections are parts of the structured data space.

Syntactic analysis allows for immersion of user's selection into structured information space. Syntactic interpretation of user's selection of data gives the first significant raise leading to full identification of information intended to be communicated by man. It needs to be mentioned that, in this discussion, we drop a category of technical details like, for instance, which programming tools are used to point out desired objects at a computer screen and how to indicate options of a selection.

Let us look at the selection of two measures in the stave. It is defined as a part of derivation tree in a grammar generating the score (part of this grammar is outlined in section 2.1). This selection corresponds to paths from the root to two indicated vertexes <*measure*> of the part of derivation tree shown in Figure 2. The selection of two triplets in lower part of Figure 2 is described by the indicated vertex <*ts_measure*>, which is also taken as one vertex path. Description of voice line selection cannot be described as easily as other selections, it requires context analysis.

3.2 Semantic Mapping as Identification of Communicated Data

Syntactic descriptions of information entities is a basis for identification of relevant area of information space. This identification is done by casting the lexicon of a given score, i.e. the space syntactic granules, onto the space of objects of sematic granules of the score. Semantic granules are subjects of understanding and of possible processing.

The meaning of paths from the root to two indicated vertexes <*measure*> (being syntactic granules) is defined as follow. It is the crop of all subtrees of derivation tree, which include both paths together with subtrees rooted in vertexes ending both paths. The structure of symbols of music notation that are included into selected two measures corresponds to this meaning.

On the other hand, crops of all subtrees of the derivation tree in Figure 2, which are equal to the subtree defined by the indicated vertex <*ts_measure*>, is the meaning of syntactic granules (in this case, the subtree has excluded its part denoted by indicated multidots vertex).

It is worth to notice that the description of the first semantic granule is a special case of the the description of the second semantic granule. Having a path, which begins in the root of derivation tree, we can find only one subtree equal this path with subtree rooted in its ending vertex.

Semantic granules define meaning of information being exchanged and allow for responding to requests. Such responses are outlined in Figure 3. Its upper part shows original score. two other parts illustrate transposition performed on recognized notation. The middle parts shows three voice lines. The upper voice line was subjected to transposition by one octave up. The lower voice line was subjected to transposition by one octave up. The third part of shows transposition of the third measure from D to G.

3.3 Granulation as a Form of Understanding

Information exchanged in communication is materialized in the form of texts of a language of natural communication. Thus, the term *text* spans not only over texts of natural languages, but also over constructions like, for instance, musical scores, medical images, etc. (we can also apply this term to constructions of languages of formal communication, e.g. to computer programs). Revealing recent sections let us say that a study on how texts are constructed is what we mean as syntax. A matter described by such a text is what is understood as semantics. Integrating syntax and semantics leads to information granulation and identification of relations between granules of information, c.f. (Homenda, 2007; Pedrycz and Bargiela, 2005). Discovering relations between both aspects is seen as understanding.

The description of music notation as well as music notation itself could be innately subjected to the paradigm of granular computing elucidation. As stated in (Pedrycz, 2001), granular computing as opposed to numeric computing is knowledge-oriented. Information granules exhibit different levels of knowledge abstraction, what strictly corresponds to different levels of granularity. Depending upon the problem at hand, we usually group granules of similar size (i.e. similar granularity) together into a single layer. If more detailed (and computationally intensive) processing is required, smaller information granules are sought. Then, those granules are arranged in another layer. In the granular processing we encounter a number of conceptual and algorithmic layers indexed by the *size* of information granules. Information granularity implies the usage of various techniques that are relevant for the specific level of granularity.

The meaning of granule size is defined accordingly to real application and should be consistent with common sense and with the knowledge base of the application. Roughly speaking, size of syntactic granules is a function of depth of the syntactic structure. Size of the syntactic granule *<score> <score_part><page><system>* is smaller then size of *<score><score_part><page><system><stave>* which, in turn, is smaller then size of *<score><score_part> <page><system><measure>*.

On the other hand, we can define size of semantic granule. It is defined as a quantity of real world objects or a length of continue concept. Size of the semantic granule V(*<score><score_part><page><system>*) is greater than size of V(*<score><score_part><page><system> <stave>*), which, in turn, is greater then V(*<score> <score_part><page><system><stave><measure>*). The relevance between syntactic and semantic granules has been discussed in (Homenda, 2006; Homenda, 2007).

4 CONCLUSIONS

The new framework on man-machine intelligent communication is presented in the paper. The term intelligent communication is understood as information exchange with identified structure of information, which is presented by a side of communication to his/its partner(s) or is exchanged between sides of communication. Of course, identification of information structure is a natural feature of human's side of such communication. An effort is focused on automatic identification of information structure based on syntax and semantics of information description. Syntactic and semantic descriptions have dual structure revealing granular character of represented information. Complementary character of both attempts allows for automation of information structuring and - in consequence - intelligent information maintenance and processing, what is the basis of intelligent communication in man-machine communication process.

In this paper the problem of man-machine intelligent communication is reflected in the area of music notation treated as a language of natural communication. However, reflection of this problem in natural language as a language of natural communication give similar conclusions, c.f. (Homenda, 2002). Thus, we can expect that integrated syntactic and semantic data structuring guides to rational interpretation of man-machine communication in many areas of human activity. This framework permits for better understanding of communication process as well as leads to practical solutions.

It is worth to notice that man-machine communication is a basis of intelligent interface of any software. An intelligent interface of a computer program in terms of its way of communication method (graphical, sound, etc.) design is cast on data structures processed by the program or exchanged between man and machine. An integration of both elements: man-machine communication and interface design is an interdisciplinary subject of studies.

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