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Music generation with formal grammars of multiple instruments and a conductor

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Que para obtener el grado de

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Presenta

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Director de tesis

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para examinar la tesis titulada:

““Music generation with formal grammars of multiple instruments and a conductor””

Presentada por el alumno:

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RESUMEN

En el contexto de la composición musical algorítmica, en el presente trabajo se propone una metodología para la generación de una obra musical completa a partir del uso de gramáticas jerarquizadas. Dichas gramáticas son proporcionadas mediante la especificación del estilo musical y parámetros de profundidad, duración y construcción para la generación de ésta. Además se describe la manera de evaluar los resultados obtenidos a partir de esta metodología. A lo largo del documento se describe la evolución de la metodología propuesta así como los detalles y casos especiales que se toman en cuenta para el desarrollo de las mismas.

ABSTRACT

In the context of algorithmic music composition, this paper proposes a methodology for the generation of a complete musical piece based on the use of hierarchical grammars. These grammars are provided by specifying the parameters of musical style and depth, duration and construction for this generation. It also describes how to evaluate the results obtained from this methodology. Throughout the paper describes the evolution of the proposed methodology and the details and special cases are taken into account in their development.

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1 INTRODUCTION

Among the disciplines that constitute human knowledge, artistic disciplines play a major role and are present in all the human creations. To help the implementation of artistic knowledge one can use branches of artificial intelligence such as expert systems, Markov chains, cellular automata, artificial neural networks, genetic algorithms and grammars, to mention a few.

Music, defined as a language, is the set of signs and rules that enable the communication of content. This allows us to abstract it through formal grammars. By grammars it is possible to generate musical tracks. A major application of music computing is the composition that is termed computer assisted music.

1.1 Problem statement

In tonal music, musical styles are based on music theory, but each differs in specific subtleties like forms, value notes and rhythms. Therefore, a methodology is needed to generate music based on tonal music theory, while learning the subtleties of the styles automatically.

1.1.1 Basic Approaches

There is a Musical Generator, which is a program that generates melodies from fractals, dynamical systems, complex maps, numbers and text. This system, although it seems complete, only approximates the string values generated by other systems and accommodates as proximity to a given note of the scale.

There are also programs like Art contextFree that, using parameters and user-defined rules, generates images of a certain type, it was added as a basic approach that looks similar to what has been done in this work but applied to images approach.

1.1.2 Problem solving

To generate a melody, and if you want to compose a cadence or get to musical discourse, it is mandatory and essential to have musical plans for the use of instruments such as the guitar or the piano.

Electronic synthesizers give the possibility of orchestrating a chord or note according to the programmed style, but do not generate a musical discourse, that is, you need to have the notions of harmony to generate a coherent progression. Moreover, synthesizers do not offer a melody on the chord orchestrated.

Current generators do not provide a strong musical theoretical basis, where they can modify the definitions of each of the parts of the track to generate and do not create a musical cadence colored based on established rules. Others only generate melodies on a scale defined without giving importance to the cadence, so lacking a musical discourse.

1.2 Background

Musical Generator is a program that generates melodies from fractals, dynamical systems, complex maps, numbers and texts. This system although it seems full, only approximates the string values generated by other systems and accommodates as proximity to given note of the scale.

There are also programs like *contextFree Art*, that, using parameters and used defined rules, generates a certain type of images, was added as a basic approach that is similar to what has been done in this work but applied to images approach.

1.3 Justification

This work is not trivial because linguistic methods are applied to generate music composition using parameterized grammars according to the learned style.

It is very difficult to give the scientific nature to music because it is considered an artistic and subjective work but music as we know and enjoy it today globally, has changed with the preferences of individuals and has evolved according to the region or culture, as rules have been provided for each style.

Some benefits obtained with the implementation of this method are:

Social: The user does not need to have a thorough knowledge of music or computer, so it can be used by anyone. It also provides inspiration to composers who need help to start something more creative. Also, if they have advanced knowledge of music, the user can define their own production rules to generate more interesting works.

Economic: That no payment is required to use copyright for each dynamically generated melody also eliminates the need to hire an expert for low-budget projects or prototypes.

Technical: Saving time spent for compositions with little musical knowledge.

Scientific: Generation and use of parameterized grammar rules.

Teaching: Support for teachers and music students in composition areas and melody / harmony analysis.

Henri Poincare said: "All knowledge is science which has math" and under this approach it is very difficult to give scientific character to music, as it is considered an artistic and subjective creation. However, the music we know and enjoy in today's world has changed with the taste of people and has evolved by region or culture, which have been providing rules for each style. And because music uses these rules it may be represented using grammars.

Here are some applications that can be given to the developed tool are listed below:

- As an aid to persons not engaged in music requiring a track as secondary support to a particular task.
- For use in music therapy, creating melodies in the required style.
- As a tool for cognitive reinforcement in music students.
- To give inspiration to composers required to create a work but in need of a creative basis for initiating or nurturing their own work.

- Musical Composition for videos, films or tasks by individuals or groups unable to acquire or uninterested in licensed music or who want to use original melodies.

1.3.1 Relevance and pertinence

The need of people to perform specific tasks without being an expert motivates the development of applications to do these tasks easily. This applies in the musical field where they have existing tracks and tunes used as background music for video or the use of melodies for game development or commercial uses. But these resources end up reusing material that can be registered under copyright or in the simple duplication of a piece in different works. It is therefore important to have a tool that generates original melodies.

I decided to do this work because I have a background in the performance of musical instruments. This training provided the necessary groundwork for the composition of musical works. This knowledge can be formalized in a mathematical model that applies to most musical styles and develops an application that generates a musical piece.

1.4 The problem

To generate a melody, especially if you want to compose a musical progression or reach the musical discourse, it is necessary and indispensable to have musical knowledge to use musical instruments like guitar or piano.

Electronic synthesizers give the possibility of orchestrating a chord or note as programmed style, but does not generate a musical discourse, i.e., you need to have the notions of harmony to generate a coherent progression, to offer a melody over the chord orchestrated.

Current generators do not provide a strong musical base where they can modify the definitions of each part from the generated track. Also they do not create a musical progression based on the rules. Other automatic composers only generate melodies on a defined scale without giving importance to the harmonic progression, thus lacking a musical discourse.

1.5 Objectives

Below the overall objective of this thesis and the specific objectives set to achieve that goal are described.

1.5.1 General objective

Generate complete musical compositions from parameters given by the user, so that the timing for each section of the work automatically generates, generate the harmonic base for each section and a melody dynamically for each respecting the times and rhythms, using sections in the manner set either by the style defined or the user.

1.5.2 Specific objectives

The specific objectives that complement the overall objective given a contribute of the present work, are listed below.

- Based on the model of the previous work, to create a context-free model for musical rules.
- Generalizing the proposed model where all modules are treated in the same way regardless of the instrument.
- Provide the possibility of multiple leaders in each module (hierarchy level).
- Provide iteration mechanisms for all sections that require repetition or modification.
- Develop a music analyser for ABC notation files.
- Create a corpus of tunes in ABC notation on different musical styles.
- Define the functions to modify and correct the created sections.
- Create the module for learning the structure of the musical work.
- Create the learning module for the progression of each section.
- Create the learning module for definition of instruments.
- Develop a tool that generates a musical work from machine learning styles of a corpus, creating rules dynamically for each module.

1.6 Contributions

The contributions of this work are as follows.

- Method for generating music based on grammars dynamically constructed hierarchically.

- Production rules to generate the progression of each section of the musical work.

- Production rules for intervals relative and absolute.

- Production rules for the definition of the metric of a melodic instrument.

- Production rules for the definition of a harmonic instrument.

- Production rules for the definition of a rhythmic-melodic instrument.

- Simple grammars based tool for generating melodies.

- Dynamic grammars based tool for generating hierarchical musical compositions.

1.7 Method of research and development

The methodology for the development of this research work consists of the following steps:

1. The study of the state of the art.
2. Analyse previous work and correct issues.
3. Create a single control module regardless of the hierarchical level that need to work.
4. Create a parser based on the proposed model. With this get the data from existing musical works.
5. Create the machine-learning module based on the proposed for each of the hierarchical levels model.
6. Define the modifying functions to the progression and sections for instruments.
7. Suggest an evaluation system for musical compositions generated by this method.
8. Increasing the corrected proposed based on experimental results method.

1.8 Structure of the document

The chapters of this document present a review of the outstanding work and have made significant contributions in algorithmic music composition. An overview of the theoretical foundations, a detailed explanation of the methodology used to address each issue raised and the results and conclusions that have been reached, and a brief description of what you will find in each chapter of this thesis is presented.

Chapter 1 addresses the subject of this work is, placing the reader in the respective branches of science. This chapter describes the performed work; reports the objectives and contributions that were derived from it and is also justified.

Chapter 2 provides a review of published works by other authors in algorithmic music composition, highlighting the contributions of each and reviewing the strengths and weaknesses of each job.

Chapter 3 describes the theoretical principles that are fundamental to understanding the subsequently work. Here is also explained in a timely manner the concepts of harmonic and melodic musical base, the type and used grammars and musical representation using a notation in plain text.

Chapter 4 gives a detailed description of the methodology used for the composition of new musical works based on grammars.

Chapter 5 gives a detailed description of the methodology used for the evaluation of automatically generated musical works. It also describes in detail the experimental results and their evaluation.

Chapter 6 presents a report of expected contributions and the conclusions of this work and the problems to be resolved for future work are discussed.

2 STATE OF THE ART

This chapter reviews the proposed methods for musical composition and some of the most relevant are listed below.

Based on the model of generation and test, Hiller and Isaacson (1957,1958) began their work of algorithmic music generation. They created the first composition made entirely by a computer. From that moment creators have used different methods of music generation, such as Markov chains (Hiller and Isaacson, 1957) in conjunction with L-Systems and grammars of parallel branch (McCormack 1996).

Other authors have used heuristics (Hiller and Isaacson, 1958) together with fractals and stochastic methods, oriented in procedures and recursive compositions (Moore).

They also have given a Case-Based Reasoning approach to the use of musical corpus. (Cope, 1991, 1993, 2001). Representing XML productions (Chan and Potter, 2006). Adopting a process of progressive and iterative composition of right-left and up-down (Pereira et al., 1997) for musical harmonization (Arcos et al., 1998).

The generative grammars (Chomsky, N. 1956) have been used to formalize the musical language (Lerdahl and Jackendoff, 1983). Based on this work, authors use probabilistic grammars (Rader, 1973, 1996) to generate traditional melodies using rules of applicability. It is the first example of meta-knowledge in this context.

They are using the interaction between agents (Minsky, 1993). They have used Genetic Algorithms to play Jazz with humans (Biles, 1994, 2001), as well as genetic algorithms with Fitness functions based on rules (Marques et al., 2000). Also neural networks (Biles, 1994, 2001) have been used for generating music.

The introduction of a conductor for music generation has been performed using a user interface to give the user the role of director. (Vazhenin, A. and Vazhenin, D. 2002) (Morita, H., Hashimoto, S. and Ohteru, S. 1991). (Reidsma, D., Nijholt, A. and Bos, P. 2008).

There is a work that uses a driver to music composition based on supervised learning. (Liang, R. and Ouhyoung, M. 1994)

2.1 Using grammars

The published studies that have used grammars for music generation have used different approaches. The most important publications are the following.

2.1.1 Formal grammars

The author of the paper *Improvising Jazz Chord Sequences by Means of Formal Grammars* (Chemillier, 2001) is based on the work of the grammars of Steedman (Steedman, 1984) and Coker (Coker, 1987) to implement expressions and replacement techniques on a set chord. He mentioned that, because there are rules where a terminal symbol is also a nonterminal, he had trouble using a parser and LEX or YACC.

The solution to this problem was the formalization of grammatical aspects. For example, there is a rule of the type G G7 → Dm7 G7 depending where two symbols, two new symbols are generated, there is also a substitution type C7 → Gm7 C7 in which two symbols must share the same range of time for a single symbol. This was sorted using slashes to define the number of chords within range, dividing this time by the number of chords, ie / C7 / last as long as / Gm7 C7 /. Implementing this in LEX and returning over chain correctly.

The system is composed of two modules. The first module generates the sequence iterations, making random substitutions in the chords. The second module selects expressions or voices for the succession of chords of the previous result by selecting the sampled voices of a database.

1. (rewriting *basic-grid* 1)

/((C) / (C) / ((G*)7) / (C7) / (F) / (F) / (C) / (C) / (G) / (G7) / (C) / (C)) /

2. (rewriting *basic-grid* 10)

/((C) / (C) / (C) / ((C#*)7) (C7) / (F) / ((F#*)7) / ((F*)7) / ((Bb*)7) / ((Eb*)) ((Eb*)7) / ((D*)7) ((C#*)) / (C) / (C)) /

In the above example you can see how the original 12 bars are retained after 10 iterations of substitution.

2.1.2 Contributions

Provides an approach to backward dependency that enables good progress to get a musical discourse.

2.1.3 Weaknesses

The author is not using any kind of musical abstraction so it is necessary to write all the rules for each particular chord.

The author mentions that a chord can be replaced by two new chords, however, does not define the length of each new chord. This is important because there are substitutions that emphasize only the next chord or used as passing chords.

2.1.4 Evolutionary grammars

The scientific paper *Automatic Composition of Music by Means of Grammatical Evolution* (Ortega and Alfonseca, 2007) mentions that the authors used the grammatical evolution to generate automatically tunes to sound like the work of a human composer. First recognized melodies translate to the audio processor AP440. Then from these tunes the parameters are obtained, to resemble a human composition. Finally grammatical evolution was used to generate the melodies specified by a fitness function.

They created a grammar for AP440 and used an initial population of 64 vectors of 32 random codons (notes). The genetic operators used were of crossover, mutation, splicing expansion genotype and another chain of codons and a cutting operator to remove some codons. They discarded 16 individuals from one generation to another.

2.1.5 Contributions

Using grammatical evolution is an approach that can adapt to different methods of generating melodies.

2.1.6 Weakness

The authors did not report the evaluation parameters of the generated melodies.

They neither defined what functions were used or how probability functions were obtained.

2.1.7 Based grammars music composition

In *Grammar-Based Music Composition* McCormack (1996) conducted a basing on Markov chains and L-grammar system using context-free grammars high complexity based hierarchies, where each of the symbols of a grammar can be a whole grammar.

This system has been developed on a workstation connected to a Silicon Graphics MIDI synthesizer. It has been implemented by feeding the system with several types of grammars to generate MIDI sequences in real time.

The algorithm used is: L-System grammar → parse grammar → iteration [Apply Rules] → Interpret melody → MIDI data or score generated.

They reached generate basic grammars to apply to polyphonic music, giving rules based on previous notes. For example:

(C E G) → (G B D)	If the CEG notes are played simultaneously, you must play GBD notes simultaneously.
CE | G → D	If the current note is G and is preceded by C and E, then play D.
(CE)|GC → D (C E)	If current G and C notes are played simultaneously and are preceded by the C and E notes played simultaneously. Playing D followed by C and E simultaneously.

To better understand this example, see Table X in section Y of this work.

2.1.8 Contributions

They provide a hierarchy of grammars to be used within other grammars.

2.1.9 Weakness

They use rules for each note, which means you have to define the entire universe rather than abstract rules by intervals.

The author's style classification may be wrong because an author has compositions of different musical styles.

2.1.10 Grammatical approach

In *A Grammatical Approach to Automatic Improvisation* (Keller and Morrison, 2007) the authors give a grammatical approach to creating licks for improvising Jazz solos. They propose an approach to the notes given as follows:

C Chord note

L Colour note

A Focus note

H Support note, defined by any of the above

S Scale note

X Arbitrary note

R Rest note

They considered time using probabilities defining a measure as the total probability, defined the times as: 1 whole, 2 half, 4 quarter 4 dotted quarter, 8 quaver, 16 semiquaver, 3/4 semiquaver in triplet, 8/3 quaver triplet, 16/3 triplet semiquaver.

They also added modifiers like + to increase to one octave note - to decrease one octave, # for sharps and b for flats. For example, C+4 represents an octave increased Do with a quarter duration.

2.1.11 Contributions

They considered a method of evaluation of the results by an expert in teaching improvisation Jazz solos also propose a way to evaluation using a case-based reasoning (CBR).

His method allows modification of grammars by the user, allowing test grammars proposed by others to define simple improvisation techniques for beginners or experienced players difficulty.

2.1.12 Weakness

The probabilities of occurrence of an event have been given empirically.

2.2 Genetic algorithms

The main works using genetic algorithms for musical composition are shown in the following sections.

2.2.1 Automatic Composition

Article System automatic musical composition (Gómez-Zamalloa, 2010). Preliminary approaches, Miguel Gomez-Zamalloa is based on work by David Cope (Cope, 2001), Michael Chan (Chan and Potter, 2006), Pereira, Grilo, Macedo and Cardoso (Pereira et al., 1997), proposes an architecture with more or less independent modules using Case-Based Reasoning (CBR) all controlled by a central control module. Each module with an independent and unique task. The modules proposed are: A generator isolated melodies generator isolated harmonies, a harmonizing of melodies, a generator of melodic lines alternative (secondary) transformer times, an evaluator of quality using CBR and a control unit.

Strengths

Modularization of the system can work more or less in some depth modules leaving future work for improvement.

The use of a hybrid system of rule-based reasoning (RBR) and CBR.

It provides a good review of the work that had been drawn up before the completion of the article.

Consider the implementation of a quality assessment module using CBR to improve their future decisions.

Weak points

Apparently the system proposed in this paper was not implemented because no other publications reference the implementation of the modules.

2.2.2 Using CBR

In the article *Composing Music with Case-Based Reasoning* (. Pereira et al, 1997), the authors present a musical based on analysis, CBR and planning techniques for musical composition solution; so that new solutions are obtained by transforming and extrapolating the knowledge derived from the musical analysis previously conducted by experts.

Each analysis represents it as a case, it can be divided into all its subcomponents and divides the musical piece according to the hierarchy shown in Figure 1 article referred obtained:

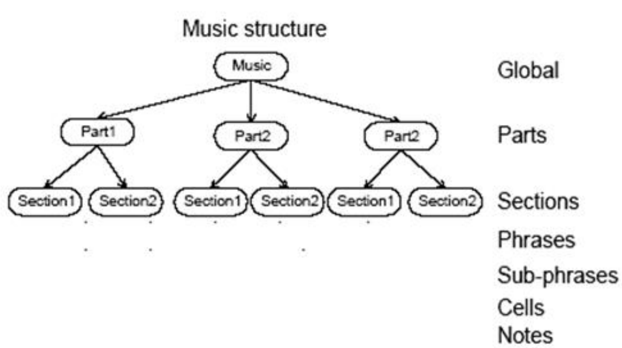


Figure 1. Hierarchical division of a piece of music

In addition to the hierarchical relationships mention that there may be horizontal relationships between components. For example, in the following figure it indicates that Section A of Part 1 is the same as section A of Part 2 but transported. See Figure 2.

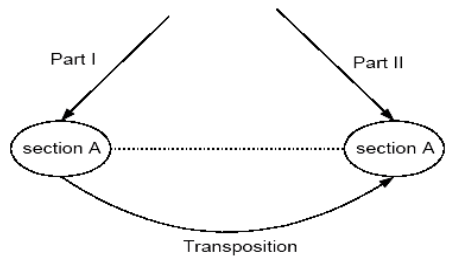


Figure 2. Horizontal relationships in the hierarchy

So each of these tree-shaped structures, with horizontal relationships between components, is a case where they extract the information in the CBR cycle.

Represent the case as a Prolog made as follows:

case_node (Case_Name, NODE_NAME, Temporal_Position, Constraints, atributes, Antecedents, consequents)

Notable attributes are "background" and "consistent", which described relations with node (respectively lower) in hierarchy, or previous (respectively subsequent) time top nodes. In this way they related two arbitrary nodes of any desired shape.

Much of the dynamism present in the representation proposal stems from the fact that a case also can be regarded as a plan using the model of Wallas for creative systems, so that temporal relationships between nodes and interpreted as causal relationships in the analysis They are treated as suggestions in the phase composition.

The composition process divided into four phases according to the model of Wallas:

- Preparation: cases are loaded into memory and problem solving is defined as a new case (case_node).

- Incubation: Corresponds to the CBR recovery phase. As a result, it has a number of nodes arranged according to a certain criterion.

- Lighting (adaptation): It is intended to adapt the first node (if it is not possible tries the second, etc).

Iterate from the preparation phase, now with the new problem to solve.

The process continues iteratively in left-right and up-down order.

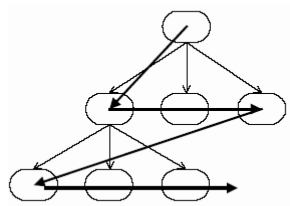


Figure 3. Iteration on the hierarchical structure

- Verification: Once fully built the new structure would begin the verification phase, whose task will be to assess the new composition according to the style in question. It is currently performed entirely by a music analyst.

As described in the recovery phase, they use a similarity metric in order to classify the nodes according to some given criterion. The authors base their judgment on the following idea: The less similar solutions could be potentially the most creative. So, first sorts the list of nodes in descending order of similarity to later reverse the first 40% placing it at the end. Of course they are aware that the chosen policy is somewhat "blind", but nevertheless say it could be a good starting point.

2.1.2.3 Weaknesses

It was originally part of a series of analyzes made by experts, which will mean before or after inflexibility.

The system has a learning phase, mainly because of the impossibility of creating new cases needed for this human intervention, particularly in the analysis phase.

The melodic similarity metric used not seem too consistent. I would look for some kind of melodic similarity metric that is able to capture certain musical characteristics of a more abstract cut, so that creative aspects of nature are captured.

The creative ability of the system to generate new ideas is quite limited. The authors justify saying that should extend the base case.

2.1.3 Methods of Representation and musical display

These are the jobs that provide a method for musical representation.

2.1.3.1 Representation with the meta-model EV

Article Knowledge Representation for Musical Composition (Alvaro, et al., 2005) have generated an EV meta-model that musical knowledge is represented in the basis of events, that is, everything that happens in music is an event, from a total development time to a sixteenth note, but this event can contain a list of events, and each event is comprised of a dynamic object, which can contain a list of dynamic objects. This produces a simple but robust way to represent musical knowledge. In Figure 4, obtained from the referenced article, the above relationship is shown.

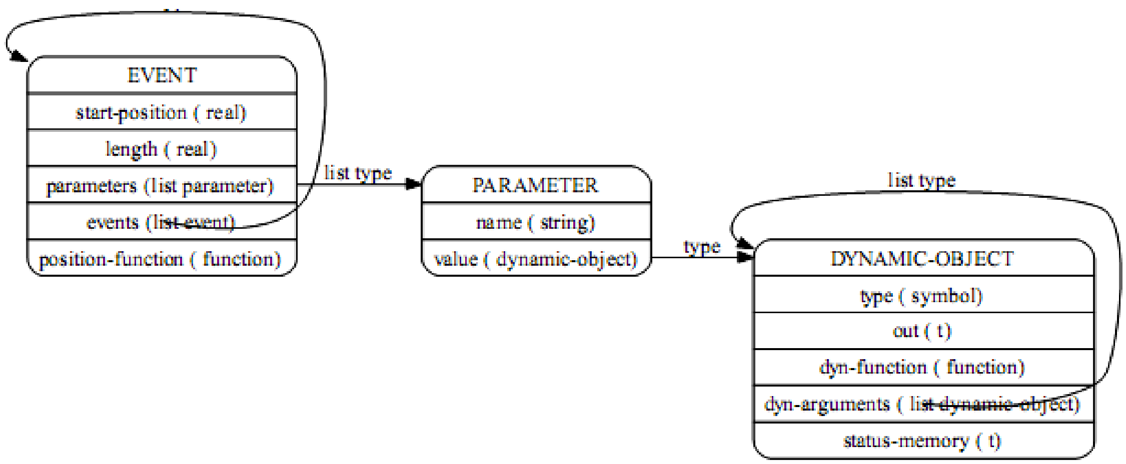


Figure 4. ontological core EV Meta-Model

The event object contains any element that can be located in time. It consists of five slots: initial position, length, parameters, events and function of position. In the slot parameter, each event has an associated parameter name and a dynamic object that has the ability to organize their own time scale, a clear example is the counterpoint.

Dynamic Objects have an evolutionary value, ie, have a living or changing magnitude. They also have a list of objects with live magnitudes, which can add value to the programmed sounds.

Strengths or Contributions

They generated an overview of the representation of musical knowledge considering cases in which difficulties can occur under this model are solved by changing a few parameters.

Not work

Do not provide comparisons with other knowledge representation.

2.1.4 Genetic Algorithms

The main items that help of genetic algorithms for musical composition are shown in the following sections.

2.1.4.1 Genetic algorithms using ABC notation

In *Genetic Algorithms and the ABC Music Notation Language for Rock Music Composition* (Oliwa, 2008) the composition of artificial music is described using different approaches, some architectures paradigms and neural networks or recurrent networks to create new musical pieces by a set of existing data.

This method is able to create the structure of a melody with arbitrary length and a diverse multi-instrumental delivery. The possibility of MIDI and ABC notation allows a very rich representation of music.

The problem with recurrent neural networks (RNN) is that in the long-term dependencies, music cannot be represented in practice, leading to the musical inconsistency. In this case the result looks promising however, only two instruments are used and the system presented is limited to 13 notes for the main instrument and 12 notes for rhythm instrument.

Each block has the same number of elements in each iteration and therefore the same separator segmentation, but each time the population stated earlier, is a different created form. This ensures that a song with a completely new structure is performed each time the genetic algorithm (GA) begins. This allows singularity in the number of instruments used and the structure of each new creation.

Each segment of a genome, has its fitness function is evaluated and assigned himself. The fitness function upward climb creates tone scales, which means that all keys must be greater than its predecessor. The fitness function is scaled down analogous to the ascending tone scale.

They note that the created musical compositions, the GA system gives a lot of freedom, not only for the rich representation but also by randomization of the number and size of the segments in the genomes, which results in the assignment of different fitness functions in the set.

They mention that the music is represented by GA, can create and play music according to the authors, exceeds the time approaches in terms of diversity, virtuosity and variety of instruments.

2.2.2 Genetic algorithms and grammars

Music Composition Using Combination of Genetic Algorithms and Kohonen Grammar (Sheikholharam and Teshnehlab, 2008) is similar to Automatic composition of music by means of Grammatical Evolution (Ortega and Alfonseca, 2007) with the difference that in the previous work based its function fitness by the AP440 processor and in this work, the fitness function is given by Kohonen grammars, where given a depth of notes, a new note is generated. That is, given AB → C or ABC → A, where the first example has a depth of 3 and 4 below. Use this to learn patterns.

The system architecture is based on two parts, one for the population of the notes and the other for the duration thereof, is a parallel process.

```
Initial population notes
    → iteration {
     Population notes
      → previous population notes + mutated population notes
      → previous notes + mutated notes + crossed population notes
```

```
    → Ideal selection using Kohoner grammar
  }
Initial population times
  → iteration {
   Population Time
    → previous population times + mutated population times
    → previous times + mutated times + crossed population times
    → Ideal selection using grammar Kohoner
  }
```

In this method, were used just 5 different types of duration times. Times are 0.125, 0.25, 0.5, 1, 2 and 4. It uses operators to connect notes as -20 to connect notes, -30 to separate notes, -40 to give the end of a bar. They generate other times and durations of notes.

2.2.3 Contributions

They propose two ways to evaluate the results. One based on rules and the other based on the same grammar learning using Kohonen learning short and long terms in music.

2.2.4 Weakness

They give a jump to the convergence problem by restarting the initial population every 10 generations.

The authors do not provide a structure of how to learn patterns Kohoner grammar.

They use the tone and time separately to generate two new populations and concatenate at the end, I think that breaks the string of a note with time for further evaluation.

2.3 Neural networks

In *Musical composition via neural computation* (Beam et al., 1998), they developed a system for editing and listening to sheet music for the musical composition. They generated a subsystem of musical inspiration, which consists of two phases: a learning phase, where the system processes which note follows after every n consecutive notes in each of the melodies of a code stored in the system, the other phase is generation, where n ratings given by the user, the system generates you the first note of the new melody, then given the first note and the last is taken to generate the next is eliminated.

2.3.1 Contributions

Everything is parameterized. That is, the user can define the depth to the input neurons, hidden neurons, level of error and chance level to avoid plagiarism and that these structures are not generated.

2.3.2 Weakness

The authors do not mention any way to evaluate the generated output.

2.4 Case-Based Reasoning

The main developments using case-based (CBR) reasoning are shown in the next subsections.

2.4.1 Automatic composition

The work *Automatic Music Composition System. Preliminary Approaches* (Gómez-Zamalloa, 2010), Miguel Gómez-Zamalloa, is based on the work of David Cope (Cope, 2001), Michael Chan (Chan and Potter, 2006), Pereira, Grilo, Macedo and Cardoso (Pereira et al., 1997). Gómez-Zamalloa proposes the musical architecture with separate modules using Case Based Reasoning (CBR) all controlled by a central control module. Each module is a separate and unique task. The modules are proposed: A isolated melodies generator, isolated harmonies generator, a melodies harmonizer, alternative melodic lines generator (secondary), a duration transformer, a quality evaluator using CBR and a control unit.

2.4.2 Contributions

The modularity of the system allows working more or less modules at a certain depth leaving work for future improvement.

The development of a hybrid system based on Rule-Based Reasoning (RBR) and CBR.

It provides a good overview of the work that had been developed before to the completion of the article.

Consider the implementation of a quality evaluation module using CBR to improve future decisions.

2.4.3 Weakness

Apparently, the system proposed in this paper was not implemented because there are no other publications on the implementation of the modules.

2.4.4 Using CBR

In *Composing Music with Case-Based Reasoning* (. Pereira et al, 1997), the authors present a method based on musical analysis, CBR and planning techniques for musical composition; Thus the new solutions are obtained by transforming and extrapolating the knowledge derived from musical analysis previously performed by experts.

Each analysis was depicted as a case, it can be divided into all its subcomponents and divides the track according to the hierarchy shown in Figure 1, obtained from that article:

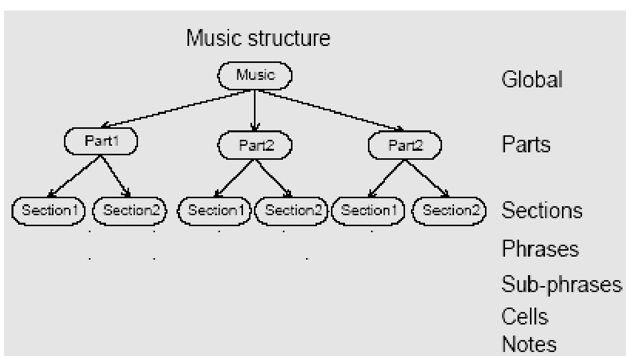


Figure 1. Hierarchical division of a track

In addition to the hierarchical relationships, they mention that there are horizontal relationships between components. For example, in the figure below indicates that the section A of Part 1 is the same as Section A of Part 2 but transposed. See Figure 2.

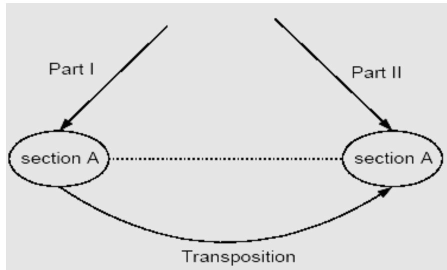


Figure 2. Horizontal relationships in the hierarchy

So each of these structures in a tree, with horizontal relationships between components, is a case where they extract the information in the CBR cycle.

They represent the case as a Prolog made as follows:

```
case_node( Case_Name, Node_Name, Temporal_Position, Constraints,
    Atributes, Antecedents, Consequents )
```

They highlight the attributes "Antecedents" and "consequents" who described relations with superiors nodes (respectively lower) in the hierarchy, or previous (respectively higher) in time. Thus two arbitrary nodes are related in any desired manner.

Much of the dynamism present in the proposed representation is derived from the fact that a case can also be considered a plan using the Wallas model for creative systems, so that the temporal relationships between nodes and interpreted as causal relationships in the analysis be treated as suggestions in the composition phase.

The method divides the writing process into four stages according to the model of Wallas:

- ***Preparation***: cases are loaded into memory and problem solving is defined as a new case (case_node).
- ***Incubation***: It corresponds to the CBR recovery phase. As a result it has a number of nodes arranged according to a certain criterion.
- ***Lighting*** (***adaptation***): An attempt to adapt the first node (if it is not possible tries the second, etc.).

Iterate from the preparation phase, now with the new problem to solve.

The process continues iteratively in left-right and up-down order.

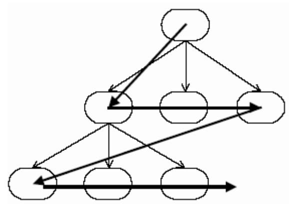


Figure 3. Iteration on the hierarchical structure

- ***Verification***: Once it has been built completely new structure, begin the verification phase, whose task will be to assess the new composition according to the style in question. Is currently performed entirely by a musical analyst.

As described in the recovery phase, uses a similarity metric in order to categorize the nodes according to a given criterion. The authors base their judgment on the following idea: The less similar solutions could potentially be the most creative. So, first sorts the list of nodes in descending order of similarity to later invest the first 40% placing it at the end. Of course they are aware that the chosen policy is somewhat "blind" even though they say it could be a good starting point.

2.4.5 Weakness

It was initially part of a series of analyzes by experts, which sooner or later will involve inflexibility.

The system has no a learning phase, mainly due to the inability to create new cases to be needed for this human intervention, particularly in the analysis phase.

The melodic similarity metric used does not seem too consistent. Should be found some kind of melodic similarity metric that is able to capture certain musical characteristics in an abstract way, so that creative aspects of nature are captured.

The creative ability of the system to generate new ideas is quite limited. The authors justify it by saying that it would extend the base case.

2.5 Methods of musical representation and visualization

These are jobs that provide a method for the musical representation.

2.5.1 Representation with EV meta-model

In *Knowledge Representation for Music Composition* (Alvaro, et al., 2005), the authors have created a meta-model EV with the musical knowledge is represented based on events, everything that happens in music is an event, from a total development time to a sixteenth note, but this event can contain a list of events, and each one is comprised of a dynamic object, which can contain a list of dynamic objects. This produces a simple but robust way to represent musical knowledge. In Figure 4, obtained from the aforementioned article, the above relationship is shown.

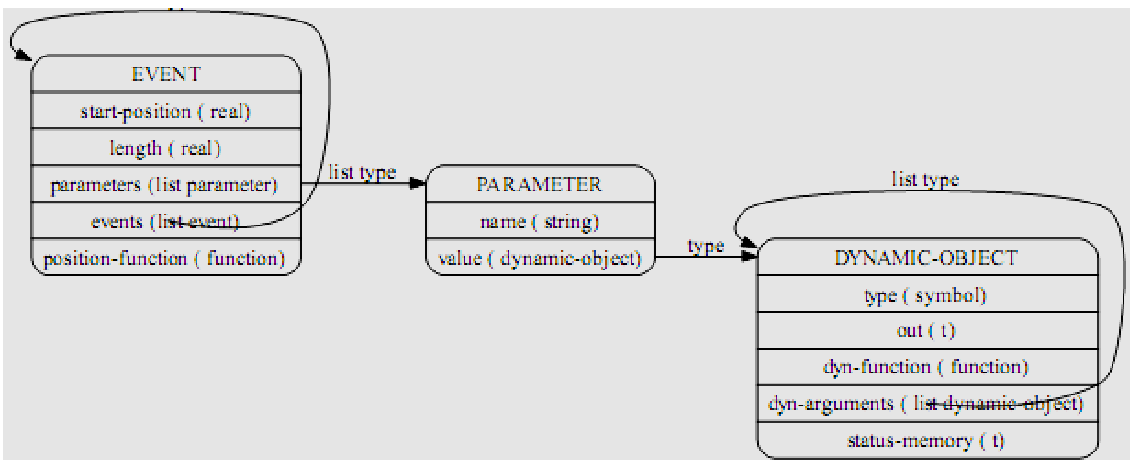


Figure 4. Ontological core EV Meta-Model

The event object contains any elements that can be located in time. It consists of five slots: starting position, length, parameters, events and position function. In the slot parameter, each event is associated with a parameter name and a dynamic object that has the ability to organize their own time scale; a clear example is the counterpoint.

Dynamic objects are evolutionary value, that is, these have a bright or changing magnitude. They also have a list of objects with dynamic quantities, which can add value to the programmed sounds.

2.5.2 Contributions

They provide a representation overview of musical knowledge considering cases in which problems can occur. This model solves these problems by changing a few parameters.

2.5.3 Weakness

The authors do not compare their work with other knowledge representation.

2.6 Relevant authors and their contributions

Joseph Schillinger. In 1947 he tried to develop a musical theory that could be useful with electronic brains.

Lejaren Hiller and Leonard Isaacson. In 1955 they began their work of algorithmic music (Hiller and Isaacson, 1957.1958), based on a "generate and test". They created the first composition made entirely by a computer. It was published as "Illiac Suite". Were based on Markov chains to generate a pseudo-random note, given a sequence of n previous notes to pass a series of heuristic tests. This model excludes everything related to the expressiveness and emotional music content.

David Cope. He developed a system that generates music from established music analysis (Cope, 1991, 1993, 2001). Your system emulates different compositions of classical composers. this system is based on a corpus and is not based on rules, thereby extracts the knowledge of the compositions as in CBR-based approaches.

Michael Chan. His work is heavily based on the work of David Cope on one side and Lerdahl and Jackendoff on the other. Accepts a corpus of tracks represented in XML, produce new works by imitating his style (Chan and Potter, 2006).

Karsten Verbeurgt, Mikhail Dinolfo and Michael Fayer. They used Markov models as a means for composition, learning transition probabilities between patterns.

Charles Ames. Proposed to deal with Markov chains in different sizes of letters.

Jon Gillick, Kevin Tang and Robert M. Keller. They use Markov chains to determine the transition probabilities between groups of different types of melodic themes.

Terry A. Winograd. Make a study based on systematic grammar of Halliday. Perform harmonic analysis of a piece, labeling chords, constituting one of the first effective analysis systems (Winograd, 1968).

Gary M. Rader. He uses probabilistic grammars to generate traditional melodies. He uses his own artificial intelligence techniques. Use applicability rules that determine when to use the generative rules. It is the first example of meta-knowledge in this context (Rader, 1973, 1996).

John McCormack. Proposed the use of L-systems and Markov chains with parallel derivation grammars (McCormack 1996).

Gerard Assayag and Shlomo Dubnov. They demonstrated the possibility of using oracles, as a factor to generate improvised musical sequences.

Fred Lerdahl and Ray Jackendoff. They tried to formalize music theory, working on the proposal by Schenker. They use a theory of generative grammars for the analysis of music (Lerdahl and Jackendoff, 1983).

Damon Horowitz. Use a theory of generative grammar as an approach to the analysis of jazz (Horowitz, 1994).

Mark Jerome Steedman. He described the use of a grammar for the jazz analysis chord progressions, but not melodies. Their grammars were expressed in terms of six rewritable rules taking as input a basic blues progression (Steedman, 1984). He deduced the rules of analysis of the corpus from eight blues progressions taken from a book of Coker (Coker, 1987).

Philip Johnson-Laird. Described the use of a grammar for analysis of melodies. It also suggests the use of regular grammars to explain the rhythmic sequences. They argue that music is an excellent test for creativity theories that addresses problems of semantics.

John A. Biles. Proposes the use of interactive genetic algorithms and neural networks to play Jazz with humans (Biles, 1994).

George Papadopoulos and Geraint Wiggins. They used genetic algorithms for generating melodies, so it requires a fitness function for genetic selection and produce the next generation of notes (Papadopoulos and Wiggins, 1990).

Heinrich Schenker. He defined a transformational system for music analysis long before Chomsky did the same with the linguistic. His method was essentially analytical, not generative.

Andrew Gartland-Jones. The use of genetic algorithms, they get their fitness from similar music to which you want to generate.

Marques Oliveira Vieira and Rosa. Using genetic algorithms with fitness functions based on rules (Marques et al., 2000).

Teuvo Kohonen. He uses a dynamically expanding context learning of deterministic patterns in music (Kohonen, 1989).

D. Burr and Y. Miyata. They applied a type of hierarchical recurrent neural networks to learn musical scales.

Mozer and Soukup. Used a recurrent neural network to learn Bach melodies.

F. Pereira, C. Grilo, Macedo L., A. Cardoso. They use a Case-Based Reasoning approach to their work. Adopting a process of progressive and iterative composition of left-right and up-down.

Pierre Barbaud. In 1958, he tried to create a generative system for tonal music, from the guidelines established by Kirker three hundred years before.

Simon and Summer. Pioneers in Artificial Intelligence. They attempt to explain the patterns of tonal music in terms of rhythm, melody, harmony and form. Design an inductive method to identify patterns. Based on studies conducted in psychology at the same university that they worked. Usually dated to 1968 the beginning of modern research in artificial musical intelligence.

S. Smoliar. In 1971, implemented in LISP several ideas of Schenker and achieved generate medieval polyphony, Gregorian chant and counterpoint to the "Bach".

E. Bilotta, P. Pantano, V. Talarico. They proposed the cellular automata use.

D. Fogel and Z. Michaelewiez. Using Genetic Algorithms with an excellent work in heuristics.

Duff, Eberhart and Dobbins. They proposed in 1989 and 1990, the possibility of using a backpropagation neural network type for the combination of different melodies.

J. R. Hilera, R. J. González, J. A. GutiérrezofMesa. They propose the use of neural networks for music composition via neural computation, creating a system of neural inspiration.

Miranda. Discusses different approaches to use evolutionary computing music (McAlpine et al., 1999).

Gary Moore. His work is based on melodies generation that attempts to simulate the techniques used by human algorithmically, and based on heuristics. Moore gives a fractals review and stochastic methods, oriented procedures and recursive compositions.

Marvin Minsky. He proposes to use agents such that the iteration among several of them produce the desired result. Each specialized in a particular skill or technique agent, taking turn higher order agents that coordinate the overall operation (Minsky, 1993).

Jamshed Bharucha. he uses neural networks to learn musical harmony.

Feulner. Used a combination of constraint satisfaction techniques and neural networks.

Sabater, Arcos y LópezofMántara. They propose a harmonization musical system CBR and assisted by rules (Arcos et al., 1998).

3 THEORETICAL FRAMEWORK

In this chapter the basic definitions and concepts necessary to detail the methodology to solve the problem addressed. Here also explains the way in which production rules defined in this work and the output format with the results presented are shown.

3.1 The sound

Sound is the physical phenomenon that creates music, as it is the intentional manipulation of this phenomenon to create structured sounds that are pleasing to the ear.

The sound is the sensation perceived by the ear to receive the pressure changes induced by the vibratory movement of the sounding bodies. It is transmitted by the medium that surrounds such as air or fluids.

The basic parameters of sound are four:

- **Frequency**: This is the number of cycles of vibrations per second of a sound body are emitted in hertz (Hz). According to this you can set sounds as "Low" and "Treble". The treble sound is the higher frequency. Wavelength is the distance measured in the propagation direction of the wave between two points with identical state of motion, ie., reaching the maximum and minimum at the same instant.
- **Duration**: This corresponds to the time interval of the vibrations that produce sound.
- **Intensity**: is the force with which a sound is produced; depends on energy. The intensity is represented by wave amplitude.

– **Timbre**: The quality that distinguishes the different instruments or voices even though they are producing sounds with the same pitch, duration and intensity. The sounds we hear are complex; ie, are the result of different frequencies sum but we perceive as one. The pattern depends on the amount of harmonics or the waveform that has a intensity sound of each, which is called the spectrum.

Silence is the noticeable absence of sound, although a relative sense, because the silence is not present in nature.

Noise is a simple or complex but disharmonic and high intensity sound, generating intolerance or ear pain and a feeling of displeasure to the individual, ie generally unpleasant hearing sensation.

Music is the set of notes and rests that is pleasant to the human ear. The kind of music that used the rules and standards of the composition enjoyable for the appreciation of our culture is the *Western music*. Pop music and traditional music is western music.

The annoying sound, when dissonance, defined as harsh, discordant, and lack of harmony exist say it is noise.

Noise is any sound that is annoying to the ear that exists in the environment. From this point of view, a person who does not want to hear it may classify the most sublime music as noise.

The **tempo** is the measure of the speed at which to play every musical figure. This is measured as the number of beats in a minute. The duration of the musical figures is defined by the number or portions of **pulses**.

The pulses are measured in sets called **bars**. The number of beats in each measure is different, but is defined at the beginning of the score. Each measure belongs to a different degree. A degree is the set of notes corresponding to a chord of the scale. Each grade has a different voltage. The relationship between stress-rest-break within a section creates the musical discourse.

Composition is the creation of a new musical work using the musical basis. Musical work is a complete composition of one or more musical pieces interrelated, musical piece is a part of the composition with a complete and independent musical argument. The arrangement of music for a combined number of instruments is named Instrumentation.

In the field of music, the term **note** refers to a particular sound by a vibration whose fundamental frequency is constant.

The names of the musical notes are derived from the poem "Ut queant laxis" written by a Benedictine monk Friulian Paul the Deacon, specifically the initial syllables of the hymn to St. John the Baptist.

After alterations and modifications carried out in the sixteenth century, the notes became the currently known in the Western system: Do, Re, Mi, Fa, Sol, La and Si.

Common notation systems in different notes are:

Table 1. Notation systems

System	Representation
Letter	C D E F G A B
German	C D E F G A H
Italian and Spanish	Do Re Mi Fa Sol La Si
French	Ut Re Mi Fa Sol La Si

In the present work we used the letter notation.

The music uses pitch that is the frequency of the notes determining how high or low it sounds. The distance differences each note in frequency; this distance is measured in **semitones**. The semitones between notes are named **interval** and were defined as shown on Table 2.

Table 2 Distance between notes measured in semitones.

	Diminished	**Minor**	**Perfect**	**Major**	**Augmented**
First			0		1
Second	0	1		2	3
Third	2	3		4	5
Fourth	4		5		6
Fifth	6		7		8

Sixth	7	8		9	10
Seventh	9	10		11	12
Octave	11		12		13

The **perfect octave** has eight full tones or 12 semitones above the keynote where the scale begins and ends.

Scale is the ascending or descending note succession of a key or mode. **Chromatic scale** includes all twelve notes of an octave. Modes are the two octave arrangements in modern music. The **modes** are either *major* or *minor*. Music written in *major* keys has a positive affirming character. The *minor* mode can be identified by the dark, melancholic mood.

Key is the system of notes or tones based on, and named after the keynote. **Keynote** also known as tonic, is the first and principal tone of a scale.

The **tone** is the intonation, pitch, and modulation of a composition expressing the meaning, feeling, or attitude of the music. **Tonal** means pertains to tone or tones. **Tonality** is the tonal characteristics determined by the relationship of the notes to the tone.

Rhythm is the element of music pertaining to time, played as a grouping of notes into accented and unaccented beats. **Beat** is the unit of musical rhythm.

The duration is an amount of time or a particular time interval. ie the length of a note.

The duration of a note is shown below:

– **Whole** note is equal to 4 beats.

– **Half** note is equal to 2 beats either the half duration of a whole.

– **Quarter** is equal to 1 beat, in the same way, is a quarter of a whole.

– **Eighth** and sixteenth are the corresponding division of the whole duration.

The principal measure of time to synchronize the instruments in time but not in tone is the bar.

Melody is the horizontal part of the music. It is the continuous succession of notes and rest in coherent form. The melody creates sentences named phrases or ideas.

Harmony is the vertical part of the music, is the pleasing combination of two or more tones played together in the background while a melody is being played. Harmony also refers to the study of chord progressions.

Chord is the construction of three or more notes in third intervals playing at same time. The principal note of a triad (consisting of a root, third, and fifth intervals) corresponding with the tonic note of the scale degree is the root. Scale degree is the distance between the keynote and root of chords in the progression measuring in intervals named as roman numbers.

Chord progression is a string of chords played in succession, this creates the musical argument. Musical **argument** is the form of the musical work that creates the tension and release feeling. **Form** is the structure or plan of a piece of music.

Bass is the harmonic component that sounds in one or more octaves below and corresponding with the notes of the chord. Bass-line is the melody of the bass.

Musical work is the composition based on a musical argument of the *release - tension - release* kind, using a succession of independent sections coordinated by a scale degree. The sections can be repeated at any time. For the ending of the piece, a section with different characteristics is appended to the succession.

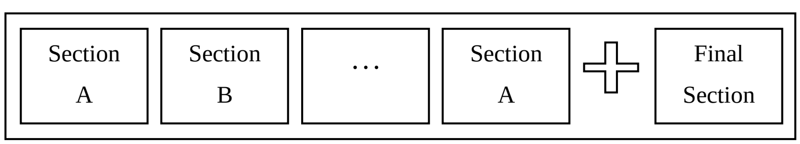


Figure 4 Structure for a complete musical work

Section is a complete musical idea, but not independent. It is the chord progression that creates an independent musical argument in the musical work. Each section is the progression in a set of chords to the scale degrees; and, at the same time, the scale degree is used to synchronize the instruments in every section. Furthermore each instrument generates an independent line of improvisation: harmonic, melodic and bass. Each section can be repeated the same or modified within a musical work.

Cadence is progression that brings an end to a phrase, either in the middle or in the end of a composition.

The term **musical form** or **musical architecture** refers to the overall structure or plan of a piece of music.

Notes

In the field of music, the term note refers to a particular sound by a vibration whose fundamental frequency is constant.

The names of the musical notes are derived from the poem "Ut queant laxis" the Benedictine monk Friulian Paul Deacon, specifically the initial syllables of the hymn to San Juan Bautista.

After alterations and modifications carried out in the sixteenth century, the notes became those currently known in the Western system: Do, Re, Mi, Fa, Sol, La and Si.

The most common ciphers notes in different systems are:

Table 2. ciphers following:

System	Representation
English	C D E F G A B
German	C D E F G A H
Spanish and Italian	Do Re Mi Fa Sol La Si
French	Ut Re Mi Fa Sol La Si

Although the first syllable of the poem of San Juan is respected in the French system for music theory it is still used Do to eliminate difficulties in pronunciation that produces the letter t.

Musical Writing

There are various forms of musical writing in different cultures, but in regard to Western music, is from the medieval music that began to use the system of musical notation that would evolve the current. In the Renaissance crystallized with the more or less definitive traits that we know it today, although like all language, has been changing according to the expressive needs of users.

The system is based on two axes: one horizontal, which graphically represents the passage of time, and a vertical height that graphically represents the sound.

The heights are read in relation to a staff that is a set of five lines and four parallel spaces and listed from the bottom up, so that the bottom line is the first line and the space between the first and the second line is the first space. It is the baseline for the placement of musical symbols.

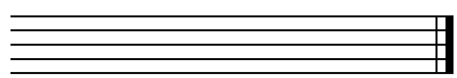


Figure 5. Representation of staff

The end of a pentagram is represented by a thin vertical line followed by a thick line parallel to it. The key:

At the beginning of each staff is placed a "key" which has the function of attributing to each of the staff lines a particular musical note. In a staff led by the treble clef on the second line we will read as Sol sound that is written in the second line, the ascending and descending notes are written in the spaces and next respectively following lines. To the sounds that fall outside the key additional lines they are written. The keys most commonly used are those of C on the third line, this key as a reference to C of 261.63 Hz, ie, the middle C on the piano. The key to Sun in second, which refers to the Sun which is a fifth above middle C, and the Fa in the fourth line, based on the Fa is a fifth below middle C.

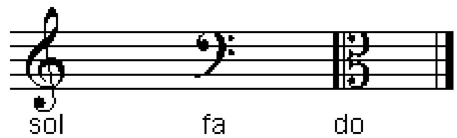
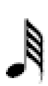


Figure 6. Form and location of the keys on the staff

The musical figures

To write the duration of sounds a system of figures representing relative durations each other, the names of the figures and their duration are shown in Table 2 is used.

Table 3. Musical Figures

Figure	Name	Duratii on	Value
	Round	1	Twice a white
	Half note	2	Half a round and twice a black
	Quarter Note	4	Half a white and twice an eighth note
	Eighth Note	8	Black and twice a sixteenth
	Sixteenth Note	16	Half an eighth and twice a thirty-second note
	Thirty-second note	32	Half a sixteenth note and twice a sixty-fourth note
	Sixty-fourth note	64	Half a thirty-second note

When we wrote eighth notes, sixteenth notes, eighth notes and sixteenth notes got used to group clasp all remaining within a time for easy reading.

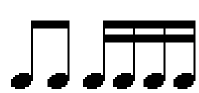


Figure 7. Notes with unions

The figures are relative addresses; the figure corresponding to the unit time is represented by the bottom number of the time signature.

The measure

Measures are the temporal units into which a musical piece is divided, representing the number of beats that fit between two vertical lines. Each vertical line that crosses the staff marks the end of one measure and the beginning of the next.

The time signature

At the beginning of the staff is a fraction. The numerator, or top number, indicates the number of beats that each measure contains; the denominator, or lower number, indicates which note receives one beat.

Thus, a score headed by a ¾ time signature will have bars or measures divided into three quarter notes, a quarter note and four eighth notes or any combination of notes of equivalent duration.

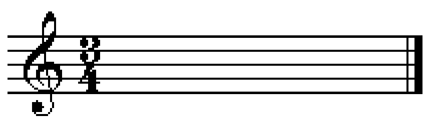


Illustration 8. Time signature

Often we use the symbols 𝄴 for time signatures of 4/4 and 𝄵 for times of 2/2.

In the following example, we see a score with a time signature of two beats where each beat is represented by a quarter note.

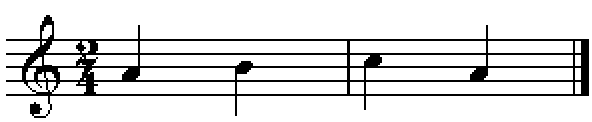


Illustration 9. Example of time signature.

3.1.1.1 The rests

Rests are represented by other defined symbols which correspond in duration to each of the notes.

Table 4. Relationship of rests and their symbols.

Symbol	Represents
𝄻	Whole
𝄼	Half
𝄽	Quarter
𝄾	Eight
𝄿	Sixteenth
𝅀	Thirty-second
𝅁	Sixty-fourth

As seen, the durations are set according to a binary relation (double or half), which does not provide subdivision of three, which will be indicated with triplets.

When you want a note or rest to add half of its duration, is placed a point to the right (dotted).

Table 5. Comparison of notes with and without dots.

Without dot		Dotted	
Note	**Equivalence**	**Note**	**Equivalence**
𝅝	𝅗𝅥 𝅗𝅥	𝅝.	𝅗𝅥 𝅗𝅥 𝅗𝅥
𝅗𝅥	𝅘𝅥 𝅘𝅥	𝅗𝅥.	𝅘𝅥 𝅘𝅥 𝅘𝅥
𝅘𝅥	𝅘𝅥𝅮 𝅘𝅥𝅮	𝅘𝅥.	𝅘𝅥𝅮 𝅘𝅥𝅮 𝅘𝅥𝅮

When you want the note to last, in addition to its value, another certain value, two notes are written, joined by an arched line called a ligation.

The following example uses the first measure ligation extension and the second deals with the dot; the two measures are equivalent.

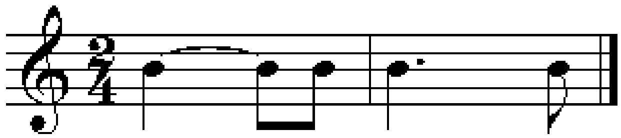


Illustration 10. Measures with ligature and dot

3.1.1.2 Alterations

Any of the seven notes can be altered in ascending or descending through alterations.

Symbols representing alterations are shown in Table 5.

In the musical writing an alteration affects any note of the same name and in the same octave within a bar.

1.1.1.1 The key signatures

To reduce the number of alterations when writing music composers resorted to the use of key signatures. These alterations, written between the key and time signature affecting all notes of that name through the piece including those in other octaves.

Table 6. Symbol and function of alterations.

Symbol	Name	Function
♯	Sharp	Raises the following note by a half tone for the rest of the bar.
♭	Flat	Lowers the following note by a half tone for the rest of the bar.
♮	Natural Sign	Reverses the effect of an alteration on a note from that point forward.

3.1.1.3 Additional notes

In general, disabilities system are solved using more or less conventional written words, usually in Italian. For example, the intensities are indicated by using an f (forte strong) or p (piano, soft), or repetitions of each to indicate more or less intensity. The speed of the pulses indicated by words at the beginning of the score that are, in order of speed: *largo*, *lento*, *adagio*, *moderato*, *andante*, *allegro*, *presto*.

3.1.2 Relationship between notes.

A healthy and young ear is sensitive to frequencies between 20 Hz and 20 kHz. However, this range varies with each person and changes with age. This range corresponds very approximately ten full octaves.

In the western musical system, it has been agreed to use only specific frequencies, which we call notes.

Possible frequencies have been divided into portions called octaves, and each octave into 12 portions we call notes. Each note is an octave frequency exactly half that of the same note in the octave above.

3.1.2.1 Tone and half-tone

A semitone is the distance or difference in sound frequency between each of the sounds of the eighth, which tempered tuning system is divided equally into twelve sounds.

It is considered the lesser of the two intervals can occur between consecutive notes of a diatonic scale. It gets its name from being equal to half the tone in a tempered scale, which is the largest of these intervals between consecutive notes in a scale.

A cent is equivalent to one hundredth of tempered semitone, a tone which is equivalent to 200 cents.

Given this frequency equal division, a constant proportionality geometrically equal to the root February 12 is achieved, that is:

$$K12 = \sqrt[12]{2}$$

A good approximation for calculating the frequencies of the notes is to consider four decimals and take K12 as 1.0595 despite a bad time, but is taken as a standard for error is 0.06 cents for simple multiplications. The error accumulates every time this is done, if shackled multiplications are performed. However, making a rounded twelve semitones chain thus the difference with the octave range is even less of a cent.

3.1.3 Tuning

The note serves as the reference for all others. how a fine tune of 440 occurs when air vibrates 440 times per second, i.e. 440 Hz. By convention, it is generally considered that this note belongs to the third eighth, giving the Do this name Do Central.

3.1.3.1 *The chromatic scale.*

The, also called dodecáfona or duodécuple scale, chromatic scale is the scale containing the twelve semitones of the Western tempered scale.

Each note is separated from its top and bottom by a semitone interval neighbors. The term "color" is understood by musicians to refer to music which includes the notes that are not part of the main scale, and as a descriptive word for those particular notes are not diatonic.

The succession of notes used in this scale is given by the seven fundamental notes of natural diatonic scale receiving names defined above and adding an alteration to the intermediate marks as follows.

Table 7. Names of the notes in the chromatic scale.

1	2	3	4	5	6	7	8	9	10	11	12
	Do#		Re#			Fa#		Sol#		La#	
	Re*b*		Mi*b*			Sol*b*		La*b*		Si*b*	
Do		Re		Mi	Fa		Sol		La		Si

3.1.3.2 Enharmony

Enharmonic notes are two notes of different names but the same sound frequency. For example Sol # and Lab are enharmonic notes because both have a frequency of 415,305 Hz for tuning in A 440.

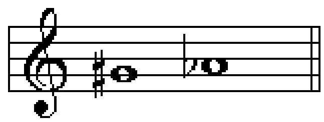


Illustration 11. Enharmony of G# y Ab

3.1.4 Intervals

An interval is the frequency difference between two musical notes, measured in degrees quantitatively or qualitatively natural notes and tones and semitones.

3.1.4.1 Names of Intervals

Counting the number of degrees between notes get the name of the interval. By having grades must include both the first and the last note. However, not all intervals of the same name have the same size. Therefore it is necessary to specify the type or grade intervals accurately determining the number of tones and semitones you have.

3.1.4.2 Classification of Intervals

In the chromatic scale we can see that not all intervals from one note to another with the same number of tones and semitones, for example, the second between C and D has a tone, while between E and F is a semitone.

Because of these differences it is necessary to specify the type or classification of intervals.

- **Tonal intervals**. They are those intervals that have a single fair value within these ranges are the range of fourth, fifth and eighth. The first interval, which actually is the unison of the same note, also falls into this category.
- **Intervals manners**. They are the intervals have a higher value and another own retail mode in which it is located. Within these ranges are the second, third, sixth and seventh.

All intervals can be increased or decreased. Table 7 shows the classification is given according to the halftones.

3.1.4.3 Consonance and dissonance.

intervals are classified as consonant or dissonant according to the complexity of the mathematical relationship of the sound frequency of the notes that compose it.

Although through history the concept of consonance and dissonance has changed and even today theorists do not always agree, we can offer the following classification.

Table 8. Name, classification and distance between intervals.

Interval	Classification	Half tones
First	Unison	0
Second	Diminished	0
	Minor	1
	Major	2
	Augmented	3
Third	Diminished	2
	Minor	3
	Major	4
	Augmented	5
Fourth	Diminished	4
	Perfect	5
	Augmented	6
Fifth	Diminished	6
	Perfect	7
	Augmented	8

Sixth	Diminished	7
	Minor	8
	Major	9
	Augmented	10
Seventh	Diminished	9
	Minor	10
	Major	11
	Augmented	12
Octave	Diminished	11
	Perfect	12
	Augmented	13

- *Perfect tunes*: the intervals of fourth, fifth and eighth when are fair.
- *Imperfect tunes:* the third and sixth intervals are already more or less.
- *Absolute Dissonances:* second intervals and major and minor seventh.
- *Conditional Dissonances:* all augmented and diminished except augmented fourth and diminished fifth intervals.
- *Semi-consonances:* augmented fourth and diminished fifth.

Furthermore, in the context of traditional harmony, the melodic interval is considered augmented fourth dissonant.

3.1.4.4 *Compound and Simple Intervals*

Simple intervals are those that are no more than an octave. Compound intervals are those that exceed the eighth.

The ninth, tenth, eleventh and thirteenth intervals are examples of compounds.

3.1.4.5 *Melodic and Harmonic Intervals.*

A harmonic interval is one in which notes are played simultaneously. In the melodic intervals notes are played in succession.

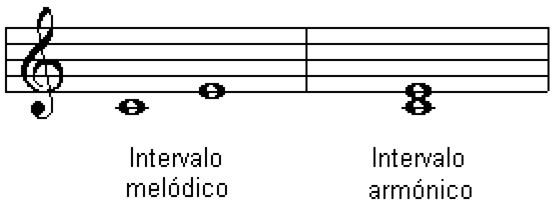


Illustration 12. The difference between a melodic and a harmonic interval.

3.1.4.6 *The mathematical relationship of intervals.*

The A is in the eighth middle C is 440 Hz. A The one octave vibrates at 880Hz. taking exactly twice the vibrations per second. This relationship is expressed mathematically as 880: 440 or 2: 1. In Table 8 are given the mathematical relationships of some intervals organized from consonant to dissonant.

3.1.5 Scales

The orderly succession consecutively of notes is referred to as a musical scale. These sounds are arranged in ascending order, i.e., from low to high, although complementarily also in descending order, one by one at specific positions within the scale, called degrees.

Table 9. The relationship between intervals

Relación	Interval
2:1	Octave
3:2	Fifth
4:3	Fourth
5:4	Major Third
6:5	Minor Third

9:8	Major Second
16:15	Minor Second

The practical utility of the musical scale is essentially didactic, and synthesizes the particular composition of a musical system, as well as expose simplified schematic and convenient way the melodic and harmonic material from which it is composed, in part or in whole, a work musical under study.

Degrees give the name of each of your notes and represent them with Roman numerals.

The two features that distinguish one from another scale are:

- The number of notes exist in the interval of an octave.
- The order of the intervals between each of their degrees.

There are many scales already defined, but you can also invent scales when composing. Composers such as Claude Debussy, Olivier Messiaen and Bartok, among others, have done in the recent past.

The scales most commonly used in today's Western music are two, the major scale and minor scale.

3.1.5.1 The Major Scale

The major scale is the most natural harmonic succession that there is, essentially defined by harmonics that consists in its most basic relationships and previously studied.

The structure of the major scale starting with the root note is given in Table 9.

Table 10. Structure of the Major Scale.

Scale	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VII**
Distance	0	Tone	Tone	Half Tone	Tone	Tone	Tone	Half Tone
Interval	First	Second Major	Major Third	Fourth Perfect	Perfect Fifth	Sixth Major	Major Seventh	Octave Major

You can build a scale starting on any note using alterations to maintain the order of tones and semitones. For example, to build a major scale on the note Re, we must alter the F and C notes:

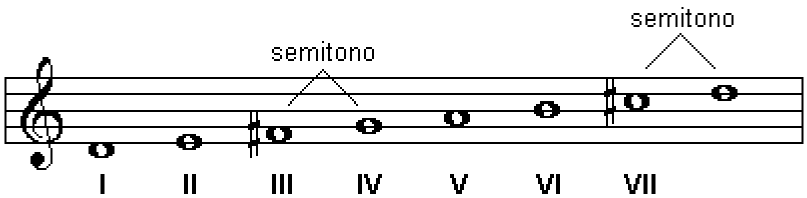


Illustration 13. Representation of the major scale.

To refer to a particular scale, we give the name of the note on which it is built and specify its structure. For the above example the name of D Major is used.

3.1.5.2 Minor Scales

Like the major scale, the minor scale has 7 notes. However there are three varieties: natural minor, harmonic minor and melodic minor. The difference between these three types of scale is the alteration of grades VI and VII.

Natural Minor Scale

The major scale has a smaller scale associated with having the same notes as the major scale and VI degrees is far greater source note. It is the relative minor scale.

This scale is created from the resulting intervals touring the source note VI grades, see Table 10.

Table 11. Structure of the natural minor scale.

Scale	I	II	III	IV	V	VI	VII	VIII
Distance	0	Tone	Half Tone	Tone	Tone	Half Tone	Tone	Tone
Interval	First	Second Major	Minor Third	Fourth Perfect	Perfect Fifth	Sixth Minor	Minor Seventh	Perfect Octave

Harmonic minor scale

The name is because one of the reasons for altering the seventh grade is harmonious nature. Altering this note allows the formation of dominant chord or dominant seventh on the V scale degree. Its structure is defined in Table 11.

Table 12. Structure of the harmonic minor scale.

Scale	I	II	III	IV	V	VI	VII	VIII
Distance	0	Tone	Half Tone	Tone	Tone	Half Tone	3 Half Tones	Tone
Interval	First	Second Major	Minor Third	Fourth Perfect	Perfect Fifth	Sixth Minor	Major Seventh	Perfect Octave

3.1.5.3 The pentatonic scales

Pentatonic scales are scales of five sounds. These scales have been used in folk music from different countries. More recently, composers like Claude Debussy and Maurice Ravel have used it in their music.

Although any scale of five sounds could be called pentatonic, the most common forms are the major and minor.

3.1.5.4 The Major Pentatonic Scale

The major pentatonic scale is based on the larger scale, but excluding grades IV and VII of this, creating the structure shown in Table 13.

Table 13. The structure of the Major Pentatonic Scale.

Scale	I	II	III	V	VI	VII
Distance	0	Tone	Tone	3 Half Tones	Tone	3 Half Tones
Interval	First	Second Major	Major Third	Perfect Fifth	Sixth Major	Octave Major

3.1.5.5 The Minor Pentatonic Scale

Like most pentatonic scale, this is based on the natural minor scale, but excluding grades II and VI of this, the resulting structure is as follows.

Table 14. The structure of the Minor Pentatonic Scale.

Scale	I	III	IV	V	VII	VIII
Distance	0	3 Half Tones	Tone	Tone	3 semitonos	Tone
Interval	First	Minor Third	Fourth Perfect	Perfect Fifth	Minor Seventh	Perfect Octave

3.1.5.6 Modal music

To get into the ways we say that a set of scales are built on each of the degrees of the major scale. They have their origin in the Gregorian modes. They are called Gregorian to the scales or modes used in Gregorian chant modes. These were monophonic character and were in use during the Middle Ages and the Renaissance. Over time they were transformed in our major and minor scales. The number of modes varies according to the time, but we could say that there were eight Gregorian modes.

After several centuries of being forgotten, these modes were varied and have been used in all kinds of music, both classical music and jazz. Although the nomenclature and names for them are different today the most used names are listed below.

Ionic

This modal is the most natural and is resulting in the current larger scale. The scale without alterations is beginning in Do. See Table 15.

Table 15. Structure of the Ionic modal.

Scale	I	II	III	IV	V	VI	VII	VII
Distance	0	Tone	Tone	Half Tone	Tone	Tone	Tone	Half Tone
Interval	First	Second Major	Major Third	Fourth Perfect	Perfect Fifth	Sixth Major	Major Seventh	Octave Major

Doric

Because your third grade is lower, it is considered a minor but a major sixth scale. Its scale without alterations is beginning Re. See Table 16.

Table 16. Structure of the Doric modal.

Scale	I	II	III	IV	V	VI	VII	VII
Distance	0	Tone	Half Tone	Tone	Tone	Tone	Half Tone	Tone
Interval	First	Second Major	Minor Third	Fourth Perfect	Perfect Fifth	Sixth Major	Minor Seventh	Octave Major

Phrygian

It is a smaller scale with second child. Its scale without alterations is beginning in Mi. See Table 17

Table 17. Structure of the Phrygian modal.

Scale	I	II	III	IV	V	VI	VII	VII
Distance	0	Half Tone	Tone	Tone	Tone	Half Tone	Tone	Tone
Interval	First	Second Minor	Minor Third	Fourth Perfect	Perfect Fifth	Sixth Minor	Minor Seventh	Octave Major

Lydian

This is a major scale with the fourth note augmented. Unaltered, the note is Fa. See Table 18.

Table 18. Structure of the Lydian modal.

Scale	I	II	III	IV	V	VI	VII	VII
Distance	0	Tone	Tone	Tone	Half Tone	Tone	Tone	Half Tone

Interval	First	Second Major	Major Third	Fourth Augmented	Perfect Fifth	Sixth Major	Major Seventh	Octave Major

Mixolydian

This is a major scale with minor seventh. It is the third best known of the modals after the Ionic which derives from the major scale and the Aeolian, which derives from the minor. The scale of this modal contains no alterations and begins at Sol.

Table 19. Structure of the Mixolydian modal.

Scale	I	II	III	IV	V	VI	VII	VII
Distance	0	Tone	Tone	Half Tone	Tone	Tone	Half Tone	Tone
Interval	First	Second Major	Major Third	Fourth Perfect	Perfect Fifth	Sixth Major	Minor Seventh	Octave Major

Aeolian

This mode is derived from the natural minor scale. Its scale unchanged is A.

Table 20. Structure of the Aeolian modal.

Scale	I	II	III	IV	V	VI	VII	VIII
Distance	0	Tone	Half Tone	Tone	Tone	Half Tone	Tone	Tone
Interval	First	Second Major	Minor Third	Fourth Perfect	Perfect Fifth	Sixth Minor	Minor Seventh	Perfect Octave

Locrion

This is a minor scale with a minor second and a diminished fifth. The scale without alterations begins in Si. It is a diminished scale because the fifth measured from the tonic is a diminished fifth. It is the most unstable scale of all.

Table 21. Structure del modo locrio

Scale	I	II	III	IV	V	VI	VII	VII

Distance	0	Half Tone	Tone	Tone	Half Tone	Tone	Tone	Tone
Interval	First	Second Minor	Minor Third	Fourth Perfect	Diminished Fifth	Sixth Minor	Minor Seventh	Octave Major

3.1.5.7 Names of degrees

Up to this point Roman numerals have been utilized to specify the degrees of a scale given, i.e., the positions occupied in succession. Onwards and for harmonic analysis, degrees will be used to define the position of a chord created from the position of a note and that plays a role with respect to that scale. These degrees besides being represented by Roman numerals, each have a name that defines its tonal function within a specified system.

Table 22. Names of the degrees.

Scale	Name
I	Tonic
II	Supertonic
III	Median
IV	Subdominant
V	Dominant
VI	Superdominant
VII	Leading note

Degree III is ambiguous. We can not define it within the three basic tonal functions, Tonic, Sub-dominant and Dominant, because, to begin with, it has no similarity to the IV and the II degree, and therefore is not Sub-dominant. And while it coincides in its composition with the degree I, it does not generate the feeling of rest necessary to pigeonhole it in this Tonic function. The same applies to the V; it has two matches, but does not generate the tension required to be considered dominant.

The VII is a somewhat special degree, and has no proper role because it is the V7 without its root, so it is considered dominant.

3.1.5.8 La tonalidad

The concept of tonality took shape during the Renaissance and became established during the Baroque period established from. It is related to the use of major and minor scales.

When we build a work using a major or minor scale, the tonic of this scale becomes the tonal center. The piece finds its rest or break in this note. We say, we are in the tonality related to this scale. For example, if the scale were that of D major, we say that we are in the key of D major.

In musical works written in the Baroque, Classical and Romantic periods, when we speak about the tone of a work, we mean that this is the main key. However, countless modulations, that is, momentary changes in tone, are produced through the work.

Chords, especially the dominant seventh, and harmony are involved in the definition of tonality and modulation processes.

3.1.6 Chords

In the western musical system, chords are very important because they are used to harmonize the tonal melodies and give meaning to compositions, i.e., to give structure and support to the melody.

Three or more notes played simultaneously form a chord. Traditionally, the chords are built by superimposing two or more thirds. The note that provides the basis to build the chord, is called the root and the other notes that compose it are called intervals that stand in relation to the root.

3.1.6.1 Inversions

We say that a chord is in state or root position if its root is the lowest note. In a chord of three notes or triad, we can also have the chord in first or second inversion. A chord is in first inversion when the third is the lowest note. It is in second inversion when the fifth is the lowest note.

The number of inversions is directly proportional to the number of notes of which the chord is formed.

3.1.6.2 Triads

Triads are chords of three notes built on intervals of thirds in the scale to which they relate. they can be major, minor, augmented or diminished.

Major and minor triads are considered perfect for always having a perfect fifth. The diminished and augmented triads are named for the type of fifth they have.

Table 23. Kinds of triads

Nombre	Third	Fifth	Descripción
Major (Maj)	Major	Perfect	In its root state, the major triad consists of three notes: the root, major third and perfect fifth.
Minor (min)	Minor	Perfect	In its root state, the minor triad consists of three notes: the root, minor third and perfect fifth.
Aumentado (Aug)	Minor	Augmented	The augmented chord starts with the root and major third of the major triad but augments the fifth one-half tone from the perfect fifth, hence the name Augmented.
Diminished (Dim)	Major	Diminished	The diminished chord starts with the root and minor third of the minor triad but diminishes the fifth one-half tone from the perfect fifth, hence the name Diminished.

3.1.6.3 Tetrads

Tetrads are chords consisting of four overlapping notes at intervals defined with respect to its root.

3.1.6.4 Seventh chords

If we add a third to any triad we obtain a seventh chord, so named because the added note occupies the interval of a seventh relative to the root.

We can form seventh chords on all degrees of scales and modes. They are named based on the underlying triad and the interval of seventh that form the chord.

3.1.7 Harmony

In Western music, harmony is the subdiscipline that studies the concatenation of several overlapping notes; it ie the organization of chords.

Table 24. Kinds of Tetrads

Nombre	Third	Fifth	Seventh	Descripción
Major Seventh (Maj7)	Major	Perfect	Major	This chord consists of a major triad with a major seventh superimposed.
Seventh (7)	Major	Perfect	Minor	This chord consists of a major triad with a minor seventh superimposed.
Minor Seventh (min7)	Minor	Perfect	Major	This chord consists of a minor triad with a major seventh added.
Minor Seventh Dominant (Dom)	Minor	Perfect	Minor	Like the previous one, this is based on the minor triad but with a minor seventh added.
Major Seventh Dominant (MajDom)	Major	Augmented	Major	This is an augmented triad with a major seventh added.
Seventh Augmented (Aug7)	Major	Augmented	Minor	Also an augmented triad, but differs from the previous in that the third interval corresponds to a minor seventh.
Seventh Diminished (Dim7)	Minor	Diminished	Diminished	A diminished triad with a diminished seventh.
Seventh	Minor	Diminish	Minor	This chord also uses the diminished

SemiDiminished (SemiDim)	r	ed	triad but with the minor seventh.

3.1.7.1 Definition of harmony

The science that teaches the formation of chords and suggests how to combine them in a more balanced manner, thus feelings of relaxation, peace with the consonant harmony, and tense and hurtful with dissonant harmony.

This definition is based on the idea that certain intervals produce in the listener a sense of tension and others produce a feeling of rest or calm.

3.1.7.2 Progressions

The harmonic progression is about the movement of the chords of a piece and are the basis for the musical melody. You can think of chords as the columns of a building and melodies as the details that are supported on these bases.

The movement of the chords is based on typical patterns or harmonic circles and variations of these that are given under basic driving rules of voices and chords substitutes.

3.1.7.3 The harmonization of scales

When a chord progression is built from the notes of a scale, it is said that the scale is being harmonized. Each note of the scale belongs to a degree depending on its position and tonal function.

The harmonic progression of major scales

Chords corresponding to a scale consist of triads derived by taking each of their degrees as root.

For the construction of chords, we will use grades defined by the scale to create third and fifth intervals to triads and third, fifth and seventh for tetrads.

In Table 25 can be seen how the triads are formed in a major scale.

Table 25. Triads of the major scales.

Scale	Structure	Intervals	Chord
I	**I III V**	First – Major Third – Perfect Fifth	Major
II	**II IV VI**	First – Minor Third – Perfect Fifth	Minor
III	**III V VII**	First – Minor Third – Perfect Fifth	Minor
IV	**IV VI I**	First – Major Third – Perfect Fifth	Major
V	**V VII II**	First – Major Third – Perfect Fifth	Major
VI	**VI I III**	First – Minor Third – Perfect Fifth	Minor
VII	**VII II IV**	First – Minor Third – Diminished Fifth	Diminished

En todas las escalas Majores, las triadas que se forman sobre los grados I, IV y V son Majores. Las que se forman sobre los grados II, III y VI son Minores y Diminished la que se forma sobre el grado VII.

Es decir, la progresión armónica para la escala Major en acordesoftriadas es:

I Maj – **II** min – **III** min – **IV** Maj – **V** Maj – **VI** min – **VII** Dim

La tabla siguiente muestra la maneraofcrear las cuatriadas para esta escala.

Table 26. Cuatriadasoflas escalas Majores

Scale	Structure	Intervals	Chord
I	**I III V VII**	First – Major Third – Perfect Fifth – Major Seventh	Major
II	**II IV VI I**	First – Minor Third – Perfect Fifth – Minor Seventh	Dominante
III	**III V VII II**	First – Minor Third – Perfect Fifth – Minor Seventh	Dominante
IV	**IV VI I III**	First – Major Third – Perfect Fifth – Major Seventh	Seventh
V	**V VII II IV**	First – Major Third – Perfect Fifth – Minor Seventh	Dominante
VI	**VI I III V**	First – Minor Third – Perfect Fifth – Minor Seventh	Dominante
VII	**VII II IV VI**	First – Minor Third – Fifth Dim – Minor Seventh	SemiDiminished

De lo anterior obtenemos la progresión armónica para la escala Major en acordesofcuatriadas:

I Maj7 – **II** Dom – **III** Dom – **IV** Maj7 – **V**7 – **VI** Dom – **VII** SemiDim

The harmonic progression of minor scales

Because there are three types of minor, natural, harmonic and melodic scales, we have a greater variety of triads in these scales.

In the harmonic and melodic minor scales we find two types of sevenths for which we have no accepted names because of their infrequent use in traditional music. In these cases we use the type of triad and seventh interval to identify them. Recently, augmented seventh and major seventh have been used to name the chords formed by the augmented and major seventh triad. However, most treatises on harmony have not adopted these terms.

Progresión armónicaoflas escalas Minores naturales

En la siguiente tabla se puede ver como se forman las triadas en esta escala.

Table 27. Triadsoflas escalas Minores naturales

Scale	Structure	Intervals	Chord
I	**I III V**	First - Minor Third - Perfect Fifth	Minor
II	**II IV VI**	First – Minor Third – Diminished Fifth	Diminished
III	**III V VII**	First – Major Third – Perfect Fifth	Major
IV	**IV VI I**	First - Minor Third - Perfect Fifth	Minor
V	**V VII II**	First - Minor Third - Perfect Fifth	Minor
VI	**VI I III**	First - Major Third - Perfect Fifth	Major
VII	**VII II IV**	First - Major Third - Perfect Fifth	Major

Es decir, la progresión armónica para la escala Major en acordesoftriadas es:

I min – **II** Dim **–** **III** Maj – **IV** min – **V** min – **VI** Maj – **VII** Maj

La tabla siguiente muestra la maneraofcrear las cuatriadas para esta escala.

Table 28. Triadsoflas escalas Minores armónicas

Scale	Structure	Intervals	Chord

I	**I III V VII**	First - Minor Third - Perfect Fifth –Minor Seventh	Dominante
II	**II IV VI I**	First – Minor Third – Diminished Fifth –Minor Seventh	SemiDiminished
III	**III V VII II**	First – Major Third – Perfect Fifth – Major Seventh	Major
IV	**IV VI I III**	First - Minor Third - Perfect Fifth – Minor Seventh	Dominante
V	**V VII II IV**	First - Minor Third - Perfect Fifth – Minor Seventh	Dominante
VI	**VI I III V**	First - Major Third - Perfect Fifth – Major Seventh	Major
VII	**VII II IV VI**	First - Major Third - Perfect Fifth – Minor Seventh	Seventh

De lo anterior obtenemos la progresión armónica para la escala Major en acordesofcuatriadas:

VI Dom – **VII** SemiDim – **I** Maj7 – **II** Dom – **III** Dom – **IV** Maj7 – **V**7

Harmonic Progression of the Minor Harmonic Scales.

In the following table can be seen how the triads of this scale are formed.

Table 29. Triads of the Natural Minor Scales

Scale	Structure	Intervals	Chord
I	**I III V**	First - Minor Third - Perfect Fifth	Minor
II	**II IV VI**	First – Minor Third – Diminished Fifth	Diminished
III	**III V VII**	First – Major Third – Fifth Augmented	Augmented
IV	**IV VI I**	First - Minor Third - Perfect Fifth	Minor
V	**V VII II**	First - Major Third - Perfect Fifth	Major
VI	**VI I III**	First - Major Third - Perfect Fifth	Major
VII	**VII II IV**	First - Minor Third - Diminished Fifth	Diminished

That is to say, the harmonic progression of triad chords built on the major scale is:

I min –**II** Dim **–** **III** Aug – **IV** min – **V** Maj – **VI** Maj – **VII** Dim

The following table shows the manner in which the tetrads of this scale are created.

Table 30. Triads of the harmonic minor scales

Scale	Structure	Intervals	Chord
I	**I III V VII**	First - Minor Third - Perfect Fifth –Major Seventh	Minor
II	**II IV VI I**	First – Minor Third – Diminished Fifth –Minor Seventh	SemiDiminished
III	**III V VII II**	First – Major Third – Fifth Augmented – Major Seventh	Major Dominante
IV	**IV VI I III**	First - Minor Third - Perfect Fifth – Minor Seventh	Dominante
V	**V VII II IV**	First - Major Third - Perfect Fifth – Minor Seventh	Seventh
VI	**VI I III V**	First - Major Third - Perfect Fifth – Major Seventh	Major
VII	**VII II IV VI**	First - Minor Third - Diminished Fifth – Seventh Diminished	Diminished

From the foregoing we obtain the harmonic progression of tetrads for the major scale:

I min7 – **II** SemiDim – **III** MajDom – **IV** Dom – **V** 7– **VI** Maj7 –**VII** Dim

3.2 Grammars

A formal grammar is a mathematical structure with a set of rules for forming chains defining allowable characters in a given formal or natural language. Formal grammars appear in many different contexts: mathematical logic, computer science and theoretical linguistics.

In a formal language, the chains formed by the formal grammar rules are called well-formed formulas, and the set of all well-formed formulas is a formal language. A formal grammar does not describe the meaning of well-formed formulas, but only its form.

The formal languages theory and studied formal languages, is a branch of applied mathematics.

It comprises a number of syntactic categories which are combined together by means of syntax rules that define how a syntactic category is created by other or symbols of the grammar.

There is only one superior cathegory denoting complete and valid strings.

Through these constituent elements a specification mechanism is defined consistent on repeat the substitution mechanism of category for their constituents, according to the rules, starting from the top category and ending when the sentence no longer contains any category.

Thus, the grammar can generate or produce each of the chains of the corresponding language and only these chains.

3.2.1 Formal definition

In the classic definition given by Noam Chomsky in the 1950s, a formal grammar is a quadruple G = (N, T, S, P) where:

– N is a finite set of nonterminal symbols (variables).

– T is a finite set of terminal symbols (constants), with disjoint with N.

– S is a distinguished symbol N, the start symbol.

– P is a finite set of production rules, each of the form:

$$(N \cup T)^* N (N \cup T)^* \rightarrow (N \cup T)^*$$

Where * is the Kleene closure.

That is, each production rule maps a string of symbols to another, wherein the first chain comprises at least one non-terminal symbol. In the case of the second string is the empty string; to avoid confusion is denoted with a special notation (usually ε, e or λ).

The alphabet of the grammar then is the set $\Sigma = N \cup T$

3.2.2 Chomsky hierarchy

In linguistics, the Chomsky hierarchy is a hierarchical classification of different types of formal grammars that generate formal languages.

It consists of four levels:

Type-0 grammars or **unrestricted grammars** include all formal grammars. They generate Perfectly all languages that can be recognized by a Turing machine. These languages are also known as the recursively enumerable languages. Note that this is different from the recursive languages which can be decided by an always-halting Turing machine.

The grammars that generate these languages may have compressors rules.

Production rules are as follows:

$$P = \{u = xAy; u \in \Sigma^{+}; v, x, y \in \Sigma^{*}; A \in N\}$$

Type-1 grammars or **context-sensitive grammars** generate the context-sensitive languages. These grammars have rules of the form $\alpha A \beta$ with A a nonterminal and α, β and γ strings of terminals and nonterminals. The strings α and β may be empty, but γ must be nonempty. The rule $S \rightarrow \epsilon$ is allowed if S does not appear on the right side of any rule. The languages described by these grammars are Perfectly all languages that can be recognized by a linear bounded automaton also known as nondeterministic Turing machine whose tape is bounded by a constant times the length of the input.

There are no rules compressors except optionally the derived axiom to the empty word.

There are rules in which a non-terminal symbol may lead to different sentential forms depending on the symbols that appear around

Production rules are as follows:

$$P = \{v \in \Sigma^{+}; x, y \in \Sigma^{*}; A \in N\}$$

Type-2 grammars or **context-free grammars** generate the context-free languages. These are defined by rules of the form $A \rightarrow \gamma$ with A a nonterminal and γ a string of terminals and nonterminals. These languages are Perfectly all languages that can be recognized by a non-deterministic pushdown automaton.

Context-free languages or rather the subset of deterministic context-free language are the theoretical basis for the phrase structure of most programming languages, though their syntax also includes context-sensitive name resolution due to declarations and scope. Often a subset of grammars are used to make parsing easier, such as by an LL parser.

Production rules are as follows:

$$P = \{v \in \Sigma^{+}; A \in N\}$$

Type-3 grammars or **regular grammars** generate the regular languages. Such a grammar restricts its rules to a single nonterminal on the left-hand side and a right-hand side consisting of a single terminal, possibly followed by a single nonterminal as right regular. Alternatively, the right-hand side of the grammar can consist of a single terminal, possibly preceded by a single nonterminal as left regular; these generate the same languages however, if left-regular rules and right-regular rules are combined, the language need no longer be regular. The rule $S \rightarrow \epsilon$ is also allowed here if S does not appear on the right side of any rule. These languages are exactly all languages that can be decided by a finite state automaton. Additionally, this family of formal languages can be obtained by regular expressions. Regular languages are commonly used to define search patterns and the lexical structure of programming languages.

Production rules for right-hand are as follows:

$$P = \{a \in T; A, B \in N\}$$

Production rules for left-hand are as follows:

$$P = \{a \in T; A, B \in N\}$$

3.3 ABC Notation

The method proposed in this paper uses the ABC notation for the representation and processing of sheet music. We decided to use this notation because it can be easily interpreted by a human and computationally processed without any pre-processing.

The ABC notation is a language for writing music using the ASCII character set. Chris Walshaw created it initially. While it is a computer-based musical language, one of the main objectives has been that humans can easily read it. It was initially developed for use with compositions and traditional folk tunes from Western Europe. The syntax also allows use metadata for each tone.

Since the ABC system is based on ASCII characters, you can use any text editor to edit music. However, there are several software packages with several facilities that can read and process written music in ABC notation.

Other software packages have provided direct output (avoiding the TeX typesetting), and have extended the syntax to allow the submission of the lyrics of the song dress with notes, multiple voices and multiple staves notation, tablature, and MIDI.

3.3.1 The format

The standard format for writing a piece of music in ABC notation consists of two parts: a header where the track metadata are defined and a part where the melody is written in letter notation. See Table 1.

```
X:<Track>
T:<Title>
M:<Meter>
L:<Unit note length>
R:<Rhythm>
K:<Key>
<accident><note><value> <repeat>|<repeat> … <repeat>|]
```

The following example illustrates the use of the ABC music notation:

```
X:1
T:The Legacy Jig
M:6/8
L:1/8
R:jig
K:G
GFG BAB | gfg gab | GFG BAB | d2A AFD |
GFG BAB | gfg gab | age edB |1 dBA AFD :|2 dBA ABd |:
efe edB | dBA ABd | efe edB | gdB ABd |
efe edB | d2d def | gfe edB |1 dBA ABd :|2 dBA AFD |]
```

In this example, X: is set to 1 because there is only one track in the file, T: is the title "The Legacy Jig", M: defines the meter to 6/8, L: Sets the value of 1/8 as a unit note reference, R: is the "jig" string to specify the style of rhythm and K:G uses that note for armor.

This example can be translated into standard notation using one of the existing ABC conversion tools. For example, the software abc2score produces an output which is similar to that shown in Figure 5.

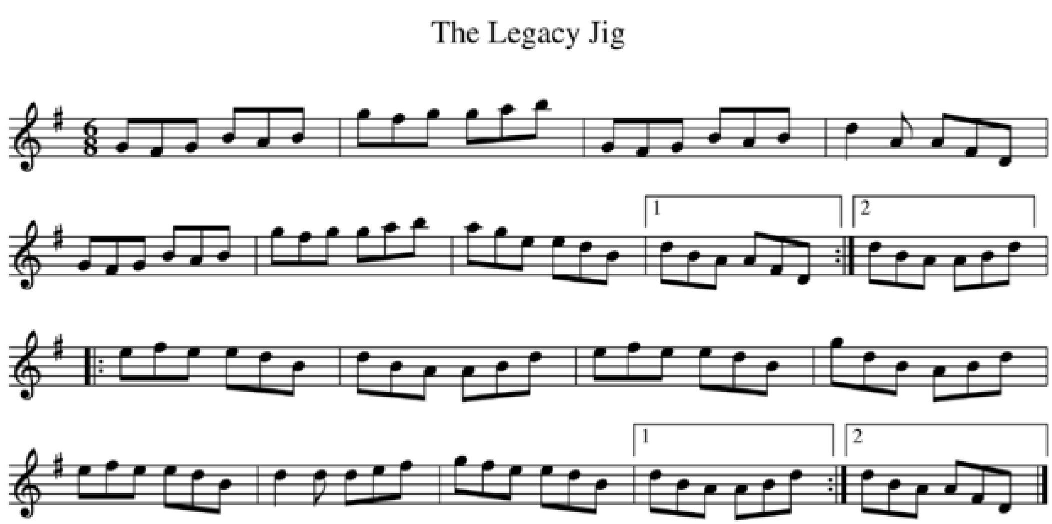



Figure 5. Score generated from the previous example using ABC notation

3.4 Formulation of the problem

Develop a methodology capable of generating Western tonal music from induction and learning context free grammars hierarchized for different levels of control and coordination of multiple instruments. The control levels of this work are the musical form of the work, the progression of the sections, rhythm, timing and progression depending on the musical degree of each measures.

4 PROPOSED METHOD

The following is a description of the proposed method for music generation.

4.1 Overview

When dealing with a musical work, it is necessary to coordinate, synchronize and intonate all the instruments. In order to do it we designated the role of the lead instrument.

Similarly, our method uses a grammar for each instrument and an additional grammar to intonate the composition between all the different instruments. Each instrument has its own grammar while the leader has its own grammar as show in the Figure .

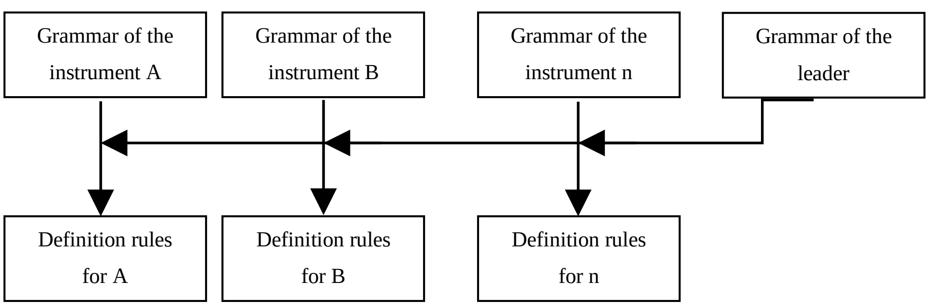


Figure 6 An additional grammar to intonate the instruments

The generation of the harmonic structure in each section of the musical piece is achieved through the grammar of the leader. The generation rules of each instrument are independent of the leader but depend on his final string for the implementation parameters to generate the instrument score.

4.2 The instrument model

An instrument is a musical style model for a single voice or musical component either harmonic, melodic, rhythmic or combined for each measure.

Instruments may contain one or more forms of the same style. Styles may contain types of notes with different degrees of freedom.

The model of an instrument is defined as a 4-tuple $I = \{S, N, T, P\}$ where,

- S Input symbol. It is a string of terminal and non-terminal symbols that model style options.
- N Non-terminal symbols. Position, force, duration or types of notes.
- T Terminals symbols. These are the notes, the silences and the duration of each.
- P Production rules. It is the change of state of a non-terminal strings composed with non-terminals and terminals, or empty string symbol.

The final string is the sequence of notes and rests with a specific duration that make musical style component with total duration of a measure.

4.2.1 Definition of the instruments

The instruments are defined by the symbols and rules described below.

4.2.2 The notes

Types of notes are sets of notes that meet certain characteristics:

- Root: Is the note from which the intervals (distance between notes) are counted in the measure.
- Chord notes: They form the chord form the degree to which the measure belongs.
- Ornament notes: They belong to the scale of degree, not the main scale.
- Scale notes: Comprising the main scale of the piece.
- Chromatics: They are all notes of the chromatic scale.

4.2.3 Style rules for an instrument

Once the rules for the music generation have been defined, they are used to define different rules for the style of each instrument. The rules of the style may describe some structure in one bar. The measure of each bar is a whole note duration, it means four beats each.

In a general way, the style rules can see as follow:

$$\begin{bmatrix} Style & St \\ Iterations & It \end{bmatrix} \rightarrow \left| \begin{bmatrix} rule & r \\ duration & d_1 \end{bmatrix} \begin{bmatrix} rule & r \\ duration & d_2 \end{bmatrix} \begin{bmatrix} \cdots \end{bmatrix} \begin{bmatrix} rule & r \\ duration & d_n \end{bmatrix} \right|$$

Where, *St* is the defined style, *It* is the number of iterations for the rule set, and d_n is the duration of the symbol. The duration of the generated string is $\sum_{i=1}^{n} d_i = 1bar$.

4.3 The leader model

One section is made up of bars consistently ordered according to the musical discourse. The musical discourse is the progression of grades with different tensions.

The leader is the model of the progression of degrees in one section. The model is defined as 4-tuple $L = \{S, N, T, P\}$ where,

- *S* Input symbol. There is some tension.
- *N* Non-teminal symbols. Represent the tensions.
- *T* Terminal Symbols. Represent the musical degrees.
- *P* Production rules. It is the change of state of a non-terminal strings composed with non-terminals and terminals, or empty string symbol.

The final string is the progression of degrees for a musical section.

In order to create the feeling of a musical phrase, the sections are generated based on a musical argument, thus creating a release – tension state. Giving the fact that one could compose the section or more bars it is necessary to create a structure to preserve this feeling without creating dissonance. This is accomplished by creating an intermediate state called bridge. With this bridge the resulting musical argument is: release – bridge – tension.

The number of bars within the section generates the musical argument. The string begins with the bridge and ends with release and tensions.

w → release [bridge] tension

w → bridge

bridge → tension bridge | bridge bridge | bridge release |release bridge

release → release tension

tension → bridge tension

The number of iterations is equal to the number of bars within the section; as a result, a new iteration will create a new bar.

To this musical argument a scale degree is assigned for each bar, according to the designated tension. The seven degrees are divided into three main tensions as follows:

release → I

bridge → II

tension → III

bridge → IV

tension → V

release → VI

tension → VII

The resulting of string symbols to this grammar is a harmonic progression represented in degrees. This string coordinates the different instruments as each degree works as parameter for them within each bar.

4.4 Parameterized grammars

Each instrument generates individual and independent strings but strongly interrelated by the scale degree. The instruments receive the information through parameters and use them to establish the adequate symbols in the rules of the string production. Furthermore, each instrument has its own parameters to indicate how they should create the strings.

The use of parameterized grammars is necessary due to the use of the intervals and the metric that is used.

4.4.1 Types of parameters

There are different types of parameters, each type gives information about the hierarchy, the instructions to be followed by the rules, or specific data for the performance of the piece.

— **Keynote**. Defines the note from the distance of which the intervals are measured. It may be any of the twelve notes of the chromatic scale (C, F #, etc..). This information changes the intervals generated to notes.

— **Scale**. Select the type of scale. It may be Major, Minor or a defined Mode. This parameter modifies the selection of the notes for the melody generation and for the definition of the chord notes.

— **Chord type**. Defines the number of notes for the construction of a chord. It is a numeric parameter in the range from 2-7. This parameter is used in the construction of the chords.

— **Depth**. Define the minimum length of time for notes. It is a numeric parameter in the range from 1-6. Is used for define the number of iterations in the melody generation.

— **Degree**. Sets the intervals used in each bar. It is a numeric parameter in the range from I to VII and represents the scale degree. This parameter is generated by the grammar of the director. It is who coordinates all instruments.

The necessary elements to create the structure of a musical piece are:

— **Style of harmony**. Select the style defined for harmonizing the piece. This parameter depends on the defined styles.

— **Bass style**. Select the style defined for bass-line to be used in the melody. This parameter depends on the defined styles.

— **Sections**. Specifies the number of different sections to be generated. It is a numeric parameter in the range from 1-N. These sections can be reused in the work.

— **Bars**. This parameter specifies the number of bars that have a section generated. It is a numeric parameter in the range 1-N. Each section needs to specify this parameter.

— **Structure**. Specifies the order of the sections in the musical piece. To each section is assigned an identifier. This identifier is used to reuse sections.

— **Cadence**. Select the type of cadence for the musical piece. This parameter depends on the cadences defined.

4.5 Sample piece

Different rules of instruments and parameters have been created for the experiment, but the construction is very similar for the rest. The rules were created as follows.

4.5.1 Instruments

These are example of different instances of musical instruments style.

The bass

The proposed style for the bassline consists in a note on each odd beat, ie, in the 1 and 3 beats of the bar with half duration everyone. Furthermore, it is alternating the root chord and the Fifth chord.

It is noteworthy that the bass notes are two octaves below the root.

The production rule of the bass style was defined as follow:

$$\text{rootDominant} \rightarrow \begin{bmatrix} \mathit{rule} & \text{rootChord} \\ \mathit{duration} & \text{half} \end{bmatrix} \begin{bmatrix} \mathit{rule} & \text{fifthChord} \\ \mathit{duration} & \text{half} \end{bmatrix}$$

The harmony

The Harmony goes hand in hand with the bassline, but in even beats. This mean, the chords will sound in the 2 and 4 beats of the bar, in triads (three notes at same time) and rests in the 1 and 3 beats everyone with duration of quarters.

The production rule for the harmony generation was proposed as follow:

$$\begin{aligned} \text{evenBeats} \rightarrow & \begin{bmatrix} \mathit{rule} & \text{rest} \\ \mathit{duration} & \text{quarter} \end{bmatrix} \begin{bmatrix} \mathit{rule} & \begin{bmatrix} \text{ChordType} & \text{triad} \\ \mathit{Degree} & \text{D} \end{bmatrix} \\ \mathit{duration} & \text{quarter} \end{bmatrix} \\ & \begin{bmatrix} \mathit{rule} & \text{rest} \\ \mathit{duration} & \text{quarter} \end{bmatrix} \begin{bmatrix} \mathit{rule} & \begin{bmatrix} \text{ChordType} & \text{triad} \\ \mathit{Degree} & \text{D} \end{bmatrix} \\ \mathit{duration} & \text{quarter} \end{bmatrix} \end{aligned}$$

The melody

There are two kinds of accents in music: Arsis, which in the action of conducting refers to the upward movement, and is related to weaker accents; and the Thesis, which deals with the downward movement and is related to stronger accents.

Each complete bar is start with whole note duration and as Thesis. The length of time is divided at half in the next iteration, designating the first part as Thesis and the second part as Arsis. The number of divisions for bar is proportional to parameter **Depth** and the different accents will correspond to the divisions.

The division between the strength and time can be seen in the Table 3.

Table 3 shows the relation between strength and time. Where S is Strong, W is weak, and Ws is Weakest.

Note	**Forces**															
Whole	Stronger															
Half	Strong								Weak							
Quarter	Strong				Weak				Strong				Weak			
Eighth	S		W		S		W		S		W		S		W	
Sixteenth	S	Wt	W	Ws	S	Wt	W	Ws	S	Wt	W	Ws	S	Wt	W	Ws

The production rule for the metric is the following:

$$\begin{bmatrix} Strength & Str \\ position & p \\ duration & d \end{bmatrix} \rightarrow \begin{bmatrix} Strength & Str \\ position & p \\ duration & d \end{bmatrix}$$

$$\begin{bmatrix} Strength & Str \\ position & p \\ duration & d \end{bmatrix} \rightarrow \begin{bmatrix} Strength & Str \\ position & T \\ duration & d/2 \end{bmatrix} \begin{bmatrix} Strength & Str \\ position & A \\ duration & d/2 \end{bmatrix}$$

Where, Str is the associated strength, *position p* is a number and represent the actual position, *position T* is Thesis and represent the next position of the first half, *position A* is Arsis and represent the next position of the second half and *duration* is the length of time.

For example:

$$\begin{bmatrix} Strength & Weak \\ position & 2 \\ duration & half \end{bmatrix} \rightarrow \begin{bmatrix} Strength & Strong \\ position & 3 \\ duration & quarter \end{bmatrix} \begin{bmatrix} Strength & Weak \\ position & 4 \\ duration & quarter \end{bmatrix}$$

It means the strength in the position 2 with duration of half note is divided in two quarter notes with strengths strong and weak correspondingly.

For the generation of the melody, a strength-time structure is created randomly, according to the defined minimum time. Once you have the strength-time structure to be used, is assigned a type of note according to the strength as shown in the next table.

Table 4 Type of note by strength

Strength	Type of note
Stronger	Keynote – tonic
Strong	Chord notes
Weak	Scale notes
Weakest	Chromatic notes

After the assignment of the type, the notes are randomly selected according to the type of note they have.

The octave of the section is defined randomly in the root octave or one octave above; this brings dynamism in phrases and makes separations marked between sections.

An example of the style is the next.

$$\begin{bmatrix} Strength & \text{Strong} \\ position & 3 \\ duration & \text{quarter} \end{bmatrix} \rightarrow \begin{bmatrix} rule & \begin{bmatrix} ChordIterval & \text{fifthChord} \\ Degree & \text{V} \end{bmatrix} \\ duration & \text{quarter} \end{bmatrix}$$

As we said before, the generation of the sections fulfill with the release – tension structure, thus can be linking one section with another in a pleasant way. However this ends on tension, so is necessary to create a resolution to give the feeling of the piece is over. For this, there must be created a cadence, simple but ending at release.

The structure of the cadences was created in the grammar of the conductor as follow.

$$w \rightarrow \text{release} \mid \text{tension-release}$$

The parameters of the cadence are the follows.

Minimum duration: Quarters.

Bass style: Whole in root.

Harmony Style: Whole in root chord.

4.5.2 An example of a generated musical piece

This is an example of the generation using this method. The parameters used to generate this piece are as follows:

Number of sections: 3

Number of bars by section: 4

Sequence of sections: 1 1 2 2 3

Minimum marks: ¼

Tonality: C

Scale Mode: Major

Chord type: triad

Harmony Style: evenBeats

Bass Style: rootDom

Cadence: 1 Bar.

```
X:1
T: Alpha
```

```
M:C

L:1/4

Q:120

K:C

%%MIDI program 1

%

V:1 clef=treble  name="Melody" snm="M"

V:2 clef=treble-8  name="Chords" snm="C"

V:3 clef=bass-8  name="Bass"   snm="B"

%

[V:1]c2/d2/a2/g2/ |z/d/z/d/z/c/e/z/ |c2/e2/c2/z2/ |f4/c4/ |c2/d2/a2/g2/
|z/d/z/d/z/c/e/z/ |c2/e2/c2/z2/ |f4/c4/ |C/z/B/z/E/E/z/E/ |F/F/z2/z/B/A2/
|C4/A2/E2/ |z2/D2/D/z/C2/ |C/z/B/z/E/E/z/E/ |F/F/z2/z/B/A2/ |C4/A2/E2/
|z2/D2/D/z/C2/ |E4/B2/D2/ |F/A/F/z/z/F/G/C/ |G4/E4/ |C/z/G2/z/G/E/D/
|c8/|]

[V:2]z2/[FAC]2/z2/[FAC]2/   |z2/[DFA]2/z2/[DFA]2/   |z2/[CEG]2/z2/[CEG]2/
|z2/[FAC]2/z2/[FAC]2/     |z2/[FAC]2/z2/[FAC]2/     |z2/[DFA]2/z2/[DFA]2/
|z2/[CEG]2/z2/[CEG]2/     |z2/[FAC]2/z2/[FAC]2/     |z2/[ACE]2/z2/[ACE]2/
|z2/[DFA]2/z2/[DFA]2/     |z2/[DFA]2/z2/[DFA]2/     |z2/[DFA]2/z2/[DFA]2/
|z2/[ACE]2/z2/[ACE]2/     |z2/[DFA]2/z2/[DFA]2/     |z2/[DFA]2/z2/[DFA]2/
|z2/[DFA]2/z2/[DFA]2/     |z2/[CEG]2/z2/[CEG]2/     |z2/[DFA]2/z2/[DFA]2/
|z2/[EGB]2/z2/[EGB]2/ |z2/[DFA]2/z2/[DFA]2/ |[CEG]8/|]

[V:3]F,4/C,4/ |D,4/A,4/ |C,4/G,4/ |F,4/C,4/ |F,4/C,4/ |D,4/A,4/ |C,4/G,4/
|F,4/C,4/ |A,4/E,4/ |D,4/A,4/ |D,4/A,4/ |D,4/A,4/ |A,4/E,4/ |D,4/A,4/
|D,4/A,4/ |D,4/A,4/ |C,4/G,4/ |D,4/A,4/ |E,4/B,4/ |D,4/A,4/ |C,8/|]
```

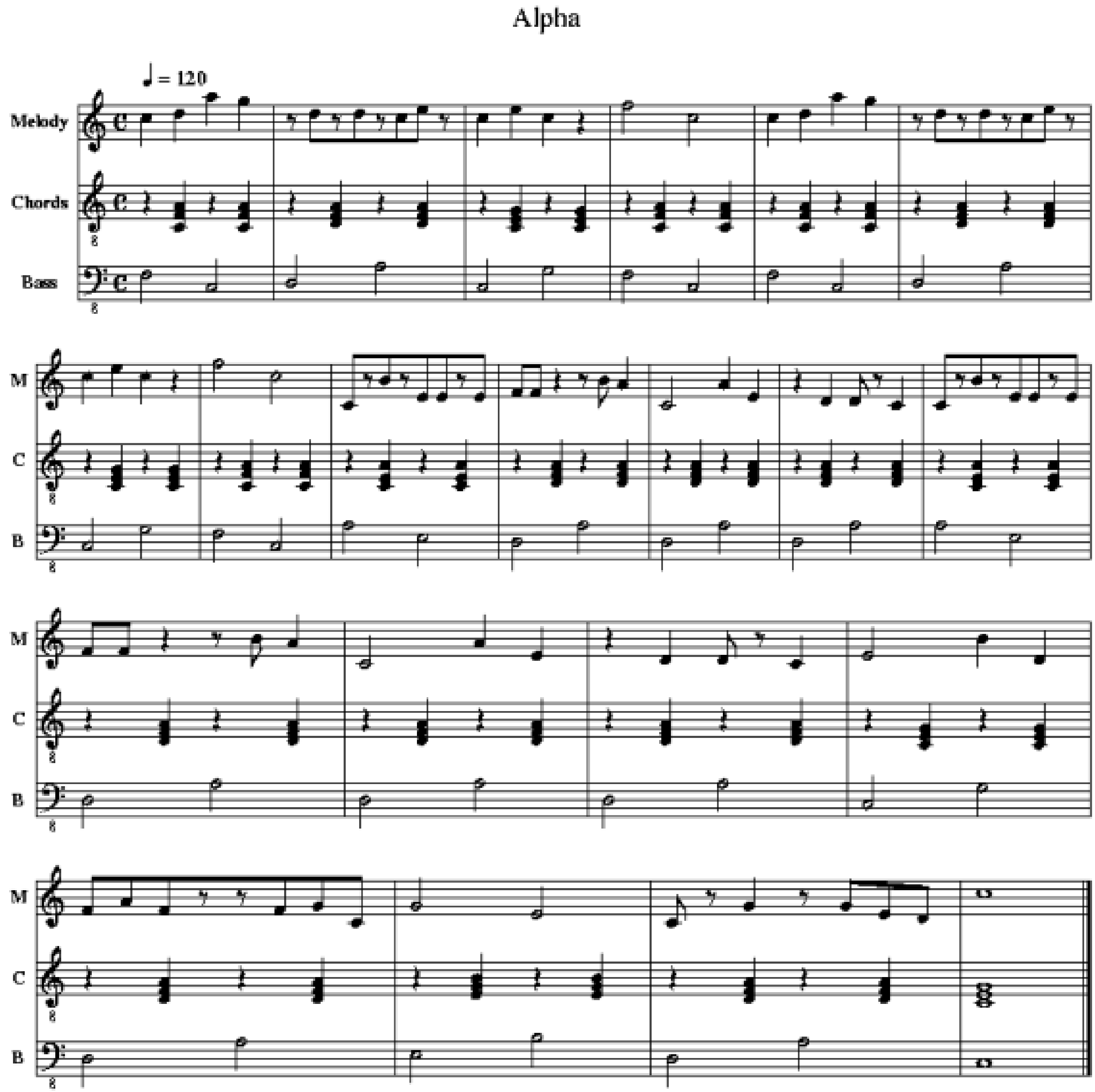



Figure 7. An example of music generation

4.6 Evaluation

The Arrow's impossibility theorem dictates, in a very general terms, that no voting system is fair and that personal preferences may not meet certain rational criteria, nevertheless, in this study we measured the judgments and people opinions. It is important to measure because our attitudes reflect the internalization values, norms and preferences that govern groups and organizations to which we belong (Briñol, Falces et al., 2007).

4.6.1 Expert and human judgments

The perception of musical appreciation is different in each culture according to regional customs. By formalizing the rules of musical generation is needed to determine the value that people make with respect to the pieces generated who listen. Doing this evaluation is important because if the generation of musical pieces through artificial intelligence tools besides fulfilling with the formalities in music conform to cultural expectations about a "enjoyable work" without the listener discriminate if the composer is human or not, then the rules of the director and the instruments meets the goal of creating quality works.

For this, we measured the attitudes that people have about what they hear. The attitude is "the predisposition of people to evaluate (...), either favorably or unfavorably" (Petty and Priester, 1996, p.131) with an essentially evaluative nature (Petty, Wegener and Fabrigar, 1997, Ajzen, 1988) or affective towards other people, objects and themes (Fishbein and Ajzen, 1975).

The questions included in a questionnaire provided extensive information alluding to the opinions, intentions, judgments, motives, habits and expectations of the subject (Palella and Martins, 2006).

For the evaluation of this method we have decided to apply two tests, one to show that the resulting generation of this algorithm is actually music, by asking about the overall quality of the piece and its component parts, and the other is a Turing test-like to verify that it is possible to discriminate whether the work was composed by a human or not.

5 EXPERIMENTAL RESULTS

Based on previous work, have been resolved dependencies in the context of musical abstraction rules of type A+B → C, ie, we eliminated the sums of the values of intervals. The definition rules have been defined for each note.

This implies increasing the number of production rules, however, has enabled the implementation of a simplest control module capable of handling all the rules without importer in which module, instrument or hierarchical level are working.

Figure 8 New control module kernel.

Each set of rules takes a parameter, parameter or function under that modify the input string.

Each processed grammar generates a string terminal symbols for this grammar, but generates the initial set of symbols for the following grammar.

To see the output of the actual work, see the Append at the end of the document.

6 CONCLUSIONS AND FUTURE WORK

6.1 Expected contributions

The expected contributions of this work are as follows.

- Generate complete musical compositions automatically, learning progression for each section of the musical work, the harmonic basis for each section and the weights of the notes in the melody for each of the sections, respecting the times, degrees and rhythms.
- Based on the model of the previous work, to create a context-free model for musical rules.
- Generalizing the proposed model for all modules are treated in the same way regardless of the instrument it is.
- Provide the possibility of multiple leaders in each module (hierarchy level).
- Provide mechanisms iteration for all sections that require repetition or modification.
- Develop a music analyser for ABC notation files.
- Create a corpus of tunes in ABC notation of different musical styles.
- Define the functions of modification and correction of created sections.
- Create the module for learning the structure of the musical work.
- Create the learning module for the progression of each section.
- Create the learning module for definition of instruments.

- Develop a tool that generates a musical work from machine learning styles of a corpus, creating rules for each module dynamically.

6.2 Partial conclusions

The ABC notation is the best representation for data manipulation with grammars.

From the hierarchy is concluded that grades are the foundation of the musical work.

In addition, the relative intervals are the basis definition of production rules.

The metric values in the division of time are what define the type of note at positions defined according to the accent and values.

Proposed for the generation of music method, an algorithm for the construction of the progression from a musical piece that coordinates instruments defined by context-free grammars from a grammar to generate a musical progression for section that was obtained.

With the abstraction of musical knowledge, has successfully managed to provide basic production rules for creating a complete musical work.

For assembly and generating a file in ABC notation has developed a tool that uses the rules of production and proposed gun overall progression using an algorithmical work, user settings for it.

6.3 Future work

Learning ruleset for: speech, progression, cadence, instruments style for speech

Develop the modification functions for each component.

Stochastic model used in CRF

None developed a purely rhythmic instrument so there is work in the instruments development such as percussions.

The metric employed in this work is for measures of 4/4. For future work is to develop the grammar to generate metrics for compound tenses.

Time values defined in this paper are for pair times. It can work in generating triplet note values according to the metric.

The type of harmonic instrument defined in this paper is based on full chords. You can work on the use of arpeggios based on a harmony or counterpoint.

For reps have to work on different patterns of modification and iteration for each measure or complete sentence.

The intensity of the voices is characteristic in human composition, so it is also an important point to future work.

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APPENDIX

In this section we show some screenshots of the system implemented using the proposed method.

The resulting string is presented in ABC notation to review the results as shown in Figure 9. You can download the MIDI file for listen the music.

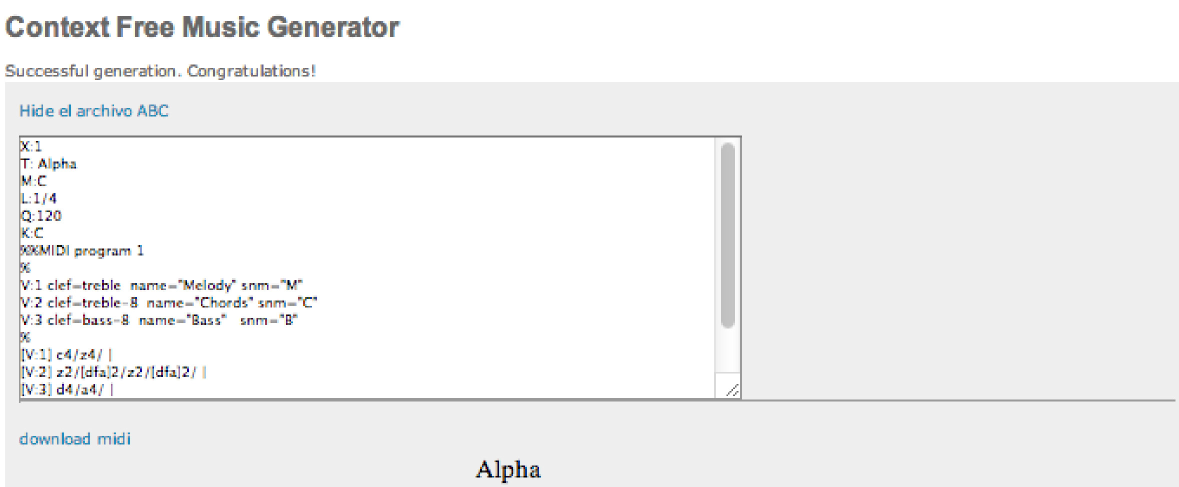


Figure 9 ABC notation file and MIDI

The result of the process is also shown in standard music notation. People with musical knowledge can review and understand in a simple way the composition generated. See Figure 10.

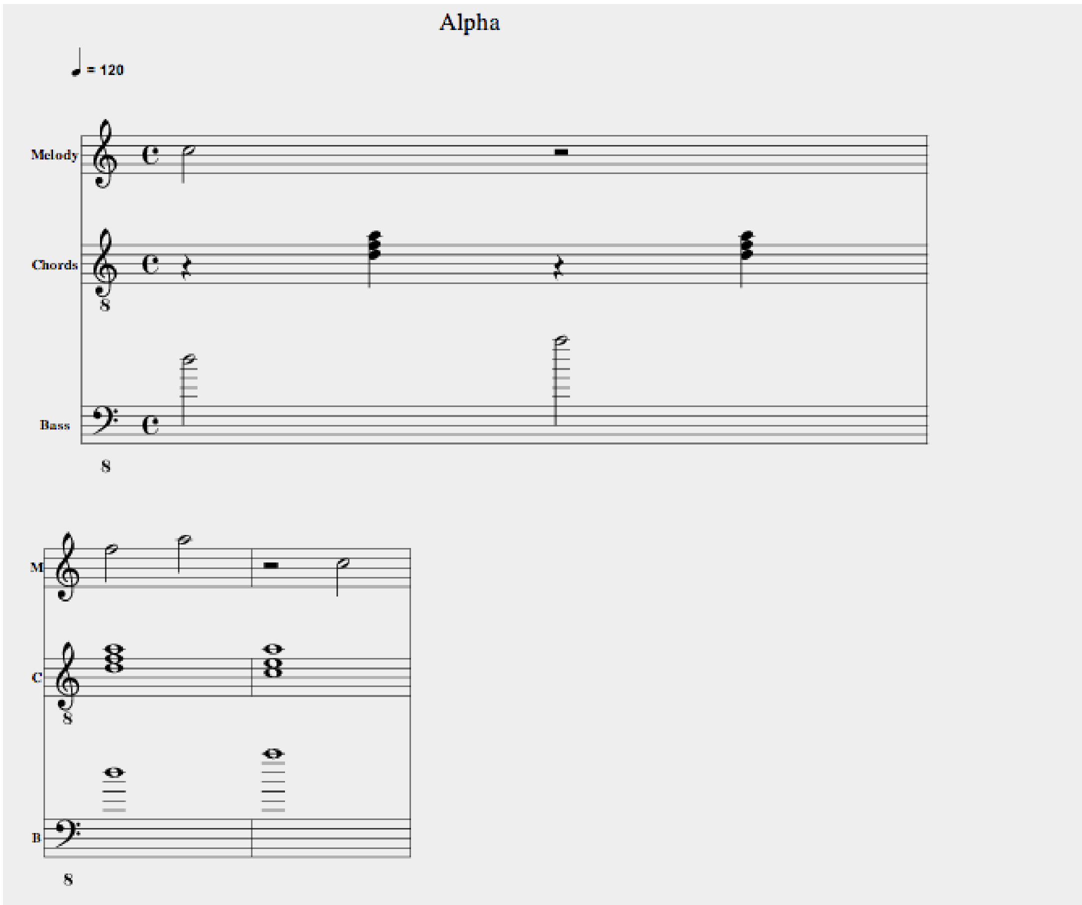
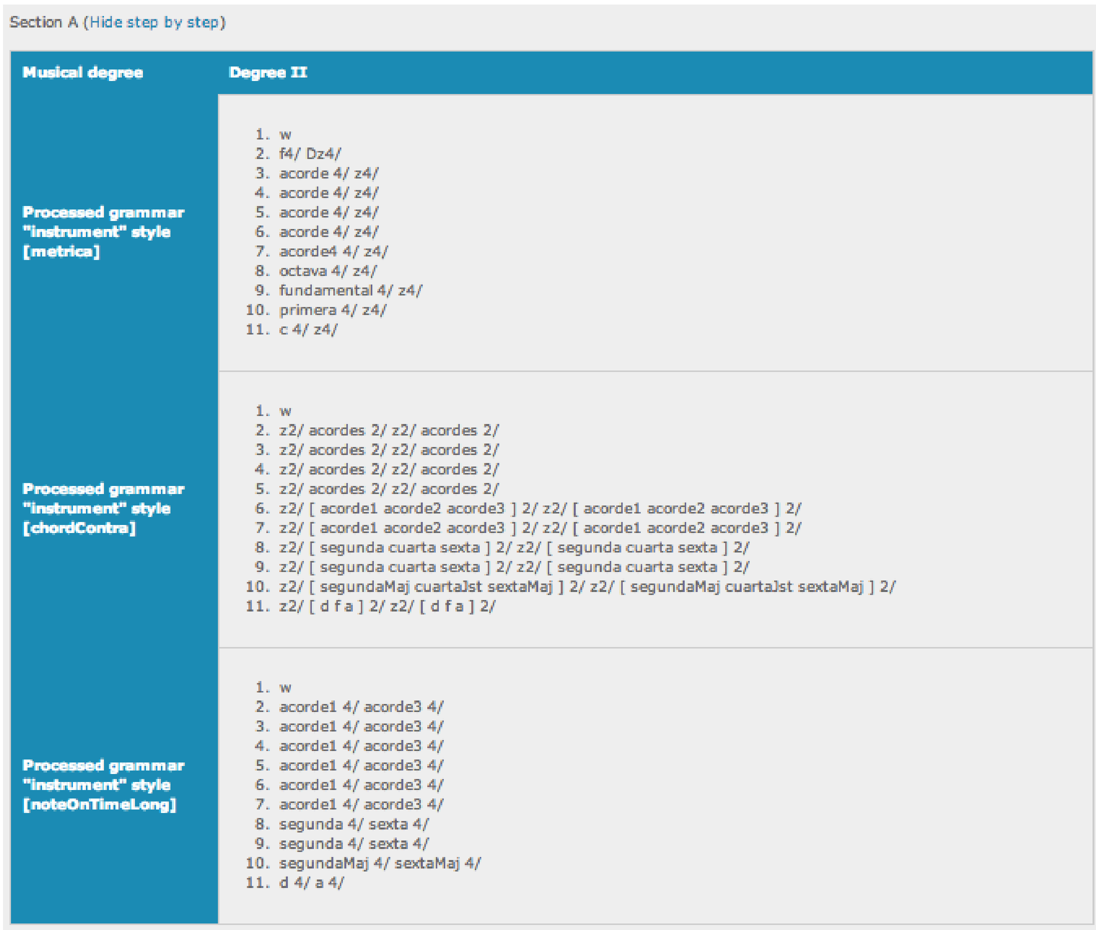



Figure 10 The music score

At the bottom of the screen can be checked step by step how it was generated each of the measures, from its most abstract form to its final definition. On the right side you can see the name of the grammar of the instrument used. At the top level is the music that serves as a parameter for each measure. See Figure 11.



Section A (Hide step by step)

Musical degree	Degree II
Processed grammar "instrument" style [metrica]	1. w 2. f4/ Dz4/ 3. acorde 4/ z4/ 4. acorde 4/ z4/ 5. acorde 4/ z4/ 6. acorde 4/ z4/ 7. acorde4 4/ z4/ 8. octava 4/ z4/ 9. fundamental 4/ z4/ 10. primera 4/ z4/ 11. c 4/ z4/
Processed grammar "instrument" style [chordContra]	1. w 2. z2/ acordes 2/ z2/ acordes 2/ 3. z2/ acordes 2/ z2/ acordes 2/ 4. z2/ acordes 2/ z2/ acordes 2/ 5. z2/ acordes 2/ z2/ acordes 2/ 6. z2/ [acorde1 acorde2 acorde3] 2/ z2/ [acorde1 acorde2 acorde3] 2/ 7. z2/ [acorde1 acorde2 acorde3] 2/ z2/ [acorde1 acorde2 acorde3] 2/ 8. z2/ [segunda cuarta sexta] 2/ z2/ [segunda cuarta sexta] 2/ 9. z2/ [segunda cuarta sexta] 2/ z2/ [segunda cuarta sexta] 2/ 10. z2/ [segundaMaj cuartaJst sextaMaj] 2/ z2/ [segundaMaj cuartaJst sextaMaj] 2/ 11. z2/ [d f a] 2/ z2/ [d f a] 2/
Processed grammar "instrument" style [noteOnTimeLong]	1. w 2. acorde1 4/ acorde3 4/ 3. acorde1 4/ acorde3 4/ 4. acorde1 4/ acorde3 4/ 5. acorde1 4/ acorde3 4/ 6. acorde1 4/ acorde3 4/ 7. acorde1 4/ acorde3 4/ 8. segunda 4/ sexta 4/ 9. segunda 4/ sexta 4/ 10. segundaMaj 4/ sextaMaj 4/ 11. d 4/ a 4/

Figure 11 Step by step of the music generation