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# REPRESENTING PROCEDURAL MUSICAL STRUCTURES WITH AN ENCODED FUNCTIONAL GRAMMAR OPTIMIZED FOR METAPROGRAMMING AND MACHINE LEARNING

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## ABSTRACT

We present GenoMus, a new model for artificial musical creativity based on a procedural approach, able to represent and learn the compositional techniques behind a musical score. The aim of this model is to build a framework for automatic creativity, easily adaptable to other domains beyond music. The core of GenoMus is a functional grammar designed to cover a wide range of styles, integrating traditional and contemporary composing techniques. Musical *genotypes* are defined as functional trees, able to generate musical scores described as *phenotypes*. To enable the maximal diversity of outputs, each process uses the same generic functional structure, no matter what time scale, polyphonic structure or additional characteristics are being employed. The goal of this highly homogeneous and modular approach is to simplify metaprogramming of genotypes, as well as maximize search space. Genotypes and phenotypes are encoded as normalized numeric vectors. This abstract representation of musical knowledge as pure numeric arrays is convenient for the application of different machine learning paradigms. The user interface developed for GenoMus is oriented to the exploration of augmented creativity, regardless of user expertise. However, a composer can create and alter manually genotypes and algorithms to modify automatic results. The system allows the implementation of user-defined processes, which will expand the procedures library.

**Keywords:** automatic musical composition · metaprogramming · procedural representation of music · artificial creativity · GenoMus

## 1 Introduction: composing composers

Composers' interest in musical language pervaded the 20th century aesthetics. Transformation and overcoming of well-established methods inherited from Romanticism led to post-tonal music. Linguistic structuralism applied to musical syntax stimulated relativization and consciousness of compositional procedures. Reversing the logic of this analytic knowledge, the methods of serial dodecaphonic music was the first step for the foundations of an inverse creative strategy: synthesize new styles from the predefinition of new rules.

Computer assisted composition enabled far more complex procedures, tedious or unfeasible to explore by hand. Eventually, composers began to use computers not only for analysis and calculation of complex structures, but for the automation of the creative processes themselves. That fact opened the door to a new approach to composition: a metamusical level characterized by modeling the processes within the minds of composers.

[*Reflexiones sobre metacomposicion, el concepto de autoria y consideraciones pedagogicas y humanas de fondo.*]

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Research in artificial intelligence demand for formalized grammars of musical structures. Besides, a model of creative mind is required to operate these abstractions. Aesthetic criteria are extremely subjective. The details of every model of automatic composition impose, consciously or not, a limited search space. Delimiting these boundaries and setting evaluation principles can be seen as metacomposition, namely composing composers.

*[Interes de la musica en el modelado de creatividad artificial - multidimensionalidad de la percepcion y analisis]*

*[Sobre la necesidad de usar el metanivel de los procedimientos antes que la partitura]*

Many approaches to artificial intelligence applied to the automatic composition of music are modeled using scores as its data source...

*[Complejidad del diseno de lenguajes de representacion musical en la composicion asistida por ordenador. Cita de algunas aproximaciones analogas.]*

*[El sistema de representacion condiciona los resultados de la creatividad artificial y son al fin decisiones artisticas y no solo tecnicas, por lo que idear una gramatica que sea lo mas amplia posible respecto de los estilos que pueda representar requiere de un diseno meditado.]*

## 2 A functional grammar to represent musical procedures

### 2.1 Foundations and requirements

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*[Conveniencia del paradigma de programacion funcional para la metaprogramacion. Antecedentes procedimientos compositivos como funciones (referencias a Haskell y LISP en la tradicion)]*

*[Necesidad de encontrar un medio de representacion adecuado a la automatizacion de analisis, a la flexibilidad de estilos, y a conjugar la programacion manual con la modularidad necesaria para las tareas automatizadas]*

*[Importancia de la codificacion como vector numerico como representacion abstracta de estructuras y resultados musicales para la aplicacion de tecnicas de IA.]*

### 2.2 Musical genotypes and phenotypes

*[Marco conceptual basico del paradigma genotipo-fenotipo (referencias de otros proyectos)]*

*[Definiciones estrictas de genotipo y fenotipo]*

*[Similitud con la programacion funcional: la pieza musical como funcion de funciones.]*

### 2.3 Function structure

- Estructuras musicales (partitura, voz, acorde, note, parametros finales) (figura ilustrativa)
- Inputs
- Outputs (genotipo, fenotipo, informacion analitica de armonia, ritmica, etc)
- Examples of functions (using different input types)

## 3 Encoding of genotypes and phenotypes

- Proposito de la codificacion en el marco del machine learning
- Codificacion como vectores unidimensionales normalizados
- Modularidad y posibilidad de manipulacion manual

## 4 Integrating traditional and contemporary techniques

- Entorno de trabajo con Max
- Ejemplo de pieza completa basado en Clapping music (La importancia de la autorreferencia)
- Un ejemplo clasico con varias voces y conteniendo armonia, dinamica y articulacion

- Modularidad y posibilidad de manipulacion manual
- Ejemplos basicos de tecnicas habituales en CAC (movimiento browniano,
- Handling of recursive techniques (fibonacci, y extension del modelo a expresiones matematicas complejas)
- Puentes entra la notacion tradicional, la sintesis de sonido y la espacializacion
- Multimedia

## 5 Scalability

- Como conjugar universalidad de las expresiones con optimizacion para tener los vectores codificados con mayores diferencias entre si.
- Estrategias de caracterizacion de perfiles estilisticos
- El problema del mapeo de funciones y su extensibilidad
- Como establecer una base de datos de conocimiento
- Metricas automatizadas de ciertos resultados

## 6 Evaluation and evolution

### 6.1 Evolutionary paradigm

## 7 Conclusions and future work

The artistic results of every algorithm designed for automated composition are strongly constrained by their own representation system of musical data. This paper presents GenoMus, a framework for the exploration of artificial musical creativity based on a generative grammar focused on the abstraction of creative processes as a metalevel of compositional tasks. We define musical genotypes as functional nested expressions, and phenotypes as the pieces created by evaluating these computable expressions. GenoMus' grammar is designed to ease the combination of fundamental procedures behind very different styles, ranging from basic to complex contemporary techniques, particularly those able to produce rich output from very simple recursive algorithms. At the same time, maximal modularity is provided to simplify metaprogramming routines to generate, assess, transform and categorize the selected musical excerpts. The system is conceived to maintain a long term interrelation with different users achieving individual musical styles. This proposed grammar can also be an analytic tool, from the point of view of composition as computation, considering that the best analysis of a piece is the shortest precise description.

Cuestiones interesantes:

- ¿Cuántas funciones primitivas son necesarias para generar musica en un determinado estilo? Hay innumerables expresiones funcionales diferentes que pueden generar la misma musica. Se puede deducir que la expresion funcional mas breve es el mejor analisis. Se pueden ver diferentes paradigmas de enseñanza/aprendizaje de la musica con estos modelos.
- ¿Como puede hacerse ingenieria inversa automatizada para extraer estructuras desde la musica?

Ejemplo de citas [1, 2] y otra cita [3].

## References

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