Armonización a 4-voces: Un enfoque y análisis desde el punto de vista de la Computación Evolutiva.

F. Fernández de Vega

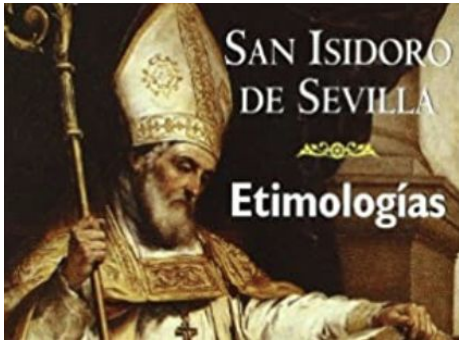
Grupo de Evolución Artificial.
Universidad de Extremadura.

Project PID2020-115570GB-C21

¿Música e Inteligencia Artificial?

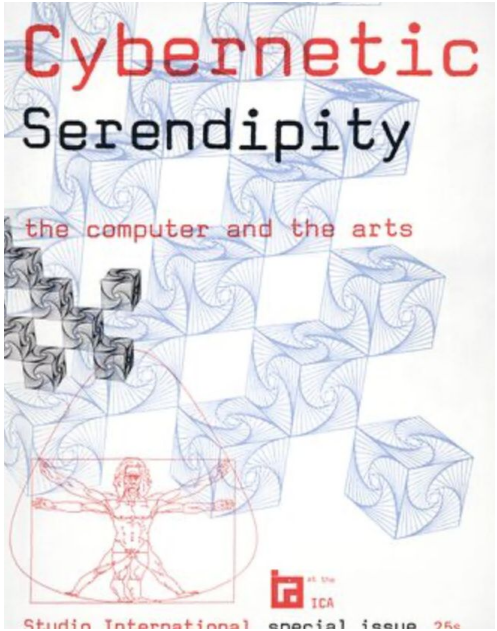
Matemáticas:

- Aritmética.
- Geometría.
- Astronomía.
- Música.

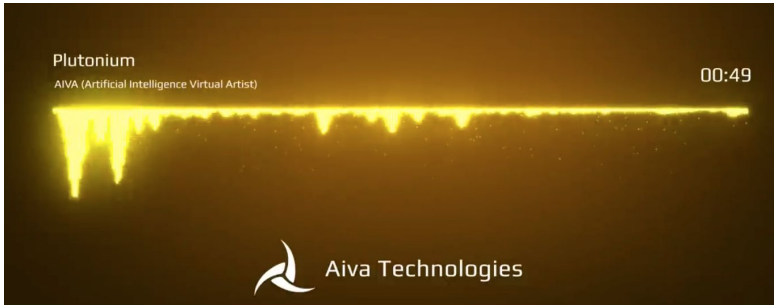


¿Creatividad Computacional?

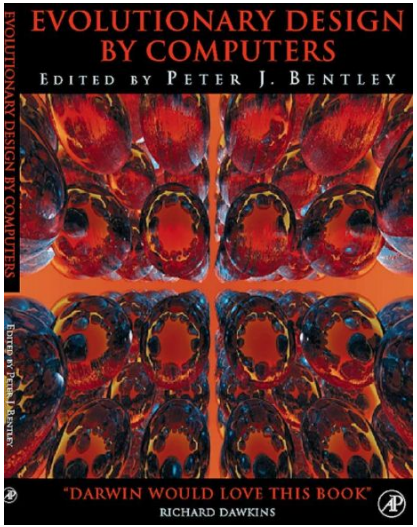
- Música, Arte y Diseño asistido por la Inteligencia Artificial.
- Un área con mucho potencial.
- Primeros trabajos a finales de los 60: https://monoskop.org/Cybernetic_Serendipity

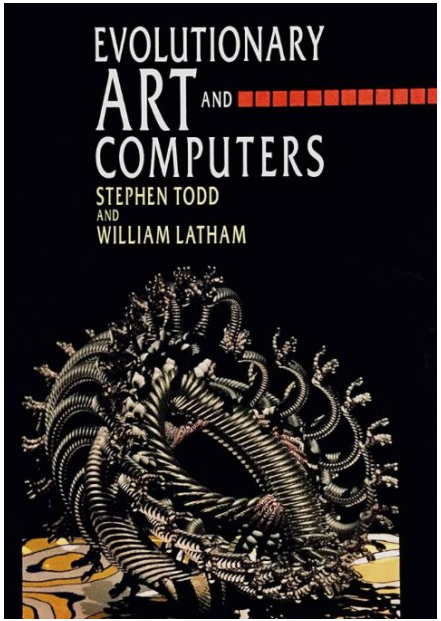


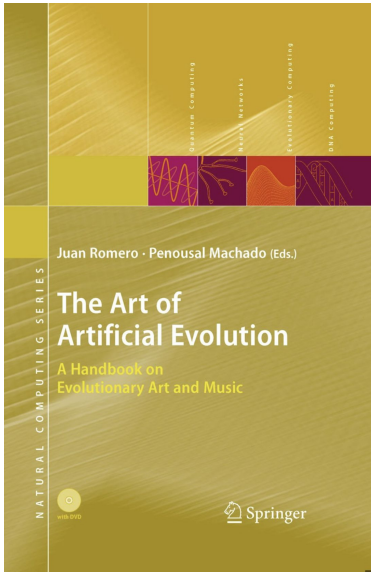
¿Creatividad Computational?



Evolutionary Art, Design and Creativity







Open problems in Evolutionary Music and Art

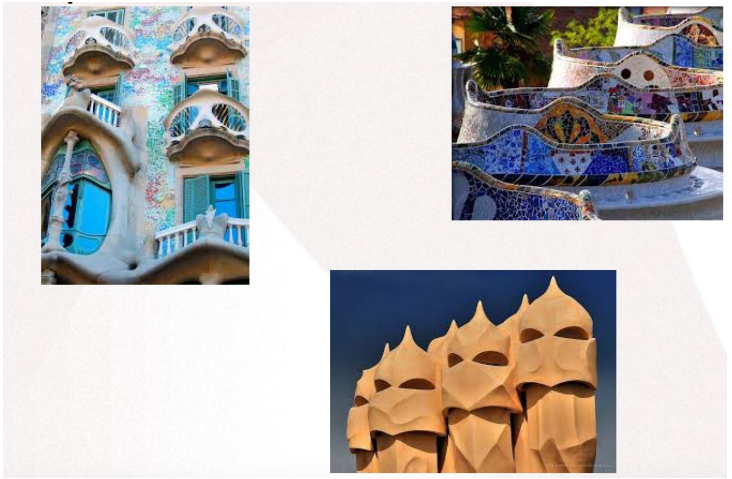
McCormack, J. (2005, March). Open problems in evolutionary music and art. In *Workshops on applications of evolutionary computation* (pp. 428-436). Berlin, Heidelberg: Springer Berlin Heidelberg.

Open problems in Evolutionary Music and Art

Aesthetic Selection: **Open problem #2:** To devise formalized fitness functions that are capable of measuring human aesthetic properties of phenotypes. These functions must be machine representable and practically computable.

What is art?: **Open problem #3:** To create EMA systems that produce art recognized by humans for its *artistic* contribution (as opposed to any purely technical fetish or fascination).

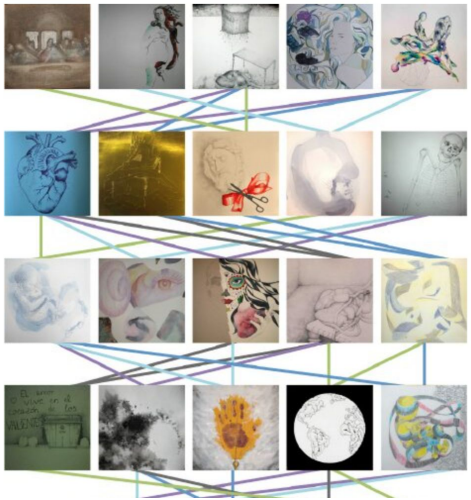
Buscando la inspiración...



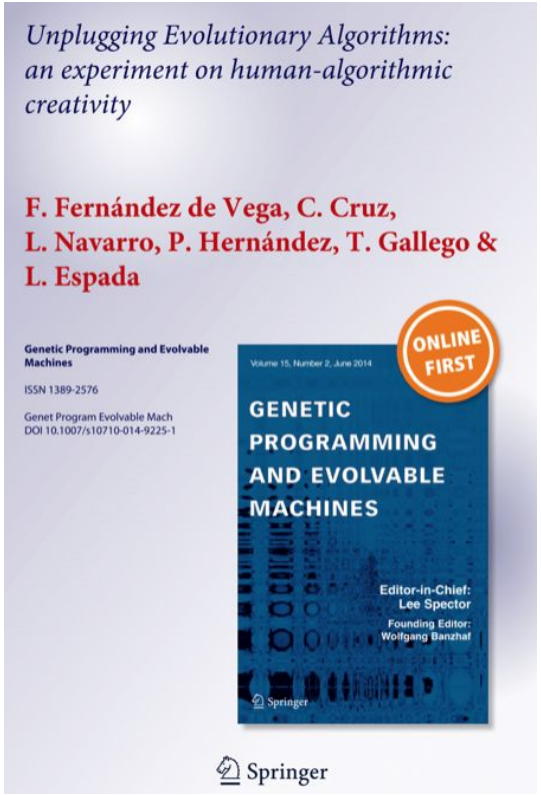
Buscando la inspiración… desde la evolución

- Interactive EA.
  - Fitness Evaluation.
  - Selection.
  - Crossover + Mutation.
- Unplugged EA.
  - Fitness Evaluation.
  - Selection.
  - Crossover + Mutation.

Algunos trabajos previos



ACM GECCO 2013 Evolutionary Art, Design and Creativity Award



XY

"...Although the ultimate goal may be the creation of artif cial intelligence that is capable of producing high quality works of art without human intervention (...) Personally I'd rather man stay ahead and in control of the very aspects of life that make it worth living, and rely on machines to help us with those things that they are currently best at, relieving us of the mundane and tedious, rather than taking over our most enjoyable pastimes and leaving creativity to man and God!"

M. Mumford, Fellow of the Royal British Photographic Society. Excerpt from XY foreword, Parlamento de Extremadura, 2014. ISBN 978-84-96757-50-9.

Algunos trabajos previos

Evolutionary Art

Evolutionary Algorithms have been frequently employed as a means for artistic creation and design, in which human artists guide the creative process, through aesthetic and conceptual evaluation, and computers are in charge of applying more repetitive genetic operations. The success of this interactive version of the evolutionary algorithm is well documented, although researchers are still struggling to find a way for properly encoding good aesthetic measures. But other possibilities exist for computer mediated artistic creation, such as applying an opposite approach: instead of allowing human beings to guide the artistic process, we could establish the main evolutionary algorithm steps as a path to be followed by human artists, such that every step is performed by his hands and brains, while the evolutionary algorithm is the framework that dictates how to progress.

This approach, that we refer to as the Unplugged Evolutionary Algorithm, was applied to produce the collective work XY, recipient of 2013 ACM GECCO Art, Design and Creativity award, as well as XYZ, a new collective artwork that has allowed us to better understand artists way of expressing creativity from the evolutionary algorithm point of view. The work is made up of sixty individual paintings and can be accessed at: http://xyz-project.herokuapp.com/. We hope the approach will not only be useful for researchers to learn from artists, which eventually could in the future allow improvements to available algorithms, but also provide new methodologies for collective art production.

F. Fernández de Vega, C. Cruz, P. Hernández, L. Navarro, V. Albarrán, L. Espada.

The front cover image was generated using the Unplugged Evolutionary Algorithm

Top: Generation 2-1
Bottom: Generation 10-1

Portada de SIGEVOLUTION Newsletters nº 8: XYZ: https://evolution.sigevo.org/issues/SIGEVOlution0803.pdf

Back Gallerie Project - Vancouver

Back Gallery Project is pleased to invite you to attend and exhibition by the collective group:

XYZ - Virtual Connections

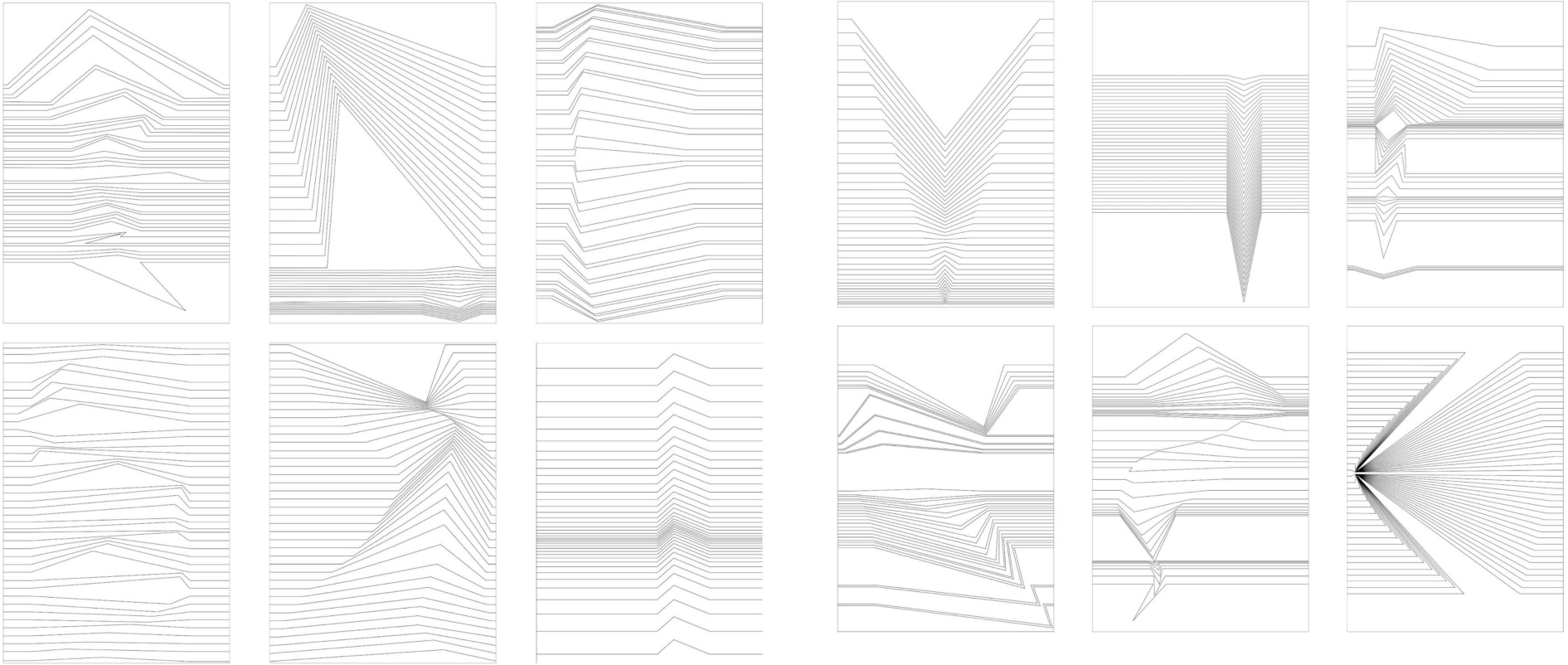
Opening Reception: Tuesday, July 26, 5-7 pm
Open to the public: Wednesdsay, July 27, 1-5pm

602 E Hastings Street
Vancouver, BC V6A 1R1
T. 604.336.7633
www.backgalleryproject.com

Show Your World

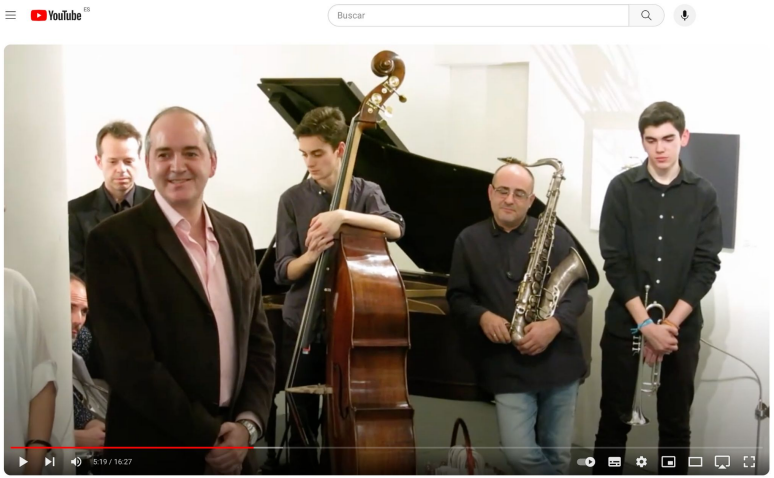
330 Me gusta • 335 seguidores

To Cry Out of Happyness - MC Gallery - Manhattan - New York



To cry out of happyness

To cry …. : Emotion in lines.



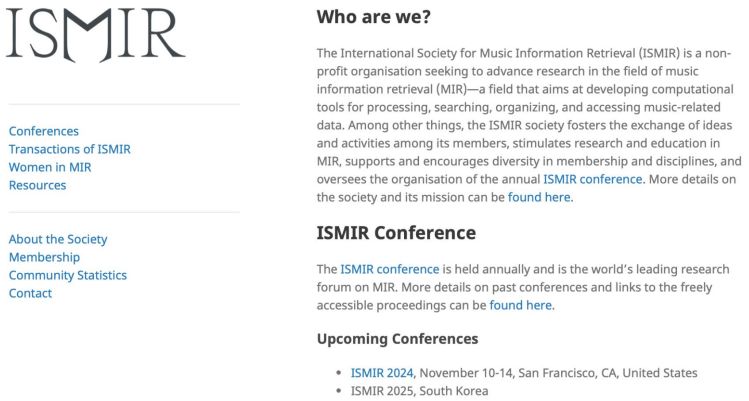
Gala Event "Show Your World" 2017, Part 1

Gallerie Louchard - Paris

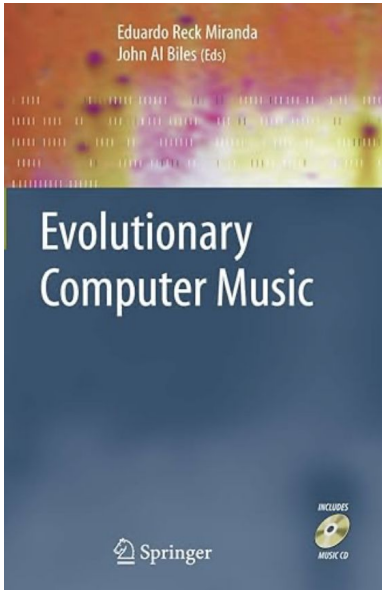
Música como área para la IA

Muchos problemas que atacar (MIR):

- OMR.
- Detección de ritmo, compás, género…
- Generación de audio
- Generación de partituras
- …



Evolutionary Music?

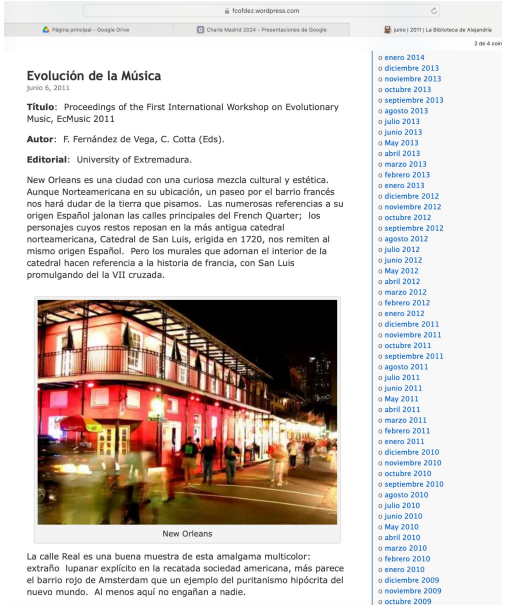


evomusart

13th International Conference on Artificial Intelligence in Music, Sound, Art and Design

April 2024
part of evo* 2024

Evolutionary Music?



fcofdez.wordpress.com

Página principal - Google Drive | Charla Madrid 2024 - Presentaciones de Google | junio | 2011 | La Biblioteca de Alejandría

3 de 4 coin

Evolución de la Música

junio 6, 2011

Título: Proceedings of the First International Workshop on Evolutionary Music, EcMusic 2011

Autor: F. Fernández de Vega, C. Cotta (Eds).

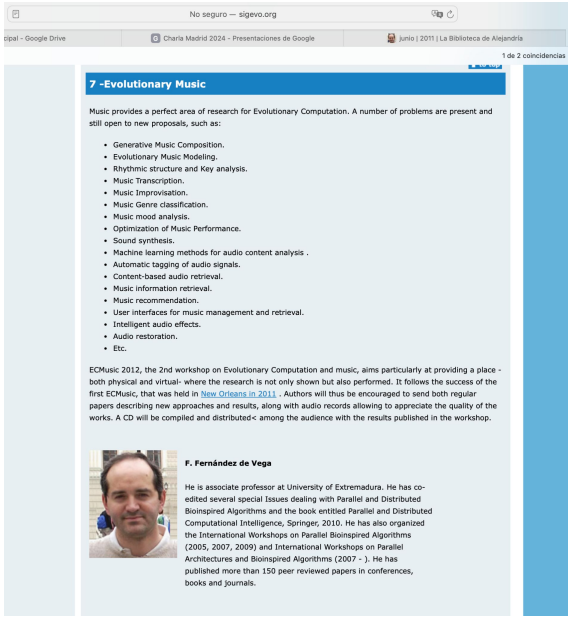
Editorial: University of Extremadura.

New Orleans es una ciudad con una curiosa mezcla cultural y estética. Aunque Norteamericana en su ubicación, un paseo por el barrio francés nos hará dudar de la tierra que pisamos. Las numerosas referencias a su origen Español jalonan las calles principales del French Quarter; los personajes cuyos restos reposan en la más antigua catedral norteamericana, Catedral de San Luis, erigida en 1720, nos remiten al mismo origen Español. Pero los murales que adornan el interior de la catedral hacen referencia a la historia de francia, con San Luis promulgando del la VII cruzada.

New Orleans

La calle Real es una buena muestra de esta amalgama multicolor: extraño lupanar explícito en la recatada sociedad americana, más parece el barrio rojo de Amsterdam que un ejemplo del puritanismo hipócrita del nuevo mundo. Al menos aquí no engañan a nadie.

- enero 2014
- diciembre 2013
- noviembre 2013
- octubre 2013
- septiembre 2013
- agosto 2013
- julio 2013
- junio 2013
- May 2013
- abril 2013
- marzo 2013
- febrero 2013
- enero 2013
- diciembre 2012
- noviembre 2012
- octubre 2012
- septiembre 2012
- agosto 2012
- julio 2012
- junio 2012
- May 2012
- abril 2012
- marzo 2012
- febrero 2012
- enero 2012
- diciembre 2011
- noviembre 2011
- octubre 2011
- septiembre 2011
- agosto 2011
- julio 2011
- junio 2011
- May 2011
- abril 2011
- marzo 2011
- febrero 2011
- enero 2011
- diciembre 2010
- noviembre 2010
- octubre 2010
- septiembre 2010
- agosto 2010
- julio 2010
- junio 2010
- May 2010
- abril 2010
- marzo 2010
- febrero 2010
- enero 2010
- diciembre 2009
- noviembre 2009
- octubre 2009



No seguro — sigevo.org

cipal - Google Drive | Charla Madrid 2024 - Presentaciones de Google | junio | 2011 | La Biblioteca de Alejandría

1 de 2 coincidencias

7 -Evolutionary Music

Music provides a perfect area of research for Evolutionary Computation. A number of problems are present and still open to new proposals, such as:

- Generative Music Composition.
- Evolutionary Music Modeling.
- Rhythmic structure and Key analysis.
- Music Transcription.
- Music Improvisation.
- Music Genre classification.
- Music mood analysis.
- Optimization of Music Performance.
- Sound synthesis.
- Machine learning methods for audio content analysis .
- Automatic tagging of audio signals.
- Content-based audio retrieval.
- Music information retrieval.
- Music recommendation.
- User interfaces for music management and retrieval.
- Intelligent audio effects.
- Audio restoration.
- Etc.

ECMusic 2012, the 2nd workshop on Evolutionary Computation and music, aims particularly at providing a place - both physical and virtual- where the research is not only shown but also performed. It follows the success of the first ECMusic, that was held in New Orleans in 2011 . Authors will thus be encouraged to send both regular papers describing new approaches and results, along with audio records allowing to appreciate the quality of the works. A CD will be compiled and distributed< among the audience with the results published in the workshop.

F. Fernández de Vega

He is associate professor at University of Extremadura. He has co-edited several special Issues dealing with Parallel and Distributed Bioinspired Algorithms and the book entitled Parallel and Distributed Computational Intelligence, Springer, 2010. He has also organized the International Workshops on Parallel Bioinspired Algorithms (2005, 2007, 2009) and International Workshops on Parallel Architectures and Bioinspired Algorithms (2007 -). He has published more than 150 peer reviewed papers in conferences, books and journals.

And beyond.

Música y Algoritmos Evolutivos

Trabajos previos

sharpmony.unex.es

I+D+i

Para el equipo de trabajo de Sharpmony es fundamental que la I+D sea algo más que un montón de documentos guardados en cajones. Estamos convencidos de que la investigación que realizamos en Inteligencia Artificial y Computación Paralela y Distribuida debe ser aplicada para conseguir resultados que beneficien a la sociedad.

Sharpmony es la primera aplicación que hace uso de más de 20 años de experiencia. Si estás interesado en nuestros resultados previos de I+D aplicados a la música, quizá te interesen estos artículos que hemos publicado en los últimos años

Francisco Fernández de Vega, J. Alvarado, A. Sánchez, M. Serrano, E. Pacioni:
Evolutionary Algorithms: A new hope for the future of music teaching. ACM GECCO (Companion) 2023: 65-66

F. Fernández de Vega:
"Enseñanzas profesionales y superiores de música asistidas por la Inteligencia artificial". Publicado en Educación, Investigación y Formación Musical: Miradas, Experiencias y Reflexiones desde los diferentes ámbitos y niveles Educativos, 2023, Dykinson. pp. 128-134.

R. Miragaia, F. Fernández de Vega, G. Reis, T. Inacio:
Evolving a Multi-classifier System for Multi-pitch Estimation of Piano Music and Beyond: An Application of Cartesian Genetic Programming. Applied Science, March 2021, 11(7).

R. Miragaia, F. Fernández de Vega, G. Reis:
Evolving a Multi-classifier System with Cartesian Genetic Programming for Multi-pitch Estimation of Piano Music. SAC '21: Proceedings of the 36th Annual ACM Symposium on Applied Computing, March 2021 Pages 472–480.

M. Morita, F. Fernández de Vega, J. Villegas:
Aplicacion de técnicas de aprendizaje profundo al reconocimiento optico de partituras SATB. CAEPIA 20/21, September 2021. Pages 411-416.

F. Fernández de Vega, J. Alvarado, M. Morita:
CAEPIA-App Competition: Sharpmony: A Computational Intelligence based tool for 4-part harmony. CAEPIA 20/21: Competition on mobile Apps with A.I. techniques. September 2021. Pages 1009-1012.

Francisco Fernández de Vega:
Revisiting the 4-part harmonization problem with GAs: A critical review and proposals for improving. CEC 2017: 1271-1278

Francisco Chávez de la O, Francisco Fernández de Vega, Francisco J. Rodriguez Diaz:
Analyzing quality clarinet sound using deep learning. A preliminary study. SSCI 2017: 1-7

Francisco Fernández de Vega, Carlos Cotta, Eduardo Reck Miranda:
Special issue on evolutionary music. Soft Comput. 16(12): 1995-1996 (2012)

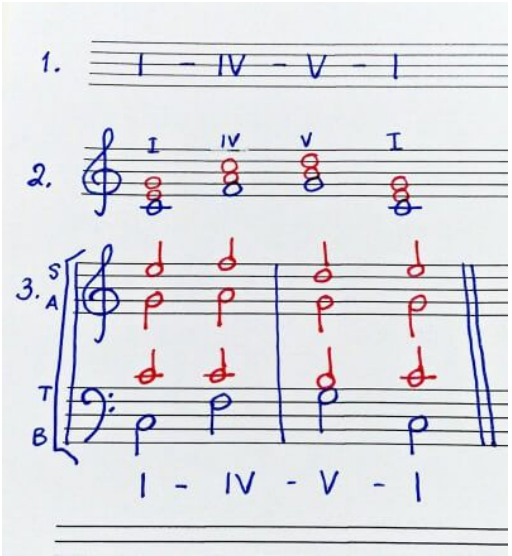
Gustavo Reis, Francisco Fernández de Vega, Aníbal Ferreira:
Automatic Transcription of Polyphonic Piano Music Using Genetic Algorithms, Adaptive Spectral Envelope Modeling, and Dynamic Noise Level Estimation. IEEE Trans. Audio, Speech & Language Processing 20(8): 2313-2328 (2012)

Armonía a 4 voces: SATB

SATB harmony

Beginning with a melody (soprano voice) students must build the remaining 3 voices:

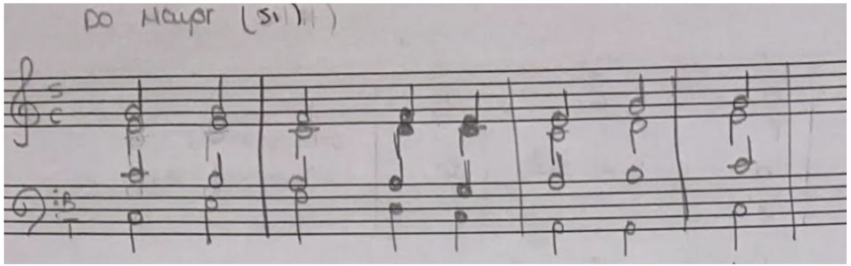
- Alto.
- Tenor.
- Bass.



4-part harmony

Students must learn harmony rules to build 4-part scores:

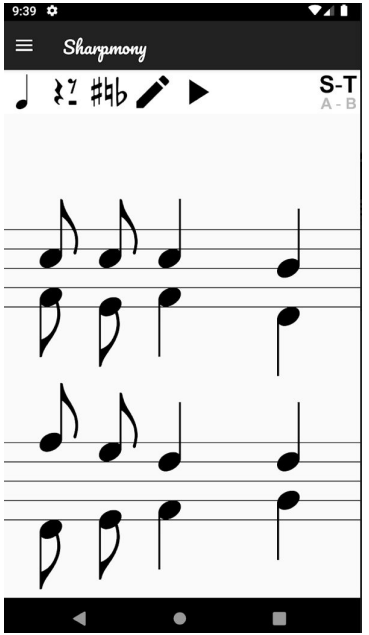
- Parallel Fifths
- Direct 8th
- Leading voice resolution
- …. more than 30 different rules/cases



Available tools: Sharpmony

- A tool for learning 4-part harmony.

- Check 4-part harmony exercises.

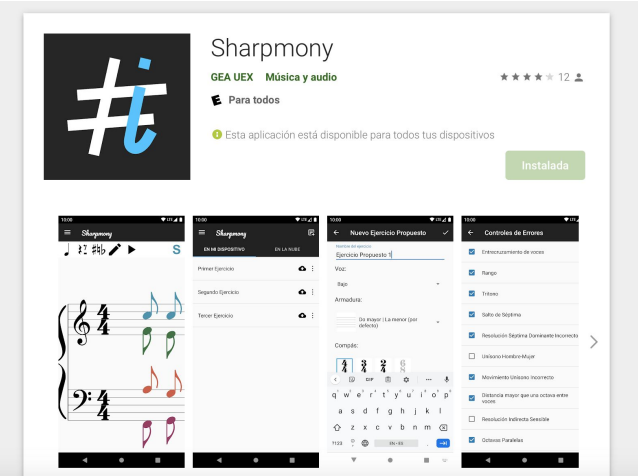


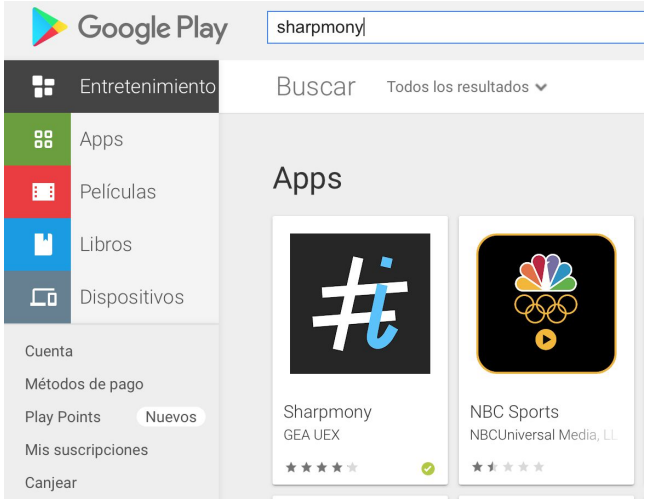
Main goals for Sharpmony

- To help music teachers and students.
- It provides an APP, a Web, and a Artificial Intelligence Cloud system to check exercises.
- We aim at providing teachers with automatic composition tool.

Sharpmony

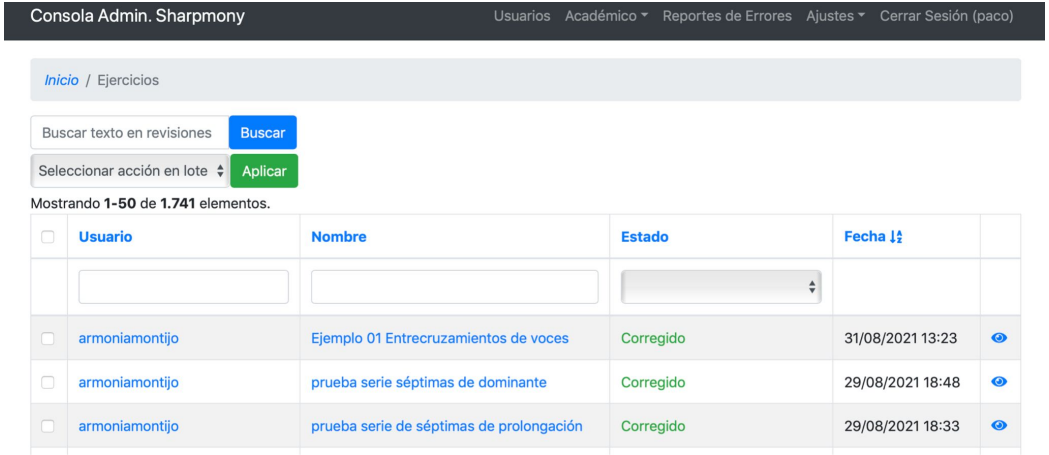
- APP para estudiantes y profesores (disponible en Google Play).





Sharpmony

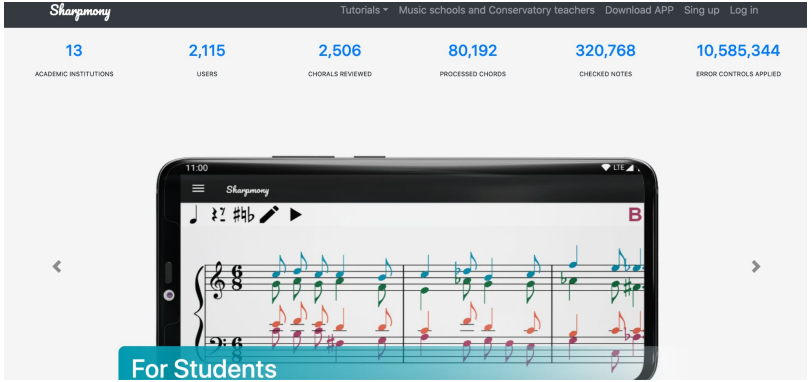
Web + Cloud System for Conservatories
teachers and students.



Sharpmony

Web + cloud: Sistema cloud con herramientas de Inteligencia Computacional:

- Kernel with harmony rules (fitness function).
- Includes secondary dominants and modulation.
- Augmented sixth, Neapolitan and diatonic seventh chords allowed.
- Sixth and Seventh chord progressions.
- Color codes for errors detected.
- Compatible with musicXML files.

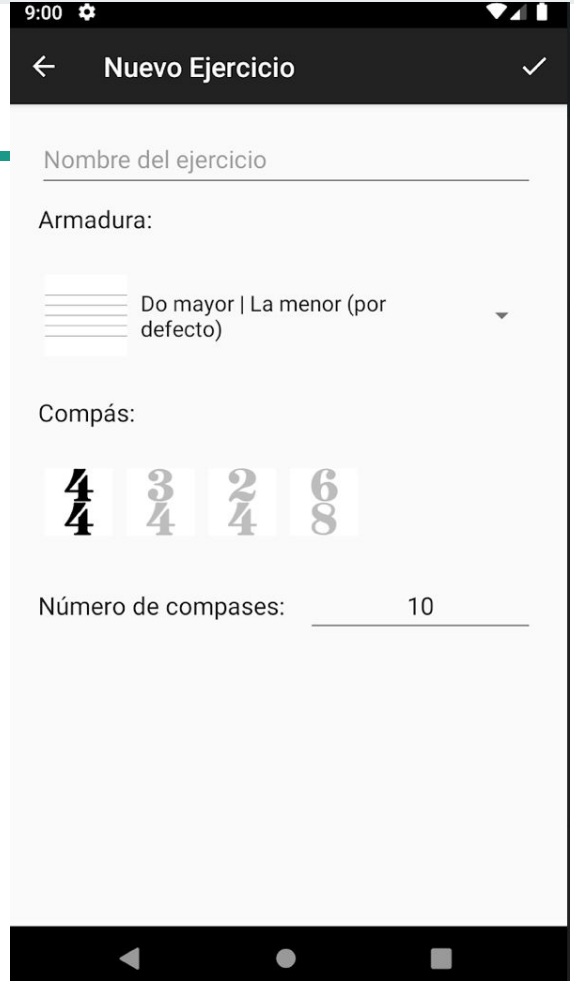


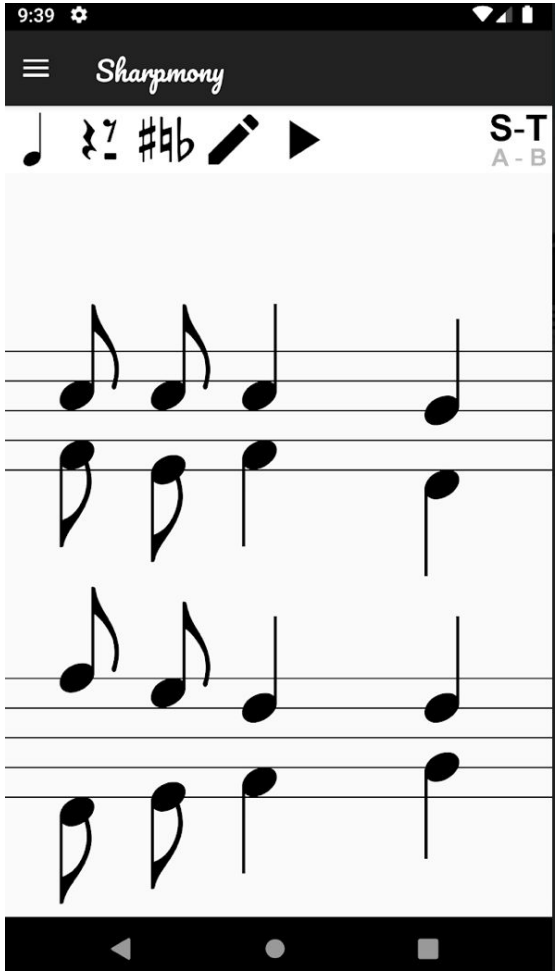
⇒ **NARANJA:** Entrecruzamiento de voces ✔
⇒ **AMARILLO CLARO:** Distancia mayor que una octava entre voces
⇒ **ROJO:** Octavas Paralelas ✔
⇒ **ROJO:** Quintas Paralelas ✔
⇒ **VERDE OLIVA:** Acorde incorrecto o no perteneciente a la tonalidad ✔
⇒ Rango ✔
⇒ **AZUL:** Disonancias ✔
⇒ **DORADO OSCURO:** Falsa relación de cromatismo ✔

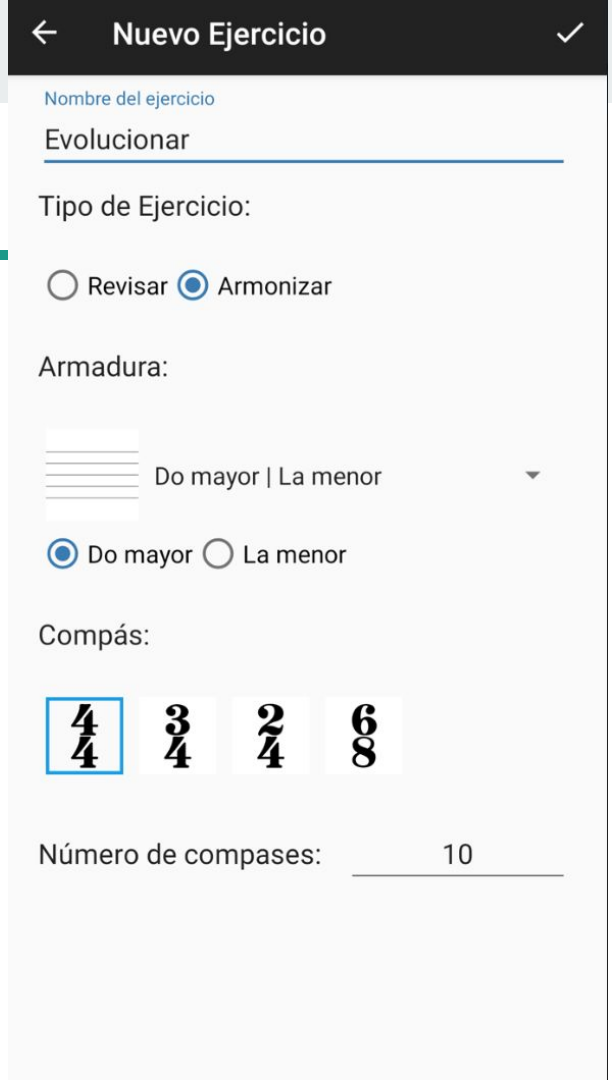
Sharpmony Harmonic Manual

The harmonic error controls available in Sharpmony are shown below. The information includes the CONTROL that allows you to activate or deactivate its use in the APP, the COLOR used to mark the errors found in the score, explanatory text of the harmonic rule and its exceptions and finally graphic examples that explain how the marked error appears in the score.

- [x] Overlapping voices (ORANGE)
- [x] Interval wider than the 10th among voices (DARK TURQUOISE)
- [x] Parallel octaves (RED)
- [x] Parallel fifths (RED)
- [x] Direct fifths or octaves (LIGHT PINK)
- [x] Wrong chord or chord not in the key (GREEN)
- [x] Voice ranges (CHOCOLATE)
- [x] Dissonance (BLUE)
- [x] False relation (DARK GOLDEN)


9:00
Nuevo Ejercicio
Nombre del ejercicio
Armadura:
Do mayor | La menor (por defecto)
Compás:
Número de compases:
10


9:39
Sharpmony
S-T
A - B

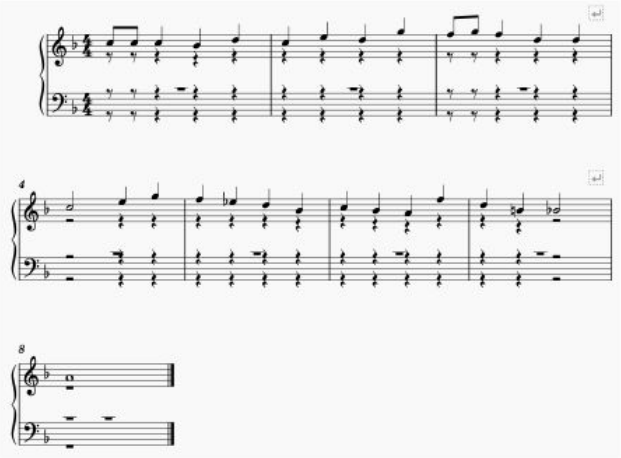

Nuevo Ejercicio
Nombre del ejercicio
Evolucionar
Tipo de Ejercicio:
Revisar
Armonizar
Armadura:
Do mayor | La menor
Do mayor
La menor
Compás:
Número de compases:
10

Sharpmony
EN MI DISPOSITIVO
EN LA NUBE
Evolucionar
Estado de la armonización
Generación: 4
Nº de errores: 42
CERRAR

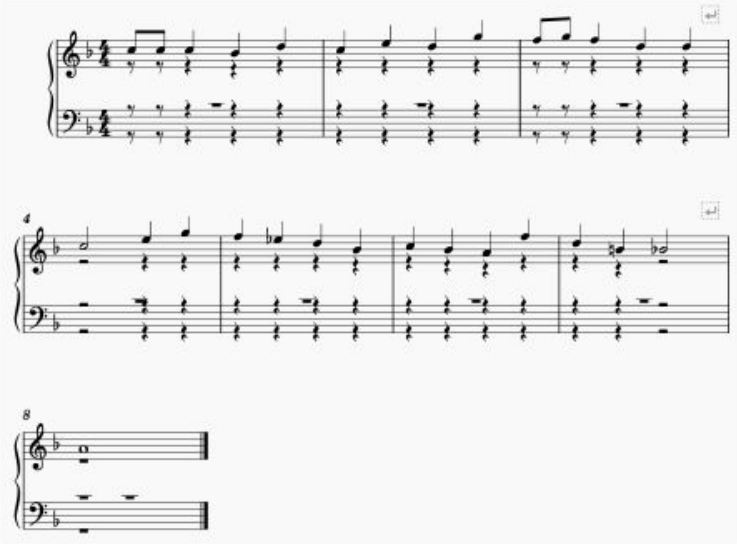
4-part harmony Evolution

The idea is to use Evolutionary Algorithms to find a good enough 4-part harmonization for a melody.

The last attempt published in 2017 (FFV, Revisiting the 4-part harmonization problem with GAs. CEC 2017).



4-part harmony evolution



Several approaches to find solutions:

- Evolving first a suitable progression, and then the notes for the voices.
- Solutions with 10-40 errors after more than 6 hours running an experiment.
- 11 rules included in the Fitness function.

The problems in the problem

Sharpmony tool includes nowadays about 50 different controls per chord.

These controls are used in the new version of the fitness function.

Sharpmony Harmonic Manual

The harmonic error controls available in Sharpmony are shown below. The information includes the CONTROL that allows you to activate or deactivate its use in the APP, the COLOR used to mark the errors found in the score, explanatory text of the harmonic rule and its exceptions and finally graphic examples that explain how the marked error appears in the score.

- [x] Overlapping voices (ORANGE)
- [x] Interval wider than the 10th among voices (DARK TURQUOISE)
- [x] Parallel octaves (RED)
- [x] Parallel fifths (RED)
- [x] Direct fifths or octaves (LIGHT PINK)
- [x] Wrong chord or chord not in the key (GREEN)
- [x] Voice ranges (CHOCOLATE)
- [x] Dissonance (BLUE)
- [x] False relation (DARK GOLDEN)

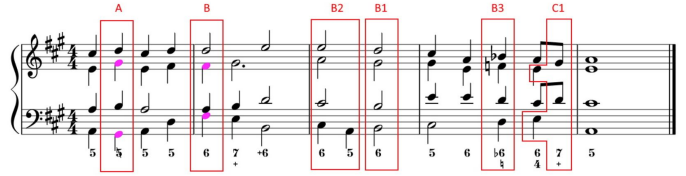
- [x] Wrong note dupplication (FUCHSIA)

In some situations, specific notes can not be doubled in a chord:

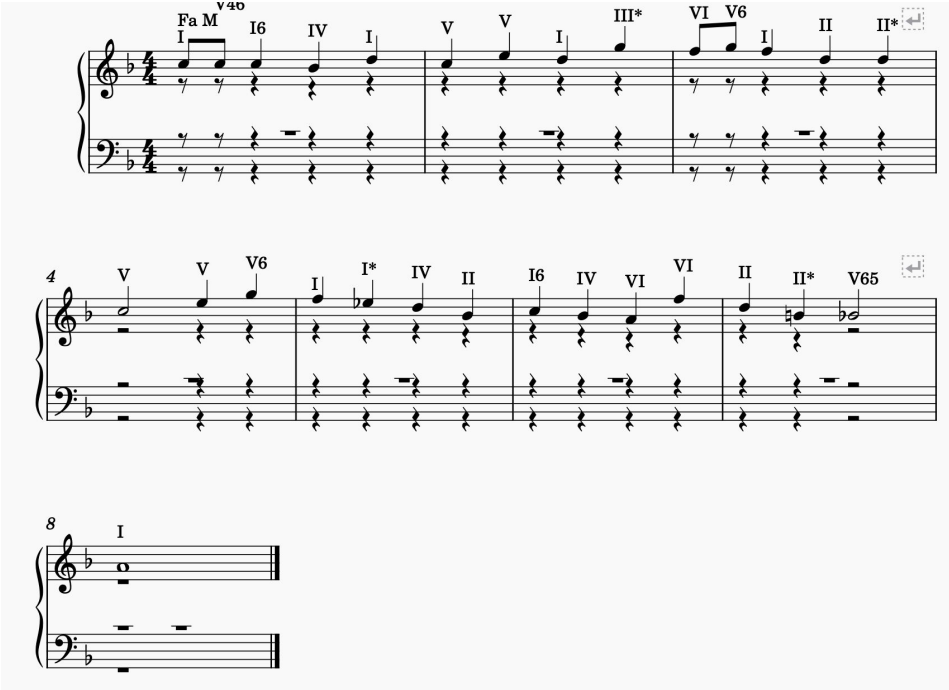
- **A)** Minor flatted 5th (diminished triad). The root cannot be doubled when the chord is in the root position or second inversion, given that it must follow an established resolution.
- **B)** First inversion triad chord (6): the note in the bass cannot be doubled. Yet some exceptions may apply
  1. First inversion of the minor flatted 5th: only the note in the bass can be doubled, It is the only one without a mandatory resolution.
  2. First inversion triad chord: The note in the bass can be doubled if there was a mandatory movement required for the bass note in the previous chord that led to this note.
- **C)** Seventh or Ninth chords: None of the notes in the chord can be doubled. Some exceptions may be applied:
  1. In a Dominant seventh chord in root position, the root may be doubled if the 5th is removed, so that the chord is incomplete.

Sharpmony will detect and mark wrong notes doubled using FUCHSIA color.

Boxes and text in the following example have been added to the correction provided by Sharpmony.

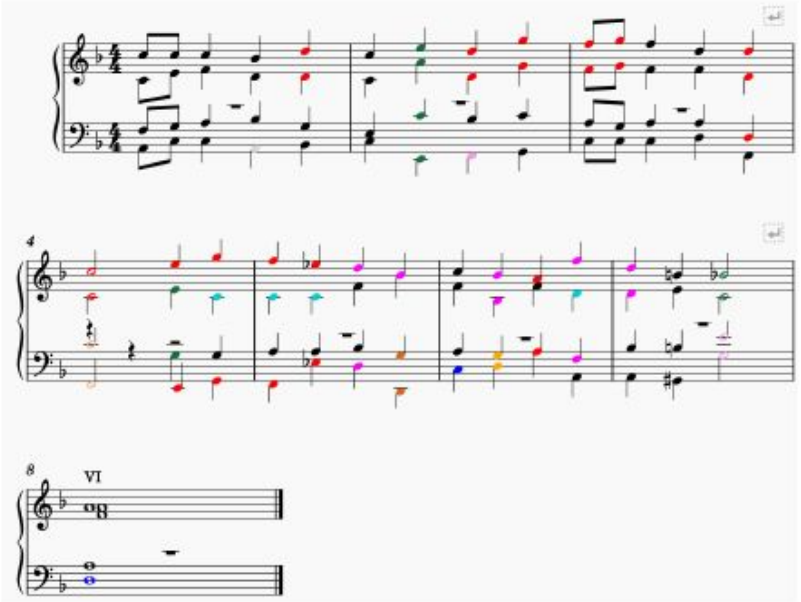


Results


Fa M
I
I6
IV
I
V
V
I
III*
VI
V6
I
II
II*
4
V
V
V6
I
I*
IV
II
I6
IV
VI
VI
II
II*
V65
8
I

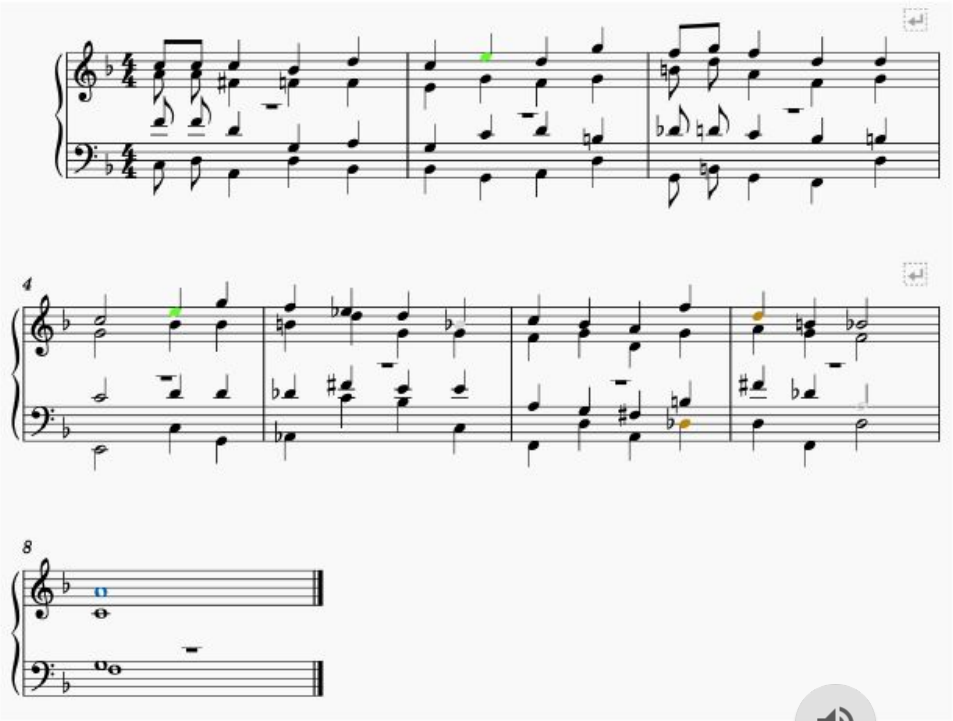
Results

The new controls applied to the best solution found in 2017 shows more than 50 errors.



Results

6 Errors after 4 hours evolving 4 individuals.: mutation+selection applied.

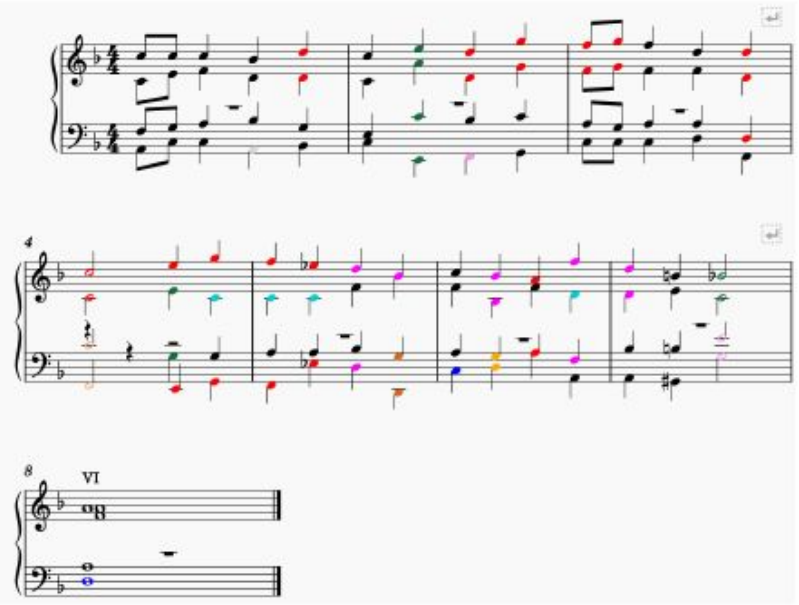


The problems in the problem

The larger the number of constraints applied, the smaller the number of solutions available.

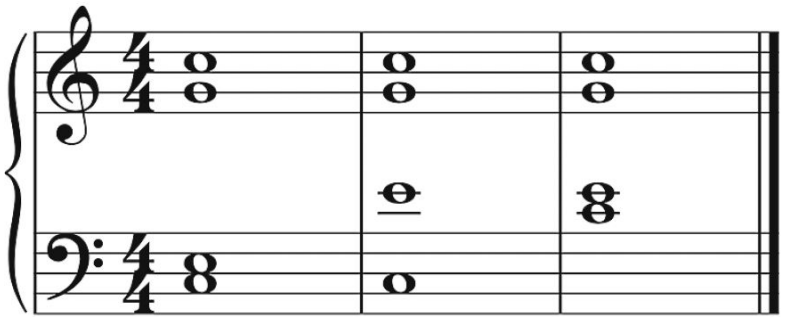
The new version allows new kind of chords, such as diatonic-seventh chords, Augmented Sixth chords and Neapolitan chord. Therefore a larger search space to look around.

The difficulty increases significantly.



Configuración de acordes

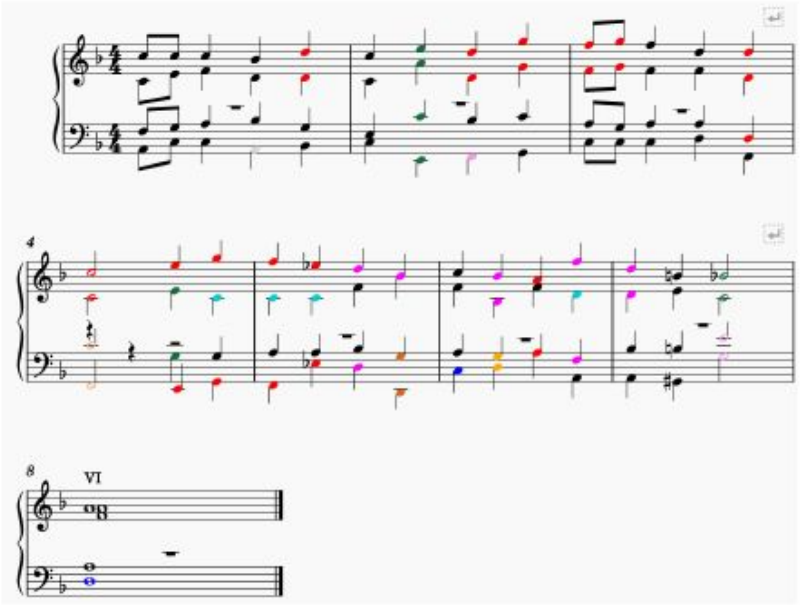
Un ejemplo: DO-MI-SOL



The problems in the problem

Considering 2 consecutive 4-note chords:

- Given that each note can be assigned to 2 possible octaves each, and that not all the notes may be present in the chord, thus allowing repetition of notes: more than 200 possible configurations per chord may be used.
- Moreover: 7 diatonic degrees (chords), + 6 secondary dominants + 3 augmented sixth chords + Neapolitan chord + Ninth chords: more than 20 different chords available per note.
- Considering a single key: 2855 possible chord disposition available.



Nuevas ideas y resultados

- Evolving a progression first is a must. Then the evolution of voices begins.
- Still, several hours are required for finding a solution (> 24h).

En el Trabajo Fin de Máster del estudiante Elia Pacioni, hemos intentado mejorar mediante:

- Paralelización.
- Precálculo de valores de fitness.
- Mutación dirigida.

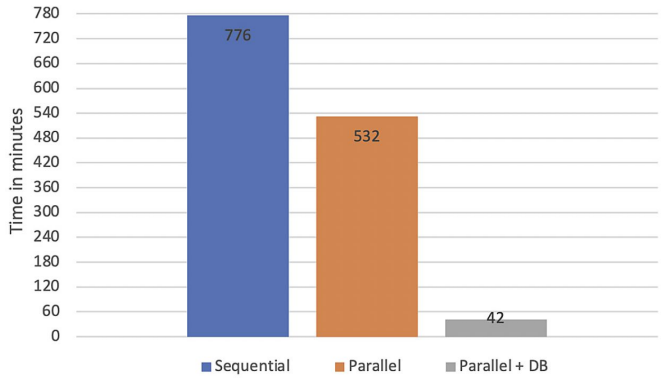
Precálculo

- 2855 posibles configuraciones de acordes válidos …
- 8155025 pares de acordes…
- 22 segundos para corregir un par de acordes …
- 5,8 años en las máquinas que disponemos (secuencial).

Nuevas ideas y resultados

Paralelización + Precálculo de valores de fitness: Tiempos de cálculo para pares de acordes.

Secuencial	Paralelo	DB	DB optimizado
22,5	11,25	3,127	0,001



Mutación dirigida

Aplicar mutación dónde más convenga.

13. Melamed, D., et al.: De novo mutation rates at the single-mutation resolution in a human HBB gene-region associated with adaptation and genetic disease. Genome Res. (2022). https://doi.org/10.1101/gr.276103.121
14. Bhandari, D., Pal, N.R., Pal, S.K.: Directed mutation in genetic algorithms. Inf. Sci. **79**(3–4), 251–270 (1994). https://doi.org/10.1016/0020-0255(94)90123-6
15. Tang, P.-H., Tseng, M.-H.: Adaptive directed mutation for real-coded genetic algorithms. Appl. Soft Comput. **13**(1), 600–614 (2013). https://doi.org/10.1016/j.asoc.2012.08.035
16. Puerta, B.R., Barrancas, F.D., Chavez, F., de Vega, F.F.: Un análisis preliminar de nuevos modelos de mutación dirigida en algoritmos genéticos. In: Conferencia de la Asociación Española para la Inteligencia Artificial (CAEPIA 2018), Granada, España
17. Carvalho, P., Magane, J., Lourenco, N., Machado, P.: Context matters: adaptive mutation for grammars. In: Pappa, G., Giacobini, M., Vasicek, Z. (eds.) Genetic Programming. EuroGP 2023. LNCS, vol. 13986, ppl. 117–132 . Springer, Cham (2023). https://doi.org/10.1007/978-3-031-29573-7_8

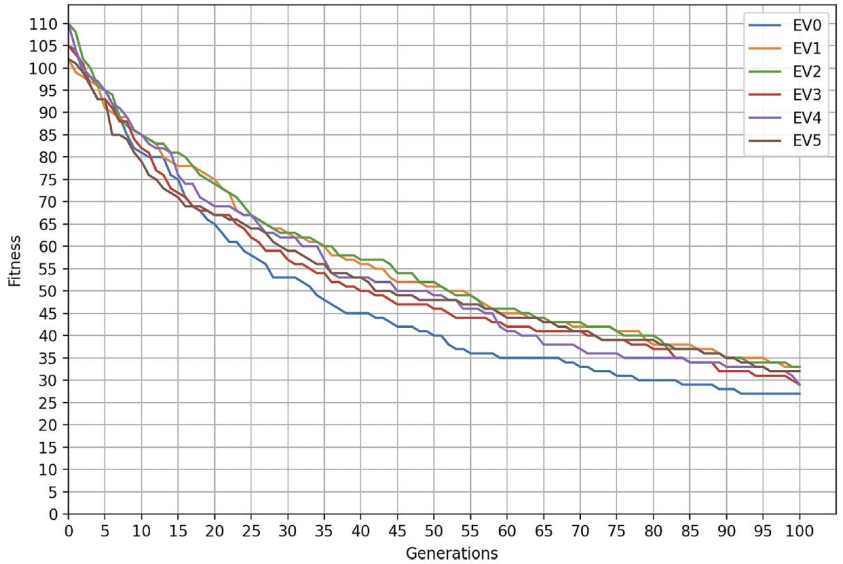
Mutación dirigida

¿Qué tal si aplicamos mutación con mayor probabilidad en lugares donde sabemos que hay errores?

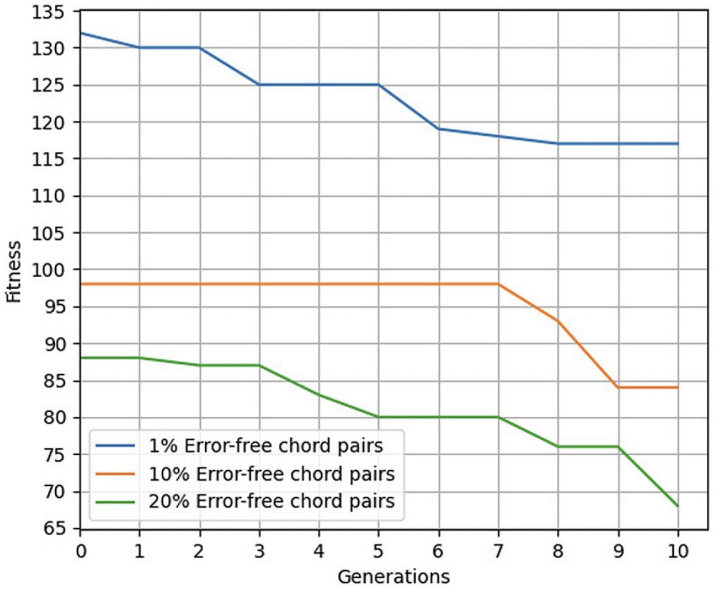
Exp	Evolving Chord Progression	Mutation
EV0	YES	100% DIRECTED
EV1	YES	100% RANDOM
EV2	YES	50% DIR. 50% RANDOM
EV3	NO	100% DIRECTED
EV4	NO	100 % RANDOM
EV5	NO	50% DIR. 50% RANDOM

Mutación dirigida

¿Qué tal si aplicamos mutación con mayor probabilidad en lugares donde sabemos que hay errores?



Modelos armónicos sintéticos



Evostar 2024

Elia Pacioni, Francisco Fernández de Vega:
On the Impact of Directed Mutation Applied to Evolutionary 4-Part Harmony Models. EvoMUSART 2024: 311-325

Nominado como mejor artículo de estudiante.

Próximos pasos

Artículo enviado a PPSN 2024 con análisis sobre reducción del espacio de búsqueda:

- ¿Es necesario utilizar todo el espacio de búsqueda?
- ¿Podemos encontrar soluciones más rápidamente en un espacio limitado?

Thank you