Harriet Padberg: Computer-Composed Canon and Free-Fugue Renascence

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Abstract:
Harriet Padberg: Computer-Composed Canon and Free-Fugue Renascence Sister Harriet Padberg's 1964 dissertation, "Computer-Composed Canon and Free-Fugue," may be the first on computerized algorithmic composition. In this work, Padberg combined traditional fugue style and 20th century serialism with a novel text-to-music algorithm contrasting largely used stochastic methods. Padberg's dissertation can be seen today as having pioneered modern text-to-music approaches - processing text into features used to define sounds, rhythms, and structures which form the basis for composition.

While the original code is made available in the dissertation, the ability to run it, experiment with it, or sonify its outputs is inaccessible; it was written for the IBM 1620 and 7072, machines which can most likely only be found in museums. The authors have thus recreated the software in Python and are releasing it as an open-source, stand-alone program. The purpose of this renascence is to allow anyone to use and interact with Padberg's system, providing a window into music technology history and the ability to reimagine the system's potential uses for new work.

Despite its originality and relevance to the work of more prominent algorithmic composition figures such as Lejaren Hiller and Max Matthews, Padberg's work remains obscure and rarely referenced. With the exception of one survey by Hiller, her dissertation is not mentioned in any of Hiller's or Mathews' papers about computer music despite both of them communicating with her and learning from her approach. Nevertheless, this piece remains a vital example of algorithmic composition research and a significant part of the history of early computer music.

1. Career Overview

Harriet Padberg (November 13, 1922 - January 2, 2014) spent her life as a member of the ministry of a Roman Catholic women's congregation called the Society of the Sacred Heart. She received a PhD in mathematics and music from Saint Louis University, after which she became a professor at Maryville University in St. Louis. Padberg's PhD dissertation, *Computer-Composed Canon and Free-Fugue*, written in 1964, is likely the first dissertation on computer algorithmic composition. In this work, Padberg combined traditional music theory methods with a novel text-to-music algorithm, contrasting the stochastic approaches that were widely used at the time.

2. Aesthetics

The aesthetics of Computer Composed Canon and Free Fugue, reflecting the aesthetics of Padberg herself at the time, are rooted in Western Classical music tradition, particularly 20th-century serialism. Padberg's interest in serialism was rooted in her educational and cultural backgrounds; she completed Masters degrees in both Musicology and Mathematics. As a devout Catholic, she was fond of ancient Greek philosophies around the associations between mathematics, music, and the heavens. In her dissertation, Padberg describes Serialism as a method by which to "re-discover" from Pythagoras the inherent relation of music and mathematical models. Her choice of the word canon to describe the piece is derived from use of the term in music literature, wherein it typically refers to a melody which reoccurs at a set interval underneath itself; a common technique in 12-tone music. The term "free-fugue"

however is not used literally. Instead, she uses the term to refer to multiple melodies appearing and crossing over one another.

Her decision to map letters to pitches draws on J.S. Bach's Unfinished Fugue, in which Bach famously built his own name into musical text, as well as later tributes to this work by Anton Webern, Robert Schumann, and Arnold Schoenberg[9]. These works were created using a direct mapping in German musical notation - A to A, B to Bb, C to C, onwards, with H mapping to B Natural. These text to music mappings vary from those used by Padberg, who did not associate pitch name directly with its text representation with the exception of A natural, which was mapped to 440 Hz. Padberg chose to use a 24-microtonal scale, largely based on the relation between characters in the alphabet and the capability of controlling with software, yet does not state any specific composer or work as the inspiration.

Padberg also drew inspiration from other past experiments in algorithmic composition. Influenced by the Illiac Suite, she also drew on the work of John R. Pierce and M.E. Shannon from Bell Labs and Richard C. Pinkerton at the University of Florida. From Bell Labs she describes three chance pieces, however criticizes them as "nothing very interesting either because the music is too surprising, too random, too unpredictable".

3. Music Therapy

During her following tenure at Maryville, she would further advance the use of computer music through her establishment of the university's Music Therapy program along- side Ruth Sheehan, paving the way for the creation of its Occupational Therapy and Speech-Language Pathology programs a few years later. The Music Therapy program would steadily expand

during its first ten years, including the creation of a work study program allowing students to gain professional experience in the field while studying. Padberg herself worked as a therapist as well and additionally went on to begin her own music ministry in 1992.

4. Algorithms

The first part of the algorithm reads in up to 160 characters of text, and maps each constituent letter to an integer which indexes a length 24 table of frequencies consisting of partials 24 through 47 of the overtone series for some root note. The letter Y is mapped to the letter I on its first appearance, and to the letter Z for subsequent appearances. Additionally, the letters W and V are assigned the same frequency. During this same pass, the input is divided into blocks containing words of five or more letters each, and words with less than five letters adjoined with neighboring words to form longer blocks. Each letter is assigned a block number, and an index into their assigned block.

Once this mapping is determined, a second pass is performed during which a number of other meta-data is extracted from the text, including the number of vowels and consonants per block, the total number of vowels and consonants for the entire phrase, and the number of notes in each octave. The set of blocks, starting from the beginning of the input phrase, whose constituent letters sum to less than or equal to 24 are used as a ``tone row", as well as the melody line of the Canon. Repeating letters in the tone row are mapped to the same note in a different octaves according to the number of repetitions and whether that number of repetitions is odd or even, making each pitch in the ``tone row" unique. The rhythm of the melody is derived via a

process that takes into account the relative primality of the length of the tone row, and the number of vowels, consonants and blocks it contains.

The algorithm outputs the composition on a punch card with two columns, one of which specifies the melody in a piano roll format with time divided into ``ticks'' representing a constant time span. Note lengths are specified by number of ticks in which the note is a ``on''. The other denotes ``the number of units of the rhythmic pattern''. The melody line is repeatedly written to the cards in an overlapping fashion, with each successive line beginning one measure after the beginning of the preceding line.

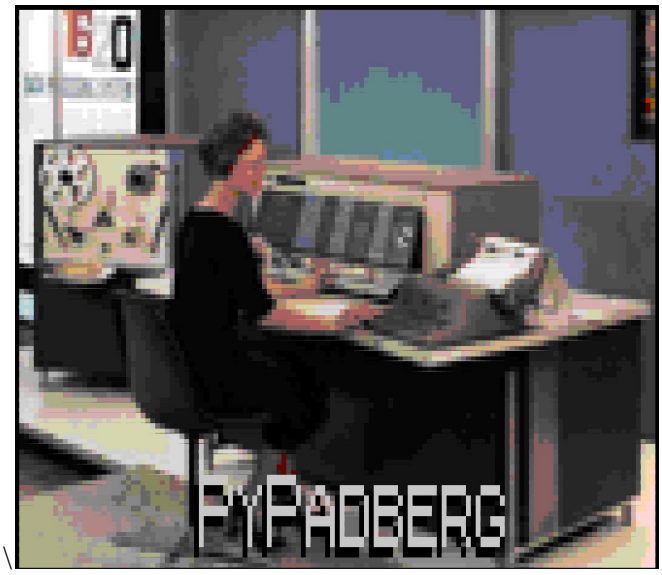
The original program was written for and run on the IBM 1620, which was an inexpensive scientific computer that could store 20-60 thousand digits at a time. Due to space constraints, the algorithm was eventually moved to an IBM 7072, where it underwent some technical changes to generalize its process such that it could generate not only Canons, but ``Free-Fugues'' for two or three voices as well.

Though Padberg's algorithm is surely the first composition technologically realized specifically on the IBM 1620 and 7072, it is predated by other uses of computers for algorithmic composition. David Caplin and Dietrich Prinz ran some of the very first experiments composing music with computers in 1955. They created an implementation of Mozart's dice game among other probabilistic music programs. A few years later, Martin Klein and Douglas Bolitho created a program called which randomly output numbers, representative of chromatic pitch classes, and structured them using a set of hard-coded rules. Hiller and Isaacson's preceded Padberg's work by seven years. However, their work sought to use the computer to produce notes and phrases

which could be arranged by musicians, whereas Padberg's algorithm is meant to produce complete pieces of music on its own. Milton Babbit's work with the RCA Mark II similarly used the computer in composition for its precision and mathematical translation abilities. Babbit's serialism features greatly throughout Padberg's thesis, providing clear influence for many of her algorithmic and aesthetic choices.

5. PyPadberg

We will now present our reimplementation of Padberg's work. This will include a demonstration of how the system works, a quick summary of how to install and a very brief introduction to how it can be customized.



```
::INFO:: Received Text - !!! 4 random symbols ^ Aa
::INFO:: Sanitized Text -   random symbols  aa
::INFO:: Processing - letter: r, freq: 751.6666, rhythm_interval: 1
::INFO:: Processing - letter: a, freq: 440, rhythm_interval: 1
::INFO:: Processing - letter: n, freq: 678.3333, rhythm_interval: 1
::INFO:: Processing - letter: d, freq: 495, rhythm_interval: 1
::INFO:: Processing - letter: o, freq: 696.6666, rhythm_interval: 3
::INFO:: Processing - letter: m, freq: 660, rhythm_interval: 2
::INFO:: Processing - letter: s, freq: 770, rhythm_interval: 3
::INFO:: Processing - letter: y, freq: 586.6666, rhythm_interval: 11
::INFO:: Processing - letter: m, freq: 660, rhythm_interval: 6
::INFO:: Processing - letter: b, freq: 458.3333, rhythm_interval: 22
::INFO:: Processing - letter: o, freq: 696.6666, rhythm_interval: 55
::INFO:: Processing - letter: l, freq: 641.6666, rhythm_interval: 330
::INFO:: Processing - letter: s, freq: 770, rhythm_interval: 1
::INFO:: Processing - letter: a, freq: 440, rhythm_interval: 1
::INFO:: Processing - letter: a, freq: 440, rhythm_interval: 1
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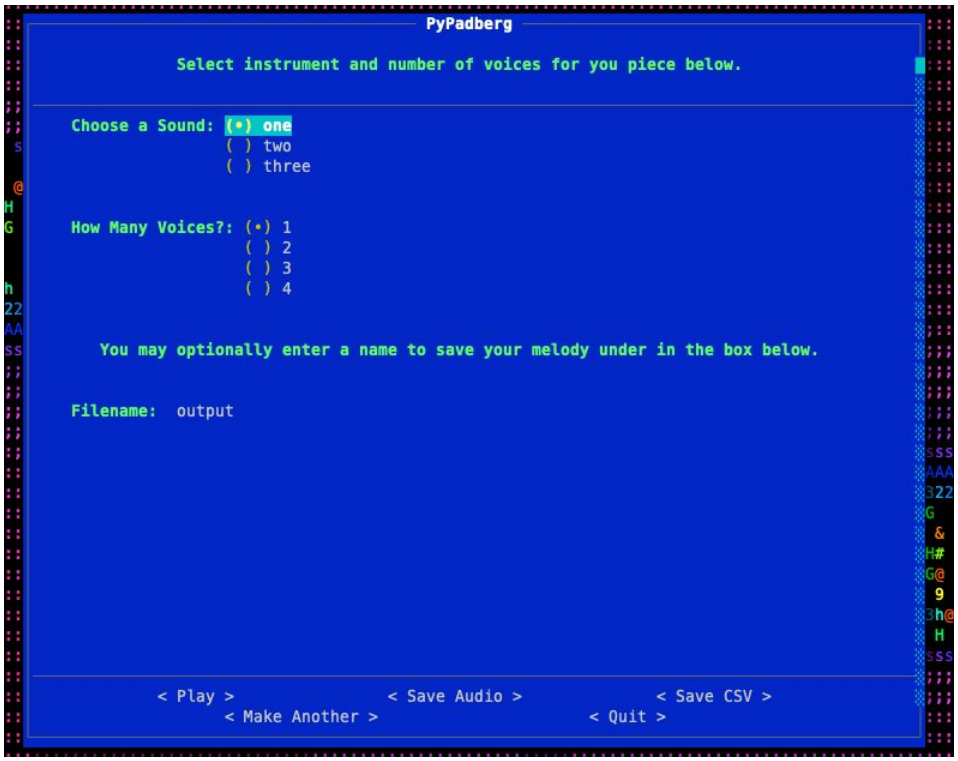

https://github.com/bgenchel/PyPadberg

6. Contemporary Composition using PyPadberg

Not Even One, by Molly Jones, was created as a submission to the 2nd Iannis Xenakis International Electronic Music Competition 4. After discovering that the panel of judges selected for the competition consisted entirely of men, Jones decided to use the PyPadberg program to express the idea that women are a significant and under-appreciated part of the field of electronic music, and thus the presence of gender diversity in this judging panel is not only important, but necessary.

[audio file, play ~0:30 second portion of *Not Even One*]

Jones began by feeding in three text patterns into the Py- Padberg program and rending their corresponding melodies using a recording of herself speaking the phrase, “The Xe- nakis Competition has no Women Judges,” a polyphonic synthesizer, and the prepackaged violin sample. The text patterns themselves are not semantically meaningful, but were developed through trial and error for the melodies they created through the program. She then saved three and four voice canon/fugue versions of each pattern as wav files, and arranged them in Ableton Live 5. The composi- tion was built primarily around the four voice canon/fugue version of one of the three patterns rendered with the voice recording, with pitched and shifted versions of the other renderings used for ornamentation, accent and layering.

7. Conclusion

In this presentation, we have discussed the obscure yet historically significant Harriet Padberg and her 1964 PhD dissertation Computer Composed Canon and Free Fugue and have presented our own recreation or reinterpretation of her algorithm, PyPadberg. PyPadberg has been open sourced both to bring this algorithm into the present dialog on music technology history and for modern composers to use. We've presented a specific example of how one composer used PyPadberg as a basis for a new work, employing PyPadberg for both its surrounding narrative and as a means of producing a particular aesthetic. Harriet Padberg's work holds relevance for contemporary composition as well as for the history of computer music.

References

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20 Minutes

1 page - 1-2 minutes HP career overview (2.1 background first paragraph)

2 page - 3 minutes HP aesthetics + influences (2.3 aesthetics)

1 page- 1 minutes mention music therapy work/speech (2.1 background second paragraph)

2.5 page- 5 minutes Algorithms how it's created

2.5 page - 5 minutes PyPadberg

2 page - 3-4 minutes MJ piece

1 page - 1 minute conclusiion