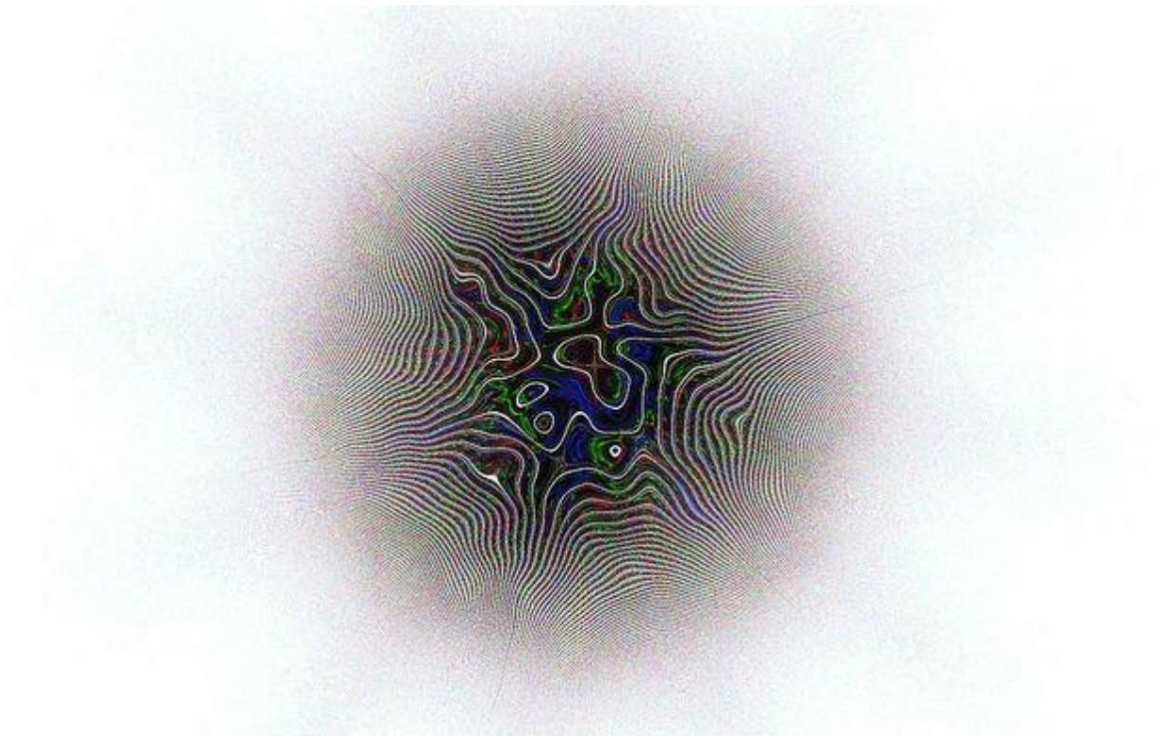
ΔΙΙΔΡΥΜΑΤΙΚΟ ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ
ΤΕΧΝΟΛΟΓΙΕΣ ΤΗΣ ΠΛΗΡΟΦΟΡΙΑΣ ΚΑΙ ΤΗΣ ΕΠΙΚΟΙΝΩΝΙΑΣ ΓΙΑ ΤΗΝ ΕΚΠΑΙΔΕΥΣΗ

LESSON

Modern Digital Technologies and Internet

"Teaching Intervention for teaching a Computer Science subject, without the use of a Computer"

M. Fidakis, H. Patrikakis



Fotinaki Christina – Maria
AM: 5619

1. Introduction – Application Framework – Objective

Subject matter: Algorithmic music composition and Markovian models.

Scope: The activity is aimed at high school students and adults.

Duration of Intervention: The duration of the intervention is defined as one (teaching) hour. 1

Purpose: The purpose of the intervention is for the participants to have a first contact with algorithmic music composition. Through a brief historical presentation of some applications of probabilistic models, from the 18th century until today (with an emphasis on randomness) and playing a different "Snake", to understand how a Markov chain works.

2. Historical Review – Bibliographic Review

An algorithm is a set of mathematical instructions that must be followed in a fixed order (especially if given to a computer) to calculate an answer to a mathematical problem. It is the set of rules that must be followed when solving a specific problem and through a systematic process to produce the answer, in a finite number of steps (Nierhaus, 2009).

Musical composition, we can claim, is governed by an algorithmic logic, since the composer organizes and develops the structure of his work in a specific way. But more specifically, by algorithmic composition we mean the conscious use of extra-musical rules, mainly from the field of mathematics, which create the predetermined and organized framework on the basis of which a musical composition is developed. These rules can take the form of simple arithmetic operations or more complex structures, such as:

statistical models, sets, functions, geometries, etc. More generally, any process that reproduces values based on specific rules can be used to determine the structural parameters of a musical composition (Lotis, Diamantopoulos, 2015).

These systems, depending on their nature, can be divided into two main categories:

- Causal (deterministic) – models whose outcome can be completely predetermined. (procedures with predetermined causal logic / appropriate data)

and

- Probabilistic (stochastic) – models whose outcome is partially or totally unpredictable (processes governed by a lower to a higher degree of uncertainty) (Komineas, Harmandaris, 2016).

Aleatorism in music, etymologically derived from the Latin "alea" meaning dice, concerns processes of complete randomness.

A first example of randomness in musical composition was the musical dice game designed in 1757 by Johann Philipp Kirnberger ("Der allezeit fertige Menuetten und Polonaisencomponist" - "The ever-ready minuet and polonaise composer"), for the accidental composition of minuets and polonaises. As a given there was a piece of music with numbered measures and a table of choices given by the composer, which led to the next measure by the roll of a die. Thus, depending on the predetermined combinations x different and interesting compositions were produced. Around 20 such games were published from 1757 to 1812 – such as Mozart's well-known Musikalisches Würfelspiel (1793) (Nierhaus, 2009-Loy, 2011).

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In 1840, the mathematician Charles Babbage, aiming at the mechanization of calculation processes, designed the "analytical engine", the first mechanical computer that accepted punched cards. Ada Lovelace (after whom the Ada programming language took its name) thought that the "analytical engine" in addition to numbers could also process the harmonic relationships of a musical composition, therefore creating elaborate music. (Nierhaus, 2009). This was made possible with the ILLIAC I computer

1957. Lejaren Hiller and Leonard Issacson programmed ILLIAC I to create the first algorithmic musical composition called the “Illiac Suite for string quartet” using musical rules and statistical models of randomness such as Markov chains. (Nierhaus, 2009-Loy, 2011).

And while Hiller and Issacson used the computer to compose music entirely from it, Iannis Xenakis took a different approach. And he - a pioneer of contemplative music, like many composers after 1950, included contemplative models in his work, but he believed that the computer should be a tool in the hands of the composer. Thus in his work “Analogique A” (1958) he used Markovian models for the creation of the musical material, making probability tables concerning the transition from one state to another for the relationship between tones-dynamics.

(Nierhaus, 2009)

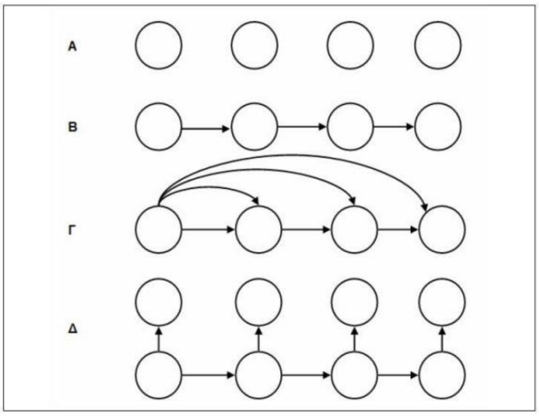
- But what are these chains/models?

The Markov chain or Markov model (Markov Model - MM) is a series of random variables, for which the probability of transition to a new state depends only on the given state of the series. In the case of musical composition, it is used to model the components of e.g.

tempo, tonal range, rhythmic values, notes, gradations, dynamics, etc. (Ramanto, Maulidevi, 2016), in order to imitate specific musical styles (which are already given to the system). However, because the variables in music are many and work simultaneously, the algorithms of music creation software they use Hidden Markov Models (HMM). HMMs consist of a set of hidden states, a set

of observed symbols and two sets of probabilities, the transition probabilities and the emission or appearance probabilities of symbols. The important difference between HMM and simple MM is that there is no one-to-one mapping between symbols and model states. That is, by seeing a symbol, we cannot tell which state the model has gone through to produce this result (Bagos, 2015).

Graphical representation of probabilistic models.



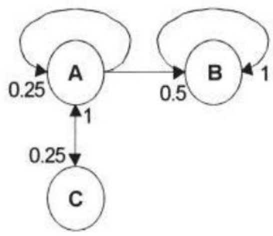
A. Basic model of independence.
B. 1st order Markov model1 .
C. Markovian model of 3rd order2.
D. Hidden Markov model

In models A-C, states correspond to observable symbols. In D the states (on the bottom line) follow one
1st- order Markovian chain , each state of which "produces" with a different probability the observable symbols. (Bagos, 2015)

A Markov chain is characterized by the table of "transition probabilities", which is more simply called the transition matrix.

Example 1
class table
transition and
chart:

	A	B	C
A	0.25	0.5	0.25
B	0	1	0
C	1	0	0



(Fig. McAlpine et al, 1999)

In the case of music creation these tables
transitions may also take into account previous states to be grouped
between the notes. In this way they create
whole patterns (in larger classes of Markovian chains) and finally result in musical phrases and not so random transitions from note to note (as in 1st order). Usually, however, after the 4th order Markovian chain, repetition occurs, which is why more complex schemes are used (Roads, 1996).

1st-order matrix

Note	A	C#	E♭
A	0.1	0.6	0.3
C#	0.25	0.05	0.7
E♭	0.7	0.3	0

2nd-order matrix

Notes	A	D	G
AA	0.18	0.6	0.22
AD	0.5	0.5	0
AG	0.15	0.75	0.1
DD	0	0	1
DA	0.25	0	0.75
DG	0.9	0.1	0
GG	0.4	0.4	0.2
GA	0.5	0.25	0.25
GD	1	0	0

1 A 1st- order Markov chain is defined as a stochastic evolution of discrete states in discrete time.

2 Includes the dependence of the 3 previous observations.

And while the approach of the previous decades wanted systems that were based exclusively on rules (rule-based) and with the necessary algorithms to produce a musical result in a second time, through machine learning (machine learning) - and more specifically with neural networks (neural networks), researches have turned to the creation of systems that aim to co-create (co-creative AI) in real time.

An early example is the artificial intelligence (AI) system called "Continuator" developed by Francois Pacet in 2002. It is based on augmented Markov chains and thus can "learn" from and interactively with the musician's playing and style. to respond (real time), thus contributing to the musical effect (Herremans, Chuan, Chew, 2017).

Now there are many projects dealing with the development of such artificial intelligence systems. The challenge they face, however, concerns the creation of long term structures and above all the creation of emotion that (automated) music can cause so that it can be used based on a narrative e.g. in games, videos, etc.

3. Intervention: Planning

The intervention is based on behaviorism and playful learning.
First the information is presented and then the students are asked to play in order to understand the concepts they learned[3] . Discussion follows.

Step 1: (17') Presentation of the information and explanations about it
Algorithmic Music and tools.
Step 2: (29') Game "Rhythmic Snake"

- Rules and performance: playing in groups and simultaneously recording the resulting rhythmic composition to understand the randomness.

- The result is recorded with applause from each team.
- Transition matrix study – graphical representation presentation.
- Discussion
- Assessment through observation throughout the application and parallel assessment through questions.

4. Reflection

The intervention can also be done in smaller classes in a simpler form in the context of music, as long as the musical values have been taught and it is possible to play the rhythmic composition.

3 Detailed instructions in the appendix.

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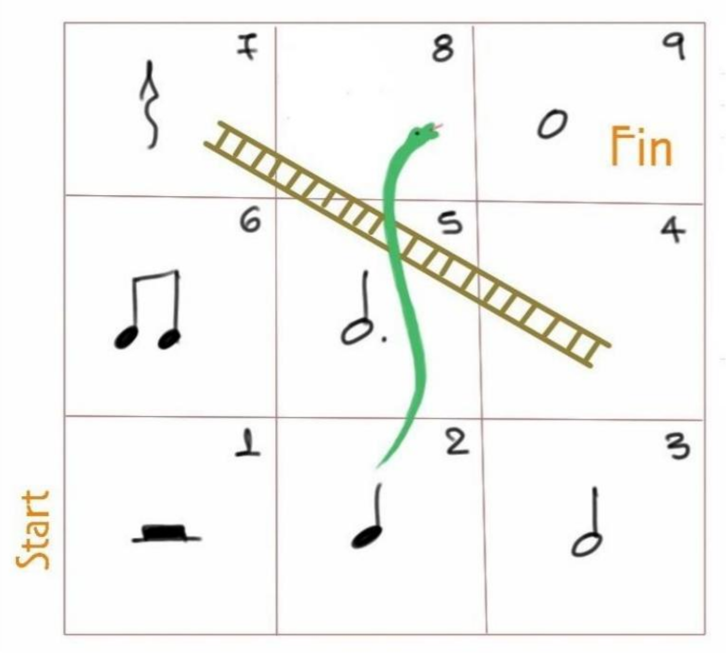
ANNEX

The application is made with the well-known game "Snake" which is based on a type of Markovian chain called absorbing Markov chain because there is a situation from which we cannot escape (Cheteyan, Hengeveld, Jones, 2011). In our case it is position 9 (absorbed state), where the game ends. Position 0 is considered the starting position.

The Rhythmic Snake



I. This peculiar "Rhythmic Snake" 3x3, in each position (square) has a musical value. Players play in groups and by flipping a coin they advance to the next state, so there are only two 50% chances each for each roll.

The teams take turns playing and each records the musical value to which the result of the throw led them (in the square it went). The steps are:

Crown = 1 step
Letters = 2 steps

II. Thus, after <u>all th</u>e groups finish, random rhythmic compositions are created. Each group prepares theirs with claps and presents it to the rest.

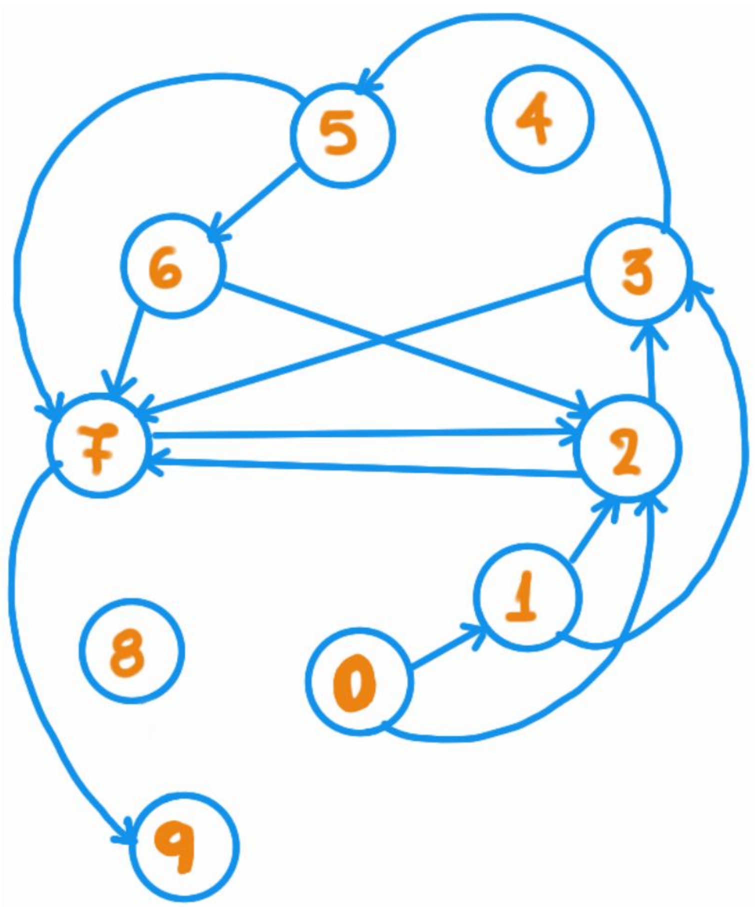
III. Then we observe the table of transition probabilities (transition matrix) and the graphical representation of the chain for discussion.

IV. The evaluation is carried out simultaneously and throughout the game, by observing the movements on the snake and by the answers to be given to questions about the probability table.

Table of transition probabilities for each position.

	0	1	2	3	5	6	7	9
0	0	0.5	0.5	0	0	0	0	0
1	0	0	0.5	0.5	0	0	0	0
2	0	0	0	0.5	0	0	0.5	0
3	0	0	0	0	0.5	0	0.5	0
5	0	0	0	0	0	0.5	0.5	0
6	0	0	0.5	0	0	0	0.5	0
7	0	0	0.5	0	0	0	0	0.5
9	0	0	0	0	0	0	0	1

Graphical representation of the chain.



<u>- Comments –</u>

The states 0,4,8,9 have
the following characteristics:

0: Only arrows leave so has probability 0. **4** and 8: are not states so have no arrows from or to.

9: Absorption state. The arrows only go and it is the end point.