
COMP1694 – Artificial Intelligence

Dr Damon Daylamani-Zad
d.d.zad@gre.ac.uk

COMPUTER MUSIC



What is algorithmic composition?

The generation of musical structures using an algorithm

- An algorithm here is a *'process or a set of rules'*

When is it composition and when is it algorithmic composition?

- Maybe when one is able to formalise the compositional process

Computer-based Music Composition

Research motivations

Music analysis

- The formalisation of music

Machine Learning research

- Emulation of human capabilities by machines

Investigation of the human creative process

- What insight does an algorithmic composition system provide?

Human computer interaction

- Where does the human end and the computer begin?

Applications

Computer Games

- Generation of non-repeating music
- Generation of context sensitive music

Art work

- Interactive installation sound art

Composition of unique pieces

- The composition method can define the piece
- Extra possibilities provided by automation of composition

Rapid production of music of a given style

- For TV, film etc



Computer Assisted Composition

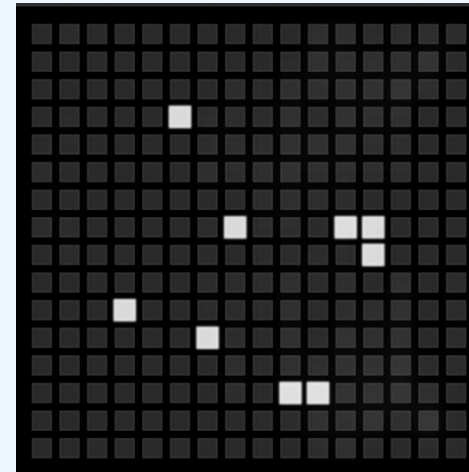
Wave-map music

Based on the water effect

Simulating the behaviour of water when it is disturbed

Unpredictable, Trial and Error, Human Creativity

ToneMatrix



Computer Music Composition Techniques

Stochastic

Rule based/ flow control

Grammar

Chaotic

Machine Learning

Stochastic

Non-deterministic, open ended

- Same starting conditions can lead to different results

Use data derived from random or natural sources

The data is mapped to different parts of the musical structure e.g:

- Pitch
- Timbre
- Rhythm
- Example: M and Jam Factory (Zicarelli, D. 1987)

Markov chains

Markov chains define the next step to take based on the previous steps

The 'order' of the Markov chain is the number of previous steps that is considered

The chains are either generated randomly or based on real data

A Markov chain description of a melody can be built then used to generate similar melodies

Most famous software:

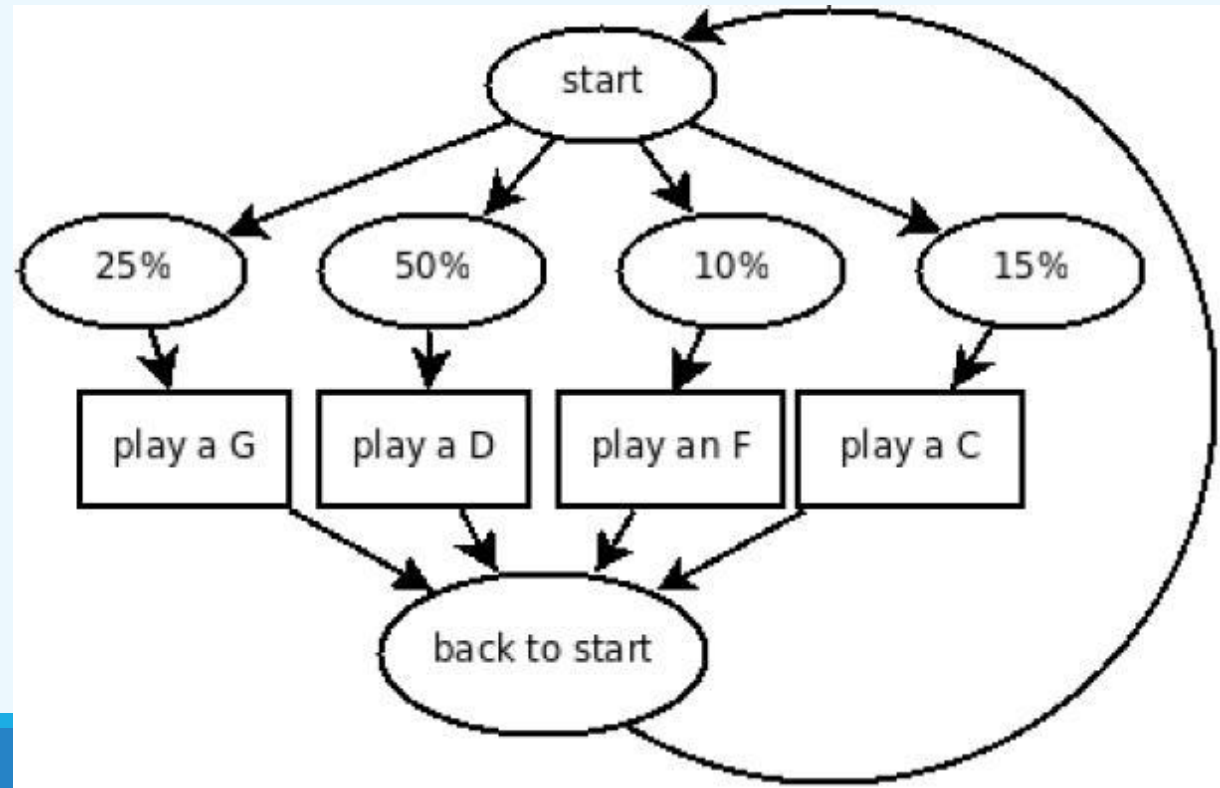
- Csound (<http://www.csounds.com/>)
- Max MSP (<http://cycling74.com/products/maxmspjitter/>)



Zero Order Markov Chain

Ignores last note

Percentages define probability of taking that path



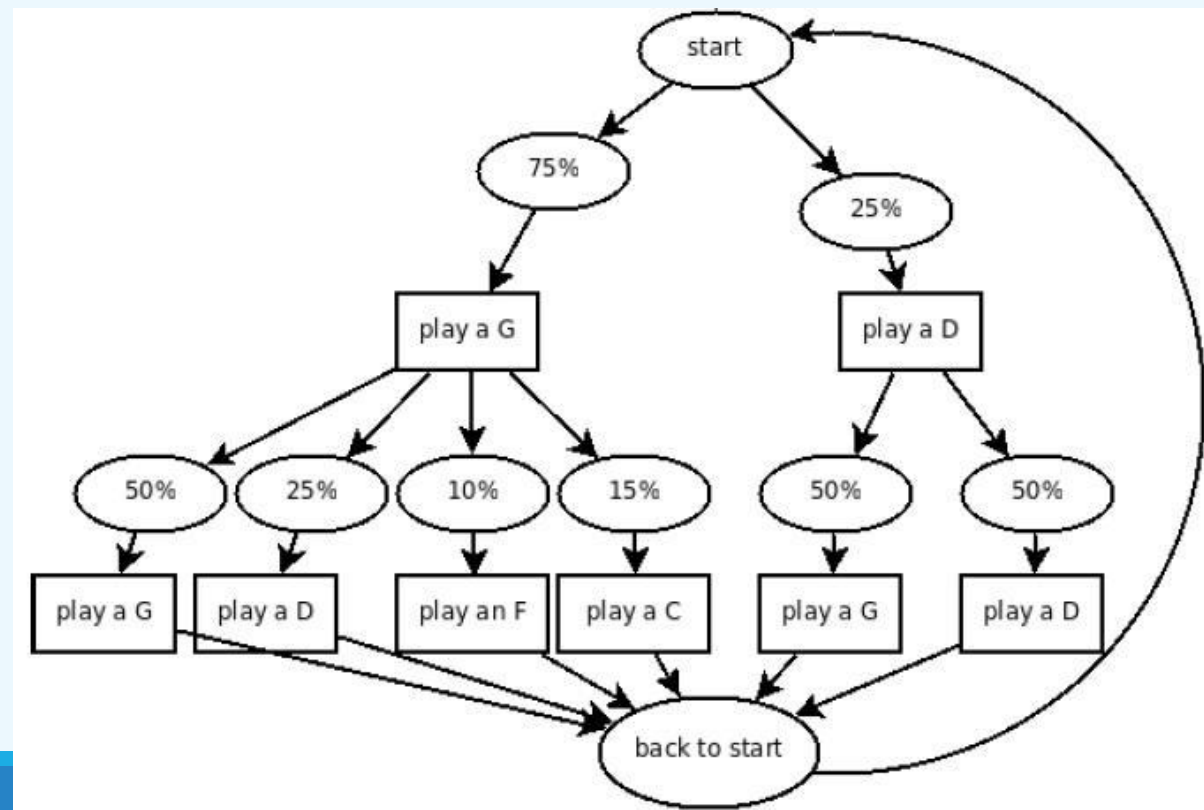
1st Order Markov Chain

Percentages define probability of taking that path

Percentages change depending on which note is played


GG	37.5	GF	7.5	DG	12.5
GD	18.25	GC	11.25	DD	12.5

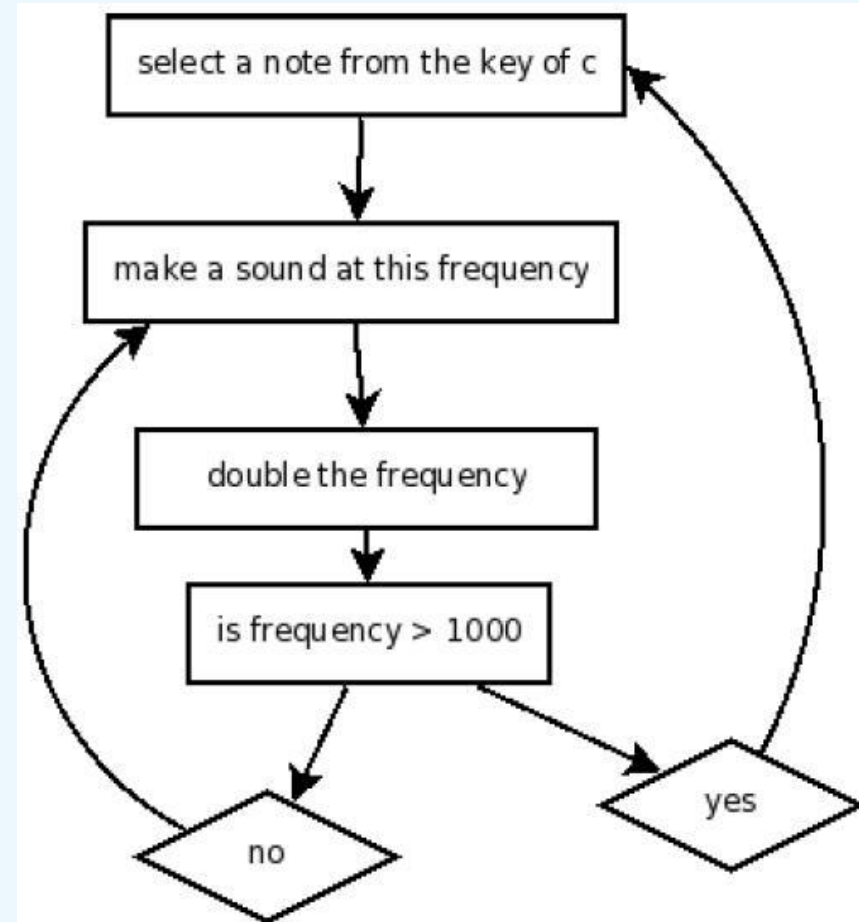
1st-order matrix				
Note	C	D	G	F
C	0	0	15	0
D	25	50	25	0
G	75	50	50	0
F	0	0	10	0



Rule based Composition

It is similar to any computer program

- EMI ([Cope](#), D. 1987, 1992)
- Cypher (Rowe, 1993) 



Grammar

Derived from Linguistics

English Language:

- Rule1: definite article, subject, verb, adjective.
- Rule2: subject, verb, indefinite article, adjective, noun.

Music:

- C major scale

Notes: C(first note), D, E, F, G(fifth note), A, B, C

Chords: G major, C major

- F minor scale

Notes: F(first note), G, Ab, Bb, C(fifth note), Db, Eb, F

Chords: C major, F minor

Grammars

A grammar is a set of rules governing the 'correct' use of a language

The grammar can be derived from a statistical analysis of a body of work by a composer

A grammar is not really generative . It is a way to test the validity of musical forms

A grammar can be used in combination with a generative process

MIDI

Musical Instruments Digital Interface standard,

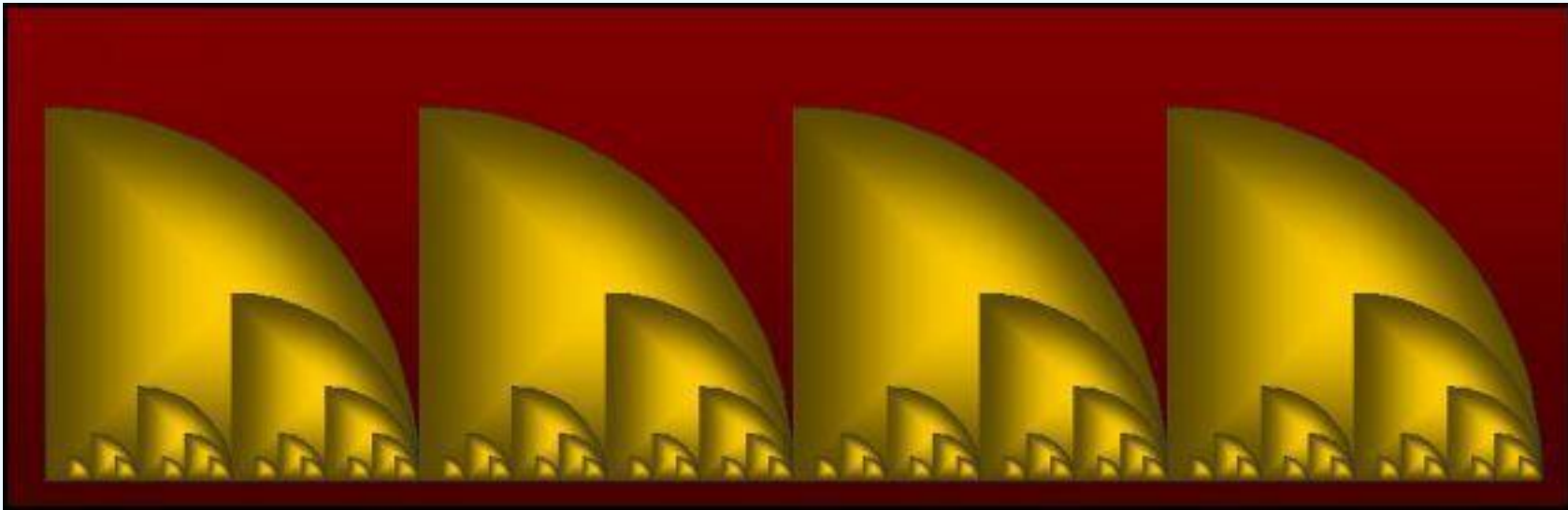
- Established in 1983

Format

- *Onset*
- *Duration*
- *MIDI Channel*
- *MIDI Pitch*
- *Velocity*

Fractals

A rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole.



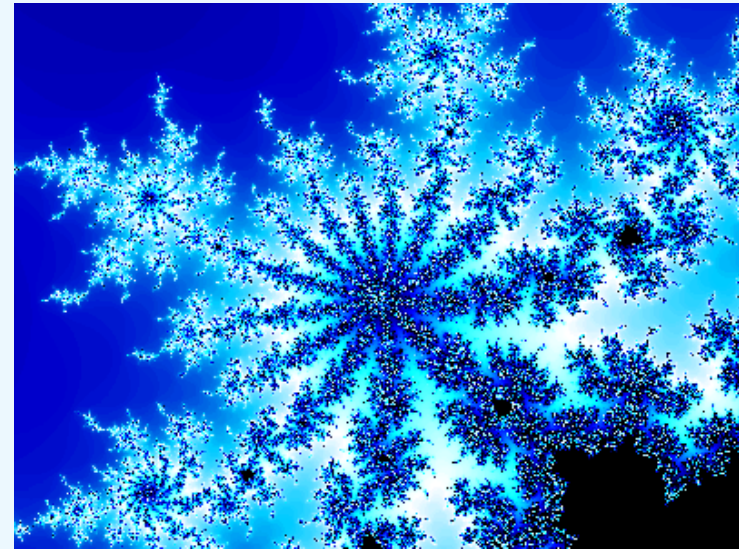
Chaotic

Many systems have been made that generate MIDI sequences using fractal maths

The self-similar nature of fractals can be tied in to the idea of different structural levels in a musical piece

Concept of mapping:

- Colour -> Timbre (Velocity)
- X -> Time (Onset)
- Y -> pitch



Machine Learning

Various artificial intelligence techniques have been applied to algorithmic composition, e.g.

- Cellular Automata
- Genetic Algorithms
- Deep Learning

Cellular Automata

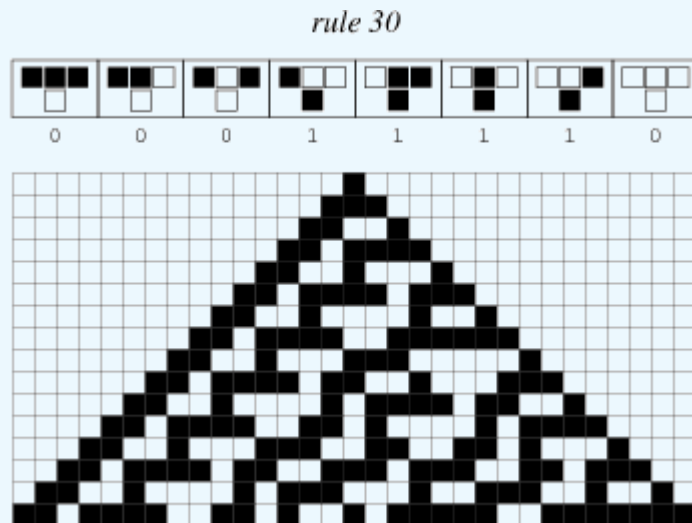
Several finite state cells which change state according to a simple set of rules

Complex phenomena can arise at the many cell/ macro level

If musical parameters are assigned to cell state, music can be generated with a complex structure

Elementary CA - CAMUS

Elementary CA



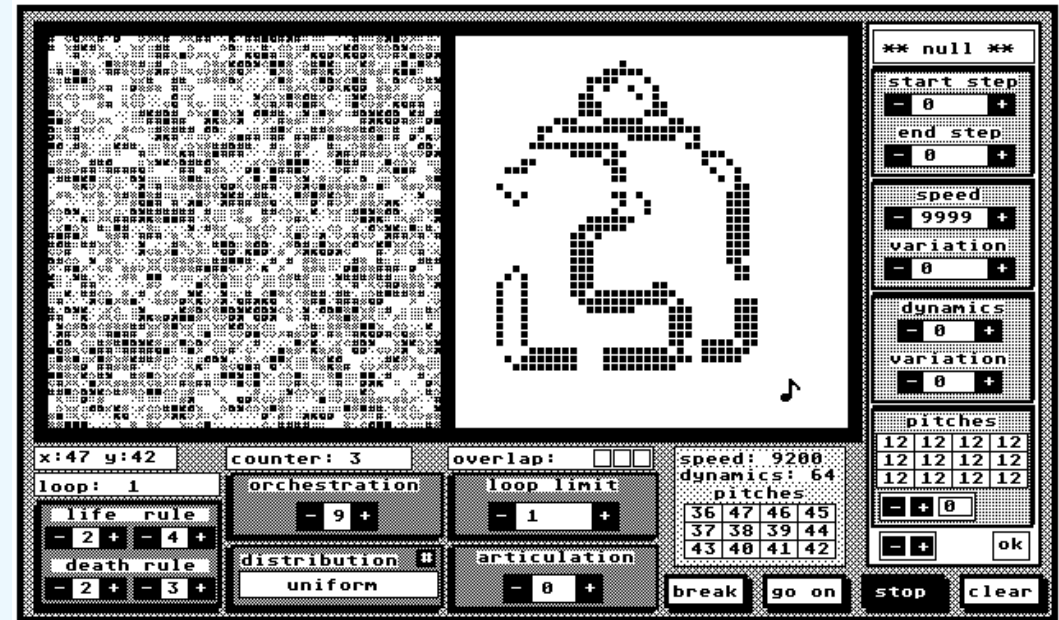
Aqua Twins



Far Horizon

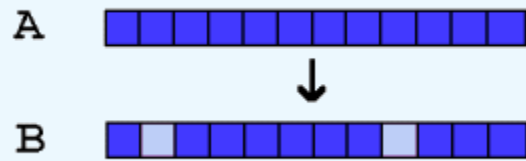


CAMUS (Miranda 2001)

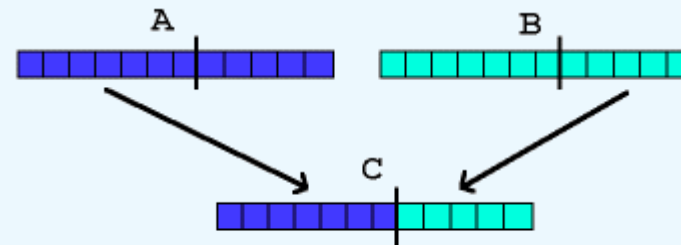


Genetic Algorithm

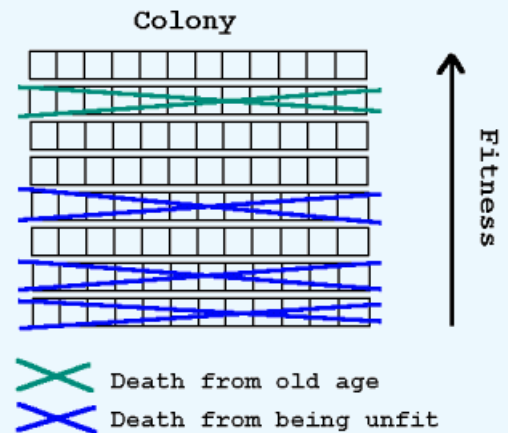
Mutation



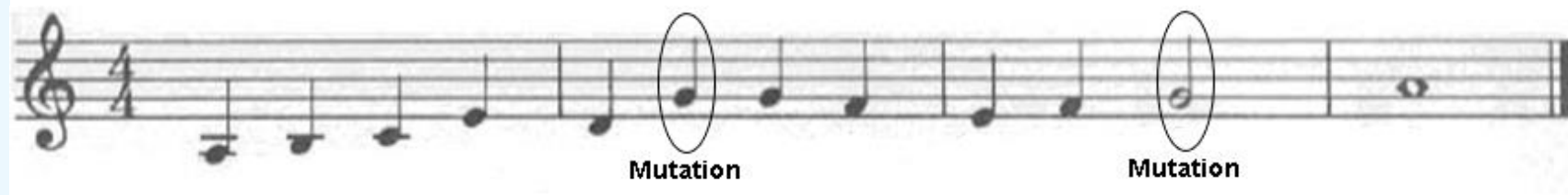
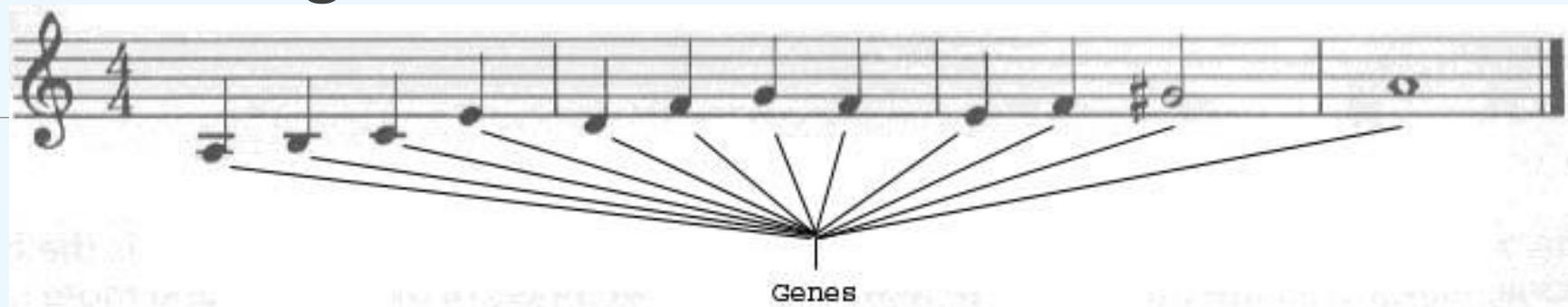
Cross-over



- Fitness Function



Genetic Algorithm



Genetic Algorithms

Musical elements such as melodies can be 'bred' using GAs

Interactive GAs present the composer with a selection of musical forms which (s)he must rate. Highly rated forms are allowed to breed and the process is iterated

Non-interactive GAs automatically rate musical forms. Part of this rating could involve a grammar check

Biles (1994, 2001, 2002a, 2002b), Horowitz (1994), Ayesh and Hugill (2005), Tuohy and Potter (2005), Daylamani-Zad et al (2006)



GA and NN in Graphics and Games



Recurrent Neural Networks (Deep Learning)

Bob's Idea

(Franklin 2006)



Project Magenta from Google Brain Team

- <https://magenta.tensorflow.org/>

Artificial Neural Networks

ANN, or just Neural Networks (NN) for short.

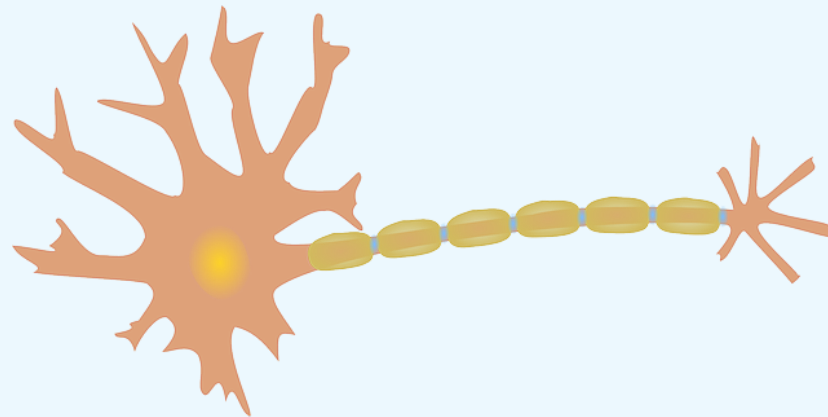
Neural networks consist of a large number of relatively simple nodes, each running the same algorithm.

These nodes are the artificial neurons, originally intended to simulate the operation of a single brain cell.

Each neuron communicates with a subset of the other artificial neurons in the network.

They are connected in patterns characteristic of the neural network type.

The pattern is called the neural network's architecture or topology.



Perceptron Algorithm

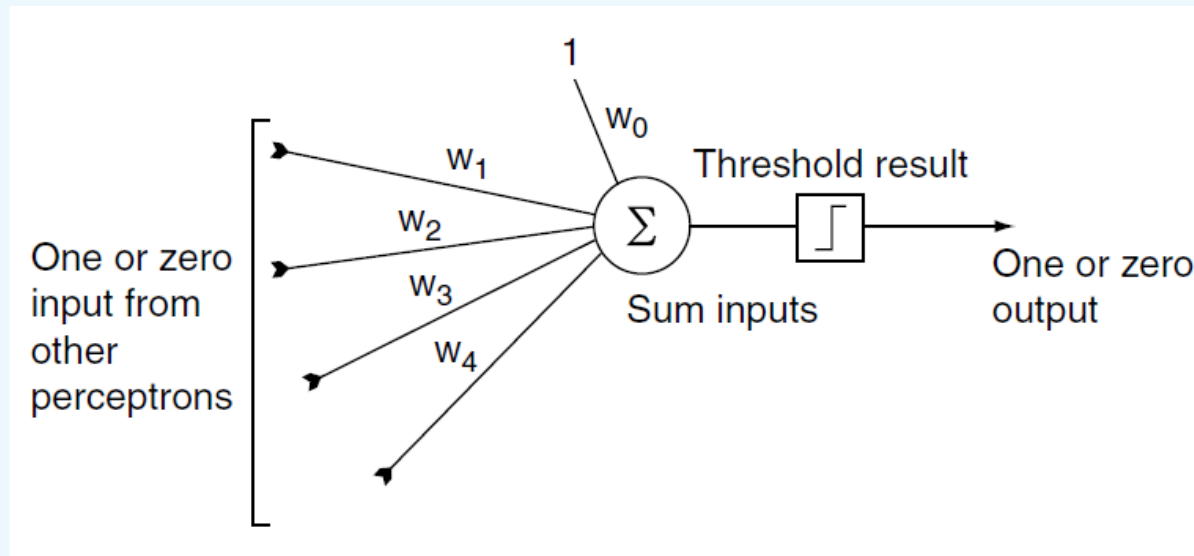
A specific type of artificial neuron.

Each input has an associated weight.

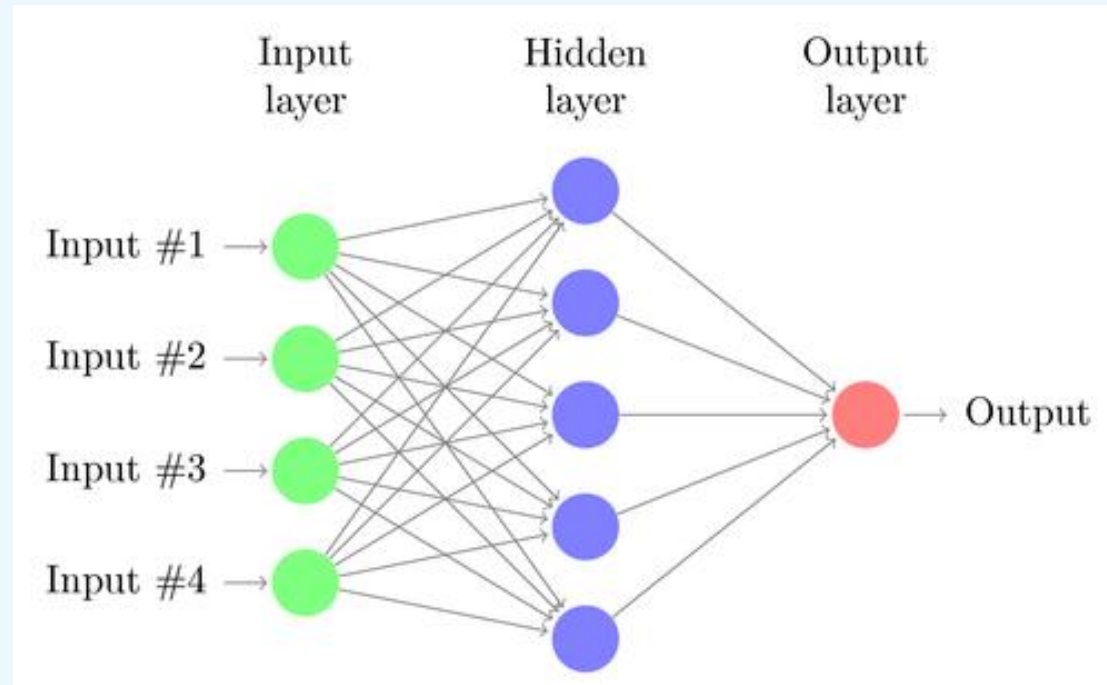
The input values (Assume 0s and 1s) are multiplied by the corresponding weight.

The final sum is then passed through a threshold function.

- If the sum is less than zero, then the neuron will be off (have a value of zero);
- otherwise, it will be on (have a value of one).



Neural Networks



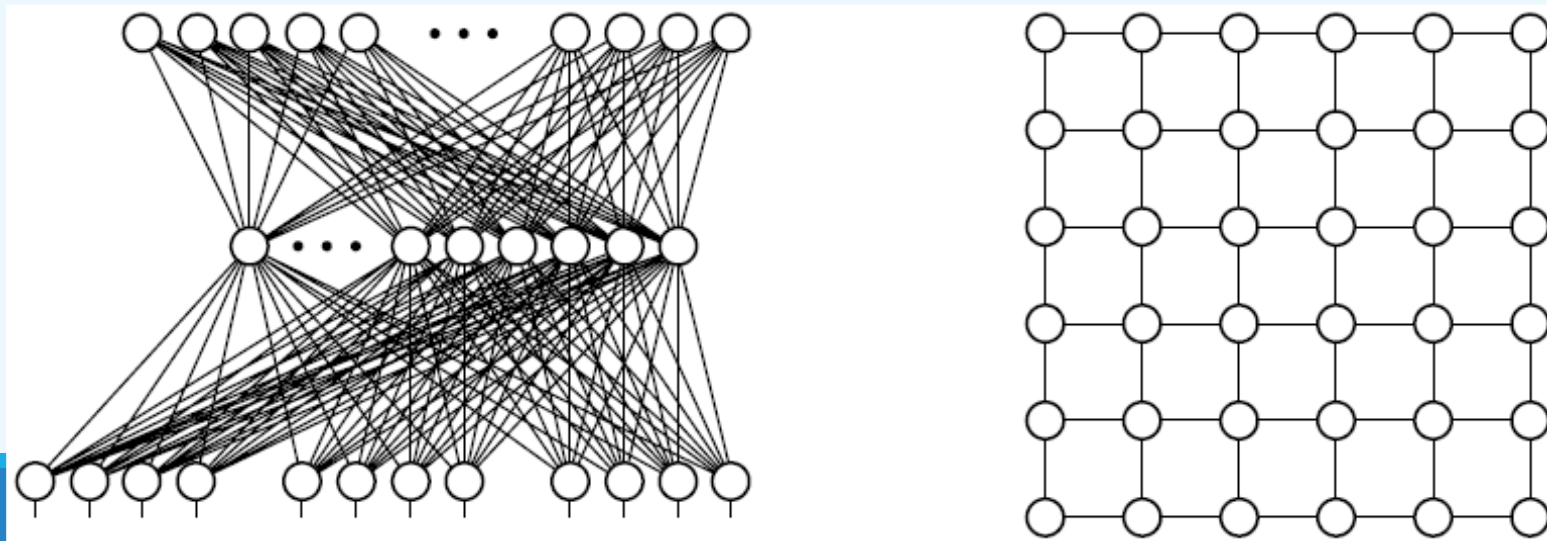
Neural Networks - Feedforward and Recurrence

The leftmost layer (called the input layer) is provided input by the programmer, and the output from the rightmost layer (called the output layer) is the output finally used.

The multi-layer perceptron takes inputs from all the nodes in the preceding layer and sends its single output value to all the nodes in the next layer. (**Feedforward Network**)

Feedforward networks can have loops: connections that lead from a later layer back to earlier layers (**Recurrent network**). Recurrent networks can have very complex and unstable behaviour and are typically much more difficult to control.

Other neural networks have no specific input and output. Each connection is both input and output at the same time.



References

Cope, D. 1982, Computer Models of Musical Creativity, Cambridge, Ma, USA: MIT Press

Franklin, J.A. 2006, “Recurrent Neural Networks for Music Computation”, INFORMS Journal on Computing, vol 18, no. 3, pp. 321–338

Rowe, R. 1993, Interactive Music Systems,

Zicarelli, D. 1987, M and Jam Factory , Computer Music Journal, Vol. 11, No. 4, pp. 13-29