



POLITECNICO
DI MILANO

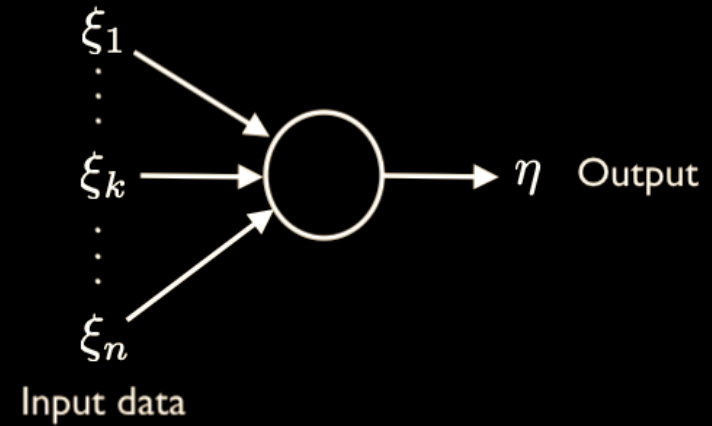
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BL  B.

COMPUTER MUSIC – REPRESENTATIONS
AND MODELS 2021/2022

INTRODUCTION

- Idea driving the project: **Sonification of a Kohonen Network** (KN), also known as Self-Organizing Map (SOM).
- **Browser compatibility**: optimised for Mozilla Firefox.



The **unsupervised learning** behavior of a KN artificial neuron has efficiency-coefficients time independent.

In KNs, forgetting rate is proportional to the weight vectors and also to a function of the **output signal (feedback)**.

KOHONEN NETWORK (KN)

- KNs are a tool for **visualize** and **convert** high-dimensional data into simple geometric relationships on a low-dimensional display [1, 2].
- A KN enables to **simulate the learning process** that allows the brain to handle sensory perception (certain cortex areas have similar properties as KNs. Examples are the processing of sound and light stimuli) [3].
- **Notice:** KNs are not a physical analogy of an expected neuronal configuration. They simply simulate the learning processing functions of certain areas of the brain cortex.

1) The learning process proceeds along **discrete time moments**: $t = 1, 2, \dots$

2) The learning process is fed with **input data** (observation vectors): $x(t)$

3) **Model vectors (nodes)** regression is made by the following process:

$$m_i(t+1) = m_i(t) + h_{c(x),i}(x(t) - m_i(t))$$

where **index “c” (winner)** is defined by the condition:

$$\|x(t) - m_c(t)\| \leq \|x(t) - m_i(t)\| \quad \forall i$$

and the **neighborhood function** (NF):

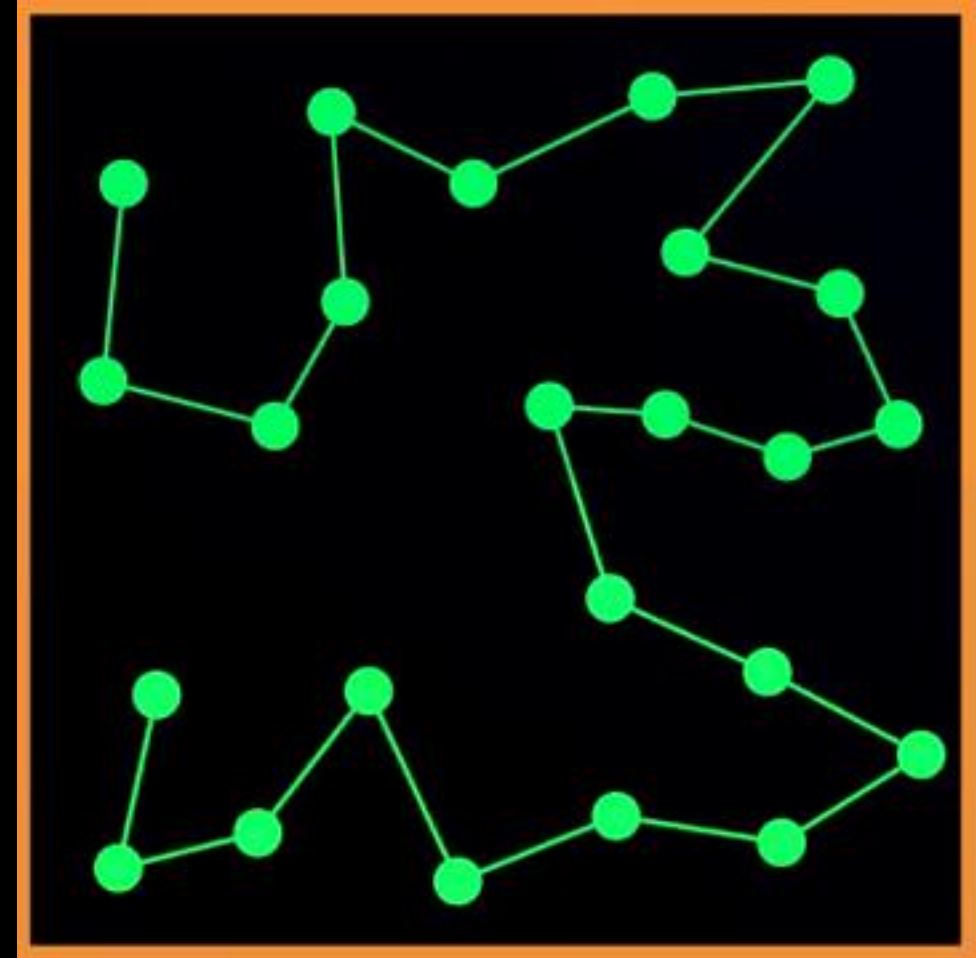
$$h_{c(x),i} = \alpha(t) \left(e^{-\frac{\|r_i - r_c\|^2}{2\sigma(t)^2}} \right)$$

$\left\{ \begin{array}{l} \alpha(t) \text{ Learning-rate factor.} \\ \sigma(t) \text{ Width of the NF.} \end{array} \right.$

They both **decrease monotonically** with the regression steps.

KOHONEN NETWORK (KN)

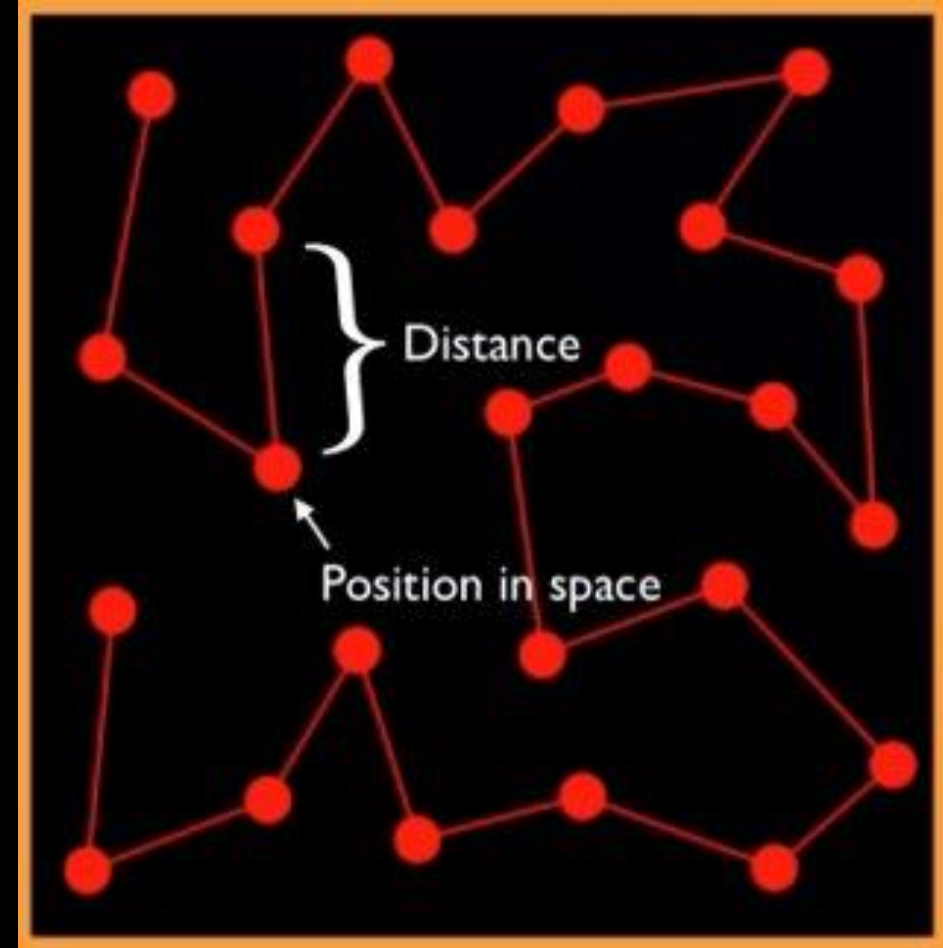
- **Weight vectors** (nodes) during the ordering process of a uniform distributed square into a curve.



Link to the video: [Self-Ordering Kohonen Network](#)

THE SONIFICATION PROCESS

- **KN Sonification** achieved extrapolating:
 1. Nodes' relative distance (Note duration)
 2. Nodes' position in space.
- By joining these features, different "pads" were developed:
 1. The **Rhythmic Pad**
 2. The **Melodic Pad**
 3. The **Harmonic Pad**

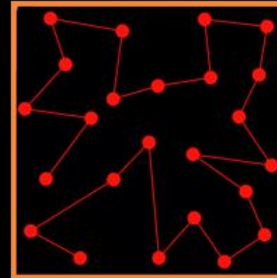


THE RHYTHMIC PAD

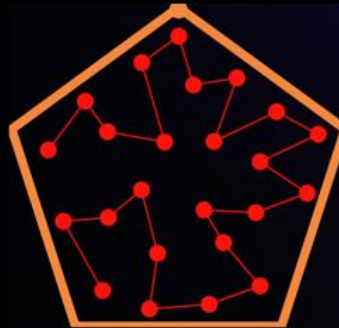
- The **Rhythmic Pad** performs solely percussive sounds:
 1. Single node associated to a single sound.
 2. Time position in the measure provided by relative nodes' distances.
 3. Metric of the measure associated to a geometric figure (see figure).
 4. Node sound is an external sample.



Triangle → 3/4 Metric



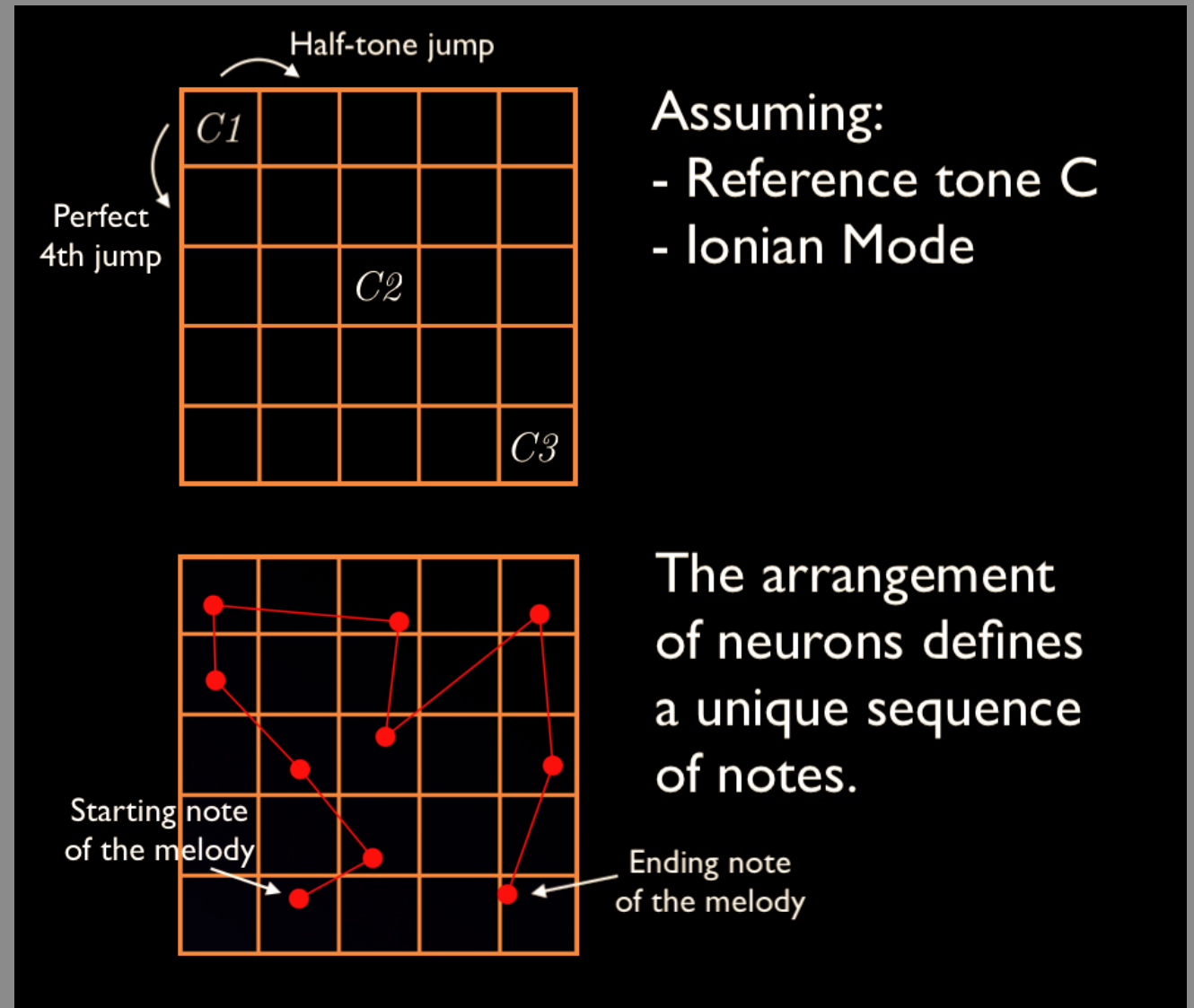
Square → 4/4 Metric



Pentagon → 5/4 Metric

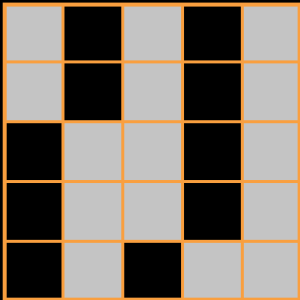
THE MELODIC PAD

- The **Melodic Pad** creates a melodic line:
 1. Single node associated to a single note.
 2. Note duration and time position in the measure provided by relative nodes's distances.
 3. Scale note set by the position of the node in space (see figure).
 4. Scale Tone and Scale Mode set by the user (different and uneven nodes configurations)
- **Notice:** each Scale Mode is characterized by a unique configuration in the grid.

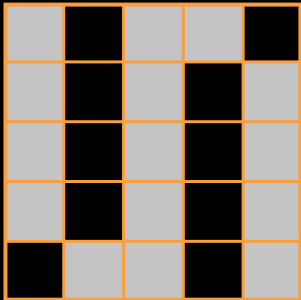


THE MELODIC PAD: PATTERNS

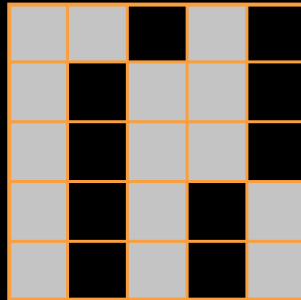
Ionian



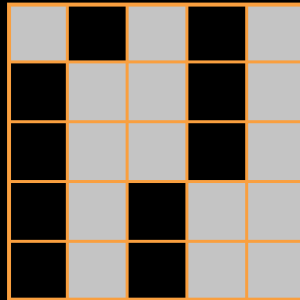
Dorian



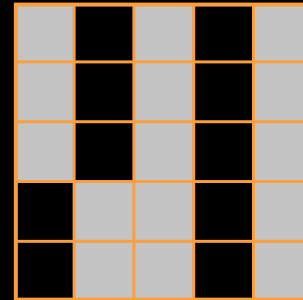
Phrygian



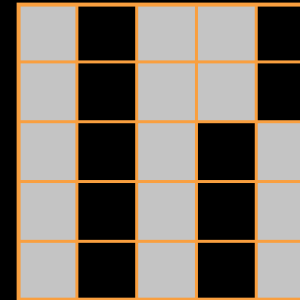
Lydian



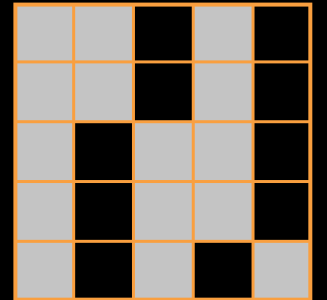
Mixolydian



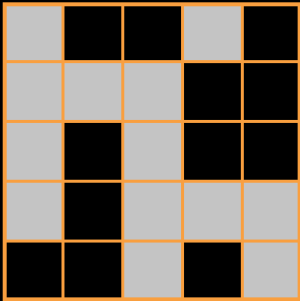
Aeolian



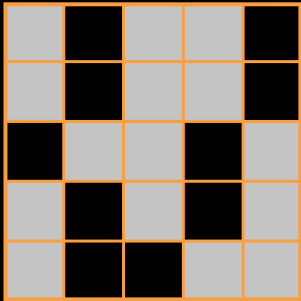
Locrian



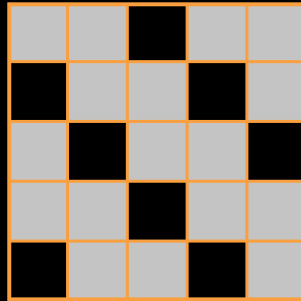
Blues



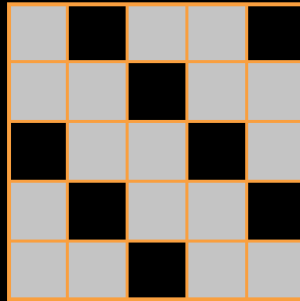
Harmonic Minor



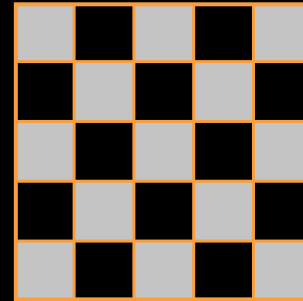
Half-Diminished



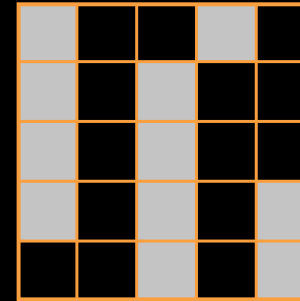
Diminished



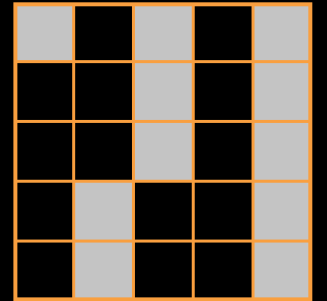
Whole Tone



Minor Pentatonic



Major Pentatonic

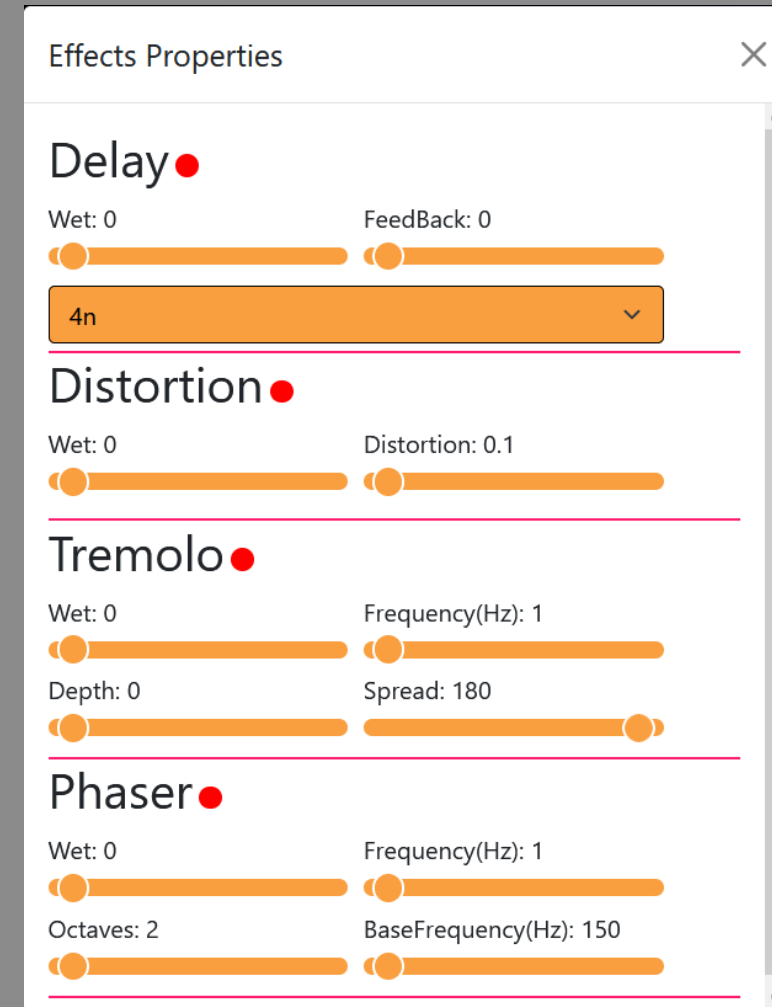


■ = Boxes corresponding to the notes of the scale

THE MELODIC PAD: SOUND AND EFFECTS

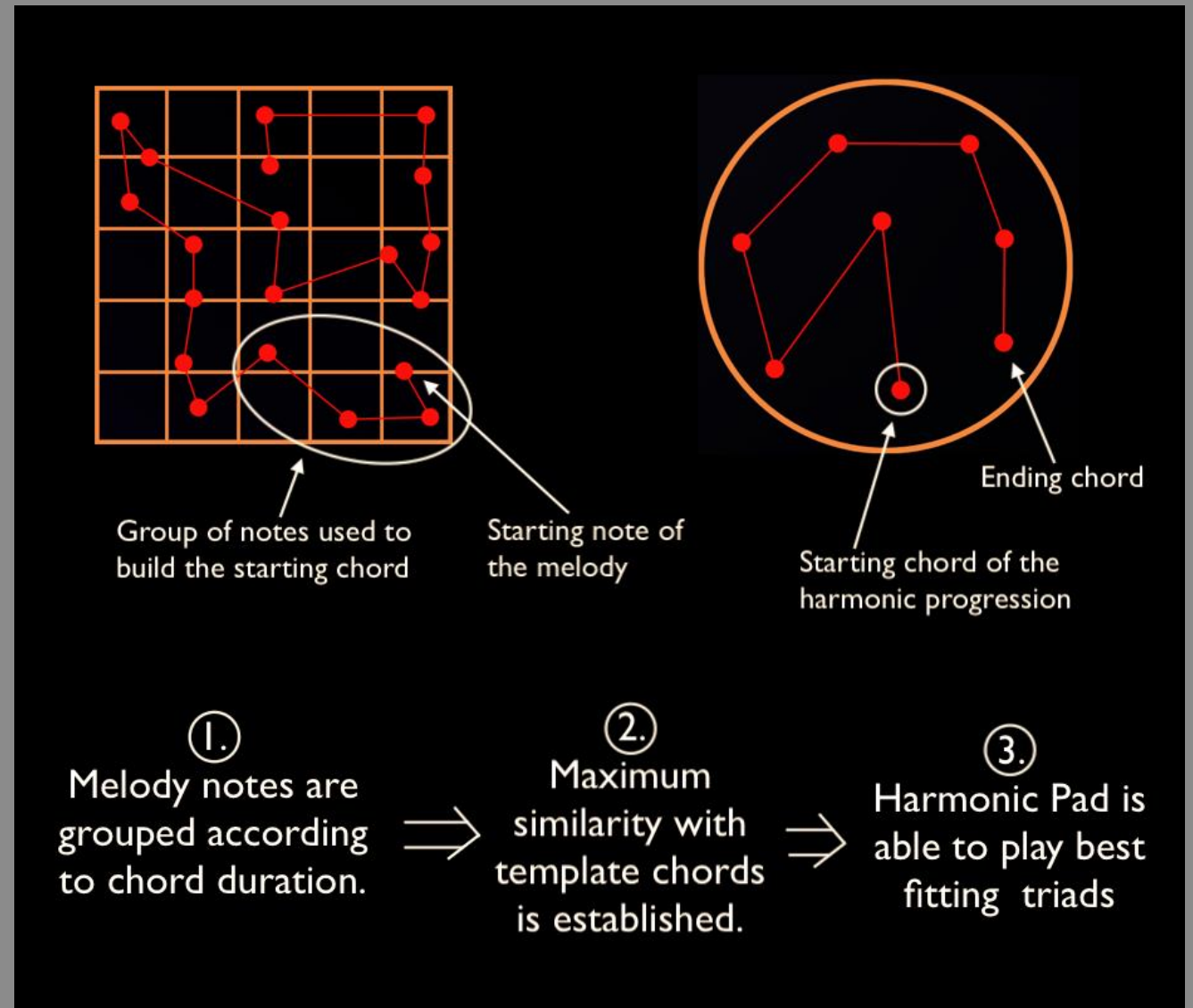
- User can change:
 1. Metric (No geometric figure associated).
 2. PolySynth Sound (Sine wave, Square Wave, etc.).
 3. Envelope properties.

- User can add the following Tone.js effects to the melody:
 1. Delay
 2. Distortion
 3. Tremolo
 4. Phaser



THE HARMONIC PAD

- The **Harmonic Pad** creates an harmonic support to the melody generated by the Melodic Pad:
 1. Single node associated to a single chord.
 2. Chord duration and time position in the measure provided by relative nodes's distances.
 3. Scale Tone and Scale Mode are the same of the Melodic Pad (set by the user).
- **Notice:** Melodic Pad loop duration = Harmonic Pad loop duration.



THE HARMONIC PAD: CHORD RECOGNITION

- The **Harmonic Pad** creates an harmonic support to the melody generated by the Malodic Pad:

1. Notes are grouped according to the chord duration.
2. An "equal tempered" binary representation is built.
3. The binary representation is matched with a template chord.
4. The best fitting chord is coupled with the melody.

- **Notice:** All chords are played with the form root-3rd-5th

1) Notes are grouped according to the chord duration.



2) An "equal-tempered" binary representation is built:
[1, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0]



3) The binary representation is matched with a template chord.



4) The best fitting chord is coupled with the melody.

[1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0] (C maj.)

[0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0] (D min.)

⋮

(C major is chosen for simplicity)

I'M HERE TO HELP YOU :)

- **Bloppity Blop** is clickable:
It will help you to use correctly the program.

... Thank you for your attention.

Hi! My name is Bloppity Blob :)
Click on me for instructions!



REFERENCES

- [1] Kohonen, T. Self-organized formation of topologically correct feature maps. *Biol. Cybern.* **43**, 59–69 (1982). <https://doi.org/10.1007/BF00337288>
- [2] Kohonen T. (2013). Essentials of the self-organizing map. *Neural networks : the official journal of the International Neural Network Society*, 37, 52–65. <https://doi.org/10.1016/j.neunet.2012.09.018>
- [3] Vrieze O.J. (1995) Kohonen network. In: Braspenning P.J., Thuijsman F., Weijters A.J.M.M. (eds) *Artificial Neural Networks. Lecture Notes in Computer Science*, vol 931. Springer, Berlin, Heidelberg. <https://doi.org/10.1007/BFb0027024>