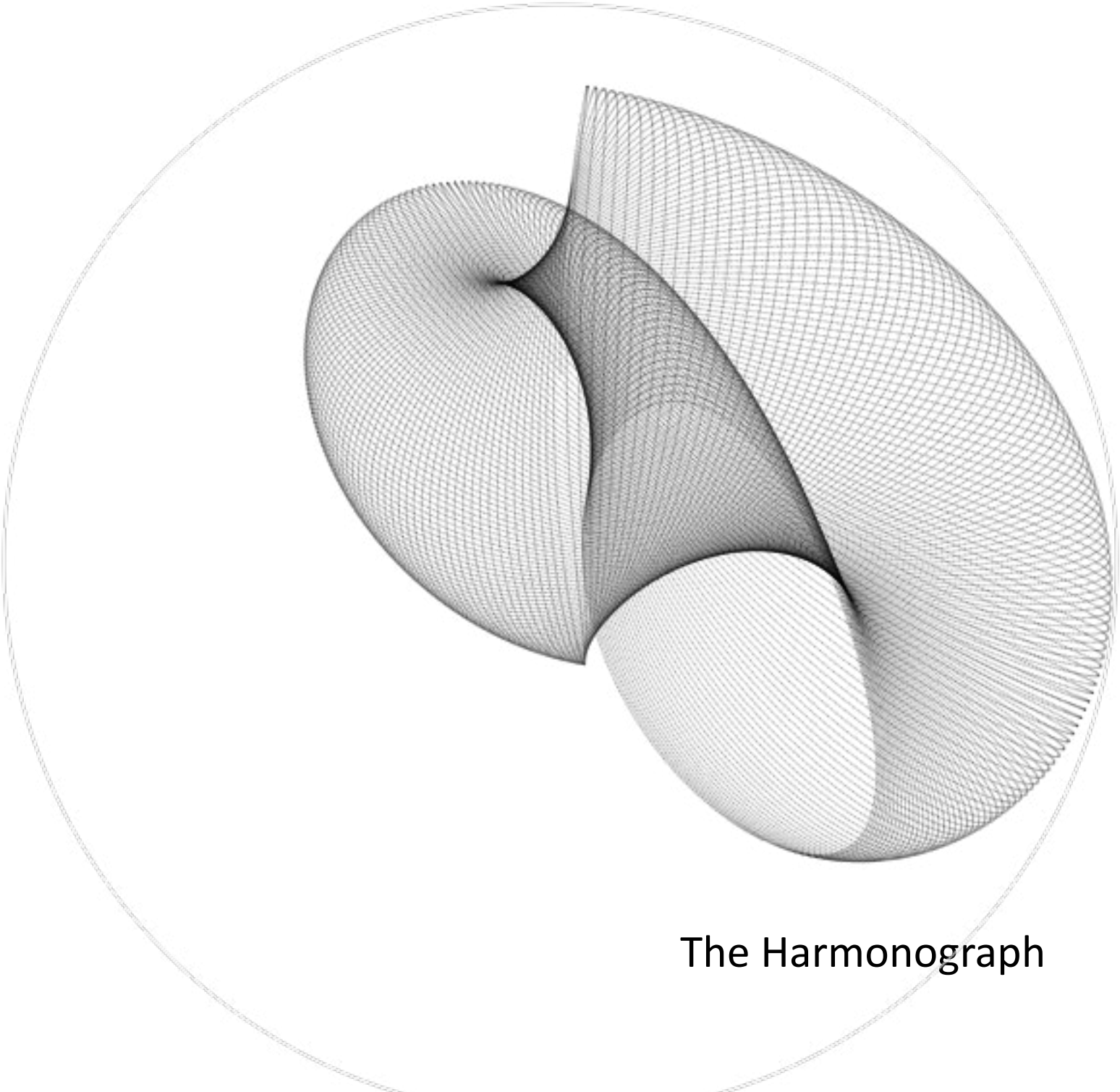


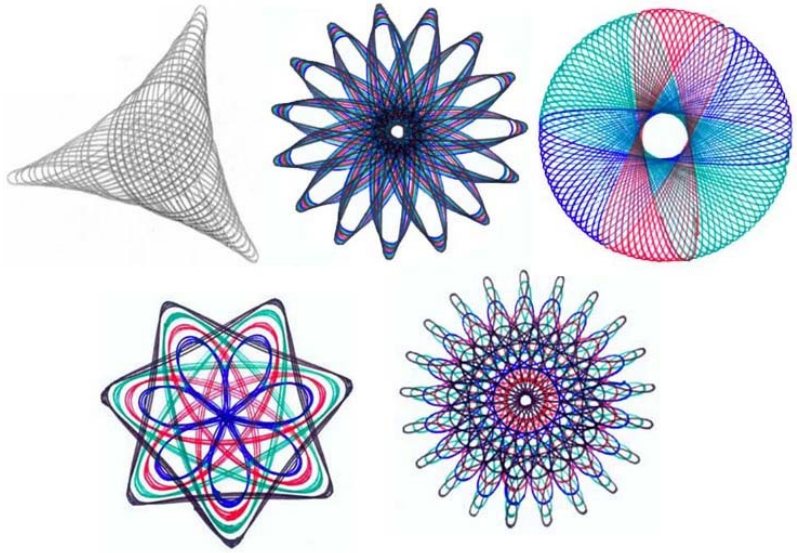
The Harmonograph

The Harmonograph

An harmonograph in a mechanical engine that use the the **swinging motion** of pendulums to **draws beautiful geometric forms** such as spirals, ellipses, hypotrochoids, epitrochoids, Lissajous figures ans self-similar complex figures (called the harmonograms)

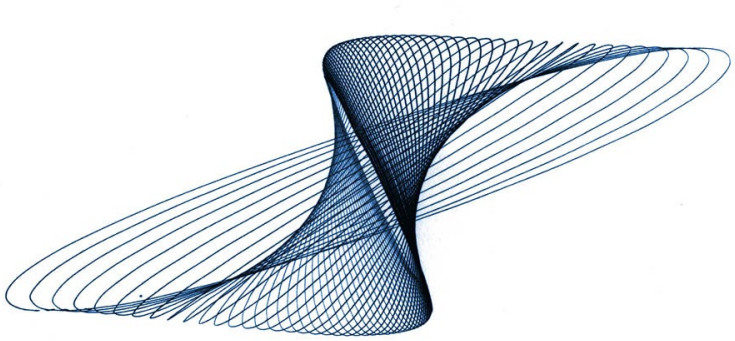
The first harmonographs date back to the **19th century**. These devices can work with two or three pendulums, and depending on the mechanism they can generate very complex figures. In the '60, British engineer Denys Fisher designed the **Spirograph**, a toy that worked as a simplified version of an harmonograph, using gears instead of pendulums. This toy became very popular.

The goal of my term project is to design a **digital version of an harmonograph** in Python.

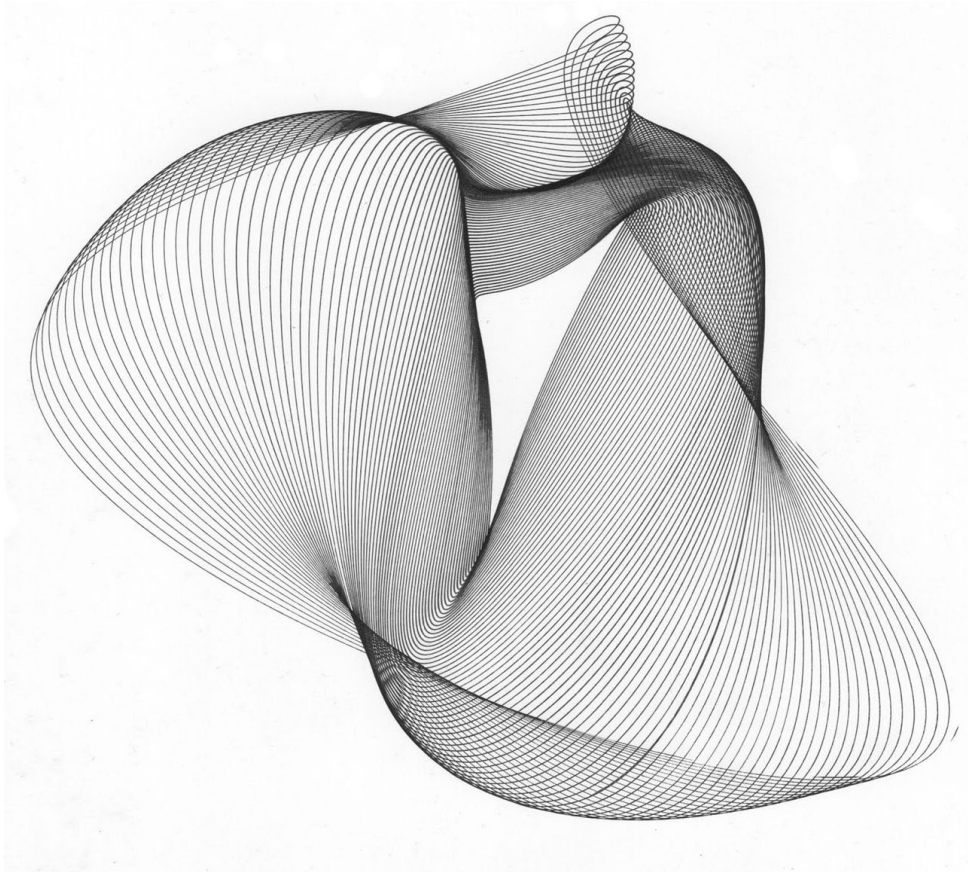


Drawings created with the Spirograph. Source: wikipedia.org

Source: http://www.karlsims.com/



Source: https://anitachowdry.wordpress.com/



$$x(t) = A_1 \sin(tf_1 + p_1)e^{-d_1 t} + A_2 \sin(tf_2 + p_2)e^{-d_2 t}$$
$$y(t) = A_3 \sin(tf_3 + p_3)e^{-d_3 t} + A_4 \sin(tf_4 + p_4)e^{-d_4 t}$$

Source: Wikipedia

The result of the project should be an **educational game** in two modalities:

A) The user **sets the mechanism** with different levels of customization freedom, including:
- the position of the gears
- the anchor points and lenght of the drawing arms
- the rotation speed of each gear
- the drawing speed

The program draws the harmonogram constrained to these settings.
The user can then interact with the result in a variety of different ways, zooming in/out, exporting a vector-graphic version and choosing a coloring pattern for the figure.
The info-mode of the game should display information about the harmonic equations and the trigonometry rules behind the drawing process. The math of harmonograph is not easy. My goal is to make it to use the program to make these rules simpler to understand for kids (and beautifully demonstrated).

B) The user is given a figure, and the challenge is to **retrieve the mechanical setting** that could generate that figure.
This can be a hard task, and can be imagines as a multilevel game starting with the basic harmonograms and increainging in difficulty to complex figures.

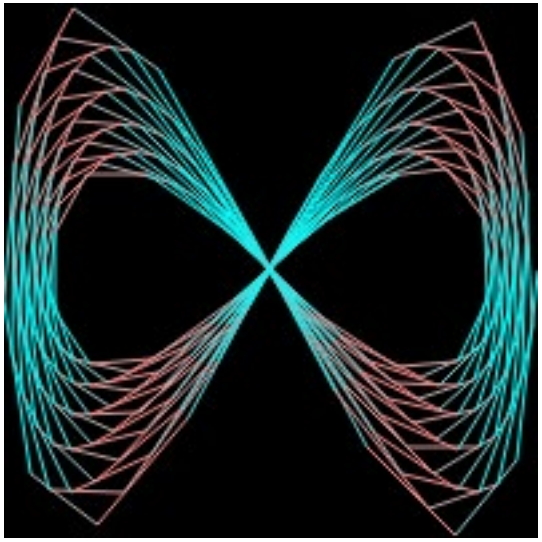
Technologies

I want to deisgn the harmonograph in **Tkinter.**
Doing sophisticated work with sohpisticated tools is great. Doing sophisticated work with basic tools is greater!

To make the GUI work more efficiently I will use:

Pillow
https://python-pillow.org/
“Python Imaging Library (abbreviated as PIL) is a free library for the Python programming language that adds support for opening, manipulating, and saving many different image file formats.” (from Wikipedia).
I will use pillow in Tkinter to speed-up the drawing

Cairo
https://cairographics.org/pycairo/
If I will include vector image exporting as a project feature, then I will use Cairo for Python to export the results as vector-images.



An image output from worldtree.software.
Source: http://www.worldtreesoftware.com/apps/harmonograph

Competitive Analysis

There exist several type of analogic harmonographs and spiro-graphs. Recently, designer Joe Freedman kickstarted the Drawing Machine, a portable, high quality machine that comes with a wide range of different gears, allowing to produce a variety of beautiful harmonograms. I want to simulate Freedman's machine or similar machines, using gears instead of pendulums.
This is a link to Freedman's machine:
https://www.youtube.com/watch?v=ygcGfnVM6Ho
It found some examples of digital harmonographs. None of these provide the same level of direct user interaction that I would like to feature. I do not plan to build upon there existing codes (I want to code my own from scracth).

Worldtree.software offers an online virtual harmonograph:
http://www.worldtreesoftware.com/harmonograph.html
STRENGHTS:
- freedom in parameter choice: I want to include a good level of freedom in parameter customization
- everything is online: since we are talking about an educational game, it would be great to have it online
WEAKNESSES:
- static interface: I wish to make the interface dynamic and have the harmonogram drawn in real time, also displaying the mechanism
- the graphic output is not compelling and a bit unprecise: I want the graphic output to be simple butprecise and elegant, potentially with the possibility to customize line/blank space colors according to user preference or to a randomly assigned palette.

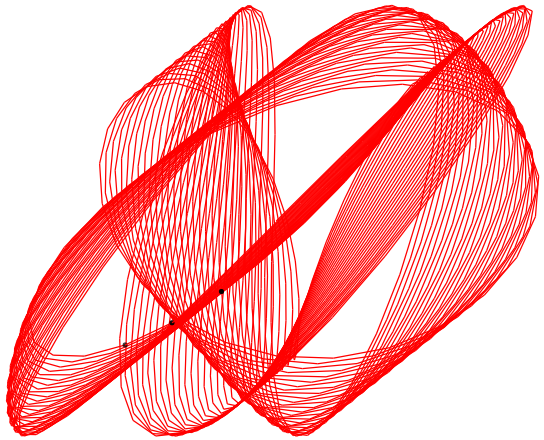
David Chudzicki also provides a virtual version of an harmonograph on his website:
http://www.davidchudzicki.com/harmonograph/
STRENGHTS:
- the real-time drawing is really nice, simple and effective. I want to include such a feature in my project too
- good level of parameter customization
WEAKNESSES:
- again, the motion of the gears/pendulums is not diplayed. I want to make it visible to the user for pedagogical purposes (the mechanism can be hidden by pressing “h” at anytime)

Harmonograph in JavaScript
http://thomas.home.fmf.nl/harmonograph/
A very nice digital harmonograph!
STRENGHTS:
- with a simple graphic interface, it clearly displays the mechanism of the pendulum. I want to do something similar, but replacing the pendulums with rotating gears (a simplification of the motion of a pendulum)
- you can speed up the drawing: this feature must be included in my project too
- you can easily export a jpg of the harmonogram.
WEAKNESSES:
- the user does not interact directly on the pendulum or canvas: the interface is the parameters. I want the interface to be more intuitive (drag and place gears,...)


David Chudzicki

- about
- posts

Harmonograph



Settings

Frequencies:
f_0 3.00 f_1 2.00 f_2 3.01

Phases:
f_0 0.00 f_1 0.00 f_2 0.00

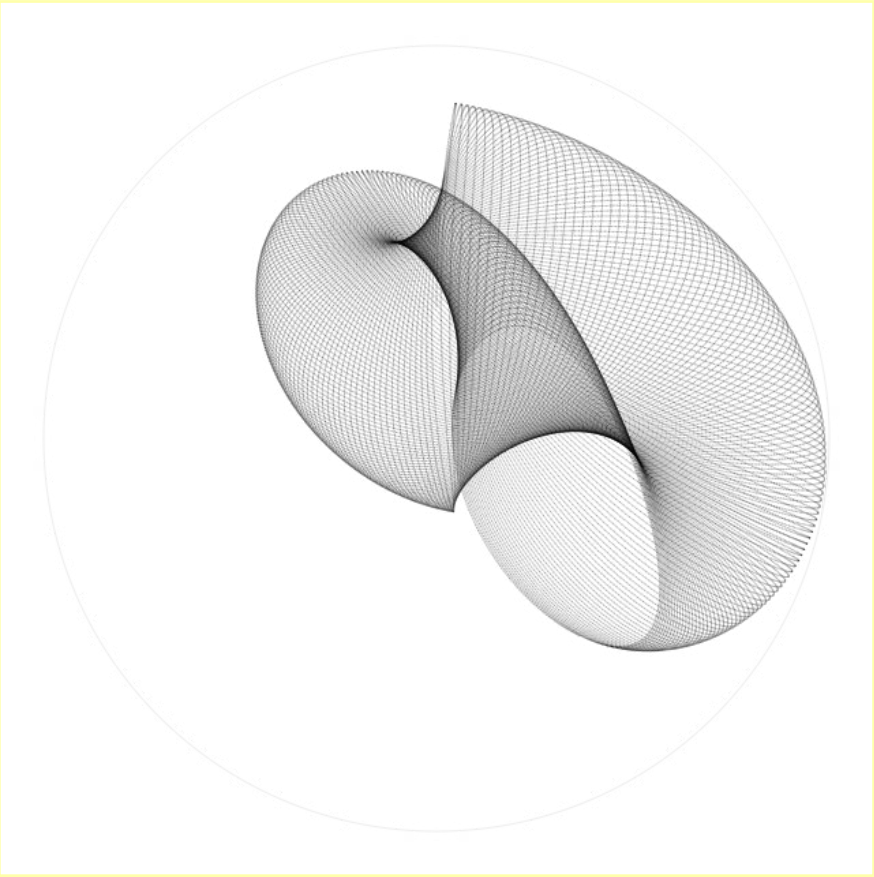
Amplitudes:
f_0 1.00 f_1 1.00 f_2 1.00

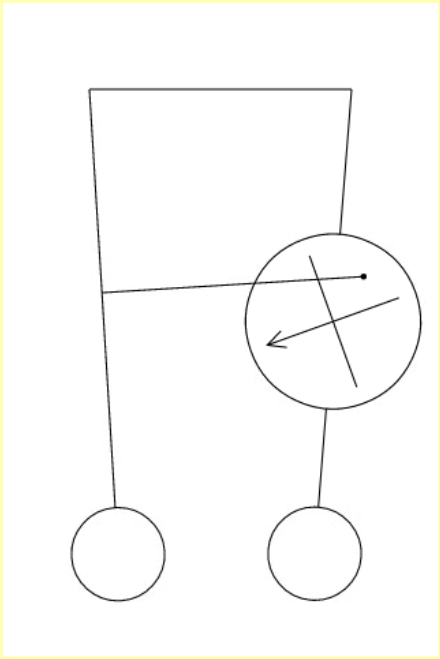
Fade out old points?

Source: David Chudzicki website

Harmonograph in JavaScript

Link to this creation





Distance between pendulums	d =	900	mm
Position of paper centre	c =	800	mm
Length of pen arm	p =	900	mm
Position of pen arm	q =	700	mm
Radius of paper	r =	300	mm
Amplitude of left pendulum	A =	10	°
Amplitude of right pendulum	B =	10	°
Phase of left pendulum	u =	0	(0…1)
Phase of right pendulum	v =	0	(0…1)
Damping of left pendulum	R =	0.001	(0…)
Damping of righth pendulum	S =	0.001	(0…)
Frequency of left pendulum	f =	0.3	Hz
Frequency of right pendulum	g =	0.302	Hz
Frequency of paper rotation	h =	0.0008	Hz

Time speedup factor: 8

Reset

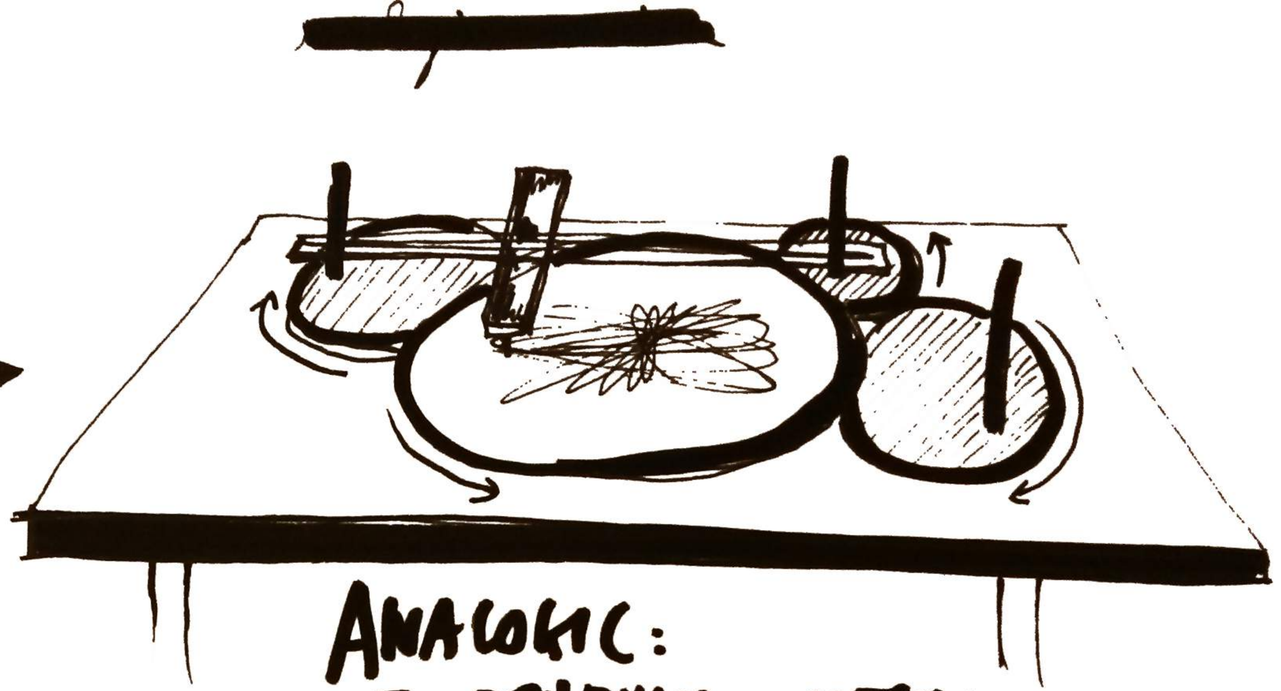
Start

Source: http://thomas.home.fmf.nl/harmonograph/

AN HARMONOGRAPH

IS A MACHINE MADE OF 2 OR MORE PENDULUMS, GEARS AND A DRAWING ARM.

IT PRODUCES NICE CYCLOID-LIKE DRAWINGS.



ANALOGIC:

3-PENDULUM MECHANISM

EDUCATIONAL APP/GAME

2-mode application:

I. Set the mechanism and draw

II. Look at the drawing & retrieve the mechanism

But can we design a Python version?
Let's do it!

GOAL: design a TKinter Harmonograph on Python to teach kids the beauty of pendulums, cycloids and trigonometry

DIGITAL:

PYTHON TKINTER

MODE (I) SET THE MECHANISM, SEE THE RESULT

1 SELECT THE GEARS

(# gears) 1 2 3

CHOOSE!

RADIUS)

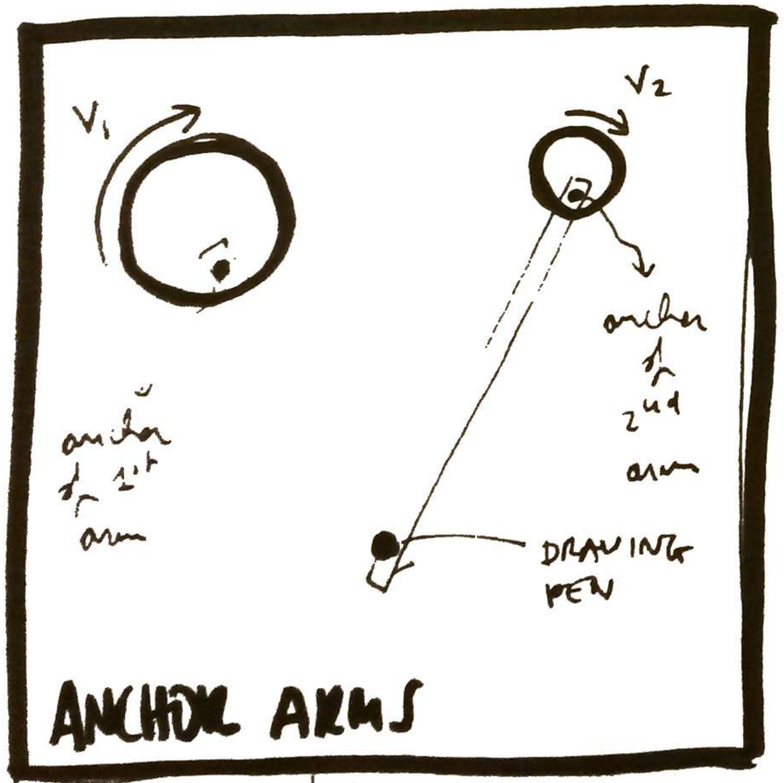
2 PLACE THE GEARS ON THE CANVAS

PLACE

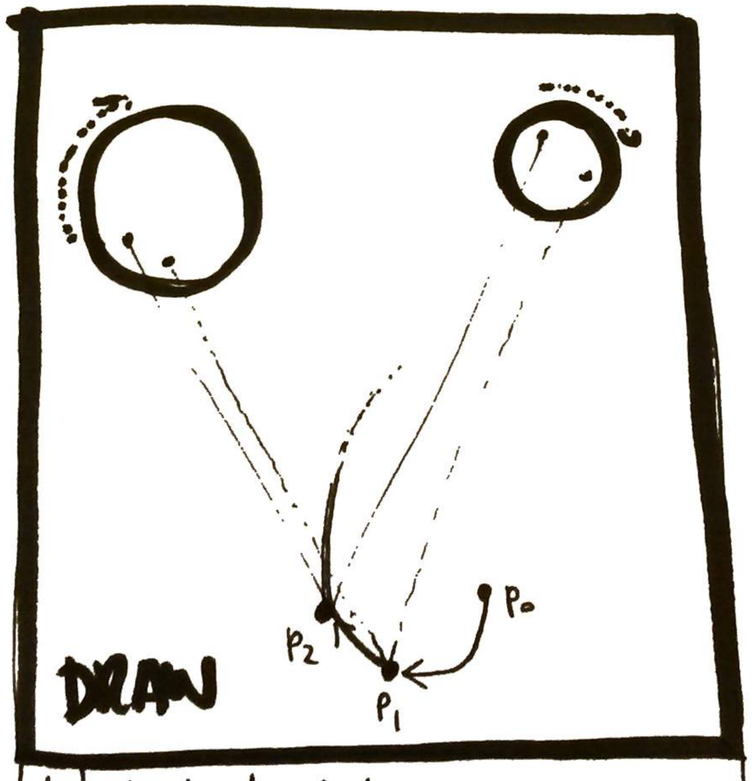
(x_1, y_1)

(x_2, y_2)

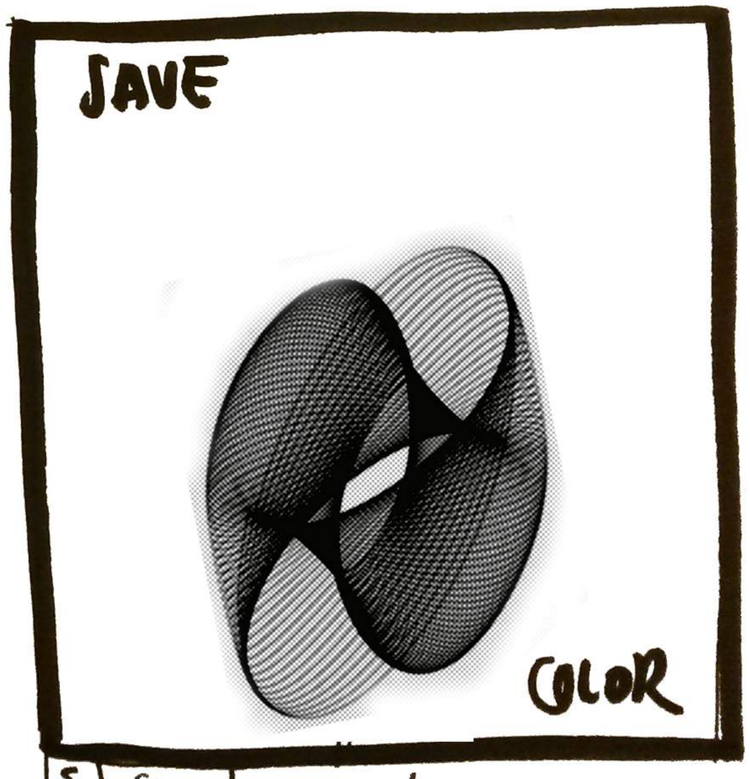
DRAWING AREA



3 choose rotation speed, visualize the drawing arms



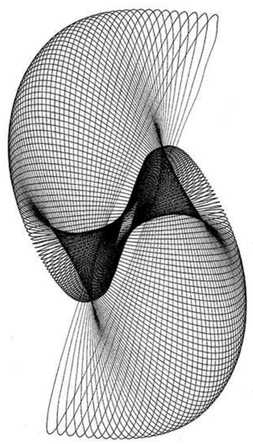
4 start drawing



5 Speed up and SEE THE RESULT

1 look at this cycloid

LOOK!



2 retrieve the gears position & dimensions

HOW WAS IT MADE?

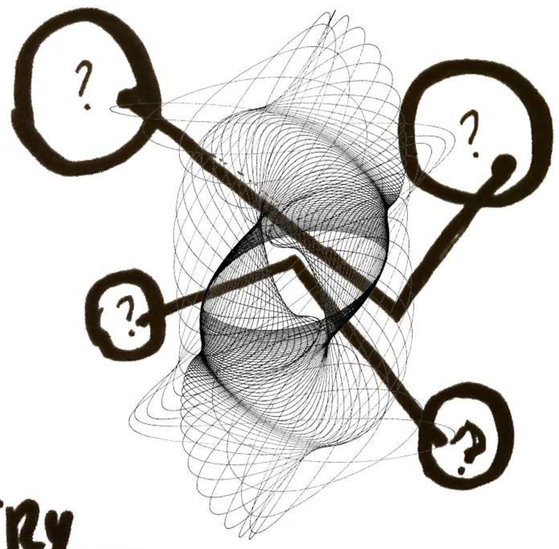
FEATURES

on display

- speed up the drawing process (or slow down) → use the slider properly
- gears visualization (ON / OFF)
- visualize with formulas
- color the cycloid by clicking inside the white spaces
- let Python color the drawing randomly

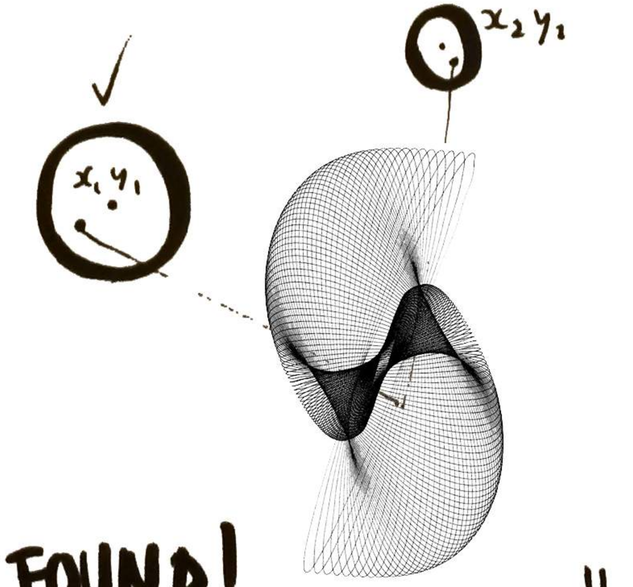
2 how was it made?

which gears? which radius?



TRY...

3 You Win!



FOUND!

II

MODE (II) LOOK AT THE DRAWING, RETRIEVE THE ORIGINAL MECHANISM

CHALLENGES:

- TRIGONOMETRY (HARD MATH TO RECREATE THE METHANISM)
- GRAPHIC USER INTERFACE (simple but PRECISE!)
- EDUCATIONAL GOAL

EXTRA POSSIBLE FEATURES:

- COLOR THE CYCLOID ON TKINTER
- EXPORT TO DXF / DWG ....
- HISTORIC / MATH EXPLANATIONS