POLITECNICO
MILANO 1863

IMAGE AND SOUND
ISPG
PROCESSING GROUP

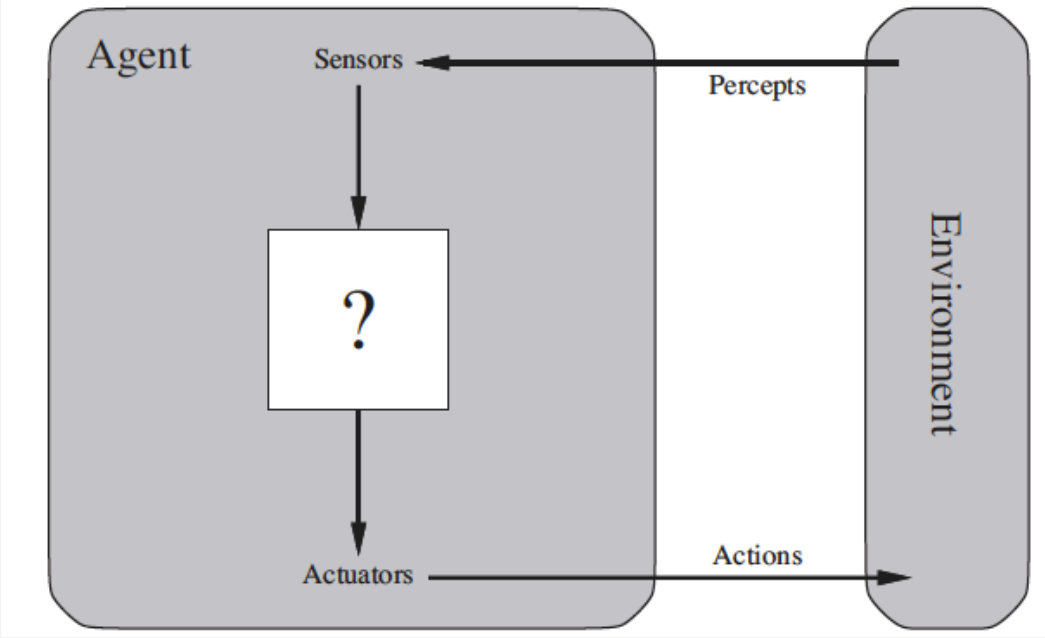
CREATIVE PROGRAMMING AND COMPUTING

Agents and Reactive agents

AGENTS - REVIEW

An agent is anything that can be viewed as perceiving its **ENVIRONMENT** through sensors and acting upon that environment through **ACTUATORS**

Agent's behaviour is described by the **AGENT FUNCTION** that maps any given percept sequence to an action

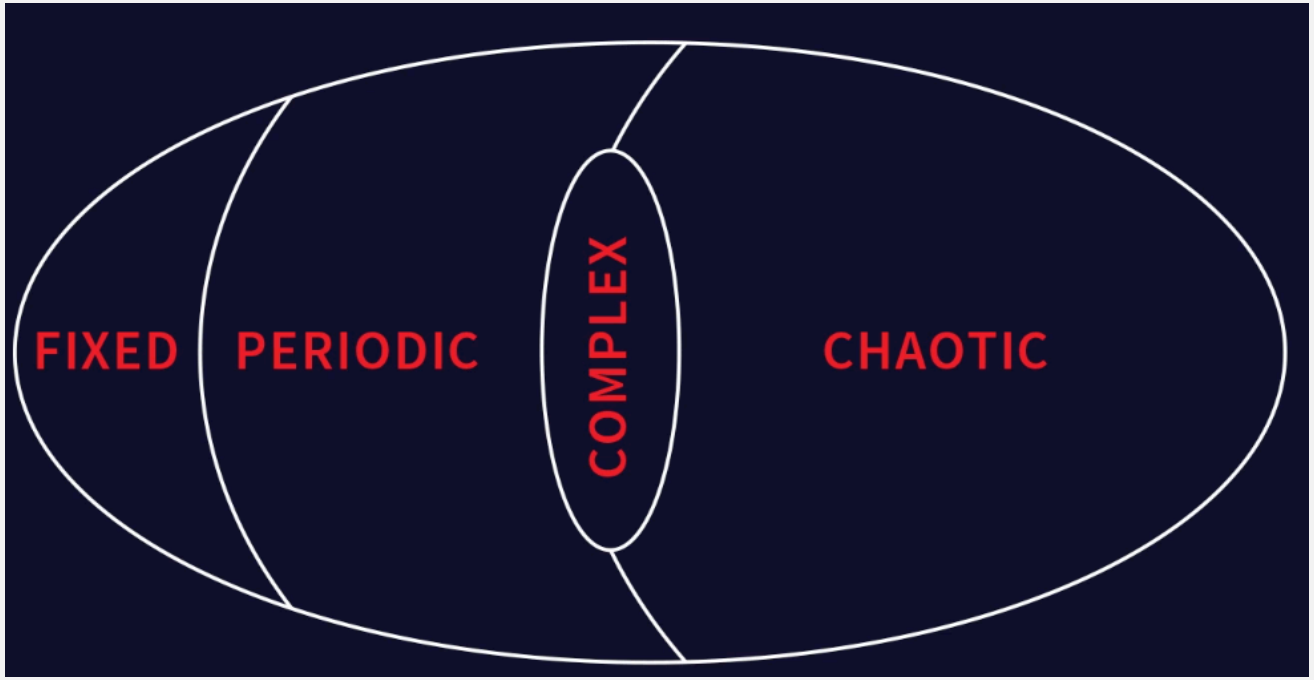


CREATIVE AGENTS

- Some dimensions for creative agents
  - Origin of agent's **knowledge**
    - ***Encoded***: the knowledge is encoded in the system by the creators (rule-based systems)
    - ***Input knowledge***: the agent is exposed to some input even if part of the knowledge is already in the system (Jazz continuator, AARON)
    - **Knowledge learned**: extracted by data (machine learning)
  - **Update** of the knowledge: static VS dynamic (evolutionary agents)
  - **Rationality** of the agent function: rational agent function requires quality measure of the action; in creativity this is not always possible
  - **Output** of the agent

CREATIVE AGENTS

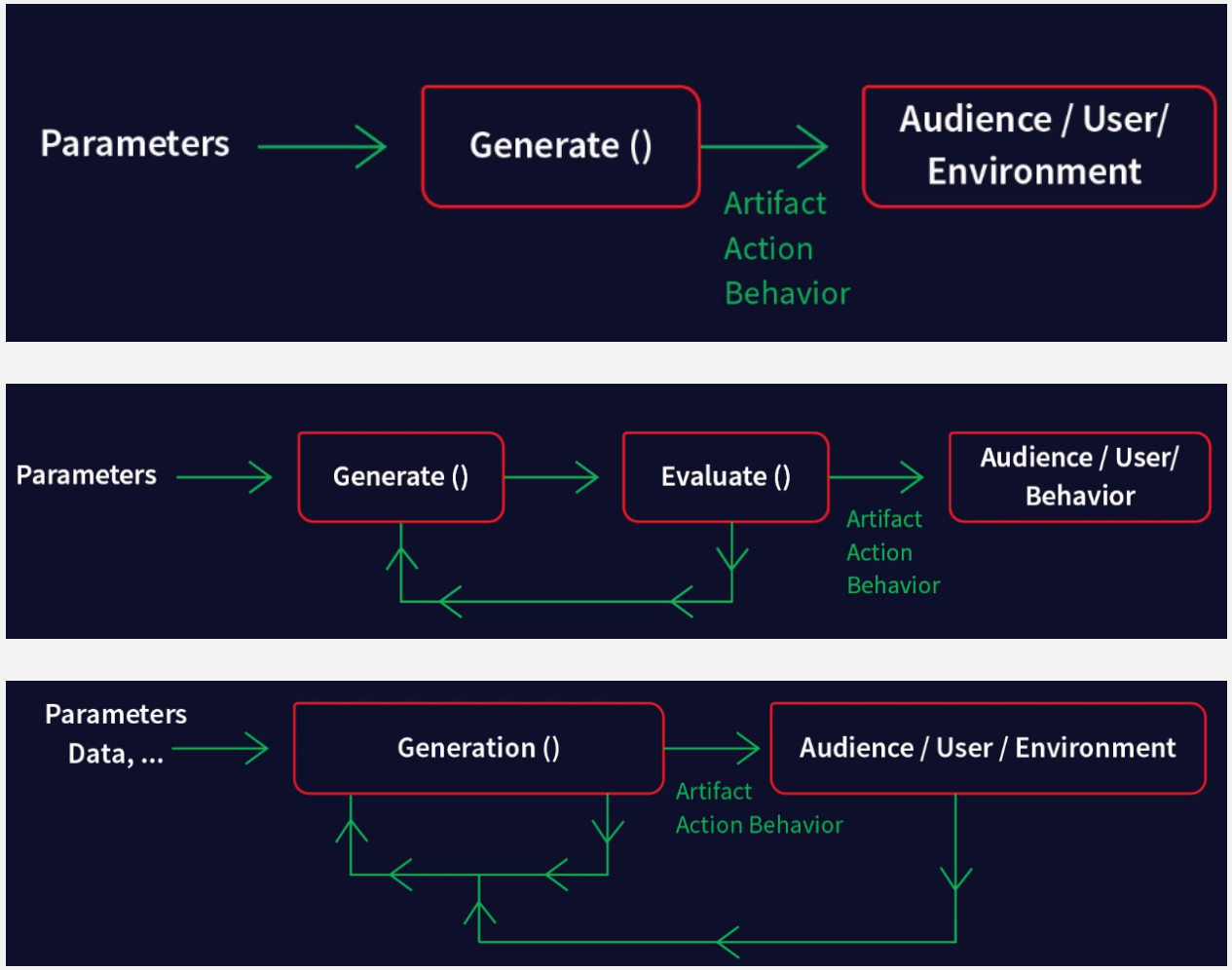
- Some dimensions for creative agents
  - **Behaviour**



- The task environment is a concept that summarize the dimensions
  - **PEAS (Performance, Environment, Actuators, Sensors)**

CREATIVE AGENTS

- Some dimensions for creative agents
  - **Behaviour**



AGENTS ARCHITECTURE

- **Cognitive agents**: maintain internal symbolic representation of the world

- **Reactive agents**: no explicit representation of the world and focus behavioural rules
  - **Reactive with no memory (Reflex)**: no internal memory
  - **Reactive with memory**: with internal states to keep track of the memory, but not cognitive

- **Hybrid**: mixing reactive and behavioural components to balance reactiveness and deliberativeness

AREAS OF INTEREST FOR THE COURSE – USE-CASES

- Creative Computing can be applied to several areas (see lecture 1 and lecture 3)
- As for use-cases in this course we focus on few of the:

  - **Automatic music composition**
  - New Musical Instrument Creation
  - **Computer graphics**
  - **Image and Video processing**

AUTOMATIC MUSIC COMPOSITION – A BRIEF OVERVIEW

- Procedures for composition date back to ancient times
  - Guido d'Arezzo developed (1026) a formal technique for composing a melody to accompany a text
  - Guillaume Dufay (1400-1476) derived tempi using the golden section
  - The isorhytmic technique (developed around 14°century) inserts a recurring pattern into different melodic layers of a composition.

AUTOMATIC MUSIC COMPOSITION – A BRIEF OVERVIEW

- Machinery for composing music automatically
  - First devices for automated performance: **carillons**
  - Olson and Belar (1951) developed a system for the probabilistic composition using a pair of asynchronous bistable multivibrators to generate random digits that represent pitch and rhythm
  - The Solidac computer served both as a playing device and as an algorithmic composition computer.
  - The Electronium (early 60s): composers asked the system to suggest a motive. When the motive is suitable, it is stored into the memory of the device. In a later stage, the user could modify it with knobs and switches.
  - Salvatore Martirano and Sergio Franco (1971) developed a system (known as Sal-Mar) for live performances.
  - Previous solutions, however, did not make use of a general purpose computer, but of ad-hoc solutions

AUTOMATIC MUSIC COMPOSITION – A BRIEF OVERVIEW

- Lejaren Hiller: a chemist that turned his intellect to Computer Music. He was the first who applied computers for algorithmic composition. His studies were a breakthrough not only for the research world, but also for the world of music (collaboration with artists such as John Cage)
- Iannis Xenakis composed Metastasis, a piece composed using stochastic formulas (by hand).
- In Italy: at the beginning efforts in Computer Music were aimed mainly at electronic analog music (e.g. Luciano Berio and Luigi Nono). Only by 1970 a hybrid computer system was developed in Pisa. By 1980 algorithmic composition became a reality.
- A breakthrough in algorithmic composition was possible with the advent of graphical interaction between the composer and the computer (first experiment by Max Mathews at Bell Labs).

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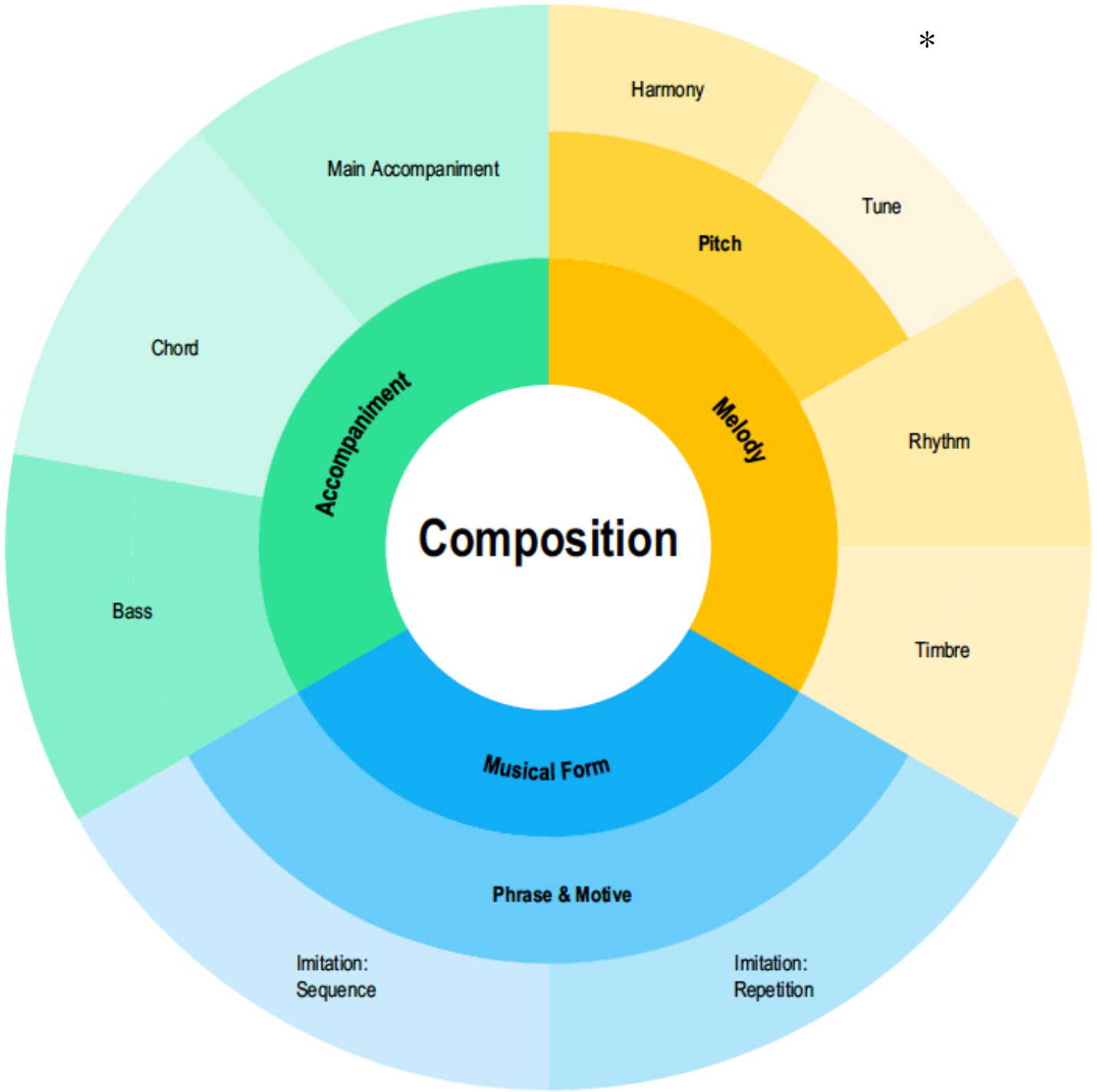
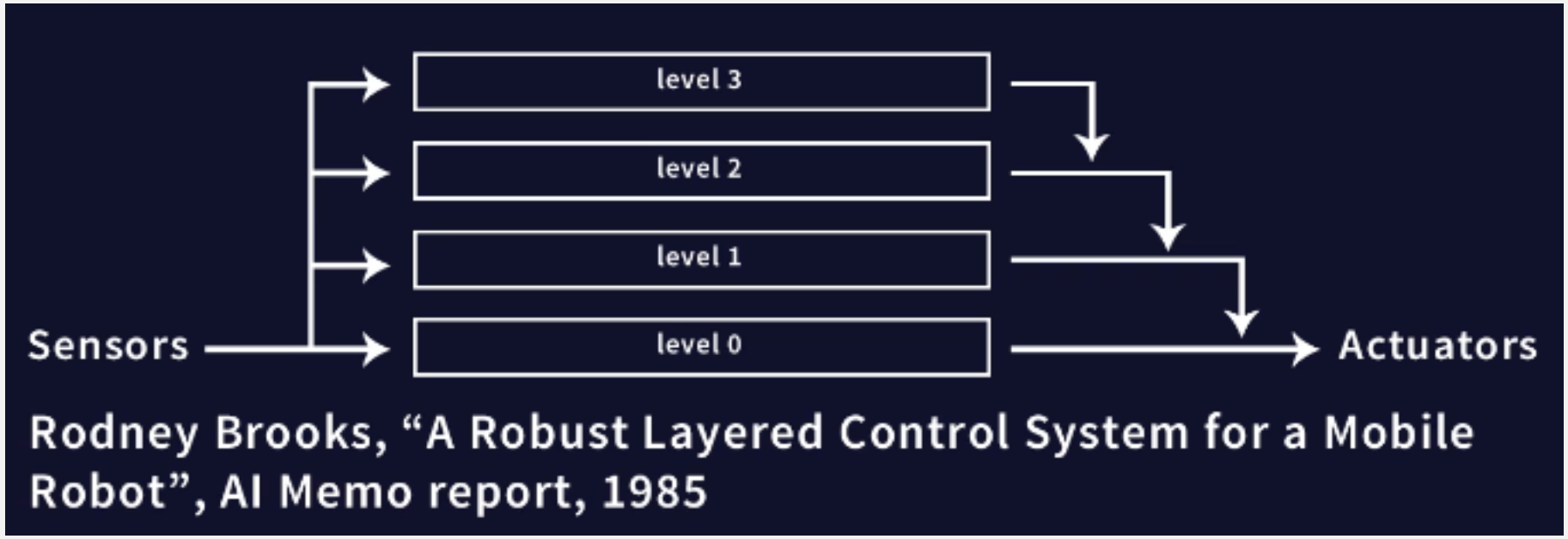

Composition
Accompaniment
Melody
Musical Form
Pitch
Phrase & Motive
Main Accompaniment
Chord
Bass
Harmony
Tune
Rhythm
Timbre
Imitation:
Sequence
Imitation:
Repetition

REACTIVE AGENTS

REACTIVE AGENTS

- Rodney Brooks from MIT:
  - Intelligent behaviour can be generated without explicit representation
  - Intelligent behaviour can be generated without explicit abstract reasoning
  - Intelligent behaviour is an emergent propriety of the interaction of simpler behaviours



Rodney Brooks, "A Robust Layered Control System for a Mobile Robot", AI Memo report, 1985

- Subsumption model

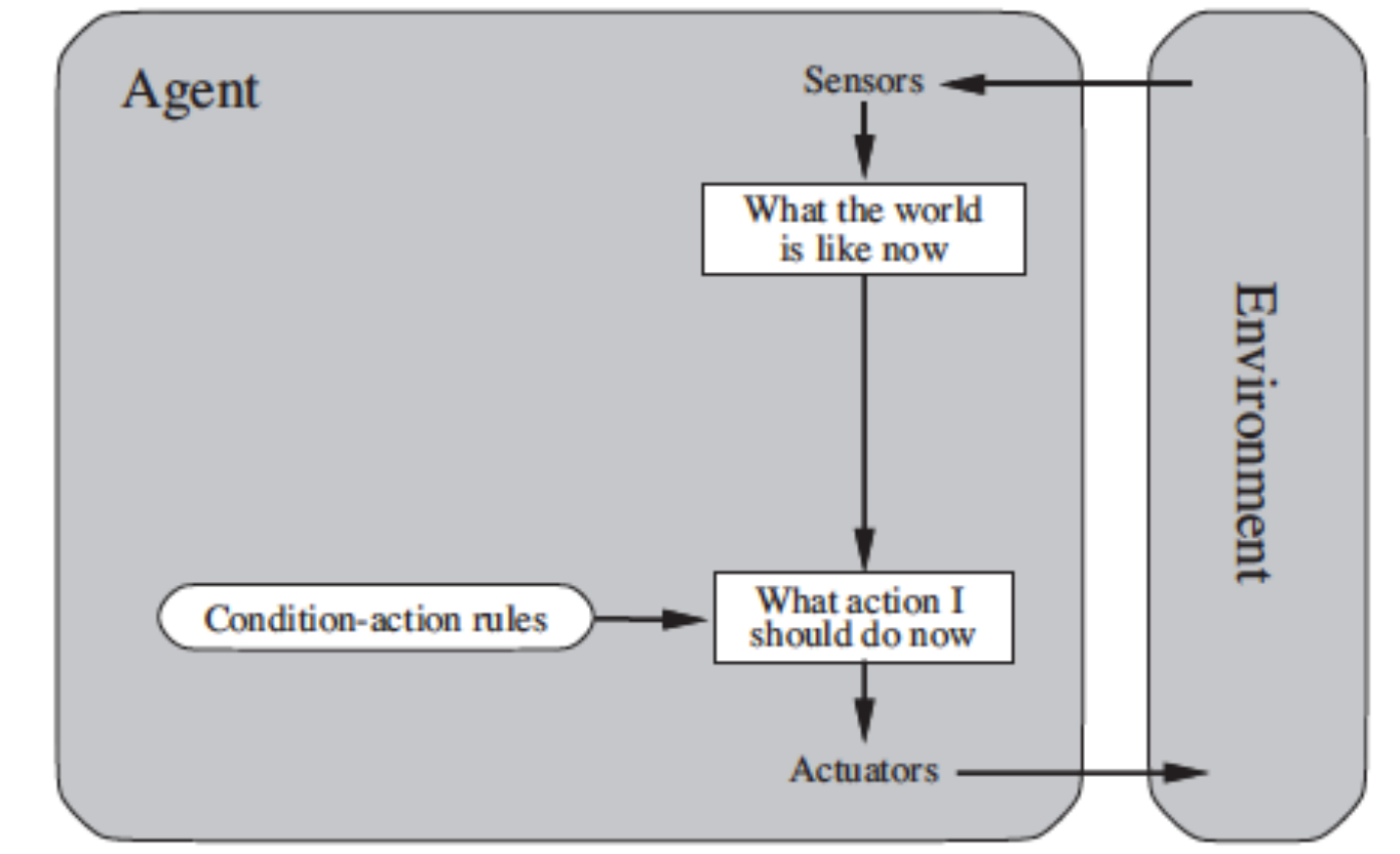
REACTIVE AGENTS – RULE-BASED SYSTEMS

- For a long time creativity has been considered as a consequence of rational thinking
- It was common to consider rational thinking the same that logical thinking
- Hence creativity was considered has the consequence of a set of rules

If you believe that A is the case, and believe that A implies B, than you ought to believe that B is the case

REFLEX AGENTS*

- These agents select actions on the basis of the **current percept** and ignoring the rest of the percept history



REFLEX AGENTS*

- They are based on **condition–action** rule
- It is inspired by the human reflex system
  - **if** *car-in-front-is-braking* **then** *initiate-braking*

```
function SIMPLE-REFLEX-AGENT(percept) returns an action
    persistent: rules, a set of condition–action rules

    state ← INTERPRET-INPUT(percept)
    rule ← RULE-MATCH(state, rules)
    action ← rule.ACTION
    return action
```

  - A reflex agent. It acts according to a rule whose condition matches the current state, as defined by the percept.

REFLEX AGENTS – INTERACTIVE SOUND

- Interactive Audio

Agent function

Perception

Sound energy extraction

Feature value mapping

$$C = [S_i * \alpha_1 * r, S_i * \alpha_2 *, S_i * \alpha_2 * b]$$

Voice Intensity

REFLEX AGENTS – AUTOMATIC MUSIC COMPOSITION

- Procedures for composition date back to ancient times
  - W.A. Mozart conceived the Musikalisches Wurfelspiel, a dice game for assembling minuets out of a set of prewritten measures of music.

1. Walzerteil

	I	II	III	IV	V	VI	VII	VIII
2	96	22	141	41	105	122	11	30
3	32	6	128	63	146	46	134	81
4	69	95	158	13	153	55	110	24
5	40	17	113	85	161	2	159	100
6	148	74	163	45	80	97	36	107
7	104	157	27	167	154	68	118	91
8	152	60	171	53	99	133	21	127
9	119	84	114	50	140	86	169	94
10	98	142	42	156	75	129	62	123
11	3	87	165	61	135	47	147	33
12	54	130	10	103	28	37	106	5

2. Walzerteil

	I	II	III	IV	V	VI	VII	VIII
2	70	121	26	9	112	49	109	14
3	117	39	126	56	174	18	116	83
4	66	139	15	132	73	58	145	79
5	90	176	7	34	67	160	52	170
6	25	143	64	125	76	136	1	93
7	138	71	150	29	101	162	23	151
8	16	155	57	175	43	168	89	172
9	120	88	48	166	51	115	72	111
10	65	77	19	82	137	38	149	8
11	102	4	31	164	144	59	173	78
12	35	20	108	92	12	124	44	131

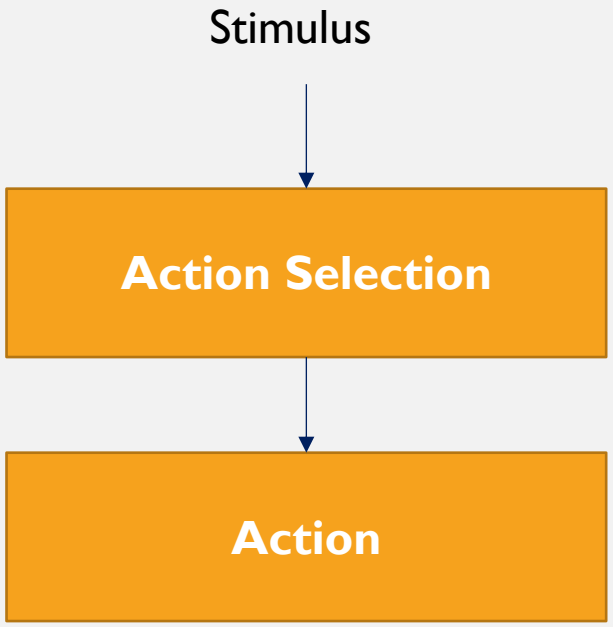
- Numeric tables from the Musikalisches Wurfelspiel. The Roman numerals over the eight columns refer to the eight parts of the waltz, while the arabic numerals in the rows refer to the possible values of two dice when throw. Numbers in cells are the pre-written part to play (from Roads96).

REFLEX AGENTS – AUTONOMOUS COMPUTER GRAPHIC AGENT

- Computer graphics agent that acts autonomously in an environment
- It can have or not a goal
- A moving graphic object has several proprieties:
  - Colour
  - Shape
  - Location in the environment
  - Acceleration
  - Velocity
- It is bases on two layers

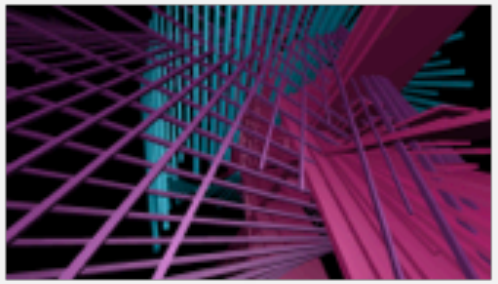
REFLEX AGENTS – AUTONOMOUS COMPUTER GRAPHIC AGENT

- It is based on the two layers architecture of the Reflex agents



REFLEX AGENTS – GESTURE CONTROL

Intelligent Harmonizer



Video - Boris - Harmoniser (1'40")

PC

gesture

OSC

visualizer

pitch

Harmoniser

Audio

Audio

Audio

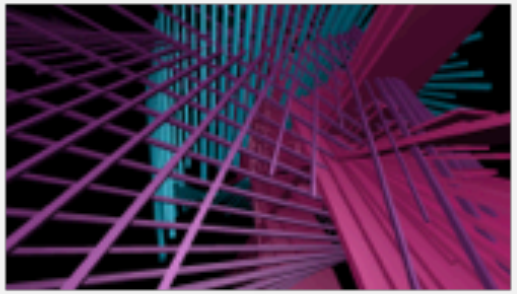
MIX

Audio

MIDI

REFLEX AGENTS – GESTURE CONTROL

Voice modulation



PC

gesture

visualizer

MIDI

Audio

Audio

Audio

MIX

Audio

Video - Boris - Chorus (11' 20")

REFLEX AGENTS

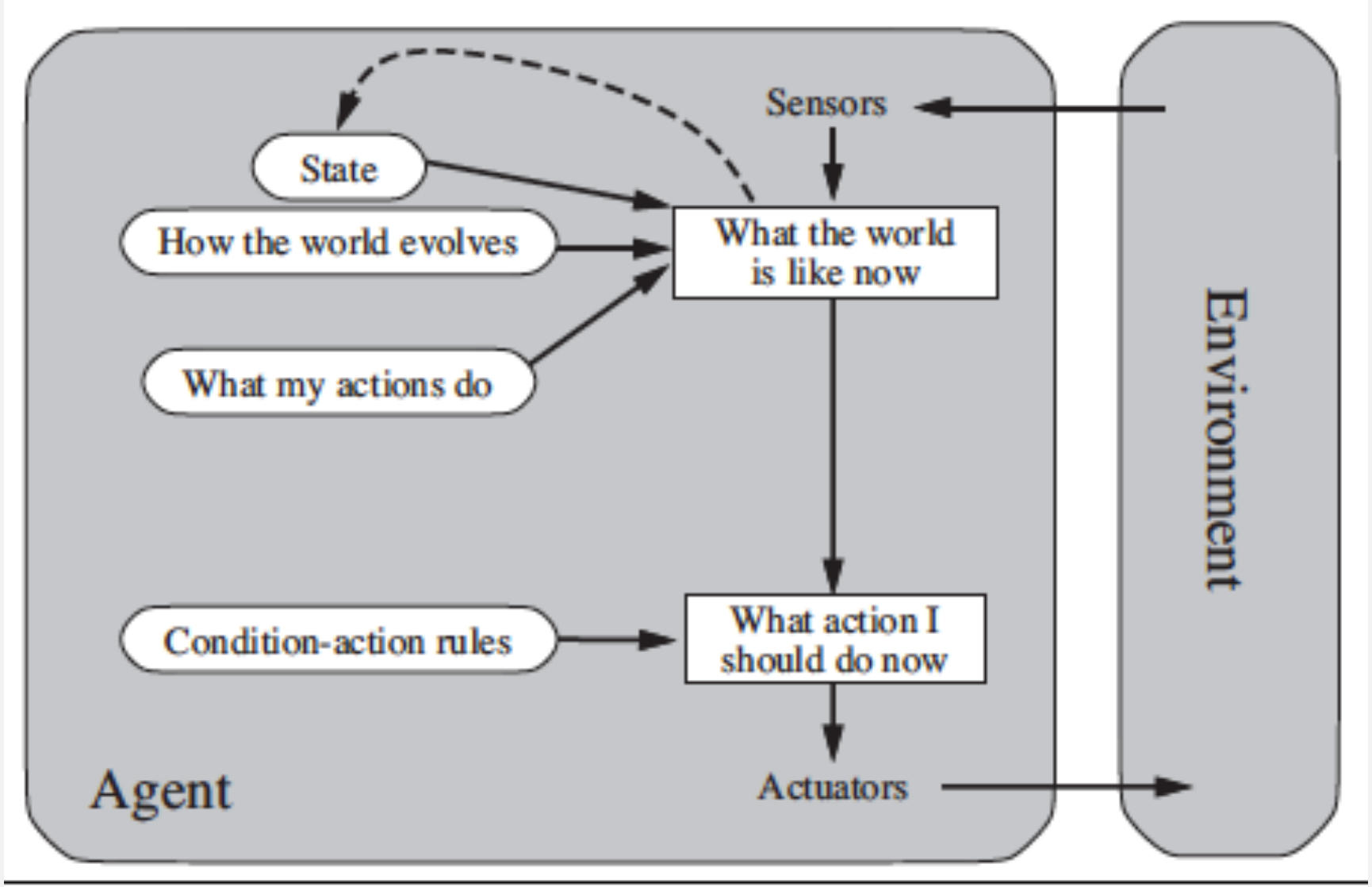
- PROS
- Reflex agents have the admirable property of being simple

- CONS
- They turn out to be of limited intelligence.
- They work only if the correct decision can be made on the basis of only the current percept—that is, only if the environment is fully observable.
- Even a little bit of unobservability can cause serious trouble

REACTIVE AGENTS – THEORY

- The most effective way to handle partial observability is for the agent to keep track of the part of the world it can't see now
- That is, the agent should maintain some sort of internal state that depends on the percept history and thereby reflects at least some of the unobserved aspects of the current state
- Needs to update the internal state information as time goes
  - need some information about how the world evolves independently of the agent
  - need some information about how the agent's own actions affect the world

REACTIVE AGENTS – THEORY



REACTIVE AGENTS – THEORY

```
function MODEL-BASED-REFLEX-AGENT(percept) returns an action
  persistent: state, the agent's current conception of the world state
              model, a description of how the next state depends on current state and action
              rules, a set of condition–action rules
              action, the most recent action, initially none

  state ← UPDATE-STATE(state, action, percept, model)
  rule ← RULE-MATCH(state, rules)
  action ← rule.ACTION
  return action
```

A reactive agent keeps track of the current state of the world, using an internal model. It then chooses an action in the same way as the reactive agent.

REACTIVE AGENTS – AUTOMATIC MUSIC COMPOSITION

- Many nonlinear equations exhibit a chaotic behaviour, i.e. their solutions move into the solution space in a way that appears random and chaotic.

- Fractals are strictly relates to chaos theory, as the solutions of many chaotic equations exhibit a self-similarity behaviour, typical of fractals.

- The term “chaos” may be misleading: the behaviour of these non-linear systems is deterministic.

REACTIVE AGENTS – AUTOMATIC MUSIC COMPOSITION

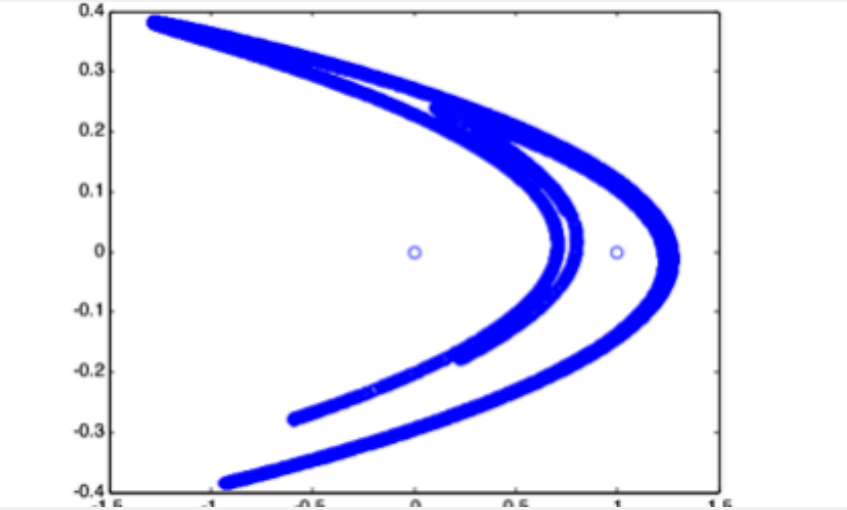
- One of the simplest chaotic systems is the **Henon attractor**

$$\begin{cases} x_{n+1} = 1 + y_n - a x_n^{\,2} \\ y_{n+1} = b x_n \end{cases}$$

Initial values:

$$a = 1.4; b = 0.3$$

$$x_0 = 0; y_0 = 0;$$



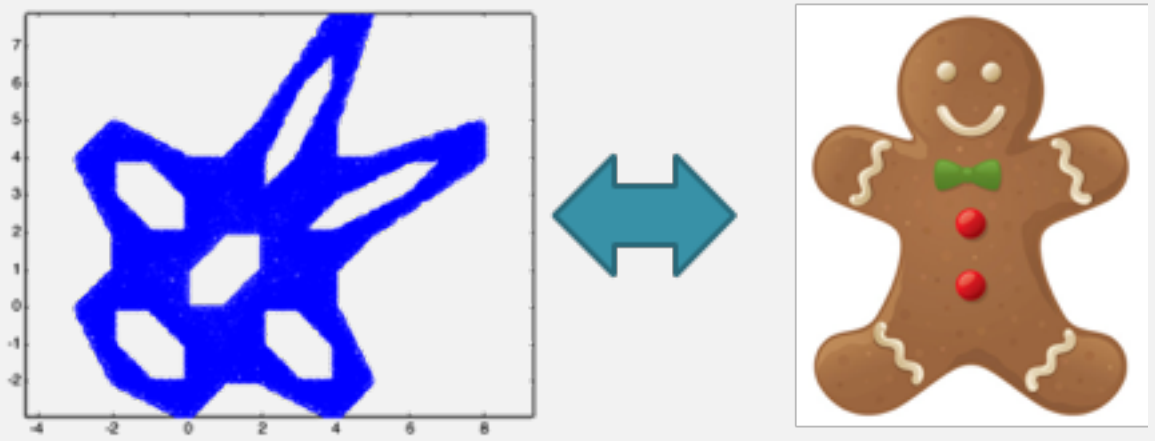
- Mapping of the value of the Henon map to the pitch
- The values of the Henon function are mapped in the interval 0-1 and the corresponding value is mapped to a pitch in a specific scale

henon_music

REACTIVE AGENTS – AUTOMATIC MUSIC COMPOSITION

- Gingerbreadman function

$$\begin{cases} x_{n+1} = 1 - y_n + |x_n| \\ y_{n+1} = x_n \end{cases} \qquad x_0 = -0.1; y_0 = 0.1$$



gingerbreadman

REACTIVE AGENTS – AUTONOMOUS COMPUTER GRAPHIC AGENT

- Let's focus on movements
- Movement can be represented be the combination of **location**, **velocity** and **acceleration**
- Location can be describe as a point in the coordinate system
- Velocity and Acceleration can be described through Euclidean vectors as forces

- **Euclidean Vector**: how to get from one point to a second point
- It can be represented using a (x,y) values: reached location with respect to the origin
- In Processing -> **PVector**

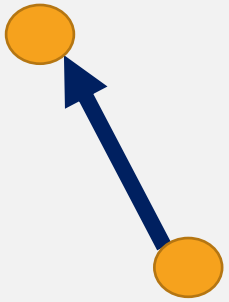
REACTIVE AGENTS – COMPUTER GRAPHICS

- Moving Object
- in order to get the vector between the two:
  - Compute the direction of **a** as P2-P1
  - Compute the magnitude of **a** as

REACTIVE AGENTS – COMPUTER GRAPHICS

- In **PVector** directions and magnitude are embodied

P1(-2,3)



P(1,4)

Velocity and acceleration of the object, how to update the position

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1}$$

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1}$$

x2 = x1+v

v2 = v1+a

BallMover

REACTIVE AGENTS – COMPUTER GRAPHICS

- An object can have a mass
- Given a moving object, velocity and accelerations can be affected by the a set of external force
  - Gravity
  - Wind
  - Obstacles
  - …

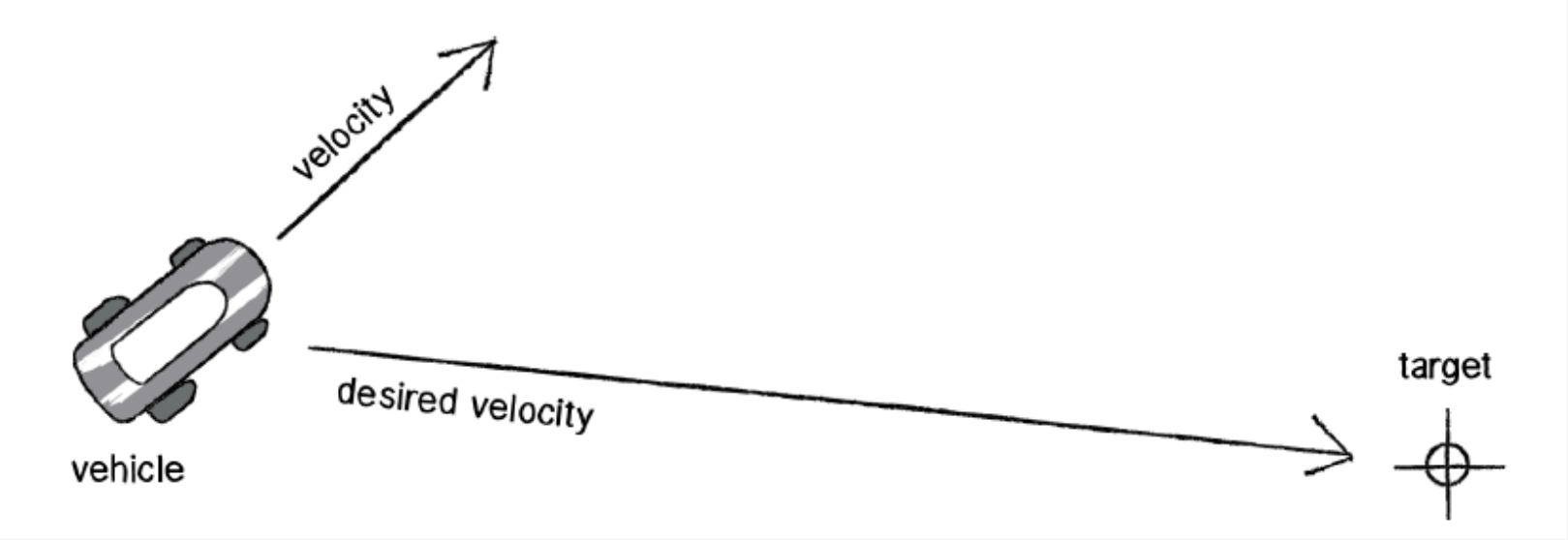
a = a+(force/mass)

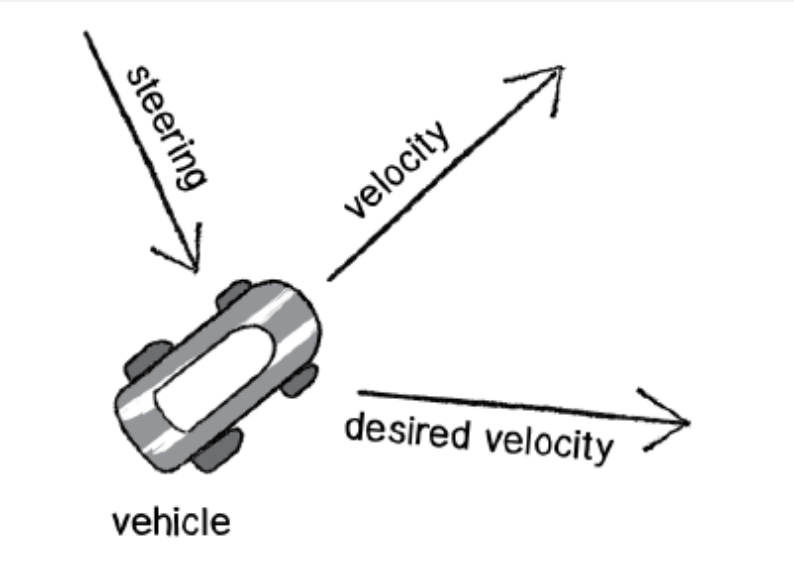
BallMoverForces

REACTIVE AGENTS – AUTONOMOUS COMPUTER GRAPHIC AGENT

Seek

- **The seek problem**: an agent looks for a way to reach a target
- Intelligent decision to steer towards the target based on its perception of its state
- The agent should look at how it desires to move (**desired velocity**), compare that goal with how quickly it is currently moving (**its velocity**), and apply a force accordingly (**steering**).





steering force = desired velocity - current velocity

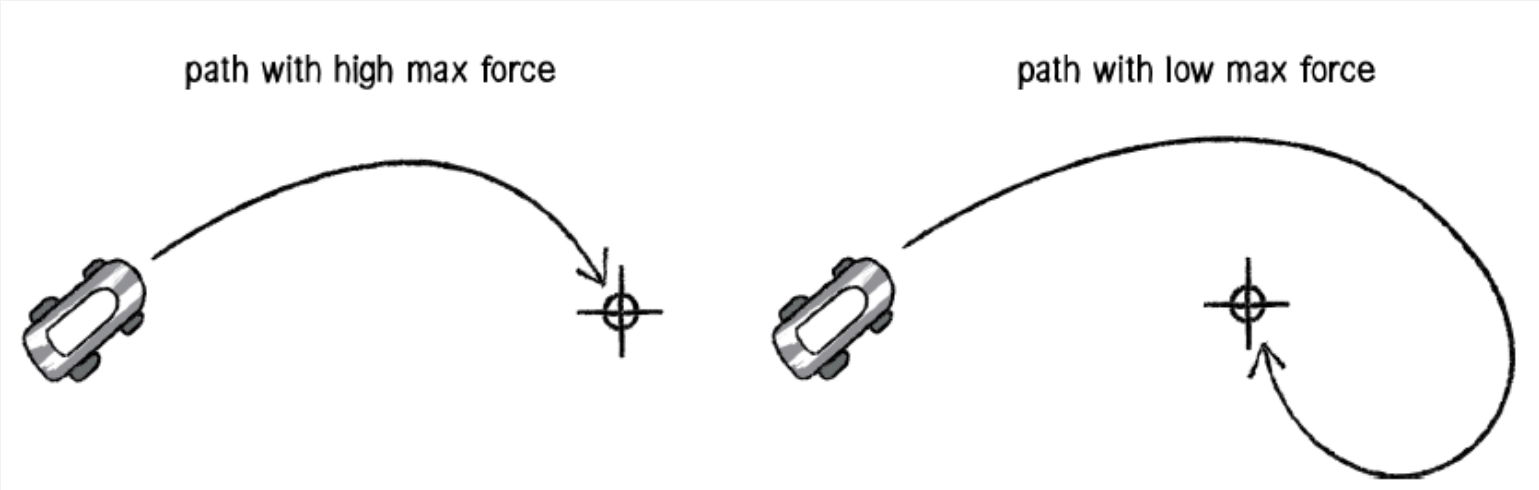
REACTIVE AGENTS – AUTONOMOUS COMPUTER GRAPHIC AGENT

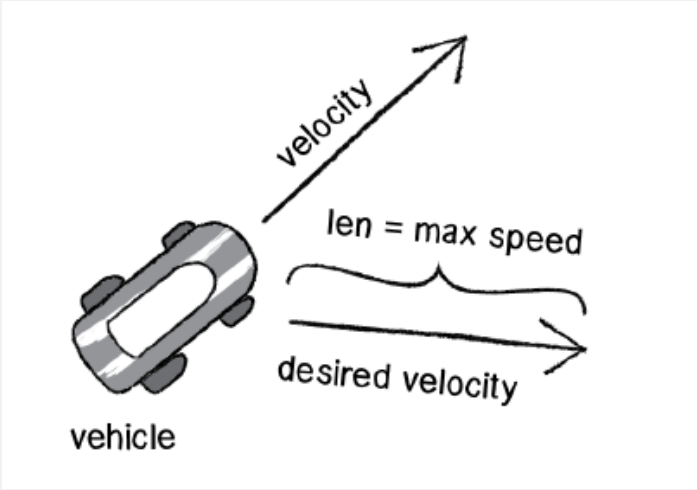
Stimulus → **Target Position**

Seek2

Action Selection → **Move toward the target at max speed**

Action → **Compute direction**
steering force = desired velocity - current velocity
Apply magnitude: maxForceStreerin and maxVelocity

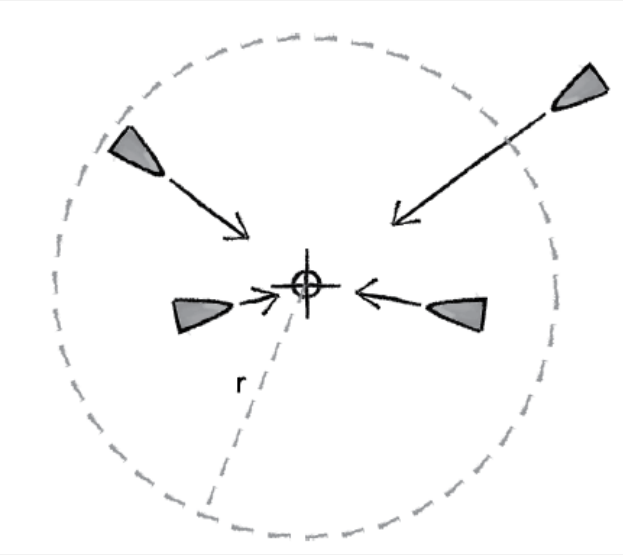




REACTIVE AGENTS – AUTONOMOUS COMPUTER GRAPHIC AGENT*

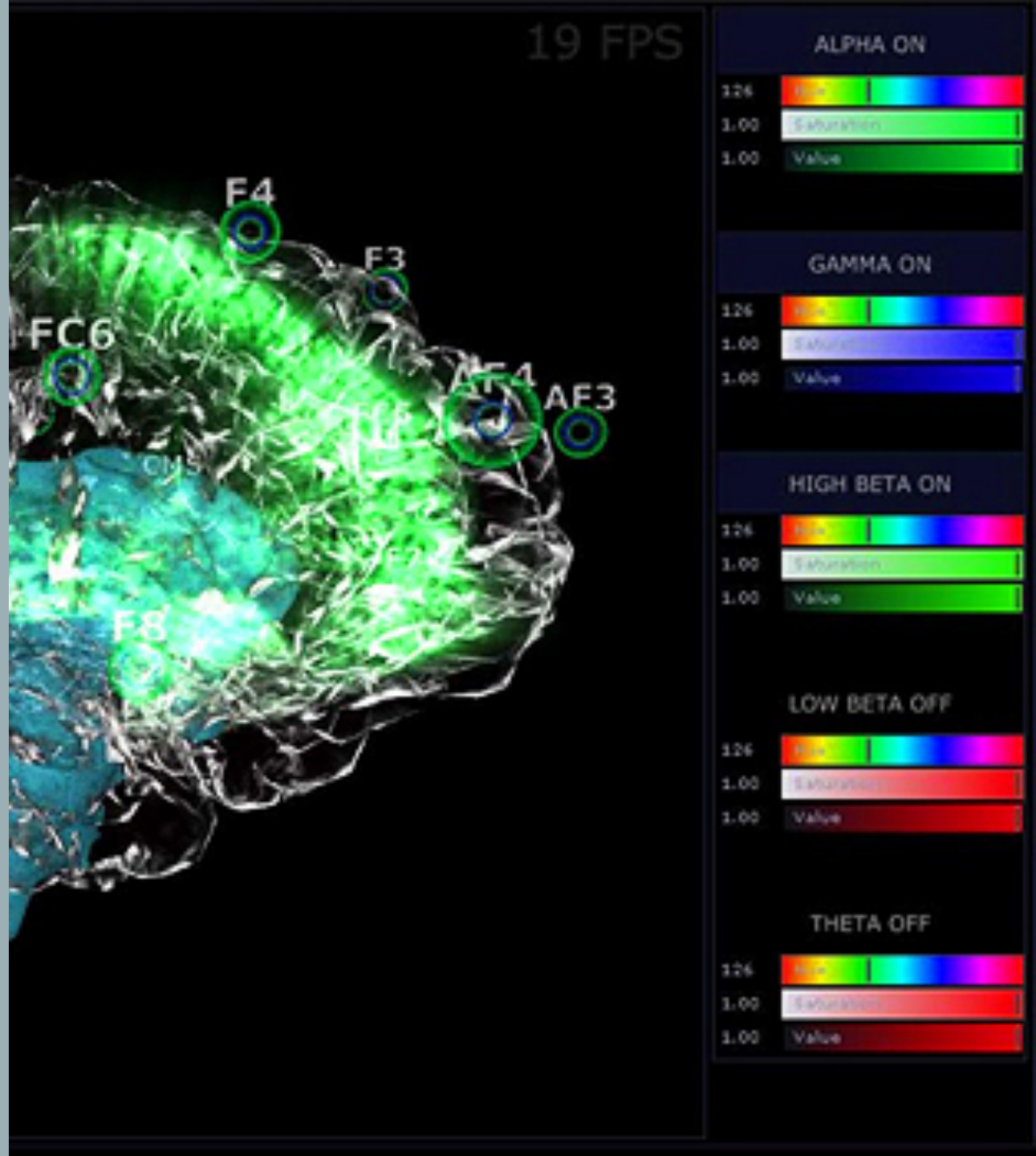
- **The seek and arrival problem** : an agent looks for a way to reach a target and slow down in order to do not pass through it
- The agent's thought process needs to consider its speed relative to the distance from its target.

- Need to define the magnitude of the velocity accordingly to the distance to the target



Arrive **Arrive Coloured**

MANAGE A CREATIVE PROJECT



CREATIVE PROJECTS

- Creative projects are not functional to solve a problem, they are build to create experience
- Very related to experience design

- Few steps:
  - **Concepting**: create the concept of the project – describe the theme, the motivation and the user experience
  - **Design:** based on the concept, create the design the project, decide techniques and tools, find solutions to implement the experience
  - **Prototyping:** first implementation of the main feature of the user experience – realized in small scale, part of it can be virtual (ex. Large projections)
  - **Production:** final realization

CREATIVE PROJECTS – CONCEPTING

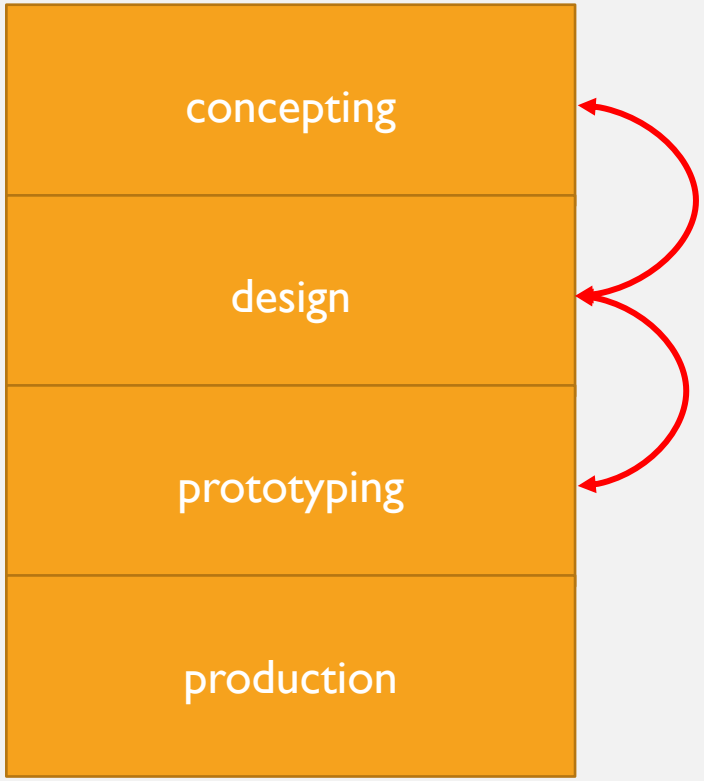
1. An artistic project often starts from a them to address
2. Define the key elements of the problem
3. Define which of the key elements to address
4. Define how to translate them into a user experience
5. Define the artistical and interactive element of the experience

Example: Climate Change

1. Climate change
2. Cannot be solve by just one person; it as practical issue, each one need to act
3. All of them
4. The users need to interact with the installation and they need to see they contribute; the contribute is part of the total contributes (evolutionary interactive installation)
5. A virtual sick tree that can be re-flourished if people give them water. Users can provide them a virtual drop of water -> *description of the three and of the interaction*

CREATIVE PROJECTS

- The are some loops in the process

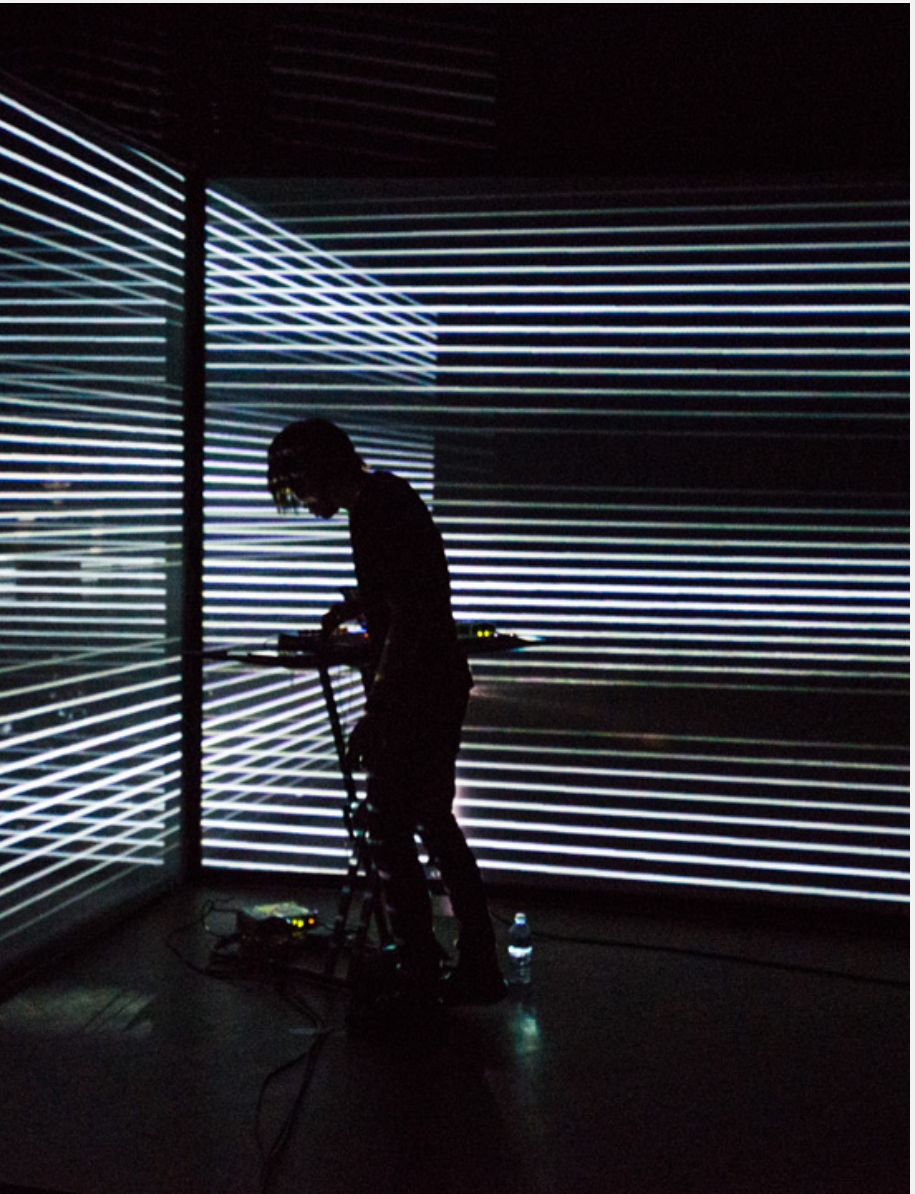


IT'S TIME TO GIVE BACK

O³ LAB

Massimiliano Zanoni
Jean Paul Carradori
Qing Li

SCENARIO AND MOTIVATION



Interdisciplinarity

Technology as part of the creative process

Technology as part of the creation of a new artistic language

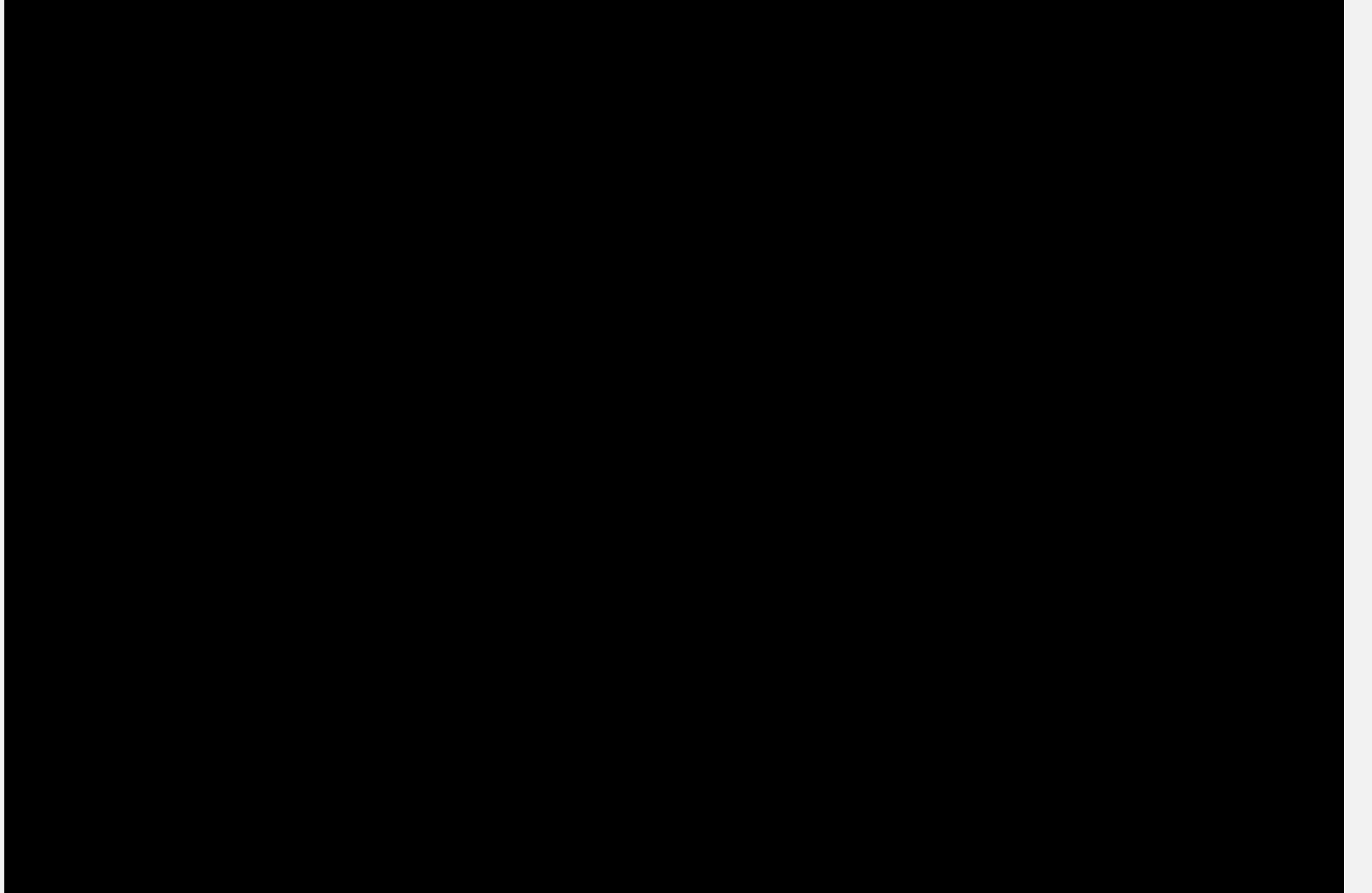
Art as part of the technological revolution

SCENARIO AND MOTIVATION

O3LAB, is an artistic group composed by technologists and artists in different disciplines

“It’s time to give back”, an installation that addresses the problem of ecology

The installation is divided into two distinct sections: a video (in loop) and an interactive installation



SCENARIO AND MOTIVATION

We started from the problem. Ecology problem is controversial for several reasons. Among them:

• **do not exists a unique single solution** – do not exists a unique solution to the problem, more likely the solution will be the consequence of our personal positive or negative actions

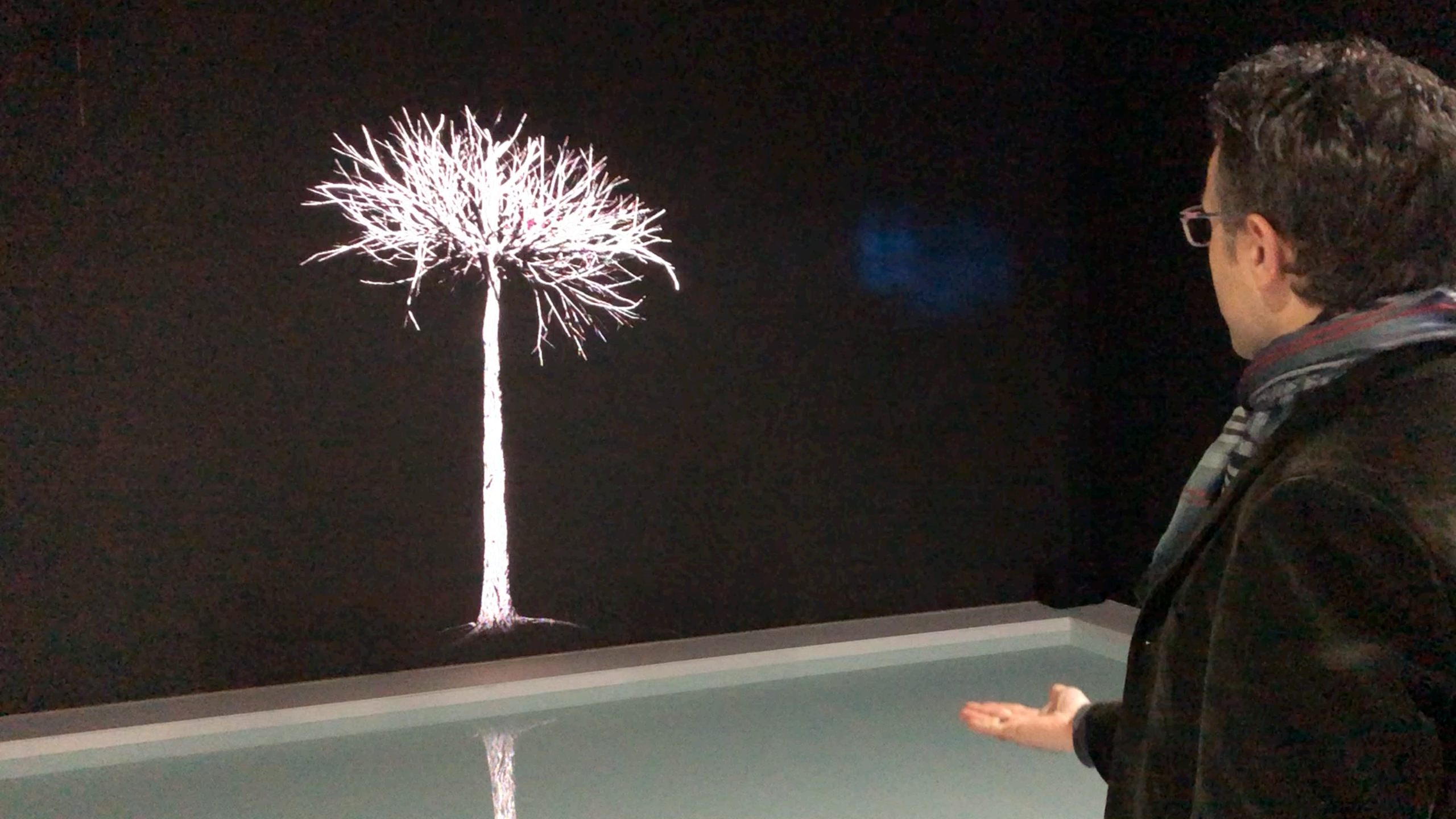
• **slow changes -** the effect of our personal positive or negative actions have only a small impact on the entire system, but the contribute of a mass of people can be highly be visible after some time of constant contribute

THE INTERACTIVE INSTALLATION

“Give it back”

- attenders can interact with the artistic subject
- the interaction paradigm allows people to make a personal and immersive experience
- the embodiment paradigm, drives them to go in deep into the ecological problem and to increase the awareness of the need of a personal contribute

Feed the tree with a drop of water



THE INTERACTIVE INSTALLATION

Goal: Embodiment of the ecology issue through interaction

do not exists a unique single solution

- Feed the tree: **a concrete action**
- The attenders need to understand how to give their contributes through the systems
- The attenders are free to choose if they want or not to give the contribute
- The attenders are free to choose the number of contributes

slow changes

- Each contribute has a visible but small effect on the re-flourishing process – 125 feeds to re-flourish the tree

THE SYSTEM

Real-Time data receiver

Coordinates adapter

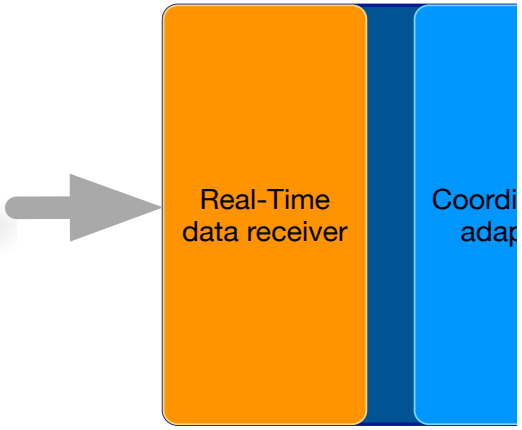
Projection controller

Perception

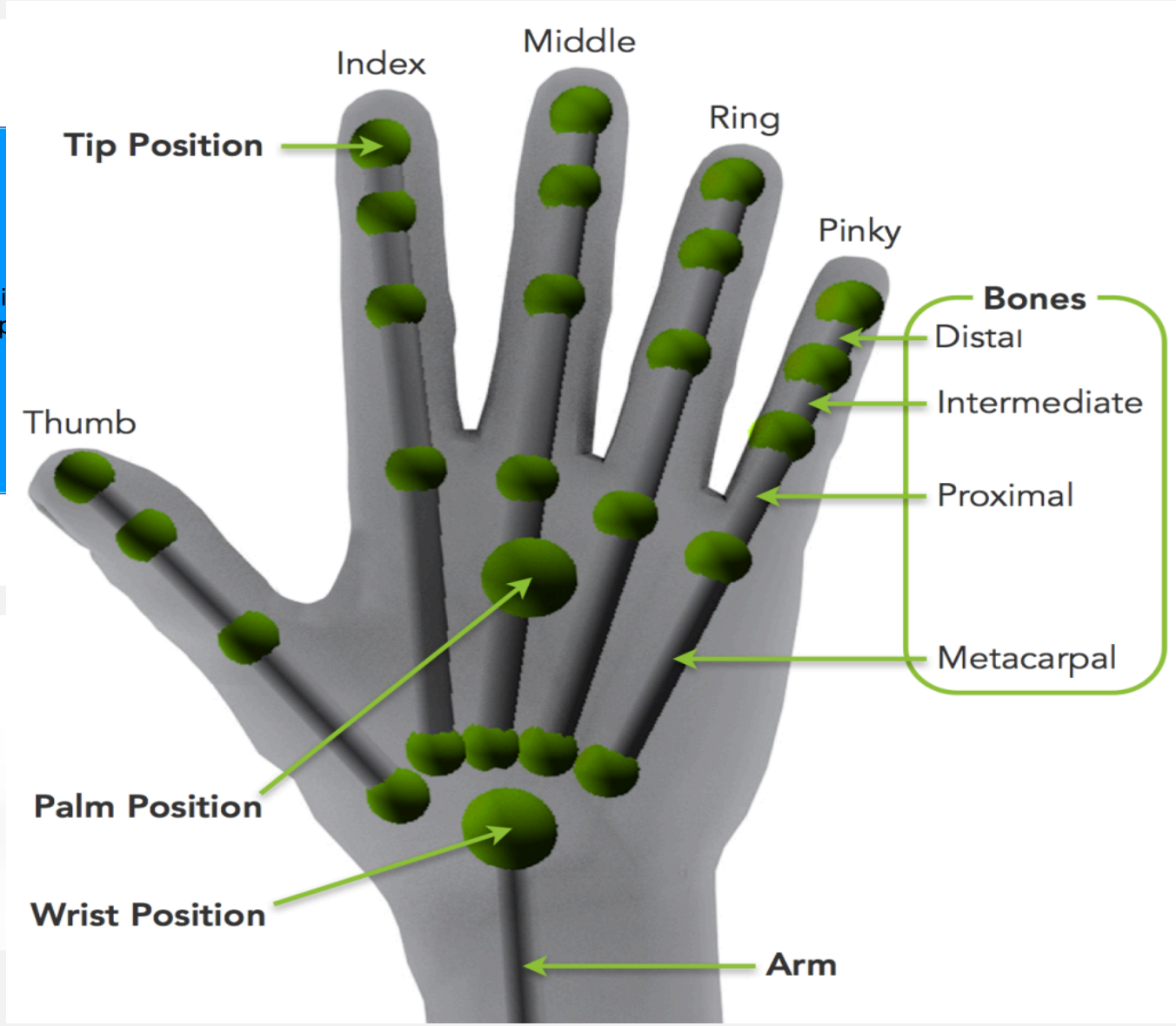
Agent Function

Actuation

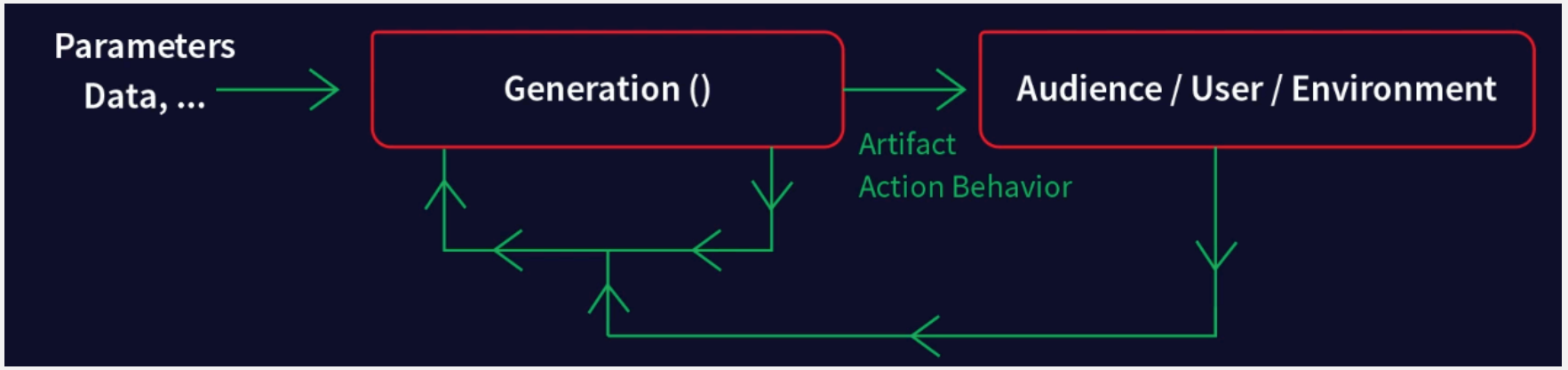
PERCEPTION



Two cameras and
three infrared LEDs
Frequency rate: 60 fps

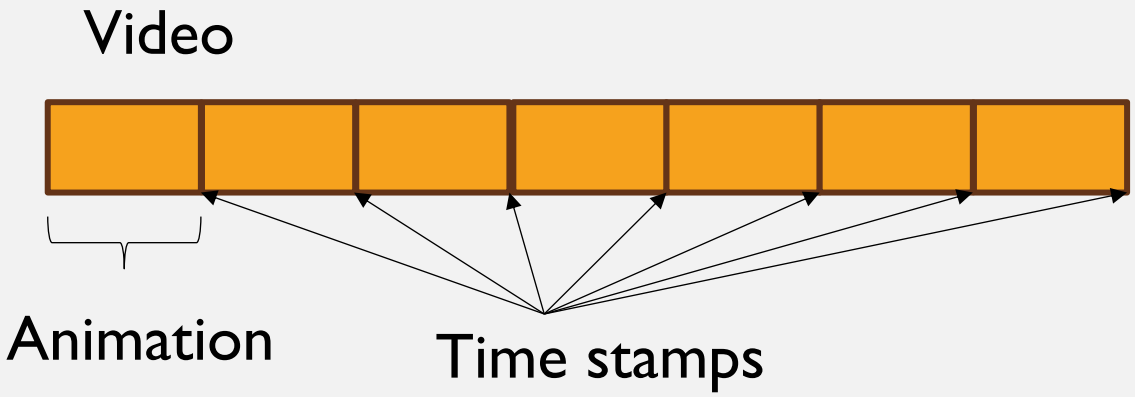


PERCEPTION



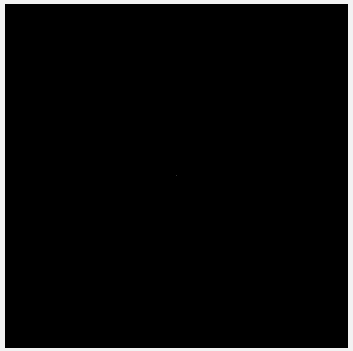
- The system wait until Leap Motion starts tracking
- We track the palm position on the space
- We use rotation information to understand if the palm is up. If the palm is not up not drop appears

PROJECTION

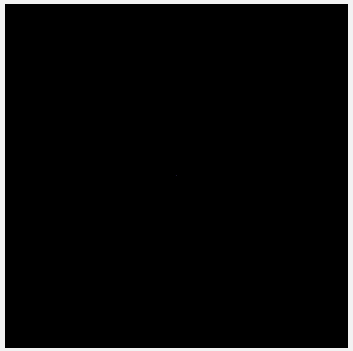


Fractal-based
SpeedTree

- 2 Layer Video
- Sync Video FPS with Execution FPS
- Discard some frames

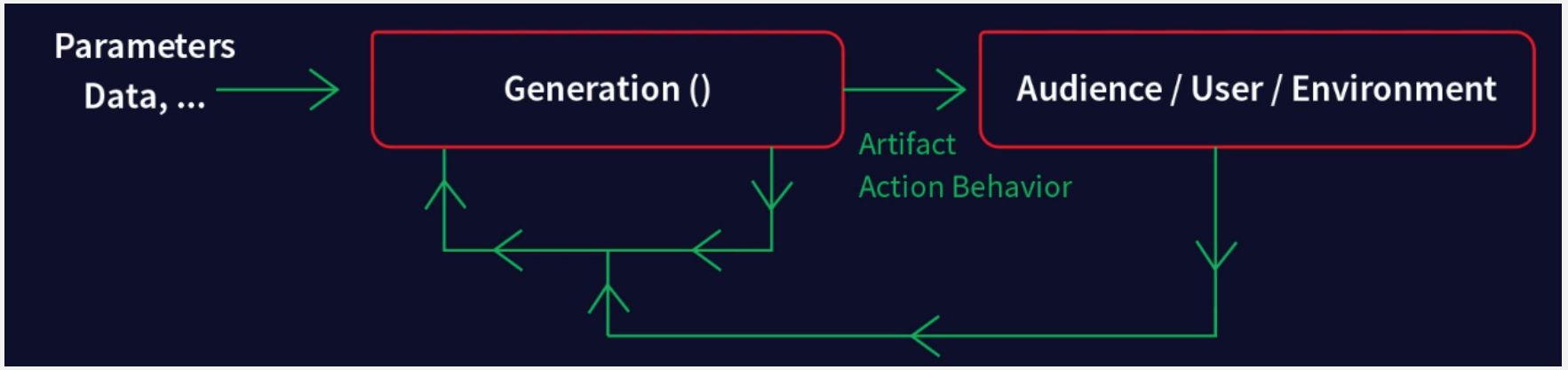


Alpha Mask



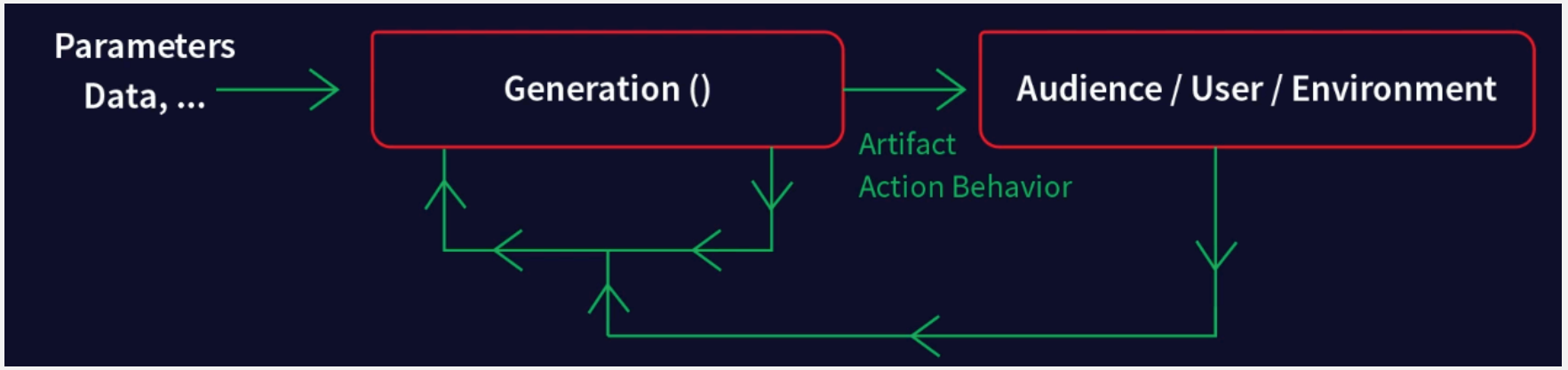
Colour Mask

AGENT FUNCTION



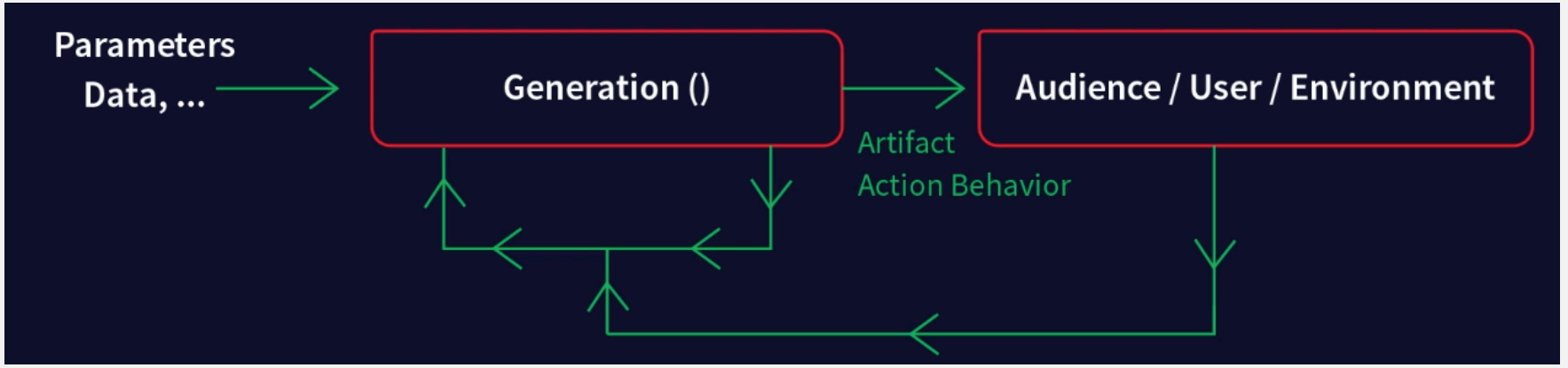
- The agent stop to perceive each time in animation mode
- If the agent is in perceiving mode, if Leap Motion sees an hand -> start tracking
- A drop appears on the screen
- Sync the X,Y position of the hand to the X,Y position of the drop
- Sync the Z position of the hand (front VS back) to the scale factor of the drop (simulate the depth)

AGENT FUNCTION



- If the drop is "very close" to the tree (scale factor smaller than a threshold) –> deliver a trigger
- The drop disappears
- The agent goes in animation mode

AGENT FUNCTION



- The agent has a status -> need of internal evaluation
- The agent impacts the world – the user react to the impact –> need of user feedback
- The user feedback is the interaction itself

EVOLUTION

Evolve the interaction experience – machine learning to understand complex gestures

Add an haptic experience

Move to landscape art - projection on a building – interaction public available on the street

MATERIALS

- **References**
  - Massimiliano Zanoni, Jean Paul Carradori, Qing Li, It's time to give back, Electronic Imaging & Visual Arts (EVA2019), Florence, Italy, 8-9 May 2019
  - Chien-Hung Liu and Chuan-Kang Ting, Computational Intelligence in Music Composition: A Survey, IEEE Transactions on Emerging Topics in Computational Intelligence, December 2016,
  - Jose David Fernandez, Francisco Vico, AI Methods in Algorithmic Composition: A Comprehensive Survey, Journal of Artificial Intelligence Research 48 (2013)

- **Further readings**
  - Daniel Shiffman – Nature of code, 2012 – Chapter 1 and 2
  - Russell - Artificial Intelligence a modern approach, Pearson College Div, 2012 – Chapter 1 and 2