Evolutionary Computer Music

At the Crossroads of Artificial Life and Music

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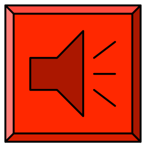
Background

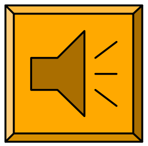
Artificial Intelligence **can** compose music

Most systems are "hard-wired" to compose in a certain style

Some of them can learn by extracting compositional rules from a given examples



D. Cope’s Mozart-like



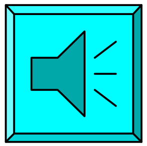
A. Camurri’s jazz

Can computers create new kinds of music?

A number of composers have designed systems using abstract models that were believed to share organisational principles with music compositional processes: e.g., combinatorial systems, probabilities (stochastic), complexity, and so on and so forth.

A great number of musical pieces were composed with such models in the 1960s, 1970s and 1980s.

A number of composers still compose with such techniques today.



Ron Kuivila’s

New inspiration: Artificial Life

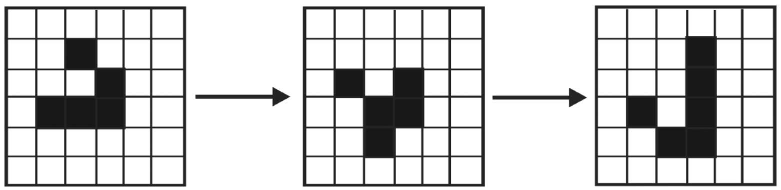
A natural progression for composers interested in exploring new generative techniques

Emergent behaviour resembling natural and/or biological phenomena; computer models/simulations of natural and/or biological phenomena; e.g., genetic algorithms, cellular automata, and neural networks

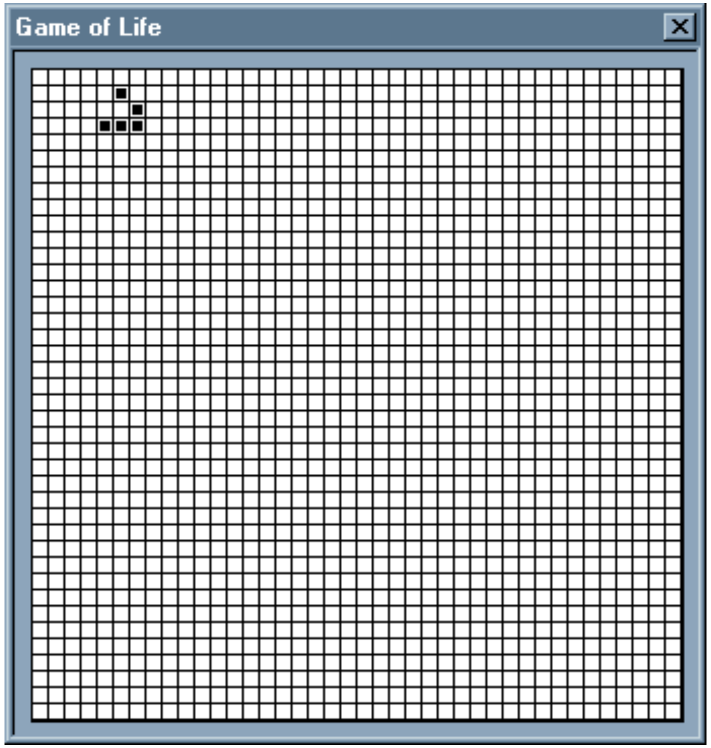
Artificial Life music?

Can the A-life paradigm help composers to create effective compositional systems?

Towards the end of the 1980s a number of composers started to create music with models that display some form of **emergent behaviour** resembling natural and/or biological phenomena; e.g., cellular automata



An example of cellular automata

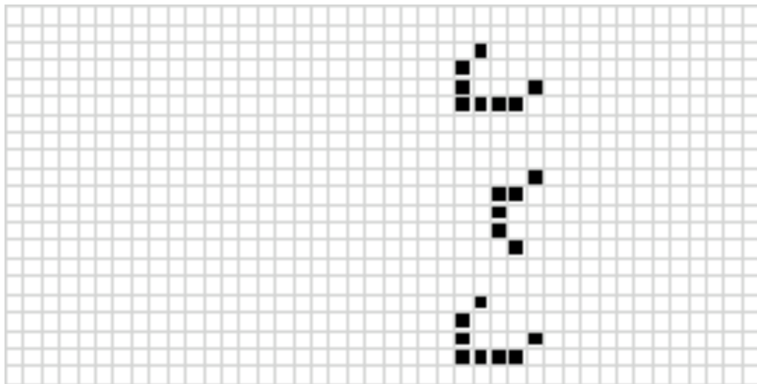


For a space that is 'populated':

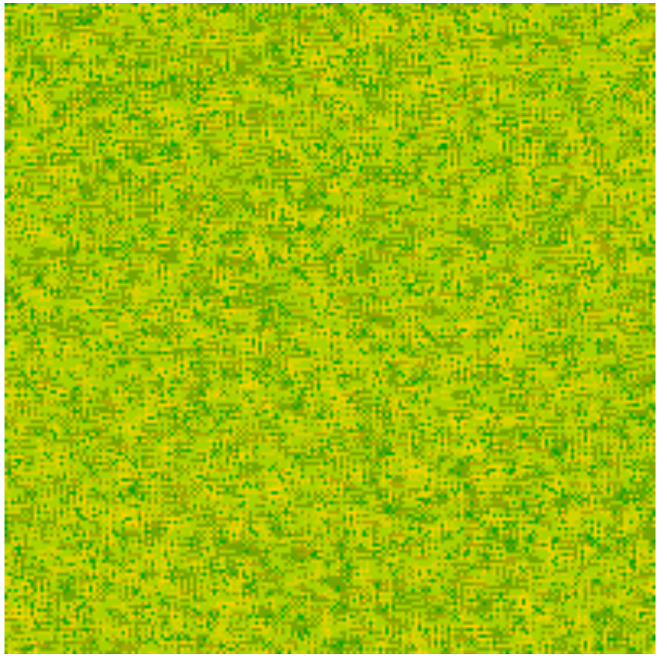
- Each cell with one or no neighbours dies, as if by loneliness.
- Each cell with four or more neighbours dies, as if by overpopulation.
- Each cell with two or three neighbours survives

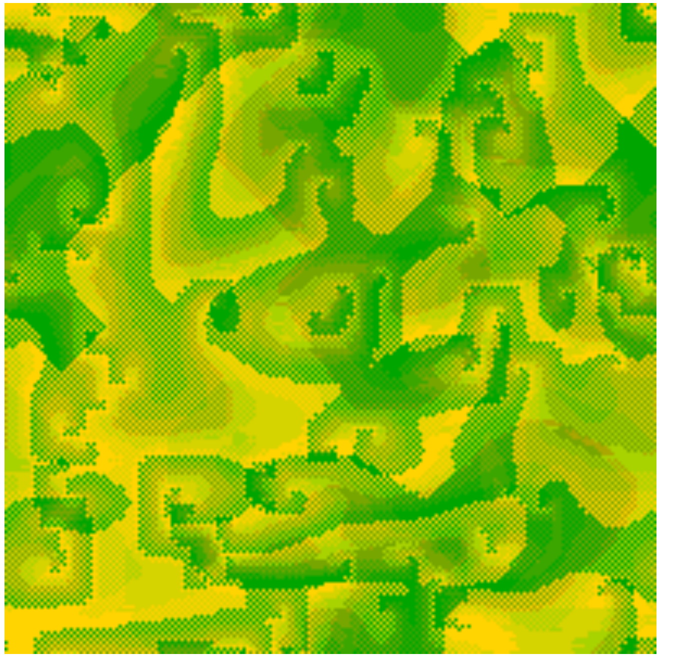
For a space that is 'empty' or 'unpopulated'

- Each cell with three neighbours becomes populated.



Another example of cellular automata





- IF $m_{x,y}[t] = 0$ THEN $m_{x,y}[t+1] = int(\frac{A}{r1}) + int(\frac{B}{r2})$
- IF $0 < m_{x,y}[t] < n-1$ THEN $m_{x,y}[t+1] = int(\frac{S}{A}) + k$
- IF $m_{x,y}[t] = n-1$ THEN $m_{x,y}[t+1] = 0$

Conclusion

Indeed, (some) A-life models do seem to embody (at least some of the) organisational principles found music.

A more profound (and more challenging) question is:

Can the A-life paradigm help us to gain a better understanding of the origins and evolution of music?

Studying the evolution of music

A-life-inspired tools to study the evolution of music (in artificial systems)

Focus on cultural evolution (but we need to understand what is innate).

Hypothesis 1: Music is not genetically coded in humans. Our physical apparatus is the innate factor that constrains musical evolution: physiology of the brain, auditory capacity (psychoacoustics), motor abilities, etc.

Hypothesis 2: Music is (mostly) a cultural convention.

"Everybody knows what music is, but that is not to say that everybody agrees on what music is." (Biles, to appear)

- **Music**: *temporally organised sound.* *(Biles)*
  - Radio
  - Bird songs
  - Ambient sounds of daily life

- Complex vocalizations had been found in:
  - Many birds *(Marler and Slabbekoorn, 2004),*
  - Mammals such as whales *(Payne and McVay, 1971),*
  - Bats *(Behr and von Helversen, 2004),*
  - Mice *(Timothy Holy and Zhongsheng Guo, 2005)*
  - …

- Primates are not as “musical” as a number of other animals that are genetically distant from us.

↓

Music might have evolved independently among various types of animals, at various degrees of sophistication.

↓

Robots might also be able to evolve Music.

Research: artificial evolution of music

Develop a theoretical framework based upon the notion that music is an adaptive complex dynamic system; i.e. emerge from the overall behaviour of interacting autonomous elements in a non-hierarchical manner

Software agents are programmed to interact co-operatively with one another, under specific physical (body/embodied) constraints and environmental conditions

Establish the fundamental properties and mechanisms that the agents, the interactions, and the environment must possess in order to create music

Experiment 1: Evolution of intonation

Rationale: if we furnish the agents with suitable cognitive and physical models, combined with realistic interaction dynamics and adequate environmental conditions, the agents should be able to evolve realistic (proto-)musical cultures ("would-be" music)

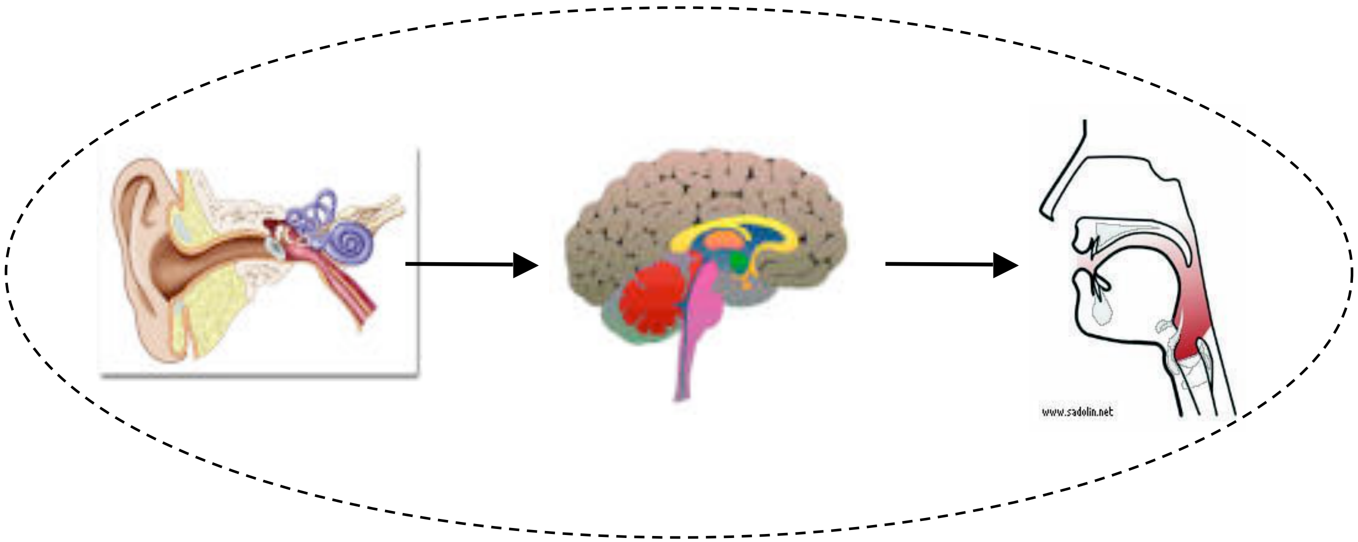
The experiment: A group of interactive agents furnished with appropriate motor, auditory and cognitive skills evolves a shared repertoire of intonations from scratch, after a period of spontaneous creation, adjustments and memory reinforcements

Methodology:

Distributed agent systems (or robots)
Agents are implemented with physical and cognitive capabilities
Simulation embodies cultural dynamics that may bootstrap the development of music

The anatomy of the agents

Hearing system
Voice/speech synthesiser
A “brain” (an associative memory and an “innate” enacting script)



- Voice Synthesizer: a physical model of the human vocal mechanism *(Boersma, 1993; Miranda, 2002).*
- Hearing apparatus: *it employs short-term autocorrelation-based analysis to extract the pitch contour of a vocal sound (Miranda, 2001).*
- Memory device holds:
  - The lexicon of sounds
  - Probabilities, thresholds and reinforcement parameters

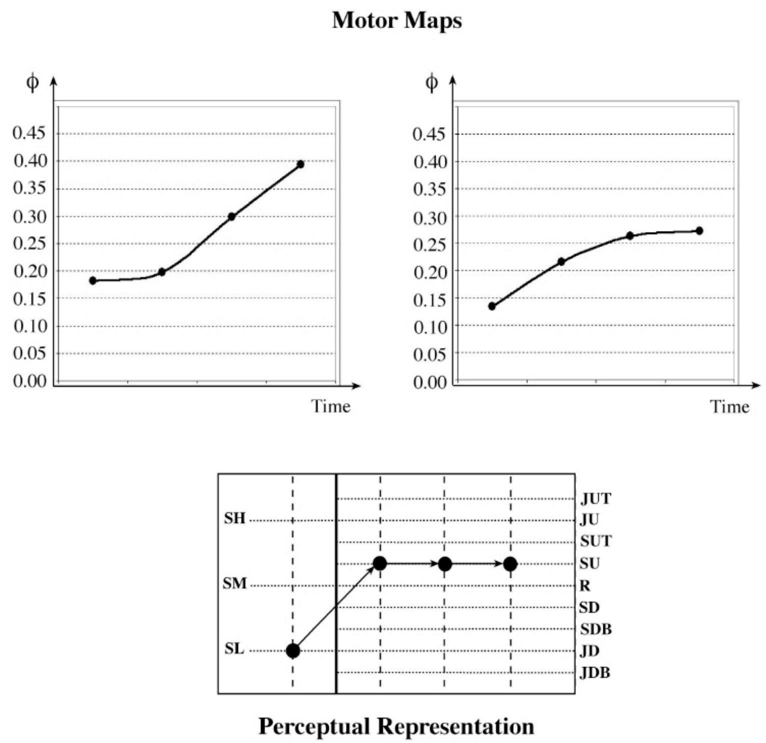
Architecture

Two modules are used to store sounds: a motor map and a perceptual map.

- The motor map stores information in terms of parameters for the voice synthesizer
- The perceptual map stores information in terms of evolution of frequency

Representation of sounds

Motor Maps: a function of pitch controllers (stiffness of vocal folds, lung pressure, etc.)



Motivation and basic instinct

Motivation: to form a repertoire of intonation in their memories and foster **social bonding**

In order to be sociable, an agent must form a repertoire that is similar to the repertoire of its peers

Sociability is assessed in terms of the similarity of the agent's repertoires

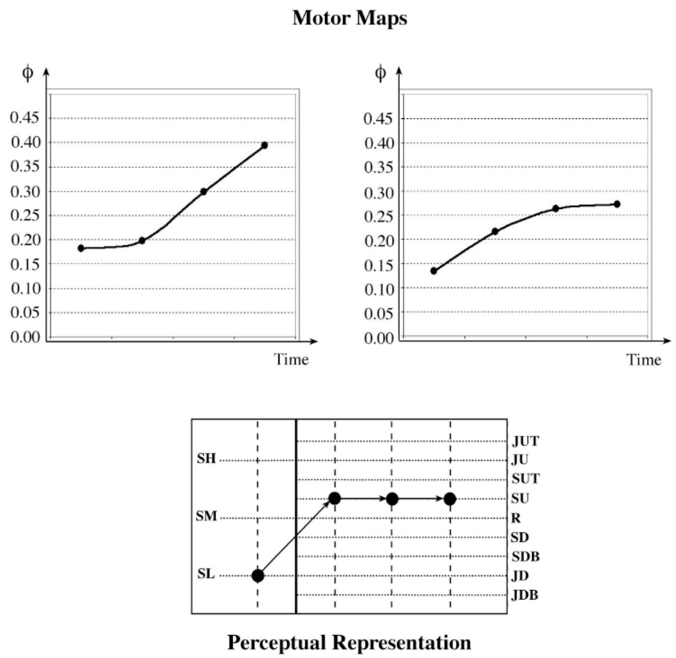
Basic Instinct: **Imitation**

Hypothesis: Mimesis is one of the key to bootstrap music in the artificial society.

What is imitation in this context?

Task of hearing an intonation
and activating the motor system
to reproduce it

Shared repertoire: the perceptual
representation in the memory
of the agents should be
dentical,
or at least very close to each
other, but the motor maps may
be different

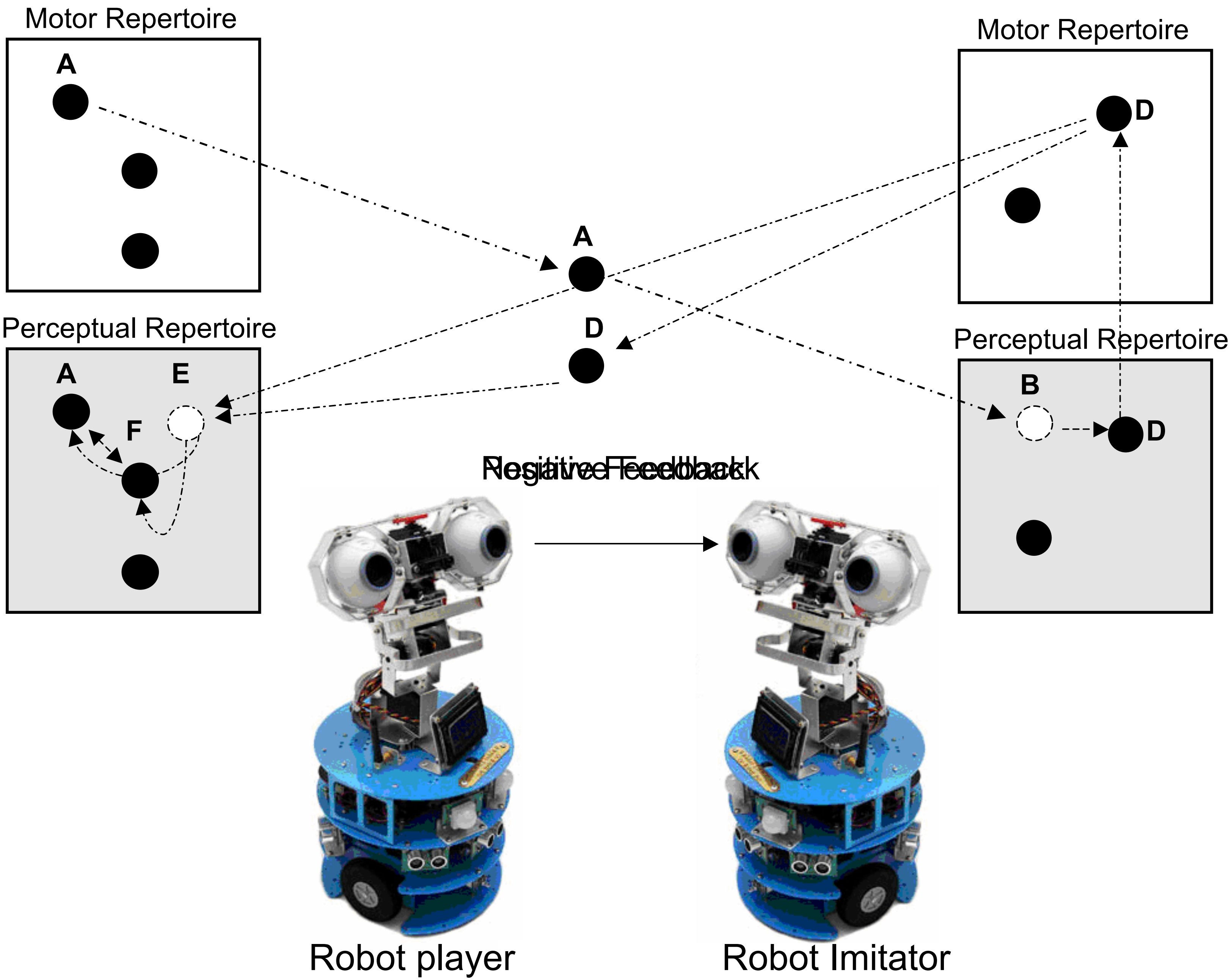


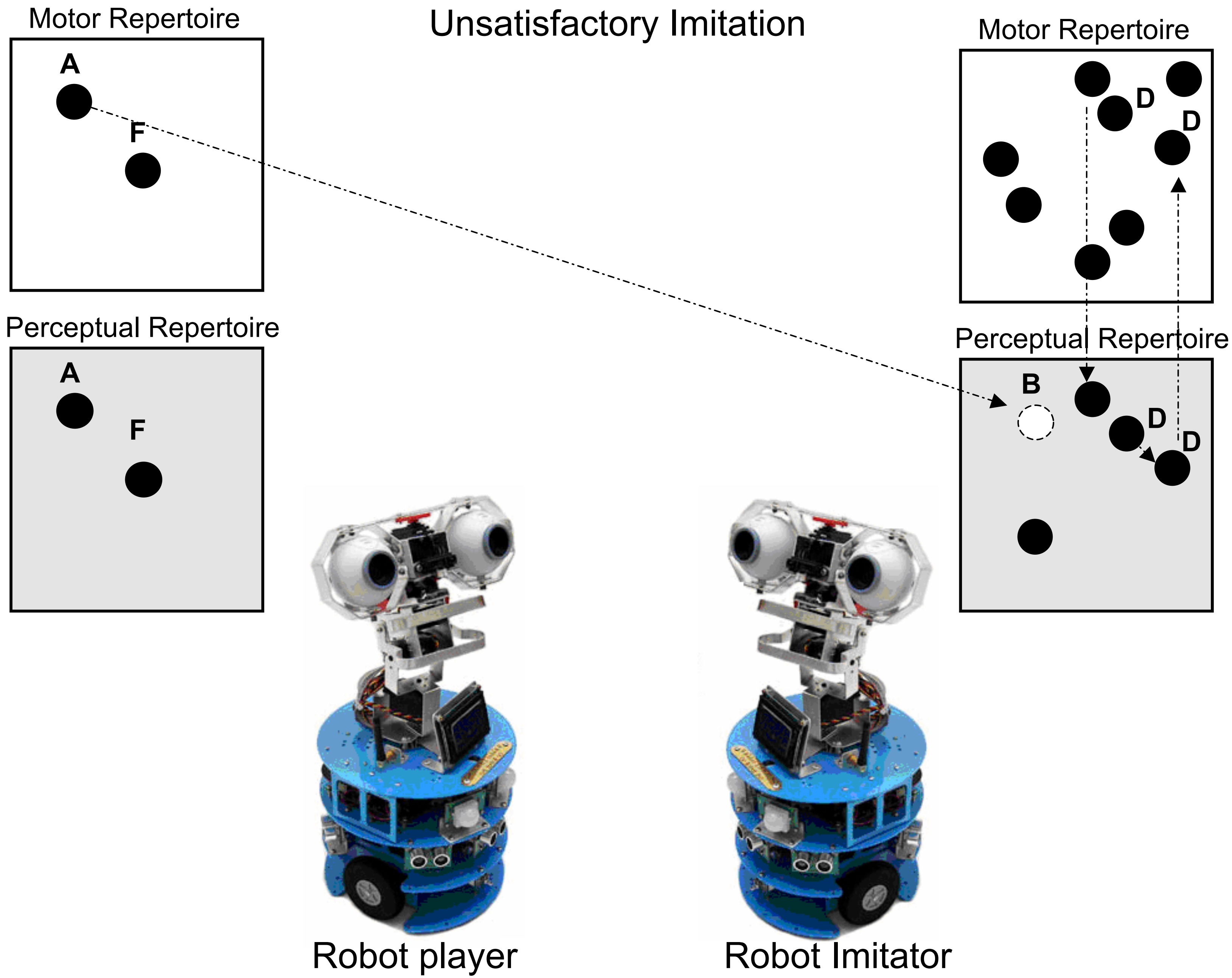
The enacting script

agent-player - AP	agent-imitator - AI
{ IF *repertoire(AP)* not empty pick motor control for ***snd(X)***; produce ***snd(X)***; ELSE generate random motor control for ***snd(X)***; add ***snd(X)*** to *repertoire(AP)*; produce ***snd(X)***; }	{ analyse ***snd(X)*** } { build perceptual representation; } { IF *rep(AI)* not empty ***snd(Y)*** = most perceptually similar to ***snd(X)***; ELSE generate random motor control for ***snd(Y)***; add ***snd(Y)*** to *rep(AI);* produce ***snd(Y)***; }

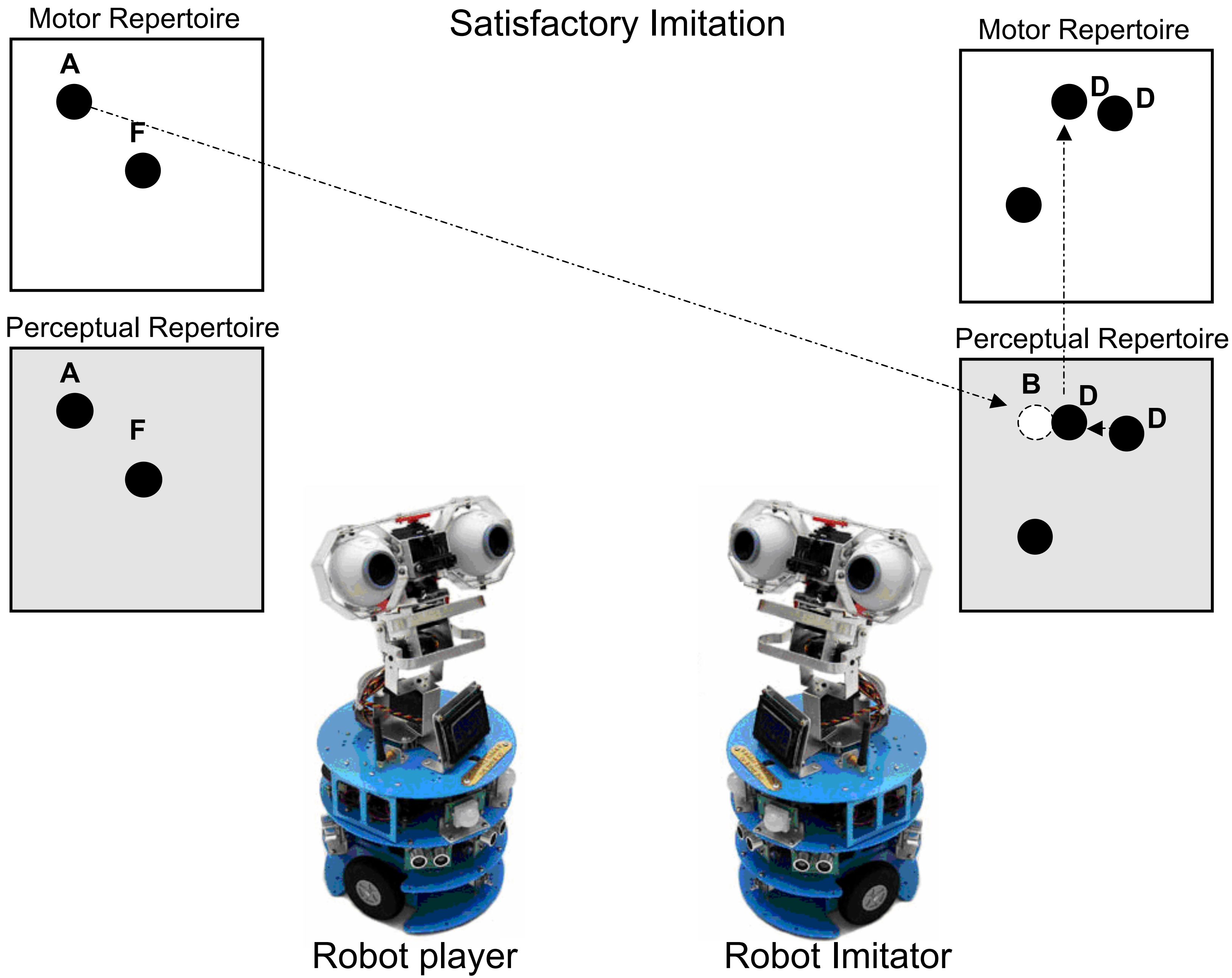
{ analyse ***snd(Y)***; }
{ build perceptual representation; }
{ ***snd(Z)*** = most perceptually similar to ***snd(Y)***; }
{ IF ***snd(Z)*** = ***snd(X)***
send positive feedback to AI;
reinforce ***snd(X)*** in *repertoire(AP)*;
ELSE
send negative feedback to AI; }
	{ IF feedback = positive
	approximate ***snd(Y)*** to ***snd(X)*** perceptually;
	generate appropriate motor control;
	reinforce ***snd(Y)*** in *repertoire(AI)*; }
	{ IF feedback = negative
	IF ***snd(Y)*** holds high reinforcement score;
	execute *add_new_similar(**snd(N)**)*;
	ELSE
	approximate ***snd(Y)*** to ***snd(X)*** perceptually;
	generate appropriate motor control; }

{ execute *final_updates(AP)*; }	{ execute *final_updates(AI)*; }


Motor Repertoire
A
Perceptual Repertoire
A
E
F
Motor Repertoire
D
A
D
Perceptual Repertoire
B
D
Negative Feedback
Positive Feedback
Robot player
Robot Imitator



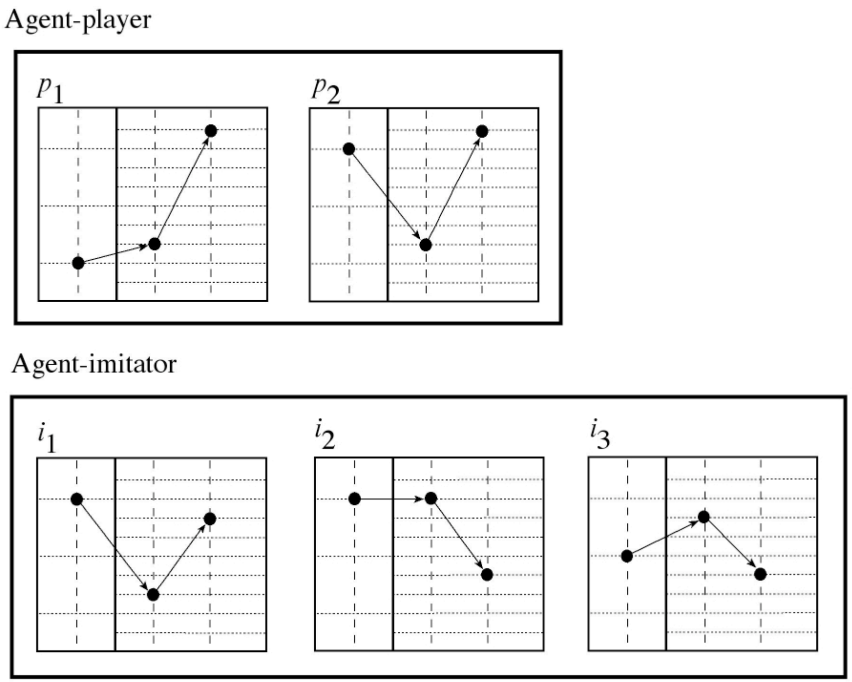
Unsatisfactory Imitation
Motor Repertoire
A
F
Perceptual Repertoire
A
F
Motor Repertoire
D
D
Perceptual Repertoire
B
D
D
Robot player
Robot Imitator


Satisfactory Imitation
Motor Repertoire
A
F
Perceptual Repertoire
A
F
Motor Repertoire
D
D
Perceptual Repertoire
B
D
D
Robot player
Robot Imitator

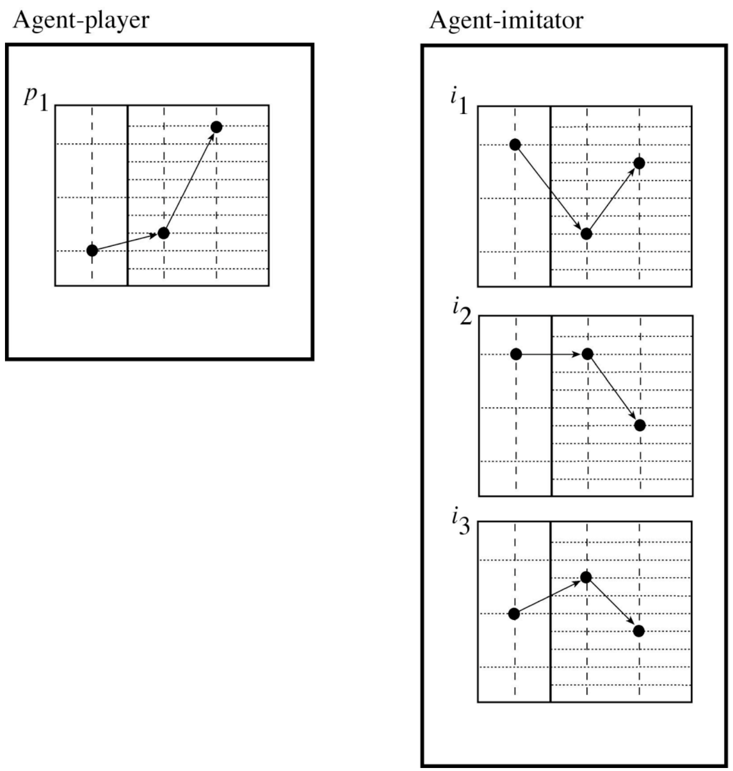
Play movie

Examples of the enacting script in action

AP = p_1
AI = i_1
i_1 closer to p_2

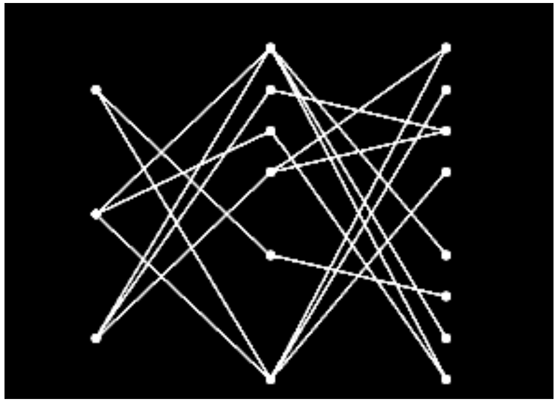


AP = p_1
AI = i_1
i_1 closer to p_1

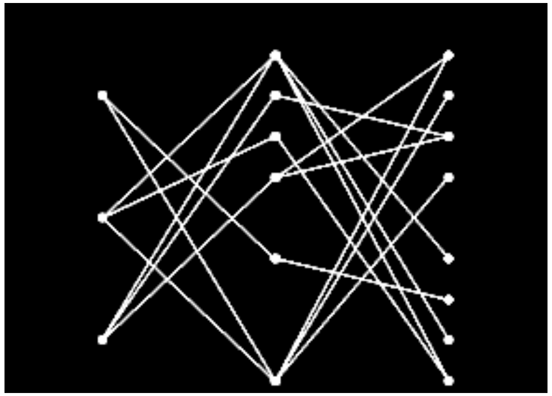


“Brain scans” : evolved repertoire

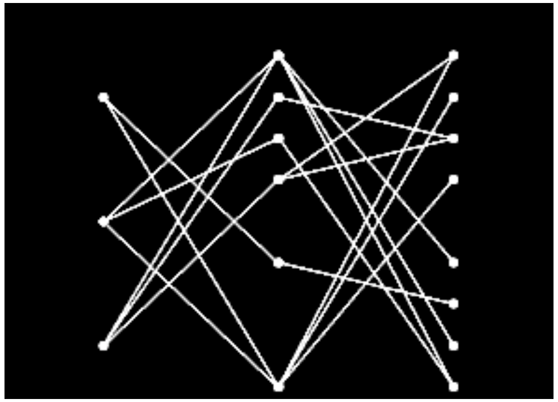
Ag-x



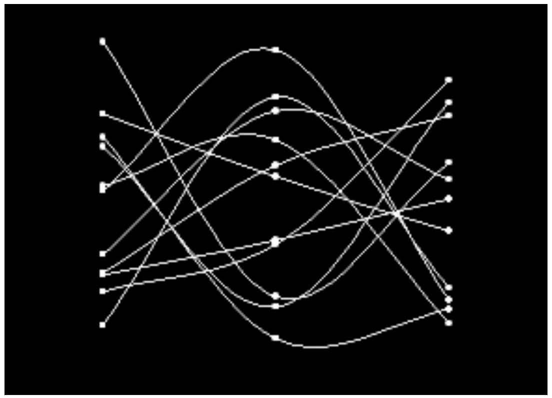
Ag-y



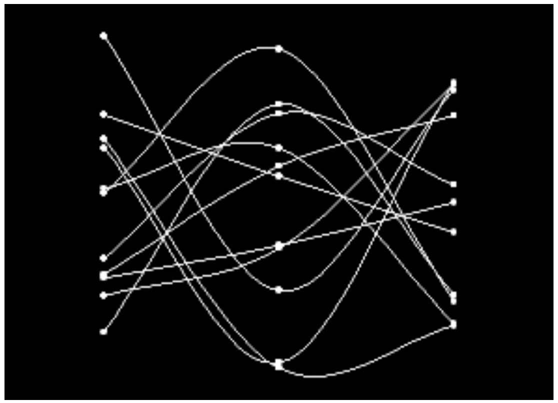
Whole community



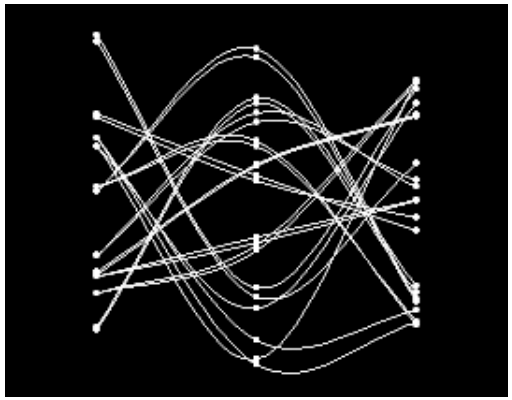
Ag-p



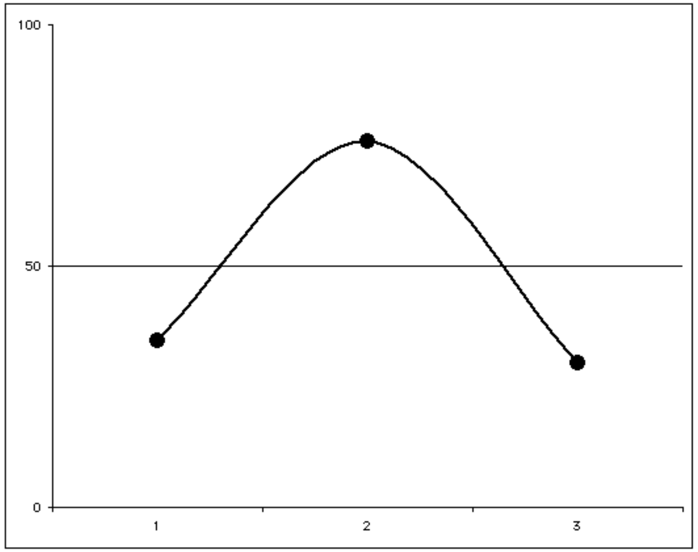
Ag-q

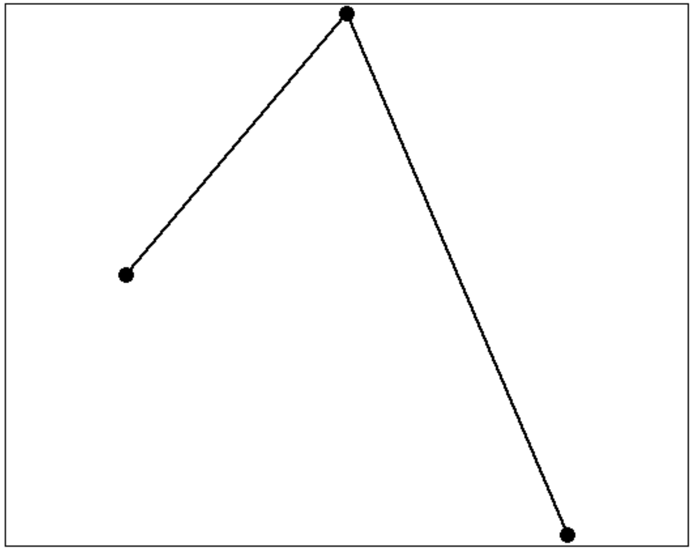


Ag-p + Ag-q



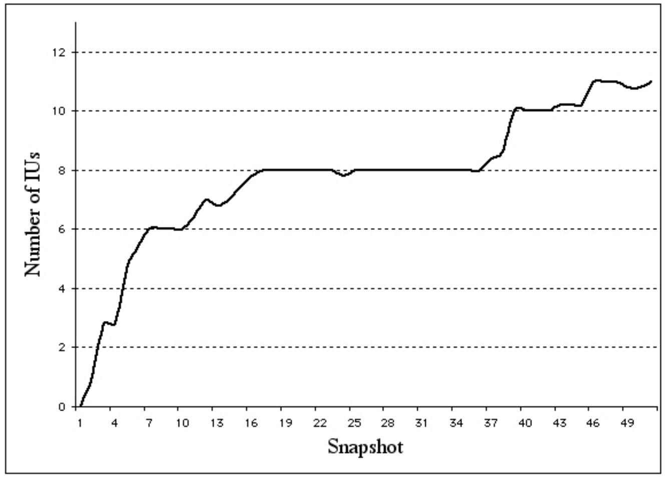
The evolution of the repertoire of an agent



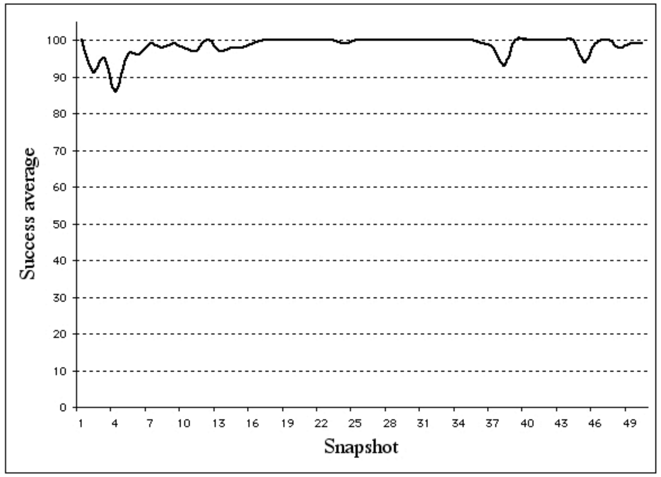


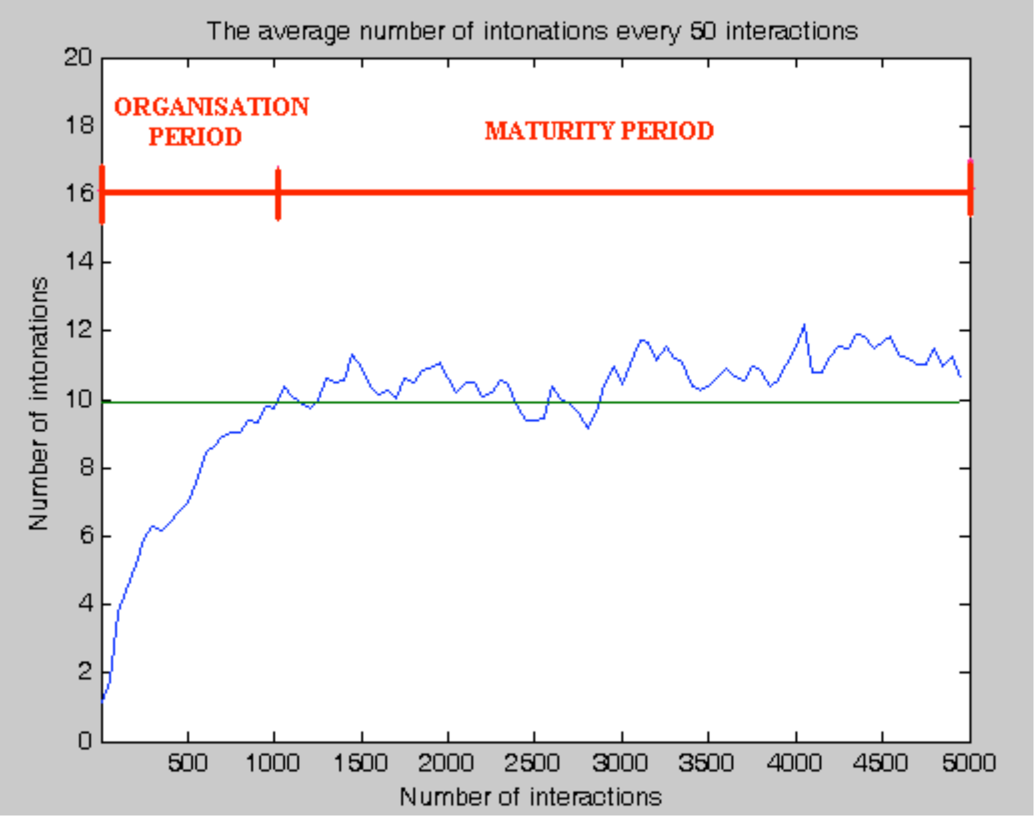
Monitoring evolution

Average size of the repertoire of the community



Imitation success





Pattern of behaviour

Comments

- The community’s repertoires of sounds invariably reach a point of stability
- The adaptation time varies according to the number of agents and the sound’s length
- More interactions are needed to stabilize the shared repertoire when the number of agents increases.
- When the number of intonations per sound increases or when it becomes variable, the time the community takes to organise is also greater.

- When using longer sounds, the average size of the robots' repertoires increases greatly. At the same time, the number of sounds shared by every agent in the community decreases.

- Longer sounds, put together with more agents make the community to self-organise into smaller groups.

- The self-organisation of the community emerges from their interactions.

- This research is encouraging because it provides strong indications that music can emerge from a society of autonomous robots.

- The model is limited in the sense that the way music is treated is not complex enough to be considered as a musical performance.

Experiment 2: evolution of musical grammar with semantics

The agents produce tunes to express specific moods;
e.g., sad tunes, happy tunes, etc.

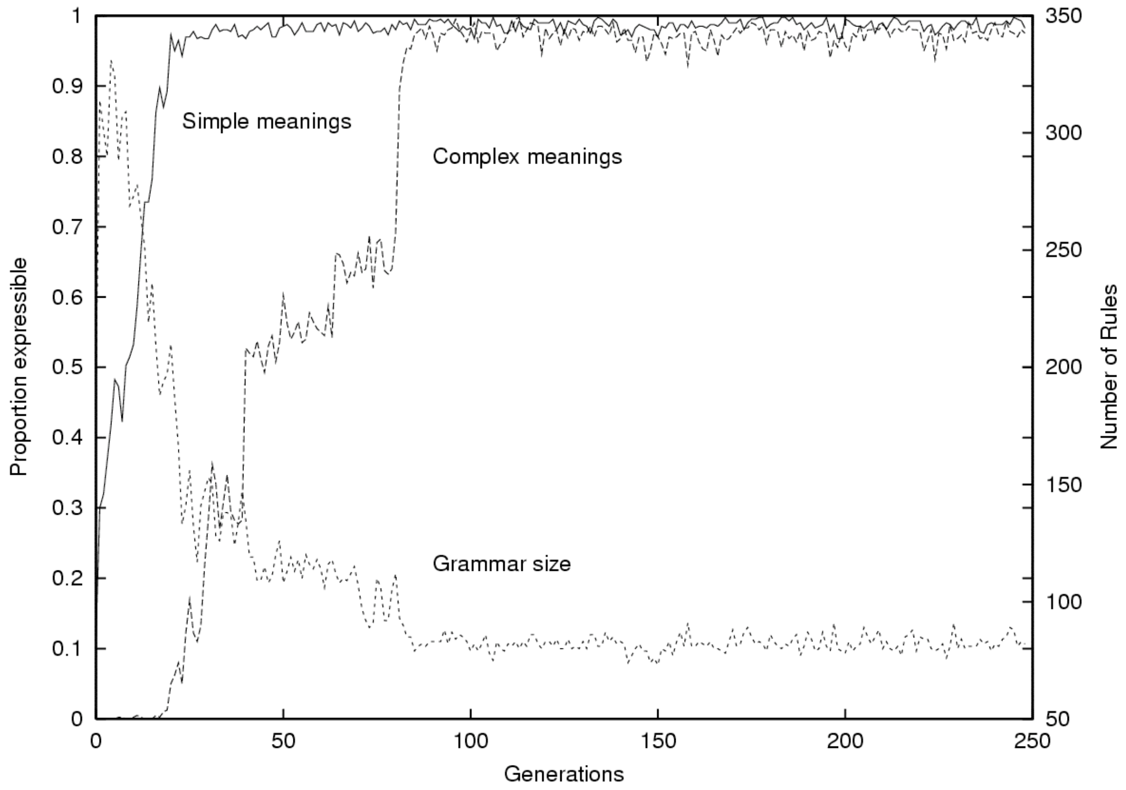
Agent “children” abstract grammatical rules from tunes produced by their “parents” over a number of generations.
(Cultural transmission; not genetic)

The agents develop grammars for generating tunes to express these moods.

Agents play a physical model of a flute

The notes are the same as for the notes produced by one of the pre-historic bone flutes found in China (9,000 years old).

Sample result



As the musical culture evolves more and more emotions become expressible and, at the same time, the size of the grammar goes down.

Ultimately, the agents are able to express arbitrarily complex emotions by using a condensed, structured, recursive grammar.

Audio excerpts of a simulation:

“joyous” tune

“introspective” tune