IAT 811: Metacreation
Machines endowed with creative behavior

Aka Computational Poetics

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Assignments: for this week

- Submit a proposal for the theoretical research:
  - The proposal (1 page) should:
    - Name the Metacreation you will focus on
    - Name the tools used (should be in the list of topics)
    - Include the proper bibliographic references (send me the PDF/scanned texts) – at least 3
  - Let's go through the different proposals
  - Ways to find projects: use the reading list, search for conference proceedings, ...
  - Let's talk about the scheduling of the presentations
  - ...
- Start thinking about your project
- Do you know Latex?

List of possible metacreations

1. Bob (Belinda Thom, Carnegy Melon University) – Sound - Agent/Unsupervised learning
2. Kinetic Engine (Arne Engelfeld, SFU, Vancouver) – Sound - MAS
3. VMMAS (Whulfhorst, UFRGS, Rio) – sound - MAS
4. Virtualatin (David Murray-Rust, University of Edinburgh) – sound - Agent/MAS
5. ANDANTE (Leo Ueda, University of Sao Paolo) - sound - Agent
6. Eden (Mc Cormack, CEMA, Melbourne) – visual - MAS/A-life
7. Continuator (Francois Pachet,, Sony lab Paris) – sound - HMM
8. O-MAX Brothers (Assayag, Ircam, Paris) – sound - statistical learning + MAS
9. CONCERT (Mozert, University of Colorado) – sound - neural network
10. CBR (Lewis, New York Technology Institute) – neural network
11. Chaosynth and CAMUS (Eduardo Miranda, Plymouth) – sound - cellular automata
12. GenJam (John Biles, Rochester Institute of Technology) - sound – genetic algorithm
13. Genetic images (Karl Sim, GenArts, Cambridge) – visual - genetic algorithm
14. Electric Sheeps (Scott Draves , Dreamworks, San Fransisco), - visual - genetic algorithm and fractals
15. Iconica (Troy Innocent, CEMA, Melbourne) – visual - A-life
16. Various Works (Christa Sommerer & Laurent Mignonneau Art) - visual - A-life
17. An interactive MIDI accompanist. (Toiviainen, P.) - sound - agent
18. SPAA or AALIVENET (Michael Spicer, Singapore) – sound - agent based
19. AARON (Harold Cohen) – visual - Expert System

- By looking at the reference lists of publications on these, you will find a lot more, ...

Assignments: for this week

- **Send me your answers to the questions about your background, "a little bit about you" (Maximum 2 pages)**
- **Readings:**
  - Stephen Wilson, Artificial intelligence research as art, SEHR, volume 4, issue 2: Constructions of the Mind, Updated July 22, 1995 (available at: http://www.stanford.edu/group/SHR/4-2/text/wilson.html)
  - M. Wooldridge and N. R. Jennings. Intelligent Agents: Theory and Practice. In Knowledge Engineering Review 10(2), 1995. (Available from the authors' web page). Section 4 can be skipped (deprecated).
  - Russel and Norvig ("the bible"), Artificial intelligence: A modern approach (second ed.). Upper Saddle River, NJ: Prentice Hall. Chapters 1&2.

In-class discussion: readings

- Stephen Wilson, Artificial intelligence research as art, SEHR, volume 4, issue 2: Constructions of the Mind, Updated July 22, 1995
- Parenthesis:
  - Wilson says: “Indeed, computer simulation of human understanding may require multimodal sensual data collection in ways we don't yet understand. Perhaps one day we will even know enough to allow communication via extrasensory perception and emanation or direct reading of brain waves.”
  - This domain is called brain computer interface (BCI) and is pretty established now (advanced enough for the first real world application to be soon marketed!).

In-class discussion: readings

- M. Wooldridge and N. R. Jennings. Intelligent Agents: Theory and Practice. In Knowledge Engineering Review 10(2), 1995. (Available from the authors' web page). Section 4 can be skipped (deprecated).
- Russel and Norvig ("the bible"), Artificial intelligence: A modern approach (second ed.). Upper Saddle River, NJ: Prentice Hall. Chapters 1&2.
- Because of the innovative topic of the course, most of our scientific readings will not be oriented toward metacreation per se. This course is an attempt to do knowledge transfer.
- We will see that things get better with A-life, a domain that as always been more open toward artistic creation, probably because of the intrinsic generative nature of the A-life techniques
- We will have to do some case studies: your presentations + a number of other systems that I will present/discuss and that you will read about.

?

Outline of today's lecture

1. Autonomous agents (Part 1)
    1. Introduction to the field
    2. Cognitive agents: the BDI model
    3. Case study: the shadow agent
2. Break
3. A two dimensional analysis of media arts
4. Assignments: for next week

Autonomous Agents (Part 1)

Based on, and inspired by slides from:
Michael Wooldridge, Jeff Rosenshein, Stuart Russel and Perter Norvig

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Artificial Intelligence

"... artificial intelligence [AI] is the science of making machines do things that would require intelligence if done by [humans]"

Marvin Minsky, 1963

- Two stances on theoretical or applied AI:
  - AI is one of the cognitive sciences. More precisely, the one that strive to model and simulate (in order to validate or invalidate) the theories advanced by the others.
  - AI is a moving front of advanced computer sciences. More precisely, developing techniques and tools that address more and more complex (in the sense of the previous definition) problems.

Artificial Intelligence

- Views of AI fall into four categories:
  - Thinking humanly (or animally):
    - High level, top down approaches: psychology, ethology, ...
    - Low level, bottom up approaches: neurosciences, animal biology, ...
  - Acting humanly: same but with a black box approach (e.g. Eliza, Turing test oriented AI)
  - Thinking rationally: search for the "laws of though" that started with Greek philosophers. In line with mathematics (logic) and analytic philosophy.
  - Acting rationally: doing the most performant (optimal) action(s) given the task (unbounded vs. bounded rationality).

→ Most of the textbooks take the last stance (dominant for economical reasons)

Artificial Intelligence

- **State of the art (partial):**
  - Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997
  - Proved a mathematical conjecture (Robbins conjecture) unsolved for decades
  - No hands across America (driving autonomously 98% of the time from Pittsburgh to San Diego)
  - During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people
  - NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft
  - `Proverb` solves crossword puzzles better than most humans
  - ...

→ **We reached the age of human-competitive AI in many domains**

Autonomous agents

- Simplified ontology of the world:
  - Whatever is not a concept has to be either an object or an agent.
  - Objects are not pro-active
  - Agents are (functions from percepts to actions: [f: $\mathcal{P}^* \rightarrow \mathcal{A}$])
- The idea of agents take roots in philosophy but also corresponds to an evolution of computer science and software engeeniring:
  - Machine code, assembly language
  - Machine-independent programming languages
  - Procedural and functional programming (C, ...)
  - Objects oriented programming (JAVA, C++, ...)
  - Agents oriented programming (JASON, 3APL, Jack, ...)

Autonomous agents

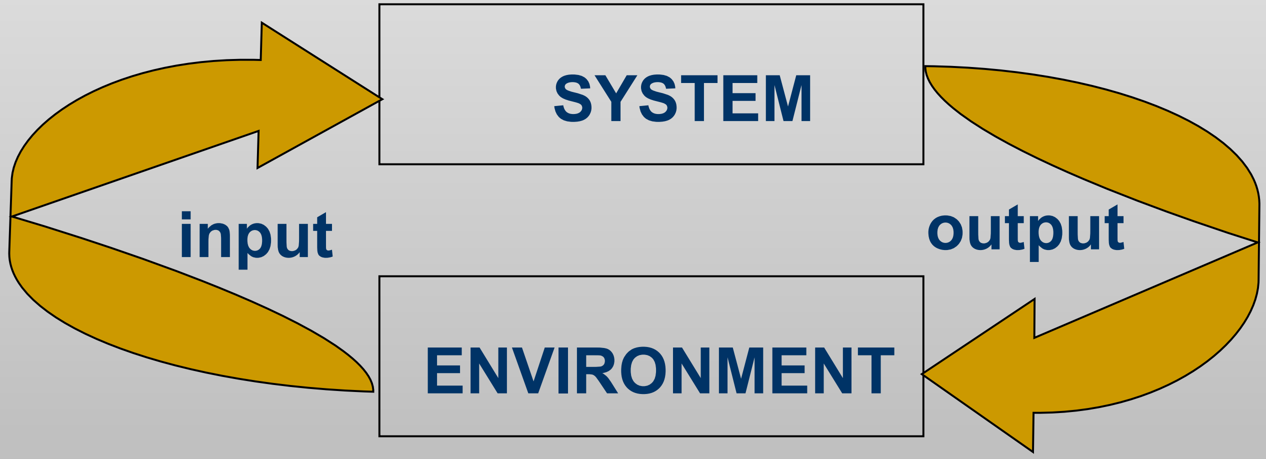
- A definition: An **agent** is a computer system that is capable of ***independent*** (autonomous) action on behalf of its user or owner (figuring out what needs to be done to satisfy design objectives, rather than constantly being told)
- A **multiagent system** is one that consists of a number of agents, which ***interact*** with one-another
- Two dimensions have to be considered:
  - Agent design
  - Society design

Agents and multiagent systems

- While these questions are addressed in part by other disciplines (notably economics and social sciences), what makes the multiagent systems field unique is that it emphasizes that the agents in question are *computational* entities.
- Agents and multiagent systems (**MAS**) is a new field (90'):
  - New paradigm in software engineering: agents can not be reduced to objects (autonomy and pro-activity)
  - Usefull in cognitive sciences: study of real agents and agent societies through simulation

Autonomous agents

- An agent is a computer system capable of autonomous action *in some environment* in order to meet its design objectives



Environment

Accessible (observable) vs. *inaccessible*

- An accessible environment is one in which the agent can obtain complete, accurate, up-to-date information about the environment's state (ex, chess)
- Most moderately complex environments (including, for example, the everyday physical world and the Internet) are inaccessible
- The more accessible an environment is, the simpler it is to build agents to operate in it

Environment

Deterministic vs. *non-deterministic*

- A deterministic environment is one in which any action has a single guaranteed effect — there is no uncertainty about the state that will result from performing an action
- The physical world can to all intents and purposes be regarded as non-deterministic
- Non-deterministic environments present greater problems for the agent designer
- A stochastic environment is one in which any action can have several effects each with a certain probability (one of the main framework for dealing with uncertainty in AI).

Environment

Episodic vs. *non-episodic*

- In an episodic environment, the performance of an agent is dependent on a number of discrete episodes, with no link between the performances of an agent in two different episode.
- Episodic environments are simpler from the agent developer's perspective because the agent can decide what action to perform based only on the current episode — it does not need to reason about the interactions between this and future episodes
- Example one-shot games versus iterated games

Environment

Static vs. *dynamic*

- A static environment is one that can be assumed to remain unchanged except by the performance of actions by the agent
- A dynamic environment is one that has other processes (e.g., agents) operating on it, and which hence changes in ways beyond the agent's control
- Other processes can interfere with the agent's actions (as in concurrent systems theory)
- The physical world is a highly dynamic

Environment

Discrete vs. *continuous*

- An environment is discrete if there are a fixed, finite number of actions and percepts in it
- Russell and Norvig give a chess game as an example of a discrete environment, and taxi driving as an example of a continuous one
- Continuous environments have a certain level of mismatch with computer systems
- Discrete environments could *in principle* be handled by a kind of "lookup table". Given the agent goal, for each (state, perception) the table would indicate what "optimal" action should be performed.

Agents as Intentional Systems

- When explaining human activity, it is often useful to make statements such as the following:
  - Philippe took his umbrella because he *believed* it was going to rain.
  - James worked hard because he *wanted* to graduate.
- These statements make use of a *folk psychology*, by which human behavior is predicted and explained through the attribution of *attitudes*, such as believing and wanting (as in the above examples), hoping, fearing, and so on.
- The attitudes employed in such folk psychological descriptions are called the *intentional* notions

Agents as Intentional Systems

- **The philosopher Daniel Dennett coined the term intentional system to describe entities "whose behavior can be predicted by the method of attributing belief, desires and rational acumen"**
- **Dennett identifies different 'grades' of intentional system:**
  "A first-order intentional system has beliefs and desires (etc.) but no beliefs and desires about beliefs and desires. …A second-order intentional system is more sophisticated; it has beliefs and desires (and no doubt other intentional states) about beliefs and desires (and other intentional states) both those of others and its own"
- **Infinite regression has to be avoided (computational limit)**

➡ **Is it legitimate or useful to attribute beliefs, desires, and so on, to computer systems?**

Agents as Intentional Systems

- **McCarthy argued that there are occasions when the *intentional stance* is appropriate:**

'To ascribe *beliefs*, *free will*, *intentions*, *consciousness*, *abilities*, or *wants* to a machine is *legitimate* when such an ascription expresses the same information about the machine that it expresses about a person. It is *useful* when the ascription helps us understand the structure of the machine, its past or future behavior, or how to repair or improve it. It is perhaps never *logically required* even for humans, but expressing reasonably briefly what is actually known about the state of the machine in a particular situation may require mental qualities or qualities isomorphic to them. Theories of belief, knowledge and wanting can be constructed for machines in a simpler setting than for humans, and later applied to humans. Ascription of mental qualities is *most straightforward* for machines of known structure such as thermostats, elevators or computer operating systems, but is *most useful* when applied to entities whose structure is incompletely known'.

Agents as Intentional Systems

- **What objects can be described by the intentional stance?**
- **As it turns out, more or less anything can. . . consider a light switch:**

"It is perfectly coherent to treat a light switch as a (very cooperative) agent with the capability of transmitting current at will, who invariably transmits current when it believes that we want it transmitted and not otherwise; flicking the switch is simply our way of communicating our desires". (Yoav Shoham)

- **But most adults would find such a description absurd!**

→ **Why is this?**

Agents as Intentional Systems

- The answer seems to be that while the intentional stance description is consistent, ". . . it does not *buy us anything*, since we essentially understand the mechanism sufficiently to have a simpler, mechanistic description of its behavior." (Yoav Shoham)
- Put crudely, the more we know about a system, the less we need to rely on animistic, intentional explanations of its behavior
- But with very complex systems, a mechanistic, explanation of its behavior may not be practicable
- *As computer systems become ever more complex, we need more powerful abstractions and metaphors to explain their operation — low level explanations become impractical. The intentional stance is such an abstraction*

Agents as Intentional Systems

- The intentional notions are thus *abstraction tools*, which provide us with a convenient and familiar way of describing, explaining, and predicting the behavior of complex systems
- Remember: most important developments in computing are based on new *abstractions*:
  - Procedural abstraction
  - Abstract data types
  - Objects
- Agents, and agents as intentional systems, represent a further, and increasingly powerful abstraction
- So agent theorists start from the (strong) view of agents as intentional systems: one whose simplest consistent description requires the intentional stance

Agents as Intentional Systems

- This *intentional stance* is an *abstraction tool* — a convenient way of talking about complex systems, which allows us to predict and explain their behavior without having to understand how the mechanism actually works
- Now, much of computer science is concerned with looking for abstraction mechanisms (witness procedural abstraction, objects,…)
  So why not use the intentional stance as an abstraction tool in computing — to explain, understand, and, crucially, program *computer systems?*
- This is an important argument in favor of agents

Agents as Intentional Systems

- Three other points in favor of this idea:
- Characterizing Agents:
  1. It provides us with a familiar, non-technical way of *understanding & explaining* agents
- Nested Representations:
  2. It gives us the potential to specify systems that *include representations of other systems*
  3. It is widely accepted that such nested representations are essential for agents that must cooperate with other agents

Agents as Intentional Systems

- **Post-Declarative Systems**:
  - This view of agents leads to a kind of post-declarative programming:
    - In procedural programming, we say exactly *what* a system should do
    - In declarative programming (Prolog), we state what we want to achieve, give the system general info about the relationships between objects, and let a built-in control mechanism (e.g., goal-directed theorem proving) figure out what to do
    - With agents, we give a very abstract specification of the system, and let the control mechanism figure out what to do, knowing that it will act in accordance with some built-in theory of agency (e.g., the well-known Cohen and Levesque model of intention)

Types of agents architectures

- An agent is a computer system capable of flexible autonomous action…
- Three types of agent *architecture*:
  - Cognitive: mental attitudes and representations of the environment (including other agents)
  - Reactive: no representation of the environment
    - Reflex: no internal states (just input->output rules mapping perception and action)
    - Reactive: with internal states (but not cognitive)
  - Hybrid: mixing reactive and cognitive components

Cognitive Agents – BDI model

- The BDI model of cognitive agent is inspired by the philosophy of practical reasoning (analytical philosophy of mind)
- The **mental attitudes**: beliefs, desires and intentions
- Human **practical reasoning** consists of two activities:
  - **deliberation:** deciding **what** state of affairs we want to achieve
  - **means-ends reasoning:** deciding **how** to achieve these states of affairs
- The outputs of deliberation are **intentions**

BDI model – Beliefs

- Beliefs are used to represent:
  - The state of the world
  - The know-how
- Beliefs can be wrong (different from knowledge)
- Beliefs are updated by:
  - Perception (internal or external): beliefs have to be revised (non monotonic)
  - Reasoning:
    - Perfect rationality: logical omniscience (not computational)
    - Bounded rationality: heuristic strategies
- Beliefs can be graduated and thus not necessarily consistent but some level of coherence is maintained

BDI model – Desires

- While beliefs are informational attitudes, desires are motivational ones
- Desires are not necessarily consistent (typically, they are not)
- Desires are not necessarily achievable
- Desires are usually given (or specified by a rule system depending on perceptions)
- Deliberation is the process of choosing which desires are to be pursued according to the current beliefs
- Deliberation results in intentions (selection function taking beliefs and desires as its inputs)

Properties of Intentions

- **Intentions pose problems for agents, who need to determine ways of achieving them.**
  If I have an intention to ϕ, you would expect me to devote resources to deciding how to bring about ϕ.
- **Intentions provide a "filter" for adopting other intentions, which must not conflict.**
  If I have an intention to ϕ, you would not expect me to adopt an intention ψ such that ϕ and ψ are mutually exclusive.
- **Agents track the success of their intentions, and are inclined to try again if their attempts fail.**
  If an agent's first attempt to achieve ϕ fails, then all other things being equal, it will try an alternative plan to achieve ϕ.

Properties of Intentions

- **Agents believe their intentions are possible.**
  That is, they believe there is at least some way that the intentions could be brought about.
- **Agents do not believe they will not bring about their intentions.**
  It would not be rational of me to adopt an intention to ϕ if I believed ϕ was not possible.
- **Under certain circumstances, agents believe they will bring about their intentions.**
  It would not normally be rational of me to believe that I would *bring my intentions about; intentions can* fail. *Moreover, it does not make sense that if I believe ϕ is inevitable that I would adopt it as an intention.*

Properties of Intentions

- Agents need not intend all the expected side effects of their intentions.
  If I believe $\phi \rightarrow \psi$ and I intend that ϕ, I do not necessarily intend ψ also. (Intentions are not closed under implication.)
- This last problem is known as the *side effect* or *package deal* problem. For example:
  – I may believe that going to the dentist involves pain, and I may also intend to go to the dentist
  – But this does not imply that I intend to suffer pain!
- Also note that mental attitudes can be nested:
  – I believe he intend me to believe it!

Properties of Intentions

- **Notice that intentions are much stronger than mere desires:**

  "My desire to play basketball this afternoon is merely a potential influencer of my conduct this afternoon. It must vie with my other relevant desires [. . .] before it is settled what I will do. In contrast, once I intend to play basketball this afternoon, the matter is settled: I normally need not continue to weight the pros and cons. When the afternoon arrives, I will normally just proceed to execute my intentions." (Bratman, 1990)

BDI model – Mean-end reasoning

- **Mean-end reasoning**: in order to determine how intentions will be achieved the agent is trying to generate a plan (planing is a domain on its own)
- A **plan** is a sequence of actions
- (Deterministic) **actions** are represented using (STRIP style):
  - a *name* which may have arguments
  - a *pre-condition list:* list of facts which must be true for action to be executed
  - a *delete list:* list of facts that are no longer true after action is performed
  - an *add list:* list of facts made true by executing the action

} Expressed in terms of beliefs

BDI agents – basic algorithm

BDI-interpreter

- (B,D,I):= Initialize-state();
- While true do
  - Update(B,D, I); // perceptions may update beliefs, desires and intentions (ex. Once fulfilled, an intention is dropped)
  - Options:= option-generator(B,D,I);
  - Selected-options:=deliberate(B,D,I);
  - Update-intentions(Selected-options,I);
  - Plan:=Planing(I,B);
  - Execute(Plan);
  - Get-new-perceptions();
- End While

BDI agent – commitment strategy

- The following *commitment strategies* are commonly discussed in the literature of rational agents:
  - *Blind commitment*
    A blindly committed denies any changes to its beliefs or desires that would conflict with its intentions. The agent will therefore continue to maintain an intention until it believes the intention has actually been achieved. Blind commitment is also sometimes referred to as *fanatical* commitment.
  - *Single-minded commitment*
    A single-minded entertains changes to beliefs that conflict with its intentions. The agent will therefore continue to maintain an intention until it believes that either the intention has been achieved, or else that it is no longer possible to achieve the intention.
  - *Open-minded commitment*
    An open-minded agent entertains changes to beliefs and desires that can conflict with its intentions. The agent will maintain an intention as long as it is still desired and believed possible
- These are just variations of the update function

BDI agent – commitment strategy

- An agent has commitment both to *ends* (i.e., the wishes to bring about), and *means* (i.e., the mechanism via which the agent wishes to achieve the state of affairs)
- Currently, our agent control loop is overcommitted, both to means and ends
- Several modification:
  - *replan* if ever something goes wrong during the plan execution (check after every action?)
  - Intention reconsideration: agent can reconsider his intentions during a plan execution - after every action (cautious) or never (bold)

➡ Raise a lot of other issues that we won't consider

BDI agents in practice

- **Practical agent programming environment:**
  - IRMA [Intelligent Resource Bounded Machine Architecture] – Lisp – 1987 – Bratman and Pollack
  - PRS [Procedural Reasoning system] – Lisp – 1988-89 – Georgeff and Lansky
  - dMars[Distributed Multi-Agent Reasoning System]-C++- 1997 – Inverno et al.
  - UM-PRS – Jam!- Java – 1999 - Michigan University
  - Jack – Java – 2000 - Agent Software
  - Jason – Java – extension of AgentSpeak - 2007
  - 3APL – 2007 – Logic programming (Prolog) and Java - Utrecht University
  - Jade - Java.

What is the link with metacreation?

- The BDI model for (rational) cognitive agents is:
  - A paradigmatic approach and one of the most advanced one: it gives you a flavour of the agent world!
  - Food for thought
  - Not directly exploited for metacreation

➡ There is room for many Ph.Ds here

  - Next week, we will study:
    - Reactive agents (heaps of applications in metacreation)
    - Hybrid systems and cognitive modeling (even more believable agents)
    - Case study of agent-based metacreations

Summary

- An agent is a computer system capable of **flexible autonomous** action in some **environment**.
- **Situatedness**: peceiving the environment via sensors and being abble to affect the environment via effectors
- **Autonomy**: capability of action without intervention, and control over internal state
- **Flexibility**:
  - Responsiveness: respond in a timely fashion to change in the environment
  - Pro-activity: actions which go beyond simple response to stimulus
  - **Sociability**: ability to interact with other agents and humans for mutual benefit

?

AI is anything in software that we don't know how to do yet.

Rudy Rawlins

Shadow Agent
A New Type of Virtual Agent

Philippe Pasquier
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HCI Lab, School of Media
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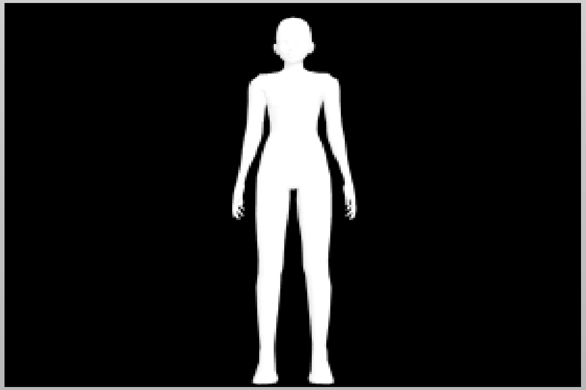
Shadow Agent: virtual agent architecture

- I will present it as an interactive art installation
- Outline:
  - Background and motivations:
    - Autonomous Agent
    - Virtual agents
  - The Shadow Agent Architecture
  - Potential Applications
  - Future Work



Autonomous Agents

- Artificial agents are systems that are:
  - Situated: perceive and act upon the environment
  - Autonomous: have control over their internal state and their actions even without external intervention

⇨ Pro-active: take decisions on their own
(not only reacting to the changes in their environment)

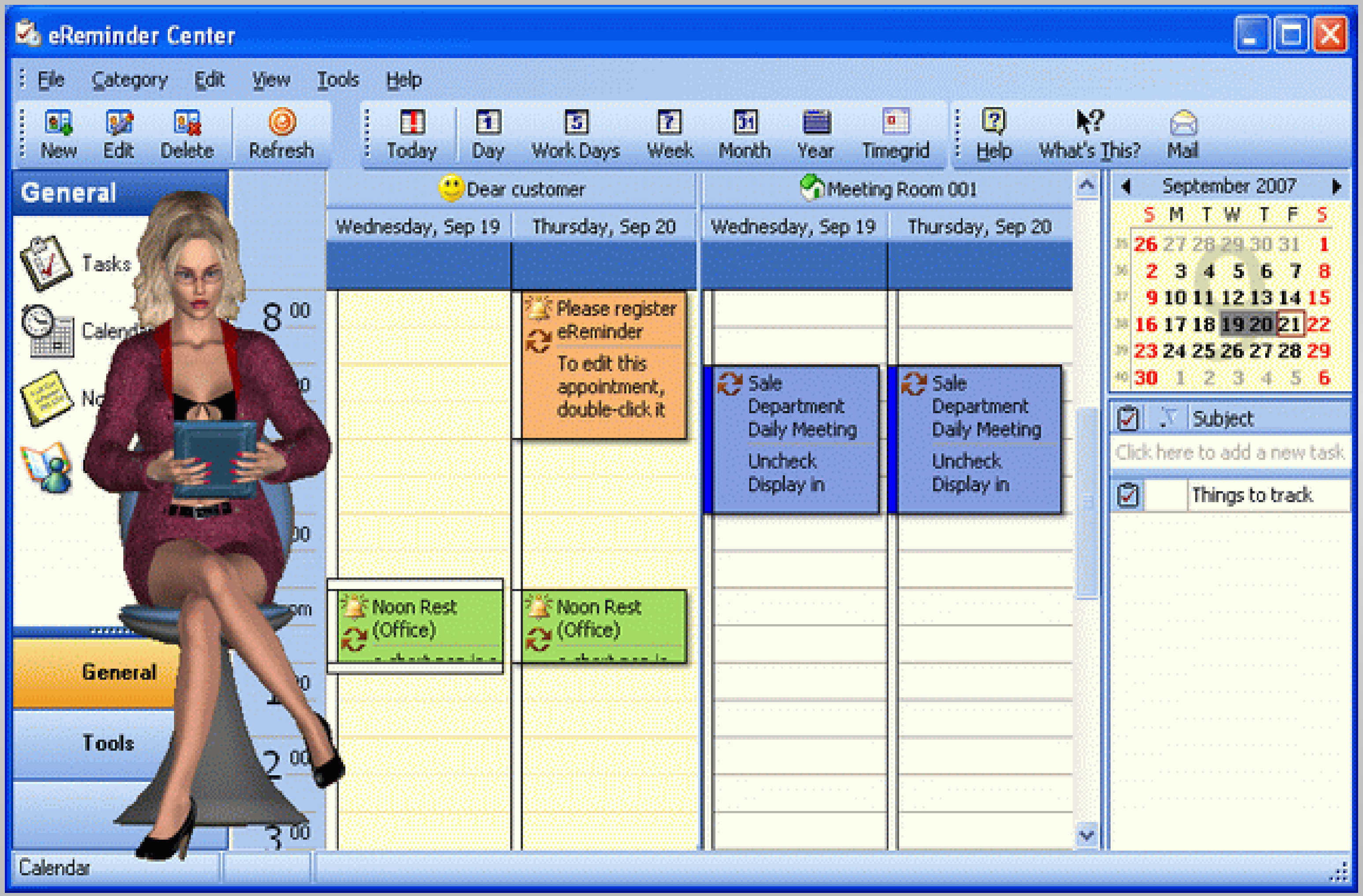
- Cognitive agents:
  - Cognitive agents represent their environment
  - Social aptitudes: capacity to interact with other agents

Intelligent Virtual Agents

- Intelligent virtual agents are human computer interfaces capable of engaging in interactions with humans:
  - Conversational agents: using written or oral natural language (various techniques from computational linguistic)
  - Using verbal or nonverbal communication
- Intelligent agents are embodied:
  - Virtual agents: graphically embodied 2D/3D graphical front-end (humanoid, animals, ...)
  - Robots: physically embodied (robotic body)

Intelligent Virtual Agents

Intelligent Virtual Agents



Intelligent Virtual Agents

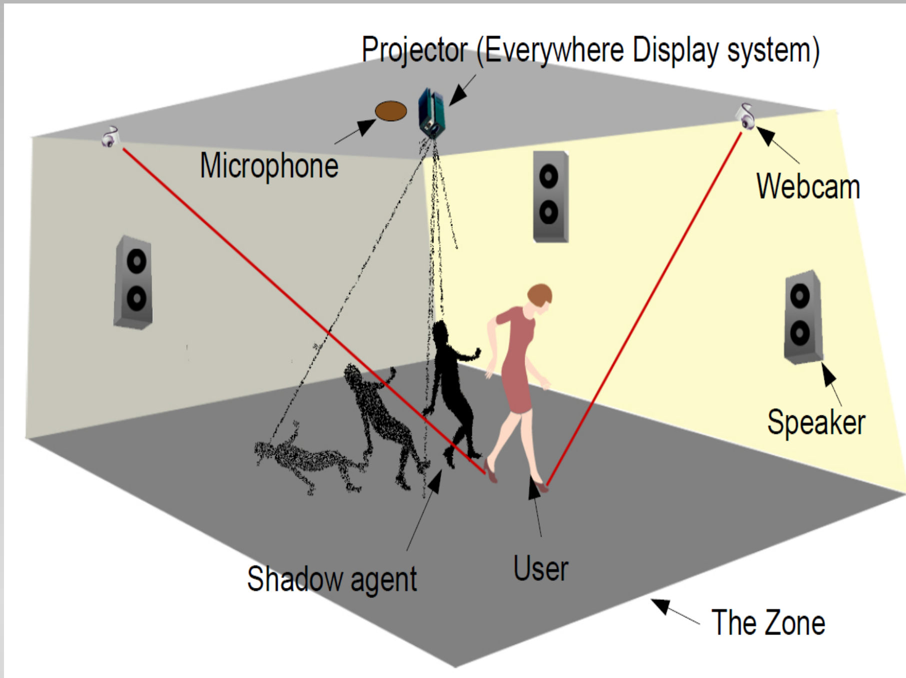
Intelligent Virtual Agents

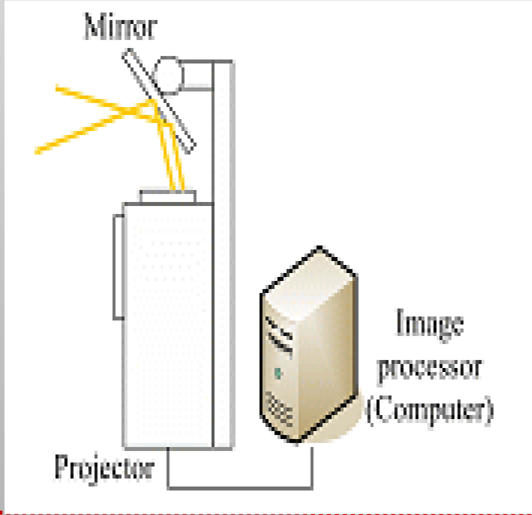
The Shadow Agent

- The shadow agent is an audio/video virtual agent projected on the floor of the zone
- This new architecture aims to fill the gap between screen-based virtual agents and physically embodied agents (robots)
- As an interactive art installation the aim is to entertain the user

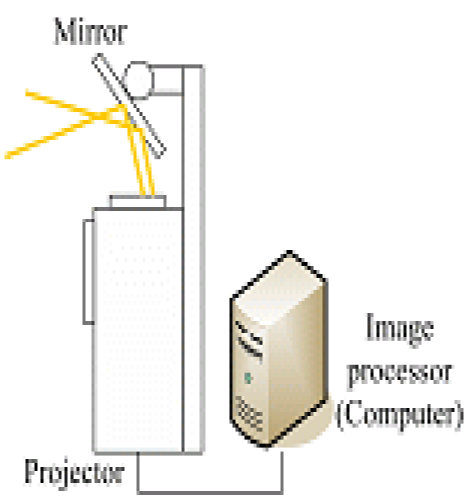
The Shadow Agent

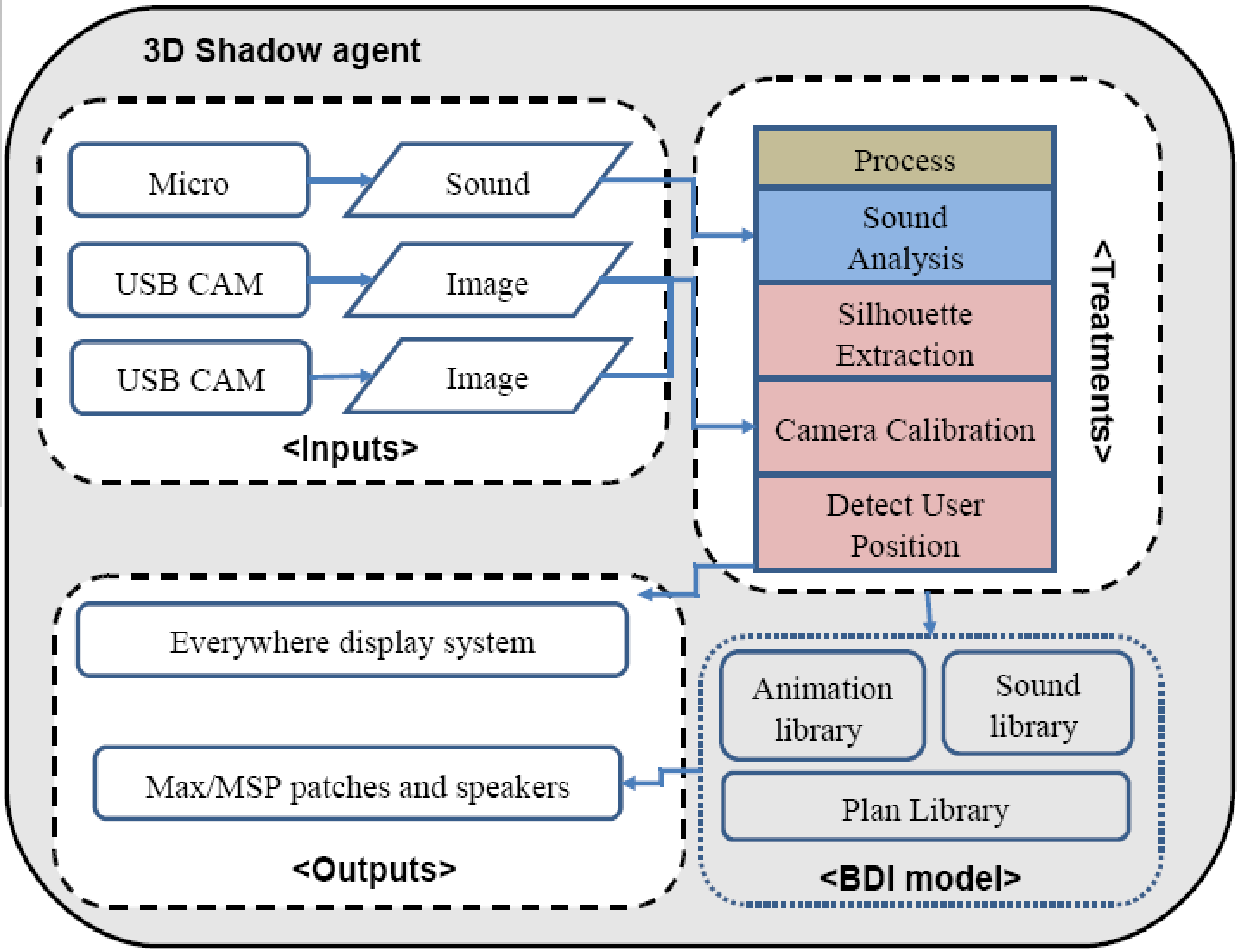
- Sensors/Perception:
  - Microphone
  - Webcams (two)
- Actuators/Action:
  - Virtual agent 2D silhouette projected on the floor (Everywhere Display System)
  - Audio speakers





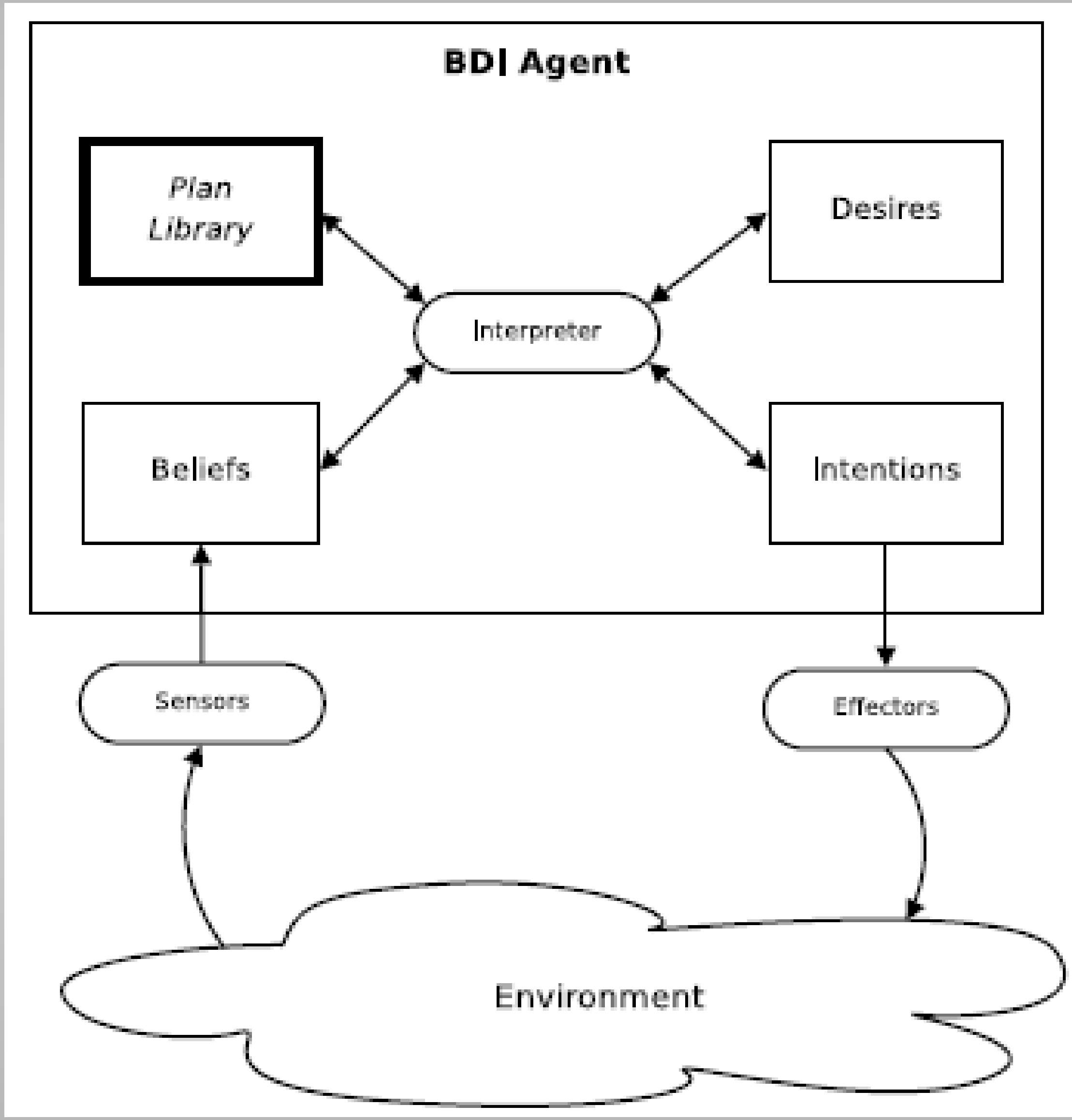
The Shadow Agent Architecture



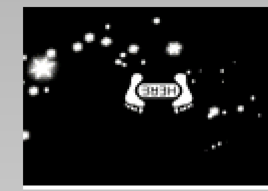


BDI Agents

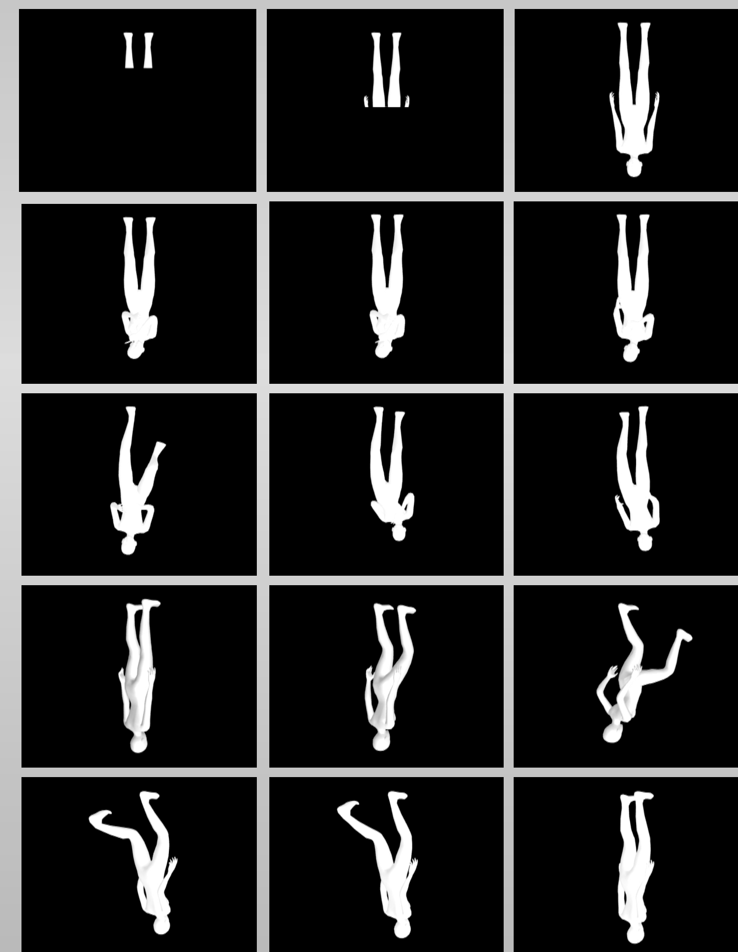
- Belief, Desire and Intention (BDI)
- The interpreter is mainly doing two operations
- Deliberation is selecting a goal among the desires based on the beliefs
- Mean-end reasoning selects (or generate) a plan (that will be executed as an attempt to achieve the goal)



The Plan Library

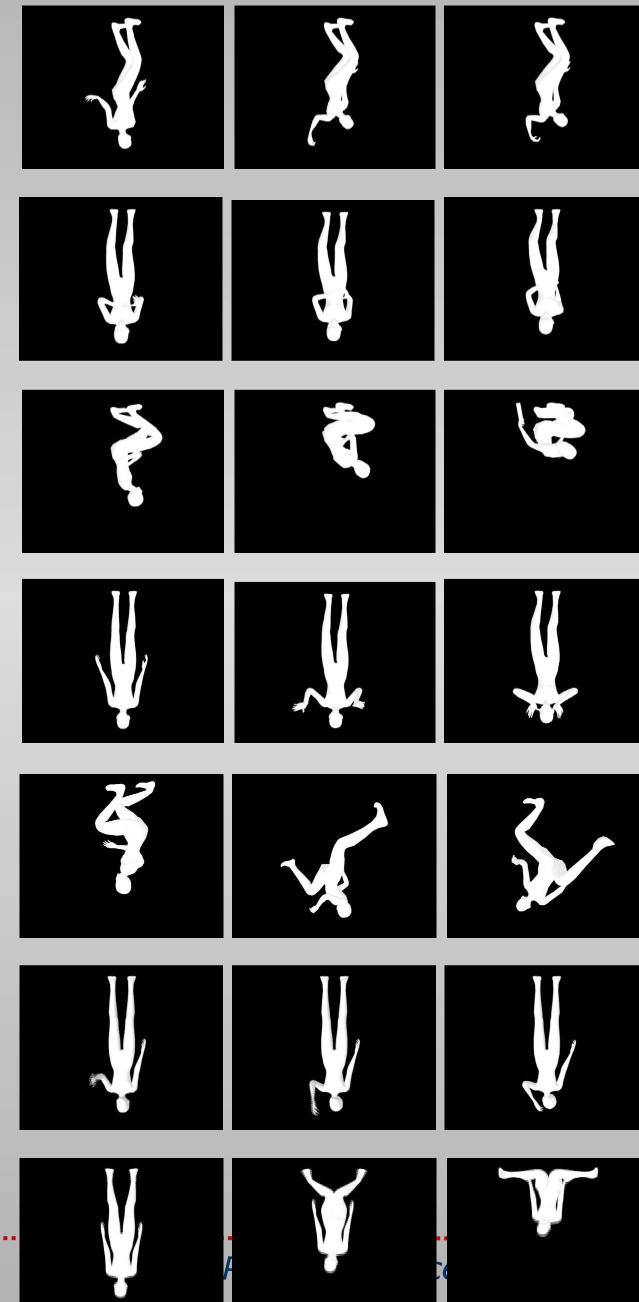


- **Plans** are triggered by the relevant perceptions (events), beliefs and goals
  - Their body indicates which animation and audio content will be used.
  - Pseudo-random selection among a bank of animations is used to introduce variety
- Examples of plans:
  - System initialisation:
    - The waiting plan
    - The apparition plan
  - The immobility / observation plan
  - The following plan



The Plan Library

- Other examples of plans:
  - The moving away plan
  - The call plan
  - The answering and teasing plan
  - The escape plan
  - The dancing plan
  - Reinitialisation:
    - The sleeping plan
    - The fading away plan



Sound Design

- **Nonverbal interaction**: while text-to-speech and voice recognition are progressing, these are still challenging
- The shadow agent uses an **abstract sonic vocabulary** (inspired by sound design for animated cartoons): breath, yawn, gasp, laugh, scream, chuckle, …
- Sounds:
  - Are associated to plans to **reinforce the expressivity** of the shadow
  - Are triggered in reaction to the user's noises and speech to increase the sensation of **interaction and responsiveness**

Future Works

- Short term:
  - Moving to a more sophisticated model for the 2D silhouette animation (to make it really flexible and generic). So far, only pre-produced animations have been used.
  - That would also allow morphing the form of the shadow toward the silhouette of the user!
  - Use a headset instead of loudspeakers for the sound design with binaural spatialisation
- Middle term:
  - Try other agent architectures (reactive agents, cognitive architectures,...)
  - Move to a multi-agent system

Possible Applications

- The shadow agent architecture is quite generic and is filling the gap between physically embodied agents (robots) and screen based virtual agents
- Amongst the possible applications:
  - Art installations (that is the prototype we try to put together)
  - Performative arts (dance, theatre and performance)
  - Computer games (exertion interface, movement based games)
  - Room assistant
  - Museum guides
  - …

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