TOWARDS A NEW GENERATION OF CONSCIOUS AUTONOMOUS ROBOTS

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Artificial Consciousness

- Perception
- Imagination
- Attention
- Planning
- Emotion

Aleksander & Dunmall 2003

- Self
- Qualia
Cicerobot Project
Cognitive architecture 1.0

Linguistic area

Conceptual area

Subconceptual area
Cognitive architecture 2.0

- Robot qualia: 2D-1/2 reconstruction of the 3D representation in the CS
- The robot phenomenological experience: the two flows of information, the internal and the external, compete for a consistent match.
- The robot acquires evidence for what it perceives, and at the same time it interprets visual information according to its internal model. Any discrepancy asks for a readjustment of its internal model.
Conceptual space

- A c-knoxel is a superquadric.
- An object is a composition of superquadrics.

\[
f(\eta, \omega) = \begin{bmatrix}
a_x \cos^{\varepsilon_1}(\eta) \cos^{\varepsilon_2}(\omega) \\ a_y \cos^{\varepsilon_1}(\eta) \sin^{\varepsilon_2}(\omega) \\ a_z \sin^{\varepsilon_1}(\eta)
\end{bmatrix}
\]

\[
k = \begin{bmatrix}a_x, a_y, a_z, \varepsilon_1, \varepsilon_2, p_x, p_y, p_z, \phi, \theta, \psi\end{bmatrix}^T
\]
Dynamic Conceptual Space

\[ m(t) = \left[ a_x(t), a_y(t), a_z(t), \varepsilon_1(t), \varepsilon_2(t), p_x(t), p_y(t), p_z(t), \phi(t), \vartheta(t), \psi(t) \right]^T \]

- Smooth motions approximated by DFT
- A simple motion - delimited by two discontinuities - can be approximated by the superimposition of frequency harmonics
Dynamic Conceptual Space
Situations and Actions

- **Situations**: objects maintain their motion states
- **C-knoxels** maintain their positions
- **Actions**: an event occurs, and some objects may change their motion state
- **Scattering of knoxels**
Situations and Actions
Avoid (av1)
precond(av1, bl1)
effect(av1, fr1)
Blocked_path(bl1)
Free_path(fr1).
Focus of Attention and Expectation
Planning in Conceptual Space

- Planning is a conscious-unconscious process
- The robot imagines the plan in CS
- Jackendoff: language helps us think
Emotions in CS

- Affective valuations and c-knoxel
- Emotions arise at the junction of plans
- Oatley and Johnson-Laird
The Self of the robot

- Self-consciousness is perception of the robot inner world
- Higher-order CS
The Self of the robot

- Flow of consciousness of the robot
Implemented architecture

![Diagram showing the architecture with labeled boxes for Linguistic area, Conceptual area, Robot qualia area, and Subconceptual area, along with a Match node.]}
Artificial consciousness experiences with CiceRobot

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Application Scenario

- **Cicerobot** is a museum guide robot tested in the Archeological Museum of Agrigento.
- Cicerobot allows:
  - Default tour
  - Interactive tour
- The user can introduce his preferences to plan an ad hoc tour.
- The robot platform is an RWI B21 robot equipped with a pan-tilt stereo head, laser rangefinder and sonars.
Application Scenario Issues

- The museum environment is a real and complex environment.
- The map contains identical parts at different places.
- All such positions yield the same visibility polygon and cannot be distinguished.
- Due to the irregularities of the floor, the odometry is not reliable, even in a few meters.
Implemented architecture
Implemented Architecture

Linguistic Area
- Linguistic Planner
- Target Designation
- Information Retrieval Module

Conceptual Area
- Initial Plan
- Simulation and Refinement
- Difference
- Comparison
- Map
- Ideal Plan
- Real Plan

Subconceptual Area
- A priori known obstacles
- Reactive Executor

Information Retrieval Module
- Target Designation
- Linguistic Planner
- Map Repository
- Simulation and Refinement
- Ideal Plan
- Real Plan
- Reactive Executor

Real Plan
- Ideal Plan
- Difference
- Comparison
- Simulation and Refinement
- Map
- Initial Plan
- Linguistic Planner
- Target Designation
- Information Retrieval Module

Linguistic Planner
- Target Designation
- Information Retrieval Module

Target Designation
- Information Retrieval Module

Information Retrieval Module
- Target Designation
Human-Robot Interaction

- The main task of the Information Retrieval Module (IRM) is to provide the user with relevant information.
- Interposing semantic modules between user and traditional search engine may help to retrieve higher level of interesting information.
- Latent Semantic Analysis (LSA), a theory related to knowledge representation and induction.
Planning

- The linguistic planner receives the IRM results and computes an initial plan.
- The planner in the conceptual area verifies the applicability of the initial plan and, if necessary, modifies it, producing an ideal plan.
- The plan execution is continually checked, and if it is not applicable, a local re-planning task is started.
Self Localization

The coordinates of the nearest marker are obtained;
Camera pan-tilt movements are performed to view the marker by stereo head;
Additional corrections to pan-tilt position are computed to place the marker at the image centers;
3D reconstruction of the marker points are performed by triangulation;
The new estimated position of the robot respect to the landmark is computed;
The absolute robot position is updated.
Before execution, the robot simulates the generated plan by using the 3D simulator, in order to check the plan itself and eventually to refine it.
Conclusions

• Open problems:
  – 3D real time representation of the perceived scene and 2D real time rendering
  – storing at time t all the information of the conceptual spaces at previous times, starting from the beginning of the robot life

• Machine consciousness helps to understand human and “non human” consciousness
THANK YOU FOR YOUR ATTENTION!