



Mind RACES:
from Reactive to Anticipatory Cognitive
Embodied Systems

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General Information

Title: *Mind RACES - from Reactive to Anticipatory Cognitive Embodied Systems*

Start Date: 1 October 2004

Duration: 36 months (till September 2007)

EC Contribution: 2.199.293 euros

Coordinator: Institute of Cognitive Sciences and Technologies (National Research Council of Italy)

Consortium:

- 1) *ISTC-CNR (Italy),*
- 2) *Lunds Universitet (Sweden)*
- 3) *Bayerische Julius-Maximilians Universitaet Wuerzburg (Germany)*
- 4) *New Bulgarian University (Bulgaria)*
- 5) *Instituto Superior Técnico (Portugal)*
- 6) *Oesterreichische Studiengesellschaft Fuer Kybernetik (Austria)*
- 7) *Scuola Universitaria Professionale della Svizzera Italiana (Switzerland)*
- 8) *Noze s.r.l. (Italy)*

Context and Relevance of the Project

Future *IT systems* will be intimately integrated with *everyday environments*, both as stand-alone objects or software entities
then

We have to consider new challenging scenarios with a set of *interaction problems* among man, environment, autonomous robots and embedded smart devices

The major claim of Mind RACES:

in order to be successfully autonomous, to deal with novel, dynamic, and trustworthy environments, *such robots and devices need to have sophisticated cognitive capabilities based on anticipation*

Only a cognitive system *with anticipation mechanisms* can be credible, adaptive and successful in interaction with the environment and in social interaction with other cognitive systems and with humans

Cognitive Systems and Anticipation

From the Objective of the 'Cognitive Systems' Action Line:
“To construct physically instantiated or embodied systems that can perceive, understand and interact with their environment, and evolve in order to achieve human-like performance in activities requiring context-(situation and task) specific knowledge”

It is really difficult to think about systems performing like (and interacting with) humans without any mechanism of anticipation

Definitions of Anticipation

- 1. An anticipatory system is a system containing a predictive model of itself and/or of its environment that allows it to change state at an instant in accord with the model's predictions pertaining to a later instant.
(Robert Rosen)*
- 2. An anticipatory system is a system whose current state is determined by a future state. The cause lies in the future (Robert Rosen, Heinz von Foerster)*
- 3. Anticipation is a process of co-relation among factors pertaining to the present, past and future of a system (Mihai Nadin)*
- 4. Anticipation is the expression of natural entailment (Robert Rosen)*
- 5. Feedforward and inverse kinetics are part of the integrated mechanism of anticipation (Daniel Dennett, Daniel Wolpert, Mihai Nadin)*

For more references: <http://www.anticipation.info>

Explicit and Implicit Anticipation

- **Explicit Anticipation**

- The organism/system is able to generate “representations” of the forthcoming events at different time scales
 - Case1. A real expectation built on a *mental* model of a future event like in planning, intentional behavior, hopes etc... (*mental anticipation*)
 - Case2. “Expectations” in the anticipatory classifiers (the sensory-motor representation of future effects of actions)

Not all anticipatory behavior is based on explicit representations of future events (expectations)

- **Implicit Anticipation** or merely *behavioral anticipation*

- The response is associated with a stimulus (a *precursor*)
- The behavior is selected to react to the event that is forthcoming (*preparatory behavior*)
 - Ex. A grasshopper jumps at a rustle “to” avoid the predator not as a reaction to the noise itself
 - Ex. The bodily activation of emotions is preparatory for the “escaping” behavior.

MindRACES Goal

The general goal of the Mind RACES project is to investigate *different anticipatory cognitive mechanisms and architectures and their functionalities*

in order to build Cognitive Systems endowed with the ability:

- to predict the *outcome of their actions*,
- to build a model of *future events*,
- to control their perception anticipating *future stimuli* and
- to *emotionally* react to possible future scenarios

Such Anticipatory Cognitive Systems will contribute to the successful implementation of the new ambient intelligence

Four Distinct Objectives

The project :

- 1) will *identify typologies of problems* which require different anticipatory cognitive capabilities; this will allow to design and implement different appropriate scenarios
- 2) will *improve existing anticipatory architectures* and will *incorporate missing anticipatory functionalities* in them. The performances of these architectures will be tested in the scenarios
- 3) will *compare* in the same scenarios *anticipatory architectures implemented from different theoretical backgrounds*
- 4) will *design, implement and test* in the scenarios *the cognitive architectures that integrate different kind of anticipatory mechanisms.*

Both simulations and real robots will be used to improve and compare single anticipatory models and to integrate them in the same cognitive architectures.

Cognitive Functions

Attention, Monitoring and Control (Work Package 3)

Anticipatory mechanisms: *Expectation-based attention shifting, attention as epistemic control, constructive perception*

- *Epistemic Actions* are actions aimed at acquiring new information from the environment usually through the shift of the *attentional focus* and its fixation which determines *what the cognitive system will perceive*

Goal directed behaviour, Pro-activity and Analogy (Work Package 4)

Anticipatory mechanisms: *Sub-symbolic planning, pro-active activation of goals, anticipation at different time scales and levels of abstractions (for instance, anticipatory classifiers), construction of models of future events based on analogy.*

- Cognitive Systems need **to select their own actions** with a set of different mechanisms: from simple reactions based on *future rewards* to higher level proactive reasoning on an *explicit model of the future*

Anticipatory Emotions (Work Package 5)

Anticipatory mechanisms: *goals activation based anticipatory affective states (somatic markers), affective monitoring of goals' satisfaction, appraisal of future events on the basis of perceived signs*

- Anticipatory character of the emotional response (fear, hope, anxiety)

Expected Results

A potential relevant contribution will be provided by *assembling* in a credible and efficient way *different anticipatory layers and mechanisms* implementing several *cognitive functions*

An important Goal is to design a visible advance of conception for the Cognitive System Architectures, where either through *layers*, or through *modularity*, or through *hybrid composition*, different cognitive mechanisms for anticipating and dealing with the environmental changes will be assembled in a *biologically and psychologically principled and efficient way*

Expertise of the Consortium

The Mind RACES consortium has been composed with partners that are expert in different scientific disciplines and complementary approaches to anticipation:

- *The Psychology of Action* (ISTC-CNR and UW-COGSCI)
- *Experimental Psychology* (NBU)
- *Situated and Evolutionary Robotics* (LUCS, ISTC-CNR, IDSIA-SUPSI, OFAI)
- *Artificial Intelligence and Cognitive Modelling* (OF AI, ITSC-CNR, NBU)
- *Mathematics and Adaptive Robotics* (IDSIA-SUPSI)
- *Affective Computing and Human Computer Interaction* (IST)

ISTC-CNR (coordinator)

The National Research Council (Consiglio Nazionale delle Ricerche) of Italy's Institute of Cognitive Sciences and Technologies (first called Institute of Psychology) was officially created in 1950.

Relevant Expertise: *two groups (Artificial Intelligence Group and the Group on Artificial Life and Robotics); neural networks, BDI models, Cognitive theory of emotions, evolutionary robotics*

Scientific Leaders: Cristiano Castelfranchi, Rino Falcone, Stefano Nolfi

Lunds Universitet

Lunds Universitet, with seven faculties and a number of research centres and specialized institutes, is the largest unit for research and higher education in Sweden. It was founded in 1666

Relevant Expertise: *robotics, connectionist systems, attention driving*

Scientific Leader: Christian Balkenius

UW- Department of Cognitive Psychology

The Institute of Psychology at the Bayerische Julius-Maximilians Universitaet Wuerzburg was founded more than a hundred years ago in 1896. Over the following years, the so-called Würzburg-school of psychology laid out the foundations for the investigation of complex thought processes and particularly an experimental approach to the investigation of higher level cognition.

Relevant Expertise: *Formal and Computational Models of anticipatory mechanisms, Anticipatory Classifiers Systems*

Scientific Leaders: Joachim Hoffman, Martin Butz

New Bulgarian University

The Central and East European Center for Cognitive Science is an interdisciplinary research Center at NBU bringing together researchers in computer science, psychology, neurosciences, linguistics, and philosophy.

Relevant Expertise: *Formal and Computational Models of Analogy, hybrid cognitive architectures*

Scientific Leaders: Maurice Greenberg, Boicho Kokinov

Instituto Superior Técnico

IST (Instituto Superior Técnico) is a large Engineering Faculty of the Technical University of Lisbon created in 1911. The research and development activities at Instituto Superior Técnico are mainly carried out within Institutes, Departments, Centers and research Groups that integrate teaching and research staff allocated to the various departments of IST.

Relevant Expertise: *Formal and Computational Models of Emotions*

Scientific Leader: Ana Paiva

Oesterreichische Studiengesellschaft Fuer Kybernetik (OFAI)

OFAI was founded in 1984 with support from the Austrian Federal Ministry for Science and Research.

Relevant Expertise: *Robotics, Connectionist Models*

Scientific Leader: Georg Dorffner

IDSIA-SUPSI's research focuses on optimal universal search algorithms, artificial neural nets, universal reinforcement learners and predictors, complexity and generalization issues, unsupervised learning and information theory, forecasting, artificial ants, combinatorial optimisation, evolutionary computation. IDSIA-SUPSI is small but visible, competitive, and influential.

Relevant Expertise: *Optimal mechanisms and algorithms for prediction and techniques for predicting at different levels of abstraction*

Scientific Leader: Juergen Schmidhuber

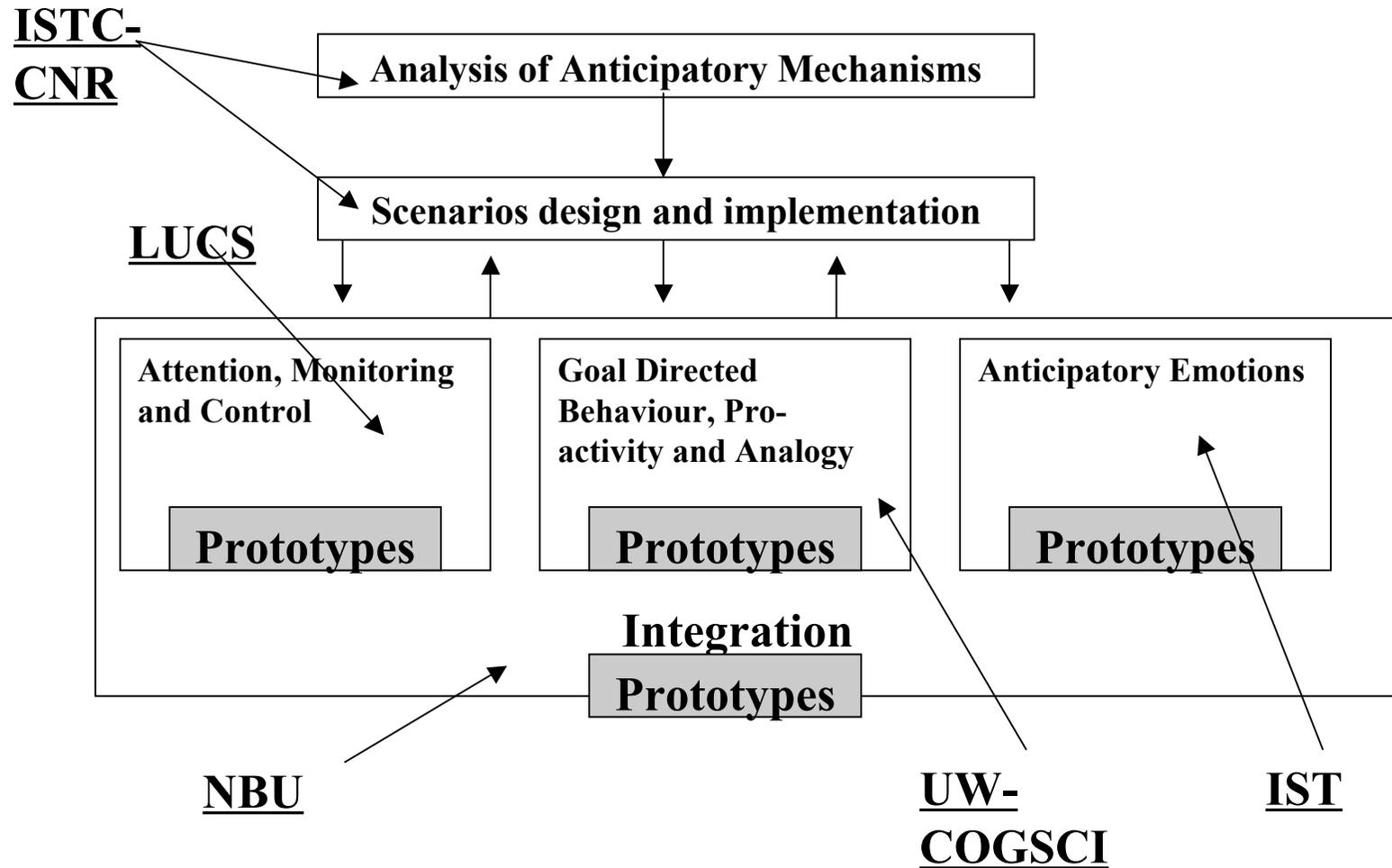
Noze S.r.l.

Noze s.r.l. is a small and very dynamic Italian enterprise (SME) that offers state-of-the-art solutions in the Information and Communication Technology field, coupling competence, innovation and affordability.

Relevant Expertise: *Communication infrastructures, Dissemination, Artificial Intelligence Systems*

Leader: Fabio Adezio

Work Package Leaders



Conclusions

MindRACES will investigate various forms
and mechanisms of anticipation

their adaptive functions

the transition from one to the other

the co-existence in complex systems
(architectural problem)

<http://www.mindraces.org>