ROBotic Open-architecture Technology for
Cognition, Understanding and Behavior

Project no. 004370

RobotCub

Development of a cognitive humanoid cub

Instrument: Integrated Project
Thematic Priority: IST – Cognitive Systems

First interim report

Period covered from **01/9/2004 to 28/2/2005** Date of preparation: **May 4, 2005**

Start date of project: **01/09/2004** Duration: **60 months**

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Revision: **1**

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1 Project objectives and major achievements during the reporting period

1.1 Overview

The main activities during the first six months of the project have been:

1. Establishing a good relationship and acquiring mutual knowledge of scientific backgrounds of all partners
2. Discussing and defining the licensing schema for the open system
3. Establishing a common repository of documents and design drawings and selecting some key standards for the exchange of design and documentation.
4. Agreeing on the overall architecture of the RobotCub Platform (iCub):
    a. Degrees of freedom
    b. Overall size and weight
    c. Sensory requirements
    d. Electronics and control structure
5. Starting the discussion about the cognitive architecture of the project.
6. Initial design of the iCub components
7. Establish links with other projects/scientists as well as the general public

1.2 Objectives of reporting

This objective of this report is to outline the activities and results obtained in the initial six months of the projects as well as the activities carried out by the individual partners.

The first objective of this initial period was to establish a good relationship between all partners involved. This was obtained through three plenary meeting organized in places facilitating formal and informal discussion. The attendance has been excellent and the discussions very stimulating. The meetings were open to out International Research Panel and their participation has been very active in offering suggestions and ideas for collaborations. For example in the project's website the group of MIT already uploaded mechanical drawings of one of their most recent robots to be used as guideline and source of suggestions and inspiration for the mechanical solutions. The same has happened for existing mechanical designs of EPFL, UGDIST and IST. The attitude of all partners toward the "openness" of the project has been enthusiastic and, in some sense, even greater than hope for. During this initial period the exchange of information and acquisition of mutual knowledge has been developing both with reference to the "bodyware" and in relation to the cognitive aspects of the project, the knowledge about human development and sensorimotor representation of actions in humans. Besides the three plenary meeting, another meeting specifically devoted to discussing some general issues of the iCub body was called in January. Agendas, documents and slides produced for all these meetings are available in the project's website (http://www.robotcub.org).

A second important objective has been the definition of the licensing schema. This was a particularly important point (even if not a scientific one) because of the goal of the project to design an "open" system. It must be said that all partners have been always very supportive of this idea and the discussion has been on the "methods" to use to open the CUB-Knowledge to everybody and this required some understanding of the licensing mechanisms that was not a common background for most of us. The main difficulty to overcome was that of finding a solution which, on one side, protects the "openness" of the results and on the other it is not too burdensome to implement. The solution, which, we believe is very satisfactory, is described in our first deliverable D1.2.

The third important achievement is the set-up of the Project's website. The relevance of this activity is related to the fact that the website has to fulfill the following needs:

a. A window of the project to the outside world
b. A repository of the project's formal deliverables
c. A repository of documents for ongoing activities. This include not only reports but also software code, electronic and mechanical drawings;

d. The official repository of the “open” design and documents.

Therefore, besides the standard need for a “public” part and a “private” part, even though at the moment we still have not released any “open” document (apart from a few publications and the D1.2 and D5.1) the structure of the website has to support the upload/download of documents with different standards including CAD mechanical and electronic drawings, software code with support for versioning, etc. For this reason along with the design of the website, the consortium had to agree on the use of documentation standards to be used to exchange data. Our guiding principles here have been on one side the adequacy of the standard but also the availability of, at least, “free viewers”. Results of these activities are described in this report within WP8. At present the “private” area of the website is accessible to all partners (including the non-EU partners) plus to a group in Karlsruhe (lead by Prof. Dillman) with whom we already started the exchange of design solutions.

The fourth achievement of the project has been the definition of the general structure of the iCub. In our last meeting at Estoril 17-19 of March, we have been able to attempt a very preliminary (and still partial) integration of the mechanical components of the head, arm, spine and hand. This was done by integrating the CAD files prepared by different partners (SSSA, DIST, IST, UNISAL and TLR) into a single CAD project. Of course there is still a lot to do but this attempt was important because on one side was useful to highlight some critical points and on the other it demonstrated that the integration procedure is on the right track. Besides the mechanical components the consortium spent a considerable time discussing about the sensory requirements of the iCub in relation to the cognitive experiments that all partners are planning. This turned out to be a somewhat difficult task (as expected) because, on one side it is easy to ask for “artificial skin” or “stereo vision” but on the other it is important to define what is really feasible and, to some extent, easy to use. This exercise is still ongoing but it has produced already a preliminary list of requirement which is now under further scrutiny. Within this topic it is worth mentioning that during our discussion about the sensorimotor requirements of the iCub it turned out that, for the study of the “communication” skills it would be very interesting if iCub could express a limited set of emotions through facial expressions. This has produced an activity (at the moment led by UNIHER in conjunction with IST) to investigate what could be the simplest yet effective way of implementing this possibility.
The main points of this important activity are described in the report of WP7 but altogether we set as a guideline that the robot will have 55 degrees of freedom, a weight of 23 Kg, and a height of about 95 cm.

The fifth activity is related to the definition of the Cognitive Architecture of iCub. This is a challenging task mainly because there is, as expected, a wide variety of approaches among the partners in terms of tools and research objectives. iCub will be a manipulating/crawling/gesturing robot and besides that iCub will be learning all these skills. Of course the RobotCub consortium does not have all the resources necessary to solve all these problems but we need to cover enough of them to give iCub the structure of a “system” (not a collection of parts). Therefore the initial discussions have been directed toward understanding what kind of tools and skills each partners is using or planning to use or develop and form a general overview of where the project stands in terms of implementing a “system”. To this goal it is particularly interesting the document prepared and discussed at our last meeting and known to the consortium as “the seven questions” document[1].
At the moment we are in the middle of this exercise and we are confident that the activities planned, mainly, in WP4 WP5 and WP6 are still achievable. On the other hand it has become clear, also as a result of the general “cognitive systems” meeting in Bled, that other projects are addressing the same issues and have alternative solutions that may be very interesting to merge. Among the planned activities there are a few aimed specifically at strengthening the links between RobotCub and a few other projects with whom we have a lot of affinity (e.g. David Vernon presented the objectives of RobotCub at the JAST Opening Conference).

The sixth important activity has been the initial design of the iCub mechanical components. In summary the group at IST has coordinated the work on head design and is currently implementing three prototypes to compare different kinematics solutions. The group at SSSA has been concentrating so far in the design of the upper and lower arm and comparing the solution proposed with implementations made by other partners. UNISAL has proposed a solution for the lower-limbs and spine that will support the crawling and the changing from crawling to sitting. It is worth mentioning here that crawling, which initially looked as it if would be an easier task than walking, is turning out to be quite complex because it imposes more stress than expected on some of the mechanical components. Also the action of crawling is not very simple but

[1] http://www.robotcub.org/index.php/robotcub/administration/meetings/lisbon_march_2005_meeting/the_7_questions

it poses challenging problems from the computational/control point of view. In this respect, a very useful activity is being carried out by EPFL, in simulating the dynamics of crawling to test the best crawling strategy but also the mechanical requirements. This activity has generated an initial dynamic model of the body of the iCub which is being used, among other things, to estimate the torques generated/required by crawling at each joint. A more detailed description of the work done can be found in the report of WP7 below and also, in an even more expanded version, in the repository of the mechanical design in the website where CAD models of all these components are available (together with reports and sketches).

Last but not least are the activities devoted to the internationalization and dissemination of the project's objectives. The main results here have been on different aspects:

a) Discussion about establishing joint laboratories with two non-EU research centers devoted to co-development of iCub
b) Cross-fertilization started with other projects of the "cognitive systems" initiative as well as with national projects in Italy and Germany.
c) Formalized support planned in the framework of training activities for two multidisciplinary scientific events in the form of fellowships for young students.
d) Planning for the organization of special sessions in conferences and workshops on scientific topics of interest to RobotCub as well as to extend the network of research centers working on the iCub.
e) Two proposals submitted to the last call of Cognitive Systems. One is particularly relevant to RobotCub because, if positively evaluated, will allow the development of the speech understanding aspects of iCub. It is particularly positive the fact that the consortium of this new project decided to adopt iCub as the platform for their planned experiments.

1.3 Problems

No major problem so far.

2 Workpackage progress of the period

2.1 WP1 - Management

2.1.1 Workpackage objectives

1. Control of the scientific and technological development of the project.
2. Project's self-assessment.
3. Internationalization and community building. The related activities will be managed by the Research Director and Technical Coordinator with the International Research Panel.
4. Coordination of training and dissemination.
5. Definition of the legal aspects of the licensing strategy.

The project's objectives are pursued through three complementary organizational activities.

1. Monthly assessment meetings of the project directorate primarily concerned with project management, open-systems support and licensing, management of IPR, and formulation of occasional calls for expansion of the partner base.
2. Three-monthly meetings of the Board of Management mainly concerned with assessment of progress, cross-area integration, and scientific innovation.
3. Six-monthly workshops involving everyone directly involved in the project, from graduate students right through to the research director. These workshops will concentrate on relatively polished presentations of current results, assessment of scientific progress by external experts, and open 'think-tank' scientific exploration of new avenues of enquiry.

2.1.2 Progress towards objectives

At the kick-off meeting a detailed planning of the project's meeting for the first 18 months was discussed and approved.

Date	set-04	nov-04	gen-04	mar-05	lug-05	ago-05	ott-05	gen-06	apr-06
Month	1	3	5	7	11	12	14	17	20
Duration	3	3	2	2	3	7	4	3	3
Proposed Dates	16-18	25-27	13-14	17-18	13-15	TBD	18-21	18-20	12-14
Place	Genova	Genova	Nice	Lisbon	Genova	TBD	Genova	TBD	TBD
	KICK-OFF	2 days workshop	One day on topical meeting	One day workshop	2 days workshop	Thematic Summer School	two days workshop and annual review	2 days workshop	2 days workshop
		Board Meeting		Board Meeting	Board Meeting		Board Meeting	Board Meeting	Board Meeting
		IRP Meeting			IRP Meeting		IRP Meeting		IRP Meeting

The table above illustrates the meeting strategy of the project which is based upon the frequent plenary meeting (on average every two months) associated to meetings of the Board of Management (one every 3 months) and meetings of the International Research Panel at month 3 and 11. The agendas of the meetings and the collection of the slides presented and important documents discussed are in the project's web site at: http://www.robotcub.org/index.php/robotcub/administration/meetings

Among the important decision taken at the meetings in relation to the management of the project:

1. Approval of the project's licensing strategy;
2. Approval of the project's standards for documentation;
3. Approval of the projects standards for data exchange (viewers for all standards are available here: http://www.robotcub.org/index.php/robotcub/administration/download/viewers
4. Approval of the project's logo and official name of the project's platform (iCub), preparation of the project's PowerPoint templates (http://www.robotcub.org/index.php/robotcub/administration/misc)
5. Registration of all available related domains (robotcub.com/info/net/org, robot-cub.com/net/org, i-cub.com/info.net/org, icub.org);
6. Decision to open our meetings to people from outside the consortium;
7. Detailed discussion and approval of the project schedule;

2.1.3 Deviations from the project workprogramme

So far there has been no need to change the original plan of the research activities of the project.

2.1.4 List of deliverables

Del. no.	Deliverable name	Date due	Actual/Forecast delivery date	Lead contractor
D1.1a	Periodic Progress Report	Month 6	This deliverable	UGDIST
D1.2	CUB's Licensing Strategy	Month 3	March 2005	UGDIST
D1.4a	Project's meeting 1	Month 6	We had three plenary meetings (see above)	UGDIST

2.1.5 List of milestones

No formal milestone in this period for this WP, however we consider the collaborative atmosphere established in the consortium as a very important milestone.

2.2 WP2 – Cognitive Development

2.2.1 Workpackage objectives

In this workpackage, we study the development of early cognition and how to model the relevant aspects of such process within the boundaries of an artificial system. In particular, we investigate the timeframe of a developmental process that begins to guide action by internal representations of upcoming events, by the knowledge of the rules and regularities of the world, and by the ability to separate means and end (or cause and effect). This research is strongly driven by studies of developmental psychology and cognitive neuroscience and it will result in a physical implementation on an artificial system.

Biologically plausible models of how early cognition evolves are being investigated, taking into account both the brain mechanisms underlying the modeled cognitive processes and the learning procedures used by the child to accommodate new concepts and assimilate already acquired ones to better fit the outside world. These models will be validated against behavioral studies of how young children solve problems of various kinds and how they use internal representations of objects and events to plan actions.

2.2.2 Progress towards objectives

To achieve the above objectives the activity in this WP has been directed along the following lines:

1. Creation of a base-line review of the different approaches each partner is taking in the modeling of cognition in artificial systems. The goal of this work is to identify the scientific, technical, and technological foundations in much greater detail than provided in the technical annex so as to ensure that the complete space of cognitive development is being spanned, to facilitate complementary work among disciplines, groups, cognitive skills, and experimental scenarios, and to facilitate cohesion among underlying scientific models.
2. Following a developmental scenario initial experimental work has been carried out in scenarios where the robotic hand has to learn to manipulate objects of different shapes, textures and materials starting with a motor control based on coupled fingers (i.e. the closure of each finger is not individually controlled). Using a few of the sensors available and a neural network with a small number of neuronal units, these coupling will be released over time to see if learning can be accelerated by following a developmental approach.
3. The definition of the structure and the identification of the main aspects of the cognitive roadmap has been initiated and a preliminary progress report was delivered at the Lisbon meeting (see also section 3.4)
4. Initial experiments on children's ability to manipulate objects and understand events in the surrounding.
5. An initial investigation into appropriate developmental levels was started for the purpose of studying interactions of the iCub with people.

2.2.3 Deviations from the project workprogramme

Nothing to report

2.2.4 List of deliverables

No formal Deliverable scheduled for this period in this WP.

2.2.5 List of milestones

No Milestones scheduled for this period in this WP.

2.3 WP3 – Sensorimotor Coordination

2.3.1 Workpackage objectives

Activities in WP3 are aimed at the definition and implementation of the development of sensorimotor skills and their contribution to cognitive developments. UNIFE partner is coordinating the contribution to the activities of this WP. This WP will contribute mostly to the implementation of cognitive abilities in the artificial system. This objective will be demonstrated through extensive testing of the robot's cognitive abilities in realistic situations, implemented in several of the existing robotic platforms, as well as through psychophysical and behavioral studies measuring the robot's interactions with humans. By month 18, we will have investigated to a certain degree the following cognitive aspects underlying the development of infants' manipulation behaviors:

1. The ability of learning and exploiting object affordances in order to correctly grasp objects on the basis of their use.
2. The ability of understanding and exploiting simple gestures to interact socially.
3. The ability of learning new manipulation skills and new communicative gestures.
4. The ability of correctly interpreting and imitating the gestures of a human demonstrator.

2.3.2 Progress towards objectives

The 11th of January we held a meeting in Ferrara devote to share the programmed plans and to delineate the future actions of the neuroscience teams along RobotCub experimental pathway on sensorimotor coordination. To the meeting have participated senior scientists of UNIFE (L. Fadiga and L. Craighero) and UNIUP (C. von Hofsten and K. Rosander), together with the post-doc and PhD students working at UNIFE. Two main lines of research have been identified as particularly relevant at this stage:

1. Study of the ontogeny of the mirror-neuron system.
2. The prediction of actions outcome.

A series of experiments has been conceived and in the following three months some pilot trials already started. Concerning objective 1, we have decided to proceed along the following directions:

1.a) It is well known that during action execution and observation there is a desynchronization of an EEG rhythm in the 20 Hz band (mu rhythm) recorded at rest on central derivations. Mu rhythm desynchronization is thus considered a functional correlate of the mirror system at work. We have decided to study the desynchronization of the mu rhythm in developing infants (from 6 months old). At present a collection of video clips have been already prepared, showing goal-directed and non-goal-directed hand actions. Some subjects have been already recorded and data are under analysis.

1.b) The pattern of eye movements during action observation is the same as that recorded during action execution. In both cases, the eyes anticipate the hand and reach the target well before fingers arrival. Thus, saccadic behavior during action observation supports the direct matching hypothesis for action recognition. We decided to study the development of this predictive behavior during action observation in developing infants (UNIUP) and in behaving monkeys (UNIFE). To this purpose, the general plans of the two experiments have been designed and UNIFE is purchasing the eye tracking system necessary to perform the experiment.

1.c) It is well known that brain regional blood flow modifies according to the functional involvement of the measured area. This is the basis of brain imaging experiments, traditionally using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Unfortunately, these techniques are not usable on infants because of their invasiveness (PET) and because their require subjects' immobility. In the recent years a new technique has been developed to non-invasively measure regional blood flow in infants. It is the near infrared spectroscopy (NIRS), which allow detecting the regional modifications of blood flow by spectroscopically measuring the absorbance of low-power infrared light by regional hemoglobin concentration. We will try to use this technique as substitute approach to brain imaging in infants. The goal is to investigate when, during ontogenesis, premotor cortex starts becoming active during the observation of actions of others. At present the various technical options have been investigated by discussing possible approach with some leading European groups. It seems that photon counting methods are the most sensitive available with current technology. We are entering now in the practical phase and we are planning to buy the necessary instrumentation within a couple of months. Experiments will be carried out by both UNIFE and UNIUP. A preliminary testing in monkeys during action execution and observation is planned in order to optimize the various recording/measurement parameters.

1.d) Some key questions concerning mirror neurons are: "what is innate and what is acquired?" "What happens to mirror neurons if the animal has never performed the seen action?" This is an incredibly difficult problem to study experimentally. First of all because if one fails to find mirror responses this does not necessarily imply that mirror neurons are not active. A negative result might be due to insufficient sampling or to experimental inaccuracy. Second, it is inconceivable to attempt this study in monkeys because of their cost and of the difficulty to cognitively deprive newborns monkeys (which need the mother continuously). Third, one would need long-lasting chronic single neuron recordings and this is a really difficult problem in neurophysiology. We will try answering these questions by using diverse approaches. The first one is aimed at simplifying the experimental procedure by studying a simplified animal model (i.e. the rat). Rats are quite skilled in manipulation, learn by observation and, more interestingly, have a rich social life. We are therefore aiming at finding mirror neurons in rats and to investigate their development by using a large scale approach (in terms of number of animals). A second possible approach concerns long-lasting recordings. We are trying to implant in monkeys area F5 (the cortical region where mirror neurons have been located) an optical recording system which detects regional changes of metabolic activity, and therefore of neuronal one. The advantage of this approach is to reduce the problems arising from electric impedance modification induced by tissue reaction around recording microelectrodes.

Concerning objective 2 (the prediction of actions outcome), we have decided to proceed as follow:

2.a) As already outlined in 1.b, during hand action execution (i.e. grasping) the eyes anticipate the hand and reach the target before the fingers. To do that, the motor system must predict the final position of the hand, likely on the basis of target objects and spatial cues. We decided to study the development of this predictive behavior in developing infants (UNIUP) and in behaving monkeys (UNIFE). The paradigm will be similar of that discussed in 1.b. Various types of grasping and sequential movements will be studied.

2.b) UNIUP already demonstrated that infants can predict the instant at which an object, moving at known velocity, becomes visible after a period of occlusion. This result demonstrates that the predictive capability of the motor system benefits from an implicit knowledge of some physical laws (i.e. velocity, acceleration, etc.). It has been shown by Thierry Pozzo's group in Dijon that among implicitly known physical laws, gravity plays an important role, influencing both actions execution and observation. In order to build a learning artifact such as the CUB, we consider fundamental the study of this aspect. Experiments will thus be performed in this field in the next future.

2.c) The instant at which our fingers touch a to-be-grasped object is foreseen by somatosensory, visual and motor neurons. At UNIFE we are studying if the same predictive capability is present during action observation. Different grasping movements seen from different perspectives are being studied by evaluating the reaction time of subjects detecting object touch by pressing a button. Results seem until now really encouraging. The relevance of the agent (human vs. robot) will be also investigated within RobotCub project in collaboration with UGDIST.

2.d) At UNIFE we are continuing monkey electrophysiology experiments aiming at investigating the role of visual feedback in hand action planning and execution. The experiments started within the framework of a past EC funded project (MIRROR), whose goal was to investigate how we recognize others' actions. Due to the fact that the same question is among the key points of RobotCub neuroscience program, we aim at continuing single neuron recordings in monkeys, in the hand-controlling premotor cortex (area F5). More detailed descriptions will follow in future deliverables.

Finally, during the last Lisbon meeting, we planned a series of experiments in collaboration with 1) EPFL, aiming at characterizing the kinematic parameters of arm reaching during execution and imitation of observed actions and with 2) UNISAL, to build a prototype of a device to record hand movements based on the measurement of pulsating electromagnetic fields.

2.3.3 Deviations from the project workprogramme

No deviations are foreseen at the present

2.3.4 List of deliverables

No formal Deliverable scheduled for this period in this WP.

2.3.5 List of milestones

No Milestones scheduled for this period in this WP.

2.4 WP4 – Object's Affordance

2.4.1 Workpackage objectives

Objectives: The goal of this WP is that of exploring and modeling the mechanisms underlying the acquisition of object's affordances. This investigation can be seen developmentally as an extension of WP3. Specific models of how the primate's brain represents affordances will be considered (for example the parietal-frontal circuit) as well as results from psychological sciences. Note how much this is linked to aspects of sensorimotor coordination on one side (WP3) and of imitation and the understanding of goals on the other (WP5 and WP6). Specifically, we will investigate:

1. What exploratory behaviors support the acquisition of affordances, what is the relevant information (visual, haptic, motor, etc.)?
2. We will develop a model of the acquisition of object affordances and how the motor information enters into the description of perceptual quantities.
3. In analogy to what observed is in the brain, we will investigate how the definition of purpose (or goal) participates in the representation of the actions an object affords.

2.4.2 Progress towards objectives

The activity in this WP has been devoted mostly to the continuation of the experiments using the existing experimental set-up. In particular the activity has been concentrating on the following aspects:

1. Implementation of visual algorithms aimed at extracting object's shape features that could be associated to object's affordances. In particular simple 3D shape such as the extraction and measure of the orientation in space of the principal axis of a 3D object.
2. Initial implementation of a reaching algorithm associating the approaching direction to the object's 3D shape (e.g. how to approach a "standing" bottle vs. a bottle lying on the table).
3. A series of experiments are being conducted where toddlers' understanding of the affordances related to object manipulation are investigated (e.g. how children go about when trying to fit objects into each other, how they learn to pile objects on the top of each other, and how they learn to fit lids on pans.

Besides these experimental activities the WP contributed significantly to the initial definition of the arm-hand kinematics of the iCub.

2.4.3 Deviations from the project workprogramme

None

2.4.4 List of deliverables

No formal deliverable scheduled

2.4.5 List of milestones

No milestone planned for this period.

2.5 WP5 - Imitation

2.5.1 Workpackage objectives

In this workpackage, we investigate imitation of goal-directed manipulation task and imitation of simple gestures, such as pointing, waving and simple pantomiming. In particular, we will look at the following cognitive stages underlying children's imitative behavior:

a) imitation of goal-directed arm motions (pointing and reaching for objects)
b) imitation of the functional goal of arm motion (grasping, pushing, dropping objects)
c) understanding the communication effect of imitation or the passage from being an imitator to become a demonstrator.

We develop functionally biologically plausible models of the brain mechanisms underlying the cognitive processes behind imitation.

2.5.2 Progress towards objectives

In modeling, we follow two major approaches: The first approach uses methods from computational neuroscience (neural networks modeling) to give an account of the functionality and connectivity of the brain areas (Broca, PMd, STS, AIP, etc) involved in imitation, using recent data from brain imaging and neurological studies in humans and monkeys.

Task 5.1: Define roadmap of imitation-based experiments.

WP5 follows closely the development of the cognitive roadmap in WP2, in order to pick a number of behavioral studies from human infants (from newborn to 2 years old) and other primates' imitation against which the models will be validated. A workshop, involving the major partners in WP2, WP4 and WP5, will be held at the occasion of the 4th regular meeting of the RobotCub consortium next July and will be devoted to defining precisely the experimental protocols to conduct sets of robotics and behavioral experiments in parallel.

Task 5.1: Early Imitation behaviors.

We started by addressing the issue of finding a generic representation of motions that allows both robust visual recognition and categorization of motion and flexible regeneration of motion. Such a visuo-motor representation would be at the core of the imitative mechanisms and would explain human propensity to visuo-motor imitation. With this goal, EPFL worked on developing a model of human three-dimensional reaching movements. This model can precisely match human reaching movement kinematics. It can also be used to predict ahead of time the target of a human reaching movement, by looking at the first part of the trajectory only. Moreover, the model is consistent with a number of experimental findings on human reaching movement reported in the literature. The model and its results have been reported in deliverable D.5.1.1.

During the last RobotCub meeting, EPFL planned a series of experiments in collaboration with UNIFE, aiming at characterizing the kinematic parameters of arm reaching during execution and imitation of observed actions. The experiments will provide data against which the model could be validated.

Task 5.2: Contribution to definition of functional CUB requirements

A list of requirements for the CUB functionalities with respect to the CUB's imitation capabilities were given to the partners responsible for the CUB design by EPFL.

2.5.3 Deviations from the project workprogramme

None

2.5.4 List of deliverables

Del. no.	Deliverable name	Date due	Actual delivery date	Lead contractor
D5.1	Evaluation of an algorithm for interpreting the kinematics of arm motion and its relationship to object motion	Month 6	April 15	EPFL

2.5.5 List of milestones

No milestone planned for this Workpackage in this period

2.6 WP6 – Gesture Communication

2.6.1 Workpackage objectives

Given the project's core scenario of a 2-year of old child this WP focuses on the dynamics of interaction when RobotCub plays with humans. A particular focus will be on the regulation of interaction dynamics, and rhythms of interaction, i.e. turn-taking, and synchronization of movements among interactants, social spaces (approach and avoidance), related to issues of immediate imitation (cf. WP5). The objectives of this WP are three-fold:

1. Development of a computational test-bed for the design of communicative (non-verbal) interactive behavior
2. In parallel to the above mentioned computational work, preliminary (small-scale) user-studies will evaluate the suitability of communicative behavior generated by existing robots

3. Development of simple verbal communication behavior, including the acquisition of one word and of simple two-word sentences;

2.6.2 Progress towards objectives

In the first 6 months of the project UNIHER has begun an investigation of information theoretic methods applied to characterizing and identifying experience (moving towards creating and exploiting enactively grounded dynamic interaction histories). The method of Average Information Distance (AID) Sensory-Motor Phase-Plots for robot self-categorization of experience was developed and validated on the Aibo platform. This work so far has resulted in the submission of 2 conference papers (IEEE CIRA'05 and Epigenetic Robotics 2005) with 2 more concerning the information theoretic approach forthcoming. UNIHER has also been undertaking research into mapping sensor space and learning motor capabilities. "Motor babbling" is used to learn a sensory layout and applied to learning sensorimotor contingencies using information theoretic measures.
Work on defining a structure for research into developmental levels in robot interactions with humans has also been conducted in the first 6 months (cf. the contribution of UNIHER for WP2). Pilot studies of Robot-Child interactions in a series of experiments using a semi-autonomous Aibo robot toward mapping interaction space were conducted with an aim to analyze requirements for engagement.
Work has begun on designing and constructing a minimal expressive head platform for the purpose of studying facial gesture and communication in human robot interaction. The head will have a range of expressions using eyes, eyebrows, eyelids, mouth/jaw and neck.

As part of WP6 activities, EPFL is developing a computational model to recognize and reproduce a variety of gestures. In particular, it emphasizes the ability of the model to predict the outcome of a motion and categorize it according to a set of labels (i.e. gesture), even when only part of the motion or a noisy subpart of the motion is presented.

2.6.3 Deviations from the project workprogramme

2.6.4 List of deliverables

No formal Deliverable scheduled for this period in this WP.

2.6.5 List of milestones

No Milestones scheduled for this period in this WP.

2.7 WP7 – Mechatronics of CUB

2.7.1 Workpackage objectives

To define the functional specifications for the initial design of the mechatronic components of the CUB, that are the Head-Eye system, the Arm-hand systems, the Spine and Leg system and the Software Architecture. - To identify the roadmap for the overall system integration, in order to guarantee the compatibility of all the CUB subsystems, both from a hardware and a software point of view.

2.7.2 Progress towards objectives

The most important activities carried out in the first six months are:

- A common reference model for the mechanical design of the platform has been defined. Final dimension and weight should fit as close as possible this model. A 3D CAD of the model is shared as a common working basis.
- Coding standard for mechanical design and mechanics-related documentation has been defined.
- Existing experiences on mechatronic component have been discussed to define a common database of component to be used in the following design.
- High level general rules have been fixed at the meeting in Nice on January 2005. This rules results in the platform specification.
- Kinematic model of the platform with first-trial specification in terms of number of degrees of freedom, range of each joint as well as dynamic performance of each joint has been defined;
- First-trial dynamic simulation and consequent force-torques evaluation has been made for mechanical design dimensioning.

- First-trial design has been carried out in two tasks. A first prototype of the head is also under testing.
- As a result of this initial design a first integration of the various subparts has been done.

2.7.3 Deviations from the project workprogramme

None

2.7.4 List of deliverables

No deliverables scheduled for this period in this WP

2.7.5 List of milestones

No Milestones scheduled for this period in this WP

2.8 WP8 – Open System: iCub

2.8.1 Workpackage objectives

1. Define the activity related to the creation, licensing, and distribution of the "Open Platform".
2. Define the mechanical, documentation, and software standards to ensure the widest acceptability of the platform.
3. Help in defining the platform and coordinate with WP2 for requirements and WP7 for mechatronic and technological issues.

The activity of this workpackage is devoted to the creation and support of the community of end-users of the open platform. At the outset, the main activity will be to define and establish the infrastructure of the RobotCub initiative. In this respect, the workpackage will define the various standard and requirements.

***The principal goal of this Work-package is to maximize the likelihood that the open platform will become the platform of choice for research in embodied cognitive systems*.** Consequently, it is important to establish standards that will facilitate this adoption and foster the continued enhancement of the platform by the community at large, and the open sharing of these enhancements. The creation of an appropriate licensing strategy for the commercial and academic use of the platform is tightly bound up with this endeavor.

2.8.2 Progress towards objectives

It was decided to adopt the name iCub for the RobotCub humanoid research platform (specifically for everything that falls under the heading of CUB Knowledge, as defined in the Consortium Agreement). The name derives from Asimov's "I Robot" and Mowgli the "man-cub" in Kipling's Jungle Book. The consortium has acquired the iCub.org domain name. The iCub.com domain name has been registered by a third party but is available for sale. The Whois.org entry for the domain indicates that the offer to purchase must exceed $5000. However, a lower bid might well be accepted. We have not decided yet whether to make a bid for it. The consortium is considering registering the RobotCub logo, the RobotCub name, and the iCub name as trademarks. This would then entitle us to apply for the RobotCub.eu and iCub.eu domain names during the sunrise period expected towards the end of 2005.

The wide-spread acceptance and adoption of the iCub depends quite critically on the licensing arrangements for iCub. Consequently, this workpackage is directly related to Deliverable D1.2 (WP1) according to which, as will have already been noted, has decided that all iCub software and documentation (including mechanical drawings and electronic schematics) will be licensed using the GNU General Public License (GPL) and the GNU Free Documentation License (FDL), respectively. This is a particularly significant decision, and is one that wasn't foreseen prior to the start of the project. Although the intention was always to have iCub open for research use, the decision as to the licensing arrangements for commercial use had been deferred. Now, however, the iCub will be free (as in free-speech) and open to all developers, academic and commercial alike, but with the strong constraint that all derived works will also be free and open. It is significant that this freedom and openness is of world-wide extent. Our belief is that this policy will greatly enhance the likelihood that the iCub will indeed become a global platform of choice for embodied cognitive systems research.

In furtherance of our goal of having the iCub accepted as the platform of choice for embodied cognitive systems research, we have been liaising with a consortium involved in preparing a proposal for IST Call 4 and they adopted the iCub as their development platform. Similarly, we presented the RobotCub's view on cognition at the JAST Opening Conference, at the IEEE-RJS conference on Humanoid Robotics 2004, and at the International Conference on Development and Learning 2004 and the reaction we received to the specifications of the iCub were very encouraging. This is important because, for example, the JAST project effectively takes up where RobotCub leaves off, i.e. at the level of social cognition and interaction between cognitive agents.

Task 8.1: Definition of the documentation and CAD standards.

Two naming conventions have been agreed, one for mechatronic drawings and another for software and documentation.

As noted above, the GPL and FDL licenses have been adopted for iCub software and documentation respectively; a set of guidelines has been created to assist developers in incorporating these licenses into their work.

We are working towards the development of a set of coding standards. Our goal is to strike a balance to avoid developing excessively rigid and prescriptive rules but yet to achieve a homogeneous style and high level of software quality for the entire body of iCub programs.

Similarly, we are developing a set of guidelines for documentation of both the software code and the mechatronic components.

Finally, we have begun the design of a comprehensive software architecture for iCub. It is important to establish this architecture early on so that cognition software developed in the various workpackages (specifically WP3 – WP6) can be relatively easily integrated. This architecture should be amenable to all types of uses: those who don't wish to interact directly at a hardware level and those who do. Furthermore, the iCub is intrinsically a parallel machine, with each device (sensor and actuator) operating concurrently. The iCub software architecture must deal with this, but provide user interface facilities with allow researchers to either ignore the complexities of concurrency or to exploit them, depending on their host computing system and programming paradigm.

Task 8.2: Documentation of mechanical design and components.

This task is on-going.

Task 8.3: Documentation of the design of the electronics and components.

This task is on-going.

Task 8.4: Software documentation.

This task is on-going.

Task 8.5: Legal and administrative issues.

The licensing issues have been concluded and we are now beginning to work on the establishment of a distribution mechanism for iCub material. This will be hosted at http://www.robotcub.org/icub/xxx, where xxx stands for the particular subject of interest (source code, licences, binaries, documentation, etc.) We are also considering using SourceForge (http://www.sourceforge.net) for distribution.

We now need to consider procedures for submission of contributions, quality assurance on adherence to standards, formal acceptance and release procedures.

2.8.3 Deviations from the project workprogramme

None

2.8.4 List of deliverables

No deliverables scheduled for this period in this WP

2.8.5 List of milestones

No Milestones scheduled for this period in this WP

2.9 WP 9 – Community Building and Self-Assessment

2.9.1 Workpackage objectives and description of work

1. Extend the base of knowledge for the definition of the CUB cognitive and mechatronic architectures and the adopted technologies by co-opting EU and non-EU scientists.
2. Promote an international project on Embodied Cognition supported by national and international funding agencies.
3. Monitor the advancement of the project toward the fulfillment of the project's objectives.
4. Organize training and dissemination activities.

The work in this WP is mostly related to organization of meetings and workshops to reach the four objectives described above. The meetings will be organized as internal or open to the scientific and industrial communities. The management bodies relevant for this workpackage are the International Research Panel (IRP) and the Board of Management (BM). Jointly they will decide on the topics to be discussed and the format of the meeting. The members of the IRP will be responsible of contacting funding agencies that may be interested in joining the International Project as well as industrial organizations potentially interested in monitoring the results of RobotCub.

2.9.2 Progress towards objectives

Task 9.1: Internationalization: organize meetings with scientists and funding agencies.

In the first six months of the projects the consortium has participated in:

1. The kick-off plenary meeting of "Cognitive Systems" in Bled
2. The kick-off meeting of the project JAST

So far there has been no formal dissemination meeting organized by the consortium but at our last meeting we invited Tamim Asfour from the Computer Science Department of the University of Karlsruhe to participate in our plenary meeting. At that meeting the Dr. Asfour also presented the activities on humanoid technologies at the University of Karlsruhe. Discussions about how to exchange information/data were very interesting.

All non-EU groups involved in the International Research Panel participated at previous meeting in Genova and presented the status of their projects in the field of embodied cognition. Yasuo Kuniyoshi (University of Tokyo, Japan), Gordon Cheng (ATR, Japan), Hideki Kozima (NICT, Japan), Aaron Edsinger-Gonzales (CSAIL-MIT, USA) and Jürgen Konczak (University of Minnesota, USA) participated in the meeting and presented their view about the objectives of RobotCub and the possibility for concrete collaboration. At present, some of the mechanical designs of these groups have been uploaded in the RobotCub website to be shared with the consortium and discussion are ongoing to establish a joint lab between NICT and University of Genova for a more effective collaboration during the design and implementation of the platform. Also exchange of students/scientists for relatively log period of time (3 to 6 months) between UNIGE and CSAIL are ongoing.

The programs and slides presented at all the meetings are available on the project's website at this address: http://www.robotcub.org/index.php/robotcub/administration/meetings

With the support of RobotCub, UNIFE is organizing a meeting in Ferrara on "The origin of human communication". RobotCub will support the participation of young scientists.

Task 9.2: Training: organize training sessions for the project's participants as well as summer school on topics relevant to Cognitive Robotics.

RobotCub is involved in the organization of a special session on Ontogenetic Robotics to be held within the 6th CIRA symposium, Espoo, Finland on June 27-30th, 2005. See also the following section 2.9.3 for details about change on plans in relation to "training activities".

Task 9.3: Assessment. At least once a year organize a formal assessment of the project.
So far we have been discussing the date of the review meeting which we propose to be in the period 18-21 October 2005.

2.9.3 Deviations from the project workprogramme

The main change worth mentioning is the decision to modify the strategy for the training activities of the project. In particular it was planned to organize a summer school related to the RobotCub scientific plan with the objective of making more homogenous the background knowledge of the young scientists working in RobotCub (the consortium is highly interdisciplinary). The reason we changed our strategy is related to the fact that we discovered that in the next few months some very interesting and high quality events were already organized by members of the consortium and it was decided to invest the funds allocated to training activities to support the participation of young researchers by direct participation to the event and by sponsoring fellowships for young researchers. In all the supported events we were assigned time to promote the activities of the RobotCub. In particular it was decided to sponsor and co-organize the events described in the following table:

Event and Website	Contribution	Robotcub Support
The origin of human communication	Luciano Fadiga	Support 10 travel grants for European Students
Brain Development and Cognition in Human Infants, Acquafredda di Maratea, Italy, 1-6 October 2005 **From Action to Cognition** http://www.esf.org/conferences/mc05118 (RobotCub's and Cogsys logos on all material)	Claes von Hofsten is conference chair and a special session on "Development in Artificial Systems" has been organized with speakers from the RobotCub Consortium	About € 10,000 charged to UGDIST "training budget" for the support of travel and accommodation of young scientists
3rd European Neuro-IT and Neuroengineering School **Neuroengineering of Cognitive Functions** http://www.neuro-it.net/Activities/Venice2005	Lectures by members of the RobotCub Consortium	No financial support provided

2.9.4 List of deliverables

Del. no.	Deliverable name	Date due	Actual/Forecast delivery date	Lead contractor
D9.1	Proceedings of the Initial Scientific Meeting	Month 6	Web-delivery	UGDIST

2.9.5 List of milestones

No relevant milestones during this period.

3 Description of work by each contractor

3.1 UGDIST

The activity at UGDIST has been divided on managerial and scientific aspects.

Workpackage 1: Management
From the management point of view, the building of the project's consortium (in the sense of establishing a good cooperative atmosphere) has been the main concern. This was pursued by organizing frequent plenary meeting and setting up a common repository of documents/data where to exchange data and information. The attendance to the meetings has been very satisfactory and also the participation in discussions has been very lively. Part of the management activities (even if informally part of WP8) has been the definition of the licensing strategy and the discussions about how to install an "easy-to-implement" open strategy.

Workpackage 2: Cognitive Development
From the scientific point of view and with reference to WP2 the goal of UGDIST work has been to foster the creation of a baseline review of the different approaches each partner is taking in the modeling of cognition in artificial systems. The goal of this work is to identify the scientific, technical, and technological foundations in much greater detail than provided in the technical annex so as to ensure that the complete space of cognitive development is being spanned, to facilitate complementary work among disciplines, groups, cognitive skills, and experimental scenarios, and to facilitate cohesion among underlying scientific models.

Workpackage 4: Object's Affordance
Initial implementation of a visual stereo algorithm aimed at providing the reaching/manipulating control algorithms with the shape information necessary to operate on object's affordance.

Workpackage 8: Open System
Work in this WP has been devoted to establishing a common framework for exchange of data (e.g. file naming conventions and standards for exchange of mechanical, electronic and software code), as well a the definition of the licensing strategy.

Workpackage 9: Community Building and Self-Assessment
Work here has been devoted to the establishment of the links with the International Research Panel of the project (already met ones), with on-going projects in the "cognitive systems" action and with other projects interested in adopting iCub as their platform for the study of embodied cognition.

3.1.1 Major Achievements

1. RobotCub Web Site and Logo.
2. Adoption of a Free Software / Open Source Software (FS/OSS) license for the iCub for both research and commercial use.
3. Contribution to the establishment of standards for coding and documentation, a mechanism for archival and dissemination of open material, and the design of a software architecture for the iCub
4. Definition of file naming conventions for software and documentation.
5. Organization of the two plenary meeting in Genova, a topical meeting in Nice a meeting of the International Research Panel meeting in Genova.
6. Presentation of the RobotCub project at the JAST Opening Conference
7. Liaison with a consortium preparing a proposal for IST Call 4 to seek their adoption of the iCub as their platform for embodied cognitive development (focused on affect-based learning and social interaction)

3.1.2 Published Papers

1. G. Sandini, G. Metta, D. Vernon: Robotcub: an open framework for the study of embodied cognition. Proceedings of the IEEE Conference "Humanoids 2004", Santa Barbara;
2. G. Sandini, G. Metta, D. Vernon: RobotCub: An Open Research Initiative in Embodied Cognition. Proceedings of ICDL 04, San Diego, 2004.

3. A developmental approach to grasping. L. Natale, G. Metta, G. Sandini. In Developmental Robotics AAAI Spring Symposium, 2005. Stanford, CA, March 21-23 2005
4. L.Natale, F. Orabona, G. Metta, G. Sandini. Exploring the world through grasping: a developmental approach. Accepted to the 6th CIRA Symposium, Espoo, Finland, June 27-30, 2005.

3.1.3 Appearance on press

- July 11, 2004: L'Europa che vuole fare le scarpe ai giapponesi. Anzi i Robot (Europe competes with Japan on Robots). Il Venerdi di Repubblica (weekly magazine of a daily newsapper "La repubblica").
- July 30, 2004: Che bella famiglia sono tutti baby robot! (The family of Babybot includes RobotCub): (weekly special pages for children of the daily newspaper "Il Secolo XIX").
- July 2004: EU-funds project on humanoid technology and cognitive neurosciences: Cordis Record control number (RCN): 23151.
- August 10, 2004: European Humanoid is going to conquer the world; Eurelios: Agence de press photographique.
- August 24, 2004: La realtà dell'Intelligenza Artificiale (reality of artificial intelligence): Il secolo XIX (daily newspaper).
- October 21, 2004: Macchine Antropomorfe, l'ultima forntiera. Che razza di androidi (what kind of androids): Panorama (weekly magazine).
- Spinney L.: Artificial Intelligence Marches Forward: As physiology and neuroscience increasingly inform robotics, maybe robots can return the favour. *The Scientist* **19**(5):18 (14 March 2005).

3.1.4 Major Equipments

No major equipment purchased

3.1.5 Deviation from Planned Activity

No big deviation from planned activities.

3.1.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Giorgio Metta	Assistant Professor	6
David Vernon	Visiting Professor	3
Lorenzo Natale	Post-doc	6
Matteo Brunettini	Junior Researcher	6
Michele Tavella	Student	3
TOTAL		**24**

Own Resources		
Name	**Position**	**Effort (pm)**
Giulio Sandini	Professor	3
Vincenzo Tagliasco	Professor	1
Francesco Orabona	PhD Student	6
TOTAL		**10**

3.2 SSSA

3.2.1 Major Achievements

The main effort of SSSA is focused on the mechatronic design, taking in account the technology limitation and the tasks to perform. The previous experience and a new overview in the recent technologies have been exploited to achieve the following:

- Definition of the iCub requirements
- Survey on anthropomorphic and robotic mechanism concerning shoulder, elbow, wrist, hand
- Survey on non-electrical actuators
- Survey on compliance implementation
- Survey on sensors, focusing on tactile sensors (contact, pressure, thermal) and proprioceptive sensors (torque and joint rotation)
- First sketch of the iCub arm

3.2.2 Published Papers

- M Zecca, S. roccella, M.C. Carrozza, H. Miwa, k. Itoh, G. Cappiello, J.J. Cabibihan, M. Matsumoto, h. Takanobu, P. Dario, A. Takanishi, “On the development of the Emotion Expression Humanoid Robot WE-4RII with RCH-1”, IEEE-RAS/RSJ International Conference on Humanoid Robots, Humanoids 2004, Los Angeles, CA, USA, November 10-12, 2004
- M.C. Carrozza, G. Cappiello, G.Stellin, F. Zaccone, F. Vecchi, S. Micera, P.Dario, “A cosmetic prosthetic hand with tendon driver underactuated mechanism, compliant joints and EMG control: ongoing research and preliminary results”, International Conference on Robotics and Automation, ICRA 2005 Barcelona, Spain, April 16-22. 2005.

3.2.3 Appearance on press

Noting to mention

3.2.4 Major Equipments

No major equipment purchased. Survey on anthropomorphic robot with the aim of purchasing an exiting humanoid robot

3.2.5 Deviation from Planned Activity

Nothing to mention

3.2.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Giovanni Cappiello	Ph.D. Student	1.2
Giovanni Stellin	Ph.D. Student	2.9
Claudia Salatino	Junior Researcher	1.2
TOTAL		**5.3**

Own Resources		
Name	**Position**	**Effort (pm)**
Paolo Dario	Full Professor	0.6
Chiara Carrozza	Associate Professor	1.8
Cecilia Laschi	Assistant Professor	1.8
Carlo Filippeschi	Technician	0.7
Roberto Lazzarini	Technician Robotic Eng.	0.7
TOTAL		**5.6**

3.3 UNIZH

WP2 Cognitive development

Inspired by our previous work on the simulation of development by the concurrent increase of sensory, motor and neural complexity; we are planning a developmental scenarios where the robotic hand will learn to manipulate objects of different shapes, textures and materials (see Fig. 1b). Starting with some of the fingers coupled together, using a few of the sensors available and a neural network with a small number of neuronal units, over time these constraints will be released to see if learning can be accelerated by following a developmental approach.

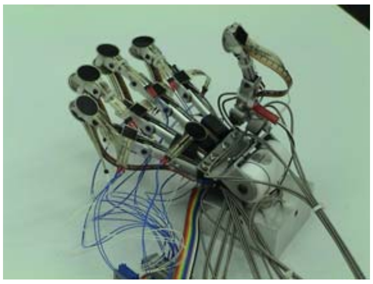
WP3 Sensorimotor coordination
An initial set of grasping reflexes have been implemented.

WP7 Mechatronics
Gabriel Gomez and Alejandro Hernandez Arieta, have spent four months improving the tendon driven robotic hand by putting different sensors: pressure for the haptic sensory modality, and bending for proprioception, as well as developing the necessary software.

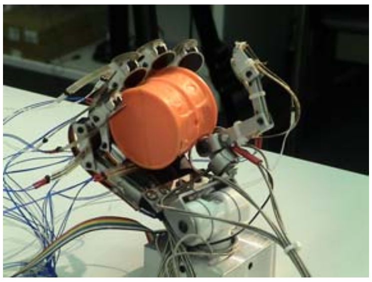
WP8 Infrastracture of Open System (CUB)
Martin Krafft has been working on an implementation of an adaptive learning framework, using the ligand-receptor concept recently investigated at our laboratory. The framework was designed as a modular and extensible construction kit to allow for flexible experimentation with neurobiologically-inspired neural networks. The underlying neural concepts allow the design of controllers which are adaptable to different platforms and to changes in the morphology (sensory as well as motor systems). The library, which is implemented in C++, consists of efficient algorithms with a low memory footprint, serialization, and a highly-generic, policy-based interface design. A first release to the general public is planned for the summer of 2005. At the moment, several timing issues need to be worked out.

3.3.1 Major achievements

We have established a robotic platform ready to perform initial experiments on sensorimotor coordination, learning and development. The platform consists of an active vision system and a robotic hand. Most of the work has been performed to improve the sensorimotor capabilities of the robotic hand. The tendon driven robot hand (see Fig. 1a) is partly built from elastic, flexible and deformable materials. For example, the tendons are elastic, the fingertips are deformable and between the fingers there is also deformable material. It has 15 degrees of freedom that are driven by 13 servomotors, a bending sensor is placed on each finger as a measure of the position, and a set of standard FSR pressure sensors cover the hand (e.g., on the fingertips, on the back and on the palm).



a



b

Figure 1. Robotic hand. (a) tendon driven system, bending and pressure sensors. (b) grasping an object.

3.3.2 Published Papers

1. Pfeifer, R. and Gomez, G. (2005). Interacting with the real world: design principles for intelligent systems. Artificial life and Robotics. Vol9. Issue 1. pp. 1-6.
2. Gomez, G. Lungarella, M., Eggenberger, P., Matsushita, K., and Pfeifer, R. (2004). Simulating Development in a Real Robot. Poster in ICDL04 in San Diego.

3.3.3 Appearance on press

„Was wir von Roboter lernen kennen“. *Technology review. Nr. 2. Februar 2005*. German edition, Heise Verlag. **pp.** 56-61.

3.3.4 Major Equipments

No major equipment purchased

3.3.5 Deviation from planned activity

Nothing to mention

3.3.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Martin Krafft	PhD. Student	3
Alejandro Hernandez Arieta	PhD. Student	4
TOTAL		**7**

Own Resources		
Name	**Position**	**Effort (pm)**
Rolf Pfefer	Professor	0.5
Peter Eggenberger Hotz	Professor	0.5
Gabriel Gomez	(PhD. Student)	4
TOTAL		**5**

3.4 UNIUP

UNIUP worked on the cognitive roadmap and on experiments on the perception of gaze direction, event perception in autistic children, gaze tracking, and reaching for moving objects. We also continued our studies of infants' manipulation of objects.
We also started collaboration with UNFE on the development of mirror movements. A meeting was held in January in Ferrara to plan this research

3.4.1 Major Achievements

<u>WP2: Cognitive development</u>.

Two tasks have been pursued during this period.
1<u>. The cognitive roadmap</u>. A progress report was delivered at the Lisbon meeting. In that we outlined the major problems that needs to be elaborated in the roadmap were outlined.
First we outlined the primary prerequisites for action:
a*. Actions are organized around tasks and defined by goals.* It is the goal that is important not the means by which it is achieved.
b. ***Perception and action are mutually dependent*.** Together they form adaptive systems.
c. *Actions are initiated and maintained by a motivated subject.*
d. Actions are guided by prospective information.
Then we discussed the importance of motivation, the definition of core abilities, and the starting point of development. Four different areas of cognitive development was identified and discussed. 1. Developing posture and locomotion. 2. Developing looking and and other modes of exploration. 3. Development of reaching and manipulation. 4. Developing of social skills.
2. <u>Developmental architecture.</u> Experiments have been conducted on children's ability to manipulate objects and understand events in the surrounding. In these experiments, measurements of gaze direction and reaching activity have been used to investigate the development of the cognitive function.

<u>WP3 Sensorimotor Coordination</u>

In this work package, we have conducted research on human infants to investigate the ontogenesis of gaze control and reaching. First, we have studied the development of horizontal-vertical gaze tracking and the development of infants' ability to catch moving objects. Secondly, we have started research on the development of infants' ability to perceive the goals of actions and on the development of mirror neurons. This research is partly done in collaboration with UNIFER. In January this year, a meeting was held in January in Ferrara to plan this research. Two kinds of experiments have been piloted. First, we have measured infants' looking patterns when observing and conducting actions. Secondly, we have begun EEG experiments find out what kinds of cortical activations are associated with the observation of actions.

WP4 Object's Affordance

A series of experiments are being conducted where toddlers' understanding of the affordances related to object manipulation is investigated. We study how children go about when trying to fit objects into each other, how they learn to pile objects on the top of each other, and how they learn to fir lids on pans. Such activities will reflect children's ability to mentally move and rotate objects, their understanding of form and size relationships and their understanding of physical laws such as gravity and inertia.

3.4.2 Published Papers

1. von Hofsten, C., Dahlström, E., & Fredriksson, Y. (2005) 12-month–old infants' perception of attention direction in static video images. Infancy, in press.
2. Gredebäck, G., von Hofsten, C., Karlsson,J., and Aus, K. (2005) The development of two-dimensional tracking: A longitudinal study of circular visual pursuit. Experimental Brain Research, in press.

3.4.3 Appearance on Press

None

3.4.4 Major Equipments

No major equipment purchased

3.4.5 Deviation from planned activity

None

3.4.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Kerstin Rosander		3
Helena Grönqvist		2
TOTAL		**5**

Own Resources		
Name	**Position**	**Effort (pm)**
Claes von Hofsten		3
TOTAL		**3**

3.5 UNIFE

UNIFE is doing experiments on the development of the capability to plan and recognize actions. It is currently is involved in monkey electrophysiology of hand-related premotor cortex during action execution/observation, in the study of predictive capabilities of the motor system during execution of grasping and during observation of similar actions of others, in the study of the mechanisms ath basis of human communication (gestural as well as verbal). We started collaboration with UNIUP and with other RobotCub teams on the development of mirror neuron system. A meeting was held in January in Ferrara to plan these researches.

3.5.1 Major Achievements

In addition to the experiments mentioned in WP3 section of this deliverable, we projected and realized a multielectrode amplifier (36 channels) to study motor representations in rats, we are developing a non invasive system to record transcranially brain activity in infants (NIRS), we are investigating the possibility to extract metabolic signals from the brain as an index of localized neural activity. We coordinated WP3 planning by involving also non-neuroscience teams. Among our most recent results, an fMRI experiment on gesture recognition demonstrating the involvement of a speech premotor area (Broca's) in action understanding, some new techniques of fMRI analysis based on new statistical ideas on the correction for multiple comparisons, the finding that many motor neurons recorded in monkey's area F5 are sensitive to the vision of monkey's own hand during grasping.

3.5.2 Published Papers

1. Fadiga L, Craighero L, Olivier E. Human motor cortex excitability during the perception of others' action. Curr Opin Neurobiol. 15:213-8 (2005)
2. Fadiga L. e Craighero L. (in press) Hand actions and speech representation in Broca's area. Cortex

3.5.3 Appearance on press

1. September 22nd 2004, "il Resto del Carlino", Italian newspaper. Two articles in Italian focusing on the importance of the cognition, and in particular on the possibility to recognize observed actions, to build an artifact interacting with others.
    - "Nasce a Ferrara il 'cucciolo di robot capace di imparare"
    - "Un bimbo robot che pensa"
2. Novembre 4th 2004, "il Resto del Carlino", Italian newspaper. Article in Italian on the presentation of the Babybot at the "Festival della Scienza di Genova": "Quilici, Barbujani e il 'baby robot' partorito dall'ateneo estense: così Ferrara diventa la grande protagonista del "Festival" di Genova"
3. Genuary 1st 2005, "il Sole 24 ore"

3.5.4 Major Equipments

UNIFE is buying an eye tracking device to perform experiments in parallel with UNIUP.

3.5.5 Deviation from Planned Activity

None

3.5.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Andrey Oleyinik	Researcher	5
Brian Toomey	Researcher	1
Luciano Pusinanti	Administrative	3
TOTAL		

Own Resources		
Name	**Position**	**Effort (pm)**
Luciano Fadiga	Professor	3
Laila Craighero	Ass. Professor	3
Claudio Bonifazzi	Ass. Professor	3
Livio Finos	Researcher	6
TOTAL		

3.6 UNIHER

Research activity has been devoted to the following topics related to WP6:

1. Investigation of information theoretic methods applied to characterizing and identifying experience (Assif Mirza)
2. Mapping sensor space and learning motor capabilities using information theoretic measures. (Lars Olsson).
3. Pilot studies of Robot-Child interactions in a series of experiments using a semi-autonomous Aibo robot toward mapping interaction space; analysis of requirements for engagement (Ben Robins).

4. Work on defining a structure for research into developmental levels in robot interactions with humans (Dorotée Francois).
5. Mechanical design (in progress) and beginning construction on interactive minimal expressive robotic face/head with eyebrows, jaw/mouth, eyes, eyelids, neck (Andrew Appleby).

3.6.1 Major Achievements

- Completed preliminary study of space of robot-child interaction and initial analysis of requirements.
- Developed concept of Average Information Distance plots for robot self-characterization of interactions along with software for Aibo.
- Organized (along with Giorgio Metta) a special workshop on Ontogenetic Robotics at the IEEE CIRA 2005 conference in June to support RobotCub research and dissemination, and promote scientific interest in the area.
- Progress on prototype minimal expressive head/face, providing feedback to IST Lisbon on expressive requirements for I-Cub.
- Specific collaborations ongoing:
  - UNIHER and IST Lisbon: UNIHER will help to integrate any suggestions arising from the studies on facial gestures into IST design of the robot head for WP2.
  - UNIHER and UNIFE: Discussions have begun on the role and mechanisms of gesture and gaze in sensorimotor learning and interaction. Also to investigate infra-red motion tracking for this purpose.
  - UNIHER and EPFL: Discussions with EPFL have begun discussions on using technology for determining head-orientation by tracking the nose to help the interaction studies being conducted at UNIHER.

3.6.2 Published Papers (submitted)

The following papers have been submitted to international conferences and are still under review:

4. Lars Olsson, Chrystopher L. Nehaniv, Daniel Polani, “From Unknown Sensors and Actuators to Visually Guided Movement" (Submitted to International Conference on Development and Learning (ICDL) 2005)
5. 2.Lars Olsson, Chrystopher L. Nehaniv, Daniel Polani, “Sensor Adaptation and Development in Robots by Entropy Maximization of Sensory Data" (Submitted to IEEE Computational Intelligence in Robotics & Automation (IEEE CIRA’05), Special session on Ontogenetic Robotics)
6. 3.Naeem Assif Mirza, Chrystopher L. Nehaniv, Kerstin Dautenhahn, René te Boekhorst, “Using Sensory-Motor Phase-plots to Characterise Robot-Environment Interactions" (Submitted to Computational Intelligence in Robotics & Automation (IEEE CIRA’05), Special session on Ontogenetic Robotics)
7. 4.Naeem Assif Mirza, Chrystopher L. Nehaniv, René te Boekhorst, Kerstin Dautenhahn, “Robot Self-Characterisation of Experience Using Trajectories in Sensory-Motor Phase Space” (Submitted to Epigenetic Robotics 2005)
8. 5.Lars Olsson, Chrystopher L. Nehaniv, Daniel Polani, “Discovering Motion Flow by Temporal-Informational Correlations in Sensors" (Submitted to Epigenetic Robotics 2005)

In April 2005, another conference paper on the pilot studies mapping the space of robot-child interaction and requirements will be submitted to IEEE RO-MAN 2005, also further papers on information-theoretic interaction history learning from sensorimotor experience will be submitted to IEEE CEC 2005.

3.6.3 Appearance on Press

Demos of University of Hertfordshire Robot-Cub work have been prepared for the Artificial Intelligence and Simulation of Behaviour Convention (AISB’05) in the U.K. April 2005. Journalists are expected to attend with possible follow-up media coverage.

3.6.4 Major Equipment

None Puchased

3.6.5 Deviation from Planned Activity

With the decision that the iCub will not speak, this WP is not focusing on acquisition of speech. Instead we have expanded effort into foundational aspects for the ontogenesis of gesture and communication, focusing on pre-cursors for the development of communication and gesture using bottom-up, enactive dynamical systems methods. In addition, in order to help ensure balanced design and adequate expressive capability for interaction in the iCub, we have undertaken design and construction of a minimal expressive robotic head for use in human-robot interaction studies. This is an extension of the UNIHER role in the project (originally only focusing on iCub mindware). This new initiative had been approved by the management team prior to start of work.

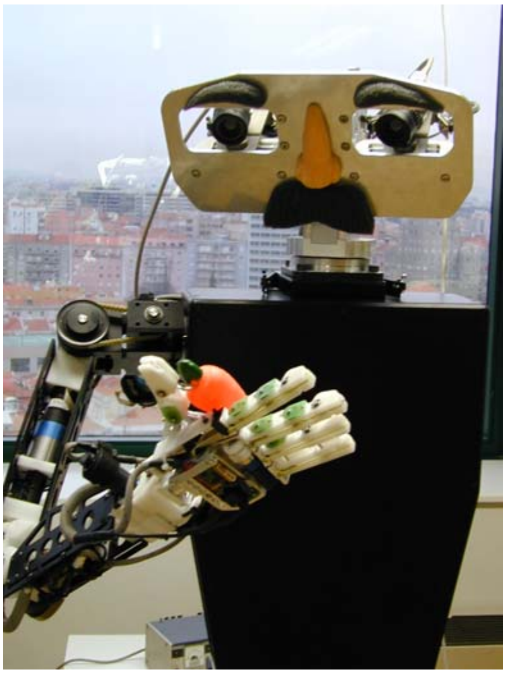
3.6.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
N. Assif Mirza	Research Assistant	5
Andrew Appleby	Technical Staff	1
TOTAL		**6**

Own Resources		
Name	**Position**	**Effort (pm)**
Lars Olsson	PhD Student	5
Ben Robins	PhD Student	1.2
Dorothée Francois	PhD Student	0.6
Kerstin Dautenhahn	Professor	2
Chrystopher L. Nehaniv	Professor	2
René te Boekhorst	Senior Lecturer	1
David C. Lee	Senior Lecturer	0.2
TOTAL		**12**

3.7 IST

The activity at IST during the first months of the project is described in correspondence to each workpackage. In addition to the work on the design of the iCub head, IST has developed methodologies and performed experiments with its current anthropomorphic arm-and-torso-head system, Baltazar (see photo on the right hand side).



Workpackage 1: Management
In addition to participating in all project meetings, IST hosted the 3rd RobotCub General Meeting, in Estoril, March 17-19th, 2005. The meeting included a visit to the laboratories at IST/ISR where the first prototype of the head was demonstrated.

Workpackage 2: Cognitive Development
A developmental approach was partly implemented and tested in Baltazar following the main three stages:

i) Learning about the self
ii) Learning about objects (grasping and affordances)
iii) Learning about others (imitation)

Most of this work is described in a paper presented at the AISB 2005 Symposium on Imitation in Animals and Artifacts, 2005.

Workpackage 3: Sensorimotor Coordination

Part of the work mentioned in WP2, IST worked on methods to build visuomotor maps from self-observation. These maps include both static and velocity (Jacobians) maps. While the static visuomotor maps are used for the first phase of grasping, the visuomotor Jacobians are used for visual servoing.

Workpackage 4: Object's Affordances
Preliminary work of using object affordances in gesture (manipulation) recognition was done.

Workpackage 5: Imitation
Low-level imitation was tested in the Baltazar platform. At this level the imitation metric is mainly the exact reproduction of the observed gesture, while the imitation of goal-directed action is the focus of current work.

Workpackage 7: Mechatronics of the Cub
During the first 6 months of the project IST has studied and proposed a set of specifications of the head as well as various design alternatives meeting those specs. A first prototype was built and demonstrated in a light tracking experiment during the RobotCub General Meeting in Lisbon.

Although not initially planned, IST has pursued work on the design of the iCub face. For this particular issue IST has worked with several arts and architecture schools in Portugal as well as discussed with UNIHER regarding specific features of the face design.

Workpackage 9: Community Building and Self-Assessment
IST has organized a competition for high school Art and Design students for the design of the iCub face and expressions. This procedure had an enthusiastic response from the students and results were shown during the RobotCub Meeting in Lisbon.

3.7.1 Major Achievements

1. Definition of the specifications of the iCub head.
2. Head design, including eye system and neck mechanisms. Three alternative designs studied for the neck: serial, parallel and parallel and cable actuation. The cable driven had the disadvantage of having the motors inside the robot chest.
3. Prototype of the iCub head with the serial neck. Demonstrated in Lisbon on March 18th, 2005. The parallel version will be assembled shortly.
4. Work on sensorimotor coordination, learning and cognitive development using the anthropomorphic humanoid-type platform, Baltazar.
5. Organization of the 3rd RobotCub general meeting in Lisbon, March 17-19 2005.

3.7.2 Published Papers

1. M. Lopes, A. Bernardino and J. Santos-Victor, A Developmental Roadmap for Task Learning by Imitation in Humanoid Robots: Baltazar's Story, AISB 2005 Symposium on Imitation in Animals and Artifacts, University of Hertfordshire, UK, 12-14 April 2005

3.7.3 Appearance on press

None

3.7.4 Major Equipments

None

3.7.5 Deviation from Planned Activity

None

3.7.6 Effort

Charged to RobotCub (estimate)		
Name	**Position**	**Effort (pm)**
Ricardo Beira	Researcher	6
Miguel Praça	Researcher	1

Rodrigo Jacob	Research Engineer	5
J. Santos-Victor	Assoc. Professor	1
A. Bernardino	Assist. Professor	1
J. Gaspar	Assist. Professor	1
J. Sentieiro	Full Professor	1.5
TOTAL		**16.5**

Own Resources (estimate)		
Name	**Position**	**Effort (pm)**
J. Santos-Victor	Assoc. Professor	1
A. Bernardino	Assist. Professor	1
J. Gaspar	Assist. Professor	1
J. Sentieiro	Full Professor	1.5
TOTAL		**4.5**

3.8 UNISAL

3.8.1 Major Achievements

To date the main effort of UNISAL is focused on the mechatronic design incorporating the mechanical designs of the spine, hip, legs, ankle and foot and the electronic design of control and drive boards for the motors and sensory monitoring circuitry.

Specifically the worked has involved:

- Development of a VR simulation of the iCUB to provide a discussion perspective for the development of the iCUB leg and spine functionality during, crawling, sitting and transition phases.
- Collaborated on the definition of the iCUB requirements with the other partners in the mechatronic design workpackage (UGDIST, SSSA, IST, TRL and EPFL). This work has developed through a series of design phases looking at the required performance and structure. This work has ensured effective integration of the components for the version 1 prototype to be produced later this year.
- Design, construction and initial testing on motor drive boards. In conjunction with UGDIST we have been considering electronic design options for the primary drive and control boards. A specification for the electronic system performance has been developed to address the full integration issues within the iCub
- Design, construction and initial testing of torque sensing systems for the joints.
- Development of a MATLAB simulation of the control efforts for the lower limbs. This provides basic data needed on the control efforts and has been used in the development of the design specification.
- Survey of mechanisms in spines and lower limbs in anthropomorphic robots.
- Development of a new hand tracking mechanism for babies, in conjunction with UNIUP. It was noted that systems to track the motion of infant hands was a key need for the study of child behavior, however, no effective methods achieving this tracking particularly for the fingers is available. Within the RobotCub group a new hand and finger tracking systems (Project ANDRIANA) is developing systems specifically for applications with small children. It is believed that it may be possible to extend this to the primate studies at UNIFE.
- Collaborated in a survey of actuators and sensing technologies.
- Prototype designs for a 3 degree of freedom spine.
- Prototype designs for 5 degree of freedom lower limb.
- Outline collaboration with UGDIST on haptic control and feedback for a dexterous robotic hand.

3.8.2 Published Papers

D.G.Caldwell, “Biomimetics in the development of Humanoid Robotics”, IARP Workshop on Dependable Robots in Human Environments, Salford, UK, 7-9 Sept. 2005.

3.8.3 Appearance on press

"Ciao l'ambasciatore", Manchester Evening News, June 2004.
"", 60 sec segment on North West Tonight, Regional Television programme, 15th April 2005

3.8.4 Major Equipments

No major equipment purchased.

3.8.5 Deviation from Planned Activity

No major deviations from the planned activities.

3.8.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Martin Sinclair	PhD student	3
Milan Bezedick	PhD student	1
Yannis Sarakaglou	PhD student	0.5
TOTAL		**4.5**

Own Resources		
Name	**Position**	**Effort (pm)**
Darwin Caldwell	Professor	2
John Gray	Professor	1.2
Nickoloas Tsagarakis	Research Fellow	4.5
Cyd Hockenhull	Technician	0.5
William Hinojosa	Ph.D student	0.5
Rene Masey	PhD student	0.5
TOTAL		**9.2**

3.9 EPFL

3.9.1 Major Achievements

The ASL3 laboratory at EPFL contributed principally to WP5 and WP6, through the development of algorithms for the recognition and regeneration of gestures, and, in particular of human goal-directed reaching motions. The BIRG laboratory at EPFL contributed principally to WP7 through the development of a physics-based simulation of the iCub, the development of adaptive oscillators for locomotion (crawling), as well as through the specification of dynamic and kinematic requirements for the CUB.

3.9.2 Published Papers

The following papers were submitted as part of RobotCub:

Maurer, A. & Billard A.G., *Extended Hopfield Network for Learning Sequences: Application to Gesture Recognition* International Conference on Artificial Neural Networks, ICANN (submitted) 2005.

Hersch, M. & Billard, A.G. (2005), An internal multimodal model for imitating 3D reaching movements, Poster presented at the AISB Symposium: Imitation in Animals and Artifacts, 12-15 April 2005.

Righetti, L., Buchli, J. & Ijspeert, A.J., Dynamic Hebbian learning for adaptive frequency oscillators, Physica D (Submitted), 2005.

3.9.3 Appearance on press
None

3.9.4 Major Equipments
No major equipment purchased

3.9.5 Deviation from Planned Activity
There were no deviations from planned activities

3.9.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Micha Hersch	PhD Student	6
Ludovic Righetti	PhD Student	6
TOTAL		**12**

Own Resources		
Name	**Position**	**Effort (pm)**
Biljana Petreska	PhD Student	2
Eric Sauser	PhD Student	1.5
Aude Billard	NSF Professor	2
Auke Ijspeert	NSF Professor	1
TOTAL		**5.5**

3.10 TLR

3.10.1 Major Achievements
The main activities done in this first period are:

- definition of a common model to be used as base for the design of the iCUb;
- definition of the coding standard for the mechanical design and documentation;
- realization of the DWG (Autocad) templates for the iCub;
- definition of first approximation weight goal of each iCub group;
- first trial integration of the work packages groups and integration analysis;
- alternative neck design for critical benchmark with the IST design;
- Mechanical design activities coordination.

3.10.2 Published Papers
none

3.10.3 Appearance on press
July 11, 2004: L'Europa che vuole fare le scarpe ai giapponesi. Anzi i Robot (Europe competes with Japan on Robots). Il Venerdi di Repubblica (weekly magazine of a daily newsapper "La repubblica");

3.10.4 Major Equipments
No major equipment purchased.

3.10.5 Deviation from Planned Activity
None

3.10.6 Effort

Charged to RobotCub		
Name	**Position**	**Effort (pm)**
Francesco Becchi	Engineer	1
Giulio Maggiolo	Engineer	.5
TOTAL		**1.5**

Own Resources		
Name	**Position**	**Effort (pm)**
David Corsini	CEO	0.5
Francesco Becchi	Engineer	1
TOTAL		**1.5**

3.11 EBRI

EBRI participation to the project is essentially to contribute knowledge about sensorimotor coordination in humans and suggesting biologically interesting solutions of the control algorithms. The financial participation is, accordingly, quite limited.

3.11.1 Major Achievements

In this initial part of the project EBRI's participation has been mostly through meetings with the coordinator and Prof. Bizzi detailing the overall experimental plan of the projects. It is expected that EBRI participation will become more active and continuous as soon as we will explicitly address the implementation/modeling of the sensorimotor coordination algorithms.

3.11.2 Published Papers

None

3.11.3 Appearance on press

None

3.11.4 Major Equipments

None

3.11.5 Deviation from Planned Activity

None

3.11.6 Effort

4 Any Other issues

References

http://www.robotcub.org