# SECOND YEAR PROJECT SUMMARY

CHRIS

Cooperative Human Robot Interaction Systems

COOPERATION

**Grant Agreement number:** 215805

**Project acronym:** CHRIS

**Project title:** Cooperative Human Robot Interaction Systems

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## 1.1 Summary description of the project objectives and aims

CHRIS is based on the premise that it will be ultimately beneficial to our socio-economic welfare to generate service robots capable of safe co-operative physical interaction with humans. Robots working in shared space with humans will provide significant benefits where robot strength, precision, persistence and indefatigability enhance human performance in certain tasks.

In order for service robots to have the capability required to work with humans in a shared space, certain conditions must be met. Perhaps most importantly, the human must trust that the robot will perform the task appropriately and without harm. To be genuinely useful the robot must be powerful enough to perform the task but inherent in this comes the potential to be dangerous. Consequently the robot must be designed with safety at the heart. CHRIS addresses this directly. CHRIS defines safety through the robot's cooperative interaction with the human, in terms of physically safe (e.g. movements are appropriate and smooth not ballistic or unpredictable), behaviourally safe (e.g. action is largely predictable and understandable by the human), and cognitively safe (e.g. actions are performed following reasoning and planning of the action, evaluation of the possible outcomes and safety implications of the action).

CHRIS will investigate human-human interaction and employ appropriate mechanisms to embed these principles in human-robot interactions. Engineering principles of safe movement and dexterity will be explored on the available robot platforms, and developed with principles of goal negotiation, communication and decisional action planning for appropriate human robot safe interaction.

A vital objective of the project is to understand how human cooperative action occurs both cognitively and physically within a set of chosen scenarios. This will be achieved through human cooperation experiments. Flowing from this, the next objective is to encapsulate these elements, and implement them on robotic platforms through interaction across all the disciplines in the research team. Essential to effective human-robot interaction is safety. To this end a key objective of the project is to assess the safety of human-robot interactions from the aspects of physical safety, behavioural safety, and cognitive understanding, and investigate ways of implementing these as robust features in robot platforms. Having identified these pre-requisites, the research team will develop the engineering principles required to ensure the robot platform is capable of controlled intelligent movement, both gross and dextrous, to perform cooperative tasks with humans safely. Key to the project results having an exploitable economic and social impact, is the rigorous testing of the robustness of the robot platforms pertaining to a changing human-robot interaction environment.

The CHRIS consortium is made up of four robotics research groups: Bristol Robotics Laboratory (BRL), Laboratory for Analysis and Architecture of Systems (LAAS-CNRS), National Institute of Health and Medical Research (INSERM) and the Italian Institute of technology (IIT) and one developmental psychology research group: Max Planck Institute for Evolutionary Anthropology (MPG). The project works with four different robotic platforms; the iCub, Jido, HRP2 and BERT2.

## 1.2 Description of work performed since the beginning of the project

**Management and dissemination procedures**

It is key to the smooth running of the project and achievement of all other objectives to have effective management procedures and effective channels of communication. The consortium agreed to such procedures from the outset, and these procedures have been in place throughout this second period ensuring information flow and timely communication across the team.

Key objectives of management have been achieved in this period. The second year of the project has included the first Annual Review meeting, two management meetings, comprising both management and technical sections, the attainment of one milestone and successful delivery to the EC of three project deliverables. The public facing website has been continuously updated during this period, and the internal project wiki has continued to prove to be a very effective management tool across the consortium for dissemination of information and storage of key documents. Smaller technical development and integration meetings have occurred regularly during this period both in person and via online collaboration networks like EVO (http://evo.caltech.edu/evoGate/). This functionality augments the communication between the whole project team thus diminishing the impact of geographical separation of the project partners. The added value gained from these online meetings and discussions, in addition to technical meetings, enables smooth integration across the discipline boundaries of psychology, human cognition, computer science and engineering. Finally, risk management has been undertaken and is working well through the employment of a risk register. Risks are identified by the project partners and communicated to the Project Manager at Project Management meetings where complete risk register is also reviewed.

Dissemination of research activity is a key factor in achieving the wider social and economic impacts of the benefits of the research program. To this end the project team have been actively disseminating results of the project and particularly the aims of the project, through attendance at conferences, workshops, media reporting and publication in journals. This has included reporting in the Financial Times Magazine (Innovation issue) and Reuters. The project website (http://www.chrisfp7.eu/) is the permanent public face for the CHRIS project disseminating to the widest possible audience. A regularly updated summary of projects activities is included on this website.

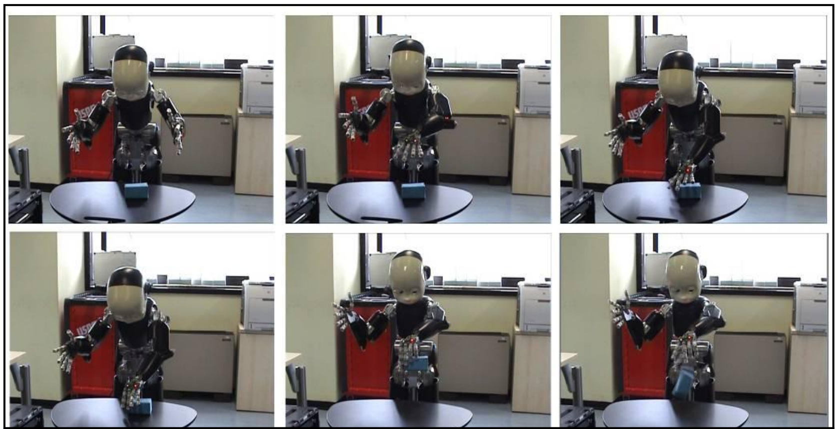
**Systems Engineering**

This is the aspect of the project that works to ensure that cooperative functions that are defined by the developmental psychologist researchers are analysed and allocated for implementation in the rest of the project work and that these components can be integrated, based on well defined interfaces. Cooperative work within the project brought the engineering activity completed in year one to the next level of detail in the system engineering specification, which defines who does what in the system and how things fit together.

**Motor Control and Mirroring**

This area of work studies techniques to perform control of reaching and grasping by the robot's arm and hand. Work in the second year was focussed on the development of a fully working robot grasping behaviour and the development of interfaces for easier integration with other robot platforms and software in the project.

We have studied force control and algorithms for learning the dynamical parameters of a manipulator, with the aim to realize low-level behaviors that are physically safe. In the past year we put particular effort into the implementation of a low-impedance controller for the arms of the iCub. In a similar context, we have performed experiments to apply formal verification methods to guarantee that a given behavior in a robot meets certain safety criteria. Finally, we have implemented explorative behaviors to start learning object affordances and use them in the context of action imitation and mirroring.


The iCub robot grasping an object on the table.

**Decisional Planning**

This research activity follows two streams: 1) A conceptual and fundamental stream: this activity involves the identification, the understanding and the categorisation of the abilities involved in shared activity in humans. The ambition here is to elaborate models inspired from the developmental psychology work and adapted collectively to a human-robot context. 2) The incremental construction of a set of sub-systems and/or the extension of sub-systems based on previous work, and their use in order to perform experiments from which lessons can be drawn for future developments.  We have proposed a conceptual architecture of the decisional component of an autonomous robot cooperative and interactive robot that can act, learn and interact with humans. This architecture is aimed to be a framework that provides a basis for a principled way to deal with robot task achievement in the presence of humans or in synergy with humans.

Several topics have been investigated such as the abilities and interactions based on perspective taking and the concept of "shared cooperative plans".  Several software components have been developed for example perspective-taking, task planning and planning for interactive human-robot manipulation tasks based on visibility and reachability components.

We have set up a testing environment that installed, instrumented and started to use an experimental hardware and software test bed that will the allow study of two different robot platforms (Jido and HRP2) and different types of human-robot cooperation situations: face to face, side by side, approach motions for fetch and carry tasks.

**Cooperative Coordination**

Safe and efficient Cooperative Coordination between humans and robots requires knowledge about how this is achieved between humans. During the second year of this project, progress has been made in the conceptualization, empirical investigation and application of the core capacities needed for coordinated cooperative interaction. Conceptually, the key concepts from analytic philosophy on cooperative interaction and shared intentionality was adopted in the first year of the project in order to create in a common vocabulary among behavioral science and robotics.  This has been extended and deepened during the project's second year. One particular focus has been on concepts of the psychological mechanism of visual perspective taking.

We have continued to design empirical tests of the core capacities for cooperation in young children, namely behavioral coordination and the representation of shared intentions. Altogether, five cooperation tasks have been developed and used in five experiments with children, including the collection, coding, and statistical analyses of the data which was presented to the scientific community in April 2009, June 2009, and March 2010. Moreover, tasks based on the psychological mechanisms of gaze following and perspective taking have been developed in collaboration with other members of the CHRIS project. In terms of the application to human-robot interaction, the consortium members have worked on adapting these tasks for collaboration scenarios and successfully tested them with two different robotic platforms. In addition, ethical considerations of research with children and naïve participants have been investigated and reported.

**Safety for Interaction**


BERT2's left hand fully assembled.

Our main aims during this work period have been to develop a robot, BERT2, that is safe during interactions with a human. To this end, we have developed a tactile sensing system for BERT2's hands, developed and tested a dynamic model and Model Reference Adaptive Compliance Control scheme for the BERT2 arm, undertaken an investigation into appropriate strategies to distinguish between self induced motor torques (due to voluntary arm movements) and torques caused by an impact with an object in the external environment. There have been some delays in completing the building of BERT2 which has allowed time for researchers to take an early lead in crucial system-wide integration work that will stand us in good stead during later years of the project.

An essential part of safe interaction is a powerful and efficient sub-system for body/hand and face gesture generation and recognition. Our work in this area has resulted in us developing a working real time motion capture model of the upper human body and a face tracking system to track the human's head rotation and eye rotation as well as the head position relative to the stereo vision system. We have also completed development of gesture recognition software, which will be the main data provider for the gesture detection module. Collaboration meetings with the developmental psychology researchers have enabled discussion and formulation of human-robot interaction scenarios and experiments. These experiments and scenarios (in a human-robot interaction context) show (a) the efficacy of several sensory modalities of BERT2 in terms of extracting meaningful information from human non-verbal cues, and (b) that BERT2 is able to convey information to humans using head and eye gaze.

## 1.3 Main results achieved so far

A detailed report on the experimental data on children’s engagement in cooperative tasks (Deliverable 4) was produced in this period. This developmental psychology input and ongoing integration work with this team has helped shape the engineering work of the project. Specifically, conceptions of coordinated action plans and shared intentions have been investigated experimentally, and the results and theoretical framework have been communicated to the consortium. Moreover, concrete scenarios utilizing these insights as well as related psychological concepts have been developed and applied within most of the robotic systems available.

Thanks to the strong cooperation and coordination within the consortium, the system engineering component of the project has been largely successful. The system requirements were generated, the architecture was specified, this was used to define detailed functions and interface. Details of this work were documented in the “System Engineering Analysis report” (Deliverable 5). At this point, Milestone 3 of the project was reached “Human Robot Interaction (HRI) and system requirements known by all”.

The challenge is to create a situation in which CHRIS project software that has been developed at different sites and tested on different robots is defined within the system framework so that it can be integrated into the global system with as little effort possible. During this second year, this activity began to show its fruit during the first integration activity at the Bristol research lab. There it was demonstrated over the course of only a few days, that software developed at the four technical institutes could interact correctly to produce new cognitive behaviours supporting cooperation on the BERT2 robot platform.

A “Grasping Controller” has been developed (Deliverable 7) and significant progress has been made in all aspects of the robot decisional planning components which include geometric and symbolic reasoning, spatial perspective-taking and task-planning aspects. There has been successful integration of gaze tracking software and a webcam into BERT’s expressive robot head which is capable of conveying emotional state and focus of attention as well as work on software modules which form a crucial link allowing all the CHRIS partners to integrate robot-specific and generic (high-level) software components.

## 1.4 Expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far).

The CHRIS project focuses directly on the difficult issues concerned with developing the system capabilities which would enable intelligent robots to cooperatively interact with humans in the same physical workspace safely. Intrinsic to this is the ability to have a suitable representation of the goal and the mechanisms to generate motor actions in order to achieve it. Concepts which are being incorporated in the system include control strategies for safe motion, situational awareness, representation of the shared goal/plan of action, and communication both verbal and non-verbal. Currently there is no single system capable of performing all of these activities for safe cooperative action with humans in co-located space, CHRIS aims to achieve this.

HRP2 robot and human in an interaction experiment.

Although the design of the project is to ensure research into capabilities rather than to produce a specific platform, potential application areas have already been identified as healthcare, domestic assistant and entertainment. Enabling robots to work in shared spaces with humans will provide significant benefits where robot strength, precision, persistence, indefatigability, or robustness can enhance the human ability to carry out certain tasks. In addition, robots can work in environments where it is unsafe or toxic for humans such as search and rescue in collapsed or smoke filled buildings, or in nuclear decontamination. The potential impact, therefore, of having such capabilities on one robotic platform – not necessarily humanoid in form – for society and the economy is huge. With a projected 80% of the future market share in service robotics, the impact of CHRIS on the development and nature of such platforms could pave the way for Europe to lead in this field.