Challenge 2: Cognitive Systems, Interaction, Robotics

Technical Background Notes for Proposers

Purpose of this document

This document refers to Challenge 2, **“Cognitive Systems, Interaction, Robotics”** within the **Work Programme 2007-08** of the **Information and Communication Technologies (ICT) Theme** of the European Commission’s **7th Framework Programme (FP7-ICT, for short)**.

It complements the Work Programme text by providing additional information on the **scope, type, and size of projects** expected to arise from Calls for Proposals under this Challenge. The Work Programme text is annexed to this document.

Avant-propos

Challenge 2 addresses several strands of R&D pursued separately under various Strategic Objectives (including Cognitive Systems, Multimodal Interfaces, and Advanced Robotics) of the 6th Framework Programme.

Unlike other Challenges under FP7-ICT, it comprises a single **Objective**: **“Cognitive Systems, Interaction, Robotics”**. This follows inter alia from the understanding that

- systems pertaining to **any of these areas** must be capable of responding intelligently and largely autonomously to gaps in their knowledge and to situations or contexts that have not been specified in their design (that is, they must be **robust** and **flexible**);
- artificial systems ought to be **more effective** in improving their performance and **more natural** in dealing with people - where dealing with people is a requirement; and
- progress, in any of these areas, towards systems with the above characteristics can only be achieved by developing and adopting **new engineering principles and approaches**, based on largely common but as yet not fully explored scientific grounds[1].

Indeed, systems pertaining to any of these areas have to understand[2] their respective dynamic environments, whether these call for navigation, grasping and manipulation, interaction with people, or simply the recognition and description of real or virtual objects and scenes.

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[1] see also: Artificial Cognitive Systems in FP7, A report on expert consultations for the EU seventh Framework Programme 2007-2013 for research and technology development (ftp://ftp.cordis.europa.eu/pub/ist/docs/cognition/cognitionwsrep-final_en.pdf)

[2] see for instance: A. Sloman: Requirements for a Fully Deliberative Architecture (Or component of an architecture) (http://www.cs.bham.ac.uk/research/projects/cosy/papers/#dp0604) FP6 project CoSy

Targets

In a nutshell, the **three targets** of Challenge 2 are:

(a) To develop (further) and validate the scientific foundations, engineering principles and approaches required to build systems with the above described capabilities;

(b) to build a strong basis for research on ways of reaching the long term goals inherent in this challenge and to provide the means for carrying out that research;

(c) to foster, monitor and coordinate at EU-level efforts of the many and varied relevant research communities in support of this challenge.

<u>Target (a)</u>

will be pursued through **Collaborative projects (CP)** as described in the ICT Work Programme, Appendix 2: Funding Schemes**;** each project will **focus** on one of the following **three areas**:

(a1) robots handling all sorts of objects and operating autonomously or in cooperation with people;

(a2) (networked) systems monitoring and controlling material or informational processes;

(a3) multimodal interfaces and interpersonal communication systems understanding people.

In each of these areas the **emphasis** is **on scientific and technological advance, whether through academic or industrial research, or an appropriate mix of the two**.

Demanding current and prospective **applications** serve to provide generic research questions and to **demonstrate the impact** of conceptual or technical innovation.

A key question:

"How should systems pertaining to these areas be designed and built so that they are more <u>robust</u>, <u>flexible</u>, <u>effective</u>, <u>natural</u> and, where necessary or desirable, <u>safer</u> and more <u>autonomous</u> than what is possible today?"[3]

The development of **marketable products** and the industrial engineering of **operational systems** based on already available and proven technologies are **not within the scope** of this target. Rather, projects are expected to **develop know-how** needed to create new products and to build systems that are desirable but cannot be built given our current know-how.

To **focus** on one of the above areas **does not mean** that a project should not consider aspects of the respective other areas; they are clearly intertwined. It is **recommended** though that **proposers clearly indicate the area** (a1, a2 or a3) which they consider the focus of their proposed project.

[3] Clearly, this is contingent on the prior question: "How can we specify what it means to be robust, flexible, etc.?", to be addressed specifically under Target b ("Understanding requirements for cognitive capacities") of this Challenge

While providing **valid and viable answers to the above key question** projects will take the approach of their choice, as appropriate given their focus, and draw on those scientific and engineering disciplines that are needed to achieve the project's goals.

All projects will in one way or another contribute to the development of **criteria for benchmarking** system properties such as robustness, scalability and adaptivity, depending on the area and application environment at issue. Each project will be expected to make the criteria it develops for assessing progress public and if possible should compare and contrast those criteria with criteria proposed by other research groups.

Where they participate, industrial partners are expected to have a **strong economic interest in the research output**. Industrial participation may also serve to provide new tools and system components where these are needed to attain the research goals.

We present a bird's-eye view of each of the above areas in terms of research problems and applications that would likely require these problems to be solved.

(a1) Robotics

Projects will contribute primarily

- to developing robotic systems that can sense and interact with the human world in useful ways;
- to designing robotic systems able to perform complex tasks with a high degree of autonomy[4].

Established engineering approaches to solving common problems in robotics (for example motion planning, navigation, obstacle avoidance), while undoubtedly yielding improvements, may only converge to solutions that are for instance not as amenable to adaptation or generalisation as one might wish[5]. Future work in this area will more and more have to deal with open-ended environments, that is, environments which are largely unplanned, loosely structured, and which exhibit non-deterministic dynamics.

It may therefore be necessary to take account of approaches that are currently at the leading-edge within robotics research communities (e.g., developmental, evolutionary, and cognitive robotics), or to develop entirely new approaches to the design, implementation and operation of robotic systems.

New ways of linking robotic perception (through vision, audition, touch, smell, as well as "non-natural" sensing modes and modalities) and robotic action (manipulation, motion, etc.), may have to be further investigated . This will involve learning strategies of all sorts that must be scalable to real-world demands. There are also strong links to issues and topics pertaining to areas (a2) and (a3) of this target.

The following (small) selection of possible research questions and issues illustrates the need for veritable breakthroughs in this area:

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[4] http://www.robotics-platform.eu.com/pdf/EUROP_SRA_May_2006.pdf, page 1

[5] *"Future robot systems will not be a simple extrapolation of today's technology but rather follow new design principles required by a wide range of possible applications."* (http://www.robotics-platform.eu.com/pdf/EUROP_SRA_May_2006.pdf, p. 12)

- **High-level cognitive skills**: *How can we integrate high-level cognitive competencies in robotic systems (for example, for reasoning, planning and decision-making, for active environmental modelling)? What should they be based on? How can we make such systems recognise, understand, adapt to and appropriately respond to human behaviour (e.g., implicit intentions, emotions) and needs, or unexpected situations in their environment? How can we make such systems improve their skills?*
- **Autonomy**: *How can robotic systems achieve goals in a largely unsupervised way?How general can these goals be? How should they be set? How proactive can or should robotic systems be? Are there "degrees of autonomy"? What are the limits of autonomy?*[6]
- **Rich sensory-motor skills**: *How can a robot acquire the sensory-motor skills needed to move and operate safely and robustly in difficult outdoor terrains or domestic and other indoor environments? What can be learned from solutions implemented in animals?*
- **Manipulation and grasping**: *What are the specific requirements on robots that are supposed to handle, individually or jointly, tangible objects of different shapes and sizes? What use can be made of new materials and hardware designs to achieve a higher degree of dexterity? What is needed in terms of sensing, manipulation and grasping capabilities, to make a robot learn and recognise the affordances of objects in its environment?*
- **Dependability**: *What reliability and safety requirements do different environments and usage scenarios impose on robotic systems? In what environments and for what types of usage is the timing of action or reaction crucial? How can dependability requirements be translated into verifiable design and implementation options, related to hardware and software? How can a robot recognise and identify safety critical situations and find appropriate actions? What use can or has to be made of advanced sensor, actuator, memory, and control elements in order to achieve key dependability features?*
- **Modular architectures:** *How can we translate requirements into robotic systems architectures*[7] *that cater for modular designs with standardisable module interfaces (hardware and software).*

Several of the questions posed under areas a2 and a3 are also pertinent here, for example on **object and behaviour recognition**, **collective behaviours** and **architectures and machines** (a2), and on modelling human-machine interaction (a3).

The gist of this Target (and a1 in particular) is to focus on the integration of complete systems. Components and miniaturised robotics R&D are not covered. However, this Challenge explicitly invites projects to **explore and validate** where needed, ***the use of***: *"advanced sensor, actuator, memory and control elements, components and platforms, based on new, possibly bio-mimetic, materials and hardware designs – e.g., for the realisation of robotic and interactive systems with greater structural and functional diversity and modularity."* Moreover, as stated in the general introduction to this Target,

[6] Here, autonomy is to be understood in its technical sense as "independence of external control". Clearly, the ultimate responsibility for technical systems such as robots, is with their designers and/or users.
[7] Note that the term "architecture" also refers to frameworks that allow for adaptation and self-modification.

projects may include the procurement of new tools and system components where these are needed to attain the research goals[8].

Application domains likely to yield generic research questions pertinent to this area are those that call for robust locomotion, navigation and obstacle avoidance in difficult terrains (as needed for example for search and rescue operations in the aftermath of natural disasters) and/or co-operation with people in complex, dynamic spatial environments (e.g., in shop floors, or for rehabilitation) with strong requirements on handling physical objects, and on safety and dependability. Such applications are likely to arise in the industrial, professional and domestic services sectors.

Industrial manufacturing, insofar as the robotic control of manufacturing processes is concerned, will be covered by area (a2) applications (see below).

(a2) Monitoring and controlling

Projects will take new approaches based for instance on models of natural cognition, to creating systems that detect, recognise and respond intelligently and robustly to objects, events and processes, in complex and dynamic natural or man-made environments. The latter include virtual spaces, such as the Internet, its contents and services.

These systems are typically embedded in some host system ("environment"). Depending on their environment and functions (as monitors and controllers), one distinguishes different physical instantiations and various – stronger or weaker - forms of embodiment, for instance **robots** (in the sense of (a1)), or **sensor networks**, or simply well-defined **collections of software entities** running on distributed processors.

Of the many research questions pertaining to this area we mention but a few:

- **Modelling:** *What kind of models do natural cognitive systems (animals and humans) generate of their environments and their own situation in it? How do they generate, maintain and use these models? What can we learn from the way natural cognitive systems work, for the realisation of artificial systems? What depth of analysis of natural cognitive systems, and what degree of abstraction is needed – if at all – to arrive at models that artificial cognitive systems can be based upon?*
- **Object representation / recognition:** *How can we represent / specify any instance of a 3-dimensional physical object or scene irrespective of variety, partial occlusion, view angle, lighting conditions, and possibly, motion?*
- **Behaviour representation / interpretation:** *How can we represent / specify the behaviour of entities in an environment so that they can be unambiguously identified?*
- **Pattern discovery and classification:** *How can we find and make sense of new patterns in data streams generated in some environment, or detect points that don't fit a hypothesis? How can we predict (and anticipate) future events in their environment (including, where relevant, the behaviour of other agents - human or not - operating in the same environment)?*

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[8] as for instance the platform developed in FP6 project Robot-Cub (http://www.iCub.org)

- **Collective behaviours:** *How can we integrate the functions of many individual subsystems (for instance robots or intelligent sensors) to form highly autonomous systems (for example: "swarms") capable of cooperating towards achieving a common goal and performing tasks with attention to context?*
- **Architectures and machines:** *How can we translate models, requirements and interpretation strategies into viable system architectures, integrating cognition, communication and control; and into specifications for largely autonomous machines that are robust and open to adaptation and self-improvement, as stipulated by Target (a)? What do these machines have to "know" by design, what are they supposed to learn, for instance through training and interaction? How can that knowledge be represented?*

In fact, investigating ways artificial systems can learn (or, more generally: modify themselves with a view to improving their performance) is likely to considerably boost progress in this area and, indeed, towards Target (a).

Some of the issues listed under (a1), for instance "autonomy" and "dependability", are also important for this area.

Generally speaking, all applications are relevant where artificial systems are supposed to

- produce information about (parts of) their environment (e.g., through classification, categorisation, recognition and description of objects, events and processes); and/or
- exert some control over processes in their environment (directly through immediate action or indirectly through suggesting human decisions).

The Challenge 2 Work Programme highlights the following application areas as sources of generic research questions (such as the above) and as validation domains:

Industrial manufacturing, especially flexible manufacturing where the *"operation of robots will increasingly depend on information generated by sensors"*, and where networks of *"interlinked robots which co-operatively transport, machine, handle and assemble work-pieces"* will be needed; it will also require *"scalable / distributed architectures for multiple robots"*. Moreover, robotic systems will have to become more integrated into the control of manufacturing processes proper.[9]

Real-time information gathering and interpretation, and situation assessment: for example, for surveillance of public areas (crime detection), environmental monitoring, the operation and maintenance of all sorts of technical systems, plant control (power plants, chemical plants, water purification plants, etc.), early warning of critical situations, scientific data gathering and analysis, etc. In many of these applications a self-monitoring capability would be of advantage.

Content analysis in virtual spaces related to real world objects and people (such as repositories of digital content accessible over the Internet), which is likely to benefit greatly from cognitive, highly context-sensitive and possibly, interactive approaches. Demanding examples include crime detection (e.g., child pornography on the Internet, and victim identification) through image and video analysis, and the interpretation of medical images (e.g., by taking episodic patient background into account).

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[9] http://www.robotics-platform.eu.com/pdf/EUROP_SRA_May_2006.pdf, pp. 12,13

Many of the systems under consideration here will have to communicate with people, in human terms. For instance, we may want them to communicate what their data is about, how it has been captured and calibrated, and how and why they are doing what they are doing. Hence, there is also a clear link between this area and area (a3).

(a3) <u>Interfaces and interpersonal communication</u>

The main challenge here is to ground the design and the operation of systems that

- require extensive human-machine interaction and communication, and/or
- support interpersonal communication at a semantic and pragmatic level

in a deep understanding of human cognitive and physical capabilities (where necessary), and human communication needs and contextual constraints.

Within reasonable bounds such systems should be capable of adapting themselves to changing user needs as they go along. To interact intelligently and in human terms with people they should be endowed with cognitive capabilities. For instance, it now appears that "spoken language needs to be treated as an intimate part of an artificial cognitive system, not simply as a fancy interface technology"[10]. As in the case of other engineering objectives (e.g., in robotics, see (a1)) it seems clear that new approaches to creating such systems have to be sought.

As above, one may distinguish systems and their particular requirements, by the environment they are operating in. Examples include robots and robotic systems (as discussed under (a1) and (a2)). Other environments that require a high degree of interactivity with human users include: virtual, mixed and augmented reality scenarios, and simulation environments allowing for direct manipulation of virtual objects; Call Centres (with a need for natural language dialogue management); multilingual conferences and translators' offices. Some systems will need multi-modal interfaces (for speech, eye gaze, force etc. input/output) that have the potential to fill new roles in user experiences pertinent to the environment in question. And again, depending on a system's environment and purpose there are many research problems awaiting satisfactory solutions, for instance:

- **Modelling:** *What are suitable models for human-to-machine, machine-to-human and computer-mediated human-to-human interaction under a variety of constraints, taking account of people's intentions, moods, emotions and non-verbal manifestations of communicative behaviour.*
- **Visualisation and manipulation**: *How to manipulate and render representations captured from real images or sampled data so that people can make sense of them?*
- **Natural language**: *How can we obtain/use contextual information to disambiguate meaning in natural language?How can we recognise an individual speaker?*
- **Architectures and machines**: *How can we translate contextual needs of individuals or groups (including aspects of their behaviour or competences) into architectures and specifications for machines?*

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[10] R. K. Moore, Presentation at IST2006, Helsinki, http://ec.europa.eu/information_society/istevent/2006/cf/conference-detail.cfm?id=1057

As speech is arguably "the most natural mode of human-machine interaction" (see footnote 3) and, we may add, language is the dominant mode of human-human communication, much of the work in this area will likely focus on issues and problems related to **spoken and written language**. It will aim to find new ways of combining statistical, knowledge driven and cognitive approaches to **language understanding, generation, and translation**, by machines.

A second emphasis is on **environments** with a need for sophisticated **multi-modal, multi-sensorial interaction** facilities that adapt largely autonomously to the individual needs of human users as well as to changes in the environment that human users are to interact with. The operation of such facilities will be based on modelling and predicting with high precision the behaviour of physical systems (including humans), at multiple levels of abstraction and various spatial and temporal scales.

Both application domains will likely benefit greatly from **advances in computational learning**.

It is expected that problems and issues peculiar to this area will also be tackled under the above described areas (a1), "Robots", and (a2), "Monitoring and controlling".

Target (b)

will be pursued through **Networks of Excellence (NoE),** as described in the ICT Work Programme, Appendix 2: Funding Schemes. NoEs will build on an outstanding background of research accomplishment among its members and will, through its activities, develop and extend this research in the pursuit of new theoretical and practical knowledge.

In this context, to support both its own research agenda and that of the wider community, an NoE proposal puts forward a *Joint Programme of Activity* (JPA), designed to progress R&D towards identified common goals. The JPA should provide a **framework for structuring research** and may include the development of research agendas and strategies, based on realistic long-term goals.

Depending on the needs of the area covered, the JPA of an NoE may also **include** the **development of experimental scenarios**, in depth **reviews of application scenarios**, the development or construction of **resources for experimentation** (e.g., annotated databases of empirical data, specific tools/platforms shareable across a research community, ontologies, specification and programming languages, test-sets and environments, etc.), the **development of performance metrics** and definitions of **autonomy and robustness levels** for artificial systems, and the **evaluation of relevant system architectures** as well as **frameworks for sharing resources and knowledge**. Benchmarking activities may be supported by suitably defined competitions.

Through its JPA an NoE should also pursue strong educational and dissemination objectives, such as a publicly accessible (distributed) web-site with all the partial results of the project as it progresses, the production of repositories of preprints, educational materials, demos, aids for newcomers, and the organisation of interdisciplinary workshops and conferences.

An NoE is expected to remain operational and maintain its identity (for instance as a "distributed institute") beyond its funding period.

Proposals are sought for NoEs covering the following three areas:

1. Learning and adaptation in artificial systems – to integrate strands of research on how artificial systems can improve their performance through various forms of learning; to increase our understanding, for instance through suitable modelling of natural systems, of the mechanisms underlying adaptive behaviours, and of the advantages and limitations of artificial learning in different "real-world" and "real-life" applications.

2. Understanding the basis of cognitive capacities – to integrate *diverse* research areas whose problems, techniques and solutions need to be brought together to understand systems with cognitive capacities and design useful new ones.

Work is expected to include inter alia, research towards:

- the creation of a common language or shared ontology to discuss both natural and artificial cognitive systems in terms of their performance capabilities, and to deepen our scientific understanding of the relationships between different capabilities (building bridges to and from adjacent disciplines such as neuroscience and psychology);
- a capability-led understanding of cognitive systems (requirements, theories, architectures, models and methods) that can be applied across multiple engineering and application domains;
- detailing and understanding better the requirements for applications such as **robots and interactive** systems in terms of performance, and to detail and understand better approaches to meeting these requirements and the trade-offs in terms of performance.

These goals are equally important. To attain the latter two, the development of experimental scenarios to evaluate performance, demonstrate generality, or measure robustness, may be crucial.

3. Language-based communication and interaction – to integrate research on new ways of combining statistical, knowledge driven and cognitive approaches to (spoken and written) language understanding, generation, and translation, by machines; to advance our understanding of the specific capabilities required of technical systems that mediate language-based interaction and communication.

It should be noted that focussing on a particular application domain or a single activity such as benchmarking, would in itself not be sufficient to warrant an NoE.

Target (c)

will be pursued through **Coordination actions (CA),** as described in the ICT Work Programme, Appendix 2: Funding Schemes.

Proposals are sought for CAs leading to increased coordination and cooperation among national and regional research programmes in EU Member States and Associated States, and covering domains that contribute to the overall aims of Challenge 2 such as learning in artificial systems, advanced robotics, artificial cognitive systems, language and human-machine interaction.

They should aim at developing strategies to generate additional funding support (to *spread* competences) or new funding initiatives (to *develop new* competences), as appropriate. The latter may include combining different programmes (eg, engineering and biology: designing 'artificial' systems and understanding 'natural' systems) in new initiatives.

Coordination projects should achieve their aims through engaging in information exchange, and definition and implementation of coordinated activities.

Practical information

Projects in any of the areas under Target (a) are likely to address a fair number of issues and questions (but certainly not all that are relevant) and hence be of the **size and complexity** that warrant the form of a **"large-scale integrating project (IP)"** (see ICT Work Programme, Appendix 2.1.b).

Projects that focus strongly on a few specific topics or issues while respecting Target (a), will take the form of a **"small or medium-scale focused research action (STREP)"** (see ICT Work Programme, Appendix 2.1.a).

NoEs (see ICT Work Programme, Appendix 2.2) will preferably be built around a core of key R&D groups/labs in Europe, working in the areas identified under Target (b). Participants will typically be research organisations (public, private, or mixed), university institutes and industry R&D labs. Multi-disciplinarity would most likely be an advantage and may in fact be required for the areas in question.

CAs (see ICT Work Programme, Appendix 2.3.a) will preferably include representatives of decision-making bodies that leverage and influence research funding at regional and national levels.

Indicative Figures:

> **IPs -** number of partners: 6 to 10; project duration: typically four (4) years; effort: 50 – 120 person-years.
>
> **STREPs -** number of partners: 4 to 6; project duration: typically three (3) years; effort: 25 - 60 person-years.
>
> **Note: Applications** underlying projects should be **commensurate** with these constraints.
>
> **NoEs –** consortia expected to comprise not more than 15 contractors, although it may reach out to researchers not affiliated with any of the contractors. Funding will be granted for up to five (5) years.
>
> **CA**s **–** consortia should have sufficient critical mass so as to promise impact at EU-level. Project duration would be up to three years (3) years.

Figures, as mentioned, are indicative; important is that a project **involves only those partners needed** to achieve its goals and no more. Partner roles must be well-defined and substantial, and should be complementary.

Pursuing **research goals** may complement or extend past work. In any event, however, these goals have to be **highly ambitious** and the work proposed with a view to achieving them should make **significant contributions** towards advancing the state-of-the-art.

All projects are expected to maximise the spread of knowledge gained, for instance by putting wherever possible, their results (including software, designs for systems, testbeds, file formats, communication protocols, etc.) in the public domain. The use of open source platforms and adherence to published standards is encouraged. Where results depend on the use of proprietary systems or where proprietary systems are being developed, provision should be made for such systems to be available at low cost or free of charge to researchers wishing to engage in work based on these results.[11]

Further information as well as examples of relevant projects and networks under FP6 and a regularly updated list of **Frequently Asked Questions (FAQs)** concerning the Challenge 2 Work Programme and Calls, will be available at http://www.cognitivesystems.eu.

INFSO E5, *Cognitive Systems and Robotics*

European Commission

January 2007

[11] This does not preclude making use of research results in order to develop proprietary systems at an organisation's own expense. It is hoped though, that those systems will be of value to research communities, thereby justifying the free use of publicly funded research results.

Annex: Extract from the ICT Work Programme 2007- 08 [12]

CHALLENGE 2: COGNITIVE SYSTEMS, INTERACTION, ROBOTICS

The increasing complexity of our society and economy places greater emphasis on artificial systems such as robots, smart devices and machines which can deal autonomously with our needs and with the peculiarities of the environments we inhabit and construct. This challenge is to extend systems engineering methods to deal with open-ended and frequently changing real-world environments. A primary aim is to develop system capabilities to respond intelligently to gaps in the system's knowledge and to situations or contexts that have not been specified in its design. In order to meet this challenge, a mix of innovative scientific theory and technology are needed, based on natural and artificial cognition, in conjunction with new systems design and engineering principles and implementations for machines, robots and other devices which are robust and versatile enough to deal with the real world and to behave in a user-friendly and intuitive way with people in everyday situations.

Artificial cognitive systems, advanced interaction technologies and intelligent robots will help open up new opportunities for industry in Europe. Reinforcing leading edge research in these domains will help extend technologies into tomorrow’s industries and markets, in fields of potentially high socio-economic significance like industrial production, learning, healthcare, public safety, environmental monitoring, and in emerging sectors such as service robotics. Autonomous surveillance systems can, for example, save crucial time in emergencies or hazardous situations. Artificial cognitive systems and intelligent robots can extend the capabilities of people to perform routine, dangerous or tiring tasks, especially in previously inaccessible, uncharted, or remote spaces on land, sea or air.

Scientific research will also improve our understanding of the mechanisms underlying artificial and natural cognition, in particular learning and the development of competences requiring goal-setting, reasoning, decision-making, language, communication and co-operation. It will enable us to build machines that can understand, learn and generate concepts and translate them across languages with degrees of robustness and versatility not possible today. And it will spur breakthroughs in advanced behaviours of robots, such as in manipulating objects and interacting socially, which are key to their further penetration into real world environments.

The proposed activity supports industrial competitiveness by addressing technological challenges and socioeconomic scenarios as identified inter-alia in the Strategic Research Agenda of EUROP, the European Technology Platform on robotics.

Objective 3.2.1.1 (3.2.3.1): Cognitive Systems, Interaction, Robotics

Target outcome:

a) **Artificial systems** that fulfil one or both of the following requirements:

- they can achieve general goals in a largely unsupervised way, and persevere under adverse or uncertain conditions; adapt, within reasonable constraints, to changing service and performance requirements, without the need for external re-programming, re-configuring, or re-adjusting.

[12] The complete ICT Work Programme and further details about the call are available at: http://cordis.europa.eu/fp7/dc/index.cfm?fuseaction=UserSite.CooperationDetailsCallPage&call_id=11

- they communicate and co-operate with people or each other, based on a well-grounded understanding of the objects, events and processes in their environment, and their own situation, competences and knowledge.

Work will result in demonstrators that operate largely autonomously in demanding and open-ended environments which call for a suitable mix of capabilities for sensing, data analysis, processing, control and acting; and for communication and co-operation with people or machines or both. Where required, systems will integrate high-level cognitive competencies; for example, for reasoning, planning and decision-making, and for active environmental modelling.

Proposals satisfying the above requirements should focus on one of the following areas:

Robots handling, individually or jointly, tangible objects of different shapes and sizes, and operating either fully autonomously (as for instance in difficult terrains with a need for robust locomotion, navigation and obstacle avoidance) or in co-operation with people in complex, dynamic spatial environments (e.g., domestic environments).

Robots, sensor networks and other artificial systems, monitoring and controlling material and informational processes e.g. in industrial manufacturing or public services domains. This may include information gathering and interpretation in real-time emergency or hazardous situations (e.g., through multi-sensory data-fusion) or in virtual spaces related to real world objects and people.

Intuitive multimodal interfaces and interpersonal communication systems providing personalized interactivity in real-world and virtual environments, based on improved human interaction modelling and understanding of contextually-referred communication, for example, by signs and signals in all modes (such as sound, vision, touch) and modalities (such as natural language, both spoken and written), through autonomous adaptation and by addressing user needs, intentions and emotions.

Work proposed in any of these areas should, as appropriate:

- develop and apply engineering approaches that cater for real-time requirements (if present) and systems modularity, and ensure the reliability, flexibility, robustness, scalability and, where relevant, also the safety of the resulting systems; and develop criteria for benchmarking these properties;
- contribute to the theory and application of learning in artificial systems, tackling issues related to the purposive and largely autonomous interpretation of sensor-generated data arising in different environments, and to novel design and implementation principles of pertinent systems architectures.
- explore and validate the use of:
  - > advanced sensor, actuator, memory and control elements, components and platforms, based on new, possibly bio-mimetic, materials and hardware designs – e.g., for the realisation of systems with greater structural and functional diversity and modularity,
  - > new, possibly bio-inspired, information-processing paradigms, and of models of natural cognition (including human mental and linguistic development), adaptation, self-organisation, and emergence; and take account of the role of systems embodiment and affordances.
  - > new ways of combining statistical, knowledge driven and cognitive approaches to language understanding, generation, and translation, by machines.

b) **A principled approach to structuring research** in relevant areas, addressing in particular learning in artificial systems, the requirements for cognitive capacities of robotic, interactive and language support systems, and including the development of experimental scenarios, the development or construction of resources for experimentation, and the development of performance metrics and definitions of autonomy levels for artificial systems.

c) **Co-ordination** with related national or regional research programmes or initiatives.

Expected impact:

- Leading-edge technology companies creating new products and services, and enhancing existing ones.
- New markets such as: extending the industrial robotics market to flexible small scale manufacturing, opening up services (professional and domestic) markets to robots, novel functionalities for embedded systems and assistive systems for interpersonal communications, such as support of dynamic translation, and effective medical diagnostics and therapeutics.
- Robust and versatile behaviour of artificial systems in open-ended environments providing intelligent response in unforeseen situations, and enhancing human-machine interaction
- Extended capabilities of people to perform routine, dangerous or tiring tasks in previously inaccessible, uncharted or remote spaces; saving critical time in emergencies or hazardous situations.
- Leading-edge research in Europe through collaborative and multidisciplinary experimentation with approaches to achieving machine intelligence and artificial cognitive systems, and through investigation of what artificial and natural cognitive systems can and cannot do.

Funding schemes

a): CP; b): NoE; c) CSA (CA only)

Indicative budget distribution

ICT Call 1- 96 M€:

- CP 87 M€ of which a minimum of 46 M€ to IP and a minimum of 15 M€ to STREP;
- NoE 8 M€;
- CSA 1M€

ICT Call 3 - 97 M€:

- CP 87 M€ of which a minimum of 46 M€ to IP and a minimum of 15 M€ to STREP;
- NoE 8 M€;
- CSA 2 M€