Large-scale integrating project

Deliverable D7.5 (2)
Report on coordination activities with other projects and initiatives

Project acronym: **DEXMART**

Project full title: **DEXterous and autonomous dual-arm/hand robotic manipulation with sMART sensory-motor skills: A bridge from natural to artificial cognition**

Grant agreement no: **FP7 216239**

Project web site: **www.dexmart.eu**

Due date: 31 January 2012	Submission date: 31 January 2012
Start date of project: 1 February 2008	Duration: 48 months
Lead beneficiary: DLR	Revision: 0

Nature: R	Dissemination level: PU
R = Report P = Prototype D = Demonstrator O = Other	**PU = Public** PP = Restricted to other programme participants (including the Commission Services) RE = Restricted to a group specified by the consortium (including the Commission Services) CO = Confidential, only for members of the consortium (including the Commission Services)

Contents

Short project overview

The DEXMART project is focused on artificial systems reproducing smart sensory-motor human skills, which operate in unstructured real-world environments. The emphasis is on manipulation capabilities achieved by dexterous and autonomous, and also human aware dual-arm/hand robotic systems.

The challenge is to allow a dual-arm robot including two multi-fingered redundant hands to grasp and manipulate the same objects used by human beings. The objects shall be allowed to have different shape, dimension and weight. The manipulation will take place in an unsupervised, robust and dependable manner so as to allow the robot to safely cooperate with humans for the execution of given tasks. This goal has always been one of the most critical issues in the design of robotic systems as it has been clear since the early days in robotics.

Successful achievement of this goal requires a significant advancement over the existing robotic manipulation solutions, concerning on one side the development of skills and manipulation procedures at a high cognitive level, the control modalities and, on the other, the mechanical structure, the kinematic configuration, the actuation and sensing system. Within the DEXMART project, research efforts will be devoted to contribute to all these challenging research questions.

Dual-hand/arm manipulation of objects in an unstructured environment is a complex task which is a compound of different strategies, constraints, goals and actions at the same time. The robotic system has to possess the ability to autonomously decide between different manipulation options. It has to properly and quickly react to unexpected situations and events as well as understand changes in the behaviour of humans cooperating with it. Moreover, in order to act in a changing scenario, the robot should be able to acquire knowledge by learning new action sequences so as to create a consistent and comprehensive manipulation knowledge base through an actual reasoning process.

Cognitive and control aspects of the robotic system play a key role within the project. On the other hand worldwide trends on manipulation systems, especially for humanoid robots, demand the development of a new technology, possibly bio-mimetic both for advanced actuation and sensing systems. In fact, the artificial hands proposed so far exhibit a wide range of acceptable solutions as far as their functionality is concerned, but most of them are too complex, bulky, expensive or unreliable for practical use outside a research laboratory. To overcome these limitations, the possibility to exploit the high power-to-weight ratio of smart materials and structures will be explored, and research efforts will be devoted to the design of new hand components (finger, thumb, and wrist) and sensors that will pave the way for the next generation of dexterous robotic hands.

Introduction

Scope

The present document includes a report on the activities carried out during the last two reporting periods of the DEXMART project. It is an update of the deliverable D7-5 (1) which was due on month 24.
The goal of the coordination activities was to enhance integration of research activities in the fields concerned by making use of existing synergies, with special attention to the field of mobile manipulation, neuroscience, and safety in human-robot interaction.

Contacts have been established with relevant EU projects as well as other national and international initiatives in the field. EU projects include running FP7 projects dealing with neuroscience and/or psychophysics for modelling human cognition during manipulation. But also contacts have been established with application and industry driven EU projects.

Classification in the European context

In the occasion of the Info Day in Luxembourg on 14th January 2010, Cécile Huet from Unit E5 - Cognitive Systems, Interaction, Robotics presented the portfolio of current and future EU funded projects. From FP7 – CALL 1 the project DEXMART is assigned to the research topics *Dexterous Manipulation* and *Human Robot Interaction*. Contacts have been established with GRASP.

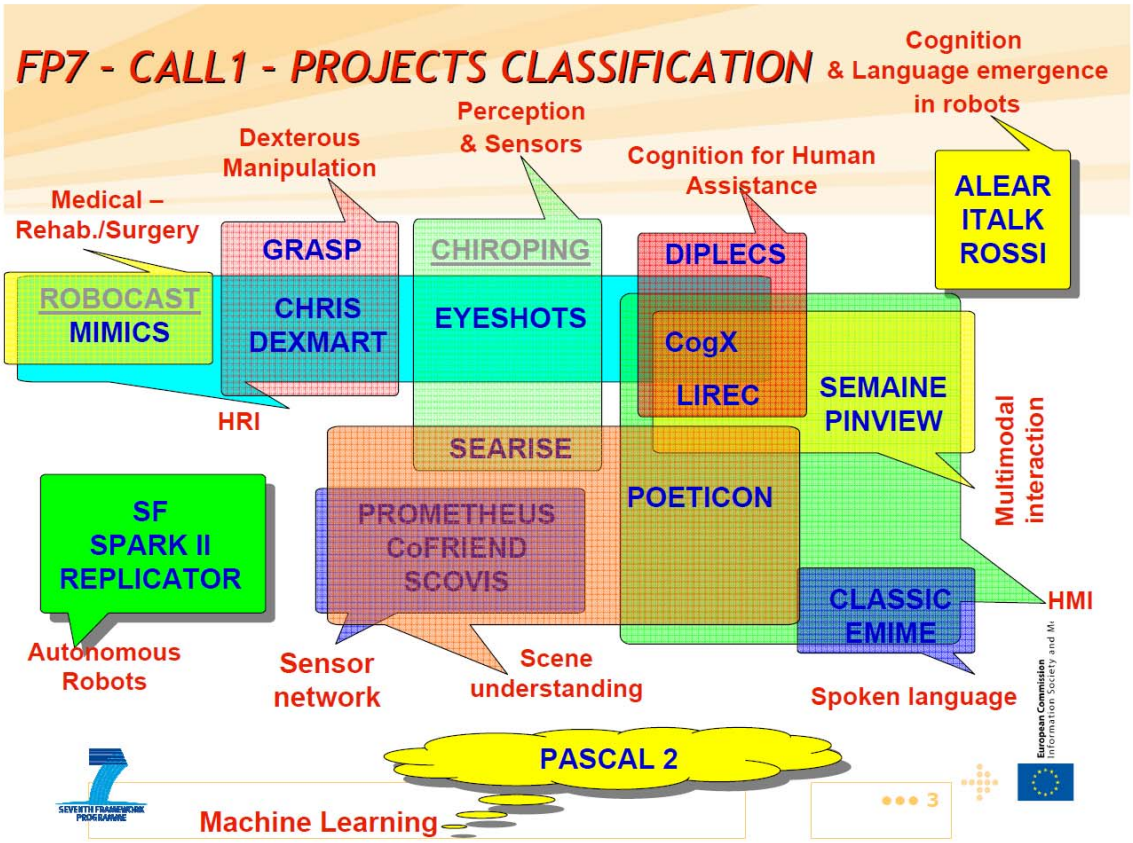

Figure 1 FP7 – CALL 1

From FP7 - Call 3 contacts have been established with HANDLE. We intensified in the second half of the project our common activities with HANDLE regarding the research on dexterous manipulation. Additionally we started some activities with BRICS regarding research on mobile manipulation.

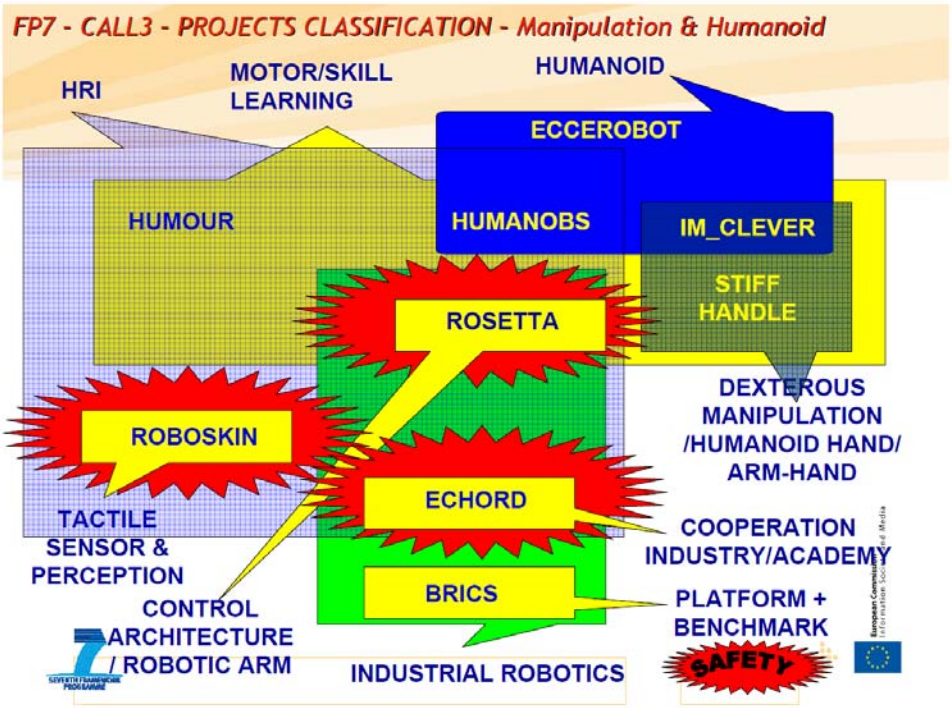

Figure 2 FP7 – CALL 3

From FP7 Call 4 contact has been established with the projects GeRT regarding the research on dexterous manipulation. Partners of Dexmart also supported the CA euROBOTICS and contributed to the European Robotics Week from 28th of November – 4th of December 2011.

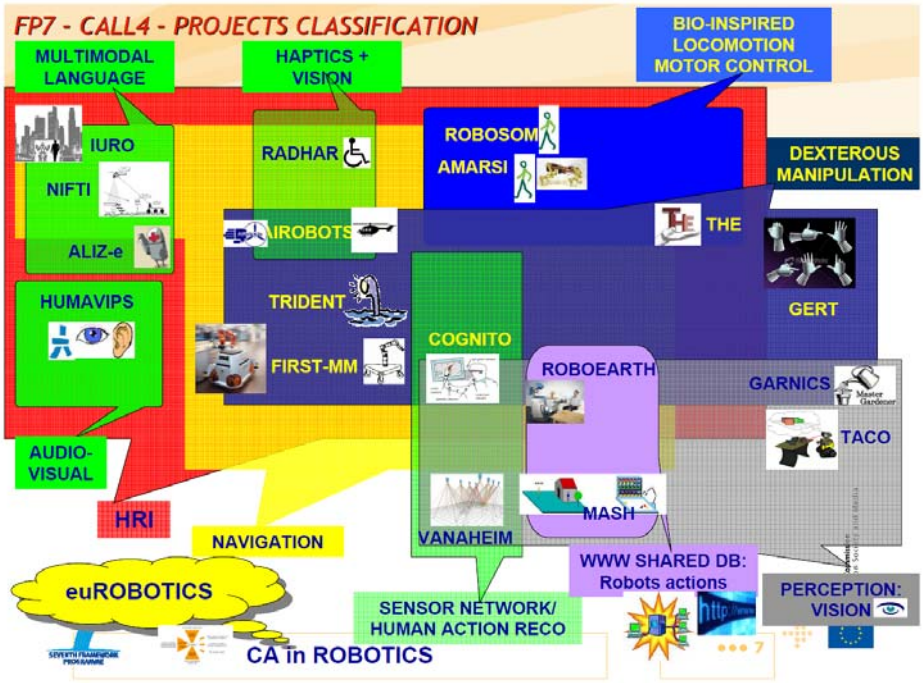

Figure 3 FP7 – CALL 4

From FP7 Call 6 contact has been established with the projects Xperience regarding the research on modelling and learning and TAPAS in dexterous manipulation in industrial environments.

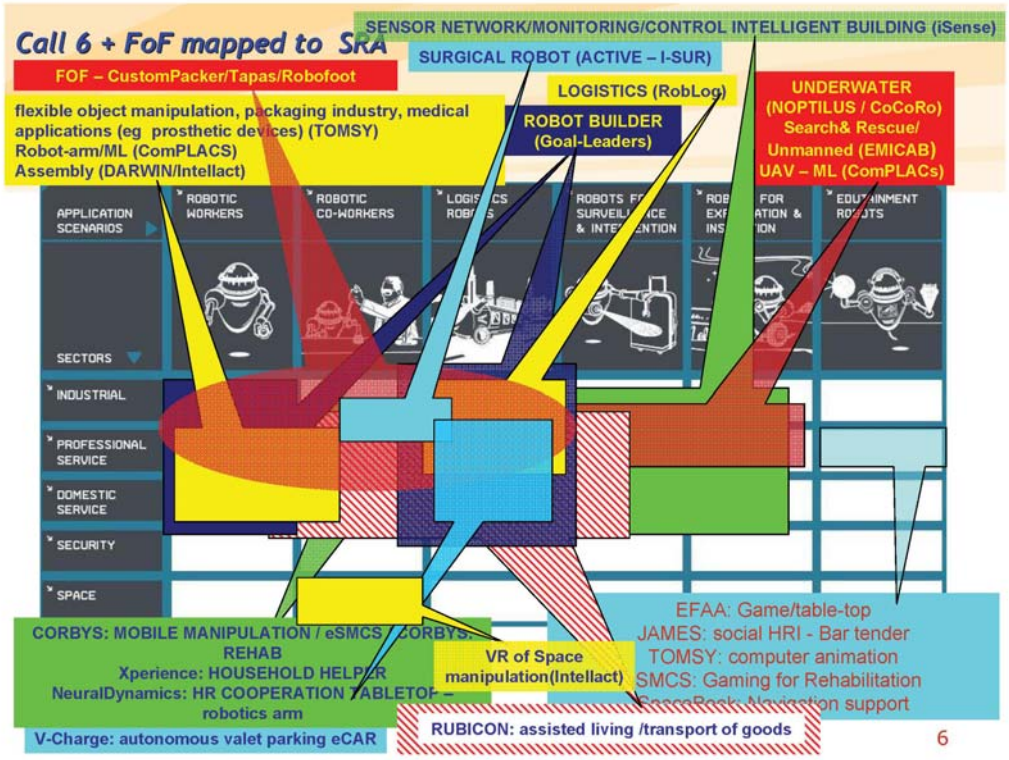

Figure 4 FP7 – CALL 6

From FP7 Call 4 contact has been established with the project Saphari regarding the research on safe human robot interaction.

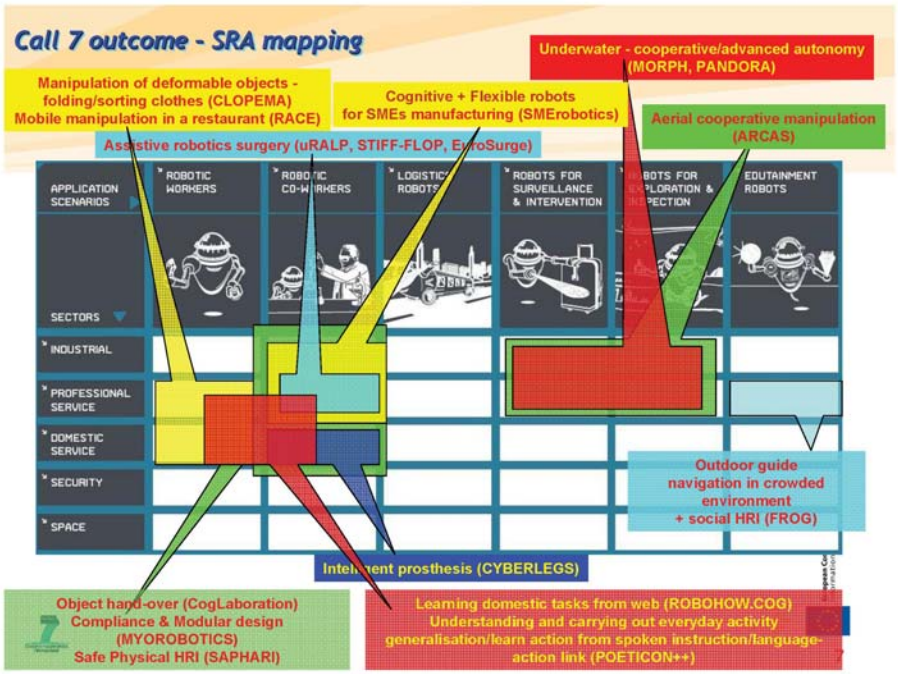

Figure 5 FP7 – CALL 7

In the following the type of contact and activities regarding the European projects are described.

Contacts on project level

- Main contacts so far have been established to the FP7 IPs HANDLE "Developmental pathway towards autonomy and dexterity in robot in-hand", and GRASP "Emergence of Cognitive Grasping through Introspection, Emulation and Surprise". Further to a meeting with the two co-ordinators of the above projects in Hamburg in October 2009, the joint workshop on "Representations for Object Grasping and Manipulation in Single- and Dual-Arm Tasks" took place at the Robotics: Science and Systems conference in Zaragoza (June 2010) with presentations from the three projects. Further, the "Summer School on Robot Grasping" was co-organized with GRASP and HANDLE within the 10th International UJI Robotics School in Benicàssim (September/October 2010).
- The DEXMART Workshop on Actuation and Sensing in Robotics, organised by USAAR and held on October 6th, 2010 at the town hall in Saarbrücken, Germany was a meeting place of the 36 DEXMART partners, who were in Saarbrücken for their periodic meeting, and an additional 34 persons representing the scientific community from all over Europe. Three of the 11 technical presentations held over the course of the day showed DEXMART developments, while two others reported on developments from the European research projects ROBOSKIN "Skin-based technologies and capabilities for safe, autonomous and interactive robots" (Giorgio Cannata, DIST, Genua) and CyberHand "Development of a CYBERnetic HAND prothesis" (Christian Cipriani, ARTS Lab, Pisa). The European Scientific Network for Artificial Muscles (ESNAM) was represented by its managing chair member Federico Carpi and his talk on dielectric elastomer actuators. A number of additional robotic developments occurring on a national level were represented: the DLR arm-hand system (DLR, Germany), flexible fluidic actuators (KIT, Germany), shape-memory wire based hand actuation (Fraunhofer IWU, Germany), robotic skin (Fraunhofer IFF, Germany), haptic glove with magnetorheological fluids (EPFL, Switzerland) and microelectrodes for neural prosthesis (Fraunhofer IBMT, Germany). Two posters and ten hardware demonstration set-ups were displayed during the closing session of the workshop. This thematic workshop organised and carried out within the context of DEXMART proved to be an effective means of networking on a European level.

- A major event in the 4th year will be the DEXMART half-day workshop "The DEXMART project for advanced bimanual manipulation" to be held within the scope of the 2011 Humanoids conference in Bled, Slovenia. Six presentations given by speakers involved in the DEXMART project and two plenary presentations by distinguished external speakers invited by the DEXMART consortium will inform the larger public present at the conference about the progress and achievements of the DEXMART project.

- HANDLE - *Developmental pathway towards autonomy and dexterity in robot in-hand manipulation*, is an Integrated Project funded by the European Commission through its Cognition Unit under the Information Society Technologies of the seventh Framework Programme (FP7). The project was launched on 2nd February 2009 and will run for a total of 48 months.
    - Major partners: UPMC, Shadow, UC3M, FCTUC, KCL, ORU, UHAM, CEA, IST
    - The HANDLE project aims at understanding how humans perform the manipulation of objects in order to replicate grasping and skilled in-hand movements with an anthropomorphic artificial hand, and thereby move robot grippers from current best practice towards more autonomous, natural and effective articulated hands. The project implies not only focusing on technological developments but also working with fundamental multidisciplinary research aspects in order to endow the robotic hand system with advanced perception capabilities, high level feedback control and elements of intelligence that allow recognition of objects and context, reasoning about actions and a high degree of recovery from failure during the execution of dexterous tasks.
    - Research topic linked to topics DEXMART: Grasp planning, benchmarking
    - Type of cooperation: Exchange of scientific knowledge

- GRASP - *Emergence of Cognitive Grasping through Introspection, Emulation and Surprise* is an Integrated Project funded by the European Commission through its Cognition Unit under the Information Society Technologies of the seventh Framework Programme (FP7). The project was launched on 1st of March 2008 and will run for a total of 48 months.
    - Major partners: KIT, KTH Stockholm, TU Munich
    - The aim of GRASP is the design of a cognitive system capable of performing grasping and manipulation tasks in open-ended environments, dealing with novelty, uncertainty and unforeseen situations. To meet the aim of the project, studying the problem of object manipulation and grasping will provide a theoretical and measurable basis for system design that is valid in both human and artificial systems. This is of utmost importance for the design of artificial cognitive systems that are to be deployed in real environments and interact with humans and other agents. Such systems need the ability to exploit the innate knowledge and self-understanding to gradually develop cognitive capabilities.
    - Research topic linked to topics DEXMART: Grasp planning
    - Type of cooperation: Exchange of scientific knowledge
    - Involved partners from DEXMART: FZI, DLR

- euRobotics - *European Robotics Coordination Action* is type of coordinated action. The project started on January 1, 2010 and is funded by the European Commission within the 7th Framework Programme, Challenge 2: Cognitive Systems, Interaction, and Robotics (FP7-ICT-244852) until December 31, 2012.

    - Major partners: EUnited Robotics, KU Leuven, UNINA, Fraunhofer IPA
    - The Coordination Action has two main objectives: (1) Improvement of cooperation between robotics stakeholders in academia and industry and (2) Promotion of European robotics. Furthermore, euRobotics aims at strengthening the European robotics community across all robotics sectors (industrial, professional service, domestic service, security and space robotics).
    - Dissemination topic linked to topics DEXMART: dexterous manipulation, new technologies, cognition
    - Type of cooperation: Promotion of and Participation on European Robotics Week from 28th of November – 4th of December 2011

Contacts on individual partner level

- GeRT – *Generalizing Robot Manipulation Tasks* is an integrated project funded by the European Commission through its Cognition Unit under the Information Society Technologies of the seventh Framework Programme (FP7). The project started on 1st of March 2010 and will run for a total of 36 months.
    - Major partners: DLR, University of Birmingham, University of Oerebro, Technical University of Darmstadt (Former team of the Max Plank Institute Tübingen)
    - In order to work naturally in human environments such as offices and homes, robots in the future will need to be much more flexible and robust in the face of novelty than they are today. This project addresses this problem by developing new methods to cope with such novelty in manipulation tasks. The overall aim of the GeRT project is: to enable a robot to autonomously generalise its manipulation skills from a set of known objects to previously un-manipulated objects in order to achieve an everyday manipulation task. Specifically, we will enable a robot to generalize from known object instances to previously unseen objects drawn from the same class. In addition we will marry low level robotic control with high level Artificial Intelligence (AI) planning approaches to enable the robot to reason about how the overall task should influence manipulations of individual objects. The result will be a robot system able to manipulate previously unseen objects to achieve an everyday task, such as making a drink.
    - Research topic linked to topics DEXMART: grasp planning, perception

  - Type of planned cooperation: Exchange of software, test platforms and scientific knowledge
  - Involved partners from DEXMART: DLR

- XPERIENCE - *Robots Bootstrapped through Learning from Experience* is an Integrated Project funded by the European Commission through its Cognition Unit under the Information Society Technologies of the seventh Framework Programme (FP7). The project was launched on 1st of January 2011 and will run for a total of 60 months.
  - Major partners: KIT, University of Göttingen, University of Southern Denmark, University of Innsbruck, Jozef Stefan Institute, University of Edinburgh, Italian Institute of Technology
  - Project Goals: (1) Xperience will demonstrate that state-of-the-art enactive systems can be significantly extended by using structural bootstrapping to generate new knowledge. This process is founded on explorative knowledge acquisition, and subsequently validated through experience-based generalization. (2) Xperience will implement, adapt, and extend a complete robot system for automating introspective, predictive, and interactive understanding of actions and dynamic situations. Xperience will evaluate, and benchmark this approach on existing state-of-the-art humanoid robots, integrating the different components into a complete system that can interact with humans.
  - Expected Impact: By equipping embodied artificial agents with the means to exploit prior experience via generative inner models, the methods to be developed here are expected to impact a wide range of autonomous robotics applications that benefit from efficient learning through exploration, predictive reasoning and external guidance.
  - Research topic linked to DEXMART: manipulation
  - Type of cooperation: Exchange of software and scientific knowledge
  - Involved partners from DEXMART: FZI

- SAFROS - *Patient Safety in Robotic Surgery* is an integrated project funded by the European Commission through its Cognition Unit under the Information Society Technologies of the seventh Framework Programme (FP7). The project started on 1st of April 2010 and will run for a total of 48 months.
  - Major partners: KIT, EPFL, University of Verona
  - SAFROS addresses the development of technologies for patient safety in robotic surgery. It defines patient safety metrics for surgical procedures and then develops methods that abide by safety requirements, formulated in terms of their metrics.
  - Research topic linked to DEXMART: Benchmarking
  - Involved partners from DEXMART: DLR

- TAPAS - *Robotics-enabled Logistics and Assistive Services for the Transformable Factory of the Future* is an integrated project funded by the European Commission through the area Smart Factories: ICT for agile and environmentally friendly manufacturing. The project started 1st of October 2010 and will terminate 31st of March 2014.
    - Major Partners: KUKA, Grundfos, Albert Ludwigs-Universität Freiburg
    - The goal of TAPAS is to pave the ground for a new generation of transformable solutions to automation and logistics for small and large series production, economic viable and flexible, regardless of changes in volumes and product type. Key components are: mobile robots with manipulation arms will automate logistic tasks more flexible and more complete by not only transporting, but also collecting needed parts and delivering them right to the place were needed. TAPAS robots will even go beyond moving parts around the shop floor to create additional value: they will automate assistive tasks that naturally extend the logistic tasks, such as preparatory and post-processing works, e.g., pre-assembly or machine tending with inherent quality control.
    - Research topic linked to DEXMART: mobile manipulation, planning
    - Involved partners from DEXMART: DLR

- Brics - *Best practice in robotics Surgery* is an integrated project funded by the European Commission through its Cognition and Robotics Unit under the Information Society Technologies of the seventh Framework Programme (FP7). The project started on 1st of March 2009 and will run for a total of 48 months.
    - Major partners: KUKA, BLUEBOTICS SA , KU Leuven, Fraunhofer IPA
    - BRICS addresses the need for common research platforms, which support integration of research results and which support the evaluation, comparison and benchmarking of result and the promotion of best practice in robotics.
    - Research topic linked to DEXMART: Manipulation, Benchmarking
    - Involved partners from DEXMART: DLR as expert during 1st BRICS Research Camp on Mobile Manipulation, October 25 - 29, 2010; Member of the advisory board.

- SAPHARI - Safe and Autonomous Physical Human-Aware Robot Interaction is an integrated project funded by the European Commission through its Cognition Unit under the Information Society Technologies of the seventh Framework Programme (FP7). The project started on 1st of November 2011 and will run for a total of 48 months.
    - Major partners: DLR, University of Pisa, Fondazione Istituto Italiano di Tecnologia, UNINA, Università di Roma "La Sapienza"; LAAS-CNRS, KUKA, EADS
    - Inspired by the results of EU-funded project Phriends, SAPHARI will perform a fundamental paradigm shift in robot development in the sense that it places the human at the centre of the entire design. The project focuses among other

things on intuitive physical interaction between humans and complex, human-like robotic systems in a strongly interconnected manner. While encompassing safety issues based on biomechanical analysis, human-friendly hardware design, and interaction control strategies, the project will develop and validate key perceptive and cognitive components that enable robots to track, understand and predict human motions in a weakly structured dynamic environment in real-time.

- Research topic linked to DEXMART: Sensory- and model-based control methods in pHRI<, Learning/interpreting human activities, Human-aware planning in collaboration
- Type of cooperation: Exchange of software, test platforms and scientific knowledge
- Involved partners from DEXMART: DLR, UNINA, LAAS-CNRS

Classification in the National context

Contacts on individual partner level

- The Collaborative Research Center 588 *Humanoid Robots - Learning and Cooperating Multimodal Robots* was established on the 1st of July 2001 by the Deutsche Forschungs-gemeinschaft (DFG) and is still ongoing.
  - Major partners: KIT, Fraunhofer IITB
  - The goal of this project is to generate concepts, methods and concrete mechatronical components for a humanoid robot, which will be able to share his activity space with a human partner. With the aid of this partially anthropomorphic robot system, it will be possible to step out of the "robot cage" to realise a direct contact to humans. In order to be a helpful assistant in human everyday life, the robot system has to have many complex abilities and characteristics:
    - A humanoid shape
    - Multimodality
    - The ability to cooperate
    - The ability to learn
  - Research topic linked to topics DEXMART: Learning from human demonstrations
  - Type of cooperation: Exchange of software and scientific knowledge, sharing of recording hardware
  - Involved partners from DEXMART: FZI

  - Type of cooperation: Exchange of software and scientific knowledge
  - Involved partners from DEXMART: FZI, DLR

- SICURA - *Safe Physical Interaction between Robots and Humans* is a research program approved by the Italian Ministry of Education, University, and Research (MIUR). The project was launched in September 2008 and has finished in September 2010.
    - Major partners: University “La Sapienza” Rome, University of Bologna, University of Naples “Federico II”, University of Pisa, University “Tor Vergata” Rome
    - The goal of the research program is the development of comprehensive methodologies allowing the use of robotic systems in anthropic environments where natural behaviour and safety issues in the physical interaction between human user and robotic devices are crucial. Significant applications of such systems include service robotics for civil use (medicine, assistance to disabled people, domestic aids, operation of humanoid robots) as well as in advanced industrial robotics (in view of a more strict cooperation between users and robots).
    - The objective of this project is to cover the whole vertical value-added chain from development and implementation of micro integrated 3D real-time camera systems on the basis of PMD technologies for the intelligent environment detection by means of an interdisciplinary coordinated project. In this area classical unsolved tasks like "bin picking", "safe human machine interaction" and "autonomous mobile systems" represent exemplary problems for the 3D environment detection.
    - Research topic linked to topics DEXMART: motion control of robot manipulators and dextrous hands with possibly varying structural compliance; modelling of the human-robot impacts; planning of robot trajectories that minimize the risks associated to unpredicted collisions; safe-oriented control of physical interactions preserving as much as possible dynamic robot performance.
    - Type of cooperation: Exchange of scientific knowledge
    - Involved partners from DEXMART: UNIBO, UNINA

- viEMA - *Vernetzte, informationsbasierte Einlern- und Ausführungsstrategien für autonome Montagearbeitsabläufe* is a German project funded by the Federal Ministry of Economics and Technology (BMWi) in the Autonomics technology program. The project was launched on 1st April 2010 and will run until 31st March 2012.
    - Major partners: FZI, BOSCH, TU Munich, ISRA Vision AG, FAUDE
    - viEMA aims on a new kind of industrial robot application scenario. While traditional robots require lots of time and expert knowledge to be reprogrammed for a new application, the viEMA robot can be set up within days and without special programming skills. This makes the use of the robot profitable even for quickly changing tasks that can only be hand-operated up to now. It also helps smaller companies to use industrial robotics as it financially justifies leasing or rent a robot spontaneously in times of high workloads. To achieve the ease of programming, the concept of "parameterizing by

demonstration" is introduced in the project. It enables the robot to use its 3D-perception to learn the handling of new parts after a coarse definition of the general program flow through an ergonomically optimized GUI. Task patterns can be stored or loaded from an online database what makes remote configuration and support easy. Key components of the transportable robot-cell are a high-resolution Laser based optical sensor, a high-speed robot arm and the Software-package that is able to integrate teaching, object-recognition, motion-planning and simulation in an easy manner.

- Research topic linked to DEXMART: Grasping, grasp planning, motion planning
- Type of cooperation: Exchange of software and scientific knowledge
- Involved partners from DEXMART: FZI