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

Large-scale integrating project ICT−216239 supported by the
European Commission under the 7th Framework Programme
Duration: 01.02.2008 – 31.01.2012
Cost: 8.1 M€ | Funding: 6.3 M€

Coordinator: Bruno SICILIANO

www.dexmart.eu

The Consortium

UNINA PRISMA Lab/DIS & DSF, Università di Napoli Federico II, Italy Prof. Bruno Siciliano siciliano@unina.it	**CNRS** LAAS, CNRS, France Dr. Daniel Sidobre daniel.sidobre@laas.fr
DLR Institut für Robotik und Mechatronik, DLR, Germany Dr. Gerhard Grunwald gerhard.grunwald@dlr.de	**FZI** Forschungszentrum Informatik an der Universität Karlsruhe, Germany Dr. J. Marius Zöllner zoellner@fzi.de
OMG OMG plc, United Kingdom Dr. Andrew Stoddart a.stoddart@omg3d.com	**SUN** DII, Seconda Università di Napoli, Italy Prof. Giuseppe De Maria giuseppe.demaria@unina2.it
UNIBO DEIS & DIEM, Alma Mater Studiorum Università di Bologna, Italy Prof. Claudio Melchiorri claudio.melchiorri@unibo.it	**USAAR** LPA & EPO,Universität des Saarlandes, Germany Mr. Chris May c.may@lpa.uni-saarland.de

The goal

DEXMART has the ambition to fill the gap between the use of robots in industrial environments and the use of future robots in everyday human and unstructured environments, contributing to reinforce European competitiveness in all those domains of personal and service robotics where dexterous and autonomous dual-hand manipulation capabilities are required

The background

COGNITIVE SYSTEMS

ROBOTICS

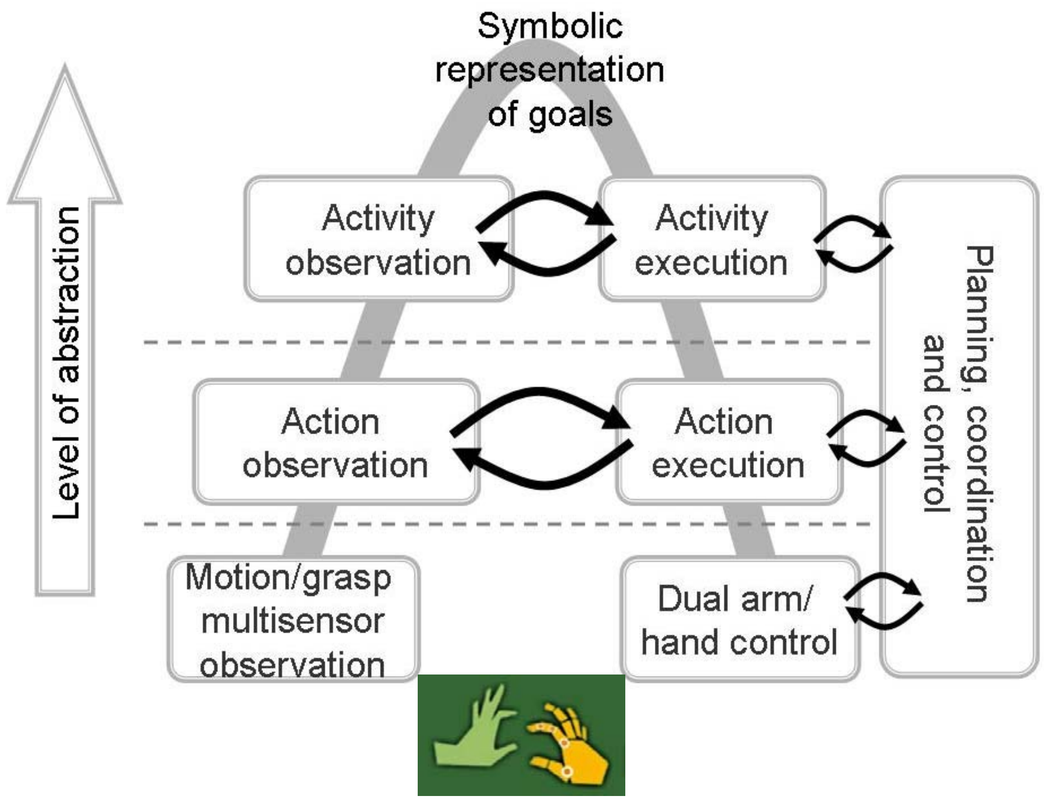
SEVENTH FRAMEWORK PROGRAMME

The contribution

DEXMART will primarily contribute to the **development of robotic systems endowed with dexterous and human-aware dual-arm/hand manipulation skills for objects, operating with a high degree of autonomy in unstructured real-world environments**

- Allow a dual-arm robot including two multi-fingered redundant hands to **grasp and manipulate the same objects** (different shape, dimension and weight) **used by human beings**
- Manipulation will take place in **unsupervised, robust and dependable manner** so as to allow the robot to **safely cooperate with humans** for the execution of given tasks
- Robotic system able to **autonomously decide between different manipulation options**, and to **learn new action sequences** aimed at creating a **consistent and comprehensive manipulation knowledge base**
- Possible exploitation of high power-to-weight ratio of **smart materials and structures**, aimed at design of new hand components (finger, thumb, wrist) and sensors for **next generation of dexterous robotic hands**

The vision

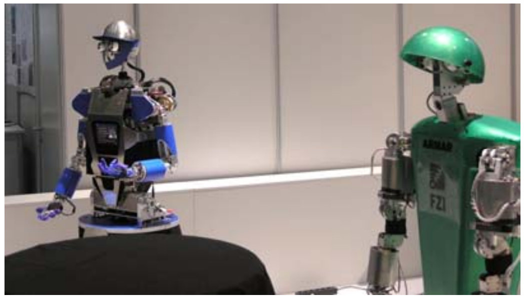


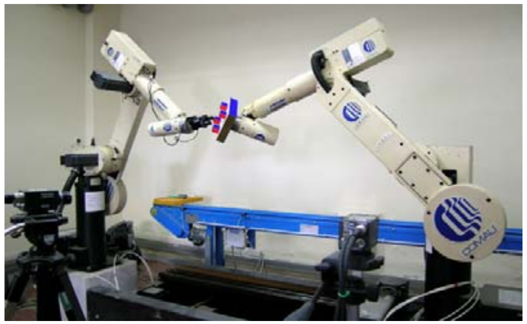
- **Hybrid control mechanisms for dexterous manipulation** – Account for high dynamics and stochastic scene behaviour, use of kinematic redundancy for optimization
- **Next generation robotic hands** – Blend of robustness with dexterity, development of new smart actuation and sensing system

- **Dual-hand manipulation models at different levels of abstraction** – Sensorimotor control, actions and activities, symbolic goals
- **Observation and execution in close coupling** – Congruency between methods and representations for action/activity observation and execution with incremental enrichment of knowledge base
- **Bridge the gap between complex task modelling and dexterous manipulation capabilities** – Manipulation models as probabilistic compound of motions, constraints, strategies, goals and scenes
- **Observation and analysis of human demonstrations** – Activity recognition for bimanual manipulation with focus on analysis of concurrent movements, strategies and goals
- **Task planning and coordination** – Knowledge based flexible task composition, execution monitoring, decision making and adaptive planning on different levels

The context

- Research domains
  - Observation, interpretation, learning and modelling
  - Task planning and coordination
  - Feedback control
  - New robotic technologies
- Benchmarking and experiments





Observation, interpretation, learning & modelling

RESEARCH OBJECTIVES	PERFORMANCE INDICATORS
Combining structuring, learning and modelling (year 2 to 4)	Convergence of system knowledge and ability enhancement of the bimanual system by learning, used background knowledge, adaptive methods like control and planning supported by an intrinsic dexterous system
Methods and mechanisms to observe human manipulation in a way that the observed actions enhance the robot's skills (year 2 to 3)	Granularity and success rate of the observation and classification: from fingertips to observation of the body; diversity of goals and success rate on observation and deduction of bimanual manipulation goals
Probabilistic abstract representation for manipulation activities, including actions and symbolic goals, to be used for planning and verification (year 3 to 4)	Usability in terms of completeness for observable goals and strategies which should be followed during execution but also performed activities including their coordination; feasibility for the execution, especially task decomposition and goal-directed activity/strategy scheduling and monitoring
New kinematic model of the human hand (year 2)	Validation of the model ability to reconstruct complex human hand motions through human observation
Taxonomy of bimanual grasping and manipulation (year 2)	Development of a taxonomy of dual-handed grasping, considering issues on all levels of abstraction; the definition will be validated and verified on the robotic demonstrators as well as by human observation

Task planning and coordination

RESEARCH OBJECTIVES	PERFORMANCE INDICATORS
Representation and decomposition at the high abstraction level of the manipulation activities including goals and strategies (year 3)	Diversity of representation/decomposition of manipulation activities into atomic dual-arm manipulation actions and used capabilities and constraints of the system; flexibility in distribution of actions and activities between the two arms and associated manipulators and controls
Scene analysis and task reasoning component (year 3 to 4)	Success rate, performance of grasp and path planning components considering task information compared to canonical unattached approaches
Reasoning over coordination schemes resulting in a decision based on global task-specific quality measures including hand, arm, object and even tool features and capabilities (year 3 to 4)	Success rate, ability to cope with stochastic behaviour of the environment with different manipulation goals; quality of alternatives resulting from the decision reasoning over the existing repertoire of subtasks and selection of manipulation alternatives and coordination schemes; involved components comprising hands, arms, objects or even tool features
Grasp and path planning (year 2)	Adaptivity of planning of dual-arm manipulation
Scheduling and monitoring goals and different strategies during execution (year 4)	Diversity of strategies, actions and goals which can be scheduled and monitored simultaneously; resolution of conflicting instructions and appropriate weighting for different actions; success rate in terms of goal achieving for manipulation tasks and reaction type of the robot on changes or unpredicted events

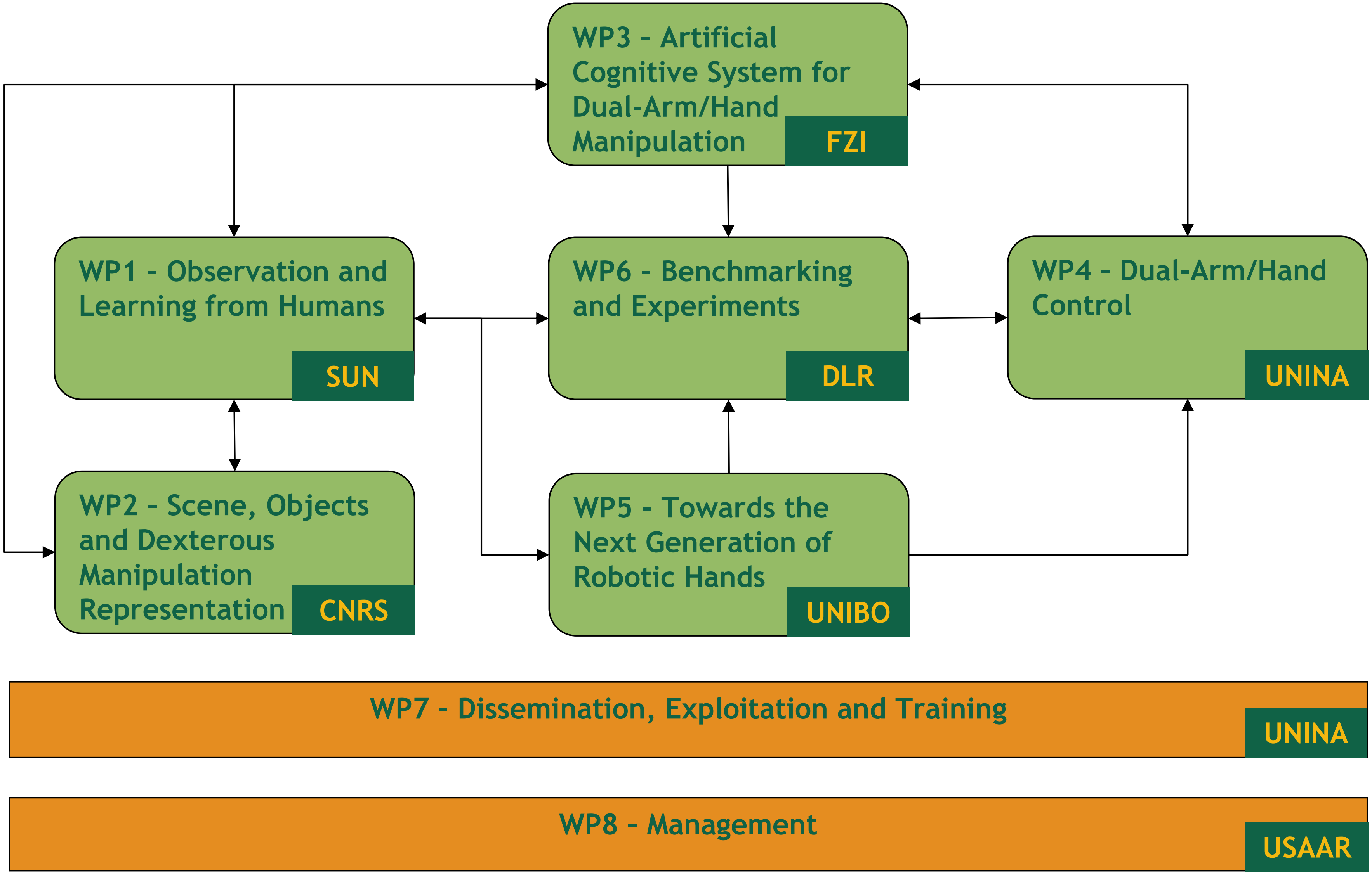
Feedback control

RESEARCH OBJECTIVES	PERFORMANCE INDICATORS
Automatic selection of the appropriate control parameters (year 2 to 3)	Choice of control parameters in force or impedance control, in the different phases of the task and for different local contact situations
Smoothness during transitions (year 2)	Lack of sudden changes in force or acceleration which can instantiate instabilities, especially in case of contact with hard surfaces
Hybrid discrete-continuous control (task coordination and feedback control) (year 3 to 4)	Different controllers suitably combined to accomplish a variety of different behavioural objectives

New robotic technologies

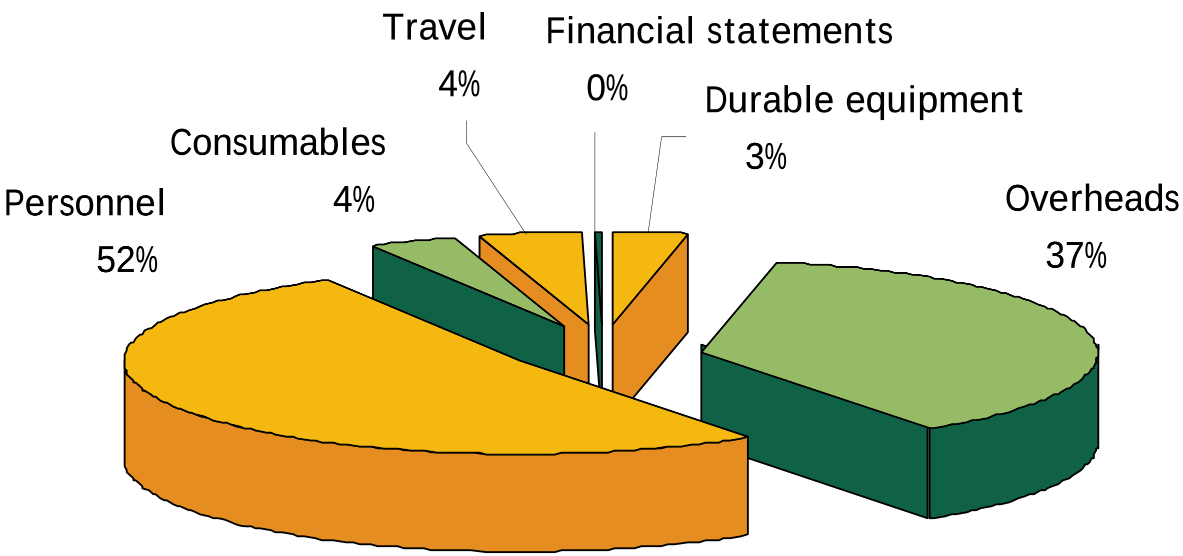
RESEARCH OBJECTIVES	PERFORMANCE INDICATORS
New actuators (year 3)	Energy density of actuators based on smart materials, size and cost with respect to conventional solutions
Combined sensing (year 3)	Performance of force, tactile and displacement sensors, cost and ease of integration with respect to conventional solutions
Robot hand prototypes (year 3 to 4)	Similarity with the human hand (in terms of size, and potential dexterity), costs, reliability (time between failures)

The work plan



The figures

- 866 person months (30 key scientists)
  - 798 pm on research and development
  - 23 pm on management
  - 45 pm on dissemination, exploitation, training
- 23 deliverables
- 38 internal reports
- 22 milestones
- Budget breakdown



The impact

- Great relevance for leading-edge European robot manufacturers
  - KUKA Roboter GmbH as external observer and advisor
    - New dimension in industrial and professional service robotics
      - Lightweight robot: result of close cooperation with DLR
- Bimanual manipulation useful in automotive industry
  - Typical assembly procedures constituted by tasks requiring manipulation of objects and tools similar to those used in general everyday environments
  - Tight collaboration between human operator and robotic system during design process
    - Designer of assembly line or technologist checking and validating maintenance procedure
- Human-centered tasks
  - Robot companions
    - Helper at family homes
    - Executing tasks in offices, public environments and in services

The end

www.dexmart.eu