DEXMART Newsletter No. 3 — January 2012

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:	FP7 216239
Web site:	www.dexmart.eu
Coordinator:	Prof. Bruno Siciliano Università di Napoli Federico II siciliano@unina.it
Duration:	01 Feb. 2008 – 31 Jan. 2012

UNINA | DLR | OMG | UNIBO

CNRS | FZI | SUN | USAAR

DEXMART is a large-scale integrating project funded under the European Commission's 7th Framework Programme, which 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 aim of this final newsletter is to outline how the research results produced by the DEXMART consortium contributed to filling this gap. It also highlights significant events and achievements and contains various informative links to interesting videos and further information. Readers interested in more detailed information about the progress in the project are referred to our project web site.

See the project in action

- Learning and execution of a complex manipulation task on Adero
- Exchange of an object with humans
- Actuation demonstrator: Beer lifter
- Final prototype of the DEXMART tactile sensor
- Postural synergies & grasps with the DEXMART hand
- DEXMART hand at Robotville

A word from the Coordinator

DEXMART has a great potential for European robot manufacturers, as typical assembly procedures in automotive industry require dual-arm manipulation of objects and tools similar to those generally used by production workers.
The new dexterous hand will be appealing to SMEs for manipulation of work pieces of different sizes, shapes and weights currently requiring different grasping tools and frequent changes.
Human–robot cooperation is to be adopted in aeronautic industry to assist humans in simple repetitive tasks, e.g. riveting and assembly. In the future, the results of the project will be useful for executing human-centred tasks in service robotics scenarios.

Highlights of DEXMART brought to mind

AUTOMATICA 2010 (12–15 June 2010, Munich, Germany)

AUTOMATICA 2010 was a major event for DEXMARTians. Different research results were exhibited by various partners at a booth organised within the euRobotics exhibition. USAAR presented the two twisted string actuation demonstration units, SUN presented a tactile sensor demonstrator, DLR and FZI had their own exhibition areas where they presented dual-arm manipulation tasks on Justin and an autonomous ice serving robot respectively.
www.automatica-munich.com

HUMANOIDS 2011 (26–28 October 2011, Bled, Slovenia)

As a final public dissemination activity, at the 11th IEEE-RAS International Conference on Humanoid Robots, the DEXMART consortium contributed a successful half-day workshop "The DEXMART project for advanced bimanual manipulation". In addition to the presentations given by project internal and external experts, an informative session with six posters describing different research areas was displayed.
www.humanoids2011.org

Robotville Festival (1–4 December 2011, London, UK)

At the Robotville Festival in the Science Museum more than 7000 visitors were able to meet over 20 unique robots and their makers, who were even on hand to demonstrate their work and talk to visitors. The DEXMART team from UNIBO and USAAR successfully presented two preliminary prototypes of the robotic hand and of the two fully-sensorized fingers to an interested crowd of people.
www.sciencemuseum.org.uk/robotville

Press clippings

Throughout the project's duration, DEXMART was regularly represented in the media on a national as well as international level. Press clippings covered announcements of recognition to individual members of the DEXMART consortium (e.g. Best Interactive Presentation Award received by SUN and Finalist for IEEE ICRA Best Manipulation Paper Award received by FZI), or articles on one of our workshops (e.g. Pressemitteilung zum 3. Workshop), or else TV reports on the progress in the project (e.g. Il Denaro TV).

Patents

We are proud to announce as a special accomplishment of the project that two DEXMART partners, SUN and USAAR, have filed local patent applications:

- SUN filed an Italian and European patent application (tactile sensor development).
  Italian Application no. RM2010A000304: "*Sensore per la misura di una forza esterna applicata a ditto sensore*".
  European Application: G. De Maria, C. Natale, S. Pirozzi, A. D'Amore, L. Grassia (2011). "*Sensor For Measuring An External Force Applied To Said Sensor*", EP11425148.1.
  Both patent applications are pending.
- USAAR-LPA filed a German utility patent on the means of propulsion or the drive system. On 28 October 2010, the patent "*Antriebssystem*" was granted.
  Utility patent no. issued by the German Patent and Trademark office: 20 2009 017 989.3 IPC No. F16H 19/06 (2006.01).

Observation and Learning from Humans

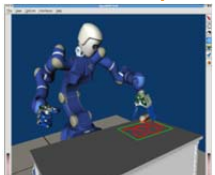
Observation of humans performing manipulation activities using full body motion has been carried out with low accuracy with the aim of **learning manipulation strategies and goals** and inferring suitable constraints to be fulfilled during the execution. Human Activity Language (HAL) and Hidden Markov Models (HMMs) have been exploited to represent and recognize **full body actions**, while **strategy graphs** have been defined and used to represent constraints. To observe humans performing manipulation activities from a detailed perspective, a **multi-modal sensor fusion architecture** has been designed and applied to a number of manipulation tasks. The data acquisition and fusion system uses a **data glove**, a **motion capture system** and **tactile sensors** installed on the glove fingertips. The sensor data are processed according to a two-level architecture, where the lowest level fuses motion capture measurement and data glove joint angles to accurately reconstruct the hand motion. The highest level usefully exploits contact force measurements and a virtual environment simulation to achieve kinetostatic consistency between motion and force data. Contact force measurements have been exploited also in the observation of human-robot object exchanges through the specifically developed **sensorized object Bidule**.

Scene, Objects and Dexterous Manipulation Representation

Having models available to describe a service robot scene at different levels with all sorts of information from the environment, the objects to manipulate and humans is a real challenge. DEXMART has enabled the development of **new tools to represent objects, obstacles and scene dynamics**, which take uncertainty into account, and to represent knowledge to be used for the execution by the development of representations on different levels of abstraction. This knowledge encompasses the scene, which is manipulated either by a human or a robot system, the human properties related to manipulation and the robot capabilities. The developed tools are **usable from the observation and learning to the dual-handed manipulation execution**.

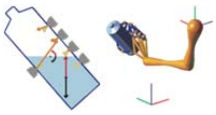
Artificial Cognitive System for Dual-Arm/Hand Manipulation

Autonomous service robots require different levels of learning, reasoning, planning and execution in order to perform bimanual, dexterous manipulation tasks in different environments with human safety demands. An artificial cognitive system has been developed, which **learns probabilistic mission planning models from human demonstrations**. Actions, which are represented as planning models for constrained motion planning, are learned on a lower level of abstraction in a **novel Programming by Demonstration system**. Systems using **graspability** and **capability maps** have been developed to improve classical grasp and motion planners in order to estimate robust and high-quality grasps as well as plan for task dependent trajectories in an efficient way. In the execution system, **human-aware motion planners** have been developed, which allow exchanging objects between humans in a safe and acceptable manner. In order to bridge the gap between the symbolic and subsymbolic planners, a **reasoning system** analyses the scene, introduces addtional actions to enable a successful execution of the task and monitors the results. Low-level force and position trajectories are generated based on human observation to make use of the similarity of the DEXMART hand and the human hand.



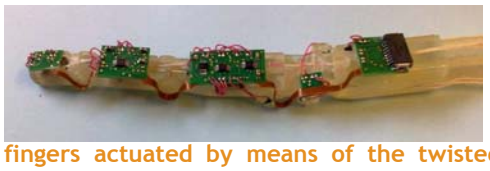
Dual-Arm/Hand Control

The control issues of a **multi-level control architecture** for a dual-arm/hand system have been addressed. In detail, for the new DEXMART hand, developed within the project, the **control system of the novel twisted string actuation device** has been designed, together with the **data acquisition system for the new sensors embedded into the hand**. An important issue in controlling a multi-fingered robotic hand grasping an object is the evaluation of the minimal contact forces able to guarantee the stability of the grasp and its feasibility. Using finger tactile information and contact force measurements, an efficient algorithm has been developed for **online computation of the optimal contact forces** for the DEXMART hand assuming that, during the execution of a (single/dual hand) manipulation task, both the position of the contact points on the object and the wrench to be balanced by the contact forces may change with time. Moreover, suitable **control strategies taking advantage of kinematic redundancy of the manipulation system** have been designed, both for single and dual-hand manipulation tasks. Based on the similarity of the DEXMART hand with the human hand, taking inspiration by neurosciences studies on human synergies, a **reduced configuration subspace based on three predominant postural synergies** of the DEXMART hand has been computed and exploited to simplify grasp synthesis and control. Finally, a **supervisory attentional system suitable for monitoring and regulating a safe and human-aware manipulation** has been developed. Depending on the disposition and the attitude of a person in the working environment of the robot, the attentional system monitors and regulates internal and external processes at higher or lower resolution.



Towards the Next Generation of Robotic Hands

Our research activity aims at developing innovative solutions concerning the mechanical design, the sensory equipment and the actuation system for the implementation of **anthropomorphic robotic hands with improved reliability, functionality and reduced complexity and cost**, considering also aspects related to **safety during human–robot interaction**, paving the way toward the next generation of robotic hands. To this end, **innovative sensors and actuators** have been developed for the integration of the mechanical structure of the DEXMART hand, and a simplified platform composed by two **fully-sensorized fingers actuated by means of the twisted string actuators** has been produced and is actually under experimental evaluation. The final prototype of the robotic hand is currently under production.



Benchmarking and Experiments

The various results of the research activities have been **integrated and evaluated in multiple test-beds**. The new sensors have been evaluated based on a number of typical indicators such as measurement repeatability, sensor linearity, and noise level. Several tests have been performed with the aim of evaluating the duration and the strength of the novel actuators, taking into account the requirements and the restrictions mainly in terms of power consumption and encumbrance. Several tests for the evaluation of the manipulation capabilities of the DEXMART hand have been performed. The experimental results have shown that planning and control allow not only to reproduce with a high level of fidelity the set of postures adopted to derive the eigengrasps, but also to synthesize and perform a wide set of grasps, throughout the whole grasp taxonomy. A prototype of the DEXMART hand has been integrated on the COMAU Smart Six robot. This set-up is used for benchmarking the task "**Exchange of an object with human**". To assess the recognition of bimanual manipulation tasks, experiments have been performed with a set of ten, pair-wise similar manipulation tasks. Learning and generalization of bimanual manipulation strategies have been analyzed in three experiments: holding a bottle and screwing down a bottle cap, bimanual pouring in and moving a chess knight. The planning and execution of bimanual manipulation tasks has been investigated and benchmarked using the "**Cleaning the desk**" scenario.