ROBOCAST

Grant agreement no. 215190

ROBOCAST

ROBOt and sensors integration for Computer Assisted Surgery and Therapy

Small or medium-scale focused research project (STREP) proposal

Objective ICT- 2007.2.1 Cognitive Systems, Interaction, Robotics

Deliverable reference number and title: D9.5 Final publishable summary

Due date of deliverable: month 36

Actual submission date: December 31st 2010

Start date of project: January 1st 2008 Duration: 36 months

Organisation name of lead contractor for this deliverable: POLIMI

Revision: Version 2

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
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)	**X**

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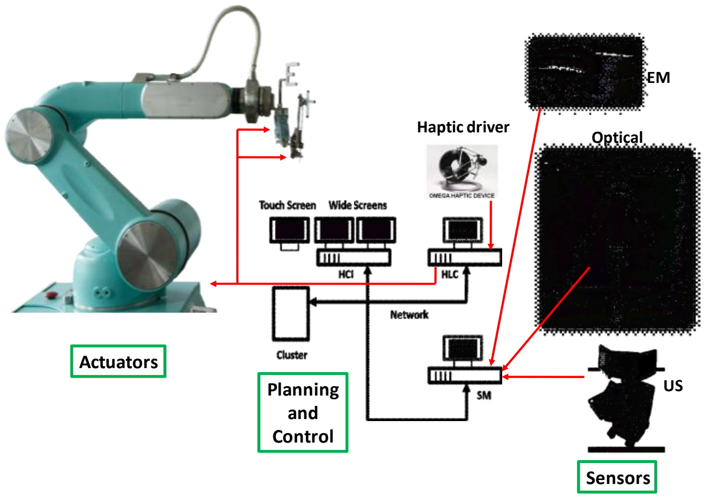

Figure 1.1 - The ROBOCAST components.

The goal of the ROBOCAST project is to provide a system for the assistance of keyhole neurosurgery. The system components are shown in Fig. 1.1. it combines a human-computer interface (HCI), with an intelligent context-sensitive communication and a haptic-drive capability, a multiple-robot hierarchical chain with redundant degrees of freedom, an autonomous trajectory planner, a high level controller and a set of field sensors. The idea has been developed into a working demonstrator for in vitro tests in the operating room (OR).

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The Project Objectives

The project introduces robotics and Intelligence Augmentation in the OR, improving the HCI with haptic drive and feedback, providing the surgeon with the assistance of an autonomous planner, increasing robots accuracy and reliability with redundant sensors.

Objective 1: Developing intelligence augmentation techniques and effective human-machine interaction.
Path planning is a key point in surgery as well as in autonomous robots. In the neurosurgical field, intelligent planning collects and manages different sources of information (surgeon experience, sensors data and knowledge database), thus increasing the patient safety and improving the intervention outcomes. Surgical planning is negotiated with the surgeon exploiting IA techniques both for autonomous task execution and effective human-machine interaction.

Objective 2: Providing robots with autonomy (management of failures, negotiation of path execution, optical sensor management).
The system is able of facing unexpected events, as lack of reliability of sensors information and decides whether to continue working in a safe but limited mode (down-graded mode) or to terminate operations (shut-down).

Objective 3: Simulating small footprint robots, saving accuracy by feedback control loop and sensor/robot/robot cooperation.
The ROBOCAST system foresees a wide use of redundant sensors both for increasing reliability and for compensating inaccuracies through a supplementary sensory feedback. Calibration inaccuracies, typical of small footprint robots with large workspace, were simulated.

Fig 1.2 The project consortium

Objective 4: Developing an effective interface between the user and the system and providing a strong integration in the OR.
This objective is aimed at increasing the surgeon acceptance of the robotic system in the OR providing a user friendly interaction (input via touch-screen and output via video and acoustic signals) and integrating the system with existing OR instrumentation. The graphical interface with a context sensitive information display, predictive behavior and intelligent augmentation, also improves operative time management.

Objective 5: Providing the system with modularity and flexibility characteristics to make it scalable and usable in different applications (surgical and industrial)
Last objective is the modularity, in order to allow re-using any module of the project into other applications and to facilitate maintenance and repair in the highly demanding surgical application.

The outcome

On the third year of the project the prototype has been assessed (Fig. 1.3) with in-vitro tests carried out in a real Operating Room (University Neurosurgery Department at Borgo Trento Hospital, Verona Italy).

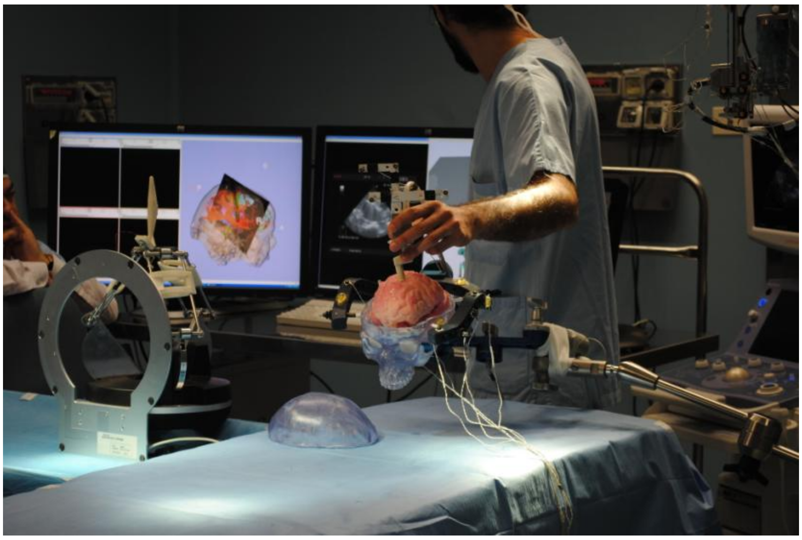
The system fulfils the following outcomes:

- Exploitation of **autonomy of robots and IA techniques for path planning**.

The system autonomously decides whether to continue operating in down-graded mode or quitting operations in case of sensors accuracy degradation. The surgical planner allows the automatic computation of the trajectory of the probe minimizing the risk for the patient. The plan is based on medical images registered on a labelled anatomical atlas, indicating brain structures and values representative of the risk of damaging brain areas or tissues: vascular, fibres, functional areas. Propositions (quasi natural language sentences) are assigned to homogeneous groups of voxels, thus developing a fuzzy knowledge database derived from the surgeon experience. Such knowledge base is processed by the inference engine that cooperates with surgeon in solving possible conflicts in the optimal trajectory search.

- **Modification of traditional surgical instrumentation to be adapted to robotics**.

The flexible probe could carry surgical instruments or optical fibres onboard. The biomimetic approach herein proposed uses a probe split into reciprocating parts that actively contribute to the advancement requiring a minimal inward push, so avoiding buckling and reducing tissue damage. In the ROBOCAST project, a 2D demonstrator (i.e. a curved path in a plane) was developed and tested in gelatine.



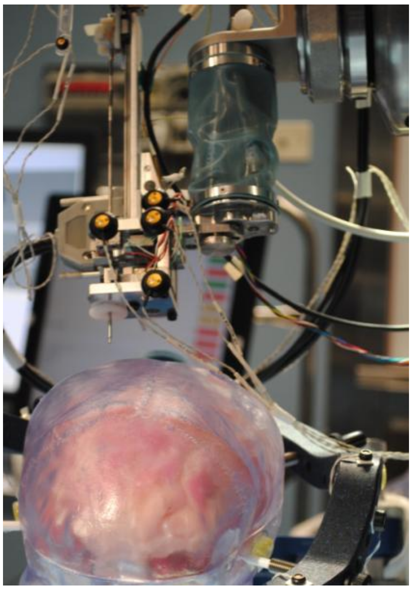


Figure 1.3 a (up) and b (right) - The ROBOCAST system deployed prototype in Verona Borgo Trento Hospital OR.

- **Respect of safety requirements of the surgical room**.

Robots closely interacting with humans and deeply integrated in the surgery space have to be safe and robust to fault tolerance. The ROBOCAST system answers the dependability technological challenge because of its redundant control scheme. Information coming from sensors allows it to have accurate and robust control: optical and electromagnetic localization devices, which act as visual sensors feedback system, force sensor, which provides the surgeon of the brain resistance sensation, a registered ultrasound (US) system, to check intra-operatively the operation plan.

- **Haptic feedback information**.

The interface of ROBOCAST is endowed with a haptic device used to convey to the surgeon the resistance of the brain parenchyma to straight probe advancement. Amplification of linear motion and/or force is provided. The force feedback information comes from the tip of the probe during the advancement under linear actuator control and it is estimated from the positional error.

- **Simple and intuitive interface with the surgeon, integrated with advanced virtual and augmented reality techniques**.

The surgeon is provided with the possibility to easy and intuitively plan surgery, to interact with the system and to update plans. Man-machine interfaces (touch-screen, haptic interface, see figure 1.3 a) allows for safe user-robot interaction and surgeons system acceptance.
Since the beginning of the project (January the 1st, 2008) **the following activities** have been carried out toward the accomplishment of the aforementioned objectives**:**

- **User requirements** definition and **System specification** were completed on the first year (WP1 and WP2).
- **Hardware and software** (WP3) **development** started in September 2008. An integrated modular robotic system with a hierarchical structure, including two modified commercial robots (PathFinder, and a parallel mini-robot – the MARS) and novel end effectors (a linear actuator with haptic force feedback and a biologically inspired flexible probe) was developed. The tele-operation performances were tested in terms of force sensing accuracy and haptic loop stability and transparency. The flexible probe proved to follow curved paths automatically computed.
- **The Software framework** was designed for pre-operative and intra-operative planning and navigation (WP4). The pre-operative planning software is a user-friendly planning wizard, including medical image processing steps (such as affine and deformable registration, segmentation, image enhancement etc.). Its design was based on the user requirements, surgical protocols and workflows defined in WP1. The entire intra-operative software suite has been based on Slicer3D, encompasses a OR-compliant user interface (Touchscreen), the full integration of 2D and 3D

morphological and Doppler ultrasound registered images. Tests with end-users were performed in project year 3.
WP5 dealt with the high level control (HLC) of the robots (trajectory planning, obstacle avoidance, redundancy management, safety check). The intelligent planner was developed in this WP, it is able to compute the probe trajectory on the basis of the numerical risk information. Logical constraints and surgeon interface for information upgrading (negotiation and debriefing) were developed.

- To facilitate system integration and assure system modularity (WP6), an **interface control framework** specified mechanical and electrical interfaces, as well as software platforms (operating systems, compilers, APIs, CADs, medical images processing software) and communication protocols.

- **Integration task** (WP7) started in September 2009, when the interconnection of the Haptic Interface with the Linear Actuator and the HLC was established. A first integrated system, with all hardware and software modules in operation, is available. The integration tests among the Sensor Manager, the gross positioner, the fine positioner and Flexible Control System was done.

- Management (WP9) and dissemination and exploitation (WP8) ended with the delivery of final report. Dissemination was oriented toward scientific community, industry, SMEs and end-users and internal audiences (i.e. POs of DG Information Society and Media, other project coordinators). Seminars of current EU projects in robotic diagnosis, surgery and therapy have been organized at international level. Final presentation in the hospital OR was accompanied by a press release that has focused the attention of the local and national press. Exploitation has been considered by almost all the partners, basically for ROBOCAST sub-modules. The consortium skills and still alive cooperation has brought to a new ICT project (ACTIVE FP7-ICT-2009-6270460) that can be considered an asset from ROBOCAST collaboration.

The impact of the project

All the activities proposed in this project specifically address the issues of **effective medical diagnostics and therapeutics**, which will enable the development of effective diagnosis and preoperative planning for neurosurgery, the purpose of which is to make treatment quicker, less invasive, and more effective. In particular, the development of a biomimetic steerable miniature probe will enable a range of **new surgical tasks** (e.g. curved trajectories between an entry point and target lesion) which are currently impossible with today's technologies. At the same time, the system will extend and refine the use of conventional instrumentation in the operating theatre through better targeting and enhanced haptic perception.
The integrated approach to planning, intervention, and assessment put forward in the study will also ensure products that provide a rapid **training process** for medical practitioners, which will deliver consistent high quality surgery from relatively inexperienced surgeons. This approach will also play a key role in the training of future medical staff by providing a systematised and structured workflow in addition to enhanced precision of interventions. The ROBOCAST project is expected to widen and accelerate the safe use of medical robotics, while the methods developed will be applicable to **other non-medical domains**. The advanced safety protocols and strategies will be particularly of benefit in those non-medical applications where robots are used in close proximity to humans e.g. military, rescue, and robotic systems for the home.
The ROBOCAST project aimed at **starting and then strengthen a new market totally devoted to surgical robotics**. Eventually, the involved SME will be able to incorporate some of the technology into their product ranges.

Project coordination team:

Neuroengineering and medical robotics Laboratory
Politecnico di Milano – Bioengineering Department

Giancarlo Ferrigno – Elena De Momi
Politecnico di Milano
Piazza Leonardo da Vinci, 32
e-mail: giancarlo.ferrigno@polimi.it
Phone: +39 02 2399 3371