Project RONNA – an overview

RONNA - Robotic NeuroNAvigation is a project that deals with research into and the design of a new innovative and competitive robotic system for application in neurosurgery. The project was launched 7 years ago by the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, with the Clinical hospital Dubrava and the Croatian Institute for Brain Research as partners in the project. Founders of the project are Professor Bojan Jerbić, PhD (project leader), Assistant Professor Darko Chudy, PhD and Professor Gojko Nikolić, PhD. The project received the first funding through the government program for technological development TEST and the Ministry of Science, Education and Sports. Further funding was received from the Unity Through Knowledge Fund, the Croatian Science Foundation and, recently, from the European Regional Development Fund (Strengthening capacities for research, development, and innovation – RC, 2 February 2008).

The main ideas of the project are:

- Improve the traditional neurosurgical stereotactic procedure using the RONNA robotic system.
- Use a dual arm configuration (two robots), one as the main robot for precise spatial positioning and guidance of surgical tools and the other as the robotic assistant.
- Use standard industrial robots in the unstructured medical environment.
- Implement intelligent and intuitive control features for simple and intuitive use of the system.

The RONNA system has been developed to the stage of commercial use as part of the project which was funded by the European Regional Development Fund. This project stage began in December 2014 and was divided into two main phases: industrial research and experimental development. In the first phase, new equipment was purchased and research involving continuous relative robot navigation was conducted. Exploration of possibilities and limitations of standard industrial robots for use in medical procedures and the development of protocols and equipment for human-robot interaction (HRI) were also part of this phase. According to the research carried out in the first phase, the robots KUKA KR6 Agilus and Universal Robot UR5 were chosen to be applied. In the second phase of the RONNA project, mobile platforms for the master and the assistant robot were developed following the rules of industrial design and satisfying special requirements related to medical equipment. They were then manufactured as first commercial prototypes. Concurrently, a prototype of an educational robot system was built for the training of medical stuff. All the research mentioned previously was conducted at the Faculty of Mechanical Engineering and Naval Architecture and the Clinical Hospital Dubrava. At the end of 2015, as part of the second phase of the project, clinical testing started as the preparation for the first robotized neurosurgical operation in Croatia. On the 10^{th} of March 2016, the first stereotactic neurosurgical operation on a real patient was finally performed successfully. That was also the first neurosurgical operation of that kind in this part of Europe. Globally, there are only few robotic systems which are suitable for use in neurosurgical applications, mainly still in the experimental stage.

The conducted surgical procedure can be divided into two phases, preoperational and operational. In the preoperational phase, a marker was attached to the patient's skull, which acts as a coordinate reference system for the operation points in the CT scan of the patient. The surgeon determined the operation points (entry and target points) in the medical diagnostic software. The coordinates were then transformed into the coordinate system of the patient's marker and immediately transferred (sent) to the robot. Thus, the preoperational phase was completed and the operational phase of the procedure could begin. Using a

stereovision system, the robot localized the patient and its spatial position and orientation through the aforementioned marker. When the connection between the robot coordinate system and the patient was established, the invasive part of the procedure began. A sterile cover was put on the robot and the unsterile robot tools were replaced with adequate sterile tools. Then, the robot navigated to the previously planned trajectories and enabled precise drilling operations by guiding the surgical drill through its tool. Subsequently, the surgeon inserted a biopsy needle into the intracranial space of the patient under the precise guidance of the robot and performed the standard biopsy procedure together with the evacuation of the cystic part of tumour from the targeted brain region. Follow-up MR scans of the patient showed that the planned brain region was perfectly reached without any complications arising from the procedure.

The most important results which were produced by the RONNA project are:

- Faster and more effective completion of a surgical operation.
- Surgical operation procedure becomes less invasive.
- Faster patient recovery (due to a shorter duration of the surgical operation).
- More effective use of hospital resources.
- Introduction of new technologies into medical practice.

Technological and scientific contribution of the project:

- Development of new control models for the intuitive use of robots in the operating room.
- Development of an original method for patient localization.
- Design of specific robot tools and instruments suitable for use in the medical environment.
- Knowledge of new possibilities for the application of robotic technologies in the neurosurgical practice.

Fig. 1 RONNA (final design)

Fig. 2 Fadi Almahariq, MD, performs bone trepanation guided by the RONNA system

The total value of the RONNA (Robotic NeuroNAvigation) project funded by the European Regional Development Fund is 3,698,461 kunas. The 16-month project was completed successfully on the 1st of April 2016. The research team from the Department of Robotics and Production System Automation at the Faculty of Mechanical Engineering and Naval Architecture in Zagreb together with the Neurosurgical team from the Clinical Hospital Dubrava will continue their work on the development and improvement of the system. The eventual aim is to make the system suitable for use in hospitals and clinical centres around the world.

More information about the project can be found on the projects official website: http://www.ronna-eu.fsb.hr/

Fig. 3 Professor Darko Chudy, MD, PhD, performs the evacuation of the cystic part of tumour

Fig. 4 RONNA presented at the Clinical Hospital Dubrava