Use Case for European Robotics in Ophthalmologic Micro−Surgery

Rapports

Informations projet

EurEyeCase

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Coordonné par KATHOLIEKE UNIVERSITEIT LEUVEN

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Résumé du contexte et des objectifs généraux du projet

Epiretinal membrane and retinal vein occlusion are common pathologic conditions with high complication rates that greatly reduce quality of life of the affected people. They can be treated by peeling the epiretinal membrane and cannulating the occluded microvessel(s) but are currently high-risk procedures. To improve their outcomes, robot-assistance control schemes for micro-positioning and micro-force manipulation surgical tasks are developed, starting by the design of a set of innovative miniature sensorised instruments. These smart instruments include proximity, contact and force sensing in an extreme compact package. In parallel, a robust online 3D reconstruction of retina, based on stereoscopic images incorporating information from OCT, pose-, contact- and force-sensing is developed togetgether with robot technology and instruments, allowing conducting clinically relevant
research on complex vitreoretinal surgical techniques. Currently, such research is difficult or impossible due to procedural complexity and limitations in surgical skills. The mechanisms that are investigated thanks to EurEyeCase technology are amongst others research towards optimal peeling and cannulation strategies. The safety and intended use of robot-assisted procedures will be demonstrated in order to prepare a first-in-vivo study at the end of the project.

EurEyeCase also identifies and creates business opportunities putting European surgical robotics on the map, notably by means of detailed FTO-analyses, expansion of the current patent portfolio, targeted market studies and product refinement in close collaboration with surgeons.

Travail effectué depuis le début du projet jusqu’à la fin de la période considérée dans le rapport et principaux résultats atteints jusqu’à présent

WP1
WP1 extracted the medical background knowledge and guidance to steer engineering developments towards clinically relevant technology. Developments on test-beds have continued in the 2nd year. The different test-beds have been evaluated by EurEyeCase clinical partners during the 2nd experimental campaign. Multiple data-gathering experiments were set up to record data. Clinicians were involved providing feedback on the benefit of employing sensor-integrated instruments during the interventions. Considerable time has been spent on refining the strategy to move towards human experiments.

WP2
WP2 develops sensors and integrates all hardware components into an advanced operating suite (including camera-based imaging systems to acquire stereoscopic images, iOCT camera integrated into the surgical microscope, a switching unit to switch between modalities). Different variations of a head immobilization systems have also been prototyped and tested. Currently different concepts to improve the OCT retina imaging and S/N ratio are being explored. The most important direct distance feedback is coming from the OCT Ascan, allowing clear identification of the retina surface. Effort was done to isolate this information and speed up measurements. Force sensor-integrated experiments have been further developed. Remote feedback by the OCT Ascan and force-sensor are used as a safety loop for robotic control.

WP3
The algorithms used pre-operatively in Y1 were optimized and integrated in EurEyeCase setup, working now real-time. An accurate retinal blood vessel segmentation has been performed with the stereo-vision system, showing large improvements (accuracy, execution time) compared to competing methods. Pre-operative modelling aspects were finalized, with the construction of the detailed textured 3D model of the retina within the stereo 3D imaging. For the OCT system, algorithmic developments have been focusing on retinal layers identification by leveraging B-scans and C-scans data. A pre-processing step has been developed to properly deal with geometrical rescaling and artifacts compensation. Preliminary results have also been obtained for retinal vessel identification.

WP4
EurEyeCase system setup v1 - focuses on the targeted clinical trials - requires documented software
and hardware solutions adequate to high TRL levels and the commercialization targets of the different partners. We have further detailed the v1 architecture, its communication interfaces, its graphical interface(s), and business logic. Regular integration meetings have been held to develop and test together the system components. In parallel to v1, the EurEyeCase system setup v2 forms the next generation setup, where advanced assistive features such as OCT A/B/C-scan labelling, stereo image processing and segmentation of instruments were further developed.

WP5
The results of the FTO analysis have been monitored and updated. Business development activities including industrial and academic collaborations have been undertaken. Importantly, several collaboration activities reaching outside the consortium have been possible. They clearly support the development of exploitation opportunities within EurEyeCase, confirming the unmet need and market opportunities in the field of vitreoretinal surgery. Finally, dissemination activities have included a fair number of publications and presentations to the international community.

WP6
In addition to bi-weekly meeting organized between software developers, physical meetings were held to integrate further all EurEyeCase components in a unique platform, successfully evaluated by the clinicians. Weekly skype meetings have also been conducted to report on the progress, raise (and solve) possible issues on all kinds of topics and discuss the strategical orientation for Y3, notably on the choice of relevant technologies to conduct human clinical trials.

The main objective of EurEyeCase is to accomplish pre-clinical validation of robot-assisted membrane peeling and retinal vein cannulation and to prepare for a first in-vivo study of robot-assisted procedures. All technological components that will be progressed to this end have their own value. A mixture of dedicated equipment, software components and systems have been identified as potentially relevant and have been further developed in close collaboration with clinicians. Integration of stand-alone systems in an OR-like environment has been achieved, with progress to improve their usability and to reduce the setup time. In parallel cannulation needles with force-sensor capabilities have been designed, manufactured, tested and interfaced to effectively indicated the instant of cannulation; OCT-fiber probes have been designed and experimented with distance based feedback strategies (visual, auditory and haptic). Progress was made to acquire and process images from stereo- and OCT-camera to enhance procedure safety. Vessel segmentation algorithms allow detecting the vessel structures. A significant effort was spent to develop a reliable software architecture that would support development and testing of the two operation modalities in a clinical setting.

Given the already advanced state of technology, EurEyeCase offers a unique opportunity to progress the general state-of-the-art in surgical robotics by deploying context-aware robotic assistance, notably via force, OCT and stereo-imaging measurement systems. The consortium is gearing up to prepare the developments to the level that they can be tested in a clinical setting ultimately including a feasibility evaluation during a human experiment. This would mean that a significant step was made
feasibility evaluation during a human experiment. This would mean that a significant step was made towards inclusion of intelligence into a surgical robotic commercial product.
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