SImOS

SMART IMPLANTS FOR ORTHOPAEDICS SURGERY

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What it's about…

Designing an innovative knee prosthesis, performing the measurement of biomechanical parameters during and after the implantation, to improve the precision of the surgery and the quality of life of the patient.

Context and project goals

The goal of the SImOS project is to design a system to measure biomechanical parameters of a knee prosthesis, in clinical field or during daily activity. This system will be constituted of partly implanted and partly external tools and could help the medical doctors during the surgery and the rehabilitation and increase the quality of life of the patients.

How the project differentiates from similar competition in the field

The main novelty brought in SImOS project is the direct clinical use of the metrics which are computable based on internal measurements of the Instrumented prosthesis. For instance the estimation of unbalance medial-lateral ligaments based on force measurements on the polyethylene insert, estimation of loosening of the prosthesis, and measurement of kinematics without soft tissue artifact to study the variation in range of motions in sagittal and non-sagittal planes. Second point which differentiates this work from previous studies is the internal (in vivo) measurement of other biomechanical quantities than forces acting on the prosthesis. These quantities include joint angles and translational motions which are not sufficiently accurate in external measurements, and prosthesis-bone micro motion which provides an insight about the loosening of the prosthesis. As the third original feature of SImOS, it is the first time that in vivo (i.e. implanted) and ex vivo (i.e. skin attached) sensors are fused to obtain highly accurate estimations of kinematic and kinetic parameters. Moreover, the choice to instrument only the polyethylene part of the prosthesis instead of a complete custom design of the prosthesis gives a flexibility and compatibility to the SImOS design to be used for all commercially available knee prostheses.

Quick summary of the project status and key results

- Design of micro-fabrication process and materials for force sensors array fabrication
- Fabrication of a sensor electronics ASIC and a communication and power supply ASIC
- Design and fabrication of the miniaturized system
- Instrumented prosthesis tested with the mechanical knee simulator

Success stories

Apart from what was told by the TV broadcast organized by Nano-Tera, during the project there was great interest from EPFL students on the topics of the SImOS project. Two journal papers were published with Master students as co-authors. In particular three semester student projects related to SImOS were carried out in 2013 and a new journal paper was submitted.

Add-on project

An add-on project was carried out, which consisted in building a fully-automated mechanical knee simulator to test the instrumented prosthesis designed in the SImOS project and validate it to be used in a human subject. The goals were multifold, first to build or complete an existing load unit system to be capable to simulate the knee movements and the forces acting on the prosthesis; Second, to control this simulator under different conditions of gait or squat movements while keeping the natural distribution of knee contact forces. By integrating SImOS instrumented prosthesis in the knee simulator, validation is done by actuating it with real data captured from Radiostereometry on 19 subjects, and also existing smart prosthesis data.

Very few mechanical knee simulators exist, the main feature of this simulator is the usage of extra actuators and sensors to simulate and measure the muscles forces acting on the knee. The main difference of this approach with existing ones is to provide the real kinematics and kinetics of a natural knee obtained through real data from biplane fluoroscopy and existing instrumented knee prosthesis. Using a MIMO approach to control the simulator, the smart instrumented prosthesis designed in SImOS is evaluated before implantation. Other kinematic aspects such as patella movement can also be studied during the activity.

The mechanical links for simulating the thigh muscles were completed. A number of stereophotogerammetry markers were placed on the simulator while four cameras were optimally located to measure the 3D kinematics of the knee simulator segments. The real data of bone movements obtained in previous X-ray fluoroscopic measurements over 19 subjects walking on the treadmill were fed to the knee simulator as well as a number of kinematic data from over ground walking. The simulated knee motions were used to validate the implantable AMR sensor-based angle estimation towards the stereophotogrammetry reference. Also two inertial measurement units were fixed on the knee simulator and used to estimate the knee angles. A method to fuse the implanted sensors and the wearable inertial sensors were tested in the knee simulator. The simulator was used to calibrate and validate the new force sensors designed in SImOS in static and dynamic conditions. Also the realistic patterns of knee contact forces were generated to test the measurements of the implantable force sensors. The knee simulator was also used to study the relation between the force and kinematics in the prosthetic knees.

Main publications

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G.Yilmaz, O. Atasoy and C. Dehollain, Wireless Energy and Data Transfer for in-vivo Epileptic Focus Localisation, IEEE Sensors Journal, Vol. 13, no. 11, pp. 4172-4179.