

## "Data fusion system for the STIFF-FLOP project"

In modern medicine, minimal invasive surgery (MIS) is a surgical operation that is performed by the surgeon through small incisions. It is an established alternative to the conventional open surgery. Its main advantage is the reduction of post-operative pain, blood loss, tissue trauma and recovery time. Additionally, the chance of post-operative infection is significantly reduced. There are also several problems associated with this surgical technique. The surgeon has limited visual and haptic feedback. The number of degrees of freedom available to the surgeon inside the operation area is also reduced. Use of current available technology result in relatively high chance of instruments damaging other tissues during transit of the MIS instruments.

Current research conducted in project like Stiff Flop (EU FP7 founded project) is focused on introducing new flexible robotic manipulators into the MIS. This kind of structures are able to bend in a snake-like way and thanks to that the number of degrees of freedom is increased during MIS. Majority of the mentioned problems can be reduced or eliminated using new technologies and the increased mobility of the tools enables the surgeon to reach targets which are inaccessible using the conventional rigid surgical instruments. Having many advantages, soft robots are also very challenging from the control and modelling point of view. Their complicated mechanical design forces the use of a novel set of flexible sensors. This, combined with the restriction to non-metal materials only causes the task of robot shape estimation to be problematic. The challenge also lies within the accuracy that is required to perform the surgical operation. In the current state of the art, there are no robust models available to predict the robot behaviour. To provide accurate and reliable positioning and control of the flexible structure multiple position estimation sources and a proper data fusion system are required.

This thesis focuses on design, implementation and tests of a robust data fusion system for the soft robot in the Stiff-Flop project. First, the various available sensor systems, manipulator mechanical design and task requirements have been analysed in order to determine the overall requirements for the data fusion system. Since modelling is a crucial element of the system, an additional analysis has been carried out to determine the feasibility of that task and identify relevant state of the art content. Because of the unavailability of ready-to-use models for such robots, a model based on beam bending theory has been developed. Additionally, this model has been quantitatively and qualitatively tested by the authors in order to verify its quality. Results of these tests have been presented in the test section of the thesis.

Two versions of the data fusion system have been developed. Each of them had been adjusted to the current situation in the Stiff-Flop project. The first version utilises all available manipulator models – the constant curvature model and the bending model developed by the authors. This concept has been successfully implemented and qualitatively tested. Because of the changes in the project and the results of the bending model verification, a second concept of the data fusion system has been developed, which is based mostly on this model. Because of the widespread acclaim of the bending model developed by the authors, it has been introduced to other subsystems of the Stiff-Flop projects. Earlier, the inverse kinematics has been using the imperfect constant curvature model. In this work, an inverse kinematics algorithm based on the bending model has been proposed.

During the work on the Stiff-Flop project and the elements of the thesis, a big challenge also lied in the cooperation of work on the software between researchers and scientists in a big consortium. This aspect has been presented in one of the chapters. Performing the tasks of the thesis required producing a substantial amount of software, inter compatibility of which had to be ensured through proper software architecture design. The developed architecture and various programs developed during the work on this thesis had been presented in a separate chapter.