ERC: Engineering Research Center for Computer-Integrated Surgical Systems and Technology (NSF Grant #9731748)

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ABTRACT: This report summarizes our three-month research experience in Munich, Germany under the NSF IREE program. The goal of our project under this program is to develop a stand-alone actuation and control unit for the da Vinci Surgical System's EndoWrist instruments. The developed device serves as a platform for the development of new da Vinci surgical instruments and surgical procedures using existing instruments without the master robots. The joint effort from MIMED (TUM) and CISST-ERC (JHU) resulted in an inexpensive software and hardware solution that is easily replicated, and can be used in surgical environment for instrumentation research. We hope that this platform will lead to future collaboration between the two research centers and other surgical robotics research teams.

INTRODUCTION

The IREE award has been granted to the NSF Engineering Research Center for Computer Integrate Surgical Systems and Technology (ERC-CISST) at the Johns Hopkins University. The ERC CISST mission included developing surgical systems that integrate novel computer and human/machine interface technologies that will revolutionize surgical procedures, extending the surgeon's abilities to achieve better outcomes at lower costs. The center has a multitude of concurrent research activities spanning medical imaging, surgical robotic assistants, biometric sensing, medical information analysis, etc. ERC-CISST is supported by the ERC Core Grant NSF EEC9731748.

The IREE supplemental award allowed the authors, Marcin Balicki and Tian Xia to spend three months (June through August 2007) at the Institute of Micro Technology and Medical Device Technology (MIMED) at the Technische Universität München in Munich, Germany. MIMED, headed by Prof. Tim C. Lueth, is a premier research center specializing in medical imaging, medical devices such as navigation systems, surgical robots, as well as micro-fluidics, rapid prototyping, and precision mechanical design. The institute has world class fabrication resources and supporting engineering staff, and is capable of granting European medical certification for medical devices in computer assisted surgery, surgical instruments and personal assistant systems. Furthermore, it is closely affiliated with the TUM University Hospital and Hospital in Leipzig. Much of its projects are funded by industrial sponsors, including BMW and Karl Storz.

The motivation behind participating in this international cooperation under the IREE grant is to directly expose young researchers to related research around the globe through lab visits and to establish strong collaboration between groups active in the medical robotic research. It is also an opportunity to learn new technologies, methods, and tools not available at the ERC CISST and in return share our knowledge and resources. Furthermore, the trip is a professional development for its participants in the areas of interpersonal skills, independence, familiarity with European scientific community and general cultural awareness.

The outcomes of the planned cooperation centered on sharing expertise and resources in a synergistic development of a device to actuate and control an existing surgical tool for the purpose of new instrument development, testing, and surgical procedure research. We hope that future collaboration will include experimental result exchange, new hardware development and joint cross continental clinical trials.

RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION

The project goal of the research travel experience is to develop a stand-alone actuation and control unit for the ad Vinci Surgical System’s EndoWrist instruments. The da Vinci Surgical System is a tele-operated master-slave manipulator system, see Figure 1a. The surgeon sits at the console and manipulates the surgical arms as well as the mounted interchangeable EndoWrist instrument (Figure 1b). This instrument has a range of motion similar to that of a human wrist and comes in variety of end-effector types for cutting, grasping, etc, see Figure1c.

Figure 1 *(a)* *(b)* *(c)*

The motivation of developing a stand-alone actuator and control unit for the EndoWrist instrument is to create a platform for the development of new da Vinci surgical instruments as well as new applications of existing EndoWrist tools without the use of the expensive and large da Vinci robotic manipulators. Both research centers are interested in such a platform. MIMED has been developing prototypes of the stand alone controller prior to our involvement. The drawbacks of their current hardware designs include expensive motors and complex mechanical construction. In addition, an intuitive software control for this type of actuator was required. Our goal was to improve the design by reducing the complexity and cost of the electro-mechanical design and developing a cross-platform software solution as well as a new human computer interface for surgery.

The joint effort from MIMED (TUM) and CISST-ERC (JHU) resulted in an inexpensive software and hardware solution that is easily replicated, and can be used in surgical environment for instrumentation research. We hope that this platform will lead to future collaboration between the two research centers and other surgical robotics research teams. Specifically, our design criteria were: (1) fewer parts, quick and simple to fabricate, (2) light weight and low profile design, when attached to the EndoWrist instrument, (3) work with both generation of EndoWrist tools, previous generation has 180 degree actuation vs. 360 degree in the current generation, (4) inexpensive and (5) intuitive control interface.

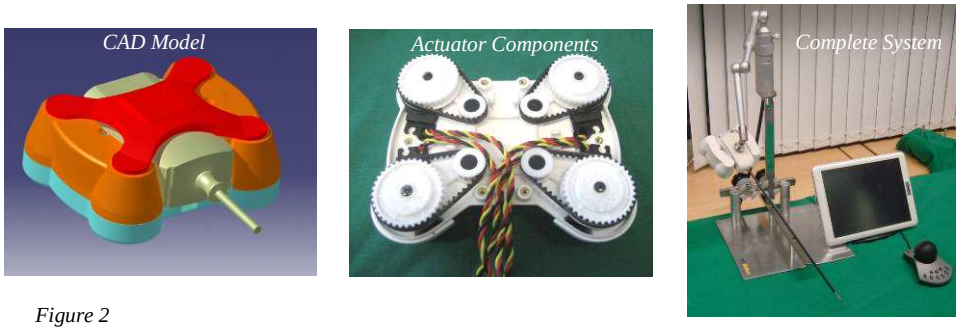

Figure 2

At the end of the exchange period, we were able to create number of prototypes that used off the shelf servomotors, rapid prototyped housing and cast plastic gearing components, see figure 2. This allowed for easy replication and modifications. The control software was based on CISST surgical software development framework from JHU, while the user interface was build using QT graphics library. The device can be

controlled from a microcontroller or a PC. The feasibility of the prototype system will be tested in the near future.

BROADER IMPACTS OF THE INTERNATIONAL TRAVEL

The structure of the NSF ERC encourages the cooperation between American research institutions, in our case, Harvard University and Carnegie Mellon University, and others. This is an excellent arrangement for improving our interpersonal skills, and enhances our research experience beyond a lab cubical. However, through the participation in the international research experience we have found that there are significant differences in the work environments, cultures, and research methodologies in the labs beyond our borders. We have gained an understanding and appreciation of these differences and shared them with our colleagues in USA. For example, MiMED's PhD projects tend to have a very practical aim, and are managed in a product development fashion. In the end, the goal was to sell the "product" to be placed in clinical use at various hospitals in Germany. Although the focus was more on the application, contributing to science was not omitted. During the development, new problems were faced and new solutions were created, often generating science and adding to the medical device/ robotic research community.

We were fortunate to be considered one of the lab members, which involved us in the weekly lab progress meetings where student discussed the previous week's findings and their project status. We also received training on various new rapid prototyping technologies, safety measures, and extensive documentation approach. We were often involved in brainstorming sessions for various projects which was a great experience for us, and added a new perspective to their team.

Besides having the opportunity to visit the most relevant research institutes in Germany, such as the DLR (German Aerospace Center) and experience their state of the art in the field of robotics, we are also exposed to TUM's industrial partners. One particularly interesting was a tour the BMW manufacturing facilities, where robotic automation is used extensively to reduce cost, alleviate facility's space limitations and improve efficiency.

One of the aims of the ERC is to create science and technology that is applicable in the surgical field and to share it with the scientific community. Through our lab visits and our residency, we have promoted ERC's CISST open source software, shared our recent findings in the area of robotic surgery and established communication with comparable research center in Europe.

It is important to mention the time we have spent outside of the research lab as well. We found out that vacations are quite important to Germans, and that respecting 4 or 6 week vacation rule is upheld even for graduate students. The idea is that rest very important to well being of the individual and in turn to his or her efficiency. Also social interaction between the lab members is an important aspect of the graduate student's life and is manifested in inter-lab sculling races, mountain bike trips, or friendly Nintendo Wii tennis game versus the faculty.

Through this experience we have gained insight in to the lives of the German people, especially of the graduate students, became more comfortable with new environments and different people, and gained confidence in our research abilities. In addition, we have a developed desire to explore not only in a lab, but also through travel.

DISCUSSION AND SUMMARY

The international research experience gave us perspective on the achievement of our research institution, the ERC CISST, in comparison to other research institutions in Germany. This allows us to better understand our standing in the scientific community. The tours and demos we attended at various research institutions in Germany exposed us to different ideas of what scientific research is and how it is conducted abroad. We were presented the diverse problems facing computer integrated surgery and medical robotic systems, and observed some innovative solutions from the leaders in the European scientific community. With the research collaboration established between MIMED in Germany and the ERC CISST through this program, a master student from Germany, Helmuth Radrich, has been conducting research at our institution for a period of 4 months. We also were able to transfer some of the skills and techniques learned at MiMed to our center, including rapid prototyping methods, and medical product certification requirements.

In addition, we summarized our experiences, both in terms of research and culture, in slides and presented them to our colleagues at the ERC. This included not only the technical aspects of our project, but also the lab management practices and research approaches we were exposed to in Germany.

In retrospect, we can suggest a few improvements to the IREE program. Even though our three month research experience abroad was very useful and interesting, a longer term stay would have been more beneficial for the progress of our project, as well as for developing more significant appreciation for the culture of Germany and Europe. Another suggestion is to provide some funds for a researcher from the hosting institution to visit our center in the US, this could attract prominent researchers to our institution to exchange ideas and to generate new science.

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BRIEF BIOGRAPHIES OF RESEARCHERS

Marcin Balicki received a BS in Interdisciplinary Engineering and M.Eng from the Cooper Union for the Advancement of Science and Art in 2001 and 2004, respectively. In 2004 he became an adjunct instructor of mechanical engineering at The Cooper Union and concurrently worked as researcher in the area of surgical navigation at the New York University School of Medicine, Orthopaedics Department. Currently, he is in his 2nd year of the Computer Science PhD program at the Johns Hopkins University. His interests lie in surgical robotics, biosensing technologies, human-computer interfaces, and multimedia art.

Tian Xia received the BSE in Electrical Engineering from University of Washington in 2006. Currently, he is in his 2nd year of the PhD Program in Computer Science at the Johns Hopkins University, Baltimore, Maryland.