



# EU/Japan Pilot Exchange Program Report

Sep 2004-Feb 2005

Katholieke Universiteit Leuven (Belgium)  
Technical University of Denmark (Denmark)

Yuka Mukaibo  
Keio University

# Personal Data

Yuka Mukaibo

Email: mukabo@mmm-keio.net

## Home Institute

### **Keio University**

Faculty of Science and Engineering

Department of Integrated Design Engineering

Maeno Laboratory

Address: 3-14-1, Hiyoshi Kohoku-ku

Yokohama 223-8522, Japan

Supervisor: Associate Professor Takashi Maeno

## Host Institutes

### **Katholieke Universiteit Leuven**

Faculty of Engineering

Department of Mechanical Engineering

PMA (Production engineering, Machine design and Automation) Division

Address: Celestijnenlaan 300B

B-3001 Heverlee, Belgium

Supervisor: Professor Hendrik Van Brussel

### **Technical University of Denmark (DTU)**

Department of Informatics and Mathematical Modeling

Address: Anker Engelundsvej 1

Bygning 101-A

DK-2840 Lyngby

Course Name: Human Computer Interaction

Course Responsible: Professor Rolf Molich

# Executive Summary

This report documents the experience and achievements as a participant of the EU/Japan Pilot Student Exchange Program from September 2004 to February 2005.

Research at KU Leuven. “A Practical Implementation of Virtual Fixtures for Robotic Surgery”. The research consisted of;

- **Literature study on related research** Problems of past studies was considered and the purpose of the research was clarified
- **Experiments** Virtual graphical fixtures were made and experiments were conducted in order to find out how mechanical properties of the fixture surface affected the performance of an operator. The results suggested. Experiments consisted of path following tasks and reaching tasks in a virtual environment, and sensory evaluation was done using questionnaires.
- **Proposal of novel interface** The results suggested properties of the virtual fixtures affect feelings of fatigue and stability for the operator, and showed there was also difference in performance. Based on the analysis, a surgical operation interface was proposed, which would enhance safety and operability.

Student life in;

- **Belgium** Living in a room of a family home, life was mainly going to and from the laboratory. Much of the time was spent on research, and I also attended classes twice a week. Also enjoyed the Belgian food and weekend excursions.
- **Denmark** With only less than a month to stay in Denmark, life there was mostly spent on campus. Assigned a room in a “mostly Danish” student residence just minutes from the classroom, I enjoyed living with and getting to know other students of the residence.

Looking back at the experience, I suggest this program consider;

- **The program period** The three and a half month period was too short for research. If students decided to take courses, the workload could become considerably large.
- **Housing arrangements** Many students had difficulty finding appropriate housing for the short period of stay in Leuven. (It was not a problem in Denmark)
- **Requirements from the Program** Participants were not really aware of what was expected of themselves prior to the program (e.g. if there was to be a presentation, if we were to put together a thesis).

## Travel Schedule

|                   |                                 |
|-------------------|---------------------------------|
| 13 September 2004 | Arrival in Leuven, Belgium      |
| 27 September 2004 | Official Start of Academic Year |
| 24 December 2004  | End of Semester                 |
| 2 January 2005    | Arrival in Lyngby, Denmark      |
| 3 January 2005    | Start of course                 |
| 21 January 2005   | End of course                   |
| 28 January 2005   | Return to Leuven, Belgium       |
| 8 February 2005   | Return to Japan                 |

# Research

My research at KU Leuven was on “A Practical Implementation of Virtual Fixtures for Robotic Surgery”

## 1. Background and purpose of the research

Minimally invasive surgery is widely used and well-known within the medical community. More automation or the aid of robotic devices currently gets major attention. With technical aid, faster operation or extension of the application to micro scale can be made possible. However, only a few studies focus on creating intrinsically safe systems when conducting surgery. Although in recent years more robotic systems are in development, commercial applications are still few.

In a surgical procedure, the operator will have control of the operation manipulating the master device in a 3-dimensional space within predetermined constraints. In order to diversify possible types of operations, the system must also be applicable to soft tissue surgery. Past methods predetermined constraints based on CT scan images, but this would not always be appropriate since there is no assurance that the tissue would be in the same place before and after the CT scanning. Therefore, a simple graphic interface is proposed through which the operator can define the constraints from visual information through laparoscopes without having to move the patient. This approach allows the surgeon to define constraints real time in the actual space where the operation is to be held. Therefore traditional procedures in which limbs or body parts, usually bones, were either secured or markers were placed in order to obtain the same axes to work on would become unnecessary. The operator, or surgeon, may create multiple constraints with a hierarchical relationship, determining the degree of constraint for each graphical constraint. Thus allowing to create an active space in which certain areas would be either impenetrable or the surgeon would feel a certain constraint but still have control to move beyond the predetermined wall, or feel no constraints at all.

This research was conducted to evaluate and determine the appropriate properties for the virtual fixtures to enhance safe and more practical master/slave manipulative surgical systems. As a master device, the haptic device PHANToM of SensAble Technologies (Fig.1) is used owing to its dexterity and large degree of freedom.

## 2. Virtual Fixtures and experiments

Different levels of constraints are known to be necessary during a surgical procedure [Davies 2003]. During a surgical operation, if the organ subject to surgery is adjacent to other organs or vital arteries,



Fig.1 PHANToM haptic device

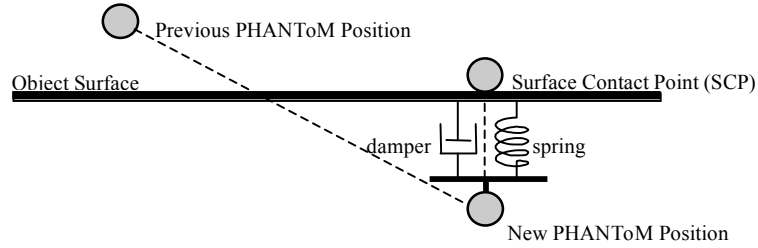


Fig. 2 Surface Contact Point of PHANToM

Table 1 Parameters of Impenetrable Surfaces

|       | Spring Constant | Damping Constant | Static Friction | Dynamic Friction |
|-------|-----------------|------------------|-----------------|------------------|
| Case1 | 0.8             | 0.0              | 0.2             | 0.2              |
| Case2 | 0.2             | 0.0              | 0.2             | 0.2              |
| Case3 | 0.8             | 0.0              | 1.0             | 1.0              |
| Case4 | 0.8             | 0.003            | 0.2             | 0.2              |
| Case5 | 0.8             | 0.003            | 0.2             | 0.2              |

virtual fixtures should assure the instrument does not harm its surroundings. Therefore, the surface of the fixture should be impenetrable. However, in some cases, for instance trying to cutting through tissue, virtual fixtures could provide virtual force feedback just to assist the process. Creating penetrable virtual fixtures could also be useful as a warning that the surgeon may be working in an area which requires precaution. In this study, virtual fixtures have been divided into impenetrable surfaces and viscous volumes.

Using Ghost SDK software, virtual geometric shapes were created as examples of virtual fixtures to conduct the experiments. Three parameters were considered in this study; spring coefficient, damping coefficient, and viscosity. Spring and damping coefficients were set based on the surface Contact Point model of PHANToM shown in Fig. 2.

Two types of experiments were conducted on test participants; path following within a virtual tube path with impenetrable surfaces, and reaching movements within a viscous volume. Five cases with different properties were provided for the impenetrable surface experiments as shown in Table 1. Test participants conducted the path following tasks with limited visual information; the subject had to move along the path based on the tactile feedback applied by the haptic device. After each task, the participant was asked to answer a questionnaire concerning level of comfort, stability, accuracy, fatigue and stress he/she felt during the task execution. For the path following tasks, time was also measured to see how performance improved among the different cases. All participants were unfamiliar with PHANToM, and were given five minutes prior to the experiment with sample programs to get used to maneuvering the device.

Examples of the path following task execution time are shown in Table 2. All subjects had faster results when the spring constant was high, meaning the surface was stiff. The average of time shortened here was 28.5%. This meant large spring constant values are effective in areas that require fast execution.

Table 2 Path following execution time

|       | Subject A | Subject B | Subject C |
|-------|-----------|-----------|-----------|
| Case1 | 55        | 25        | 34        |
| Case2 | 45        | 17        | 22        |
| Case3 | 58        | 27        | 47        |
| Case4 | 35        | 42        | 32        |
| Case5 | 60        | 21        | 32        |

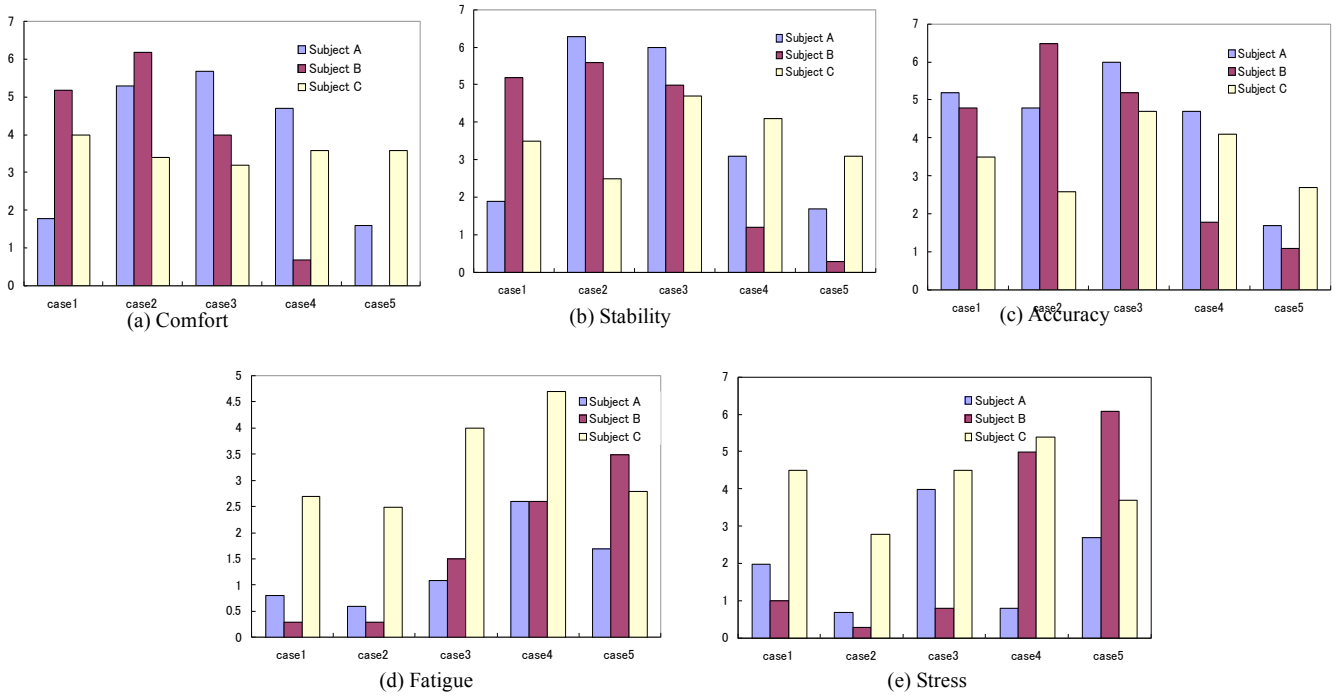


Fig. 3 Sensory evaluation (Impenetrable)

Table.3 Experiment results analysis

| Parameter                | Merits                        | Demerits                     |
|--------------------------|-------------------------------|------------------------------|
| High spring constant     | Less stressful<br>Less tiring | —                            |
| High damping coefficient | High Stability                | More tiring<br>Less accurate |
| High friction            | High accuracy                 | More tiring                  |

Execution time was also shortened in cases where friction coefficients were small, in this case, by 30.5%. However, no significant results could be obtained from changing the damping constant; therefore we can consider damping does not directly affect the execution time of a task.

Results for the sensory evaluation of the path following task are as shown in Fig.3. A summary of the results are given in Table.3. The perception of “comfort” varied among the different participants, therefore results provided no noticeable characteristics. However, the evaluation of fatigue factors was clear; high spring coefficients proved less tiring, where as high damping coefficient and high friction both

made tasks more tiring. Although damping and friction were disadvantages when arguing fatigue, damping gave operators a greater feeling of stability, and high friction enhanced the feeling of accuracy.

Results of the viscosity experiments show that implementation of virtual viscosity to a workplace could be beneficial. Although, a majority considers the viscosity as more tiring, users feel more stable and can get a strong feeling of accuracy and control during the operation. Indeed, during the reaching tasks, people tended to exceed an aimed point where there were no virtual constraints. However, when viscosity was implemented, the reactive force that is applied to the user through the master device helped compensate for the extra energy and led to more stable and accurate manipulation.

### 3. Proposal of Surgical Assistance Interface

Based on the results, I proposed the fundamental structure of a novel surgical interface consisting of three types of virtual fixtures; forbidden areas, tube passageways, and viscous volumes.

#### (i) Forbidden areas

When wanting to define an area which is forbidden for the surgeon to enter, the surgeon can implement geometric fixtures or walls that are impenetrable. From the experiments, results have shown that with an impenetrable fixture, the spring coefficient should be set at a high value to effectively avoid the area. The damping coefficient of the surface could also be set high to maintain stable manipulation during the operation.

The surgeon may set the spring coefficient low if the position and shape of the forbidden area is not important to the operation. Setting too many highly stiff fixtures may restrict the workspace, thus reducing effectiveness.

#### (ii) Tube passageways

When the surgeon has to move from one place to another frequently, the tube passageway could be implemented. These are tunnels that are impenetrable from the inside, and assures the surgeon fast and safe access to the other end. In such cases where the end effector moves from one place to another, the surface parameters of the tubes should be set so as to realize fast movement. Therefore, spring coefficient are set high, damping low, and dynamic and static friction coefficients set low. .

#### (iii) Viscous volumes

Experimental results showed that implementing virtual viscosity helped stable feeling during the execution of a task. Viscosity also enhanced the feelings of accuracy, which means that the surgeon can move the manipulator more instinctively. Therefore, in the proposed interface, the surgeon can define volumes that display viscosity inside. Primitive geometric shapes can be inserted to the workspace in places where the actual operation takes place, and where caution is necessary in executing tasks.

Different types of fixtures can all be implemented into one scene to create a safe surgical environment with layers of virtual fixtures. The surgeon may define a hierarchical relationship depending on the priorities of the operation, thus avoiding interference among the different fixtures.

### Reference

[1] B. Davies, "Robotic devices in surgery", *Min Invas Ther & Allied Technol*, 2003: 12(1-2) 5-13



## Exchange Student Life

Life as a student in both countries was extremely comfortable and enjoyable. In either country, I was very impressed to know that most of the people I met spoke English very well and I never felt the frustration for not being able to communicate. People were always friendly and willing to help which made my stay ever more fruitful.

### Belgium

In Leuven, I stayed at a family home, with a 57 year old lady who rented out rooms that she had free after her children had grown up and left. She had three rooms to rent and the kitchen, bathroom and toilets were shared, but I never experienced having to wait for my turn since there was usually only one other than myself (apart from the landlady). Rent was €300/month, a little expensive compared to the other students, but it was worth every cent. Thanks to the landlady, the house was very tidily kept but always warm and cozy. The rent included electricity and water, etc., but there was no internet access or a common television in the home.

To get around the city, I rented a bicycle for the three and a half months there. It was necessary since the department of mechanical engineering was about 2km from where I lived. Bike rental for students was operated by a non profit organization called 'Velo' which was very inexpensive. Students of KU Leuven were also granted access to the bus network within the Leuven area, which was useful especially in bad weather.

Food in Belgium was very good, and inexpensive. During the week, I would have lunch at the university cafeteria with my colleagues. Breakfast and dinner I usually prepared at home, with occasional kebab and frites.

Weekdays would start by getting up at around 8:00am. After preparing I would have breakfast and take a quick look through the newspaper (I subscribed for the International Herald Tribune for three months), and leave for school between 9:00 and 9:30, arriving at the lab within 10 to 15 minutes. After working on my research in the assigned corner in the lab, I would go for lunch with the other Japanese students, and sometimes with a Belgian student. Research continues in the afternoon, until 6:00 to 7:00 pm, sometimes later. Usually one of the Japanese students would suggest going home, and we would go home together. If I didn't have any special plans, I would drop by a supermarket on the way home and be home between 8:00 and 9:00pm. I then would prepare myself something to eat and spend the rest of the evening reading or doing assignments from class.

In the weekends I often got together with other exchange students since Belgian students would usually go home to spend the time with their families. There were many students from a variety of countries, so I had no problem finding someone to spend some time with. I sometimes went out with my landlady, and she took me out on her car to places hard to reach by train or bus.

I also enjoyed the many activities the university provided in the evenings, which I could attend after I was done with my work in the lab. For example, there was a lecture by key personnel of the Court of Justice or the European Communities on the challenges of the EU, which was particularly interesting for me since the EU had just expanded to 25 countries, and the issue of Turkey was gaining much attention.

There was also a lecture on post development which was equally interesting.

### Denmark

The life in Denmark was a little different compared to Belgium. To start with, the international affairs office found me a room in a student residence on campus, a five minute walk to the classroom. The room had a shower and toilet, and only the kitchen was shared with 24 other residents. The residence was apparently very popular, and I was very lucky to have been able to find a vacancy there. Most of the other residents were Danish, which was good for me to get to know some Danish students, since I would only be staying in Denmark for less than a month. The kitchen was more like a common room, very spacious with a television and even a darts board and soccer game. There was internet access in my room, and also a telephone line, but I had no phone.

There were no bike rentals as there was in Leuven, and since the campus was far from the station to walk, weekdays were mostly spent on campus.

Food I took mostly at home except for the weekends. There were many reasons for this. One would be because everything was so expensive in Denmark, even in the cafeteria. Secondly, there weren't many places to eat near the university, and the closest would be going to the station. Days were short (I was there in January) and nights could get very cold, which kept me from leaving the warmth of my room, saving time and energy.

Since I took a course in Denmark, and the class started at 8:30, I had to get up earlier than I did in Leuven. There would be lectures from 8:30 to 12:30 with usually 3 coffee breaks. After the morning lectures, I would go home to cook myself lunch. There were never lectures in the afternoon, but the professor always had assignments for us to do, which were done in groups of two to three, so we would get together in the afternoon, at 1:00 or 2:00pm in the library or the computer room (known as the DATABAR) to discuss and put together a report for the assignment. Usually this would go on until 7:00 or 8:00pm. After that, I would either stay at the library or DATABAR a little longer to read and answer emails or go home to eat. During my stay at DTU, I had a lot of work to do concerning classes at KU Leuven and from my home university, so after dinner I would usually be facing my computer to work on the assignments.

# Suggestions to the Project

## 1. The period of the program

After my 5 month experience, I strongly felt that the three and a half months at KU Leuven was too short to do research and to achieve a certain amount of results with substance. If the student was already well aware of the field of study and had started with the research before going abroad, I believe the situation would be different. I did have contact with a PhD student concerning my research, but I hardly had time to prepare for the research, since it was very different to the study I was doing then at my home university. I recommend the students be given more time if they are to focus solely on research. If that is not impossible, I suggest that the supervisor of the host university and the student thoroughly discuss the theme of research before the program so that the student has at least a brief idea of how the research would commence. I regret not reading through papers of related studies before the program since that took much of my first couple of weeks in Belgium.

I also attended two lectures, "Introduction to Management", and "Behavioral Decision Making", and attended Introductory Dutch classes for the first two months, but the workload was too much, I dropped out of the Dutch class after two months. But I strongly recommend students to try to attend a course. Research can be pretty individual, and you spend a lot of time on your own. But if you follow a course, especially a course with which involves much interaction among the students, you really get to experience how differently things are taught and I definitely benefited from the courses and was able to make many friends.

## 2. Housing arrangements

Although I was lucky and found a place to stay after one day of searching, many of the students had trouble finding a place to stay at Leuven. I strongly recommend a system that secures a place to stay for the students prior to arrival. This also concerns the lack of information provided, which is mentioned later.

I also suggest the program encourages students to stay in a room with shared kitchens and bathrooms. I think that such accommodations provide a good opportunity for students to communicate with different people from other countries, and especially since the students will only be living there for a limited period of time, they should cherish the time they are given to enjoy cultural exchange. In Belgium, I lived in a family home, I was privileged to experience a typical Belgian home. In Denmark it was very different, where the kitchen was shared with 24 other students, and it was great fun to be able to communicate with other students. I enjoyed every moment of it. This was my first experience to live alone, and in the beginning I wanted to live in a studio, with a private bath and kitchen, but I am so glad I didn't.

## 3. Requirements of the program was unclear

We were not told in advance what exactly was expected of us in this program. In my case, it was not until there was a meeting with the professors and other exchange students in the beginning of October,

that I knew we were to make a final presentation at the end of my stay to share the achievements of my research, and was also to hand in a thesis. Concerning the intensive course at DTU, we were not told when to apply or which courses to choose from, and had it not been for my colleagues, I may not have been able to apply in time. Since I had applied for a very popular course (apparently over 100 students applied for the course which had only 40 places available), I may have ended up on the waiting list, or not have been accepted at all.

#### 4. Confusion of Information

There seemed to be a lot of mix up during the whole program. I guess it was because the program itself was new, but with the time difference between Japan and Europe, such mix-ups could sometimes take a while to clear. First it was concerning housing. I have mentioned earlier that it was difficult. In the beginning, I was told “a standard student room which normally comes free from students leaving Leuven to study abroad” would be reserved for me. But it turned out no such room was prepared and I had to go find a room after arrival. Then it was concerning the scholarship. Some students were told to send a facsimile to their home institutes to prove they were participating in the program while other students were told to just send an email. There was a lot of different information concerning the return flight. I was first told I could only return to Japan from Copenhagen, while a student following the same schedule as me from Hokkaido University was allowed to return from Brussels. In the beginning I was told to return to Japan within 5 months (which was by February 12th), where as later, I was told to return within the first week of February.

I suggest information is more thoroughly discussed among the different universities to avoid such confusion. None of the problems I experienced was vital that it affected my research or my life, but things may have progressed more smoothly had I been given more reliable information from the start.

## Summary

To be blunt, the five months that I was able to spend in Europe was a great experience I will treasure for life. I enjoyed every moment of it. Probably because I was brought up abroad, in the U.A.E., I feel extremely comfortable living in a multi-cultural environment, and working together with people of the same age from various countries. And this program provided me with precisely that.

While at KU Leuven, I was able to spend quite some time on my research, and managed to reach a conclusion with what I was working on. But the time was far from enough for my thesis to reach the quality I would have liked. As I may have mentioned earlier, I regret for not having started working on the theme in advance had I the time to do so. But I do not regret having spent time taking courses. All the classes I attended was very beneficial, and since I deliberately took courses not directly connected to my field of study, much of what was being said was new to me, which I found intriguing. Classes gave me an opportunity to speak with other students from different faculties, which was something I also looked forward to. I was amazed at how we could come up with such different solutions to the same problems. The classes are bound to influence my ways of thinking in my career.

Time at DTU was more relaxed, since the schedule and exercises of the course were clearly stated at the first lecture, including the time expected to spend on the assignments etc. Assignments themselves were also pretty straight forward. Since exercises were done in groups, it was another opportunity to get to know other students of other countries.

I have learnt much more than just what was being taught in the courses and what was written in the papers I read. So much was different from what I had known and was used to in Japan. It was a while since I last lived abroad, but it surely has brought back the senses and has strengthened the curiosity toward cultures other than my own. This experience is sure to influence my future, and I hope that I can reap the benefits of the five months. I have made many friends that will surely cherish them.

I would finally like to take this opportunity to express my gratitude to the organizers and professors who made this program come true. I did not expect to experience so much in such a short period of time, and although I would have liked to stay longer in Europe, the five months have been truly meaningful I hope many students will follow in years to come to enjoy the program as much as I did.