Report on the DEMAMECH Exchange Program

2005 – 2006

Joachim Priesnitz

TABLE OF CONTENTS

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2 Executive Summary

I was planning for a long time to study a few month abroad. But I never dared to think about studying in Japan. I heard of the DeMaMech Exchange Program in May 2005 the first time. After thinking about it one day, I decided to grasp this oppurtunity and apply for it. I chose some topics I was interested in and sent my application form to the supervisors. A few days later I received the message that I am accepted. I never believed that it could be so easy to go another country, especially to Japan.
According to my study plan I wanted to go to Japan in September. So everything was quite short-dated. I also had to finish a project in Berlin which I started in that term. I even had to apply for a new passport since my old one was expired. While waiting for the German authorities to certificate my passport I had the first contact with the International Center of Keio University. The support and the help of the people there was really amazing. I applied for the Certificate of Egilibility which is necessary to receive Visa for Japan. I also filled application forms for accomandation and was asked to make a tentative choice for lectures. A few weeks later I received my passport and could finalise all applications. Then I just had to wait for getting the Certificate of Egilibility for a few weeks.
Meanwhile I planned to get some basic knowledge of the Japanese language. So I took a Japanese class at my home university in Berlin. It was not very effective because I had to work as well. So these two weeks just brought me some basic phrases and the fear that this language is impossible to learn.
In August there was a DeMaMech workshop for two weeks in Berlin. All participants of the exchange program attended. It was a nice oppurtunity to get to know all students from Belgium, the Netherlands and Denmark. By seperating the crowd into smaller groups according to the student's host universities in Japan it was possible to get familiar with people you would probably meet again in Japan.
The other point of of the workshop was to learn more about Japan in general. We could listen to former exchange students of the program and could learn something from their experience in Japan. That was quite reasonable and supportive because there is always a certain insecurity when you go to a total foreign country. Concerning to formal things like dormitory, insurance and similar things that was very helpful. But still I tried to not to hear too much about the life in Japan because I wanted to make up mind on my own without having prejudices or other's opinion in my head.
The included Japanese lectures were pratical oriented. But when I finally arrived in Japan I really regreted that had not enough time to acquire more language skills in advance.
After all preparation I finally fixed my travel schedule, booked the flights and went to Japan.
I arrived in Japan in September. I was picked up by a student who could speak English very well. So I thought the fear of bad English skills was wrong. But it showed that this was a false conclusion.
My senpai showed me the lab, the universtiy and led me to my dormitory. I was introduced to all people who were in the lab by accident. The official introduction followed in the first lab meeting. The first weeks were filled with many welcome parties in dormitory and university.
Several days after my arrival I also met my sensei the first time. We were talking about different things and also came to the research. He told me and two Turkish students who arrived in the same week that we have all freedom and can chose each topic we would like to. That determined the next weeks of my study life. I was reading papers and was talking to students in order to find out what is going on exactly in the lab.
I also decided to take two lectures. One technical and one Japanese class. And so I started to settle in Japan.

3 Travel Schedule

Outward flight:	September 2005 British Airways from Berlin to London British Airways from London to Tokyo (Narita)
Return flight:	May 2006 British Airways from Tokyo to London British Airways from London to Berlin

4 Research and Lectures

I. INTRODUCTION

After reading a lot of papers and talking to many students I decided to work on bilateral control. That was quite challengeing because my knowledge about control theory was limited to simple basics. So I had to learn a lot of basic things at first. Therefore I took the class “Intelligent Machine Systems” of an Prof. Murakami who’s laboratory is closely realted to mine. Although the lectures was quite difficult for me it was helpful for my project since the content was dirctly associated to it.
As mentioned before I had to define my project on my own. That is quite unusual for European standards and even more difficult within a limited time period. My project can be described as follows.

Many surgical processes are done using techniques of minimally invasive surgery (MIS) [1]. The purpose of this technology is to reduce the patient’s trauma to a minimum. Therefore the surgical devices are highly limited in their dimensions. In certain circumstances this process may require staying in an inconvenient position for a long time. Due to this it is getting more and more popular to apply teleoperation techniques using surgical robots. In that case the operator can operate the user interface of the robot (master device). The movement of the master will be transferred to the environment manipulating slave device by any kind of actuation system. Despite these opportunities a disadvantage of teleoperation can be the loss of the human sense of touch. Manipulating objects with the slave without any feedback from the environment makes the operation difficult or even impossible. Therefore it is very reasonable to apply a bilateral control that includes both the force transmission from master to slave and a force feedback from the environment to the master’s operator. With such a control system the operator can get haptic information from the manipulated environment, e.g. softness, stiffness or even surface condition in the case of tactile sensing.

Fig. 1: conventional forceps for laparoscopy

There already exist some bilateral devices for haptic surgery. Most times it is applied to common forceps used for laparoscopy.The slave device is limited in its dimensions in order to achieve the minimally invasive approach of keyhole surgery. That means the actuation system should be separated from the slave if its corresponding miniaturization is not possible. Hence there is a gap to bridge between slave and actuation system in order to transfer force. A very common way is just to use thin rods connecting slave and actuator. In that case the flexibility in positioning the slave is constrained by the bending resistance. Since positions of the instrumental setup and space during surgery are quite limited an increase of the surgical robot’s flexibility is very desirable. That is supposed to be achieved by the proposed system. Here the force transmission is achieved by a very flexible actuation system. The necessary force is generated by a simple linear motors. The connection between motor and slave is realised by an elastic cable similar to a Bowden wire. This device consists of an inner steel wire rope and an outer tube. The inner wire can move friction reduced in the tube. The outer wire is still elastic and bendable so that the slave can be moved flexible relatively to the motor. In a certain range the cable allows the transmission of both pulling and pushing forces.

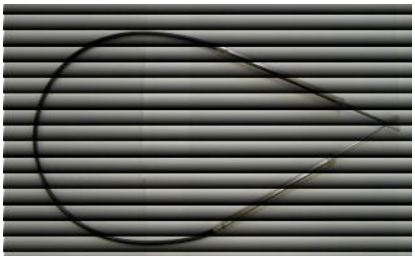
Fig. 2: flexible actuator cable

II. MASTER

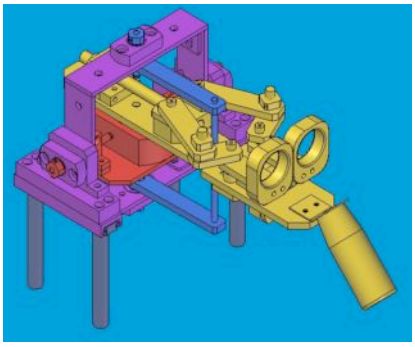
Fig. 3: master device

The master device which is used as the user interface of the system is already assembled. It is designed like a common forceps' opening and closing mechanism. Additionally it is pivoted which means that the bearing permits rotary motion around two axis' (pitch and yaw). Furthermore it is movable in translative direction within a small range. The device offers interfaces for the two rotary motions and the translative motion of the forceps mechanism. For a bilateral control each interface has to be connected to both an encoder and an actuator for the force feedback. For actuation a rotary motor can be used. Sometimes it might be difficult to encode or adjust a position of rotary motion especially in the case of a small angular range. So it is reasonable to use a linear motor and convert the rotary motion into a linear one by using an appropriate mechanism.

III. SLAVE

A. Design

The slave device needs exactly the same degrees of freedom like the master system. That means rotation around two axis and the translatory motion. Furthermore a grasping mechanism must be included. Here a usual forceps is applied and adapted to the this purpose. The requirements of high flexibility are satisfied by using universal joints. Anyway there is also some constraint necessary in order to guarantee the stability of the structure. Using universal joints achieves a flexibility which makes possible just to use linear actuation for all kinds of motion. This effort opens up the application of the wire actuators. Connecting linear motors and slave device by these cables allows a high freedom of movement. Another achievement is the opportunity to keep up small dimensions of the slave device if the actuation can be displaced within a certain distance. Since these wires are designed for a general use and are not specially adapted to this application the dimension are not as small as it would actually be possible. Anyway the device is proposed as a kind of prototype.
Four flexible actuators are used. One for the grasping action and three for all other motions. A challenge is the solution for the problem of the middle axis. It has to include both the actuation for the grasping motion and the centre of rotation.

B. Kinematics

Figure (5) shows a simplified model of the slave's kinematic properties

α : desired angle (pitch)
r : radius of the plate z : necessary displacement

$$\tan\alpha = \frac{z}{r} \qquad (1)$$

Fig. 4: design of slave

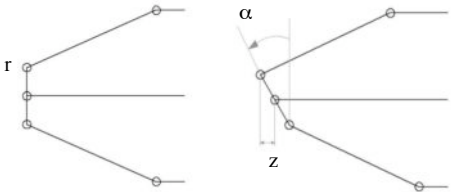

Fig. 5: simplified kinematics of the slave device

IV. ACTUATION AND CONTROL SYSTEM

A. Sensorless Force Control

As mentioned before all motions of the system can be driven by linear motors which are connected with flixble actuators. Therefore the control of the system is simplified.
The equations for a simple linear motor are given by:

$$M \cdot \ddot{x} = f_{out} - f_{dis} \qquad (2)$$

$$f_{out} = K_f \cdot i_a \qquad (3)$$

here is:

M : actuator's mass
f_{out} : motor force
f_{dis} : disturbance force
K_f : motor thrust constant.

The disturbance force includes viscosity and Coulomb friction effects and other negligible terms. The most important part of the disturbance force is the external force which is applied from outside.
For an appropriate control force and position of the actuator are required. In most cases industrial force sensors cannot meet the high demands of an accurate control. Hence it is desirable to achieve a control architecture without the use of a force sensor. For that reason a disturbance observer is applied to each linear motor. Hereby an estimated disturbance force $\hat{f}_{dis}$ is obtained and is fed back. The observer structure includes a first-order low-pass filter $\frac{g}{s+g}$ .If the cut-off frequency g of the low-pass filter is chosen large enough the estimated disturbance force is quite similar to the real one. Therefore the disturbance force can be compensated and a robust motion and control can be achieved. That makes a force sensor unnecessary so that only a position encoder is needed to control the motor.

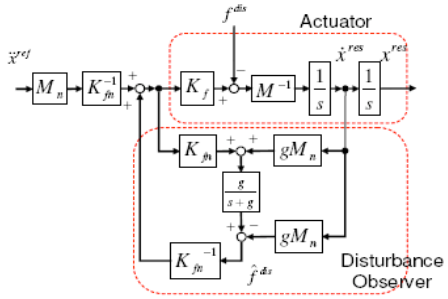

Fig. 6: disturbance observer

B. Force Feedback

For a bilateral control it is necessary to get information about position and force values of the master and slave. As mentioned before measurement of force by sensors is difficult to achieve. Therefore another sensorless structure is applied. This so called reaction force observer estimates the disturbance with using the same structure like the disturbance observer.

C. Bilateral Control

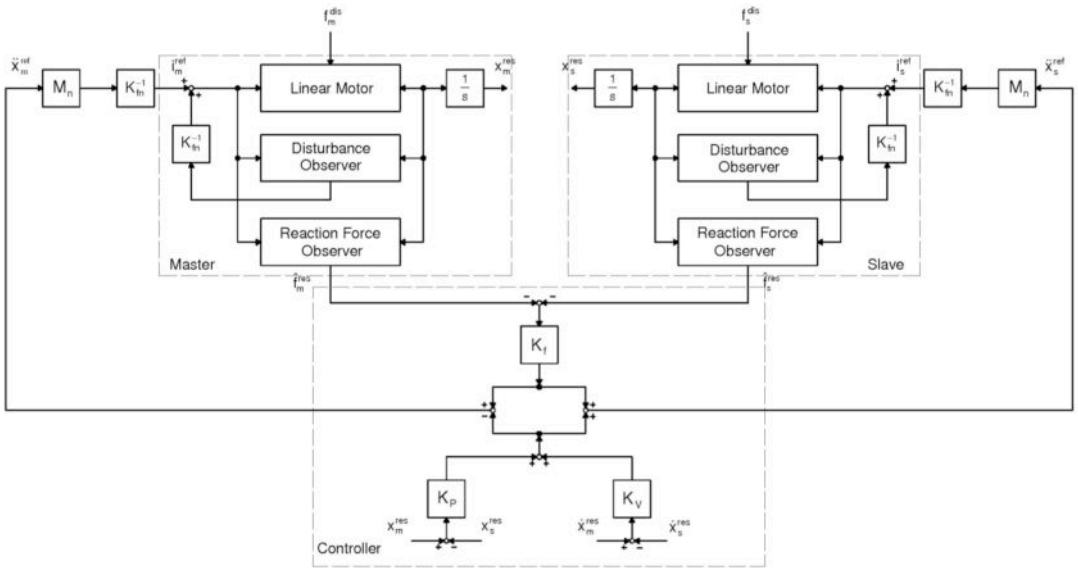

Fig. 7: bilateral control

The usual structure of bilateral control is shown in figure (7). The acceleration values (subscript 'm' for master and 's' for slave) are obtained as follows:

$$\ddot{x}_m^{ref} = K_v \cdot (\dot{x}_s^{res} - \dot{x}_m^{res}) + K_p \cdot (x_s^{res} - x_m^{res}) - K_f \cdot (\hat{f}_s^{res} + \hat{f}_m^{res}) \quad (4)$$

$$\ddot{x}_s^{ref} = - K_v \cdot (\dot{x}_s^{res} - \dot{x}_m^{res}) - K_p \cdot (x_s^{res} - x_m^{res}) - K_f \cdot (\hat{f}_s^{res} + \hat{f}_m^{res}) \quad (5)$$

Thus the complete system looks as shown in figure (8).

V. CONCLUSION

I designed and fabricated a haptic forceps. After simulating the control system in C/C++ I connected the slave to the motors and the master device.

All in all I defined, planned and realised a project quite autonomously. I had to face many difficulties but at least I did it. I learnt a lot of stuff about control theory which I had never done in my home university. I will also take more classes in control theory in Berlin in order to improve my knowledge in that field.

5 Exchange Student Life

International students in Keio are placed in international student houses. In my case it was the Hiyoshi International house. The campus was accessible by a walk of five minutes. Also the next station was close. By train it took 25 minutes to go to the center of Tokyo (Shibuya). The location of the dormitory was very good.
The accommodation itself was also very comfortable. Although the room was quite small like one could expect of Japan. You shared the appartement with another student. Everybody has his own room. Toilet, bathroom and kitchen was used by both residents. The techincal equipment was great. Microwave, gas stove, waching machine, telefon, internet connection and air condition were all included. By the additional support for the room rent the price-performance ratio was incredibly good.
The housing consists in four building of four floors each. The capacity of the house must be more than 100 students. Most of them are international ones from all over the world. Most of them are master students from other Asian countries. There are also living some Japanese students in the dormitory. They act as resident assistants. That means they support international students or organizing events in the house. For the social interaction there were some living rooms, so called lounges, which could be used everytime. You could also borrow a key from the residents managers so that u could also went there off the manager's job. The lounges all afford a large TV screen and also tumble-dryer. All in all the life in the dormitory was very comfortable and you could have a lot of fun with the residents. The great support and generosity of residents assistants and managers should be mentioned in thanks.
You meet most of the residents in the university as well. The international classes were all located in the close Yagami campus. In the beginning of a term there are some welcome parties organized by alumni clubs. There you can meet international students from other campus and different study majors. There are also many Japanese students, especially former or future exchange students. Since they are planning to study abroad or already did it, it was quite easy to communicate with them in English or even other European languages.
According the fact that you most times surrounded by international students in classes and at home, the lab life was the most important opportunity to communicate with Japanese students. Although you could communicate with them in English quite well, I really regreted my missing Japanese skills. Since they are not communicating in English among each other you cannot participate most of the conversations very easily. But that's what one should accept when you study abroad. There were also some international students in my lab so that it was never really boring in the lab. Also if you just go up to Japanese lab members they were always friendly, supportive an d really tried to communicate.
A fixed component of the student's life is the lab meeting. Since my lab was a member of a certain association of several labs (so called 'sum') there were many students (around 40) attending the meetings. That means in return that many sudents had to present their research. So the meetings took place at least two times a week and had an average duration of more than two hours. The presentations were mostly held in English whereas the discussion between professors and the presenter was Japanese. Unfortunately that was the main part of the meeting. So I had time to read papers or to improve my Kana skills. All in all the meetings were quite hepful to learn more about the research of the other students. Still it was relatively time consuming.
Despite research, lectures and meetings there was always time to discover the Japanese way of life. During the first weeks everything was new and exciting. Even ordering food was an adventure. The free time opportunities in the Tokyo area are really awesome. Places like Nikko or Kamakura in the nature constitute a big contrast to the skyscrapers of Shibuya, Shinjuku or Minatomirai. The bargain of izakayas, clubs, shops and karaoke bars is amazing.
In cultural aspects it was also great to see shrines or temples in the middle of Tokyo. The real feeling and the impressions of entering terribly crowded trains, crossing a street with a few hundred other people or just walking through the noise of all the screens and luminous advertisings cannot be described in words.

Additionally to all these ‘usual’ opportunities there took place some special events as well. To enter the Emperor’s palace (only possible two days a year) with thousands of Japanese people and experience their respect and enthusiasm for him was amazing. There were also other unforgettable events like Sumo or Sakura (cherry blossom festival). Impressive was especially the Sokeisen. That’s a baseball match between Keio and Waseda university within a tournament of the five most important universities in Tokyo. The enthusiasm and support of their team was already awesome. But the way everbody payed tribute to the opponents was really unbelieavable.

6 Summary

I really had a great time in Japan. I didn’t learn only a lot of technical stuff but also a lot of things about the people, the culture and the daily life in Japan. I can just thank everbody who made this opprtunity possible and who supported me in any way.
Of course I had to face difficulties. But that is just part of the experience of studying abroad. Although the English level is quite low it is really simple to settle in. All people are friendly, helpful and polite. You can trust almost everybody.
It was really interesting to learn about students life in other countries. The differences to the German way are quite big. The experience to work on your own was special and challenging. Still after several month you also start to recognize things that are not so good as you might had thought during the first month. After a certain time you also start to see disadvantages or faults in society or daily life. But that is just a matter of personal opinion. All in all Japan is a a great to live in for several month. You can have a lot of fun and can experience many new things. Still you will start to compare it with your home sometime. And of course you will be happy to be back home.