DeMaMech Exchange Student Report

Design, Manufacturing and Mechatronics

Student: E.F. van West

Home University: Delft, University of Technology

Host University: The University of Tokyo

TU Delft

東京大学 THE UNIVERSITY OF TOKYO

Table of content

Personal Data

Name: Ewoud van West

Email: Westef@gmail.com

Home Institute:	Host Institute:
Delft, University of Technology Faculty: Mechanical Engineering Department: Advanced Mechatronics www.ocp.tudelft.nl/am	The University of Tokyo Faculty: Precision Engineering Department: Advanced Mechatronics (Higuchi, Yamamoto & Torii Lab) www.intellect.pe.u-tokyo.ac.jp
Address: Mekelweg 2 2628 CD Delft The Netherlands	***Address:*** 7-3-1 Hongo, Bunkyo Tokyo 113-8656 Japan
Supervisor: Dr. H.H. Langen	***Supervisor:*** Dr. A. Yamamoto

Executive Summary

On 16 September I left Holland for 11 months to Japan to do my master thesis research at Tokyo University. I knew the laboratory I was going to was famous for their research in the field of Advanced Mechatronics. It was a unique possibility for me to not only study at world level of my study field, but also to do this in a completely different country and environment. I saw it as a big challenge to broaden my horizon both technically and personally.

I got involved in a new project named: "*Development of a haptic tweezer".* This project aims to develop a new object handling tool for sub-millimeter sized objects. Objects of these sizes can experience problems due to electrostatic "sticking" effect. Nowadays, the tools used for handling such small objects are mostly based on gripper tools, effective in the macro world, but this "sticking" effect presents problems. We suggest a new object handling tool, which can handle these small objects contactless and with assistance from a haptical interface. The name for this tool is *haptic tweezer*, as the tool should be as easy and instinctive to operate as a normal tweezer. In the development of the *haptic tweezer*, we realized two prototypes to study the different aspects of this new tool. One is a macro variant, which could handle a 12 mm sized iron ball by means of magnetic levitation and the haptical interface Phantom Omni. The second prototype, micro variant, was a downscaled version of the first one and could handle a 1 mm iron ball. The results of my work shows that using a haptical interface can indeed be very beneficial as assistance in a real world application. Secondly, I showed that in the case of magnetic levitation it has interesting features to use it for contactless object handling.
These prototypes are just part of the development to a *haptic tweezer*. Much more research is needed to make a good practical working prototype for the sub-millimeter object handling. With the research conducted in 10 months a start has been made and I hope that it can lead to a successful continuation of this project.

From a personal point of view, this exchange program was a great experience. The Japanese people really changed my way of thinking about certain aspects in life. They sometimes have a completely different way of thinking than that we are used to in Holland and to be able to experience that by being there for 10 months is a wonderful thing. I hope to continue my relation with Japan in the future as I met many interesting people and made many friends and I am impressed by their sophisticated society. I think it is a very interesting country to be professionally active for some time during my life, so I will look for possibilities in the near future.
All this was made possible by this exchange program and therefore I am very grateful to have been a participant. My gratitude goes to the organizers and supervisors for their help and for this great chance.

Travel Schedule

Below the travel schedule I followed for my exchange program.

Date	***Activity***
16 September 2004	Amsterdam ➔ Tokyo
1 October 2004 – 31 July 2005	10 month research
28 July 2005 – 3 August 2005	International Conference in Canada
21 August 2005	Tokyo ➔ Amsterdam
21 August 2005 – 28 August 2005	Workshop in Berlin

Research, *Haptic Tweezer*

For 10 months I conducted my master thesis research in the Advanced Mechatronic laboratory of Tokyo University. I was involved in a new project named: *“**Development of a Haptic Tweezer**”*.

Introduction

The background of this research lies in the difficulties of object handling. With recent technologies, the variety in size and the type of objects has increased and new challenges for object handling have arisen. In the field of micro-system assembly or MEMS, for example, components or parts have become so small that they can be very difficult to handle. One problem is the electrostatic force, normally negligible in the macro world, but dominant in the micro world. Electrostatic force makes conventional techniques for object handling ineffective. Parts may stick to handling devices such as tweezers or grippers and that makes it difficult to release the part, see also Fig. 1. Another problem is contamination of the object, since some objects are very sensitive to foreign matter and contact should be avoided.

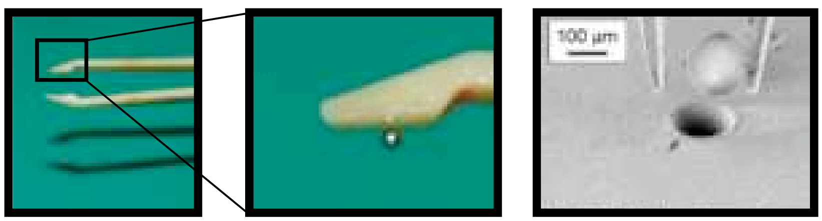

Fig. 1 Sticking Effect

Roughly, one can say that this sticking effect becomes visible for spherical objects when their size comes in the sub-millimeter region. Current methods for object handling in this sub-millimeter region are mostly based on gripper methods from the macro world. With our project we would like to investigate and develop a new method for <u>contactless</u> object handling which uses a haptical interface to assist the operator. This haptical interface can provide information to the operator through the sensation of touch and assist in performing a task smooth fully. This new method should provide the operator with a natural and instinctive new tool to handle small objects. This concept is graphically shown in Fig. 2.

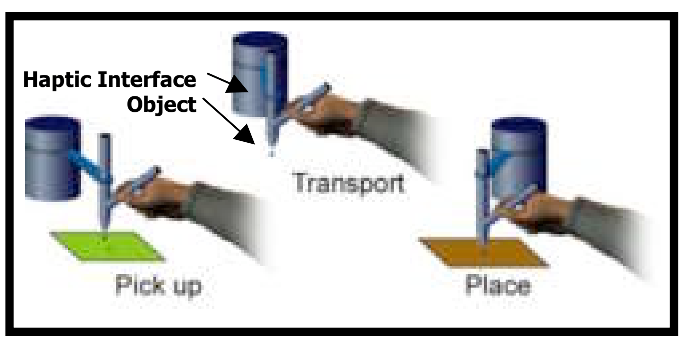

Fig. 2 Concept of Haptic Tweezer

We developed two prototypes to illustrate the beneficial aspects of this concept.

- Macro version of a *haptic tweezer*
- Micro version of a *haptic tweezer*

Macro Version

The macro version of a haptic tweezer was developed to investigate both the potential of contactless object handling and to study the usefulness of the haptic interface for object handling assistance. It combines the haptical interface with a magnetic levitation system to handle a ferromagnetic spherical object, an iron ball. Below is just a brief description of the prototype. More details can be found in my master thesis or for this specific macro version in the following paper: "Augmented Dexterity in Contactless Object Handling using a Haptic Interface", which can be found through the IEEE Explore® website.

The haptic interface is a Phantom Omni from SensAble Technologies. This interface has 6 degrees of freedom (6DOF) and it can apply forces in all 3 translational directions and sense the position from all 6 DOF. It is used to give a force feedback to the operator through a stylus.

Connected to this stylus is the magnetic levitation device. An E-core and coil make up the electromagnet, which generates the magnetic force to suspend the iron ball. The gap between the iron ball and the stator is sensed by an optical parallel beam linear sensor and the controller uses this position signal to generate the proper current of the power amplifiers to drive the electromagnet. A permanent magnet is added on the stator to provide a bias flux to enable zero-power control.

In zero-power magnetic levitation, the controller minimizes the current output by forcing the steady state position of the suspended object to the position where the attractive force from the permanent magnet is equal to the weight of the suspended object. This causes the current to converge to zero, and, therefore, virtually no power is consumed when the system is in steady state. The main characteristic of zero-power control is that it has "negative stiffness." Increasing the load, for example, results in a smaller air gap, because that is where the new equilibrium position is, and the control current becomes virtually zero. Although this behavior is characterized as "negative stiffness," the system itself remains completely stable.

The great advantage of this type of system for object handling is that, for practical purposes, the system is not limited to one specific load; it adapts to load changes and maintains low power consumption. A simple schematic overview of the combination is given in Fig. 3 and the realization of the first prototype is shown in Fig. 4.

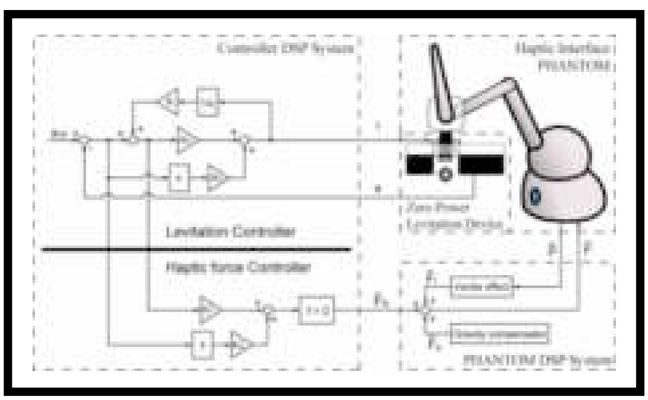

Fig. 3 Schematic Overview

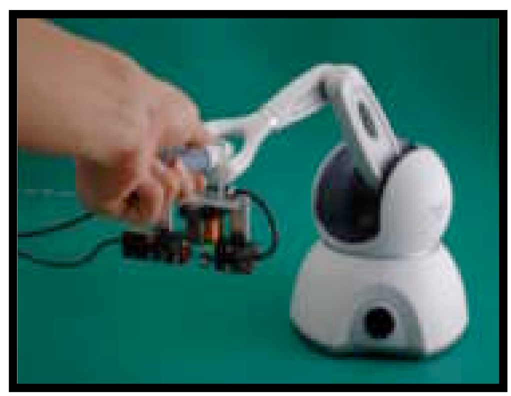

Fig. 4 Realization of macro version

The main purpose of the haptic interface is to assist the user in object handling in such a way that instability of the levitation is prevented and the object can be picked and placed naturally. To evaluate the improvement of performance for object handling, an experiment was carried out in which 10 subjects had to perform a pick and place test under two circumstances, *with* haptical assistance and *without*. This same experiment was also carried out under a visual limitation because the beneficial aspects would become clearer if visual information to the operator is limited. This is graphically shown in Fig. 5. The subjects were asked to pick and place an object (iron ball) as many times as possible within one minute.

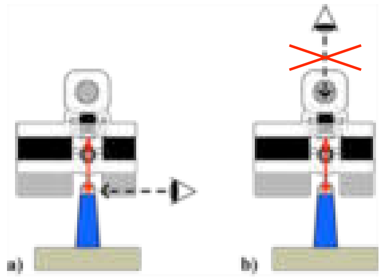

Fig. 5 Visual information of levitation state
a) With visual information of state b) Without visual information of state

The results of this experiment with test subjects are shown in Figure 6. They clearly show an increase in performance in all cases when the haptic assistance is active. The experiment with visually impeded operation however shows a stronger increase. Here, the operator has to rely more strongly on the haptic sensation, which is a more natural way to receive information. When objects indeed become smaller, visual information will be more difficult to obtain as where the haptic force sensation can be easily scaled and perceived. These results indicate that using a haptical interface for contactless object handling leads indeed to better results.

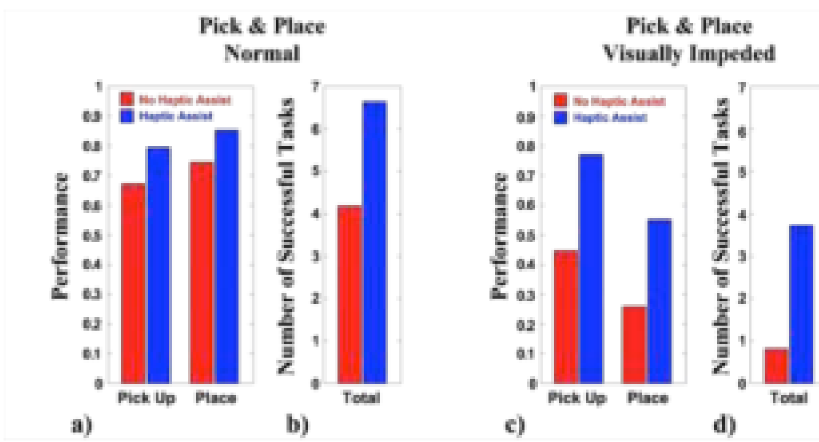

Fig. 6 Results of Pick and Place task
Normal Pick & Place: a) Performance b) Total successful tasks
Visually Impeded Pick & Place: c) Performance d) Total successful tasks

This Macro version was the first prototype to experiment both with contactless object handling and with using a haptic interface in a real world application for assistance. Therefore, it is not realistic that this version will be further developed. It did show however the beneficial aspects of different parts of our concept. A second micro prototype was build to get another step closer to our concept.

Micro Version

The macro version had given promising results and therefore a new downscaled setup was build to make similar experiments which should be one step closer to realizing the *haptic tweezer*. Unfortunately, I cannot go into too much details of this setup because of the page limitations of this report. I included however some photos of the setup in which a 1 mm iron ball is levitated and handled by an operator with one DOF. They show two optical displacement sensors, a voice coil motor which acts as haptical interface, the magnetic levitation device (coil and magnet), the iron ball and a movable placing platform. The Micro version is really a downscaled version of the macro version so the working principle is the same. Results were even more promising for the micro version, since this system was more sensitive and thus more profit could be gained form using a haptical interface.

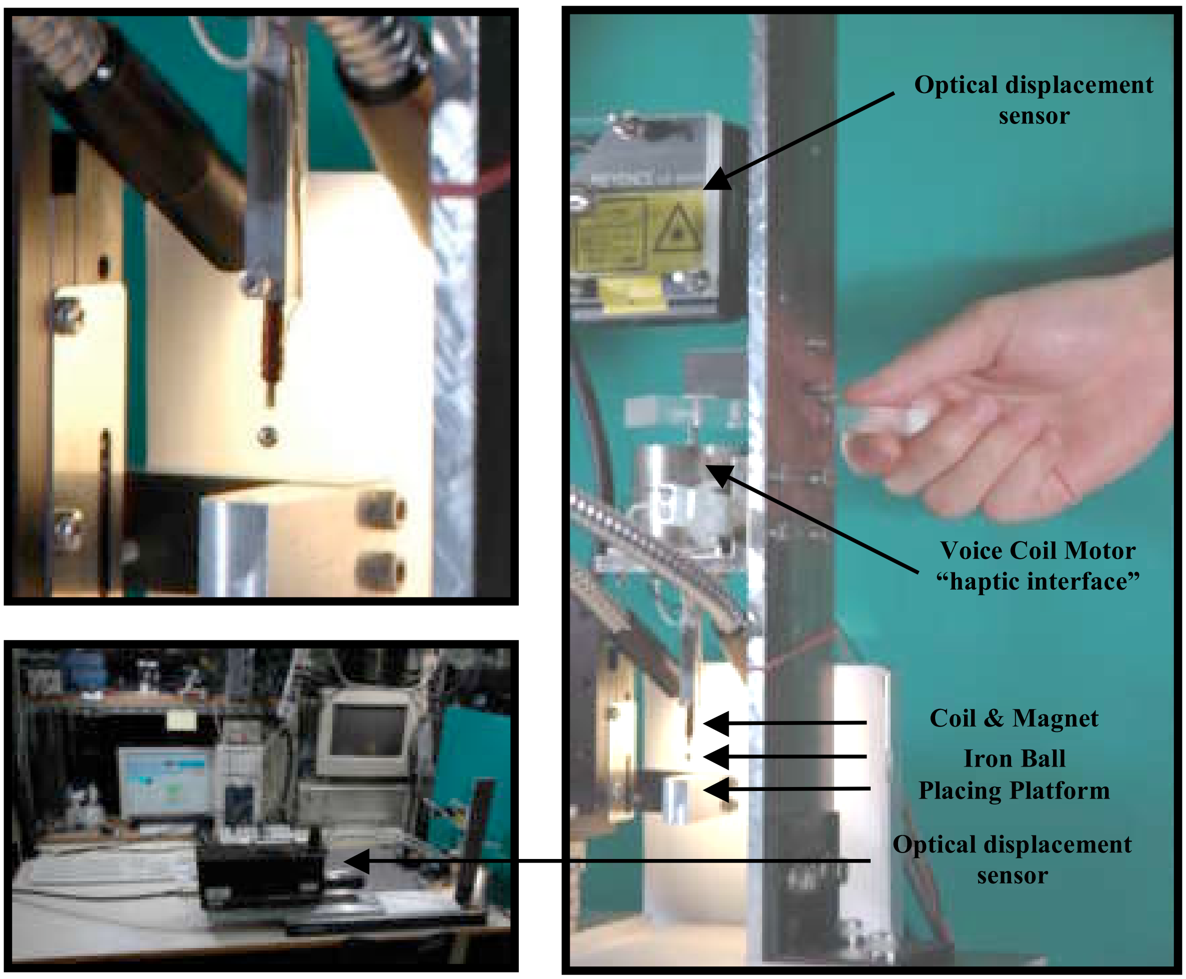

Fig. 7 Photos of micro version

Conclusion

Both the macro and micro version prototypes showed the potential of a new object handling tool, named *haptic tweezer*. These prototypes were mostly study-objects to learn about the different aspects of the combination of a haptical interface with a contactless levitation technique and a human operator. More research in this field has to be conducted for the realization of a real practical object handling tool as is proposed with our concept.

Exchange Student Life

Laboratory

The student life in Japan is very different from the life in Holland. This holds for both doing research and time spent on other activities. Research in Japan is very much experimental based. The focus lies on the experiment and the data which is accumulated from it. Combined with theoretical back-up these results should converge into a satisfactory outcome for the project. In Holland however, you typically must have performed a more thorough theoretical analysis before you can build an experimental setup and actually produce data. Sometimes, research is limited to theoretical results and simulations only. One reason behind this is financial. In Japan, the professors typically have higher budgets to spend on research. This shows in the equipment present in the lab and also, like mentioned above, in the amount of experimental setups that are achieved in Japan compared to Holland.

Another big difference is the working hours. Where in Holland your working day is from 8:30 am till 5:30 pm, in Japan everybody makes longer hours, including the professor. Students even wait with going home until after the professor has left. These longer working hours doesn't mean that the students also get more work done. Their working efficiency is lower than compared to Dutch students, although I must mention that I got the feeling that students in Higuchi lab were more efficient than Japanese students in other laboratories. So, in terms of work, the load is more or less equal.

Communication within the laboratory was interesting. The English level of students is much lower than we would expect from University students. This was never a problem however. With creativity and an open approach we always could get the main ideas across. My supervisor's English however was very good, which was of course very beneficial for the research activities. For the Japanese students it was nice to have a student in the lab with better English skills to help them with correcting their international papers and presentations. I was happy that I could also be a beneficial contribution to the lab in this regard and to return the favor of helping other students as I had asked for many help myself.

Outside Laboratory

The university had arranged a room in the Lodge for International students. This small furnitured room, provided all the basic needs for staying 10 months in Japan. It was located on university ground, but unfortunately on another campus and therefore I had to commute every day for about 45 minutes to the laboratory. The cost was VERY low for Japanese standards, as the average monthly bill was around 15.000 yen. For a tall Dutchman the room was a bit on the small size, but taking all aspects in account, it was a good accommodation for me. In this lodge only international students are housed and therefore you have a good opportunity to make also international friends.

For me I used this room mostly as a sleeping address. I did not spend much time in the room as I was either in the lab studying or outside enjoying.

Sightseeing

Japan is a very beautiful country and excellent to explore for sightseeing. The great diversity in sights makes it interesting for almost everybody, as I think everybody can find something to his/her like. I experienced that even 10 months is too short to explore everything and I only got a first acquaintance with this fascinating country.
Since the main reason for being in Japan was research, sightseeing was only possible in the weekends and in holidays. During my stay I was able to make trips to places like Kyoto, Nara, Hiroshima, Hakone, Nikko, Gunma, Chichibu, but also exploring Tokyo was very rewarding.
Since I am a photo enthusiast, I took over 6.000 photos during my time in Japan and for anyone with a genuine interest in them; I welcome you to contact me.
Traveling in Japan can be difficult because of the language, but the warm willingness of the Japanese people to help, makes this only a minor problem.
I would like to encourage everybody to visit this wonderful country and I hope they can share similar nice experiences as I had during my time in Japan.

Summary

Performing my master thesis at Tokyo University for 10 months was a great experience. Not only from a technical point of view it was a great chance for me to do this research in technologically high developed Japan in a laboratory famous for its research, but also for me personal it was great learning experience.
I could successfully do all my research in the time available and use my free time for traveling, sightseeing and enjoying Japan. The organization of this exchange program was very well executed and also the supervision went smooth and pleasant. There were minor difficulties, mostly due to the language, but they were easily overcome.
I am very grateful to be have been selected for this program and it really made a colorful contribution to both my personal and educational life.