Final Report of EU-Japan Exchange Program DEMAMECH

Steffen Heyer
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1. Personal Data

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2. Executive Summary

When I heard in 2004 in a lesson of Prof. Krause about the Japan-European Union-Exchange Program, I was instantly convinced to go to Asia/Japan. Interesting opportunities to study abroad for mechanical engineering are only a few and mostly for the USA or close European countries and so it was a good chance, seeing another culture area and see how there study on the other side of the earth. In the end I was quite surprised about the fact, that there was no problem joining the exchange program due to the fact that it was nearly unknown at the TU Berlin. A bit irritating was the scholarship-handling, witch in my opinion fits to the costs in Japan but arrived only two weeks before my departure.

In the end of August 2005, all the other European participants and I attended the two-week DeMaMech preparations workshop in Berlin. I liked the Japanese curse but honestly, later in Japan in the very first weeks, I remembered nearly nothing. The lectures about history and culture in Japan were highly useful for me and deliver a good insight on Japanese life.

The travel to Sapporo over London and Tokyo was about 30h and when I arrived, one of my future laboratory members picked me up at the airport. The first impression of my home for the next 10 month was hardly affected be an old Japanese Man, who spoke about the hiring contract and things like that – I understood nothing und just signed some paper with the feeling of selling my soul.
The next few days, some registration formalities had to be done – health insurance, bank account and alien registration. My lab-members were a great help in these time.

I chose me research topic “Construction of a workspace model by using PenTag” because it sounds interesting to me and seamed to fit in my study specialisation: production-engineering. The name of my laboratory in Japan was “Digital Systems & Environments” managed by Professor Onosato.
I started with learning something about the PenTag and object-labels in general. It was difficult due to two things – at first the existing program for dealing the PenTag was written in C++ with Visual Studio witch was a completely new for me. The second obstacle was the report about the PenTag was written in Japanese.
After a brainstorming phase I decided to make some changing on the original PenTag and programmed a software witch supports the new approach. Because of problems in the beginning and I could not finish the research and report in Japan. At home, I was still working on the topic to adapt it for my German supervisor.
Asking my lab-members unfortunately just bared some lags of English of the Japanese Students and my lags in Japanese (witch was not existing at all in these times). When I was I child, I tried to learn Japanese by my own. I started 3 times without any result but on the Hokkaido University, every foreign student has the possibility to join Japanese curses. I choose in the first semester the grammar 1 and oral-communication class and in the second grammar 2 and kanji-writing. Grammar and kanji were very useful and helped me learning the language with a very speedy. When I leaved Japan, I was able to handle all-day-life situations easily and understood a bit. Speaking is still a problem.
I took the possibility of going to a Japanese exhibition and had a great time in Tokyo.

In July 2006, I left Sapporo/Japan with thousands of new experiences about Japanese culture, food, style of working and living in a foreign country. Also my skills in advanced programming increased highly and so I have got no regrets, taken the opportunity of joining the exchange program. In future, I will at least go for holiday back to Japan for visit friends and some familiar places and eat real delicious Sushi.

3. Travel Schedule

Outward Journey

2005/09/12 and 9/13 Berlin	London – Tokyo (Narita)	*British Airways*
2005/09/13	Tokyo (Narita) – Sapporo (Chitose)	*JAL*

Return Journey

2006/07/13	Sapporo (Chitose) – Hongkong	*Cathay Pacific Airways*
2006/07/14	Hongkong – London	*Quantas*
2006/07/14	London – Berlin	*British Airways*

Additional trips

2005/12	Tokyo	*AirDo*
2006/03	Europe	*British Airways*
2006/06	Tokyo	*AirDo*

4. Technical Report

Introduction

My research topic at the Hokkaido University was “Construction of Work Space Model by using PenTag”. The object label PenTag provides the possibility to get information’s about orientation, translation and ID of the label by tracking with a normal or a more advanced camera.
With this information, it is possible to generate a digital copy of the real world. All objects, on those the label is attached, can be identified by connecting the 3D information of the object, the position of the label on the object and the position of the label in the working environment. The topic of that thesis was to realise such a system.

PenTag

The object Label PenTag as the very essential part of the work will be explained here. The shape is a 30x30x3mm high plate with a pink surface colour, five black points arranged on if, and a yellow basement.

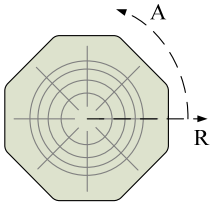

Fig. 1 PenTag configuration

In *Fig. 1 PenTag configuration*, the schematic pattern of the PenTag is shown. There are 20 possible angles and 5 radiuses where all 5 dots are located on. The theoretical number of possible PenTags is over 1.1mio but for a sufficient identification, only about 1000 different combinations can be used. Ascertaining the PenTag position can be divided into 4 steps.

1. *Detection of general position* X , Y

   This means that the incoming image of camera system will be analysed for the colour of the PenTag – which is in the original design pink.

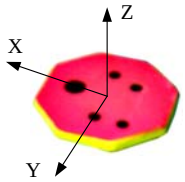

Fig. 2 PenTag: Coordination Axis

   In *Fig. 2 PenTag: Coordination Axis*, you can see the PenTag and the 3 coordination axis. X and Y can be captured out of the camera image without special calculations. It is the centre of the pink pixel-accumulation.

2. *Detection of the 5 points, ID calculation (I1 & I2) and calculation of* Φ_Z

   The recognition of all five black points and there location is the next step. The normal size of these points is 3mm but one, the first has a radius of 5mm and helps on the one hand for indication of all points (counter clockwise indicating) and on the other hand for Φ_Z calculation with the vector between PenTag-centre and centre of this biggest. Both are shown in *Fig. 3 PenTag: Point-indication & the Rotation around Z-axis*.

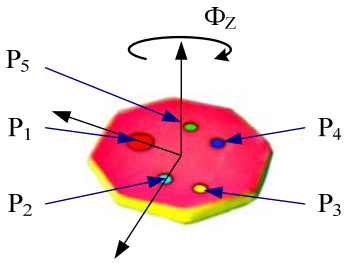

Fig. 3 PenTag: Point-indication & the Rotation around Z-axis

The point-coordinates are the input for PenTag-ID calculation, which consists of I1 and I2.

$I_1 = \frac{|P_{431}||P_{521}|}{|P_{421}||P_{531}|}$ and $I_2 = \frac{|P_{421}||P_{531}|}{|P_{431}||P_{521}|}$ with $P_{431} = \begin{bmatrix} x_{P_4} & x_{P_3} & x_{P_1} \\ y_{P_4} & y_{P_3} & y_{P_1} \\ 1 & 1 & 1 \end{bmatrix}$ (example matrix).

3. *Comparing of real and Image points for calculation of* Z, Φ_X^* & Φ_Y^*

I1 and I2 are compared with I1 and I2 combination of all in the used environment introduced PenTag. The real untwisted set of the five point-coordination's and the set of the camera-captured point-coordination's will be used as input in a minimization-calculation, which depends on camera-PenTag distance Z and the rotation around the other two axis Φ_X^* and Φ_Y^*. This equation is solved with the Rosenbrock method with gradient check and the graphic relations can be seen in *Fig. 4 Relation between distance Z and rotation around X & Y*.

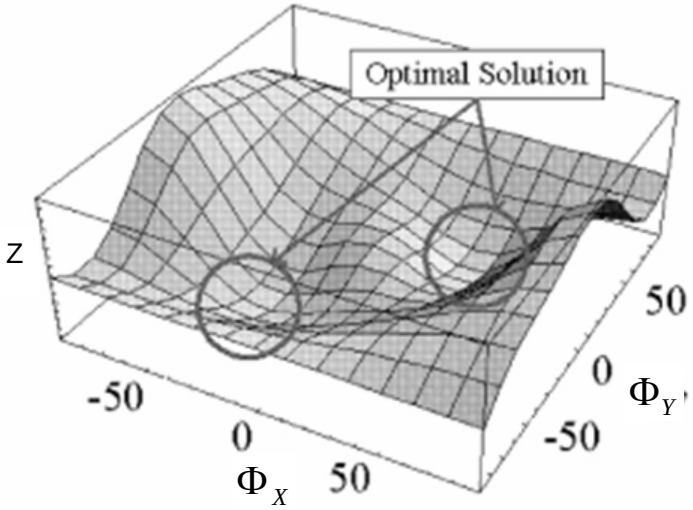

Fig. 4 Relation between distance Z and rotation around X & Y

The problem is that there are two possible solutions due to the geometric invariance of 2D image form 3D scenery. Z is correctly calculated but for Φ_X^* and Φ_Y^* exists two possible solutions.

4. *Elimination of the geometric invariance*

The yellow basement gives the clue, how the PenTag-rotation is in general. On that side the yellow basement is detected on (with the same method like the pink PenTag – with colour recognition), is closer to the camera. This boundary condition is needed to eliminate the geometric invariance. In *Fig. 5 PenTag with Geometric Invariance*, the problem is displayed. Without the basement, no statement about the PenTag-orientation can be made.

Fig. 5 PenTag with Geometric Invariance

After working out these 4 steps, the PenTag is completely located with position and orientation within the 3D-environment in front of the camera.
There are several starting points to improve the object label PenTag. The most obvious is the pink appearance. It is not sure, that consumers would really accept a pink PenTag on any product. The second point is the height of 3mm – it should be possible to design a flat solution. The last point is the maximal number of 1000 different PenTags. In a complex environment, the number of entries could be even higher. With all announced aspects will be handled under *Approaches*.

Approaches

For all tree starting points, several solutions were discussed and the finial result is presented here.
Pink appearance:
The best solution for an object label is a label which is not realized be the customer. The favourite method is to use fluorescent ink and an Ultraviolet source. This solution allows an easy transfer and adaptation of the existing PenTag and as special equipment, only a UV-source is needed. This UV-source is an array of about 90 UV-light emitting LED's.
Height & number limit
For increasing the number of possible objects and decreasing the label-height, the PenTag-basement is removed and on every object more than one flat PenTag will be attached. Different arrangements on an object allow differentiating different objects while using the same PenTags. The number of possible object, which could be in use simultaneously, increased enormous.

Realisation

The realisation of the new PenTag colour is done after test of 8 different inks. The most capable is "Magic Lumino Paint", a green fluorescing ink. The result is shown in *エラー! 参照元が見つかりません。*. The used UV-source is the announced array of LED's, simply attached on the camera with Lego bricks. For an industrial and more professional solutions, a special base will be designed.

Fig. 6 Fluorescing PenTag without and with UV-light & UV-source

The second part, using more than one PenTag per object was mostly a mathematic and programming problem. A look-up-table for the real configuration of every created PenTag and the locations of these PenTags on objects are realized with XML.

For calculating the object position and orientation within world coordinates (overall coordination system of 3D environment), at first the PenTag in Camera coordination's has to be detected and calculated. The origin of every camera coordination system itself has to be measured before running the whole system (this is done with in the environment placed PenTags – so called location-PenTags), shown in *Fig. 7 Camera-Locating in 3D Environment*.

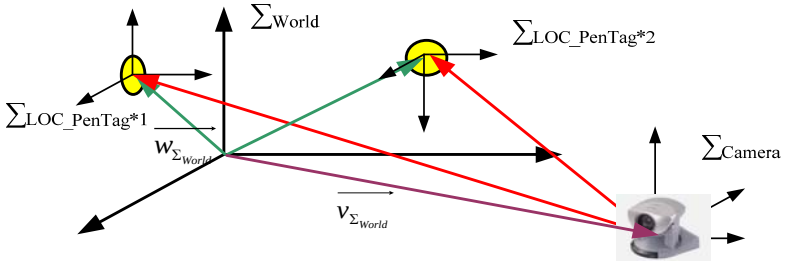

Fig. 7 Camera-Locating in 3D Environment

The mathematic coordination transformation can be expressed with: $\overrightarrow{v_{\Sigma_{World}}} = T_{\Sigma_{PenTag*i} \to \Sigma_{Camera}} \cdot \left(T_{\Sigma_{PenTag*i} \to \Sigma_{World}}\right)^{-1} \cdot \overrightarrow{w_{\Sigma_{World}}}$ with $T_{\Sigma_{PenTag*i} \to \Sigma_{Camera}}$ as transformation matrix from camera to PenTag coordination system and $T_{\Sigma_{PenTag*i} \to \Sigma_{World}}$ transformation matrix from world to PenTag coordination system. How the locating of an object is realized can be seen in *Fig. 8 Multiple-Camera Object-Locating in 3D Environment*.

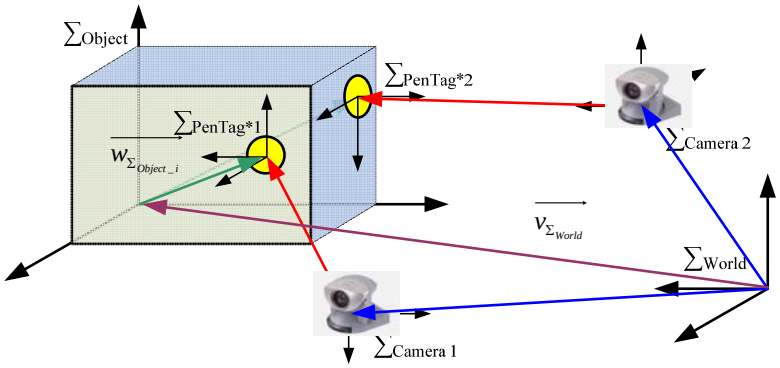

Fig. 8 Multiple-Camera Object-Locating in 3D Environment

$\overrightarrow{v_{\Sigma_{World}}} = T_{\Sigma_{Camera\_i} \to \Sigma_{World}} \cdot T_{\Sigma_{PenTag*i} \to \Sigma_{Camera\_i}} \cdot \left(T_{\Sigma_{PenTag*i} \to \Sigma_{Object}}\right)^{-1} \cdot \overrightarrow{w_{\Sigma_{Object\_i}}}$ with $T_{\Sigma_{Camera\_i} \to \Sigma_{World}}$ as PenTag to camera, $T_{\Sigma_{PenTag*i} \to \Sigma_{Camera\_i}}$ as camera to PenTag and $T_{\Sigma_{PenTag*i} \to \Sigma_{Object}}$ as object to PenTag transformations matrixes, the position of an object can be calculated.

Program

The implementation is done in C++ with a server-client (TCP/IP) structure. Every camera is controlled by one client application. All needed information's are provided by the server, which also gathers all PenTag location and calculates the object locations. These locations are presented in an GUI to the user and could also be send (also TCP/IP) to an superior application for additional tasks (e.g.: 3D output).

Outlook

The announce programs are written in C++ with MFC (Microsoft Foundation Class), which cause several limits. It's not possible to run a MFC program under Linux or UNIX systems. But these operating systems are mostly in use in industry and research. A transfer into Java is aspired.
Another point is the UV-light. It has to analyzed, how other kind of light (e.g.: near infrared or infrared) are capable to solve the given task. This change could also use the IR-light facilities of a new web-camera of the DSL/IST laboratory of Hokkaido University.
In future, the new PenTag system will be possible to observe more precise and faster 3D-scenery to make this product attractive for real industrial task.

5. Exchange Student Life in Japan

Japan is different! That's what is clear but the captivating question is: How much? I try to picture my experience in Japan/Hokkaido.

Food

The European idea about Japanese food is mostly something between Sushi, Fugo (globefish), whale and every times rice. Honestly, that was what I thought too.

This isn't right but not completely wrong. For example, in the beginning I ate a lot of rice with every kind of fish or chicken in one of the many Hokkaido-University students-cafeterias. These cafeterias offers every day (except Sunday and holidays) various types of Japanese food (e.g.: fish, rice and ramen, a Chinese noodles soup) – indigenous and cheap.

Close around the campus, a lot of small restaurants every kind of Asian food. For example a soup, called soup-kare, where you can choose the level of spiciness. Also grilled meat or Italian pizzas are available so that everybody could find at least some food, he or she normally prefer. But I also want to announce Natto, something with soy beans, which is one of these specialties, most foreigners don't like. Another example is UNI-sushi, sushi made with sea urchin inwards. But everybody should at least try everything one time, usually it's quite delicious.

Working & Daily Life

"Japanese work till late night." In my time, I saw two different sides of this preconception. Normal staff in a company or salaried people in University work in most cases very long. The students are the opposite side. My experience is that Japanese students are like most other students in the world – normally relaxing and just before exams of meetings the working-intensity raises significantly.

My day normally happened for 80% within the laboratory due to two facts. On one hand because of the work I had to do and the other hand, the laboratory was the only place with available fast Internet. My dormitory, the Foreigner-Student-House, provided an internet access but in a very bad quality (speed, reliability).

Also available in the dormitory was a kitchen, 3 showers for about 50 people, washing-machines, a TV-room and 2.5x5m large rooms with a bed, fridge and wardrobe. The good thing about this dormitory: it was cheap and dry. Anyhow a kitchen was available; I'd never cook in Japan – buying food in the super marked or going out in a restaurant is in the end the same price.

Joining a Japanese course is on Hokkaido University as simple as is could be – just an internet form. In my time abroad, I went to grammar and Kanji courses which give me the possibility to speak with simple sentences structure and understand normal Smalltalk.

These Japanese-courses were held in the Foreign-Student-Centre, a good place for finding friend.

It wasn't possible for me to join normal lectures, due to the face that every lecture is in Japanese and have compared to Germany extremely high fee.

Normal study on a Japanese university is a bit different to the German system. First 1.5 years are full of lectures. After this time, everybody chooses a laboratory and stay in this laboratory until he or she make his or her master. Distinct from, these laboratories with there members are some kind of family, which is in my opinion a socially very helpful institution.

Sightseeing

During my stay in Japan, I could visit Tokyo twice. The city is very nice and a bit bigger than everything, I've been seen before (but Sapporo is still better for living!). The disadvantage about Tokyo and Japan at all is the very expensive transportation system, which stops around 0:30 in the evening.

Another kind of experience, I made on Hokkaido. The island has a lot of green areas with and offers a bunch of beautiful sceneries. Outdoor Onsens, traditional spas, are a good place to enjoy the view; especially in winter with snow (winter on Hokkaido and snow means nearly the same).

I think Japan is sometimes different to the western life but no reason of avoiding this country.

6. Summary

I took part on the DeMaMech exchange program from September 2005 until July 2006 on Hokkaido University. At this time, I joined the DSE laboratory of Prof. Onosato and worked on “Construction of Work Space Model by using PenTag”. Beside my research, I learned basic Japanese and had the opportunity to visit Tokyo and other interesting places.

I never regret my choice, going to Japan for studying abroad. I’m sure that the personal experience with this culture and the skills, I made within the ten month, will help me personally and later in my working life. I made a lot of friends – not only Japanese than also from all over the world.

I totally recommend the DeMaMech program to everybody, who want to take this unique chances to enlarge the personal horizon.