Report
on the
DeMaMech EU-Japan Exchange Program
2005 – 2006

Henrik Stier

Contents

1 Personal Data and University Information

1.1 Personal Data

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1.3 Host Institute

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Supervisor: Prof. Shun'ichi KANEKO

2 Executive Summary

I was accepted as a participant of the *DeMaMech* exchange program in May 2005, I'd chosen four interesting, to my study related research topics during the application process. It came to the decision of Hokkaido University as host university and Professor Kaneko as my supervisor. In the following I contacted the *DeMaMech* coordinator at Hokkaido University, Professor Onosato, and my supervisor to receive the Certificate of Eligibility and to arrange an accommodation in a dormitory as well as first information about the research topic. With the Certificate of Eligibility I got the visa from the Japanese embassy in Berlin within 3 days. I also arranged the flights to Japan and join an intensive Japanese course for beginners at my home university.

In August, I attended the two-week *DeMaMech* preparation workshop in Berlin. There I met all the other participants of the exchange 2005/2006 and additionally some students they attended the program last year. We heard lectures about history and culture in Japan, different aspects of engineering like Virtual Product Creation, Micro Engineering, or Life Cycle Management. Also we took part in a beginners Japanese course and we prepared in group work presentations about the host cities and universities as well. But first of all I'd profit in Japan from the experiences of the former exchange students.

After arriving in Japan in the mid of September 2005 I've done a lot of registration formalities at the responsible ward office and the university, open a bank account and join the Japanese health insurance system. I obtained a lot of help related to these things from my tutor, Yukiyasu Domae, he was also my co-worker in the laboratory. In the first days I've got an introduction from my supervisor in the research topic, robust object tracking based on orientation coding. My first task was to implement a template matching algorithm based on the idea of Orientation Codes in C++ to understand the basic principle of the research. After finishing this my supervisor together with my tutor and me made a schedule of the research work for the following months.

Based on my first program for understanding the basic principle and some other theoretical considerations I start to implement an algorithm for real-time object detection and tracking in video sequences. Concerning to this programming work I elaborated knowledge about camera control and the Intel OpenCV package by my own, to give an example. While the implementation process I made some suggestions for improvements and new functionalities. I had to present intermediate results of my work at the weekly laboratory meeting. I worked as registration staff at the SPIE ISOT 2005 conference which was held in Sapporo Convention Center in early December and organized by my supervisor. Thereby I socialized with a lot of interesting people. In addition I got the chance to join another computer vision conference in Yokohama (ViEW 2005). Secondary I joined a Japanese course at Hokkaido University.

Finally my co-worker and I held a presentation of our research work at the 12th Korea-Japan Workshop on Frontiers in Computer Vision in February 2006. For this conference we wrote a paper "Tracking-Oriented Feature Extraction based on Texture Richness Analysis" that is published in the appropriate conference proceedings. In addition I wrote an independent research paper.

I left Japan in the mid of February 2006 with a lot of new experiences, enhanced knowledge about computer vision and many new Friends, Japanese as well as other foreign students from all over the world.

3 Travel Schedule

3.1 Outward Journey

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

3.2 Return Journey

2006-02-13	Sapporo (Chitose) – Tokyo (Narita)	ANA
2006-02-15	Tokyo (Narita) – London – Berlin	British Airways

4 Technical Report

4.1 Introduction

The aim of my research was to implement a new method of robust object tracking, based on orientation coding, richness analysis, and some applications thereof. Systems which are based on image processing technologies are widely used in real world environments, especially in industrial ones. Such examples include inspection, monitoring, and measurement applications. The environment conditions are generally good enough, but there are also a lot of situations that cannot be handled by conventional systems. The problem is often a change of the illumination conditions, e.g. the change from sunshine to cloudiness in outside areas or even the day/night lightness difference. Another problematic point is object deformation which appears mainly in face detection and tracking humans. My research includes the implementation of a method for feature extraction that is robust under irregular conditions, a method to find subimages, called templates, to track automatically and finally a template matching algorithm, called OCM, that performs stably in real environments. To evaluate the results of the proposed algorithm some comparisons with other methods are realized.

The program that realizes the proposed method is developed with Microsoft Visual C++ 6.0. For the video capturing and image processing functions the Intel Image Processing Library and the Intel Open Source Computer Vision Library (OpenCV) are used. The video material is based on AVI-Files, which are made by a digital camera using an adequate tripod to reduce the influence of camera shake. Raw data is also provided by a simple web cam.

4.2 The Algorithm

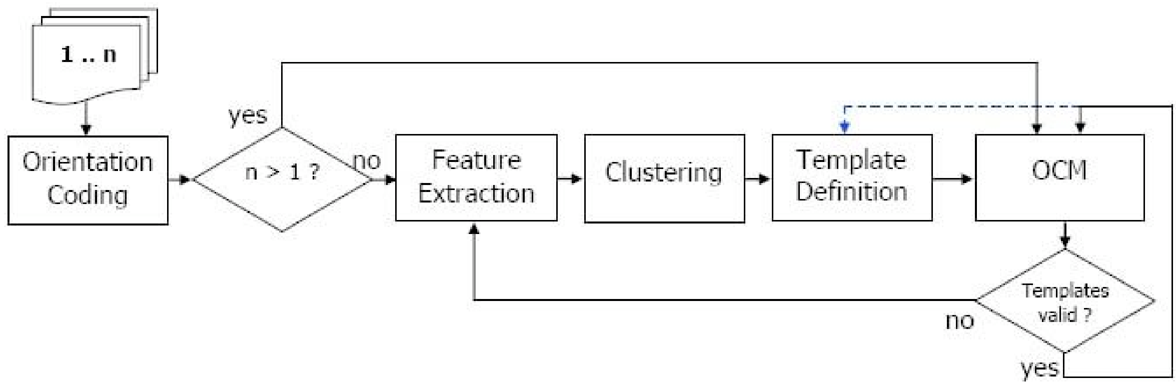
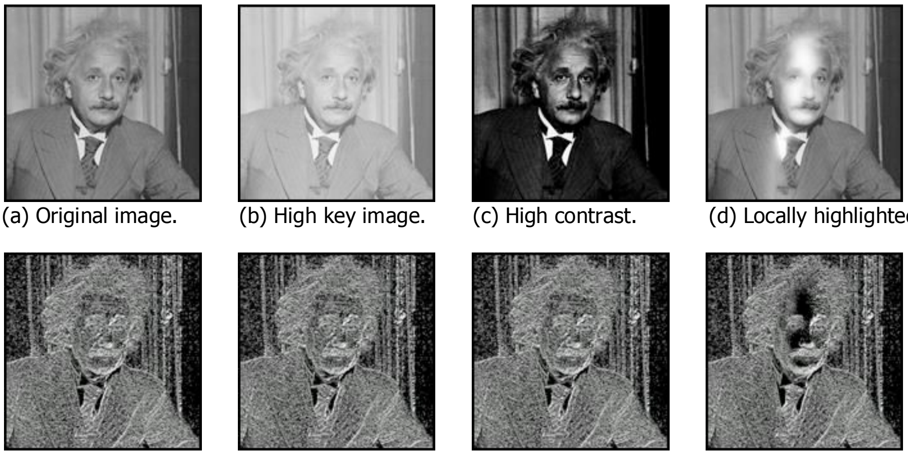


Figure 1: Flowchart of the algorithm.

The structure of the proposed method is shown in Fig. 1. The first step in the algorithm is to capture and separate frames from a camera device or a video file. For each frame the Orientation Code (OC) is computed. OC is the groundwork for the feature extraction method as well as for the tracking algorithm. In the initialization frame, and in the case of redefining templates, a feature extraction method must be executed. The result of this procedure is a specified number of interesting points, called features. For automatic template definition these points must be grouped. Therefore a clustering algorithm (k-means) is used. The templates are extracted at the centroids of the grouped features and tracked in the following by Orientation Code Matching (OCM), for the tracking run is feature extraction and clustering no more required. The result of OCM is checked to recognize a necessary redefinition. The dashed arrow represents the updating of templates that occurs every third frame.

4.3 Orientation Coding

The orientation code (OC) is used by OCM. In contrast to other matching techniques like correlation coefficient (CC) or sum of squared difference (SSD) the gradient orientation information of a gray scaled image is used. The mentioned methods utilize only gradient magnitude or edge features. It is difficult to get good tracking results under irregular conditions with these methods. Operators like Laplacian have to apply to get good results in some cases. But especially a change in brightness, like shadowing or local highlighting, causes the gradient magnitude to vary too much, so the results turn out bad. Gradient information is the most invariant feature in these cases. OC computes images such that each pixel represents an orientation code. These codes are equal to the quantized orientation angle at the corresponding pixel position in the raw image. This means, the result typifies a maximum intensity change around neighbouring pixels of the input image. So one can notice that OC obtains the shape as well as the texture of objects in an image scene. Consequently it becomes invariant to object translation as soon as there are effects of shading and illumination variations. Fig. 2 shows an accordant Example.



(a) Original image. (b) High key image. (c) High contrast. (d) Locally highlighted.

(e) OC of (a). (f) OC of (b). (g) OC of (c). (h) OC of (d).

Figure 2: Invariance of Orientation Codes (OC) in illumination change.

4.4 Feature Extracting

The main idea for the stable tracking algorithm is based on a method to find interesting points, called features, in a scene. An interest point is defined as any point in an image or frame of a video-sequence for which the signal changes two-dimensionally. It is important that these extracted points have good texture properties to get accurate results with the tracking procedure. Also it is very important that features on moving objects (e.g. humans) be extracted well. There are several interest point detectors described in literature. Interest point detectors can be classified by their operating mode into intensity based, contour based, and parametric model based methods. Intensity based methods compute a measure that represents the attendance of an interesting point straight from the gray-values of a raw image. Contour based methods extract shapes and search for maximum curvatures or inflection points along the outlines to define features. Also polygonal approximations with a following intersection search corresponds to this category. Parametric model methods fit parametric intensity models to the image signal. For this research an intensity based extraction method which utilizes richness as an evaluator for extraction-effective regions is used. As input, the OC-image is used. The flowchart of the feature extracting procedure is shown in Fig. 3. Another tried extraction method is computation of density of orientation codes, but a comparison showed that the results of the entropy filtering are even better. The output of these techniques is an image where structured regions are highlighted. The features are located at the most highlighted points in this image.

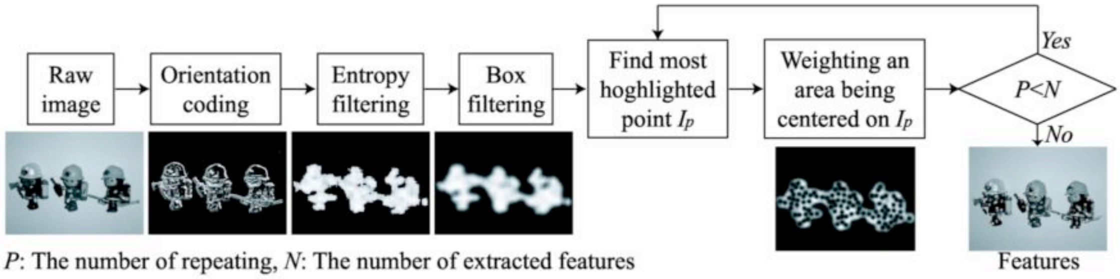


Figure 3: Procedure of Feature Extraction.

In the smoothed image (by box filtering), the n most highlighted points must be found to localize n features. For this, the image is scanned block-wise to find the most shining point I_p. This localization is memorized as a feature position, and an area that is centered around I_p is weighted by an inverse Gaussian window function. This procedure must be repeated n times.

4.5 Tracking

If objects which are to be tracked have no landmarks, I had to find a way to automatically define templates (or Regions of Interest – RoI) for tracking. Landmarks have a high richness and can easily be extracted by the described method. Templates are set to their locations. In other cases, extracted features are well-suited to tracking, but there is too much to track. Therefore, it is needed to generate few templates from this feature distribution. K-means, a well known and simple clustering algorithm to group features and calculate their centroids, is used for this purpose.

The features have been classified into a specified number of clusters, templates can be adopted to the cluster centroids. Their position information is used in grouping extracted features. Other adequate data could therefore be the richness values. The first step of the k-means algorithm is to define k initial centroids, this number is fixed and depends on the quantity of features. These are uniformly distributed in the first frame. The centroids could be specified also by coincidence within a segmented area. Then, for each feature, the distance to these centroids is computed and the feature is assigned to the closest one. When all features have been assigned, the centers of the k clusters have to again be determined. The last two steps must be repeated until the centers do not move any longer.

Orientation Code Matching (OCM) is a template-matching algorithm based on orientation coding. OCM is robust against changes in illumination and is effective for matching deformed objects. First, OC of the source image must be computed. The template, which has the size M×M, is also extracted from an OC image around an accordant location, that is determined by feature extraction and clustering. M×M areas of OC image, extracted for each pixel position, are compared with the template. The similarity measure referred to as the mean of absolute residuals to find the best match is based on an absolute difference criterion. To reduce computation cost and speed up the matching process, the comparison of regions with low richness can be skipped.

Error detection is a very important topic during the tracking process. An error means that a template did not match with the scene or is found in a wrong location. Both circumstances can be investigated in the same way. Reasons for such failures are mainly low texture information, occlusions, or the tracked object moved out of the regarded scene. First, an analysis of the minimized OCM similarity measure was tried. But these values are inappropriate, because they are always unsteady and nearby. Instead, the displacement of the central point for each template is used; if the distance of centers in consecutive frames exceeds a defined threshold a misplaced template is realized. After an error is detected, a redefinition process should be executed. For this, a new feature extraction and cluster recalculation is necessary. It is conceivable to use the last known template positions for cluster initialization, but there is no strong discrepancy ascertainable. The redefined template is extracted at the appropriate cluster centroid, for the remaining templates nothing changes. In cases without any errors, all templates are updated every third frame at their current position. This is an advancement compared to updating templates each frame, because proper motion of templates is prevented. This includes marginal movements (by one or two pixel per frame) of the template or equally undesirable non-moving in case of movement of the tracked object. This proceeding also favourably affects the number of redefinitions.

4.6 Results

The proposed method for finding and tracking objects in video sequences was evaluated with different video sequences and scenes observed by a USB webcam, in all cases the size of the raw video data is 320x240 pixel. The chosen scenes included different kinds of illumination, changes of illumination (e.g. by covering a light source), moving and deformation of objects as well. In all cases the camera position is static to prevent the influence of camera shake; the zoom settings are also not changed all along.

The outcome over-all is very good; even the positions of templates are localized at good positions on tracked objects. Among necessary updates, adequate positions for updated templates are found and tracked by OCM. The frame rate in example runs with three tracked templates is about 6.5 fps (Pentium 4, 256MB RAM).

4.7 Future Works

To make real-world applications possible, the frame rate have to be increase. For this the algorithm must be improved in computation cost and robustness, especially the part of orientation coding and orientation code matching. As an important research topic some formalization of tracking and template modification will have to be considered with experiments using real world data.

5 Exchange Student Life in Japan

5.1 Introduction

I spend five months as an exchange student at the Hokkaido University in Sapporo, Japan. In this time I also visited other parts of the country, for example during the winter holidays or while joining conferences. I enjoyed the daily life as well as sightseeing and spending time with friends from all over the world very much.

5.2 Daily Life and Sightseeing

During my stay in Japan, I lived in an international dormitory near the university, but I didn't spend much time in the dormitory, except for sleeping and to do one's laundry. The building was quite old and in spite of daily cleaning sometimes very dirty; especially the kitchen and the common bathroom.

Curtly after arriving in Sapporo I bought a used bike from a university organisation. This helped me a lot in everyday life, for commuting to the university just as for short trips in the vicinity of Sapporo like the Sapporo Art Park. After incipient snowfall in early December I couldn't use it any longer.

Normally I brought breakfast in a bakery on the way to the university and take lunch and dinner in one of the cafeterias or in restaurants outside the university. I also bought foodstuffs and other things in convenient stores or other supermarkets; for the most part opened 24/7. I didn't missed any things from Europe, especially I like the Japanese food very much.

I used my stay in Japan also for sightseeing trips, by bike (exploring the vicinity of Sapporo), by train (e.g. Otaru, a harbour city on Hokkaido), and by plane (Tokyo/Yokohama). In the holiday around Christmas and New Year I spent two weeks in Yokohama, which was a vantage point for several trips to Tokyo as well as to Osaka and Kyoto. I spent the New Year's eve with other *DeMaMech* students in Tokyo. I've got the chance to visit conferences and I used my free time there also for sightseeing, e.g. for visiting Kamakura, a pretty nice city in the southwest of Tokyo, with the *Daibutsu*, a very huge Buddha statue. I visited laboratories of Hitachi in Yokohama including a clean room for optical wafer inspection at invitation of a Hitachi manager. In February I stayed a few days in Tokushima and Takamatsu on the island of Shikoku, there I visit many temples and shrines as well as a laboratory of the Kagawa University. The really huge and filigree ice and snow sculptures of the Sapporo Snow Festival were very impressive and fascinating for me.

At all I made many new friends in and outside the university from all over the world as well as Japanese. Even though the level of spoken English was sometimes very low, a conversation was almost possible. The Japanese were always very friendly and polite, so it was an enjoyable time for me.

5.3 University Life

In the first days after arriving I got an introduction to my research from my supervisor. Also I familiarize myself with the research by reading papers and internet search. While my research I had every time a contact person if I had problems or questions and I was completely free in managing my time and research work. I got useful feedback from my professor and other students of the laboratory in weekly meetings or personal discussions. In addition I stayed in contact with my concerned professor in Germany over the whole time.

I joined a Japanese course at the International Student Center of Hokkaido University and thus I'm able to express myself in daily life situations like in restaurants or while shopping. The conversation in the laboratory was completely in English, some students had sufficient English skills. Except me there were three foreign students, from China, in the laboratory and one of my lab-mates was a former *DeMaMech* participant.

Beside the research work in the laboratory were a lot of celebrating activities with and without special reasons in the lab, e.g. welcome parties for new lab-members or festivities before and after New Year, or just a collective dinner in a restaurant. In addition there were other events, especially welcome and get-together parties, organized by the faculty and different student organisations of Hokkaido University.

6 Summary

From September 2005 to February 2006, I spent five months as a *DeMaMech* exchange student at Hokkaido University, Japan. Before I left Germany, I attended a two-week preparation workshop in Berlin, where I got useful information about Japan and the Japanese language as well as interesting engineering topics.

After arriving in Japan I'd done some formalities and got an introduction to my research theme. My task was to develop an algorithm for detection and tracking objects under irregular illumination conditions. I'd done this work successfully. I was involved in writing a paper and preparing of a presentation for the 12^{th} Korea-Japan Workshop on Frontiers in Computer Vision 2006. I also wrote a detailed research report and joined a Japanese course at the Hokkaido University.

As well as researching at the university, I also enjoyed life outside the university. I went sightseeing, made friends and went out with them. I'm very glad to have been able to go to Japan with the *DeMaMech* exchange program and hope others will also have such a great experience there as I did. I hope I came back to Japan soon, maybe for an internship or for working after I'm graduated.