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April 29, 2007

Dr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 440 Design Specification for Motion Capture System

Dear Dr. One:

Please find attached the document, *Post Mortem for the SensIT Motion Capture System,* giving a final summary of our product for ENSC 440.The product is a real time system which captures the position and orientation of an object, providing a 2D digital representation and simulation of the object's movements on a computer. The system may be used later as an analysis tool to study the human body movements in different applications such as dance performances.

The purpose of this Post Mortem is to provide a detailed overview of the current status, timeline, and budget of the Motion Capture project. The attached document also includes personal comments from each of our team members on our learning experience during the project.

SensIT Technology Ltd. consists of four inventive, motivated, and devoted engineering students: Azadeh Jamalian, Ata Naemi, Sa'ed Abu-Alhaija, and Ivan Lee. If you have any questions or concerns about our project, please do not hesitate to contact me by phone at (604) 780-6583 or by e-mail at sensit-ensc@sfu.ca.

Sincerely,

Azadeh Jamalian
President and CEO
SensIT Technology Ltd.

Enclosure: *Post Mortem for the Motion Capture System*

Post-Mortem for a

Motion Capture System

Project Team: Azadeh Jamalian
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Submitted to: Lakshman One (ENSC 440)
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School of Engineering Science
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1 Introduction

During the past decade, the technology of motion capture to trigger computer music Based on the performance of dancers has been of interest for composers and choreographers, bringing together visual artists, composers, dancers and finally engineers. The SensIT Motion Capture System is the starting platform for the motion capture system which will be utilized by professional dancers as an analysis tool to study their dance movements. Our low cost system will be capable of capturing precision and real time movements of an object moving in 2D.

2 Current Status of Project

The system can be divided into four sub-systems: a control unit, an optical capture unit, image analysis software, and 2D animation software. The control unit consists of the microcontroller and the IR LED's which are attached to the object under study. The control unit sends infrared radiation to the optical capturing device, which consists of a USB webcam. The raw information captured by the USB webcam is then sent to the main computer. The image analysis software analyzes the raw data and finally sends the calculated coordinates of the object to the 2D animation software. Figure 1 shows the block diagram of the SensIT Motion Capture System.

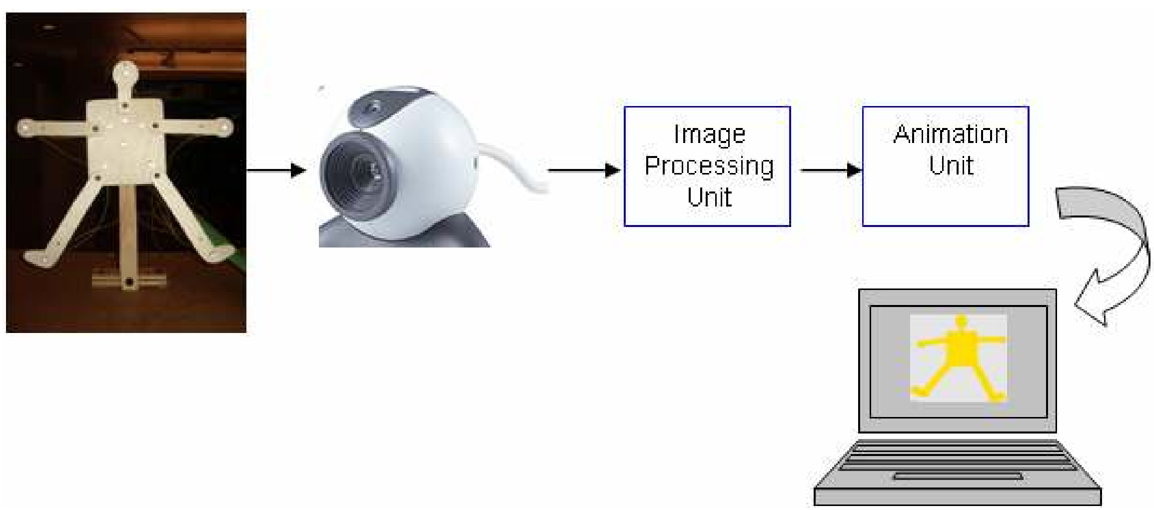

Figure 1: Block Diagram of the Motion Capture System

Further, Table 1 outlines the parameters of the product along with their range:

Table 1: Parameters of the Product

Parameter	Range
Frame Rate	10 frames/sec
Max Motion Frequency	2Hz
Max Range of Monitoring	1m
Accuracy	±10%
Precision	100% (clear line of sight)

The Animation Unit provides a software user interface that will display the correspondent orthogonal 2D images of the object under control, thus creating a 2D representation of the model.

The graphical user interface is an event driven interface based on a PC computer with computer monitor as the output display medium. The user interface is comprised of various windows as will be described in following sections. The design of the software is completed using the Microsoft Visual C++ 6.0, utilizing the Microsoft Foundation Class for GUI development.

Interfacing the software applications with hardware is accomplished through the use of USB port of a PC computer. And also the integration of Image Processing software unit and Animation software is accomplished through the I/O file read and write implementation.

3 Deviation of the Device

3.1 Overall System

The actual Software and Hardware implementations were generally carried out as planned, but off course there were modifications required throughout our design stage. We will discuss these implementation deviations in terms of hardware, low level, and high level soft wares.

Finally, high level software, the animation unit, has been modified in terms of implementation algorithm and parameters, to reflect time and cost constraints. The represented space has been lowered and the implementation algorithm has been changed to track only the coordinates of the LED's mounted on the moving joints of the object under control.

The accuracy of our system is now 0.10m, as opposed to 0.01m as stated in our functional specifications. This is mainly due to the angle of sight limitations of our IR LED's and also the frame rate limitation of our USB webcam utilized in our system.

Although the accuracy is lower than what was claimed earlier, but it should be noted that the deviation is significantly smaller if the frequency of motion is investigated at a lower rate so that the USB webcam is capable of capturing the motion.

Also note that the system performance can be significantly improved with allocation of more time and higher budget. We were limited to the sampling rate of 30 frames/sec from our utilized USB webcam and also angle of sight limitation of IR LED's which is around 45 degrees.

3.2 Hardware Unit

The implementation of the hardware unit required minor modifications to the original design discussed in the *Design Specification.* In particular, the initial power supply circuitry which involved using a 3V lithium ion battery and a boost regulator was modified to use the 9V battery and a linear regulator. The reason for this change is because the parts for the boost regulator were not available at the time and the lead times were long. The linear regulator supplies a steady and stable 3.3V to the system; however, it is not as efficient as the switching regulator.

3.3 Low Level Software System

The low level software system was developed as it was described in the *Design Specification*. The only exception would be that the Capture Control Unit (CCU) does not contain adjusting frame rate algorithm which we believed to be a synchronization method between the system and the hardware kits. This algorithm was derived since there is no direct communication line between two systems. However, we decided to have twice the frame rate in the low level system compare to the hardware system and this frame rate ratio is obeying the Nyquist Rate. In the actual system, the frame rate of the software system is about 30 frames per second.

4 Future Plans

Individuals of this team all have different plans for their future, some are going on coops, some are starting their undergraduate thesis and others are finishing their undergraduate studies. Thus, any further future plans will be put on hold unless they are carried out by future ENSC440 groups or co-op students. The following discusses the enhancements and improvements that will be implemented in the future.

4.1 Overall System

- Capture motion in 3D to enable a more realistic and flexible capturing of the motion.

- The system should be able to take the frame captures at a rate of at least 50 frames per second.

- More intelligent algorithm will be implemented for the animation unit to assign the coordinates of IR LED's.

- A calibration unit will be added to the Image Processing Unit to account of different distances of the Object from webcam.

4.2 Hardware Unit

- Use a boost regulator (switching regulator) discussed in the *Design Specification* to improve the efficiency of the power circuit which ultimately increases the life-time of the battery.

- Make a wearable suit with the IR LED's attached to it and test the program with a human being.

- Use high efficiency IR LED's with a wide viewing angle in order to lower the power consumption and enhance the system's performance.

- Multiple IR LED's will be mounted on each joint of the object under control to eliminate the angle of sight limitation of IR LED's.

- Use one-time programmable microcontrollers for the production model to lower the costs of the system.

- Add an indicator for the user when the battery is low since the IR light is not visible by the naked eye.

4.3 Low Level Software System

- *Direct communication line between the low level and high level software system:* the current system adopts text file for communication line between the low level and high level software system. However, this method will slow the system since the file I/O takes many clock cycles. Additionally, the high level system keeps loops if the information in the text file is changed and this infinite loop affects the low level systems performance. Therefore, constructing the pipe between two systems will increase the overall performance.

- *Use high performance camera:* our system uses web camera for image capture device. The best performance in frame rate for web camera is about 30 frames per seconds. Our system fully uses the maximum frame rate but we found that the system need much higher frame rate since there are many algorithms involved to successfully complete the task. We expect that we need a camera which can support at least 120 frames per second.

- *Use other programming language:* the current system is developed in C++ language in MFC. MFC is good for developing a program which has high interface with the end user. However, the low level software system does not directly communicate with user, therefore using MFC will degrade the performance. MFC has itself a infinite loop which keeps checking if user presses any button in the window.

5 Budgetary and Time Constraints

5.1 Budget

The initial system was considered to design was a 3D motion capture system. After further discussions with specialized factually members in the field, we were advised that the 3D system is very complex and will require much longer than four months. Moreover, we could not find a sponsor for the expensive 3D system. We discussed these issues with Dr. One and decided on a simpler 2D motion capture system. We received an amount of $400 of funding from the university. The estimated and actual costs of the system are shown in Table 2 and 3 respectively.

Table 2: Estimated Cost of the Project

Equipment	Estimated Cost
Sensors/markers + interface-electronics	$400
Sources + interface-electronics	$400
Computer interface-electronics	$100
User Interface	$80
Cables	$20
Total Cost	$1000.00

Table 3: Actual Cost of the Project

Equipment	Estimated Cost
Sensors/markers + interface-electronics	$60
Sources + interface-electronics	$80
Computer interface-electronics	$0
User Interface	$60
Cables	$10
Total Cost	$200

5.2 Time

We did not have an ideal start to our project since we spent longer than we anticipated on deciding the topic. However, through handwork and dedication, we managed to meet the deadlines we set for ourselves. We aimed to be ready by April the 10th and we were ready fully ready by April the 14th since some of the group members had final exams on the 10th and the 13th. We had extra time at the end to implement an application of the system (a wireless mouse) which we showed during the demo. The design of the individual units of the system went smoothly and we kept updating each other as we were working in parallel. We ran into some unexpected problems during the integration stage but we left ourselves enough time to handle the challenges we were faced.

6 Inter-Personal and Technical Experiences

Atae Naemi

This 440 project was a unique experience for me. The project was full of challenges and was a great source of learning and experience for me. Throughout the progress of the project, I have had a chance to acquire and master a set of new skills that I am certain they will be of great help in my future studies and also in my carrier endeavors. I have had the chance to strengthen my programming skills in C++, as well as circuit designing and debugging skills.

But aside from the technical skills achieved throughout this project, I have been revealed to two major experiences that I think are more informative than the technical skills. First, my involvement in the process of integrating different parts of a big project and working as in a group in resolving the upcoming problems aiming at our common goal. And secondly, I have understood the true and most practical way of debugging process that must be carried out to arrive at our ultimate goal.

And finally this course has provided me with the opportunity to master my communication skills and my group work skills. And at the end I wanted to note that working with my group members has been extremely worthwhile.

Azadeh Jamalian

The most valuable skill I learned during the implementation of the SensIT Motion Capture System was how to manage a group of people with widely varying backgrounds to work together towards achieving a common goal. Since our project was made up of different functionally separate subsystems, I learned how to design my major system component, the OpenGL modeling, while also considering the needs of the hardware, image processing unit, and mechanical sections. These experiments made me acquainted with engineering design and development process, expert in troubleshooting and problem solving, and endow me to a great extent with engineering development discipline. Finally, I gained some insight into the challenges of starting up a company with limited resources.

Sunghoon Ivan Lee

During the last 13 weeks of development, I leant the definition of the teamwork. We researched, planned, developed and integrated the system in order to successfully complete our goal.

During the researching period, I upgraded my research skills. We are living in information-ocean called internet and we must have skills to fish what we really need from many sources available to us. In the early stage of research, we did not even have a clue about what kind of software language we are required to communicate with the web camera. I have researched all software development kits (SDK) and software tools we need. We have successfully installed Microsoft Platform SDK and DirectX SDK which need many steps to be mounted on our software tool (MS Visual Studio 2005.)

I learnt the importance of planning during our project period. I believe we could have done much better job if we could have forecasted what we will be struggling when we actually followed our planning. For example, the integration between the low level and the high level software could be done so that it can upgrade our system performance if we have forecasted what will be happened if we develop system in two different software environment. More detailed and sophisticated planning was a crucial step we needed.

I was able to apply my software developing skills in real situation which did not have any answer as it was in my courses at SFU. I need to understand example code that the distributors of SDK provided us and mount a module which I have designed on the top of those example codes. Besides actual programming, I learnt how to analyze the structure as well as functions in code to understand the whole system.

Integration was the most challenging stage that I have found during the development. It was the integration between two systems that are developed by two different engineers. It was far difficult than I have imagined and I realized that planning for integration is very important. I learnt how to communication between two engineering team and also between two software systems.

Overall, I have learnt how to work as a team. In my opinion, teamwork is fully depending on communication skills. Even though there are several engineers developing different parts in a system, everyone must understand what is going on in the system in order to reach an optimal solution to a problem as a team. I learnt how to listen to people and how to talk to people.

Sa'ed Abu-Alhaija

I remember the panics and confusion we were going trough before the beginning of the semester. After talking to Dr. One, we decided that the initial project was not appropriate. We later had to change our project to be realistically achievable within four months. Therefore, the first thing I learned from this course is to choose and research your projects carefully. The research stage is very vital and realistic goals must be set based on adequate research. It is not about what you wish to achieve, it is about what you actually can push yourself to achieve. Challenges make the work more enjoyable and satisfying but one has to be careful that they do not set unrealistic goals.

In terms of technical skills, I had to build and deign the hardware unit. We used the popular PIC microcontrollers and programmed them using assembly language. One of my targets was to minimize the power consumption so I had to learn techniques, such as putting the microcontroller in sleep mode when not used, in order to reduce the current drawn by the circuit. Regulators are very common in circuit boards and I had the opportunity to use one in my design.

Throughout my studies at SFU and my co-ops, I was always supplied with the components I need. The components for the labs are usually given and the purchasing departments at the companies deal with vendors. This project gave all of us a chance to go through the process of choosing the part most suitable for us by comparing datasheets and availability as well as dealing with local vendors such as Active Electronics, RP Electronics, and SMI Electronics. Digikey and Arrow are also other larger vendors known worldwide so it is a definite asset to know them.

I also noticed the importance of diversity of skills within a group. Each group member brought something unique to the project as well as focused on a particular area of the project, however, being aware of the other members' work proved vital in the integration stage. The communication skills and the great group dynamics that we had throughout the term were essential to our success. We tried to solve problems within the group and asked for help when we needed to. We saw the impact of good organization throughout the term at the integration stage since we did not have any misunderstandings. I personally improved my problem solving techniques significantly and can work well with groups to find the cause and solution for problems. Overall, the group members worked really well together to meet the targets and I am very pleased to have had the opportunity to work along with my group members.