School of Engineering Science • Burnaby, BC • V5A 1S6
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March 4, 2007

Steve Whitmore
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Project Proposal for Motion Capture System

Dear Mr. Whitmore:

The attached document, *Proposal for a Motion Capture System*, outlines our project for ENSC 440 (Engineering Science Project). In this document we will propose our revised project which has been scaled down compared to our initial proposal.

Based on our extensive research and meetings with several experts in motion capture systems and sensing networks, we realized that our initial proposed project, a 3D human body motion tracking system, would require more time and financial support in order to be completed successfully. After meetings with Dr. Lakshman One, we agreed to modify our project to a 2D motion capture system of a moving object. Therefore, we have simplified our system from 3D to 2D solution and we will only capture the physical parameters to create a 2D simulation. The two coordinate positions along with the rotational angle of the object would precisely represent the position and orientation of the moving object. Our modified version of the project has already been discussed with Dr. Lakshman One and he has accepted our new proposed system given the time limitation and complexity involved in the initial project; further, he has asked us to rewrite a new proposal for our revised project by March 5th.

At the end, I would like to thank you for your time and consideration. If you have any questions or concerns about our proposal, 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: *Proposal for a Motion Capture System*

School of Engineering Science • Burnaby, BC • V5A 1S6
sensit-ensc@sfu.ca

March 4, 2007

Dr. Lakshman One
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Project Proposal for Motion Capture System

Dear Dr. One:

The attached document, *Proposal for a Motion Capture System*, outlines our project for ENSC 440 (Engineering Science Project). Our goal is to design and implement a real time system which captures the position and orientation of different joints of a moving object, providing a 2D representation and animation of the motion of the object in computer. The system will be used later as an analysis tool to study dance movements and to compose or conduct music based on these studies.

The purpose of the proposal is to provide an overview of our proposed system, a synopsis of the design considerations, our sources of information and funding, and an estimate of our budget, team organization, and information on project scheduling. The document also investigates other forms of motion capture systems which are brought into play in other industries such as sports, biomedical researches, animation and video games industries.

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 proposal, 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: *Proposal for a Motion Capture System*

Project Proposal for a

Motion Capture System

Project Team: Azadeh Jamalian
Atae Naemi
Sunghoon Ivan Lee
Sa'ed Abu-Alhaija

Contact Information: Azadeh Jamalian
sensit-ensc@sfu.ca

Submitted to: Lakshman One (ENSC 440)
Steve Whitmore (ENSC 305)
School of Engineering Science
Simon Fraser University

Submitted Date: March 4, 2007

Revision: Version 2.0

Executive Summary

Both music and dance are rich media of communication, but they communicate little about the benefits that one can offer in mutual exchanges. Dance and music can be traced back to prehistoric times and, as rhythm and sound are the result of movement, and music can inspire movement, the relationship between the two forms can be thought of as unified. Indeed, music and dance may have evolved as an alliance system: music instigates dance and reciprocally, dance evolves music.

Currently, at Simon Fraser University the departments of Computing, Music, and Engineering are intrigued by the project which focuses on studying dance movements and composing or conducting music inspired from these movements. Particularly, our company aims to develop a motion capture system which has the potential to become the initial step of a bigger project. Our goal is to design and implement a real time system which captures the position and orientation of different joints of a moving object, providing a 2D representation and animation of the motion of the object. In future developments, this system could be expanded to capture movements of an actual dancer.

Recently, different types of systems and technologies have been employed to capture human motion in different industries. Mechanical capture, passive/active optical systems, and magnetic capture technologies are examples of the available motion capture systems. Each of these procedures having its own advantages and drawbacks and considering the requirements and specification of the project undertaken, the best suitable method can be selected accordingly. However, for the purpose of analyzing dance movements, the capture system needs to be wearable, have large capture volume, and it needs to be wireless so that it would not interface with the performance. Hence, designing a motion capture system with all these ideal specifications is essential.

The document proposes developing a motion capture system which will utilize the infrared optical technology and USB webcams, enabling precise tracking of an object's movements with advantages of lower costs, ease of use, flexibility, and most importantly the elimination of wirings. We believe that our system provides an accurate analysis tool to be used by other interested researchers in order to study dance movements and later to compose and conduct music, or to perform light settings based on these studies.

SensIT Technology consists of four engineering students with experience in analog and digital circuit and control systems design, signal processing, and computer programming. SensIT members are also skilled in software and hardware design, from real time operating systems to microprocessor assembler programming.

We propose the engineering cycle for the project will encompass research, design, and implementation. The completion date for an operational prototype is scheduled as April 1, 2007; hence, the project's cycle will span a 13-week period. The estimated budget for the project is 1000, which we expect to obtain from a variety of sources.

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1. Introduction

History persistently reveals the stories of the mutual influence between composers and choreographers. The interconnection and mutual interest between musicians and choreographers has resulted in numerous projects combining arts, media, and engineering fields.

During the past decade, the technology of motion sensors 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. Among the list of projects accomplished to this end, the well-known motion sensing device, Very Nervous System (VNS) created by David Rokeby is of great popularity and importance.

The objective of our project is to develop a comprehensive motion capture system that will sense the exact detailed movement of a moving object; and thereafter, based on the data obtained from the markers, the 2D motion of the object will be simulated on the computer. The simulation can be accomplished by mounting several optical markers on the object and then auto capturing several frames using a webcam in a way that in each frame only one of the markers is on. Having captured the required frames, the data is then transferred to analytical software which compares these frames to detect any motion and performs further analysis and simulation of the obtained information. In order to verify the functionality of the motion tracking system and the extent of the system's accuracy, the custom-made programmed software will simulate the physical movements of the dancer and all the corresponding trajectories, along with under taken paths, will be generated on the computer revealing the proper functionality of our sensing system.

The accurate motion tracking of an object which is the ultimate aim of our project is of high interest and importance; one of the most important applications of our system is in the music composing and conducting industry. The data obtained from the analytical software can be fed to composition software to create composition data and then directed to Synthesizer software to generate the corresponding audio sounds. Recently, the project of music generation based on motion of a dancing performer is being held integrally between three departments of Engineering, Computing, and Music at SFU, and in fact, our research- based project's prospects to be employed as an analysis tool to study dance movements in the bigger project are excellent.

The proposal provides an overview of our project, outlining design considerations, sources of information, funding, and project scheduling. Alternate solutions and existing forms of the system are discussed and critiqued. Projected financial requirements and sources of funding are provided, as are project, Gantt, and milestone charts.

2. System Overview

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. The functional description of the 2D motion capture system can be illustrated in the following diagrams.

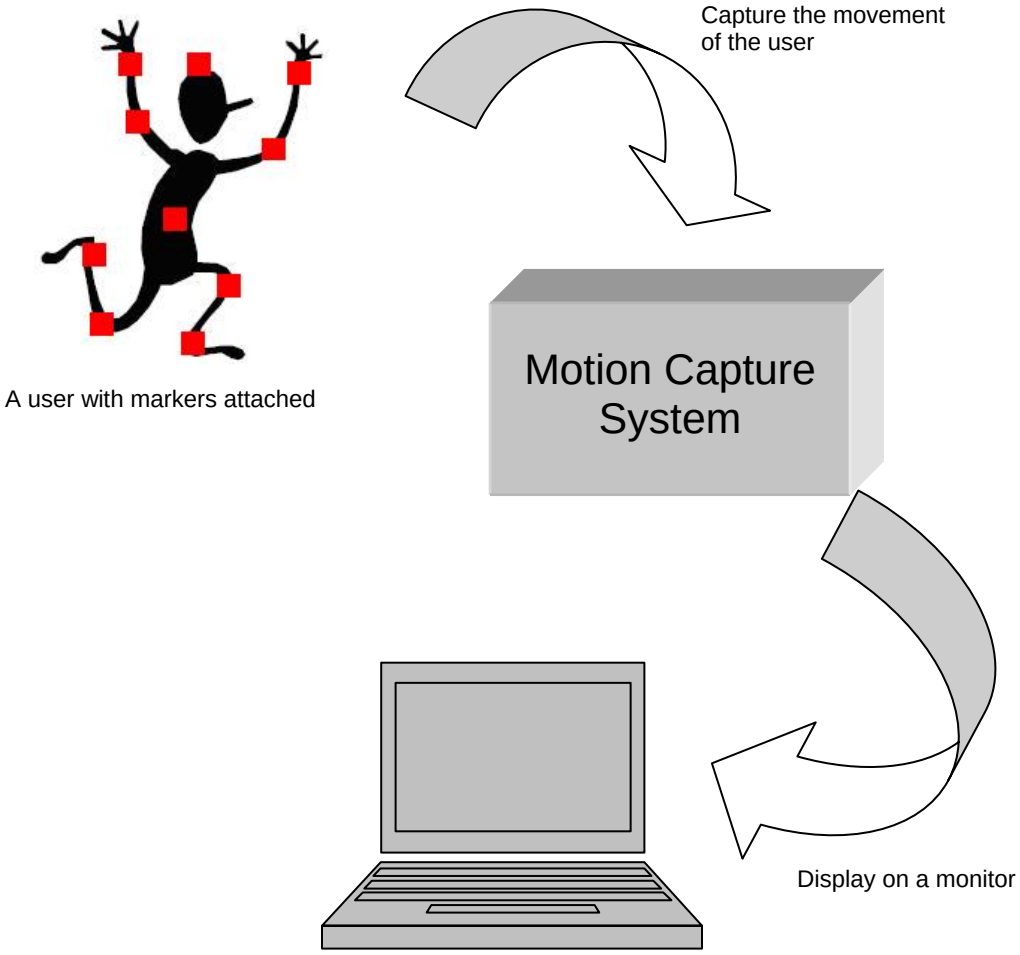

Figure1: Graphical description of the system

Figure 2 illustrates how the system will be processed. When the system is activated by the user, the USB webcam starts capturing frames from a dancing doll (moving object) in a way that in each frame only one of the markers is on. These frames will be analyzed and processed in analytical software. The animation software then, creates a two dimensional animation image based on the data received from the analytical software and displays it on a monitor. The process is repeated until the user deactivates the system.

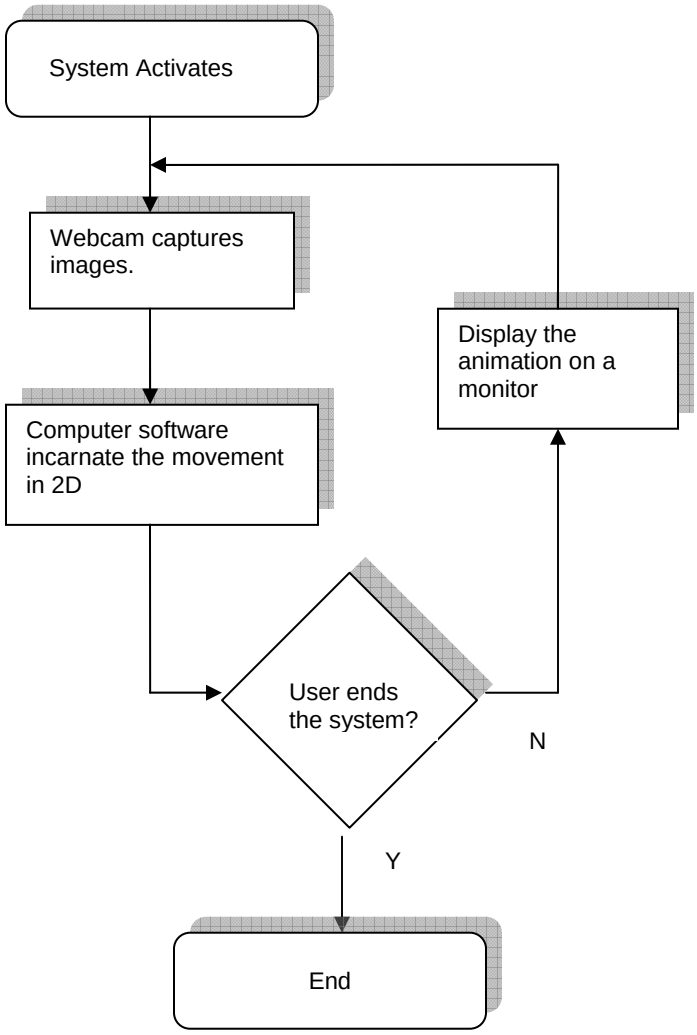

Figure2: Flow chart of the system

3. Possible Design Solutions

Currently, with the rapid growth of new technologies and the existing diversities, many different methods to capture or track motion have been developed. Each procedure has its own specifications and advantages and considering the requirements and specifications of the project undertaken, the best suitable method can be selected accordingly. Some of the possible technologies currently used are listed below.

The first method is the Optical system. Optical systems as evident from their title, utilize cameras which capture continuous projections of the performer; these motion captures are then transferred to the computer software for further analyses of positions, angles, velocities and other physical parameters. Note that two types of Optical systems are available in the market, Passive and Active optical. The basic difference between the Passive and Active systems is the fact that in Active systems, every single system marker has a distinguishable identity. In other words, each marker is recognized by the optical system within the other markers which provides the Active optical systems with higher resolution compared to their Passive counterparts.

The next capture system is the Magnetic systems which utilizes sensors possessing transmitters and receivers. Magnetic systems calculate position and orientation by the relative magnetic flux of three orthogonal coils on both the transmitter and each receiver. The range and orientation is calculated by mapping the tracking volume to the relative intensity of the voltage or current of the coils. The disadvantage of these systems is the fact that the wiring from the sensors tends to preclude extreme performance movements.

The third category of tracking technologies is the Acoustic tracking system which uses ultrasonic frequencies for motion tracking. The system consists of a set of microphones and speakers; the microphones emit ultrasound pulses that are captured by speakers. Multiple speakers and microphones are used to properly locate the sensor. The tracking method utilized has several advantages of not being impacted by materials, being able to reach longer ranges and being available in fairly small sizes. But the main problem with these systems is the fact that they need a clear line of sight between transmitters and receivers.

The last category of capturing systems is the Mechanical motion capture systems. Mechanical systems directly track body joint angles. Due to the way the sensors are attached to the body, Mechanical systems are often referred to as exo-skeleton motion capture systems. A skeletal-like structure is attached to the body of the performer and as the performer moves, so do the articulated mechanical parts, and therefore, permit measurement of the performer's relative motion. The advantages of Mechanical systems are that they are real-time, relatively low-cost and, with wireless systems, have unlimited capture volume.

4. Proposed Design Solution

Our Proposed solution is to build a wearable wireless optical markers network as an object movement tracking device. Our project is a research- based project which has the potential to be used as an analysis tool to study dance movements in a bigger project, Dance- Music Project (DMP)[1]. DMP is to be undertaken integrally between the departments of Engineering, Computing, and Music at Simon Fraser University, and the main goal of the project is to compose or conduct music and to perform light settings based on the motion of the dancer in performance.

Our company is not the first group who has addressed the notion of capturing and tracking motion; many available technologies have accomplished similar functionality. However, the use of wireless optical markers and USB webcam network eliminates the disadvantages existing for alternative technologies. Our wireless network is able to precisely track object's movements with the advantages of eliminating wires, ease of use, and ease of reconfiguration. Furthermore, since the markers emits infrared light, the user is not able to detect the light and thus continuous changing state of the markers will not interfere with the user's performance. The system also avoids the interference from the environment and lastly it utilizes low-cost and potentially exchangeable markers.

Certainly, designing such a wireless system with high accuracy and high resolution requires a significant amount of money and time. Thus the main constraints in completing the project are the limited budget and timeframe. SensIT is investigating funding from engineering department at SFU and hopes they will provide an adequate amount of funding. Further, the project spans only for about four months and obviously many tasks must be accomplished within this time by only four students. By end of the four months, we are aiming at a simple prototype module which will be versatile for the startup step for DMP.

Having allocated more time and funding for the project, we would be able to expand more toward the point where the system captures the positions, angles, velocities, accelerations and impulses of different joints of an actual dancer in three dimensions. Alternatively, wireless sensor network can be used for the physically impaired, for enabling them to compose music based on their physical body movements captured by the sensing network. And lastly the sensing system output could be utilized to control the lightings and/or volume control of audio speakers system in a concert theater.

The number of applications for motion capture system is considerable. For our ENSC 440 project, however, we have decided to design the module specifically for purpose of analyzing dance movements; hence, it is specifically designed to be satisfactory for a dancer.

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[1] This is not the actual name of the project. The actual name has not yet been decided; DMP is just for the purposes of this paper for the easier reference to the project.

5. Sources of Information

The movement capturing or tracking system has been researched in many institutes including universities and industry laboratories over the past years. Many applications are now available in the market. For example, Nintendo's new game console Wii was released on November 19, 2006 in North America and it is now taking the second leading position in the market. The Wii console includes a specially designed game controller which can detect its own movement.

The Movement Capture System team believes that many references are available to take advantages of. The project has been discussed with Lakshman One, the lecturer in the School of Engineering Science at Simon Fraser University and it has a potential to become the startup project of a bigger one which provides the team a great source of information and funds.

In technical aspect, many references are available such as communication course text books, publications, and open online references. The online references will be the main source of information. Human movement tracking using a wearable wireless sensor network written by Yifei Wang at Iowa State University is one of the great sources available. The team found that several researches have been carried out at Simon Fraser University which gives us the opportunity to directly contact professors and related people for advice and direction; for example, Human Movement Tracking Technology written by Axel Mulder at Simon Fraser University, shares very similar goal of the team.

And finally, an expert in the fields of animation, robotics, and sensors would be of a great value as a potential reference for our project. The expert could potentially help us in the initial selection of the most suitable sensors for our purpose and also in the stage of manipulation and analyses of sensors data in order to animate and simulate the movements of the performer on computer monitor. We will be contacting Dr. Shahram Payandeh and Dr. Boney Gray for their valuable experience and knowledge of the related fields.

6. Budgets and Funding

6.1 Budgets

Table 1 outlines a tentative budget for the wearable wireless sensor network. All the sub-components have been grouped to the corresponding functional units. For instance, all the mounted transmitters on the performer are grouped in the Sensors/markers + interface-electronics unit. The Computer interface-electronics also include an Analogue-to-Digital converter. Most components have been overestimated by at least %15 to compensate for contingencies.

Table 1: Tentative Budget

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

6.2 Funding

As of any design process, the initial engineering process will require more capital than that of the estimated value for the prototype production.

Considering the high cost associated with our project, several sources of funding are being considered. The most primary fund being considered is the inter-disciplinary Grant from SFU. Due to the mutual interest of Art and Engineering departments in our project, negotiations have started for an inter-disciplinary grant sponsored by SFU. Secondly, SSI which is the application procedure for the Engineering Science Student Endowment Fund is also being taken into consideration. Lastly, the Learning Disabilities Association of BC which has an allocated funding source on potential projects and researches has been contacted due to our project's potential application on the physically impaired motion tracking for music composing or other applicable fields.

All our team members have accepted the fact that the team may not be able to collect enough initial capital to sufficiently fund the entire project. In such circumstances, our team members are willing to share any remaining financial costs of the project equally. An accurate recording of all financial transactions will be kept to ensure the proper reimbursement to the team members.

7. Schedule

The Gantt chart in Table 2 shows the general breakdown of tasks as well as the amount of time spent to execute each of them. Also, a Milestone chart is shown in Table 3 which corresponds to the deadlines of certain tasks.

Table 2: Gantt Chart

ID	Task Name	Jan '07				Feb '07				Mar '07				Apr '07				
		31	7	14	21	28	4	11	18	25	4	11	18	25	1	8	15	22	29
1	Research																		
2	Proposal																		
3	Functional Specification																		
4	Design Specification																		
5	Hardware Design																		
6	Software Design																		
7	Integration/Prototype Testing																		
8	Debugging/Prototype Modification																		
9	Presenation/Demo																		
10	Documentation/Google Documents																		

Table 3: Milestone Chart

ID	Task Name	Jan '07				Feb '07				Mar '07				Apr '07				
		31	7	14	21	28	4	11	18	25	4	11	18	25	1	8	15	22	29
1	Proposal				Mon 1/22														
2	Written Progress Report						Mon 2/5												
3	Functional Specification								Mon 2/19										
4	Design Specification										Mon 3/5								
5	Oral Progress Report												Thu 3/15						
6	Documentation/Google Documents														Thu 4/5				
7	Presentaion/Demo															Tue 4/10			

8. Team Organization

Successful projects require a great deal of origination to ensure that the required skills and expertise are available. The team members selection was not random but rather took into consideration their strengths and interests. The members selected and their majors are: Sa'ed Abu-Alhaija (Electronics Engineering), Azadeh Jamalian (Systems Engineering), Ivan Lee (Computer Engineering), and Atae Naemi (Systems Engineering). The electronic, mechanical, and software tasks require a variety of specializations and therefore, each team member will contribute significantly to the project. All of the team members are enthusiastic and looking forward to the challenges ahead.

For the sake of efficiency and accountability, different team members have been assigned specific titles. However, the structure is fairly informal and each team member will be involved in a variety of tasks. Azadeh Jamalian was nominated to be the President and Chief Executive Officer (CEO). She will make sure that the project is executed as planned and will deal with any general issues that arise. Finding funds and managing finances are some of the responsibilities of Ata Naemi who is the Chief Financial Officer (CFO). The Hardware Manager will be responsible for the development of the tools required to capture the motion is filled by Sa'ed Abu-Alhaija. Finally, Ivan Lee is the Software Manager and he will be responsible for the development of computer program to visualize the motion.

The team's meetings are more often at the start of the project to ensure that the responsibilities are distributed evenly and to make decisions on the specifications of the project. A timesheet of the members' available times has been constructed and is available online through Google Documents which is a great tool of communication between team members. Any team member can add topics to the meeting's agenda in advance. We also use Google Documents to make announcements and discussions. Throughout the semester, we will be having regular meetings to discuss the progress of the project and resolve any conflicts. A different person takes minutes at each meeting and uploads them online for the whole team. The duration of each meeting is usually 30 minutes to 1 hour depending on the agenda. Team members missing during the meeting can access the meeting's minutes and view the tasks assigned to them.

The assignment of tasks is usually carried out on volunteer basis but at the same time, making sure the work load is distributed fairly. The team does not lack the required skills and enthusiasm as each team member has a great interest in the project. The design of the complete Motion Capture System is complex but we will set different targets as the project progresses. Executives and managers have to ensure that the goals are met on time.

"Warning: You Are Already Behind Schedule" is an advice from a previous TA which motivated us to start planning and thinking about the project as soon as we settled on the idea. The team is determined to execute the project successfully as well as support each other technically and morally.

9. Company Profile

Azadeh Jamalian - President and CEO

I am a fifth year Systems Engineering student at Simon Fraser University with two co-op terms finished at Photo Violations Technologies. My field of strength is digital/ analog signal analysis and conditioning as well as analog/digital circuit design. In addition, through course work and work experiences I have gained programming skills in C, C++, Java, and assembly languages. Some of my main projects involved designing a channel fading simulator implemented in MatLab, designing a circuit to display composite baseband video signals on the screen of an analog oscilloscope, and designing switching voltage regulators by the TL497. In addition to all, I have hands-on experience in testing and troubleshooting and have excellent communication and team working skills.

Atae Naemi - Chief Financial Officer

I am a fourth year Systems Engineering student at Simon Fraser University with three co-op terms at Broadcom. My field of strength in hardware is analog and digital circuit design along with circuitry analyses. Regarding my software skills, I have the familiarity to programming in C, Java, Assembly, VHDL, and scripting languages (Tcl and Perl). Some of the projects that I have been involved with in the field of Systems option, design and modeling of the SCARA robotics system programmed in C, and analysis and process control of a surveillance robotic system. And lastly with my business, marketing and problem solving skills I would contribute positively to the team.

Sa'ed Abu-Alhaija - Hardware Manager
I am finishing the last year of my Electronics Engineering Degree at SFU. During the past four years, I have gained a strong background in analog and digital design as well as developed excellent programming skills in MatLab, Java, C, and assembly languages. My one year Co-op at QImaging involved designing a large number of CCD PCBs used in their latest cameras. I was also in charge of converting all of the QImaging cameras (electronics and mechanics) to RoHS compliance (the restriction of the use of certain hazardous substances). I have expert knowledge of Protel DXP to design the schematics and layout of PCBs. My project planning and teamwork skills will prove useful throughout the project and I am looking forward to working with my group members.

Sunghoon Ivan Lee – Software Manager

I am a fourth year Computer Engineering student at SFU with three co-op terms finished. My field of strength is designing, planning and managing software development as well as digital and analog communication analysis. In 8 months contract with VTech Telecommunications, I designed and programmed software in C and LabVIEW which communicates with an external digital machine. I am currently working on my bachelor's thesis which is an advanced research in video compressing and experiment in MatLab.

10. Conclusion

SensIT Technology is devoted to researching, designing, and developing a comprehensive motion capture system that will sense the movement of a dancing doll, and simulate its movements on computer based on the obtained data from the markers. The project is research based and is intended to be used as an analysis tool by the interested professors and researchers at SFU to investigate the music composition based on dance movements.

The *Motion Capture System*, utilizing wireless optical network technologies, will have the advantages of elimination of wirings, ease of use, and ease of reconfiguration over alternative motion capture systems being employed in other fields such as biomedical research, sports, video games and animation industries. In addition, SensIT system will be cost efficient, mobile and reliable.

The proposed schedule shows how the project will be preceded and budgets and funding will cover the financial aspect of the project. Sources of Information well explain where the team reference information in order to design the system.

The team is formed with the best four engineers in the field. Their skills, experiences and desire will lead the team to successfully complete the task.

Sense the new joy of life!

Sense It!

11. Sources and References

1) Mulder, Axel. **"Human movement tracking technology"**. *School of Kinesiology, Simon Fraser University*. July 1994

2) Tauler, Jaime. **"Virtual Dance Monster (VDM)"**. *Digital Arts and Compute Science, Stetson University, Deland*.

3) Wang, Yifei. **"Human movement tracking using wearable wireless sensor network"**. *Iowa State University, Ames, Iowa*. 2005

4) **"Dance and Media Technologies"**. *MIT Press Journals, Vol. 24, No.1*

5) **"International Journal of Human-Computer Studies"**. *Volume 59, Issues 1-2*

6) Wikipedia, The Free Encyclopedia. <http://www.wikipedia.org/>