SONITUS SOLUTIONS

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September 24, 2003

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

Re: ENSC 340 Project "Precision ultrasonic 3D motion tracking"

Dear Dr. Rawicz,

Attached is the *Functional Specifications* for our ultrasonic 3D motion tracking system. The purpose of this system is to track the movements of a user and feed the data into any personal computer in real time.

The *Functional Specifications* outline every requirement in this project. These goals include physical characteristics, hardware performance, as well as software design. We will also be providing a test plan to which we will adhere to in order to ensure that we meet our goals.

Sonitus is composed of six highly motivated and resourceful individuals: Alan Chuang, Kenneth Fong, Henry Lin, Warren Lee, Edward Loo and Richard Sheng. If you have any questions or concerns about our proposal, please feel free to contact us by phone at (604) 771-9719 or by e-mail at sonitus-340@sfu.ca.

Sincerely,

Richard Sheng

Richard Sheng
President
Sonitus Solutions

Enclosure: Functional Specifications of the 3D Movement Tracking System

Functional Specifications for a 3D Ultrasonic Motion Tracking System

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Executive Summary

In today's changing world, technology is advancing at a rapid pace. As users demand more and more advanced programs, application software is moving into 3D space. At Sonitus Solutions, we see that the market is ripe for a 3D input system. Thus, we have decided to create the Sonitrac. Sonitrac is a system that will use ultrasonic transmitters and receivers in order to track the location of various modules placed on the user's body. Software will then interpret that information for its own use.

In stage one of research and design, Sonitus Solutions plans to create a prototype of the Sonitrac. The prototype will be able to:

- Transmit and receive ultrasonic signal
- Send data into the PC through the RS-232 serial port
- Correctly triangulate the position of each transmitter
- Display the positions of the transmitters in a graphical manner in real-time
- Save the positions of the transmitters into a text file

In stage two, Sonitus Solution will be developing a production model of the Sonitrac, which will implement all of the functions we plan for in the final product. Some of these functions include:

- The ability to pause the system using a button on the mobile unit.
- 2D positional graphs on selected channels, in which velocity and acceleration graphs can be derived and displayed.
- Display an orthogonal representation of the user, which will further develop into a 3D representation using Direct3D
- Load and replay a saved session
- Seamless switching between battery power and AC power in the base station
- Recharging mobile unit by attaching it to base station

Stage one of design is to be completed by December, 2003. Stage two of design will be contingent on the result of the prototype, which would give a clear indication of the feasibility and effectiveness of Sonitrac.

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1. Introduction

This document is the functional specification of Sonitus Solution's Sonitrac. Sonitrac is a 3D tracking system that will use ultrasonic technology in order to determine the location of numerous modules. With the modules placed on the body of the user, Sonitrac will be able to determine the posture and movements of the user in real-time. Software will then be able to use this data for various purposes such as displaying them on screen as a 3D model of a person. This is an example of one of the numerous applications possible with this system, and will be the objective of stage two of research and design.

1.1. Scope

The main purpose of this document is to outline the functional goals of this project. These targets include user interface descriptions, as well as hardware and software requirements. A test plan is also outlined to ensure that the final product meets all the specified requirements.

1.2. Glossary and Abbreviations

GUI	Graphical User Interface
LED	Light Emitting Diode
P3DMTS	Precision 3D Motion Tracking System
R&D	Research and Design
RAM	Receiver Array Matrix
RF	Radio Frequency
STP	Standard Temperature and Pressure
Channel	An active transmitter whose coordinates are to be determined
Failure	The system ceases to detect an object's position, and cannot resume without human intervention.
Receiver	A device which reads in a signal
Transmitter	A device which sends out a signal
User Space	The area in which the user is expected to be in when using the system

1.3. Notation:

The following conventions are used to designate the requirements for the design of the *Precision 3D Motion Tracking System* (P3DMTS).

R_#.#-$ -designates a requirement where the blank is replaced by:

D -for Documentation & User Training
G -for General requirements
H -for Hardware requirements
S -for Software requirements
T -for Test Plan requirements

And the $ is replaced by:
1 -indicates the specification is required only for the prototype unit
2 -indicates the specification is required only for the production unit
3 -indicates 1 & 2

2. System Overview

Sonitus Solutions has chosen to use the acoustic technology for Sonitrac, which consists of a base station, a mobile unit, a receiver array matrix, and a PC software user interface. The receiver array matrix will be composed of receivers attached on a rigid frame that defines the allowable user movement space. Receivers will detect ultrasonic waves emitted from the transmitters of the mobile unit attached at various locations on the user. The base station will then provide the elapsed time of the detected sound waves to the PC software, which will pin-point the exact coordinates of each transmitter channel. The software user interface will then display correspondent orthogonal 2D images of the user body.

Sonitrac will be a superior product because it allows flexibility of space, provides cost efficiency and accuracy, and is lightweight and easy to set-up. Users only have to connect the base station to their computer through the serial port and run the software. After setting up the four receiver poles around them, the user can attach the mobile unit and the sensor bands on to their body. Once the user is ready, they can control the program via the mobile unit. Please see the figure below for a visualization of the product.

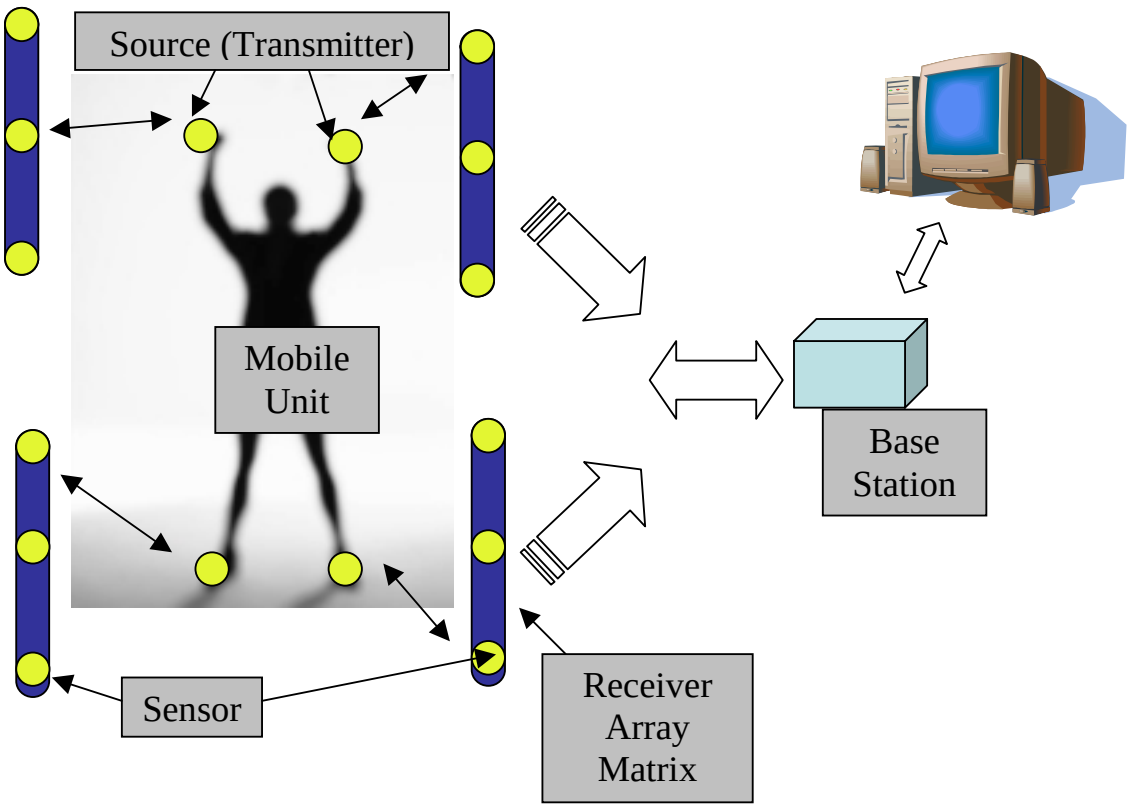

Figure 1: System Overview

3. Design Requirements

The following is a list of characteristics that we will build into Sonitrac. The list is separated into five major sections: Overall Performance, Software, Hardware, Reliability & Serviceability and Documentation & User Training

3.1. Overall Performance

RG 1.01-3 The system should be able to determine the coordinates of an object accurate to ±0.01m at STP.

RG 1.02-3 The overall system delay should not exceed 20ms.

RG 1.04-3 The P3DMTS should be able to track the object within a 15.625m^3 volume

RG 1.05-1 For demonstration purpose, the system should be able to update coordinates of each transmitter (channel) module at a rate of 10Hz.

RG 1.06-2 The system should be able to update the coordinates of each transmitter modules at a rate of 1 KHz.

3.2. Software

3.2.1. User Interface

RS 1.01-2 The system should allow the user to determine the camera position (viewing angle).

RS 1.02-1 The system should provide an orthogonal 2D representation of the human body (or portion of) while updating the positioning in real-time.

RS 1.03-2 The window size can be set to “full-screen” mode or set to a normal resizable “window”.

RS 1.04-2 The pause button located on the Mobile Unit allows the user to pause the system. Once this button is pressed again, the system will continue running.

RS 1.05-3 Data (the coordinates received) will be logged into a text (.txt) file of particular channels chosen by the user, where the file name is saved as the date and time of the session.

RS 1.06-3 The program can be exited through the File menu, or by simply pressing the ‘x’ button on the right-hand top corner.

RS 1.07-2 2D positional graphs can be obtained on selected channels, in which velocity and acceleration graphs can be derived and displayed.

RS 1.08-2 The display character's size will be proportional to the actual size of the user.

RS 1.09-2 3D representation of the user will be displayed using Direct3D.

3.2.2. Operating Conditions

RS 2.01-3 The system will run on Windows 98 or higher.

RS 2.02-2 The system requires DirectX 7.0 or higher installed.

RS 2.03-3 The system will run on a computer with the following specifications:
Minimum System (PC): 266MHz CPU, 32Mb RAM 2Mb Graphics Card, 10Mb Free Hard-Drive space
Recommended System (PC): 450MHz CPU, 64Mb RAM, 16Mb Graphics Card, 50Mb Free Hard-Drive space

RS 2.04-3 The system requires a RS-232 serial port on the computer used.

RS 2.05-3 The system software will be installed through an executable install file provided in our install CD.

3.3. Hardware

3.3.1. System Specifications

3.3.1.1 Environmental

RH 1.01-3 The system should not produce more than 30dB at a frequency lower than 20 KHz.

RH 1.02-3 The system should not produce any effect detrimental towards wildlife outside a radius of 50m.

RH 1.03-3 The system should not emit any identified harmful radiation.

3.3.1.2 Operating Conditions

RH 1.04-3 The system should operate between the temperatures of 0 to 50°C.

RH 1.05-2 The system should remain functional between the air pressure range from 0.9 to 1.1 atm.

RH 1.06-3 The system should remain functional under all domestic humidity.

RH 1.07-2 The system should resist an impact of 3 G's.

3.3.2. Base Station

3.3.2.1 Power Management

RH 2.1-3 The base station should be able to run on a regular 120V 60Hz outlet.

RH 2.2-2 If the regular outlet power is disconnected, a 9V backup battery should automatically power the base station.

RH 2.3-2 The transition between outlet power and battery power should not disturb the normal operation of the system.

RH 2.4-3 The base station should not consume more than 1W of power.

RH 2.5-3 The maximum instantaneous current dissipation should not exceed 500mA.

RH 2.6-3 There will be a power on/off button and a power LED.

RH 2.7-2 A LED will be implemented to indicate when the back-up battery powers the base station.

3.3.2.2 Physical Dimensions

RH 2.8-3 The base station should not be larger than 0.3m x 0.2m x 0.1m

RH 2.9-2 The base station should have adequate ventilation holes.

3.3.3. Receiver Array Matrix

RH 3.1-3 The RAM will receive its power from the base station.

RH 3.2-3 The RAM will buffer the received signal to be used by the base station

RH 3.3-3 The height of each pole will be 2.5m tall.

RH 3.4-3 The RAM should encapsulate a volume of 15.625m^3.

RH 3.5-2 The RAM should be foldable and occupy less than 0.1 $m^3$of storage areas.

3.3.4. Mobile Unit

3.3.4.1 Power Management

RH 4.1-3 The mobile unit is powered by a 9V battery.

RH 4.2-2 The 9V battery will be rechargeable within the mobile unit by attaching it to the base station.

RH 4.3-3 The mobile unit will not consume more that 0.5W.

RH 4.4-3 A power switch and a power LED will be implemented.

3.3.4.2 Physical Dimensions

RH-4.5-3 The mobile unit should be no larger than 0.15m x 0.08m x 0.03m

RH-4.6-3 The mobile unit should weigh more than 0.5kg (excluding body suit)

RH-4.7-3 The mobile unit will be mounted onto the user.

3.3.5. Interfacing

RH 5.1-3 The base station will communicate with the PC using a RS232 (serial) connection.

RH 5.2-3 The baud rate of the serial communication should be at least 115.2 kbps

RH 5.3-3 An RF communication channel will be established between the mobile unit and the base station.

RH 5.4-3 The RF module will transmit with a carrier frequency of 913MHz.

RH 5.5-3 The RF module transmits at a rate of 40kbps.

RH 5.6-3 The mobile unit will generate a 40KHz ultrasonic signal.

RH 5.7-3 The RAM will detect the ultrasonic signal generated by the mobile unit within the user space.

3.4. Reliability & Serviceability

RG 1.1-3 The unit should have a mean time between failure (MTBF) exceeding 1,000 hours. (3)

RG 1.2-3 The buttons and switches should have a duty cycle of at least 1,000,000 cycles (3)

RG 1.3-3 The unit should not be serviceable by the end user. (1)

3.5. Documentation & User Training

RD 1.1-1 Documentation for mock-up version of this device will consist of a user manual with instructions in English.

RD 1.2-2 Documentation for the production version of this device will consist of a user manual with instructions in English, Spanish, Japanese, French and Chinese.

RD 1.3-1 The user manual will be written for an audience with minimal experience with electronics devices, and include descriptions of basic functionality.

RD 1.4-2 The manual will also include material for more experienced users such as using the various advanced graphing features, and data loading.

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RD 1.5-3 The manual will also include a troubleshooting section.

RD 1.6-3 Some user training will be necessary for the use of this device.

RD 1.7-3 Training for the production device will be provided by the unit's documentation and a trained service personnel.

RD 1.8-3 Users of the proof of concept device will be instructed by the project developers, or must use the device under the supervision of the project developers.

4. Test Plan

In order to ensure that we were successful in our implementation of the functional specifications, we have devised several test plans. These tests shall be passed for the system to function as expected.

4.1. TH.1 Ultrasonic Transducers

Tests on the functionality of the transducers will concentrate on their sensitivity over distance and orientation.

Procedure

A 40KHz, 20V peak-to-peak sinusoidal signal will be applied to the ultrasonic transmitter terminals. The output from the receiver terminals will be measured along with the relative position and orientation of the two units.

4.2. TH.2 RS232 Communication

Tests will be conducted to ensure the reliability of hardware to PC communication.

Procedure

Test data will be sent from the base station to the PC through RS232 connection. The received data will be compared to the actual data being transferred.

Pass Condition

The received data equals the transferred data with 80% accuracy.

4.3. TH.3 RF Communication

Tests will be conducted to ensure proper data communication between the Receiver Module and the Transmitter Module.

Procedure

Test data will be generated by the function generator and applied to the Transmitter Module. The output will be compared at the Receiver Module for accuracy.

Pass Condition

The Received Data equals the Transferred Data with 95% accuracy

4.4. TH4 Power-stress Test

Tests will be conducted to ensure the durability of the power supply circuitry of all units.

Procedure

1) Apply the proper voltage to the power terminals and leave on for 24 hours.
2) Rapidly turn on and off the power to the system.

Pass Condition

The units are still functional after these two stress tests.

4.5. TH5 Ultrasonic Receiver Circuitry

Tests will be conducted to determine the performance of the Receiver Circuitry and modifications will be made to meet requirements as per the functional and design specifications.

Procedure

Apply a 20V peak-peak sinusoidal input to an ultrasonic transmitter and set up various distances and orientations relative to the Receiver Circuitry. Observations will be recorded at the output of the Receiver Circuitry.

Pass Conditions

Each parameter observed meets the requirements as per the design and functional specifications.

5. Conclusion

We at Sonitus Solutions believe that these requirements will specify a product that has excellent performance and unsurpassed usability. By following these specifications, Sonitrac will have outstanding potential to compete with other existing solutions in the research market or entertainment industry. Stage one of R&D is scheduled to be completed by December, 2003. Scheduling for Stage two will be contingent on the results of our proof-of-concept module.

6. Referenced Materials:

http://www.cs.sfu.ca/~amulder/personal/vmi/HMTT.pub.html

http://www.cs.sfu.ca/~amulder/personal/vmi/HMTT.add.html#acoustic

http://www.wave-report.com/tutorials/MoTrak.htm

http://www.ensc.sfu.ca/users/whitmore/public_html/courses/305/305.htm

http://www.ensc.sfu.ca/undergrad/euss/essef/index.html