September 13, 2012

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

Re: ENSC 440 Project Proposal for a Motion-Controlled Manipulator

Dear Dr. Rawicz,

The *Proposal for a Motion-Controlled Manipulator* is attached with this letter, which summarizes our project planning. In this project, the core idea is to design a software system to control arm-like manipulators by motion sensing of the arm and hands.

This proposal will start with an introduction explaining the inspiration of our idea. Then, a system overview will be presented, followed by detailed sub-system explanations. In each part, the expected problems and planned solutions will be illustrated as well. This document also contains potential future development and markets.

MotiCon is composed of six enthusiastic and creative engineering students: Kevin Wong, Kay Sze, Jing Xu, Hsiu-Yang Tseng, Arnaud Martin and Vincent Wong. If you have any question, please feel free to contact us by phone at 778-889-9950 or by email at vpw1@sfu.ca

Sincerely yours,

Vincent Wong
President and CEO
MotiCon

Enclosure: Proposal for a Motion-Controlled Manipulator system

Motion-Controlled System For Multi-Purpose Robotic Arm Operations

Kinect-based, remote-controlled Manipulator

Project Team: Vincent Wong
Jing Xu
Kay Sze
Kevin Wong
Hsiu-Yang Tseng
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Submitted to: Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science

Executive Summary

> *Some surgeons with extensive robotic experience say it takes at least 200 surgeries to become proficient at the da Vinci and reduce the risks of surgical complications.* [1]

Unsuccessful surgeries by the “da Vinci” robot due to surgeon inexperience, and training doctors to use the device are costly for hospitals and can be attributed to the poor and unintuitive controlling interface. Undeniably, intuition is a powerful aspect in controlling robotic arms such as the “da Vinci” robot, which presents a steep learning curve due to the difficult controls [2]. Other anthropomorphic robotic hands, such as Cartesian, cylindrical and spherical robots for pick-and-place work, also face similar issues with using complicated joystick and button controls.

Our company offers a solution for the users to control their robotic hands, by offering a “blackbox” to integrate a high-resolution depth sensor to control robotic hands. The benefits of this product are to:

- Offer a simpler and less expensive method of controlling a robotic arm
- Utilize intuitive hand and arm movements to control, therefore reducing the learning curve
- Increase the degree of freedom and flexibility of registered hand movements

MotiCon consists of two PhD students in Engineering, Jing Xu and Hsiu-Yang Tseng; and four Undergraduate Engineering students, Vincent Wong, Kevin Wong, Arnaud Martin and Kay Sze, all of whom have vast experience in analog/digital design, software programming and mechanical design.

The engineering development we are proposing for this project will consist of research, design and construction of the product. The development will span 13-weeks and result in an operational prototype to move a robotic arm (with at least of 5 DOF), will be completed on December 10, 2012. Overall, the tentative budget for this project is $975, which will be obtained from several sources detailed in the corresponding “Budget and Funding” section.

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1. Introduction

"As far as the customer is concerned, the interface is the product." - Jef Raskin

As technology advances worldwide, controlling machines becomes increasingly difficult and complex for people. For example, as the number of degrees of freedom increases, so does the number of commands the manipulator has to receive, which increases the steepness of the learning curve and makes controlling less intuitive for users. This is an issue in the industry because companies have to spend unreasonable amounts of money to train their employees to use specific machines.

MotiCon is now offering a way of using an infrared depth sensor to remotely motion-control a robotic arm. This new technology uses the arm motion to precisely control a pre-defined manipulator, which helps users to intuitively control the robotic device. For example, the user would only have to move the wrist in order to change the orientation of the "EndoWrist" on the da Vinci robot, which is far more intuitive than using the corresponding joystick.

Imagine, a world where the only thing the user has to do is show the motion he wants the robot to perform. With our solution, industrial companies can reduce their expenses by adopting the motion-controlled manipulator because workers will easily understand this intuitive new way of controlling. Companies will not have to pay large amount for employees to be trained to their specific robotic implementations. In the medical field, biomedical devices such as the "da Vinci" robot can now be operated by hand motions of the surgeon. And for weak and frail hospital patients, robotic substitute arms can be controlled by small movements to allow hand grips for patients. With this new technology, **MotiCon** can improve the works and lives of thousands of people by transforming a simple motion into complicated robotic arm commands.

This document provides an overview of our product, discussions on the prototype design and funding of this project as well as on the team management and the scheduling planned for this collaboration.

2. Product Overview

In our system implementation, we will design a system with several inputs and outputs. The input will be obtained by a single infrared projection onto a certain area. The infrared rays will disperse on the incident surface, which may include moving body parts, and reflect into the infrared sensors of the system. These will produce the input, and through signal processing of the acquired light, the system will produce the corresponding output voltages into a mechanical device, such as a robotic arm or manipulator, which will imitate the motion detected by the moving body part. Here is a figure displaying our system implementation as a "Black Box":

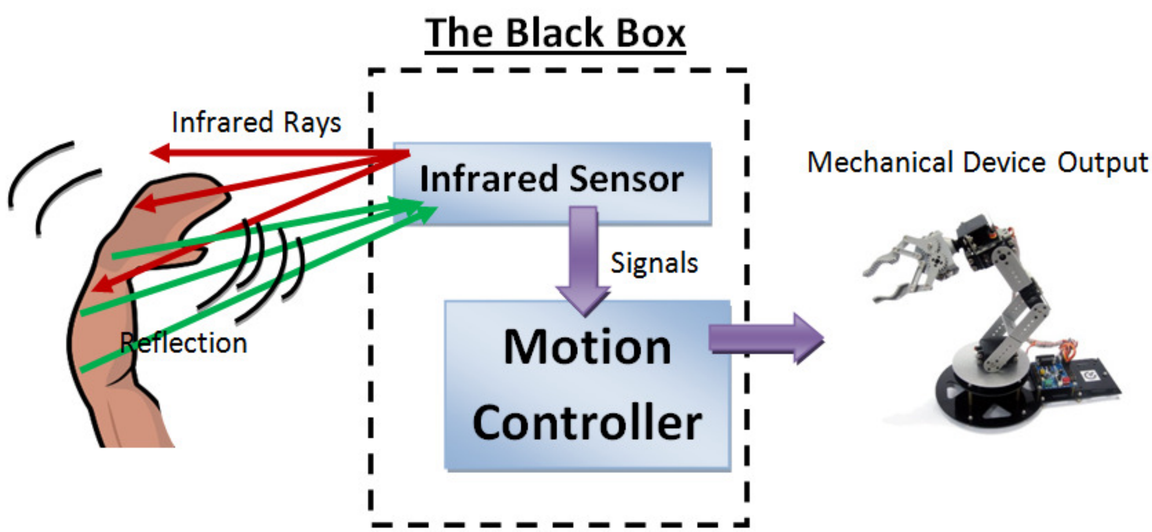

Figure 1: Concept Overview

The "Black Box" shown consists of an infrared emitter and sensor, and a MotiCon Motion Controller. The inside of the "Black Box" will be invisible to the user, which will only have access to the programmed interface. The motion controller can be expanded into three components, an infrared/RGB sensor, a processor, and a microcontroller.

3. Prototype Overview

Here is a flow chart describing our prototype exactly as these components inside the “Black Box”:

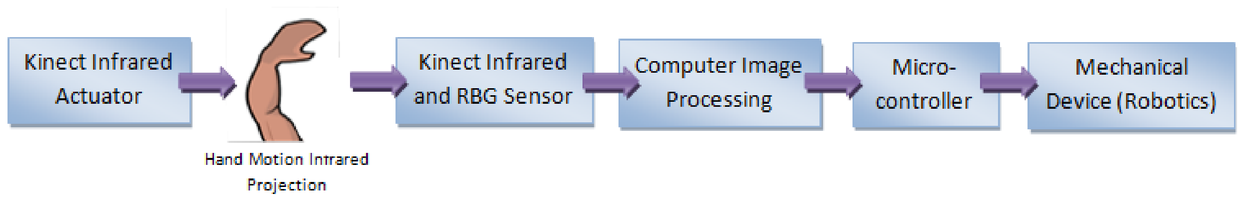

Figure 2: Data Flow Chart

Each of the prototype components in this flow chart will be described in detail in the following subsections.

3.1 Kinect Device

The Kinect device consists of: one infrared sensor, one Red-Green-Blue (RGB) sensor, and one infrared light actuator. The infrared light actuator acts as a diode that emits infrared light at approximately 780 nm. The actuator is coupled with specific lenses so that the infrared light emitted is dispersed, rather than collimated. The dispersion of infrared light allows the sensor to detect a large spatial volume in front of the camera. The purpose of the infrared sensor is for capturing depth, or distance, along each ray of the dispersed infrared light. However capturing the reflection of dispersed light means that the optical resolution is inversely proportional to the distance of the user; hence as the distance between the user and the camera increases, the ability for the camera to detect fine movements becomes worse.

The other sensor is an RGB sensor, which is simply a normal camera. Basically this sensor is an imitation to the Red, Green, and Blue cones within human eyes; it will detect visible light, and separate them into its corresponding Red, Green, and Blue components. The RGB camera itself can only capture Two-Dimensional images, as it cannot distinguish between difference depths of the objects. However when the RGB sensor is coupled with the infrared sensor, the whole camera is able to capture Three-Dimensional motion-sensitive images of the world.

The other components of the Kinect camera include four microphones with two on each edge, and a motor that allows rotational and translational motions along the joint where the camera and the base are attached. The usage of Kinect will be integrated only within the prototype, whereas the final product will have a higher resolution infrared actuator/sensor.

3.2 Computer System (Processor)

Once the computer receives information from the Kinect sensor via the USB port, we will use data processing software such as MATLAB or create our own programs using the languages C or C++ to analyze the acquired data from the sensor. The choice will be made considering the complexity and originality of each system. The Kinect sensor provides both depth and RGB information, therefore analysis of the data will allow overlaying of the two sets of images onto each other. We can then correlate the two sets of images for performing a full segmentation and successfully motion track the detected object.

After properly segmenting and motion tracking the specified object (e.g. the arm and hand), we can record the transformation matrices corresponding to the motion, then map these matrices to a vector of seven components, each one with respect to each of the seven degrees of freedom.

3.3 Microcontroller

We will be using a microcontroller for receiving commands from computer and sending it to the mechanical portion, as this option is the cheapest, the most versatile, and the simplest to use. The candidate we have chosen for our microcontroller is the Arduino Mega Microcontroller, which generates high resolution Pulse-Width Modulation (PWM) input signals to be sent to the manipulator. The Arduino Mega is also capable of controlling all five motors (according to our robotic kit) simultaneously, and therefore can be highly cost-effective, rather than to use motor control boards, which lacks flexibility for controlling multiple types of motors. Possible languages to use for programming this microcontroller will include: Java, C, C++, etc.

3.4 Robotic Arm Kit

This will include a pre-built robotic arm currently controlled using panel buttons and/or joysticks. In order to demonstrate a “proof-of-concept” for our project, we will dismantle the button and joystick panel, and connect the voltage inputs to the microcontroller, with each joint motor connection attached to its corresponding output at the microcontroller. Upon correct image processing of the acquired data from the Kinect sensors, the microcontroller will receive the proper instructions on which motor to actuate, the magnitude for which to actuate, and the duration of time for which to actuate, in order to allow a precise imitation of the robotic movements to the users body movements.

4. Budget and Funding

4.1 Budget

Here is a tabulated result of our equipment list, and the estimated cost of each unit.

Table 1: Tentative Budget

Equipment	Estimated Cost
Kinect Sensor	**$125**
Robotic Arm Kit	**$600**
Robotic Accessories (Gears, Screws, etc)	**$100**
Electronic Accessories (Op-Amps, Transistors)	**$50**
Logitech HD Pro Webcam C920	**$100**
Total Cost:	**$975**

4.2 Funding

The funding for this project will come from multiple sources:

1) Dr. Marinko Sarunic's Grant Funding

In the interest of his research group's possible future work to be integrated with motion-controlled devices and algorithms with mechanical instrumentations, such as robotic surgical tools, Dr. Sarunic has agreed to sponsor us for the motion-detection components involved in our project, which is the Kinect Sensor.

2) ESSEF

The purpose of Engineering Science Student Endowment Funds (ESSEF) is to provide Engineering Students at SFU opportunities to create educational, and potentially entrepreneurial, projects. As a traditional source of funding for the courses ENSC 305/440, ESSEF has agreed to fund our project with an amount of $700.

3) Engineering Department

The SFU Engineering Department has agreed to provide us with up to $50 worth of electronic components, such as op-amps and transistors.

5. Timeline Schedule

The following table our scheduled project milestones throughout this semester.

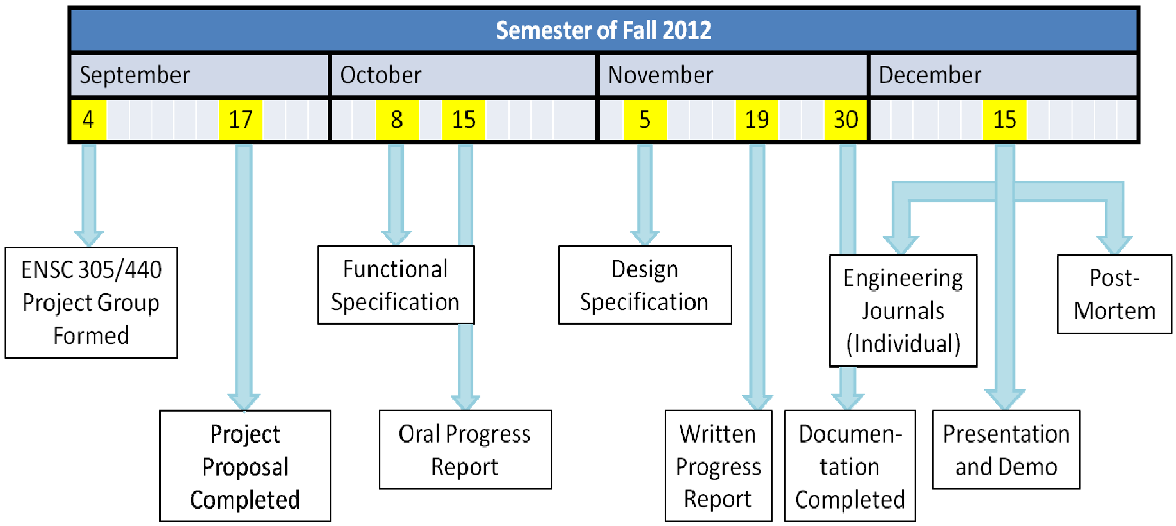

Figure 3: Milestone Chart

Here is the Gantt Chart displaying the timeline for each task within the project itself.

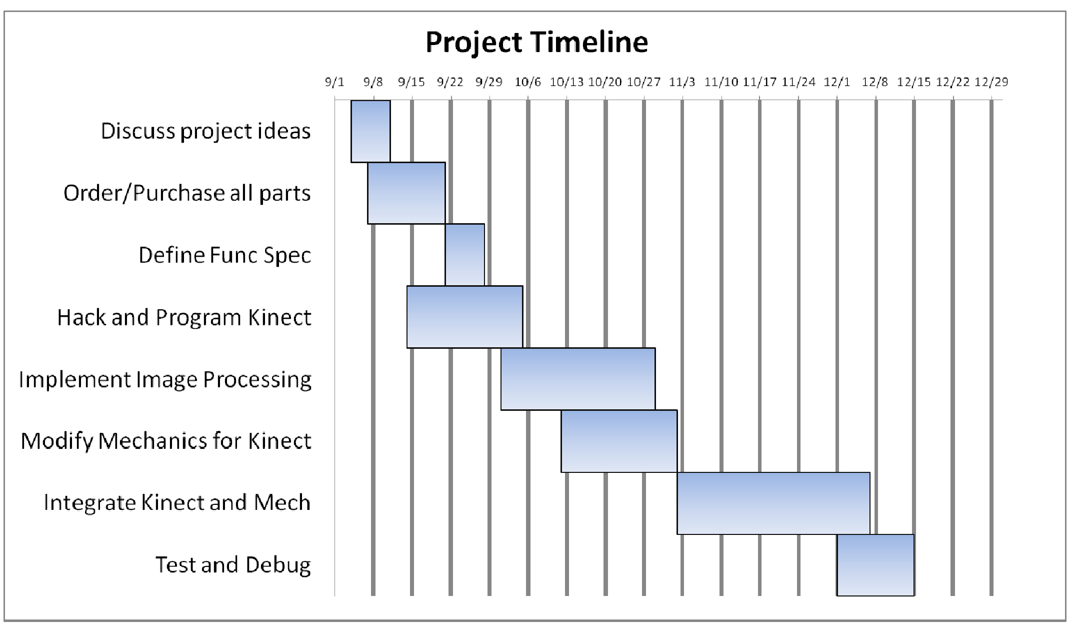

Figure 4: Gantt Chart

6. Team Organization

The team consists of six talented engineers: Hsiu-Yang Tseng, Jing Xu, Kevin Wong, Kay Sze and Vincent Wong and Arnaud Martin. Hsiu-Yang Tseng and Jing Xu are both pursuing PhD in Engineering Science, whereas the four other members are 5th year Biomedical Engineering undergraduate students. Our diversity of skills allows each of us to contribute to all aspects of this project.

MotiCon's internal structure is organized such that each member is responsible for a specific engineering field in the design of the implementation, whereas documentation is done cooperatively. For corporate structure, Vincent Wong is the President and CEO in charge of resolving internal conflicts and directing the progress of the project. Kevin Wong and Arnaud Martin, who are both Chief Financial Officers (CFO), are in charge of the financial budget and operation of the project. Jing Xu and Hsiu-Yang Tsang, who are both Vice Presidents of Operations, are in charge of the technical aspects of the project. Kay Sze, Vice President of Marketing, is responsible for generating company capital and marketing strategies. The internal structure is loosely separated into the following teams:

Software:

Jing Xu is a PhD candidate at SFU. She is a strong programmer, and is especially fluent in C++ and Matlab developing environments. Through her experiences in China, she has also developed strong project and team management skills. Her software development experience will become a strong asset in the development of the software responsible for processing the data acquired from the Kinect sensor.

Kevin Wong worked as a software tester using Linux in his first Co-op. He is experienced with the languages C, C++, and Java. With his experience in vigorous testing and software development skills, Kevin Wong will ensure the highest quality software, bug-free, program used for developing the computational and image processing algorithms used to process data acquired from the Kinect Sensor.

Firmware:

Arnaud Martin is experienced in Verilog and C programming, thanks to multiple implementations of FPGAs and microcontrollers. He also has competencies to use and implement wireless communications on chips, such as WIFI or ZIGBEE. His skills in PCB designing, mechanics and robotics will also be helpful for the construction of the manipulator.

Vincent Wong is experienced in C programming and Linux OS from taking ENSC351 in which he got an A+ in, which is necessary to program the microcontroller. In addition, his skills in hardware (e.g. PCB designing and fabrication) allows him to understand the firmware aspect to driving the robotic arm.

Mechanical and Hardware:

Hsiu-Yang Tseng received his bachelor and master degree in mechanical engineering with many project experiences and skills especially in microtechnology and bioengineering applications. He has worked as an intern in industry for R&D. These experiences help him with broad perspective in the field. He also studied fundamental mechanical problems such as thermal-fluid, material mechanics, and system dynamics, which are essential to product development.

Kay Sze finished her 8-month coop term in the SFU-Kinesiology Biomedical Lab. At the end of her coop, she has successfully upgraded the whole program to Matlab platform, which consists of a data acquisition part and a forcing function section. During the coop term, her supervisor provided her a chance to learn building a mechanical system using Matlab. These experiences allow her to develop the mechanical and hardware aspects efficiently.

To ensure successful group dynamics, concise communication and meeting deadlines, the team has designated to meet twice every week to discuss the progress of group tasks, and to collaboratively share the knowledge, research and development on the implementation. Members are encouraged to attend meetings because of group lunches. Members that miss the meeting will be updated on the project's status, but it is solely the person's responsibility to contact the rest of the group and inform them of their absence. Each member's mutual relationship is friendly, respectful and cooperative.

Task assignment will be allocated based on each member's strength and weaknesses, and upon completion of our assigned tasks, we will collectively review the work and test it. Note that, although our corporate structure is organized, each member's interest should be considered and heard, so that the project's different aspects can be collectively worked on as well. In conclusion, all of MotiCon's members understand that the importance of teamwork, good work ethics and consistent communication are key to a successful project.

7. Conclusion

The motion-controlled manipulator is offering a new way of controlling different robots, from simple excavators to more complicated machines, such as the "da Vinci" surgical robot. The movements are detected through a depth sensor and analyzed by a computer. The controller is then able to precisely move the robot in a similar way as detected by the depth sensor. Whatever the situation, this new technology brings a new dimension in comparison to the currently non-intuitive panel controls.

MotiCon is going to work precisely according to schedule, with a fair allocation of tasks among each of the group members. Each member will be in charge of a significant part of this project, which implies that they have the responsibility of the project's realization.

The originality of this project is its vast application in multiple robotic products in the everyday life. The responsibility of each team member and their motivation ensures **MotiCon** will become a successful company with an idea that will re-define existing user interfaces controlling robotic arms**.**

References

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