

ECE 480 Design Team 8

Motion Capture for Runners

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Executive Summary

The team is tasked to design and test a product to capture the motion of runners. This product will analyze the form of a runner and compare it to an elite runner under various running conditions. Through sensors placed throughout the body and real-time feedback, the runner will be given a visual alert of improper running form. Sponsored through the Air Force Research Laboratory, the team is challenged to find an innovative and low cost solution to capture and analyze motion. They hope to use this technology to further understand motion of flexible structures of aircrafts and spacecrafts.

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Introduction

Many people have little knowledge of the efficiency of their running form. By improving their form, runners can significantly improve their performance.

Runners can improve upon the efficiency of their gait by comparing their running form to that of an elite athlete. To achieve the measurements necessary for this analysis, IMUs (inertial measurement units) can be placed along the body to capture limb and joint motion. IMUs contain numerous gyroscopes and accelerometers that electronically measure position and movement of the measurand. (Inertial Measurement Units, 1) The data collected by the IMUs must then be analyzed by software to provide feedback to the runner. Data collected from gait analysis is comparable to data collected from sensors on flexible portions of an aircraft. Therefore, the motion of flexible aircraft can be better understood through the similar analysis of running form.

The objective of this project is to design a motion capture device that can be worn by runners in order to improve their running form. The device must be portable and unobtrusive, so as not to impede the runner. The product must be able to send real time data about the runner's form to provide accurate feedback with which improvements can be implemented. The product must also be able to function with different sized runners, as not all runners will have the same proportions. The feedback provided must also be easy to interpret, in order for the runner to make alterations in their form at will. Lastly, the product should be as low-cost as possible, making it accessible to many different users.

Background

An efficient running form is a prerequisite for being able to run for long distances at a relatively constant speed. According to many resources, the efficiency of a runner's technique is directly proportional to the quality of their posture. Many mainstream body movement disciplines claim good posture involves having a relatively straight spine with little bend. When the runner leans more, more of the body's muscles need to work to hold the body upright (Dreyer, 1). Good running posture also involves good leg motion, and efficient endurance running requires a slight knee lift. Quick leg turnover and short strides are also recommended. These factors all facilitate fluid forward movement instead of diverting and wasting energy. It is found that having a reasonably short stride prevents both hamstring and knee injury, as well as provides good circulation in the legs. When running with proper stride length, the runner's feet should land directly underneath the body, and as their feet strike the ground, their knees should be slightly flexed so that they can bend naturally on impact. (Hahn, 1)

It is apparent through research that different running conditions significantly change the form of the runner. In the case of running uphill, arms need to be put to good use to increase the momentum by swinging arms; knees need to be brought high, compared to running in normal conditions or jogging, in order to keep a proper posture while running uphill (Jhung, 1). Running at a faster speed involves lifting knees higher to achieve maximum leg power as well as increasing the arm swing span. Also, leaning slightly forward to let momentum flow is crucial (FitSugar, 1).

A similar study had recently been published in SICE Annual Conference 2012 by researchers from University of Hosei in Japan. They mainly focused on measurement and analysis of running form using three dimensional acceleration and gyroscopic sensors. The authors defined an efficient running form to be one that can carry a person's center of gravity forward with the least amount of effort. In this research, a small-size, wireless sensor equipped

with three-axis acceleration sensors and three-axis gyro sensors was mounted on subject's back. The collected data was transmitted to a PC via Bluetooth, and then analyzed in MATLAB (Asai, 1). A similar concept will be applied in the proposed solution to obtain the data necessary to accurately measure running form.

Design Specification

The following criteria will be used to judge which design best fulfills the requirements of a motion capture system with feedback. These criteria influence the practicality of our design and other important points such as feedback delay. Feedback delay is the time from when the initial measurement is made by the IMU to when the feedback is provided to the runner. In order for the runner to appropriately change their running form, the feedback delay should be minimal.

Battery (Size, Life)

The battery is a crucial part of the design, as it provides power for every IMU and transmitter. Since the battery must be worn on the runner, the battery's size should be as small as possible. However, the battery must also be able to last through multiple testing cycles.

Wireless Communication (distance, power consumption, and bandwidth)

The wireless communication we utilize should have low power consumption, but also have a large enough bandwidth and range needed to transmit measurements.

IMU (power consumption, size, axes, sampling speed, accuracy, method for attaching)

The IMU chosen should keep its size and power consumption to a minimum. This makes the testing easier for the runner and helps prolong the life of the battery. The number of axes, sampling speed, and accuracy of the IMU should all be high enough to ensure that the data can be processed effectively. Another criteria to consider is the manner in which the sensor will attach to the runner. A simple, yet effective mechanism is preferred.

Cost

The design should strive to be as inexpensive as possible. Given the uncertainty of our funding situation, there may be places in our design where compromises must be made.

Conceptual Design

IMU Chips

The product must be able to acquire data efficiently and accurately in order to provide effective feedback to the user in a timely manner. With this in mind, IMU chips with multiple-axis capabilities are extremely important when measuring a runner's form. The chips that the team has looked at as suitable choices for the project include the SEN-11486, the SEN-10724, and the DEV-11055 (Sparkfun Electronics). All three chips are sold on the Sparkfun Electronics website. Functions such as wireless data transfer, programmable software, and accurate measurement of position are fundamental requirements for an effective product.

IMU Placement

In order to get the most efficient data from the user, the team has agreed on using five sensors in order to get accurate feedback from the user. The five sensors will communicate with each other in order to provide real-time feedback to the runner in an efficient manner. The location of the sensors will vary based on the efficiency measured by the team when testing is commenced.

Location of Runner

The location of the runner will greatly affect the overall use of the product. Runners who usually exercise outdoors would be more inclined to desired functions that include GPS tracking along with running efficiency. Along with outdoor running, a device that would be able to process all the data acquired from the sensors would be required in order to give real-time feedback. Runners who would spend the majority of their time indoors on machines would have little use for GPS, and would also be able to use either a portable laptop PC or other electronic device to process the data acquired from the sensors.

Type of Transmission

The three main types of transmission that the team is focusing on include Bluetooth, GPS, or other wireless communication technology. Wireless communication is more widely used and able to send information much further away than Bluetooth. The downside is that wireless configuration can be rather complicated, especially when connecting multiple devices. GPS was also included as an idea for data transmission. GPS would be used to provide data with the location of the runner based on satellite feedback. With this in mind, the team has decided on using Bluetooth for communication since the distance between the user and the PC will be at a minimum, and overall, Bluetooth is simpler to configure and more cost-efficient.

Runner Feedback Indication

Visual feedback would provide the runner with indication on whether they are currently running with efficient or poor form. Visual indication would include a feedback system using LEDs, which would indicate running efficiency. LEDs can be used multiple ways, including using colors such as green and red to indicate good and poor running form. Multiple LEDs may be included to give a more precise indication rather than just adept or poor.

Efficiency of Feedback

The aspect of timely feedback is extremely important when dealing with athletics. Since the product will require real-time feedback in order to provide assessment to the runner, delay of communication between the computer software and the sensors needs to be at a minimum. The processing and data acquisition must be relatively quick in order to get an adept interpretation of the user's form.

Proposed Solutions

Based on the desired specifications and qualities of the motion-capture device, this product will be used for runners running inside on a treadmill. This is was decided due to restrictions on wireless communication lengths, and the desire to have real-time updating feedback for the user. Since 5 IMUs will continuously send data, it's most convenient to use a computer that will be nearby the runner to process the information and provide real time feedback. The use of 5 IMUs seems the most ideal method to capture the efficiency for the runner. The 5 IMUs will be capable of measuring displacement based on the positions of the other sensors. This will mean that the sensors will be required to communicate wirelessly. The sensors will be worn on the body and the placement of these sensors will be decided during the testing process. .

The baseline for proper elite running form will be documented from a Michigan State University varsity track/cross country runner. They will be asked to wear the IMUs on their body and run under different conditions, such as jogging, sprinting and running up a hill. Since different forms are used during these conditions, the user will be able to use this product for all running exercises.

Wireless communication is essential to this project. Either Bluetooth or other wireless products will be implemented. This product will send raw data from the 5 IMUs to a computer that will process it. Software will be purchased to have a proper interface with the sensors and the computer. Once a number can be generated from the computer, a program will be written by the team to calculate displacement and other measurable components. Calculating these displacements is important because every runner has a different body type such as body length. By calculating displacement, the numerical value will be normalized. The feedback will be sent to the runner through an audio or visual indicator on the wrist. This wireless communication for feedback will be independent from the the IMUs sending data to the computer. Since the runner will have a body-worn indicator, the only feedback that the computer will transmit is signals for an audio or visual indicator. This indicator will show the runner if they are running improperly. The factors that will be compared to the elite runner will be stride length, arm motion, and back position. The figure below shows a block diagram of what our product will do.

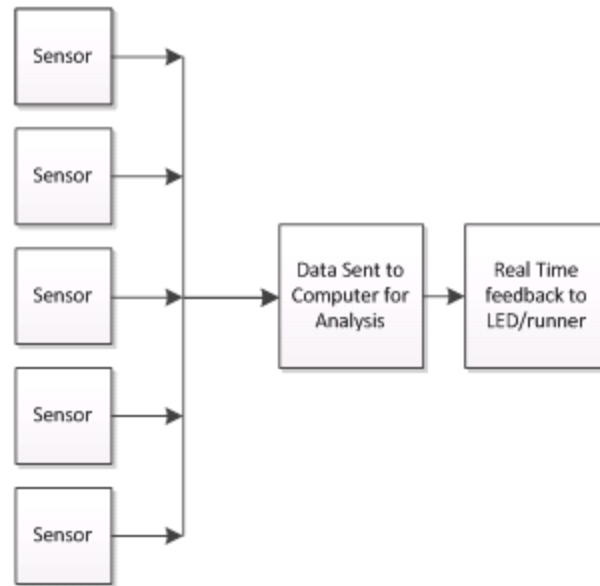


Figure 1: Block Diagram of Motion Capture

Testing Plan

Testing the product will consist of evaluating the wireless communication, the functions of the IMU, and proper feedback. Initial testing of the sensors and communication to the processor will be required. To make sure the 5 components' functions are working, a team member will attach the sensor to a body part. Once they have performed sufficient body motion, the other team members will be evaluating if the numerical values of the sensors are showing proper values. Different body movements will be tested to further evaluate the software and sensors performance. The wireless communication should accurately send the raw data from the sensors to the computer to be analyzed.

Once the team is confident of the product working, the product will be tested on a runner from the Michigan State University track or cross-country team. This runner will be the baseline for the product. Software will be written to numerically compare the users versus the elite runner. Further testing will be done to evaluate the software that will be written for the comparator of the user and the elite runner.

Another aspect would be proper feedback from the computer back to the runner. If the user goes above or below the baseline, the computer will warn the runner. Delay time of the feedback, as well as accurate warning will be tested and evaluated. Since real-time feedback is required, proper programming will be needed to minimize the delay for the runner to be warned.

Debugging of the software, trial and error of placement of the IMUs, proper receiving and sending data wirelessly, and other factors will be tested thoroughly to successfully complete the proposed challenge.

Project Management Plan

Proposed Schedule/Gantt Chart:

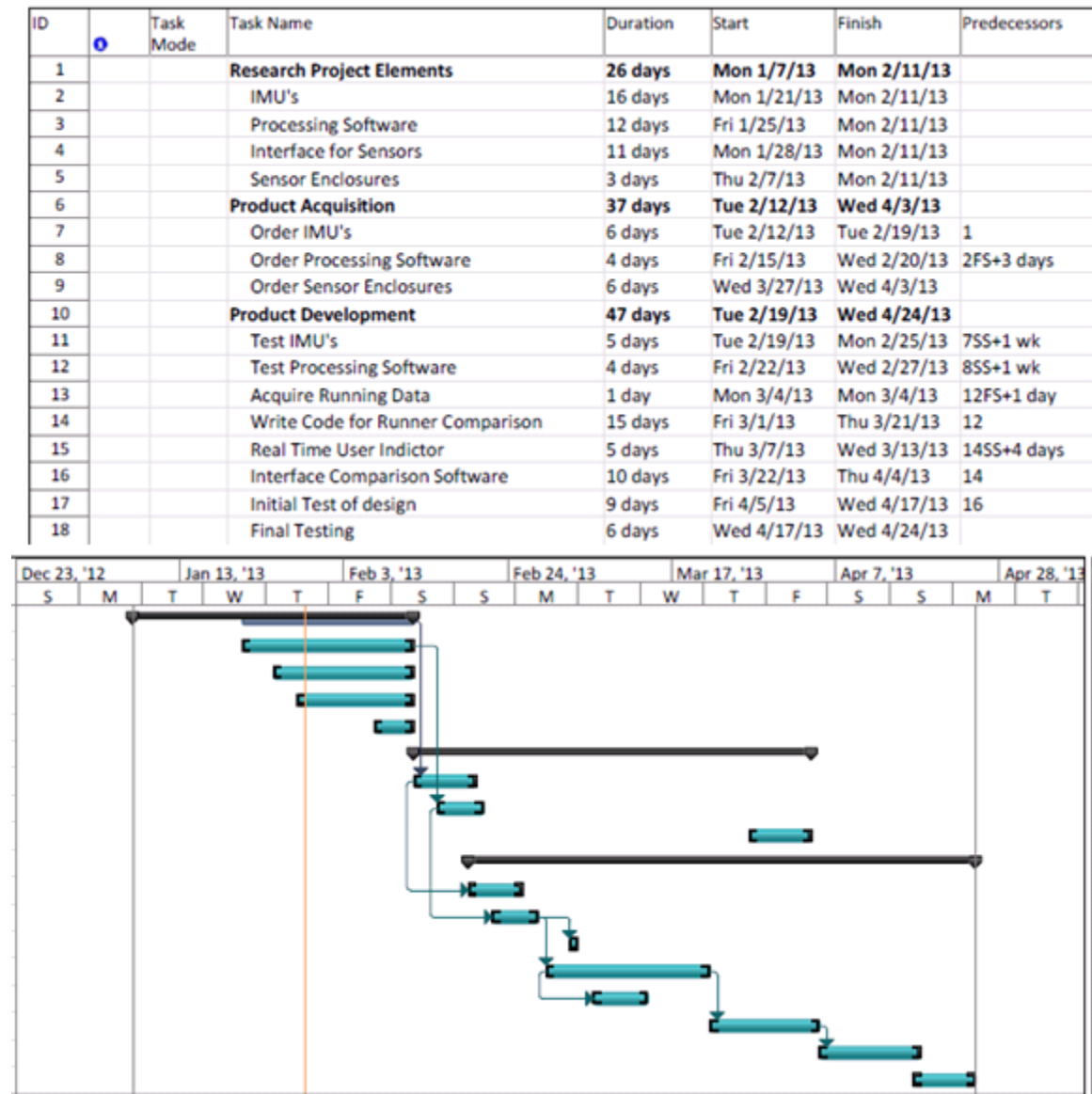


Figure 2: Shortened Gantt Chart

Team Roles:

Team Member	Technical Roles	Non-Technical Roles
Blake Frantz	Hardware Testing and Design: Coordinates the design of the project to the parts to be used. Ensures that the processing software will coordinate and display the proper data.	Presentation Preparation: Coordination of presentations using Microsoft Power Point, reviews and finalizes postings on website, ensures proper timing and display of information.
Zhichao Lu	Product Design and Development: Ensures that the overall design of the project is feasible and user friendly. In charge of making sure the overall system meets all goals.	Document Preparation: Coordinates the preparation of documents including proposals, reports and posters. Ensures proper length and project information.
Alex Mazzoni	Software Development and Debugging: Coordinates the development of comparison software, ensures that product software will interface and communicate properly with each other.	Web Site Preparation: Coordinates preparation of project web site and the maintenance of the design team's web site. Coordinates layout of information in an easy to understand manner.
Nori Wilkins	Hardware Testing and Design: Coordinates the design of the project to the parts to be used. Ensures that the processing software will coordinate and display the proper data.	Management: Manages project, including the calling of meetings, seeing that all deadlines and roles of team members are met, revision the project plan in response to changing circumstances.
Chenli Yuan	Product Design and Development: Ensures that the overall design of the project is feasible and user friendly. In charge of making sure the overall system meets all goals.	Presentation Preparation: Coordination of presentations using Microsoft Power Point, reviews and finalizes postings on website, ensures proper timing and display of information.
Dan Zilinskas	Software Development and Debugging: Coordinates the development of comparison software, ensures that product software will interface and communicate properly with each other.	Lab Coordinator: Manages the physical lab equipment, interfaces with the ECE shop and part ordering personnel. Ensures that part lead times are all at an acceptable time period.

Figure 3: Team Roles

Projected Budget:

Estimated Budget			
	SEN-11486	SEN-10724	DEV-11055
IMU's	$\$49.95 \times 5 = \$249.75$	$\$99.95 \times 5 = \$499.75$	$\$79.95 \times 5 = \$399.75$
Processing Software	Approx. \$249.99	Approx. \$449.99	Approx. \$299.99
IMU Enclosures	$\$25.00 \times 5 = \$125.00$	$\$25.00 \times 5 = \$125.00$	$\$25.00 \times 5 = \$125.00$
Arm Bands/IMU Fastener	$\$13.95 \times 5 = \$69.75$	$\$13.95 \times 5 = \$69.75$	$\$13.95 \times 5 = \$69.75$
Miscellaneous	Approx. \$50.00	Approx. \$50.00	Approx. \$50.00
TOTAL	\$744.49	\$1,194.49	\$944.49

Figure 4: Projected Budget List

Risk Analysis:

There are a few issues that have arose while researching and preparing a design. The largest issue found is product and software interfacing. It will be a challenge to make sure that the IMU's coordinate with both the software that is purchased and the software that will be created by the team. Accurately transmitting the data (in the presence of noise) that the IMU's collect is an additional software interfacing issue. Another challenge that the team will face is IMU battery life. With the wireless communication technology enabled, the IMU's will draw a lot of power, constantly sending and receiving data.

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