Judo Sensor Vest

Project Proposal

Team:

Max Baumgartner (mtbaumg2)

Alex Gaynor (bchmnng2)

Janak Mehta (jrmehta3)

TA: Samuel Sagan

ECE 445 Senior Design

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Introduction

Objective

Problem Statement: There are often controversial decisions made by judges or referees in competitive judo matches due to the limitations of distance and viewing angles.
Solution: A vest with force sensors and accelerometers that can more accurately detect the moves and throws executed to help the judges in their scoring.

Background

This problem of controversial decisions has been persistent in judo even at the highest level of competition like the olympics. One recent controversy was the 2012 olympics in the 66kg division quarter-finals when Ebinuma Masashi fought Cho Jun-ho [1]. The controversy stems from a scoring decision by the referees whom after video review took away a *yuko* (quarter point-a now discontinued score as of 2017) from Ebinuma which turned a match that should have been over into overtime. Both players were unable to score and the match ended, Cho was declared to be the winner by decision after showing a dominant late game however, this call was rescinded to give Ebinuma the victory after the judges deemed his previous throw was significant enough for him to win. While the yuko score is currently being considered for removal, the fact remains that international level judges even with the help of video cameras had made huge blunders in scoring. The Judo Vest is a design that is intended for practitioners to better understand their throws and for judges to be able to make better calls during matches and to prevent further controversies in the wonderful sport of judo.

High-Level Requirements

1. The vest must be highly durable as well as compact and non-intrusive.
2. It must demonstrate properly for a handful of select judo moves such as *ogoshi* (hip throw), *osoto-gari* (leg sweep) and *kesagatame* (pin). If time permits, we will also

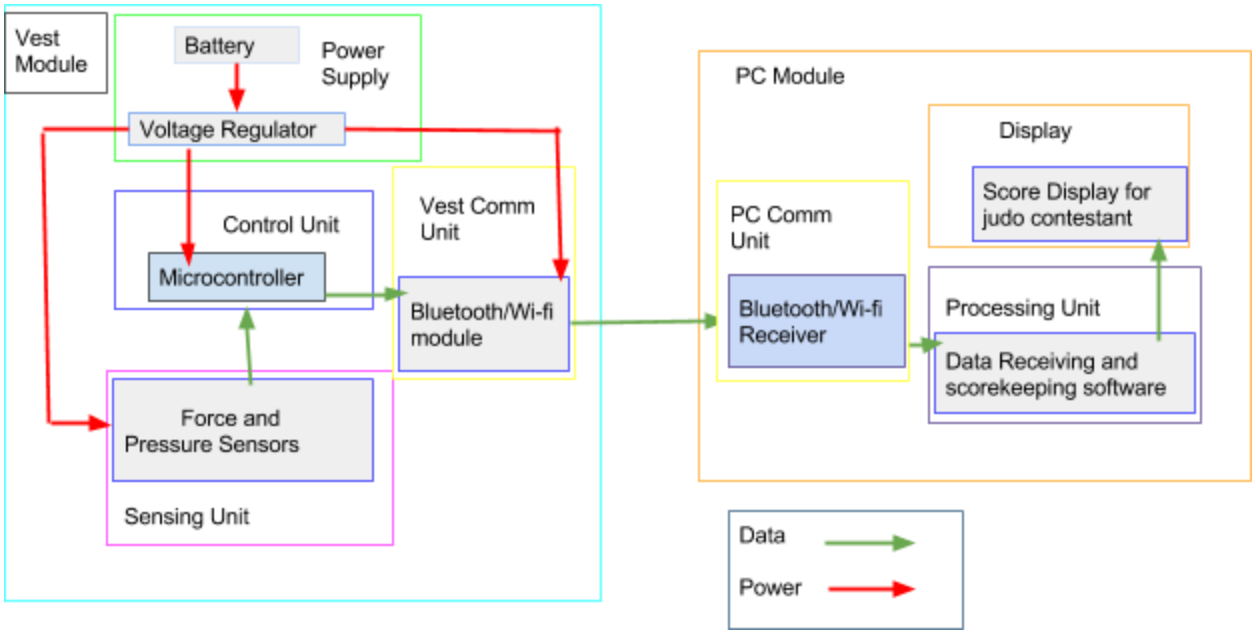
implement a feature that allows the wearer to tap out while on the receiving end of an armbar.

3. The vest must be able to detect large impacts as well as force over a period of time and transmit the appropriate signal to a computer for scoring purposes.

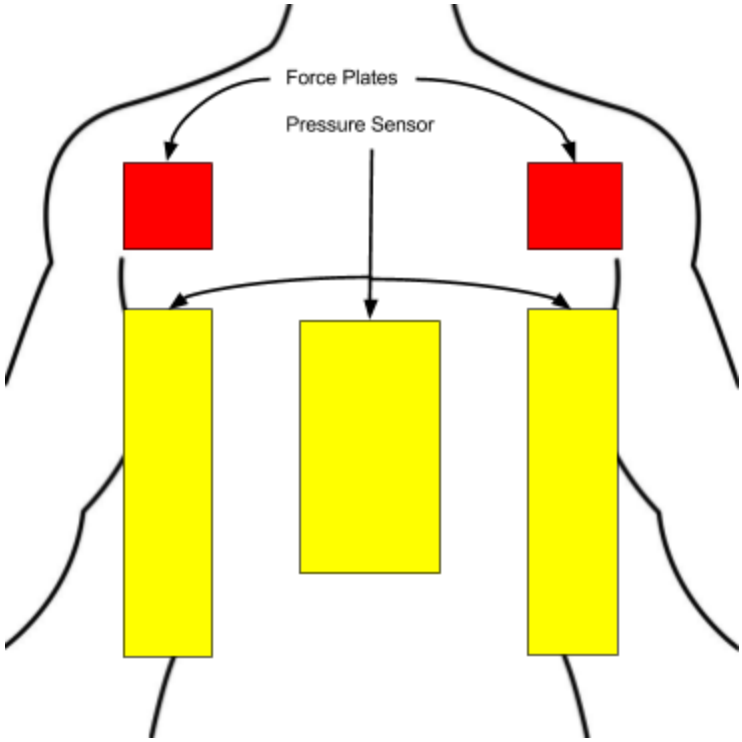
Design

Block Diagram

The project consists of clearly-defined modules, each one accomplishing a specific purpose in the project. The vest itself will be made of a reasonably lightweight, resilient material. The force sensors will be able to withstand the full force of a throw (at least a few hundred Newtons per sensor), while the pressure sensors will be capable of withstanding a pin (can be up to a couple hundred Newtons, spread across several sensors). With these, the vest will be capable of properly discerning whether a force was a throw, a pin or a tap-out, and there will be clear criteria for determining each of these. In addition, there will be a dedicated communications module that will allow the vest to broadcast its score remotely to a computer over a range of at least 10 yards. The microcontroller will take in the inputs from the sensors and decide which signal to broadcast to the communications module. The processing unit will take in the data and calculate whether a point should be awarded to the wearer's opponent and then display the score.



Physical Design



Dimensions and layout of project. The sensors on the back should roughly fit a size 3.5 to 4 judo gi so roughly 45x60cm on the back. The ideal placement of the sensors would be 2-4 sensors on the latissimus dorsi with a cluster of 2-4 sensors placed along each side of the spine around the upper part of the thoracic region totalling to about 6-12 sensors on the back for determining the score of a throw. There will additionally be some force pads on each shoulder blade, to confirm if a pin has occurred, and in the upper chest region to allow the user to tap out during an arm bar. Ideally, all of the sensors could be placed on a modified rash guard or its equivalent which would only add minor interference to the movement of the user. The control unit placed on the front of the thighs and no larger than 20x12cm vertical strip. This is to ensure that the microcontrollers as well as the communications unit does not get crushed when the user falls on their back and will not see too much physical contact with opponents during a match or sparring session.

Functional Overview

1. **Power Module**: Since the design needs to be wireless, a battery pack will provide the power to the worn circuitry. It provides power to the Sensor module, Control unit and the communications module.
    a. **Battery Pack**: Power will be provided by a pack of 4 1.5V batteries. Totalling to 6V.
    b. **Voltage Regulator**: To protect the circuitry from burning out, a voltage regulator will reduce the battery voltage to a safer level appropriate for the model of microcontroller and sensors we use.

    Requirements: The power module should be able to supply enough power to the sensor, control and communications module. Must supply at least 5V to allow the force sensors to operate at a functional level.
2. **Sensor Module**: To get an accurate reading of the force and the position of a fall and the validity of a pin, a series of force sensors and/or accelerometers will be used to measure how the user falls and if they have escaped a pin or not. The sensors will be placed in locations most likely to be impacted when one of the moves in our scope is executed. The most durable sensors will be used to detect a throw, while more sensitive ones located in the shoulders will be used to detect pins and tap-outs.

    Requirements: The sensors should provide accurate readings from which we can detect the kind of move executed on the user. Force sensors should be able to withstand about 2500N and be able to pass that information to the control unit.
3. **Control Unit**: Arduino or an ARM microcontroller to receive raw data from the sensors and send data over to the communications module. We may even do some rudimentary processing here depending on how powerful of a controller we use here.

    Requirements: The control unit should be able to receive information from the sensor module and pass that data to the communications module. Should transmit information within 10-15 ms to minimize latency. The control unit should also be able to handle at the bare minimum 8 force sensors operating simultaneously.

4. **Communications Module**: Since judo requires a lot of movement in 3 dimensions, the sensor signals will have to be transmitted wirelessly. To this end, we will make use of a wireless module (Bluetooth, wifi, etc.) that is included in the circuitry worn by the user and will transmit a signal when the sensors are activated. This signal will be intercepted by another module linked to an external computer. We could send data in the form of TCP packets.

   Requirement: This module has to send data to a computer wirelessly via bluetooth or TCP. This transfer speed should be a minimum of 15 MBps to minimize latency.

5. **Processing Unit**: We will run a program on a computer to receive data from the communications module and process it into meaningful information. Depending on what sensors were activated, it will decide what kind of move was dealt and how many points are to be awarded to the opponent.

   Requirements: Should be able to accurately detect the kind of move executed from the sensor data. Accuracy of recognizing move should be more than 95%. The program also should not take longer than 20ms from receiving the sensor data to display information on the display module.

6. **Display Module**: The resultant information that can be gleaned from the data will be displayed on the computer in a visual format to show the score and sensor readings.

   Requirement: Should display results from the processing unit. Should intuitively display score and activation information of the sensors.

Risk Analysis

Potential risks in the design are the communications module which without proper functions would severely inhibit the ability of the vest to send out data regarding a throw or a pin, another area of risk are the force sensors along the back of the vest which have a potential to break considering the fact that throws on average generate more than 1500N on a 66-72kg individual there is a concern that the sensors could malfunction during usage which could inhibit accurate readings on the vest. To ensure the the sensors do not break during usage extra padding will be placed on the back of the vest that provides safety and will allow the sensors to still function.

So far, the most challenging aspects of the project look to be selecting sensors that can stand up to the force of throwing while not impeding movement or causing discomfort to the wearer. Another challenge will be in selecting a microcontroller that is compatible with not only the sensors, which it must be able to run 6-12 simultaneously, but a reliable wireless communication system. There will also be a challenge in getting the system to communicate with an external computer, as well as possibly implementing a handshake acknowledgement to improve reliability of transmission. Currently we have a desire to use TCP over a WiFi connection to ensure that we have enough range to receive a signal as well as a reliable protocol that can achieve our desired handshake acknowledgement for transmitting data from the vest to the computer.

Another issue that arises with force sensors in full-contact sports would be the issue of false positives. There's a risk that during a match, when an opponent attempts to grab the user on the back or attempts and fails a throw that the sensors would trigger giving an incorrect score during a match. To address this risk we've added multiple sensors in areas where users are likely to land when thrown correctly but will not see too much physical action or force outside that when being thrown by the moves that we will be testing. These areas are listed in the physical design portion of the proposal and consist mainly of the the sides as well as lower back area.

Ethics and Safety

Ethics

Since users will use the vest while doing judo, the risk of injury is always present. We will aim for high safety standards and will provide sufficient warnings of the potential dangers that may be involved in the usage of our product. This aligns with IEEE code of ethics #1: "To accept responsibility..."[2]. We will be honest in our claims and estimates based on our data and will not make any false claims for the sake of the progress of the project. This aligns with IEEE code of ethics #3 We will work closely with the professors and the TAs and will use their constructive criticism and review for the improvement of the project. We will give credit to every person who contributes to the development of this project [2].

As we're creating a device used for full contact sport we will try to make the device as safe as possible for the user to prevent the device from harming people as well as preventing people from using the device for harm. This is evident in our desire to place the control unit in areas with low physical contact and ensuring that all components will be insulated in protective layers to prevent harm to both user and device. Due to our scope of our project and the limitations of current force sensors this device may not be able to properly accommodate people above the 66-72kg weight class though we will try to the best of our abilities to develop a device that can be used by anyone in compliance with the non-discrimination clauses in the IEEE code of ethics #8.

Safety

1. Since we are using a battery as a power supply for a wearable vest that will be sustaining impact, there is a danger of the battery getting damaged and hazardous materials being leaked. As such we will take extra precautions to ensure the protection of this battery so no harm may come. We will also provide sufficient warnings indicating the possible danger.
2. Our product also contains circuitry that cannot be exposed to water. Doing so may result in a short which may destroy the circuit or may even result in injuring the user. To ensure that such an event will not occur we will try to make the materials enclosing the circuitry and sensors to be sweat/water proof.
3. Given that judo is a full-contact sport we've decided to place the microcontroller in where we believe it will see the lowest amount of action. This is decision is further solidified by the fact that it is currently illegal to grab an opponent's leg. Still, as it is a sport there is a risk that there will be rule breakers who will deliberately try to grab the legs. To ensure the safety of the circuits and the wearer there will be extra padding surrounding the thighs to prevent any of the circuitry potentially digging into the wearer's skin.

Sources

[1]"Ebinuma judo quarterfinal ends in controversy | the Japan times," The Japan Times, 2012. [Online]. Available: http://www.japantimes.co.jp/sports/2012/07/30/olympics-judo/ebinuma-judo-quarterfinal-ends-in-controversy/. Accessed: Feb. 9, 2017.
[2]"IEEE IEEE code of ethics," 2017. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. Accessed: Feb. 9, 2017.