GPS-911 Ballistic Vest for Police Officers for Automated Assistance Request based on Real-Time Sensing and Thresholding

Team:

Balleristics

Vanderbilt University

Team Members:

Vivek Shah-Bachelors of Biomedical Engineering and Chemical Engineering, 2017

Zachary St. Clair-Bachelors of Biomedical Engineering, 2017

Alexander Boyer-Bachelors of Biomedical Engineering, 2017

Paul Hart-Bachelors of Biomedical Engineering, 2017

Nicole Steiner-Bachelors of Electrical Engineering, 2017

Kaitlyn Snyder-Bachelors of Electrical Engineering, 2017

Matthew Rogers-Bachelors of Chemical Engineering, 2017

Executive Summary:

Police officers face myriad challenges in their line of work. In 2013, there were **over 48,000 assaults** on police officers in the United States. Of these officers, **over 60% were alone** when they were attacked, and 30% were seriously injured. As such, there exists a significant need to provide police officers an independent monitoring mechanism should an officer be incapacitated or seriously injured.

The most important protective mechanism utilized by police officers is a ballistic vest. Current ballistic vest provide mechanical protection against blunt force injury, primarily gunshots and knife-associated stabbing. Ballistic vests protect vital regions of interest, including the heart, and lungs. The construction and ubiquitous usage of the vest suggest it can be affordably retrofitted to provide biometric and environmental information in addition to protecting the officer from bodily harm. **Our integrated "GPS-911" vest detects heart rate, blood oxygenation, extracorporeal blood, and respiratory rate along with sensing external forces applied to the vest and officer orientation.** These functions are applied through integration of a photoplethysmograph, blood glucose sensing, piezoelectric film, and an accelerometer into the ballistic vest. Biometric information is transferred to a bluetooth module and transmitted to a cloud storage location using an officer's smartphone. Data is processed using a proprietary algorithm, and measurements beyond a predetermined set of parameters warrant an automatic alert sent to the central dispatcher along with associated information.

While independent integration of biometric sensor technology is possible, **there does not exist a means to comprehensively and integratively retrofit and commercialize existing ballistic vests.** As police departments across the country face budgetary limitations, the GPS-911,

provides an affordable integrated device and reliable subscription based monitoring system that requires minimal capital investment.

The GPS-911 vest is contingent on successfully integrating a series of biometric sensors. Independently, the functionality of every biometric sensor utilized - photoplethysmograph, blood glucose sensor, and piezoelectric film - is well defined. The challenge presented is not the development of new biometric sensing methods, but rather integration of the components in a way that provides high durability, reliability, and responsivity. Following integration of the sensors, the GPS-911 vest will require 510k approval due to the FDA Class II device classification of the components utilized in the device. In particular, the photoplethysmograph, a technology that uses light and near-light radiation reflected through tissue to determine heart rate and blood oxygenation, will render the whole device as a Class II device.

As the GPS-911 is a commercial device, no Medicare or Medicaid strategy will be necessary. Rather, the market is focused on the nearly 8,000 police departments and localities across the United States which have fewer than 10 officers. These police officers are most frequently forced to work without a partner. GPS-911 serves as a "virtual partner" to these officers. Following an initial investment of $100 to acquire the integrated biometric sensor system, the GPS-911 can be retrofitted on existing police vests worn daily by officers. A subscription fee of $5 will provide access to the results of the proprietary algorithm to discern instances of abnormal biometric activity or serious injury as well as trigger automatic and immediate alerts to summon backup. Once established amongst smaller departments, GPS-911 has the potential to significantly enhance response times should any of the 477,000 sworn police officers across the United States face a dangerous situation.

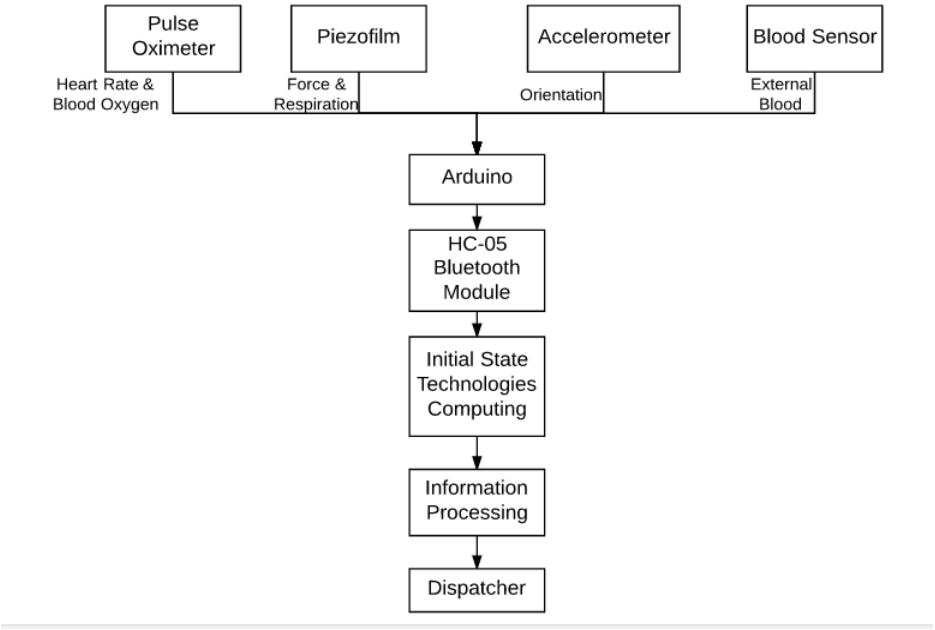
Problem Description:

Police officers require a protective measure that functions even when the officers are incapacitated. This protective measure needs to determine when an officer is in dangerous or life-threatening situations and automatically relay relevant information to the police station. Ideally it should also integrate smoothly into an officer's daily routine and gear so as to facilitate unhindered continuation of standard policing activity.

Problem Objective:

GPS-911 seeks to save lives by providing continuous biometric data for on-duty officers to their local station, all while fitting seamlessly into the existing structure of standard-issue ballistics vests. Multi-layered piezo film measures pressure changes in the pectoral region of the vest to give the officer's respiratory rate and also detect the impact of projectiles upon the vest. Other sensors detect blood in the pectoral region by responding to the presence of glucose outside of the body. Additionally, integrated plethysmographic sensors attach to the clavicular region to provide heart rate and blood oxygenation data from the officer. GPS-911 also uses accelerometers to detect abrupt changes in an officer's orientation or acceleration, such as that which would occur during a car crash. All of this data is processed by an embedded microcontroller which communicates with the officer's phone via Bluetooth. An application on the officer's phone then utilizes a custom algorithm to analyze the incoming biometric data to assess the officer's physiological status. Based on this assessment, the GPS-911 application determines whether or not to alert the station to a dangerous situation for the officer.

Prototype (Outline) of Final Design:



Patent Search:

While there was a patent on a previous device for detection of bullet impacts leading to a distress call the proposed device will monitor the user's biometrics and use these readings to determine if a distress call needs to be sent. The current distress call requires an officer to press a distress button and the proposed device will be significantly more complicated.

Anticipated Regulatory Pathway:

Our device will follow the 510(k) regulatory pathway with the FDA. Two of the component devices, the plethysmograph and glucose monitor, have been designated as class II devices by the FDA. This information, combined with the fact that we plan to market the device to municipalities, means that a premarket notification to the FDA will be necessary. In order to do this, we will also need to demonstrate that our sensors are substantially equivalent to existing predicate devices. Because our sensor have the same intended use as predicate devices and similar technological architecture, we believe we can readily prove substantial equivalence and follow the 510(k) regulatory pathway.

Reimbursement:

Our device is not being marketed to hospitals, clinics, or patients. GPS-911 is intended for use as a diagnostic device in a policing environment and will not be purchasable through insurance companies. There will be no reimbursement by Medicare or Medicaid for our device.

Estimated manufacturing costs:

Our preliminary design and proof of concept will consist of six modules: the main processor, piezoelectric film, communication module, integrated pulse oximeter, accelerometer, and blood sensor. For prototyping we estimate a total per unit cost of $75 and a bulk per unit cost of $35.

Table 1: Estimated Costs Breakdown

Module	Description	Est. Prototype Cost / Unit	Est. Bulk Cost / Unit
Power, Wiring	USB Rechargeable Battery Bank	$10.00	$7.00
Container	Customized Arduino Acrylic Box	$10.00	$5.00
Main Processor	Arduino Uno R3	$24.99	$3.50
Communications	HC-05 Module	$8.25	$8.25
Piezoelectric Film	Pressure Sensitive Conductive Sheet	$3.95	$3.95
Pulse Oximeter	MAX30100 Pulse Oximeter and Heart-Rate Sensor	$6.25	$2.75
Accelerometer	H3LIS331DL	$10.20	$5.41
Blood Sensor	TBD	TBD	TBD
Total:		$73.64	$35.86

Additional costs are expected to arise from further customer design requirements, custom board and module integration, resiliency and encapsulation of device, final assembly, and quality assurance. The main processor, communications module, and accelerometer are expected to be integrated in an acrylic container, with wiring to the Pulse Oximeter and Piezoelectric Films.

Integrating a blood sensor will increase expected costs. Prototype cost will be minimized by purchasing individual processors and electronic components and individual assembly. Manufacturing cost will be minimized through bulk purchase, custom PCB board assembly and integration of components.

Potential Market:

GPS-911 will initially be focused on the nearly 8,000 local police departments that have fewer than 10 officers in their department. Smaller departments frequently utilize officers alone due to budgetary constraints. As such, our target market will be the mayors and city councils, with additional attention paid to police commissioners and Commissioners of Management and Budget, of smaller towns in order to approve limited budgetary increases that allow for purchase of the GPS-911. Police officers will be the primary users of this device. Of the roughly 80,000 officers mentioned at small local police departments, we expect 5,000-30,000 officers to adopt the system in the first three years. The initial cost of the device will be $100 dollars. Subsequent subscription fees for biometric analysis using our proprietary algorithm will be $5 per month. In turn, officers will be actively supported through the "virtual partner" automatic dispatch system, thus providing faster and more informative communication regarding the situation faced by an officer in a dangerous situation, especially if the officer is incapacitated and alone. Distribution of the GPS-911 will be accomplished through contracted manufacturers from an initial facility where the integrated device will be constructed.