Modular Solutions for Next Generation Search and Rescue Helmets

EEL4914 Senior Design 1

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Group #21

Anthony, Jacob - Electrical Engineering

Cummings, Shakira - Computer Engineering

Hudson, Stephen - Electrical Engineering

Medrozo, Harriet - Electrical Engineering

Dr. Lei Wei, Dr. Samuel Richie

PROJECT NARRATIVE DESCRIPTION

When Group 21 gathered together they began their discussion of what each member hoped to leave this senior design collaboration with. None of the members of group 21 truly had project specific goals that they wanted to attain. So Group 21 began discussing what they felt were root problems that needed to be solve. One of the ideas spurred the topic of Black Panther. Which brought one of the members to excitedly state that they wanted to create an Iron Man helmet, a fully functional Iron Man helmet to be more exact.

A fully functioning Iron Man helmet was unrealistic as a senior design project. There would be too many complicated systems of that would need to be created: an artificial intelligence (AI), surveillance systems, targeting systems, item recognition software, locations systems, and communications to list a few. Despite how unreachable recreating the Iron Man helmet seemed, Group 21 felt they had a concept to work with.

The question then begged, “Who would benefit from using some of these systems integrated together?” Usually, the military is the first thing that comes to mind when creating an Iron Man-like helmet. However, other groups could use hands free systems, such as: search and rescue crews, doomsday preppers, emergency responders, outdoor hobbyists, and anyone that wants a cool toy.

After Group 21 found its target market, they picked the features that were of necessity to the user: communication, vision, and location. These three systems are the basis of almost all other systems members of the target audience use. Some characteristics of the overall design also needed to be discussed. Many personnel who this project would benefit, as a line of work ,have a lot of equipment; so this system would need to be lightweight. It would need to stay powered as long as possible without external power. This system would also need to be reliable and resistant to bumps and jarring.

REQUIREMENT SPECIFICATIONS

- Device to provide direction, orientation, and location
- GPS will provide accuracy a minimum of 3 meters
- Transceiver will be able to transmit and receive signals between 800MHz and 900Mhz range
- RF amplifier operates between 800MHz – 1000Mhz
- Night-vision capabilities (IR band) at 10 meters
- Images will be able to be saved for reviewing at a later time
- IR beacon to display at 25 meters
- Night vision at 20 meters
- Range detection with potential for tracking technology
- Power supplied will be 14400mAh for 24 hours or 7200mAh for 12 hours

PROJECT CONSTRAINTS AND RELATED STANDARDS

<u>Communications Module</u>
The Federal Communications Commission (FCC) of the United States of America governs radio frequency communications. Regulations concerning devices using radio frequencies are specified in Title 47 of the United States Code of Federal Regulations (CFR). Agencies such as European (ETSI EN300-220-1 and EN301 439-3) North American (FCC part 15.247 and 15.249) also regulate transceivers.

Localized Location System Module

Restriction on Hazardous Substances As of July 1, 2006, the Product is compliant in all material respects with DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive) and Amendment 2005/618/EC filed under C(2005) 3143, with exemptions for lead in solder pursuant to Paragraph 7 of the Annex to the RoHS Directive applied. The foregoing is limited to Product placed on the market in the Member States of the European Union on or after 1 July 2006. Trimble has relied on representations made by its suppliers in certifying this Product as RoHS compliant (20).

Power Module

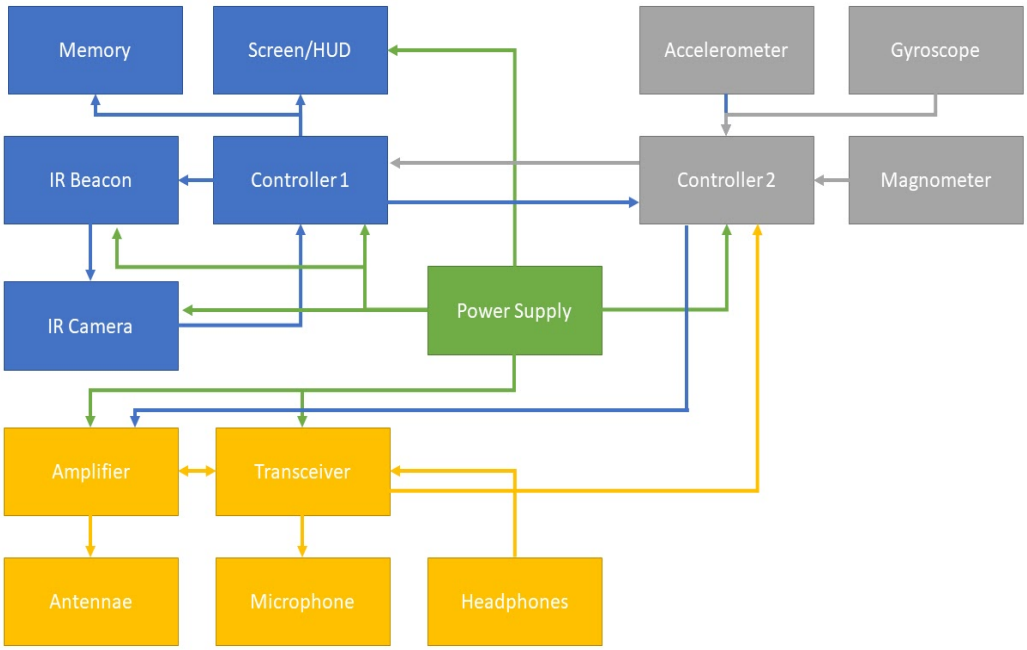
IEEE 1725-2011 -IEEE Standard for Rechargeable Batteries for Cellular Telephones

IEEE 1184-2006 - IEEE Guide for Batteries for Uninterruptible Power Supply Systems

Constraints

- Budget
- Range/Antenna Reach
- Federal/State Regulations

HIGH LEVEL PROJECT BLOCK DIAGRAMS



Augmented Vision Module, Lead: Jacob Anthony
Communications Module, Lead: Harriet Medrozo
Location Module, Lead: Shakira Cummings
Power Module, Lead: Stephen Hudson

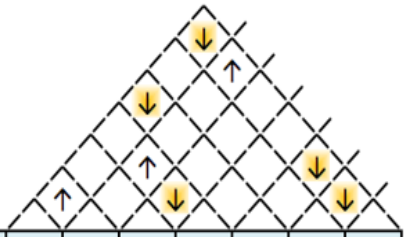
HOUSE OF QUALITY TRADE-OFF TABLE

Project: First Responder Helmet
Revision: 1
Date: 9/14/18

Correlations	
Positive	↑
Negative	↓
No Correlation	

Relationships	
Positive	↑
Negetive	↓
Strong Postive	↑↑

Direction of Improvement	
Maximize	+
Target	◇
Minimize	-



Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) / Functional Requirements	Column #	1	2	3	4	5	6	7
						Direction of Improvement	+	+	+	-	+	+	-
							Output Power	Eficiency	Communications Radio Singnal range	Weight	Accurcy of Heads up display	IR camera Clairty	Cost
1	||||	10%	2	1	Long lasting battery +		↑↑	↑↑		↓			↑↑
2	||||||	14%	3	3	Ease of Use+								
3	||||||||	19%	4	4	Maintaince -								↓
4	||	5%	1	2	Cost -		↓	↑↑					↓
5	||||||||||	24%	5	5	Durable +					↓			
6	||||||||||||	29%	6	6	Customizable(interchanagable modules) +		↑↑	↑		↑			↑
						Target	8W	50%>=	2-3 miles	100 Oz (typical first responder helment weights 77oz)	global position and orentation of user	>= 8 megapixals	$470 per helmet

COMMUNICATIONS MODULE

The objective of the communications module is to provide clear, reliable voice communications between users. This is important in search and rescue operations due to the potentially hazardous situations that workers may be in. Clear and reliable communications may be the difference between life and death in hazardous situations. Potential applications for clear and reliable communications are countless. Some possible uses can be applied to the military, first responders, personal/family emergencies, commercial security and sports/coaching communications. The communications module for this device will consist of the following: transceiver, RF amplifier, antenna, microphone and headphones.

Transceiver

A radio frequency transceiver module operating in the 800Mhz and 900MHz license-free Industrial, Scientific, and Medical (ISM) frequency band will be used (14). This transceiver module should have capabilities of high-speed data rate of up to 160kbps (14). The goal of the transceiver module is to provide means for transmission and receiving capabilities. In the case of RF interference, two transceiver modules will be implemented, one operating in the 800MHz range and one operating in the 900MHz range, to enable frequency hopping for more reliable communications (14).

RF Amplifier

The primary function of an RF power amplifier is to take low power radio frequency signals and boost them to higher power signals (4). The power amplifier should be designed for operations within the 800Mhz – 1000Mhz range. The design intent with the RF amplifier is to work in conjunction with the antenna to boost the low-powered signals. Several important factors to consider when choosing which RF amplifier to integrate into the design are gain, power output, bandwidth, power efficiency, and input/output impedance matching (4).

Antenna

An omnidirectional antenna needed for the communications module should be able to communicate at least 5 miles.

Microphone/Headphone

Push-to-Talk or Push-to-Transmit (PTT) is a communications method that involves half-duplex communication lines (3). Half duplex communication is a way to transmit data one direction at a time (3). This means that while one person is transmitting a signal, multiple other receivers can pick up the signals at the same time. While transmitting the signal, the user cannot receive any signals himself/herself. The PTT button acts as a switch to toggle between transmit-mode and receive-mode (3). An advantage to having PTT integrated into the microphone/headset for this communications module is that it enables only one user to speak at a time. This is particularly useful so that all users receiving will only be able to hear one transmitter at a time. The functionality follows the methodology of clear communications.

AUGMENTED VISION MODULE

The augmented vision module needs to enable the user to see in low light conditions. The module needs to be able to see in smoky conditions, at night, or in places where there is little to no natural light, such as caves or buildings. The module will need four separate pieces of hardware: a camera sensor, a display screen, a file storage device, and a control unit.

Camera Sensor
The camera sensor needs to be able to operate in low light conditions. Cameras that can do this are illuminated IR cameras, thermal imaging cameras and light amplifying cameras. Each of these cameras use slightly different technology to see in the dark. The driving choice of the camera sensor will the cost of the camera. There are night vision cameras that can see for several thousand meters, however, they cost several thousands of dollars a piece. On the other hand for a few dollars you can buy a IR illuminated camera that has a lower picture quality.

IR Beacon
Each helmet will need an IR beacon. This beacon will be an IR LED of some kind to allow others within line of site to be able to know where you are in the low light conditions. The camera will be able to detect the IR beacon and it will show up bright on the display screen.

Display Screen
The display screen will need to be a small screen that can be put in front of the user's eye when needed and removed from view when not needed. The display screen will take the input from the camera via the control module.

Control Unit
The control unit will need to be able to take the video feed from the camera module, record the feed to a data storage device such as a SD card and, display the feed on a display screen for the user.

File Storage
The file storage system will need to record the users actions should they want that function. The two main types of file storage that will work at this size is SD and micro SD cards. A micro SD card works best with a smaller footprint and mass.

LOCALIZED LOCATION SYSTEM MODULE

If someone from our rescue team is in trouble, finding their location will be of utmost importance. The rescue safety helmet design will have a location module for reasons such as this. For this device, an accelerometer, along with a magnetometer, a gyroscope, and a global positioning system technology(GPS) will be the best option for the location module. This method of locating will not run into the problems that a Wifi locator would have in, say for instance, finding a connection in a building with a falling infrastructure.

Cell phones already use this technology. They use motion tracking to know the position the phone is oriented in and where the phone is in physical space (6). This information is sent by pings to multiple satellites calculating where you are based on angles of intersection (GPS).

The rescue and safety helmet would use a 9-axis motion tracking device and a GPS. The 9-axis motion tracking device is designed for battery operated high performance consumer products. It is made up of a 3-axis accelerometer, a 3- axis gyroscope, and a 3-axis magnetometer. The 9-axis motion tracking device is light in weight, making it a good choice to add to a design that needs to weigh as little as possible. The MEMS (micro-electro-mechanical systems) gyroscopes, for example, are small enough to fit inside a phone.

Accelerometer

An accelerometer function is axis-based motion sensing (6). An accelerometer has a sensor made of microscopic crystal structures that give an output voltage when stressed due to accelerative forces. The accelerometer interprets the output voltage to find the direction the object it is pointing in (6). Short term movements can be tracked, because the accelerometer keeps track of direction due to gravity (9). We want the safety and rescue helmet to conserve as much power as possible, during search and rescue missions. Accelerometer-only data helps conserves power in devices that log a lot of data (8).

Gyroscope

Most accelerometers are limited to what they track and are not consistently accurate (8). Adding a gyroscope to an accelerometer allows distance travel without user input (8). A gyroscope measures the rotation or angular velocity of an object(13). It provides information about the accelerometer in all directions and rotations around each axis (9). Emotiv Inc., a bio-informatics and technology company, emphasizes that the addition of the gyroscope helps accurately maintain both the instantaneous and long-term earth frame reference for gravitational and linear accelerations (8). Gyroscopes have been used in short term full-space head tracking for video game devices (9). Gyroscopes have also been used in tracking the distance traveled by a runner to find their way back home (9). Keeping track of the distance of our rescue team member to get him or her back to the home base could be a very useful feature in our safety and rescue helmet.

Magnetometer

A magnetometer, combined with the accelerometer and GPS, tracks real position and orientation in space (9). A magnetometer is an instrument used for measuring magnetic forces, especially earth's magnetism(12). It measures the direction, strength, or relative change of a magnetic field at a location. The compass is a type of magnetometer, which is a significant reason to include it in our safety and rescue helmet. A phone, for example, will use the magnetometer with the data from its accelerometer and GPS to calculate the whereabouts of the phone's user (6).

Global Positioning System Technology (GPS)

A GPS will use the accelerometer, gyroscope, and magnetometer in locating an object. A GPS will use the information from these sensors, sending pings to satellites, to calculate where the object is based on the angles of intersection (6).A GPS does drain battery from communicating and calculating (6). This will have to be kept in mind when writing the software and choosing the power source for the safety and rescue helmet design.

Existing Projects and Products

Motion tracking systems to measure a sports player's position, velocity and acceleration are starting to become more present in today's technologies. Companies such as Johan Sports have developed a device that contains a 9-DoF (Degrees of Freedom) MEMS Inertial Measurement Unit(IMU) and a GPS receiver. In addition, a four-sensor fusion algorithm is used to further filter disturbances (10). The tracking device is worn in a vest on the player's upper back and obtains the data (10). In the same way, the safety and rescue helmet will use a motion tracking sensor and GPS to locate the team members of the rescue team during their missions.

POWER MODULE

The purpose of this module is to provide sufficient power with a reasonable power buffer to the communications module, localized systems module and augmented vision module. It is meant to work for a duration of time comparable to a typical shift of a first responder. Because of the energy intensive actives listed above there will, in all likelihood be multiple power modules to ensure reliable power allocation to the all of the modules.

Battery

The battery will be rechargeable and operate for long durations of time. To this end, a lithium ion battery is chosen as it has the most suitable battery chemistry for this particular application. Due to its lightness in weight high energy density. There is no need for periodic self-discharge as with other leading battery chemistries, and the discharge rate is half that of other battery chemistries as well.

Power management API

The API will monitor the performance of the power system it will control the idle sleep and it will set quick wake modes all without user interference. It will also monitor the durations of the set modes. The API will perform the following four services:

Battery Monitoring

This will keep track of the power level of the battery, this will provide vital information that is needed when power operating decisions need to be made. Namely the mode of operation, i.e. active mode, standby mode and off (Some batteries do this automatically).

Accounting

The API will also keep tabs on the usage of the individual modules or maybe even the individual components used. In order for any API to function efficiently power allocation to different components needs to be known. This can be implemented in either via hardware solutions or software solutions.

Auto resume

When a component has been set to standby mode it must be brought back to active mode before normal operations can be resumed. Auto resume will be the mechanism in place that will do that.

Auto suspend

When a component is no longer needed auto suspend will be the code that switches that component to off or standby. This is an important feature because it takes more power to bring a component back to life from off rather than from standby which has a huge impact on the power level of the battery. The auto suspend will have to make these decisions automatically via some algorithm.

Power Supply Design

- Battery manager and charging circuit
    - Charging procedure for lithium ion battery
- Power path controller
    - Controls switching of power to power conditioning circuit
    - Supplies power to load, first with wall AC then with battery DC
- Power Conditioning Circuit
    - Regulates DC voltage to a lower voltage level via transformer for embedded device using switching regulators to provide efficiency not seen in linear regulators
- Power Supply Design = PMICs
    - Designed with consideration for EMP electromagnetic interference

Group #21 Budget			
BUDGET			
Detail			
EXPENSE	**AMOUNT**	**QUANTITY**	**TOTAL**
Transceiver module	$30.00	4	120
RF Amplifier chip	$10.00	4	40
Antenna	$10.00	2	20
Headphone/Microphone	$20.00	2	40
GPS Device	90.00	2	180
MEMS Motion Tracking Device	$15.00	2	30
Camera	$190.00	2	380
SD card	$25.00	2	50
Electronics	$50.00	2	100
IR Lens	$10.00	2	20
Screen	$25.00	2	50
Power Supply	$100.00	2	200
PCB costs	$100.00	2	200
Military tactical helmet	$35.00	2	70
Total		**$**	**1500**

INITIAL PROJECT MILESTONE FOR BOTH SEMESTERS

The intent of EEL4914 Senior Design 1 is to initiate the engineering design process. The following phases are to be fulfilled:

1. Identification of problem
2. Research and development of proposed solutions to problem
3. Identification of specifications and requirements
4. Brainstorm and evaluation of viable solutions to problems

The following project milestones should be completed by the end of the Fall 2018 semester for EEL4914 Senior Design I:

- September 14, 2018 – Divide and Conquer Documentation
- September 28, 2018 – Update to Divide and Conquer Documentation
- November 2, 2018 – 60 page Draft Senior Design Documentation
- November 16, 2018 – 100 page Draft Senior Design Documentation
- December 3, 2018 – Final Senior Design Documentation

The intent of EEL4915 Senior Design 2 is to complete the engineering design process. The following phases are to be fulfilled:

1. Design and development of prototype
2. Testing, re-testing, and re-design of prototype
3. Finalized product meeting all specifications and requirements
4. Presentation of finalized products and results

The following project milestone should be completed by the end of the Spring 2019 semester for EEL4915 Senior Design II:

January 2019

- Initial breadboard design and testing
- Initial components testing
- Initial PCB design complete
- Initial system integration
- PCB design sent out for manufacturing
- Finalized component testing
- Committee members contacted via email

February 2019

- Receive PCB from vendor, populated, tested and re-designed
- Initiate PCB integration
- System integration continues
- Website and presentation initiated
- Finalize committee members

March 2019

- System integration continues - PCB received

populated, tested and re-designed

- Continued design on website and presentation

April 2019

- Finalized product
- Finalized presentation
- Finalized website
- Senior Design presentation to committee
- Senior Design Showcase

CONCLUSION

The modular solutions to the search and rescue helmet are something that Group 21 is excited and passionate about. The thought of being able to further assist search and rescue teams with an modular pieces of equipment is meaningful due to its potential cost savings factor and integration of both new technology and proven solutions. This design would better the communications between team members in case of separation. The safety and rescue helmet would have better detection of victims in danger in places where there is disruption of view. Moreover, the lives of our rescue team could be saved, by locating where they are during a mission. Group 21 believes this project will integrate engineering and innermost care for people.

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