Conceptual Design and Planning for Drone Triage Project

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I. Introduction

During a disaster, speed and efficiency are vital to saving lives. Triage is the practice of categorizing injured victims by a priority level to receive treatment for their injuries. Currently, before the triage process can begin, first responders must search for all injured people throughout the devastated area; once the injured people are located, triage is performed on the injured victims. The problem with this current triage process is that the time spent searching for injured people can mean the difference between life and death for those victims. This is why DARPA has issued a challenge called the DARPA Triage Challenge, or the DTC. The purpose of the DTC is to provide another way to assist medical responders in evaluating the condition of victims of a disaster quickly and efficiently using uncrewed aircraft vehicles, or UAVs, otherwise known as drones [1]. The goal of this project is to make just the sensing system capable of evaluating a person's vitals and then categorizing them by a priority level. The sensing goals for this project will be to measure presence of heartbeat, quantified value of respiratory rate, and cognition testing using voice activity detection (VAD). These components will be used to evaluate the medical state of a person who has fallen victim to a disaster and provide a priority triage level for everyone.

A. Fully Stated Problem

Create a sensing system that will detect an individual's heartbeat, respiratory rate, and cognition in accordance to the START model to provide a triage level response necessary for injured victims in a mass casualty situation. The system will comply with the following constraints.

a) System shall obtain the presence of a heartbeat.

a) This constraint is derived from the START model as one of the steps of triaging a person [2]. This constraint is to detect if a victim is present and has a present heartbeat.

b) System shall detect the operating heartbeat frequency for a human at approximately 0.45 to 2.92 Hz.

a) This constriant is derived from a Harvard health publication that describes the operating heartbeat frequencies for all age brackets [3]. The system will detect between these frequency ranges to determine if a heartbeat is present, it would be ideal to also obtain the actual heart rate as well.

c) System shall accomplish all functionality from at least one meter away.

a) This constraint is derived from Darpa's requirements for the Drone Triage Challenge or DTC [1]. The purpose of the DTC is to save lives and the drone would need to go from person to person in a quick manner to save the greatest amount of lives.

d) System shall obtain the breathing rate.

a) This constraint is derived from the START model as one of the steps of triaging a person [2]. This constraint will be used to determine if the victim is in a state of shock as defined by the START model.

e) System shall detect the operating breathing frequency for a human at approximately 0.13 to 1 Hz.

a) This constraint is derived from the breathing rates for all age brackets [4]. The System will detect between these frequencies and then the computing system will convert this into breaths per minute or bpm.

f) System shall give vocal commands.

a) This constraint is derived from the start model as one of the steps of triaging a person [2]. This constraint will be used along with the speaker subsystem to evaluate the cognitive ability of a victim.

g) System shall listen for a human response to a command.

a) This constraint is derived from the START model as one of the steps of triaging a person [2]. This constraint will be used to determine the cognitive ability of the victims.

h) System shall limit the audio frequency received between 80 to 255 Hz.

a) This constraint is derived from the operating frequencies of human vocals [5].

i) System shall not store any voice recordings.

a) This constraint is for compliance with the two party consent laws for select states.

j) System shall operate at full functionality for 15 to 60 minutes.

a) This constraint is derived from Darpa's requirements for the Drone Triage Challenge or DTC [1]. The purpose of the DTC is to increase the yield of lives saved so it is ideal that the drone operate for an extended period of time.

k) System shall have a power system in the form of a battery.

a) This constraint stems from this system being attached to a drone so some form of portable power will have to be supplied.

l) System shall display triage results and vitals wirelessly.

a) This constraint stems from this system being attached to a drone so some form of wireless communication will be required to display results of the triage algorithm and the measured vitals.

m) System shall weigh less than 20 pounds.

a) This constraint is derived from Darpa's requirements for the Drone Triage Challenge or DTC [1]. Since the system will be attached to a drone it is inherent that the system weight be at a manageable level for a drone.

n) System shall operate the speaker at approximately 90 dB.

a) This constraint's intent is to give the listeners a loud enough tone so they can hear the commands given [6].

o) System shall operate the speaker between 20 Hz to 20 kHz

a) This constraint is to ensure that the sound the system is putting out can be perceived by human ears [7].

p) System shall display results in close to real time.

a) This constraint is derived from Darpa's requirements for the Drone Triage Challenge or DTC [1]. The purpose of the DTC is to increase the yield of lives saved so time will be a major factor in saving lives in a mass casualty situation.

II. Background

DARPA has issued a challenge titled the DARPA Triage Challenge, or DTC. The goal of the DTC is to develop a contactless way to evaluate the vital signs of a person who has fallen victim to a disaster and use this data to sort the victims based on their medical status. This data is then to be sent to medical responders who will be able to respond quickly and effectively to a victim that needs the most urgent medical care.

There are two stages that are included in the DTC: the primary triage and the secondary triage. For the primary triage, the main goal is to develop a system that is attached to an uncrewed aircraft vehicle, or UAV or drone, that can quickly and efficiently evaluate the medical condition of victims of a disaster and can transmit that information to medical responders. The goal for secondary triage is to develop non-invasive contact sensors to re-assess and monitor trauma victims after their most urgent injuries have been treated [8].

For this capstone project, the team will be focusing on the primary triage where we will develop a system that can sense the immediate medical condition of a disaster victim. The team will only be focusing on the sensing system and will not attach this system to a drone due to the two-semester time constraint of Capstone projects. DARPA's current problems with the triage system include scaling issues with the sensors on the UAV, they are unable to assess the medical needs of a victim that visually appear stable, and physiological data from the victim. The main goal of the DTC primary triage is to test speed and accuracy for the sensors on the UAV.

1. *START Model*

a) The first step of the START model is to give an audible command to victims that can walk. To accomplish this goal, the system shall have a speaker that gives a command to all victims. This will be used to sort out the victims in need of secondary triage which is out of the scope of this project [2].

b) All of the sensing goals for the system are dependent on a victim being present, so the system shall detect the presence of a victim [1][2].

c) The second step of the START model is to detect the breathing rate of the injured victims. To accomplish this goal, the system shall detect the breathing rate in breaths per minute [2].

d) The third step of the START model is to detect if a heart beat is present. To accomplish this goal, the system shall detect the presence of a victim's heart beat [2].

e) The final step of the START model is to evaluate the mental status of a victim. To accomplish this goal, the system shall receive a response from a victim and make a decision on mental staus [2].

f) The system shall take all information from the sensing devices and triage a victim based on the START model [2].

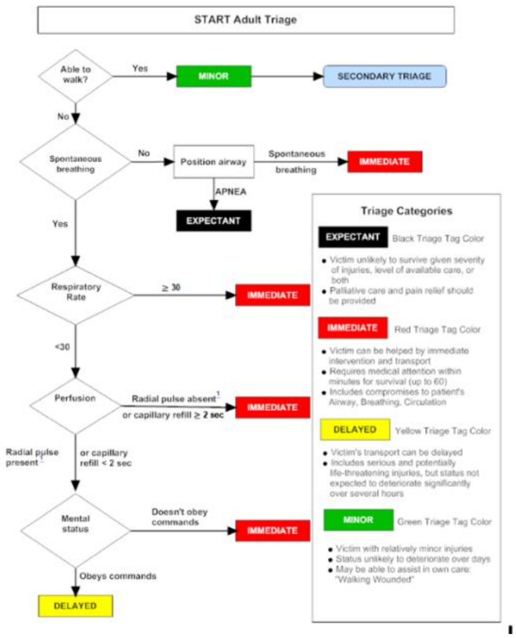

Fig. 1. The above chart displays all categories of the START Method [2]

2. *Additional Project System Information*

a) Drone Requirement: To determine the maximum weight, the entire sensing system can be in order to fall under the twenty-pound maximum weight limit issued by DARPA, a specific drone must be chosen to act as a model for the project. The specific drone chosen is a Matrice 300 RTK drone. The Matrice 300 RTK drone can hold up to a maximum weight limit of 2.7 kg or approximately six pounds [9]. The weight of the drone without the sensing system is approximately 6.3 kg or approximately 13.89 pounds [10]. These weights combined fall just under the maximum weight limit of 20 pounds set by DARPA, so the sensing system that will be developed over the course of this project must fall below six pounds.

b) Lacking Visual Sensor: According to the START model, a person is sorted into the minor category if they can walk. Due to this project lacking a visual sensor to better fit the scope of the project and what the team members can accomplish in the time frame of Capstone, the sensing system will be unable to detect if a person is walking for a fact. Because the system cannot detect if a person can walk or not, the solution to this problem, that also fits the scope that has been set for this project, is to assume that every person that would originally be sorted into the minor category, will now be sorted into the expectant category. Although this method has its downsides such as dropping the efficiency and performance of the system slightly, the downsides do not outweigh the upsides of this method. The upside of this is the fact that injuries will be overestimated rather than underestimated.

c) Case Section: The mount subsystem that will be implemented into this project will simply hold all of the components that are to be used in the overall system together and place them in a convenient manner to be determined by the team.

III. Ethical, Professional, and Standards Considerations

Ethically speaking, the positive impacts that this project could have on society involve the advantages of an early-stage development of a sensory system that can be attached to a UAV to determine the medical condition of a victim during a disaster. In other words, the development of this system could potentially save the lives of many victims during a natural or military disaster. By the end of next semester, this project could potentially be picked up by a future team to become a system that saves multiple lives quickly and efficiently. Whoever picks this project up in future Capstone groups and adds to it will ideally already have a working microphone system to communicate with victims as well as breath detection, breath analysis, heartbeat detection, and heartbeat analysis after this part of this project is complete. They will also ideally find it relatively easy to attach to a drone, especially as we consider the weight of our reference drone to meet DARPA's weight constraints [1].

Globally speaking, this technology may also be utilized by the United States military to potentially spy on foreign militaries with whom they are at war. This is not an intended use for this technology. To prevent such spying and/or sabotage, the system will not have the capability to save the images taken by the camera as is required by the one-party/two-party consent laws [11]. As required by such consent laws, these images will simply be processed and analyzed, not saved.

Environmentally speaking, there is also the worry for any power system that it could potentially have a negative effect on the environment. As the power system is designed, each individual plans to take the environmental impact of each component into account to minimize the negative footprint this system has as it is powered. If a similarly priced sensor or power component is found that also has a lower environmental impact, choosing the one that lowers the system's environmental footprint will be considered.

Taking specific standards into consideration, all standards and constraints defined by DARPA will be considered and followed [1]. Depending on the context of the usage of the battery power subsystem, all power standards set by the US government will be followed, including but not limited to Safety Standards for Primary, Secondary, and Lithium Batteries assuming it is relevant, Standard for Rechargeable Batteries for Multi-Cell Computing assuming it is relevant, Standard for Safety for Lithium Batteries assuming we utilize lithium batteries specifically, Standard for Safety for General Requirements for Battery-Powered Appliances assuming it is relevant, and Standard for Audio, Video, and Similar Electronic Apparatus–Safety Requirements assuming it is relevant [12]. Since radar is being considered for heartbeat and breath detection and analysis, standards relating to radar may need to be considered and followed [13].

IV. Conceptual Solution

The conceptual design is an important aspect to the overall design process because it assists the team and designers of the project in future phases of the project. The conceptual design lays the general groundwork for a system and its specific subsystems functions making it easier for the designer to research and design specific components that can perform all the actions specified in the conceptual design. This conceptual design will provide a blueprint on what the total system will do and allow for a more detailed 'how' the system will accomplish these functions to be easier to achieve.

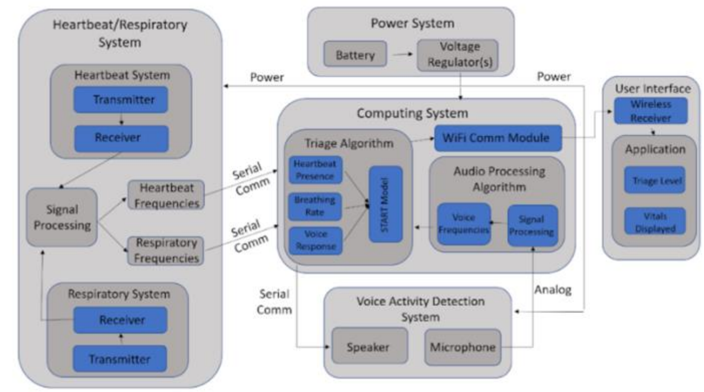

Fig. 2. Pictured above is the Block Diagram of the System

1. *Power Subsystem*

a) Functionality: The subsystem will be responsible for powering all necessary devices that are present as part of the total sensing system. This subsystem can be broken down into a source of power along with some form of voltage regulators to match the necessary voltage needed by each device attached. Due to the total sensing systems needing to be mobile, a battery will be used to supply power and be regulated to the desired value.

b) Connections: Internal to the power subsystem the battery will be the input to the voltage regulator circuit(s). Then the power will be outputted as a wired connection to the Heartbeat/Respiratory Subsystem, Computing Subsystem, and the Voice Activity Detection Subsystem.

c) Analytical Method of Compliance: This subsystem will need to comply with constraints 10, 11, and 13 from the Introduction. Once specific components are selected, the team can determine the system's overall power consumption needs, determine a viable source from data and analysis found through research, and test the source through trial periods in the range 15 to 60 minutes. The team will choose a battery that supplies the necessary amount of power to the system. The team will approximate the load and conduct analysis to make the best choice. The team will conduct research into different drones and their payloads to approximate the maximum weight allowed for the sensing system. The team will then choose a battery to power the system while being considerate of the calculated sensing system weight constraint derived from the overall weight of 20 lbs and the prior selected components including the sensors and computing subsystem.

2. *Computing Subsystem*

a) Functionality: This subsystem is responsible for the housing and computing of the voice detection algorithm and the overall triage algorithm as well as wirelessly transmitting the results to the user interface. The voice detection algorithm will take in raw data from the microphone, process it, and take out the data found between a vocal frequency range and send the results to the triage algorithm. The triage algorithm will take in data sent from the Heartbeat/Respiratory Subsystem and the voice detection algorithm and compute whether a heartbeat is present, what the breathing rate is, and if the individual is responsive, These results will then be compared to the START triage method model to output the triage level necessary for the individual being tested. The result of this algorithm will then be wirelessly transmitted to the user interface.

b) *Connections:* This subsystem will have serial or digital communication input lines coming from the heartbeat/respiratory subsystem, as well as an analog input line coming from the microphone. The subsystem will have two outputs: one serial digital communication going to the speaker in the Voice Activity Detection system and one wireless RF signal transfer of the triage output data.

c) *Analytical Method of Compliance:* This subsystem will need to comply with constraints 12, 13, and 16 from the Introduction. The team will conduct research into different wireless communication platforms and choose the option that provides an appropriate distance of communication and an appropriate bandwidth for the essential information being transmitted. Central sensing, audio, and processing components will be selected prior to power components to ensure weight restrictions are appropriately calculated. The team will employ the use of digital signal processing techniques to process the data at close to real time. This can be measured through timing the process of collection to results of data.

3. *User Interface*

a) *Functionality:* This subsystem is responsible for displaying the triage level (expectant, immediate, or delayed) need of the individual being tested as well as the individual's vitals to a user. The data will wirelessly be acquired from the computing system which will allow for the user interface to be in a remote location compared to the sensing system. The information will be displayed to the user through an application either on a laptop or potentially a mobile device. This will show a color corresponding to the individual's need based on the START model and display the heart rate and respiratory rate.

b) *Connections:* This subsystem will only have one input connection which will be acquired through RF by a wireless receiver and will contain all the data necessary too create the application for the user interface.

c) *Analytical Method of Complience:* This subsystem will need to comply with constraints 12 and 16 from the Introduction. The team will conduct research into different wireless communication platforms and choose the option that provides an appropriate distance of communication and an appropriate bandwidth for the essential information being transmitted. Measured trials may be conducted to test the collection-to-display time of data.

4. *Voice Activation Detection System*

a) *Functionality:* This subsystem is responsible for sending out a call and response test using a speaker and a microphone. The speaker will only play the call action if the triage algorithm tells it to. Once the speaker has played the call action the microphone will acquire audio data that is sent directly to the computing system for voice activity detection. As to not waste time this subsystem will only function if an individual's heartbeat is present, as per the START model.

b) *Connections:* This subsystem will have two connections, the first an digital serial communication input coming from the computing system to play the respective call action. And the second is an analog output signal connection that will feed the computing system with the raw data acquired from the microphone.

c) *Analytical Method of Complience:* This subsystem will need to comply with constraints 3, 6, 7, 8, 9, 13, 14, and 15 from the Introduction. The team will employ the use of common measurement devices coupled with audio testing with human subjects to ensure the output audio signal of the system is audible at a minimum distance of 1 meter and the input audio signal from the subjects is detectable at a minimum range of 1 meter. A speaker system will be implemented to output a preprogrammed (prerecorded) audio signal. A microphone will be used to capture the subjects' responses to the output audio signal. Human speech is complex; therefore, the team will employ the use of digital signal processing techniques to filter out unwanted noise and extract a subject's response from the audio samples based on the human vocal range of 80 to 260 Hz. The algorithms used to process the input audio signal will not store the audio samples for more than the time that is required to process the samples. Central sensing, audio, and processing components will be selected prior to power components to ensure weight restrictions are appropriately calculated. The team will take samples of the output audio signal using an external audio capturing device to ensure the magnitude of the signal is approximately 90 dB. The team will use live-human subjects to determine if the output audio signal is loud enough to be audible. The team will use live-human subjects with an audible frequency detection range of 20 Hz to 20 kHz to determine if the output audio signal is audible.

5. *Heartbeat/Respiratory System*

a) Functionality: This subsystem is responsible for acquiring data based on chest wall movements of an individual at both heart beat frequencies and respiratory rate frequencies. This is done by transmitting signals and waiting to receive the signal back at a receiver end. This signal can now be processed to retrieve the chest wall movements at heartbeat and respiratory frequencies. The data can then be sent to the computing system to be used for the triage algorithm.

b) Connections: This system has two connection outputs. The first is a digital serial communication output that sends the data relevant at the frequencies of a human heartbeat to the computing system. The second is another digital serial communication line that sends relevant data at the frequencies of respiratory rate to the computing system.

c) Analytical Method of Complience: This subsystem will need to comply with constraints 1, 2, 3, 4, and 13 from the Introduction. Data collected from live-subject tests will be analyzed to determine the accuracy of the heartbeat sensor. For example, the team will evaluate the number of false positives and false negatives of a heartbeat detection. The team will ensure that the heartbeat sensor is rated to detect frequencies within the range 0.45 to 2.92 Hz. Common measurement devices will be used to measure the accuracy and precision of the sensors at varying displacements from the human subjects. The team will ensure that the respiratory sensor is rated to detect frequencies within the range 0.13 to 0.42 Hz. Central sensing, audio, and processing components will be selected prior to power components to ensure weight restrictions are appropriately calculated.

V. TIMELINE

This project of developing a sensing system that can determine a victim's medical status using contactless methods will require many components to achieve this goal. The first subsystem that must be completed is the power subsystem. The power subsystem must be completed first since all other subsystems in the system will have to rely on the power system to function properly.

Russel will oversee the power subsystem and ensuring that the power subsystem is able to power all other subsystems present in the overall system, as well as not providing an excess amount of current and voltage that could potentially damage or destroy the other subsystems. As Russell is developing the power system, the software portion of the project will begin alongside the construction of the power system. Logan will oversee developing the software and programming that will allow the computing system to process all the information that the sensors will acquire. During this time, other members will assist Logan and Russel if needed. Once the power system has been constructed, the next step will be implementing the other sensing subsystems into the power system and testing the sensing subsystems to see if they are functioning properly. These actions will be performed by Andrei and Raymond. During this time, Raymond and Andrei will first begin work on the heartbeat and respiratory rate subsystems. Once these two subsystems have been completed, work on the audio detection subsystem will begin. Once the software portion and programming are complete or nearly finished, Raymond, Andrei, and Michael will start to implement the software into the sensing subsystems to verify that the subsystems are working as intended in relation to the project goal.

Once this task has been completed, progress on the user interface shall begin. The user interface will be composed of a mobile app that will operate on a mobile device such as a phone or a laptop that will communicate wirelessly with the overall sensing and computing subsystems. The development of the app will be overseen by Logan, and the wireless communication aspect will be overseen by Russel and Raymond. As the user interface and wireless communication is being developed, Andrei and Michael will work on the housing system that will simply hold the sensing subsystems, the computing subsystem, and the power subsystem together in convenient locations. Once all these tasks are complete, the team can move onto testing the entire system in the testing and experimentation phase of the project. Once experimentation and testing has concluded, the team can revise and improve the project if necessary.

Task name	Start date	End date	Assigned	Status	16-Apr-23	17-Apr-23	18-Apr-23	5-May-23	14-Aug-23	21-Aug-23	28-Aug-23	4-Sep-23	11-Sep-23	18-Sep-23	25-Sep-23	6-Oct-23	13-Oct-23	20-Oct-23	23-Oct-23	30-Oct-23	6-Nov-23	13-Nov-23	20-Nov-23
Parts Ordering	16-Apr-2023	18-Apr-2023	Andrei	Open																			
Summer Break and end of 1st semester	5-May-2023	15-Aug-2023																					
Prototype Construction	16-Aug-2023	20-Sep-2023		Open																			
Programming	16-Aug-2023	31-Aug-2023	Logan	Open																			
Power System Construction	16-Aug-2023	22-Aug-2023	Russel	Open																			
Heartbeat Subsystem Implementation	22-Aug-2023	27-Aug-2023	Raymond and Andrei	Open																			
Respiratory Rate Subsystem Implementation	22-Aug-2023	27-Aug-2023	Raymond and Andrei	Open																			
Audio Detection Subsystem Implementation	27-Aug-2023	31-Aug-2023	Raymond and Andrei	Open																			
Software Implementation into subsystems	31-Aug-2023	10-Sep-2023	Andrei, Raymond, and Michael	Open																			
User Interface Construction	5-Sep-2023	20-Sep-2023	Logan	Open																			
Wireless Communication Construction	5-Sep-2023	20-Sep-2023	Russel and Raymond	Open																			
System Housing Construction	10-Sep-2023	20-Sep-2023	Andrei and Michael	Open																			
Experimentation and Testing	21-Sep-2023	20-Oct-2023		Open																			
Experimentation	21-Sep-2023	20-Oct-2023	Logan, Andrei, and Raymond	Open																			
Recording	21-Sep-2023	20-Oct-2023	Michael and Russel	Open																			
Final Presentation Preparation(2nd Semseter)	21-Oct-2023	1-Nov-2023	All Members	Open																			
Prototype Revisions	30-Oct-2023	20-Nov-2023		Open																			
Programming (Revisions)	30-Oct-2023	10-Nov-2023	Logan	Open																			
Power System Construction (Revisions)	30-Oct-2023	2-Nov-2023	Russel	Open																			
Heartbeat Subsystem Implementation (Revisions)	2-Nov-2023	7-Nov-2023	Raymond and Andrei	Open																			
Respiratory Rate Subsystem Implementation (Revisions)	2-Nov-2023	7-Nov-2023	Raymond and Andrei	Open																			
Audio Detection Subsystem Implementation (Revisions)	7-Nov-2023	10-Nov-2023	Raymond and Andrei	Open																			
Software Implementation into subsystems (Revisions)	10-Nov-2023	20-Nov-2023	Andrei, Raymond, and Michael	Open																			
User Interface Construction (Revisions)	10-Nov-2023	20-Nov-2023	Logan	Open																			
Wireless Communication Construction (Revisions)	10-Nov-2023	20-Nov-2023	Russel and Raymond	Open																			

Fig. 3. Pictured above is a Gantt chart of the projected timeline

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