DARPA Drone Triage Project Proposal

Michael West
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, Tennessee
mwest44@tntech.edu

Raymond Mule
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, Tennessee
rjmule42@tntech.edu

Andrei Matei
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, Tennessee
amatei42@tntech.edu

Logan Newport
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, Tennessee
lmnewport42@tntech.edu

Russel Gadd
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, Tennessee
rlgadd@tntech.edu

I. Introduction

During a disaster, speed and efficiency are vital to saving lives. Currently, there is no method available that can scan a large area for disaster victims and can also evaluate their medical condition quickly and effectively. That 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 utilizing uncrewed aircraft vehicles, or UAVs, otherwise known as drones. For our capstone project, the goal is to develop the sensing system that will eventually be attached to a drone that DARPA requires for their challenge [1]. The sensing goals that we are going to accomplish are a sensor to measure heartbeat, a sensor to measure breathing rate, a camera as well as a night vision camera, and a speaker and microphone. All these components will be used to evaluate the medical state of a person that has fallen victim to a disaster to fulfill the challenges that DARPA has issued.

II. Background & Constraints

As stated in the introduction, DARPA has issued a challenge called the DARPA Triage Challenge, or DTC. The goal of this challenge is to develop a way to evaluate a person who has fallen victim to a disaster and use this data to assist medical responders in quickly separating victims into several groups indicating if they are in dire need of medical attention, are in a stable condition, or are dead or unable to be saved.

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 that can transmit that information to medical responders. For the secondary triage, the goal is to develop non-invasive contact sensors that can be placed onto a disaster victim's person after their most urgent injuries have been treated [2]. The purpose of these non-invasive contact sensors is to acquire data from a specific victim about their medical data to further treat the victim's injuries and ensure that their life can be saved.

For our capstone project, we will be focusing on the primary triage where we will develop a system that can sense the immediate medical condition of a disaster victim. We will only be focusing on the sensors, and we will not attach this system to a drone due to the restraints that have been placed upon this project. DARPA's current problems with the triage system include scaling issues with the sensors on the UAV, they are unable to assess medical needs to a victim that visually appear stable, and physiological data from the victim. The main goal from DARPA is to test speed and accuracy for the sensors on the UAV. Some constraints enforced by DARPA include the sensors on the UAV must be contactless and the only visible light on the UAV and sensors must be the legally required amount [1].

Another restraint that affects our project is the Federal Aviation Administration, or the FAA, and their temporary flight restrictions, or TFRs, that prohibit the flight of drones during major sporting events, national emergencies, or disasters. Before going through any process to gain permission to fly during TFRs, a drone pilot must take a test called the Unmanned Aircraft General - Small (UAG) to even become a drone pilot. To receive permission from the FAA to fly during TFRs, an extensive process known as the Special Government Interest, or SGI, must be completed to gain permission [3]. A drone pilot can also be a Part 107 Remote Pilot with a current certificate to be able to fly during TFRs. A Part 107 Remote Pilot is a drone pilot that is allowed to fly at night, over people, and over moving vehicles without a waiver. If a drone pilot is not a part of the Part 107 Remote Pilot, the drone pilot can also fill out a Certificate of Waiver or Authorization, or COA to gain permission to fly during TFRs. Finally, to complete the SGI process, a drone pilot must fill out an Emergency Operation Request Form and send it to the FAA [5]. One other restraint that may be placed onto our project from the FAA is that if the drone with all the sensors attached to it weighs more than fifty-five pounds, a drone pilot must apply for exemption via Section 44807 or apply for a Special Airworthiness Certificate [4].

There are also some standards set by the Institution of Electrical and Electronics Engineers, or IEEE. These standards assigned by IEEE mainly focus on the drone portion of this project, which is not our primary objective for this project, but the regulations that are placed upon drones by the IEEE are standard IEEE 1937.1-2020 and IEEE 1936.1-2021. Standard IEEE 1936.1-2021 lists some requirements that a drone needs to be safe for consumers such as a flight program, flight control system, ground control station, payload, control link and data link, and takeoff and landing system. Standard IEEE 1936.1-2021 also covers drone safety and management requirements that must be followed which includes: airworthiness, air traffic requirements, qualification of operators and personnel, insurance, and confidentiality. The other standard that the IEEE assigns to drones is the IEEE 1937.1-2021. Standard IEEE 1937.1-2021 describes requirements that must be present in payload devices found in drones.

Standard IEEE 1937.1-2021 splits drone payload interfaces into three categories: mechanical interface, electrical interface, and data interface. Mechanical interface describes how the payload device is attached to the drone, electrical interface describes an electromechanical device that joins electrical terminations, and data interface describes communication protocols that must be followed. Standard IEEE 1937.1-2021 also describes how a drone payload interface's performance is evaluated [6][7]. A drone payload interface's performance is evaluated by how well it is protected from extreme temperatures, high humidity, water, dust, shock, vibration, and other foreign objects that could damage the interface. As stated earlier however, the standards set by IEEE mainly affect the drone aspect of this project which is not our main goal. The main goal of this project is to develop the sensing system that would eventually be attached to a drone to be used in disaster relief situations.

There are also many standards specified by IEEE regarding radars, which would be a component that shall be used in this project. However, most of the standards found on the IEEE standards website were just updates on new radars that have been developed as technology advanced. The most up-to-date standard covering the definition of radars is IEEE 686-2017. IEEE 686-2017 covers a multitude of different types of radars and their unique applications as well as other terms that are related to radars [8].

These are the constraints, standards, and regulations that we will have to abide by as we develop our project. There is a defined process called the START model (Simple – Triage - And - Rapid - Treatment) by which triage should be conducted. START has four categories that define the status of a person, these categories include: minor, delayed, immediate and expectant. The minor category signifies the person has relatively minor injuries and is expected to be in a stable state that does not require immediate medical attention. The START model would consider a person to be minor if they are able to move on their own and can respond to audible commands. The delayed category signifies that the person has potentially suffered life threatening injuries but is considered to be in a somewhat stable state that can receive medical attention at a later date. The START model would consider a person to be delayed if they are unable to move under their own power, have spontaneous breathing, respiratory rate of less than thirty, capillary refill in less than two seconds with a radial pulse present and are responsive to audible commands. The immediate category signifies that the person has suffered life threatening injuries and requires immediate medical attention in less than sixty seconds. The START model would consider a person to be immediate if they are unable to move under their own power, still spontaneous breathing, a respiratory rate greater than thirty, absent radial pulse, capillary refill greater than every two seconds or unresponsive to audible commands. The expectant category signifies that the person has suffered life threatening injuries and is not expected to survive given immediate medical attention. The START model would consider a person to be expectant if they are unable to move and all breathing has ceased. For this project, we will follow the guidelines set by the START model to evaluate the medical conditions of disaster victims [9].

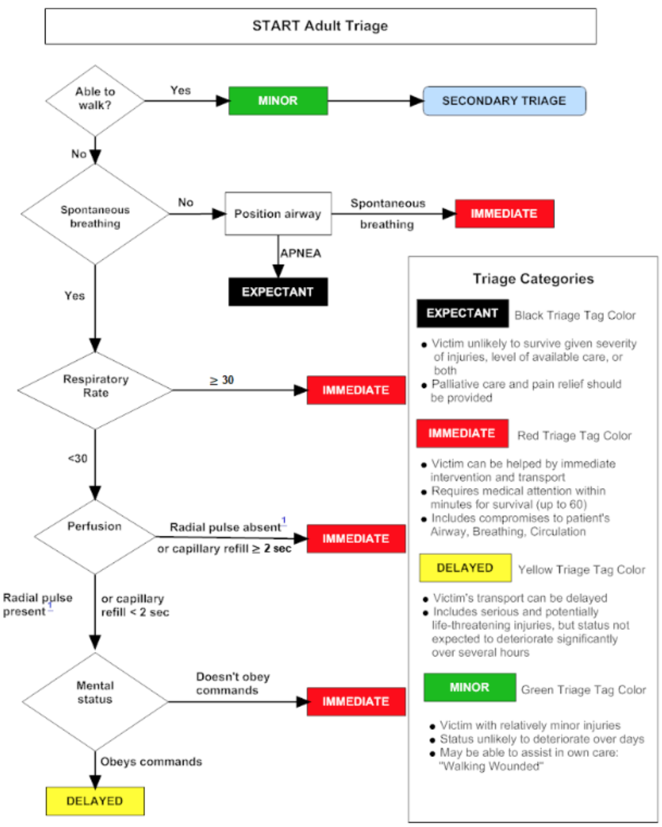

Fig. 1. The above chart displays all categories of the START Method

III. Resources

Various sensors must be implemented into our project to fulfill the goal that has been assigned by the DARPA Triage Challenge, and thus to fulfill the goal that has been set for Capstone. As stated previously, our goal is to develop a system that can detect the presence of a person's heartbeat, breath rate, movement/body detection, and cognitive abilities. In total, four sensing systems will be implemented allowing each one of these tasks to be accomplished.

Contactless measurement of an individual's heartbeat has become a growing area of research in the past years and has been successfully achieved as evidenced by Riccuiti [10]. This paper looks at two successful methods of contactless measuring of an individual’s heart rate using radar technology and video processing using an RGB camera. The radar technology works by sending out “chirps” which can precisely measure the position of the subject which then calculate the rate of heart movement. The RGB camera method functions by detecting slight variation in skin color caused my blood flow movement through tissue. This project will focus on using radar technology technique similar to the one used by Riccuiti. The project must also function in night conditions, meaning any sort of RGB camera use is not possible. Due to the success achieved with Riccuiti’s research, an automotive radar sensor (such as the TI AWR1843 used in the experiment) will be used to precisely detect the presence of heart rate. Such devices range from $300-$350.

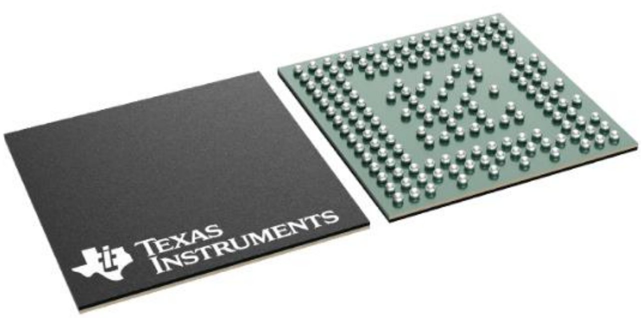

Fig. 2. Pictured is a TI AWR1843 [11]

Much like heart rate monitoring, contactless respiratory monitoring has also received a growing amount of interest and success in the research field with positive results. Massoroni reviews four such contactless methods used to detect breathing rate [12]. The first method uses environmental respiratory sounds to detect inhalation and exhalation sound changes. This method uses a microphone placed near the trachea and an amplifier to calculate a breathing rate. The second method uses air temperature differences to detect heat flow from nostrils due to breathing. A thermal camera is used to reflect the air temperature difference on an individual's face. The third method uses depth sensors to detect chest wall movements. Like heart rate monitoring, position sensors such as radar or lasers can be used to detect change in an individual's chest movement. The final method uses RGB cameras and visual sensors to detect changes due to breathing on the visual spectrum.

Due to harsh unknown mass causality environments, RGB camera and thermal camera won’t be able to function. This project will focus on the other two methods, sound and depth sensors, primarily utilizing radar technology for depth sensors because DARPA does not allow lasers or visible light to be used within the system [2]. There is potential in using the same radar device for both heart rate and respiratory rate monitoring due to multiple transmitters and receivers on radar sensor devices such as the AWR1843. To be clear, this project will utilize either depth sensors or respiratory sound detection for respiratory rate detection. A microphone such as the Sony ECM-77B mentioned by Massoroni can cost between $200-$300 while the UWB depth sensor can cost between $100-200.

Fig. 3. Pictured is a Sony ECM-77B microphone [13]

This project will utilize whichever method is most feasible and cost efficient. The presence of an individual along with mobility detection can be achieved using a simple camera. To combat night conditions, another IR night vision camera will be added. These two cameras coupled together will be able to allow an operator on the other side of the system to make a contactless decision on the presence of a body and its mobility status. A lot of small modular cameras exist for such a task including ones such as the Seeed IMX219 that already integrate with other computing modules such as the INVIDIA Jetson. Each camera sensor module can cost between $20-$30.

Fig. 4. Pictured is a Seeed IMX219 [14]

To determine an individual’s cognitive ability, a simple speaker microphone system will be used to interact with each victim. DARPA has confirmed that this method is a valid approach as long as a contactless method is used [2]. This project will utilize a sort of walkie talkie system that will allow an operator to quickly communicate in real time with an individual to assess cognitive abilities and any possibly unseen injuries or to quickly determine if the victim is in a stable condition. The intercom system ranges from $30-$45 for a simple speaker plus microphone system.

The final aspect of this project is the computing system. This system must tie in all the information from each sensing module and combined with the triage information mentioned before to give an accurate reading on an individual's triage status. Many such computing devices exist, but this project will focus on the use of a raspberry pi or an Nvidia Jetson. These devices not only have the capability to integrate with some of the sensing modules, but also have the computing power to handle this system's workload. Such computing devices cost between $150-$200. In total, including all the components that are potentially needed to achieve the goal that has been set by capstone and DARPA, it will cost approximately between $650-$900 to purchase all these components.

IV. Measure of Success

The goal for this project is to develop a system that can sense and evaluate the medical condition of a disaster victim that can be used in a triage for disaster relief. For this project, we shall develop a system that has the ability to detect the presence of a victim’s heartbeat using a contactless method, and potentially retrieve a specific quantified value of the individual's heart rate. The heartbeat sensor will have the ability to determine if a victim’s heartbeat is too slow or too fast to define if the victim is worth saving or not. To test this subsystem, a test subject will be placed under the sensor attached with a contact heart sensor. The data from the contact sensor will be compared to the contactless sensor allowing for the comparison of the two which will test if the system is accurately detecting the presence of a heart beat along with potentially measuring a specific heart rate.

The system shall also detect the presence of an individual's respiratory rate through contactless sensing that can check to see if a victim is breathing or not. We would like for the breath sensor to potentially be able to derive a specific breath rate value and act similarly to the heart beat sensor where the sensor determines if the victim can be saved, or if it would be the better option to move onto the next victim. Similarly to the heart rate subsystem, the respiratory subsystem will be tested by comparing a contact method of repertory rate detection with the system's contactless method against living individuals and non-living objects.

The system shall also have both a camera and an IR night vision camera that can act as a visual sensor that will assist the operator in determining the presence of a victim and any visible injuries that a victim may possess. This subsystem will be tested by its accuracy for an operator to detect human individuals and specific injuries on the human body with only the visual cues found from the camera sensors.

Finally, the system shall be able to communicate and relay back an individual's cognitive ability and responsiveness. This task will be achieved using a walkie talkie system. The purpose of the microphone and speaker is to ask a victim if they are stable enough to assist themselves. This will test if a victim still possesses cognitive abilities and responsiveness. It will also assist the relief efforts by quickly ruling out victims that possess little to no serious injuries, which will allow more time to be spent assisting victims that have serious injuries that must be quickly tended to by a medical team. This subsystem will be tested by simply assessing the accuracy of information relayed from a victim to the operator at a set distance away.

V. Obstacles

One obstacle that we will have to overcome is a lack of experience. Many team members have never worked on the field before, only working in a classroom or pre-designed lab setting. To combat this obstacle, team members will be expected to do extensive research to gain knowledge that can assist in solving any unknowns that will be encountered during the development of this project.

Another obstacle that we may run into is a lack of time to work on said project due to this being a two-semester project or a thirty-to-thirty-two-week timeframe. Many team members not only have other classes they are required to work on a weekly basis, some of them also have parttime jobs that may take time during the weekend. Scheduling around both will need to take place to combat this obstacle and ensure that the project’s progress stays on a steady pace towards completion.

Another obstacle that will likely be faced is funding, as many of the more ideal pieces of equipment that could be used for this project are significantly more expensive than was initially expected. Some ideal resources may be too expensive for the university, and they may only agree to pay for cheaper components, so cheaper alternatives must be found to ensure that the scope of the project is slightly altered or not altered at all.

However, after extensive research on the components that are to be used in this project, it has been found that funding will not pose as large an obstacle as initially thought. After said extensive research, some other obstacles have been immediately brought to light. One of these obstacles is finding a way to ensure that the sensors can communicate with a computing system that enables a user to absorb all the information that is being displayed to them. To combat this obstacle, even more extensive research will be required from group members to ensure that a solution to this problem can be found.

Another obstacle that was found is a lack of knowledge on if the radar used in this project will be able to detect a person’s heartbeat if the person is wearing a large amount of clothing. The solution to this problem will either be found through research or in the testing and experimentation phase of this project.

VI. Anticipated Timeline

The anticipated timeline for this project will span over two Tennessee Technological University semesters, or approximately thirty to thirty-two weeks in total. The project initially started in January, where the first several weeks were focused on choosing a project assignment as well as forming a teamwork contract with the project's group members. Once the teamwork contract was finished and the project to develop a system that senses a person's vital signs and medical condition was chosen, the next step was writing the project proposal. Once the project proposal is done as well as rectifying any errors found in the project proposal, the next step is to create a presentation to display our project proposal to other Capstone I members as well as starting to develop a conceptual design for our project.

The project proposal, project proposal presentation, and conceptual design will be within the months of February as well as the beginning of March. During the month of March, the conceptual design should be completed, and work on the conceptual design presentation, which presents the conceptual design of the project to another Capstone I group, will begin. Once the conceptual design and conceptual design presentation have been completed, work on the detail design of this project shall begin. The detail design will be worked on throughout the entire month of April. Once the detail design of the project is completed, Tennessee Technological University's summer break will begin and last from the first week of May through the middle of the month of August. During this time, progress on the project will be put on hold due to the break.

Once Tennessee Technological University's Fall semester begins, the project will be picked back up once all group members have progressed to the Capstone II course. If the detail design was not completed during the month of April, some time will be spent in August to complete the detail design of the project. Once the detail design is complete, the parts required to construct the project must be ordered. The parts ordering process will last approximately a week which will be the end of the month of August.

Once all parts have been acquired, construction of the prototype of the project will begin. The prototype construction process will last several weeks into September and leak into the month of October. Once the prototype has been constructed, testing and experimentation will occur to ensure that the project functions as intended, and if not, will leave time to rectify errors that have been found during this testing phase. Once experimentation and testing have been completed, work on the final presentation practice of the project shall begin which will last from October to the beginning of November. Once final presentations practice has concluded, any extra errors that have been found during the testing and experimentation phase of the project will be rectified or improved. Towards the end of November, final documentation and final project posters will be worked on and completed. Once all these tasks have been completed, the final presentation will be performed, and the project will end in completion.

VII. Broader Impacts

The impacts that this project could have on society is 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. The development of this project could potentially save the lives of many victims during a disaster. In a perfect future where all objectives are clearly met and even some extra functionalities are applied, 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 camera and microphone system to communicate with victims as well as breath detection, and heartbeat detection after our part of this project is complete. They will also ideally find it easy to attach to a drone to fulfill the primary triage goal that DARPA has issued [1].

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