Conceptual Design and Planning for Drone Triage Project

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

Russell Gadd
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, Tennessee
rcgadd42@tntech.edu

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 a heartbeat, breathing rate, body detection, visible injury, and cognition using various sensors. These components will be used to evaluate the medical state of a person who has fallen victim to a disaster in order to fulfill the DTC.

II. Background

1) 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].

2) 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].

3) 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].

4) 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].

5) 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].

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

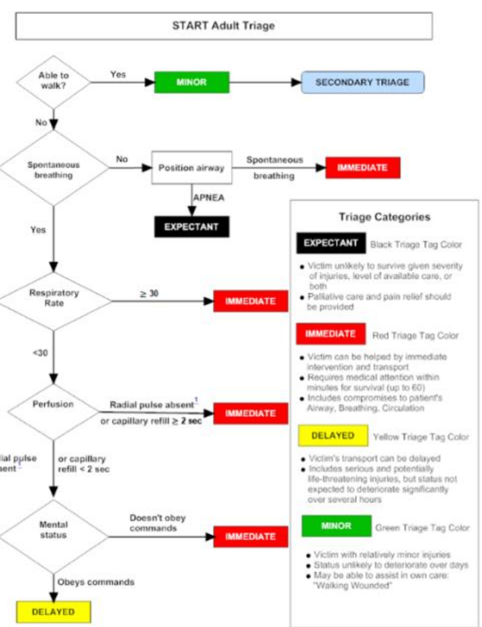

Fig. 1. The above chart displays all categories of the START Method [2]

III. Ethical, Professional, and Standards Considerations

IV. Sub-Systems

A. System Case Housing

1) Functionality: The function of this subsystem is to hold all of the subsystems, excluding the displayed output, together. The casing is also responsible for protecting the other subsystems from the hazardous elements such as strong winds and heavy rain. As of now, the team has decided that the best course of action on how to construct the case to be used to house the other subsystems will be 3-D printed. If the case is to be 3-D printed, it will allow adaptability of the case to ensure all components can fit within it, it will be strong enough to protect the components from natural elements, and it will be light enough to fit within DARPA's weight limit [1].

2) Connections: This subsystem will be connected with the other subsystems present in the overall system using a physical connection that holds all of the other subsystems in place as well as protecting them from natural elements such as strong winds, heavy rain, and dust.

3) Constraints: The subsystems must be accessible by a technician. DARPA has constrained the overall weight of the drone triage system to be no more than 9 kg or just under 20 lbs. In future stages where the triage sensing system is amalgamated with a drone, the type of drone will be dependent upon the weight of the sensing system. The casing should protect the components from inclement weather such as heavy rain, strong winds, and dusty weather conditions. The drone with the sensing system must also not emit any extra visible light other than the legally required amount which is a white or red blinking LED that acts as an anti-collision light. The sensing system must also fit onto a singular vehicle [1].

4) Analytical Method of Compliance: To conform to the constraints set by DARPA, the group must design a lightweight case that enables all components, the case, and a potential drone that will be added in future capstone projects, to fall under the 9 kg weight limit set by DARPA [1]. This could be accomplished by designing the case using a 3-D printer since the filament used would be very lightweight. The case must also be strong enough to protect the components from harsh weather conditions. This could be accomplished by constructing the case using a 3-D printer first, then testing to see if there are any openings in the case that elements such as water and dust can seep through. Once all openings have been found, steps to ensure these openings can be closed can begin. These openings in the case could be closed through water sealing pastes that block the flow of water and other elements. Repeating this process of sealing any openings on the case will ensure that the project can abide by DARPA's constraint of allowing the sensing system to operate in harsh weather conditions [1]. The following is not a constraint from DARPA, but the group must ensure that the case does not obscure the view of any sensor that is to be used in this project. This can be accomplished by using a clear plastic plane that will protect any sensors that must have a view of the victim. The clear plastic plane must be implemented in this project to ensure that no sensor is obstructed, as well as to abide by DARPA's constraint of the system being protected from weather conditions [1]. The case must also cover any excess light that the components might emit to ensure that the project follows DARPA's constraint of no extra visible light other than the legally required amount [1]. This can be accomplished by taking the entire sensing system including the case and all components properly connected into a dark room. Once the system has been moved to a dark room, the group can identify any excess light that is being emitted from the system and start to cover the excess light using methods such as tape or any other covering methods. The case must also be small enough to potentially fit onto a single vehicle to abide by DARPA's standard [1]. To accomplish this, the case must be designed in a 3-D modeling software to ensure that the case is an appropriate size, as well as being able to fit all of the components within it.

B. Power System(s)

1) Functionality: The function of this system is to provide power to each of the subsystems found in the system case housing. The output is expected to be DC to each system. There may be a necessity for more than one power device depending on the specific parts used for each other subsystem.

2) Connections: The power system (or set of power systems) will be connected to every other subsystem via wiring within the system's case housing.

3) Constraints: Power systems are reasonably the largest and heaviest component to be implemented with any form of vehicle design. Power systems may be of a high level of complexity and are subject to an extensive list of regulations. The power system for the drone triage sensing unit is no different. The power system must integrate with the power system of the drone or be separate but comply with DARPA's regulations on drone size and weight [1]. The power system is dependent upon the individual consumption requirements of each electrical component within the design and therefore must be capable of supplying multiple forms of electrical energy. The power system must be mobile, must be rechargeable and/or replaceable, and must provide enough energy to power the system for 15-60 minutes [1].

4) Analytical Method of Compliance: The purpose of this subsystem is to power the other subsystems that will be used in the overall sensing system. This power system, as stated in the section above, will most likely be the heaviest component in the sensing system, but it must be light enough to ensure that the entire system does not exceed the 9 kg weight limit set by DARPA [1]. The power system must also be adaptable enough to power all of the subsystems that rely on it without damaging the components due to an excess amount of current or voltage.

To ensure that the power system does not damage any of the additional components, research on each specific component must be completed to know the exact voltage and current limits that each component possesses. Additional components that regulate voltage and current such as transistors will most likely be necessary to ensure that the power system will not damage the other components of the system. The power system must also be powerful enough to ensure that the sensing system will last the entire duration of time specified by DARPA which is a minimum of fifteen minutes and a maximum of one hour [1]. Research on the specific components that make up the power system will have to be done to ensure that the time duration will be met, as well as to ensure that the system is light enough that it does not exceed the weight limit set by DARPA [1].

C. Computing System

1) Functionality: This subsystem will be used to house the algorithms used to process all sensor data and conduct autonomous triage in accordance with the START method and to wirelessly transmit the processed data to the displayed output subsystem [2]. This system will function by taking in digital data from the heartbeat system, digital data from the respiratory system, digital data from the visual system, and analog signals from the audio system as inputs. The system will then run the visual data through an image processing algorithm and the audio data through a voice activity detection (VAD) algorithm. The output from those two algorithms will combine into one algorithm that will output a final triage level result to the display system.

2) Connections: The computing system will have serial communication connections to all sensing subsystems, a connection to the power system, and a wireless connection to the user interface or displayed output system. The computing system will be strategically placed within the system case housing to accommodate for its numerous serial connections as well as its wireless connection.

3) Constraints: This unit is the central component of the drone triage project as it is the part of the entire system that collects crucial data, processes the data, and relays the raw and or processed data to an emergency responder. To process this data the sensing unit is going to require an MCU capable of communicating with our sensors, displayed output, cameras, and speaker subsystems.

4) Analytical Method of Compliance: The purpose of this subsystem is to allow all of the sensors to be able to communicate with one another and process the information gathered from the sensors. The computing system then takes all of this information that has been gathered by the various sensors throughout the system, and sends it to the user interface to be read by medical responders.

D. Displayed Output

1) Functionality: The function of this subsystem is to display the information that has been gathered by all of the sensing subsystems present in the entire sensing system and processed by the computing subsystem. This subsystem will be responsible for allowing a medical responder or medical professional to view a victim and that victim's medical status as defined by the START method to assist the medical responder in determining if it is worth trying to save that victim, or if it would be more beneficial to move onto another victim that can be saved if the victim receives medical attention at that moment [2].

2) Connections: This subsystem will be connected to the computing subsystem using wireless connections. Since the overall goal of the DARPA triage challenge is to connect the sensing system to a drone, the displayed output must be dependent on the sensing system to enable the drone to carry the sensing system freely and perform at a moderate distance away from the displayed output [1].

3) Constraints: DARPA intends for the displayed output to be utilized by a medic [1]. The displayed output must provide the situational awareness that a medic would need during primary triage in the early moments of a mass casualty event such as casualty status. The displayed output must be self-explanatory, mobile, and communicate with the computing system without interfering with the sensors [1].

4) Analytical Method of Complience: This subsystem is responsible for displaying important information gathered by the sensors, and putting it into a readable format to assist medics in showing them the medical status of a particular victim. As stated in DARPA's constraints, the displayed output must be mobile, so the displayed output can not function off a computer or large computer monitor [1]. The displayed output will have to be within a handheld smart device such as a tablet or phone in order to comply with this constraint. The displayed output must also be able to be interacted with using wireless methods to ensure that it does not interfere with the performance of the drone carrying the sensing system. To ensure that these constraints are met, extensive research must be completed to ensure that a method where the sensing system can wirelessly communicate with a handheld device such as a tablet can be done.

E. Visual Sensor

1) Functionality: This subsystem will be used to detect a victim's body, to detect if the victim is moving, and to detect for any visual injuries that are present on the victim. This system will function by simply taking in visual data and sending it as a digital input into the computing system. In order to accomplish these goals, the visual system will most likely have to be a camera to capture the visual data that is necessary. The visual subsystem will then gather the visual data that is needed, and it will send the data to the computing subsystem where the visual signal will then be processed to be used in sorting the victim using the START method [2].

2) Connections: This subsystem will be physically connected to the housing case to ensure that it remains in a stable position and is protected from the elements. This subsystem will also be connected using physical connections such as wires to the power subsystem and serial communication into the computing subsystem. The visual sensor must be connected to the computing subsystem to ensure that all information gathered by the visual sensor can be relayed to the computing subsystem where the visual signals captured by the sensor can be processed. The visual sensor must also be connected to the power subsystem to ensure that the visual sensor can function properly and be able to acquire all of the data necessary to be able to sort a victim accurately using the START method [2].

3) Constraints: According to the DARPA guidelines for the drone triage project, the sensors used to evaluate the condition of the victim must use contactless methods of measurement to measure the vitals of the victim [1]. The sensors used must also be safe for the human skin and eyes. The sensors used must also operate at a minimum distance of one meter from the victim, and a maximum distance of thirty meters from the victim [1].

4) Analytical Method of Complience: This subsystem is responsible for detecting a victim's body, a victim's movement, and a victim's injuries. In order to detect a victim's body, movement, and visible injury, this subsystem will most likely be a camera of some kind. Extensive software that is able to process visual signals must be implemented to ensure that this subsystem is able to detect the victim's body, if the body is moving, and to detect any visible injuries found on the victim's body.

F. Audio Sensor

1) Functionality: The function of this subsystem is to test the cognitive ability of a victim, allowing the victim to be quickly categorized using the START method [2]. In order to verify the cognitive ability of a victim, this subsystem will give out a command to the victim using a speaker. The victim will then answer the command with their voice. This subsystem then acquires the audio signal generated by the victim, and then sends the audio signal to the computing system for it to be processed. If the victim responds to the command using a cohesive response that answers the command, the victim will then be identified as well with minor or few injuries. If the victim responds to the command with a non-cohesive answer or does not respond at all, the other subsystem sensors will then activate to further assess the medical status of the victim in order to correctly organize them using the START method [2].

2) Connections: This subsystem will be physically connected to the housing case to ensure that it remains in a stable position and is protected from the elements. This subsystem will also be connected using physical connections such as wires to the power subsystem and the computing subsystem. The audio sensor must be connected to the computing subsystem to ensure that all audio information and signals gathered from the victims can be transported to the computing subsystem where they will be processed. The audio sensor must also be connected to the power subsystem in order for the audio sensor to properly function and gather all necessary data in order to fulfill the requirements for this project.

3) Constraints: According to the DARPA guidelines for the drone triage project, the sensors used to evaluate the condition of the victim must use contactless methods of measurement to measure the vitals of the victim [1]. The sensors used must also be safe for the human skin and eyes. The sensors used must also operate at a minimum distance of one meter from the victim, and a maximum distance of thirty meters from the victim [1].

4) Analytical Method of Complience: This subsystem is responsible for determining if a victim still possesses cognitive ability through a call and response tactic. These tasks will be done with a microphone and speaker or just a speaker. The speaker will shout a command to the victim asking them to comply with it. How the victim responds will assist in assessing the medical condition of the victim. If the victim complies with the order and is able to move, they are in little danger allowing for more time to be spent assisting victims who are in critical condition. If the victim does not comply with the command, additional sensing must be done using the other subsystem sensors to accurately and quickly determine the victim's medical status. The microphone aspect will be implemented to see if the victim is able to respond to the command given by the speaker with words. In order for this to be implemented, software must be implemented to allow for signal processing of a human voice. This will allow the system to determine the victim's medical status without the need for a human operator.

G. Heartbeat Sensor

1) Functionality: This subsystem will determine if the injured victim has a heartbeat and then send the information back to the computing system.The system will function by acquiring data from a sensor and processing it into a digital signal that can be sent as an output from the heartbeat system to an input in the computing system This subsystem is likely to be achieved via radar impulses directed at the injured victim. This subsystem satisfies the requirement of determining if a heartbeat is present of the victim outlined by the START method [2]. This subsystem will then send information pertaining to the heartbeat of the victim to the computing system to run through the triage algorithm.

2) Connections: This subsystem will be physically connected to the housing case to ensure that it remains in a stable position and is protected from the elements. This subsystem will also be connected using wires to the power subsystem and serial communication to the computing subsystem. The heartbeat sensor must be connected to the computing subsystem to ensure that all information gathered and processed by this subsystem can be relayed to the computing subsystem where it will send all of the processed data to the displayed output for the medical responder to view. The heartbeat sensor must also be connected to the power system to ensure that the sensor can function properly where it can gather and process all the data necessary to sort a victim using the START method [2].

3) Constraints: According to the DARPA guidelines for the drone triage project, the sensors used to evaluate the condition of the victim must use contactless methods of measurement to measure the vitals of the victim. The sensors used must also be safe for the human skin and eyes. The sensors used must also operate at a minimum distance of one meter from the victim, and a maximum distance of thirty meters from the victim [1].

4) Analytical Method of Complience: This subsystem will be responsible for detecting whether or not a heartbeat is present within a victim. To ensure that this sensor follows all constraints set by DARPA, this sensor will most likely use radar technology to detect the presence of heartbeat [1]. To ensure that the radar is safe for human skin and eyes, extensive research on the specifications of how the radar performs must be conducted to ensure that the radar does not emit any harmful radio waves onto a victim. An unknown that has recently been uncovered is how these radars might affect victim's who possess electrical components within their bodies such as pacemakers. Research must be done to ensure that the radar used for the sensor will not have a harmful effect on the victim's components that are within their bodies. Research must also be done on the radar's specifications to ensure that it performs within the distances specified by DARPA which are between one and thirty meters [1]. Extensive software must be implemented into this subsystem to ensure that the radar can detect the presence of a heartbeat of a victim as well as process it and send this information to the computing subsystem of the entire system.

H. *Respiratory Sensor*

1) Functionality: This subsystem will determine if the injured victim is breathing and then send the information back to the computing system. The system will funcion by acquiring signal data from the sensor and processing it into a digital signal that is sent as an output from the respiratory subsystem and an input to the computing system. This subsystem is likely to be achieved via radar impulses directed at the injured victim. This subsystem satisfies the requirement of determining if breathing is present in the victim outlined by the START method [2]. This subsystem will then send information pertaining to the breathing of the victim to the computing system to run through the triage algorithm.

2) Connections: This subsystem will be physically connected to the housing case to ensure that it remains in a stable position and is protected from the elements. This subsystem will also be connected using wires to the power subsystem and serial communication to the computing subsystem. The respiratory sensor must be connected to the computing subsystem to ensure that all information gathered and processed by this subsystem can be relayed to the computing subsystem where it will send all of the processed data to the displayed output for the medical responder to view. The respiratory sensor must also be connected to the power system to ensure that the sensor can function properly where it can gather and process all the data necessary to sort a victim using the START method [2].

3) Constraints: According to the DARPA guidelines for the drone triage project, the sensors used to evaluate the condition of the victim must use contactless methods of measurement to measure the vitals of the victim [1]. The sensors used must also be safe for the human skin and eyes. The sensors used must also operate at a minimum distance of one meter from the victim, and a maximum distance of thirty meters from the victim [1].

4) Analytical Method of Complience: This subsystem will be responsible for detecting whether or not a victim is breathing. Similar to the heartbeat sensor, this subsystem will most likely use radar technology as well. There is also potential for the heartbeat sensor and the respiratory sensor to share the same radar ,significantly cutting costs on the overall project. Since radar technology is planned to be used for this subsystem as well, the same constraints that have been applied to the heartbeat sensor will be applied to this subsystem as well, so extensive research must be done to make sure that the radar technology is safe for the human skin and eyes as well as not damaging any electrical components found within a victim's body such as a pacemaker. Research must also be done to ensure that the specific radar will operate within the distances set by DARPA which are between one and thirty meters [1].

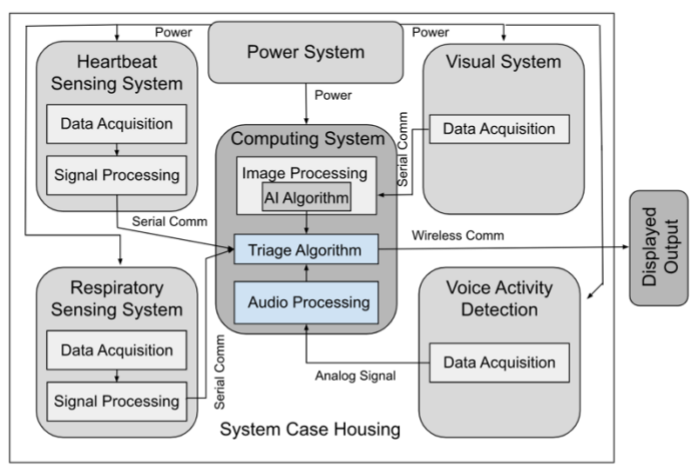

Fig. 2. Pictured above is the Block Diagram of the System

V. Timeline

References

[1] *DARPA Triage Challenge*. [Online]. Available: https://triagechallenge.darpa.mil/. [Accessed: 14-Feb-2023].

[2] "Start adult triage algorithm," *CHEMM*. [Online]. Available: https://chemm.hhs.gov/startadult.htm. [Accessed: 14-Feb-2023].