Effectiveness of a Multi-Mode Sensor Fusion Against Stealth Technologies

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The Problem and Possible Solution

Stealth and military aircraft use four stealth measures to shield themselves from opponents: visual, infrared, acoustic, and RADAR. For the past 30 years, stealth aircraft have been hard to detect, which creates a huge problem because advanced offensive weapons can overwhelm military defense systems. Therefore, limiting the power of the stealth aircraft is a necessity to prevent destruction if another war breaks out, and sensor fusion might be the answer. Sensor fusion combines the inputs from multiple sensors into one data stream. This project examines the effectiveness of a sensor fusion against an aircraft with stealth technologies.

Methodologies Used to Create Devices for Testing

Sensor Fusion

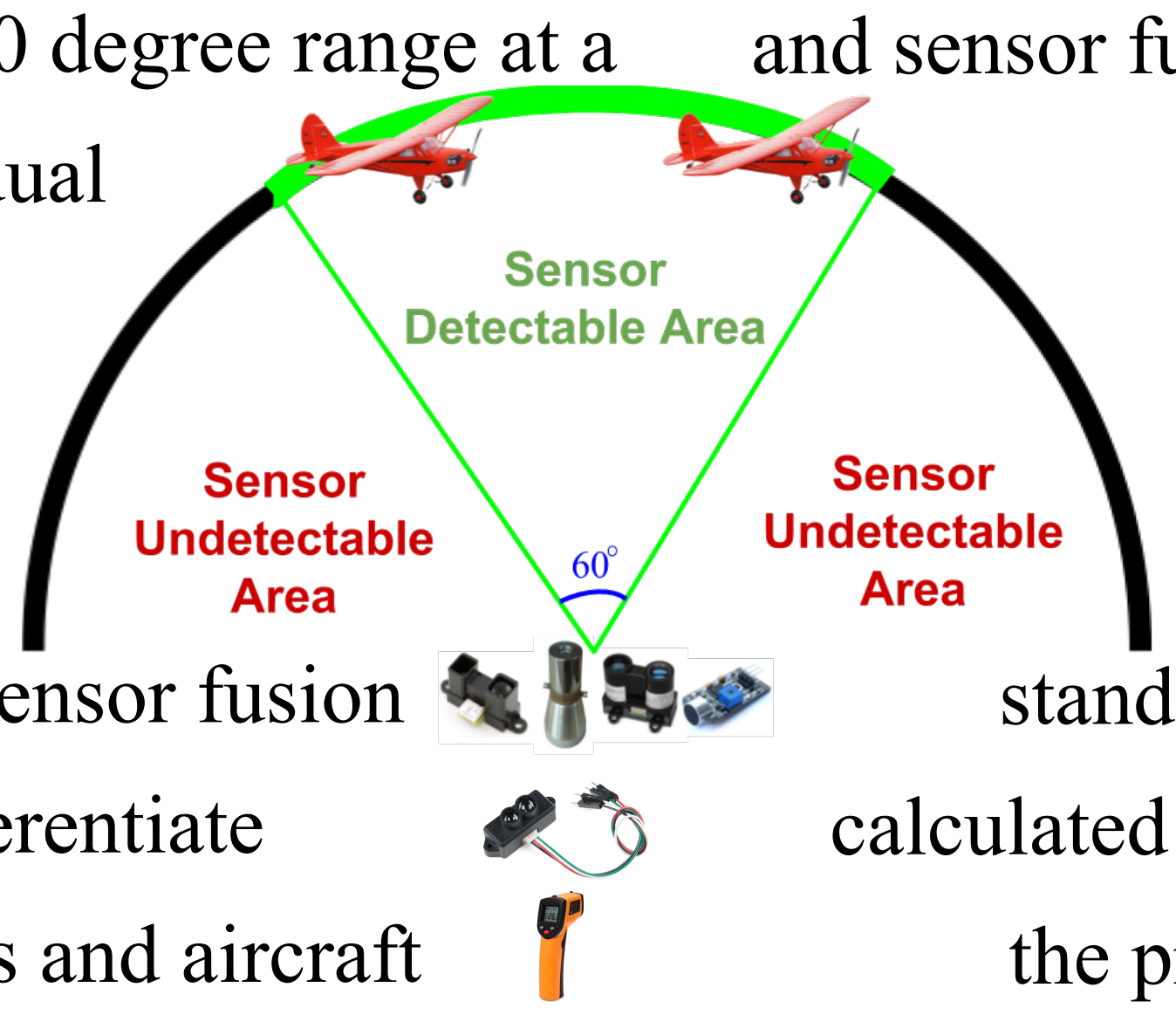
Two ultrasonic sensors were programmed and wired with different frequencies, an infrared light LIDAR, and a laser LIDAR onto two Arduino microcontrollers. Combining the data from these four sensors with the data of an infrared thermometer and an iPhone sound detector, a sensor fusion algorithm was created that equally accounts for all six sensors. The sensors were attached to a wooden board using screws placed as close to each other as possible.

Remote Controlled Model Stealth Aircraft

An aircraft was built from scratch by using 2D Computer-Aided Design models to laser cut depron boards for the structure of the aircraft. These foam boards were used because they can absorb some of the sound and electromagnetic frequencies transmitted by the ultrasonic and LIDAR sensors. Then, servos were connected to ailerons and rudders, and connected all servos, electronic speed controller and motor to a receiver, while using a FlySky remote control transmitter to control everything. The plane's stealth was increased by flattening and sharpening it and putting sound mufflers and a cold cloth around the motor.

Research Methodologies

Testing sensor fusion against aircraft

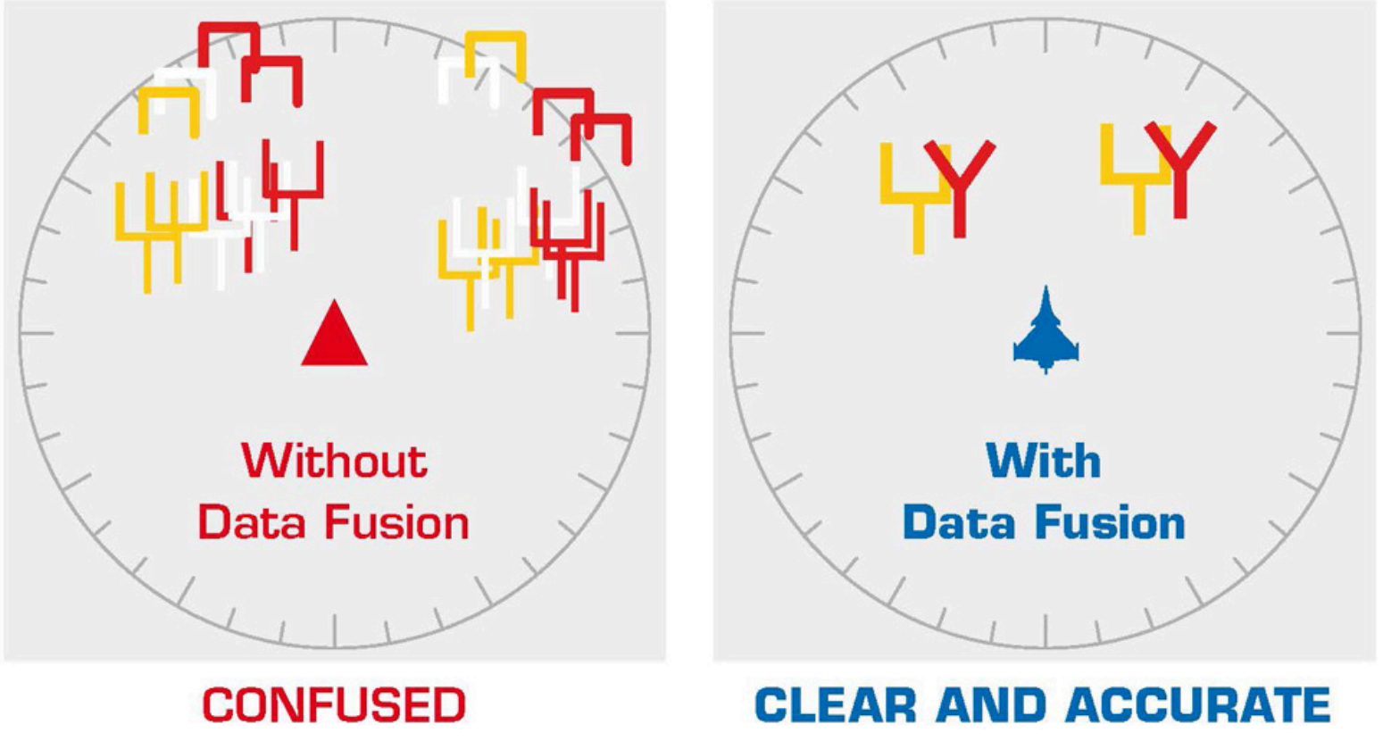


The motor was turned on while the plane was moved with a mechanism in a 60 degree range at a constant attitude with all individual sensors and sensor fusion detecting for 1 minute. Afterward, different flying objects were tested against the sensor fusion to prove that the fusion can differentiate aircraft from other flying objects and aircraft counter-measures.

Data acquired

Quantitative data was collected from each sensor and sensor fusion. 300 data points were collected that form a range of 1-200. The data points were averaged out. (A high number means that an object is easier to detect.) Furthermore, the standard deviation of each set of data was calculated to show the variance of the data and the precision and reliability of the sensor.

Data Analysis and Conclusion



Based on the results, although it seems like these four individual sensors are capable of detecting aircraft, the aircraft often deploy countermeasures, such as hot metal objects that emit infrared signals or loud sounds that can fool acoustic detectors. However, the infrared or acoustic emission of these countermeasures drops rapidly once exposed to cool air because they can't sustain their emission alone for a long period of time. Therefore, just using ultrasonic, LIDAR or RADAR sensors might give us many locations rather than actual aircraft. When the sensor fusion was tested against the stealth aircraft, it had an average detectability number of 150. In contrast, a balloon and a Frisbee had an average detectability number of 78 and 90, much lower than the detectability of an aircraft. Here, the sensor fusion can detect the location of an object and determine if the object is an aircraft. Therefore, it is evident that, due to the sensor fusion using a greater combination of data, the information that is produced could provide greater detail and multiple characteristics of an aircraft, including location, distance, and type.

Data and Findings

Fig. 1. Internal Electronics of RC Aircraft

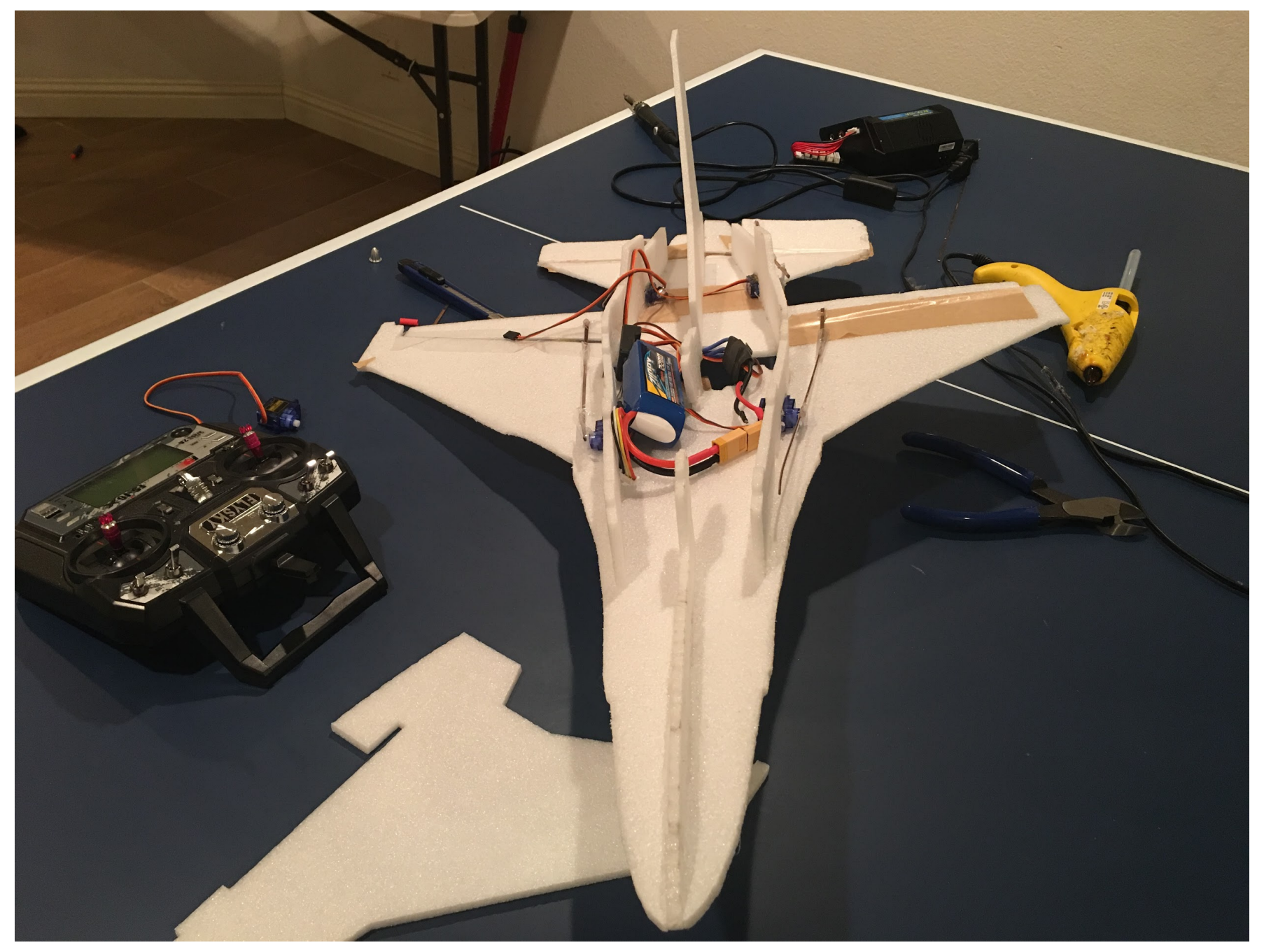


Fig. 2. Sensor Fusion

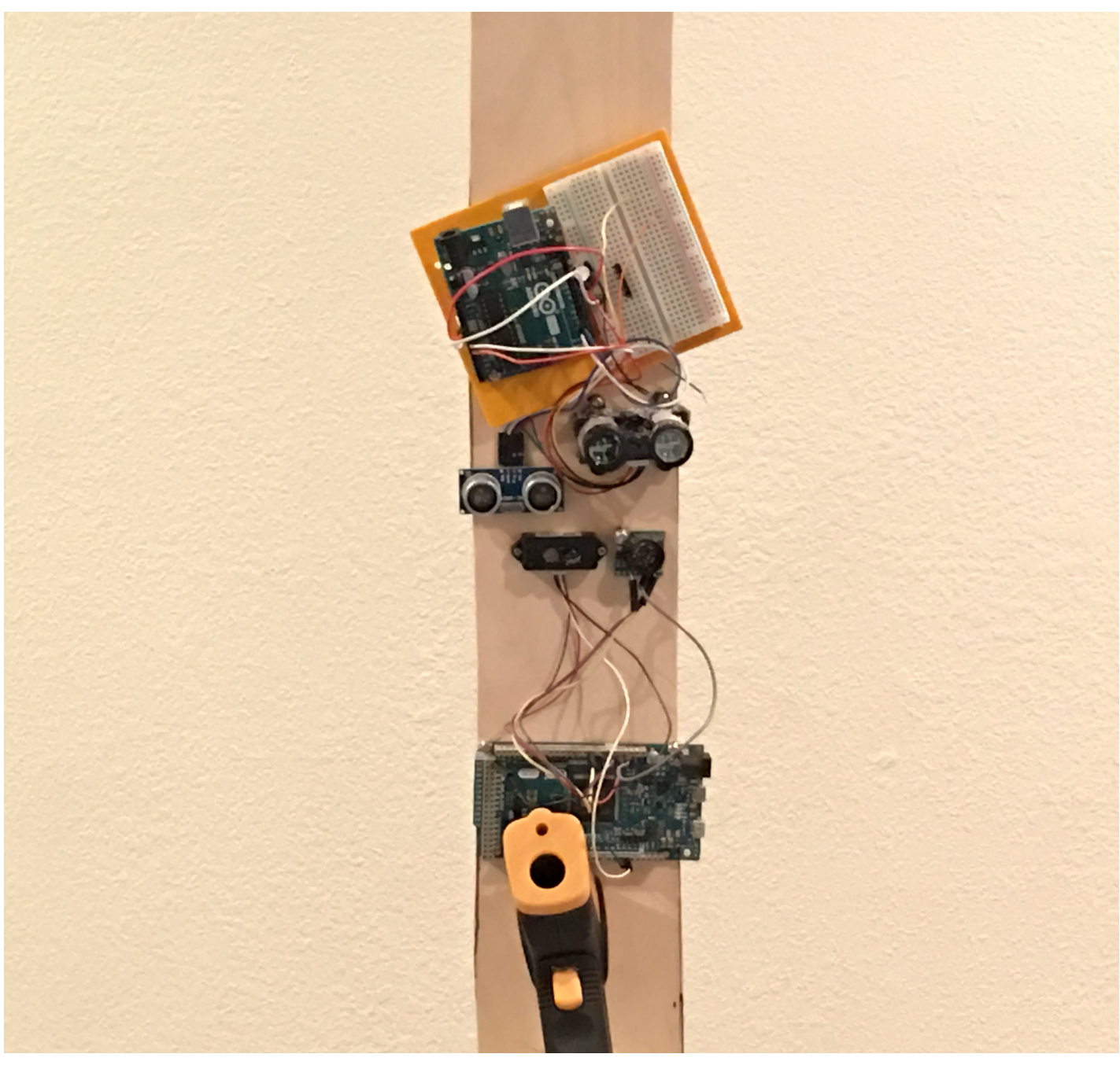
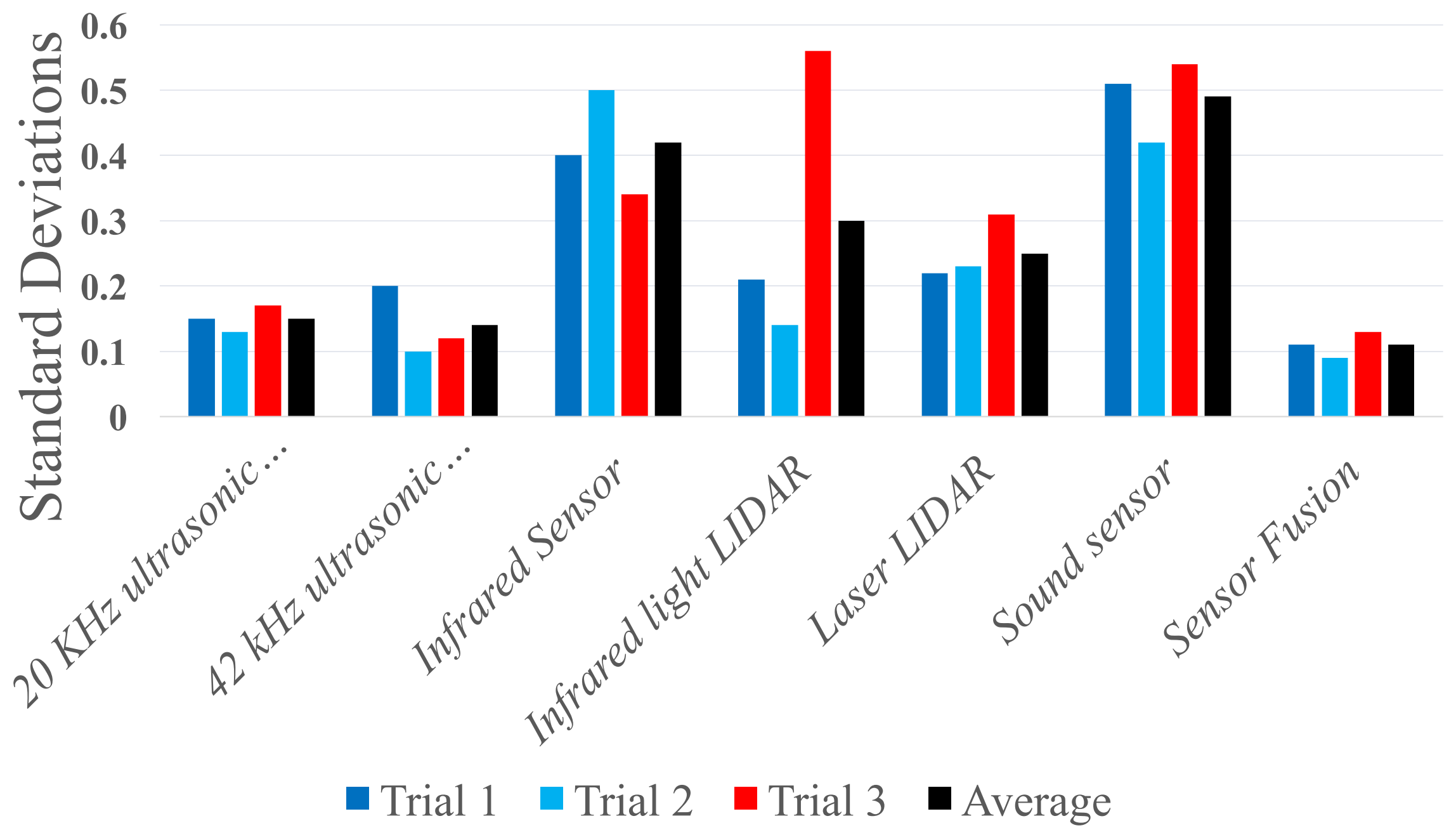


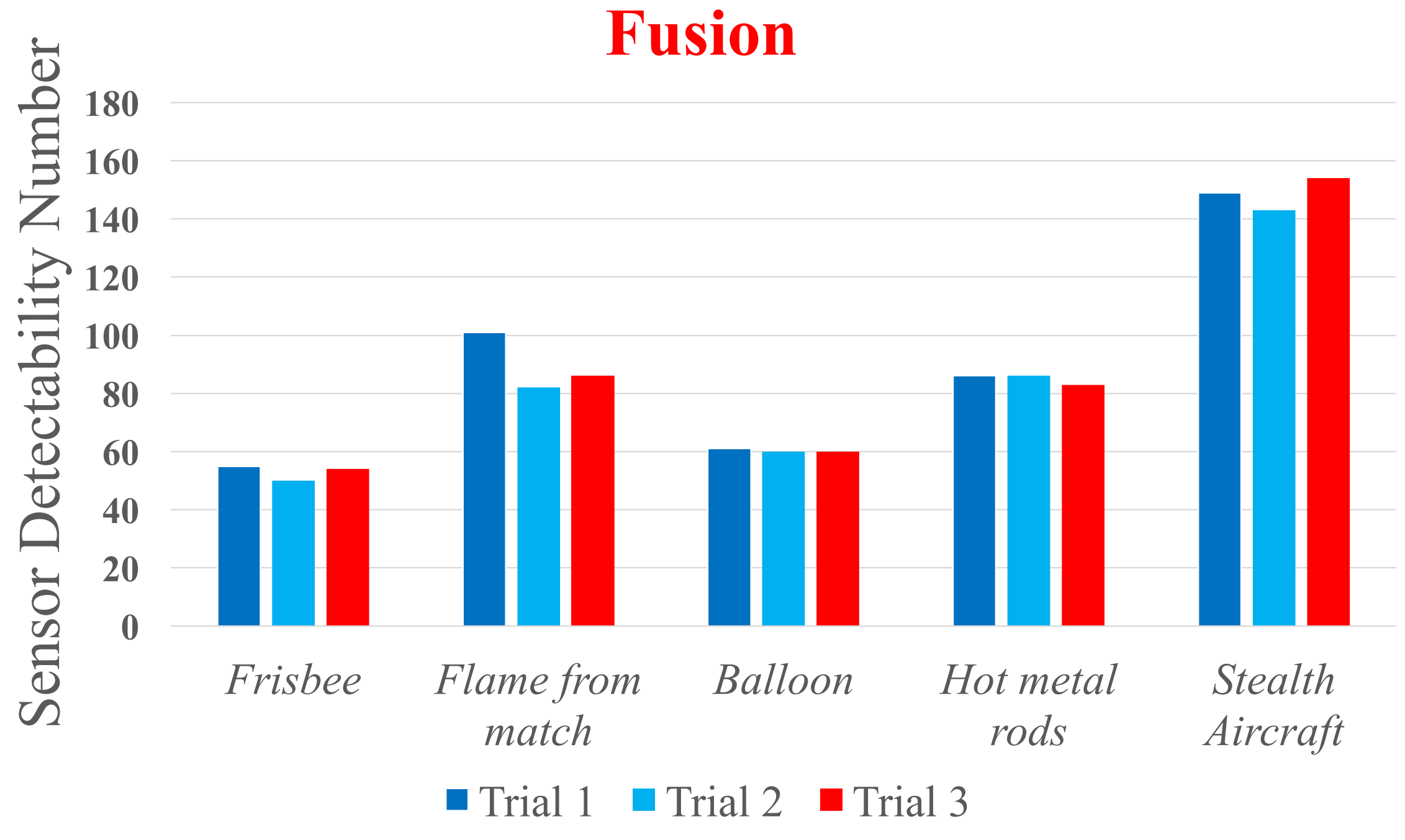
Fig. 3. Finalized RC Aircraft

Fig. 4. Sensor Reliability



This graph of the standard deviation and variance of each data set shows how reliable each sensor is, and it is evident that sensor fusion is more reliable than individual sensors.

Fig. 5. Flying Objects/Countermeasures Detectability Number Against Sensor Fusion



This graph shows the sensor detectability number of an object as measured by my sensor fusion. It is evident that the sensor fusion has a much larger detectability number for a real aircraft than aircraft countermeasures.

Implications and Next Steps

Through experimenting and analyzing the data, the sensor fusion proved to be more effective in detecting an aircraft that uses stealth technologies compared to individual sensors. This is important because most countries' militaries use individual sensors to track aircrafts, with one group of people managing each sensor. With real-time sensor fusion, military defense systems will have more relevant information to analyze, and more accurate information of an aircraft, which will result in a better chance of defending the attackers. Currently, the sensor fusion produces crude outputs, and only informs me about the detectability of an aircraft and the distance of the aircraft from the sensor. For example, the output only shows when the aircraft is 5 feet away from the sensor, but it does not show whether it is at 150 degrees or 30 degrees. To accurately measure the location of the aircraft, the sensors will need to be merged digitally using the computer software LabView. With this, the sensor fusion can show the location of the aircraft in a 2D or XY plane. Afterwards the equation that created the sensor's depth perception can be incorporated to create a Z plane. This will create an XYZ plane or 3D environment, and it will produce a location of an aircraft in real-time, with its distance from the sensor and a precise direction in either radians or angles from the perspective of the sensor fusion. A sensor fusion similar to the above description is closely resembles one that is used in militaries. Therefore, the conclusion can be further supported that a sensor fusion is more effective in detecting stealth aircraft.

Acknowledgement/References

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