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Lidar based obstacle detection and collision avoidance system for Micro-Aerial Vehicles

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ABSTRACT:

This experiment is to illustrate interfacing of Lidar sensor and DC motors of a Micro-Aerial vehicle (MAV) using Arduino UNO and L293D IC to avoid the obstacles detected. Micro aerial vehicle is a kind of a miniature UAV and one of its applications is remote spy observations. TF-Luna single-point ranging LiDAR, which works on the Time of Flight (TOF) principle, is used for obstacle detection. It measures stable, accurate, and highly sensitive range measurement and these are the exact requirements for an MAV collision avoidance system (CAS). Arduino UNO is a microcontroller andL293D IC is a typical Motor Driver IC which allows the DC motor to drive in any direction. The algorithm developed in the Arduino is to acquire the distance of any distant obstacle to the MAV, along with its relative velocity with the MAV from the Lidar data. Then it controls the motors through L293D IC to avoid collision with the obstacle. This distance calculation is crucial for any CAS of an MAV, while the velocity data is an advancement for its CAS.

Keywords: Lidar - Light Detection and Ranging, MAV - Micro Aerial Vehicle, FOV - Field of View, TOF - Time of Flight, CAS - collision avoidance system.

1. INTRODUCTION:

Advances in current technology have enhanced the use of Unmanned Aerial Vehicles and Micro Aerial Vehicles for a variety of tasks and services during the last decade, reducing human effort. Although different obstacle detection and collision avoidance technologies for Micro Aerial Vehicles are available, each has its own set of limitations.

The Micro-Aerial vehicles are in high demand due to their capacity to execute operations both indoors and outdoors depending on their applications. Unmanned aerial vehicles are restricted on various operations due to their size and weight, however the Micro-Aerial vehicle can be employed for many tasks excluding the heavy payload jobs. Micro-Aerial vehicles are smaller and lighter, allowing them to operate at low altitudes or in hazardous environments. Micro-Aerial vehicles (MAV) have a higher power efficiency, resulting in greater endurance. An MAV can perform multiple operations such as surveying, mapping, data collection, etc. To avoid multiple collisions, a Micro-Aerial Vehicle's obstacle detection and collision avoidance system is necessary. The unexpected occurrence of various obstacles, such as birds in open spaces or fixed objects, can be avoided by installing such a system on the Micro-Aerial vehicle. The obstacle detection and collision avoidance system installed on Micro-Aerial Vehicle helps the flight controls system to detect the obstacle and therefore navigate the vehicle in free path.

MAV is a smaller and more complex version of a UAV. Modern MAV can be as small as 5 centimeters which is effortful to control in both indoor and remote operations. This makes the Autonomous Collision Avoidance System (CAS) for an MAV as a must. When the CAS relies only on the distance data, its algorithm will only respond to obstacles that are close to it, but not to the approaching obstacles, which are not yet in the avoidance range. In such a case, avoiding high-speed obstacles is quite hard. By determining the relative velocity of the obstacle with the MAV the algorithm is modernized, avoidance range is increased and avoids any high-speed obstacle in the given Field of View (FOV).

2. HARDWARE

2.1 COMPONENTS USED

2.1.1 ARDUINO UNO

The Arduino UNO used in lidar based obstacle detection and collision avoidance system is a single-board microcontroller, which has operating voltage of 5 volts and the input voltage from 7 to 20 Volts.The microcontroller has 14 Digital //O Pins in total with 6 Analog input pins. The DC power Jack and the USB port can be used to supply power to the microcontroller. The Microcontroller has 2KB of SRAM and 1KB of EEPROM.

2.1.2 L293D

The L293D is an integrated circuit chip and can be operated using less power. The L293D motor driver has the capability to adjust speed and directional control for DC Motors. This motor driver can control the speed and direction independently for two different motors.

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2.1.3 TF-LUNA-LIDAR SENSOR

The Lidar sensor has the operating Range upto 8 meters with the distance resolution of 1cm and the frame rate 100 Hz.The Field of view of the sensor installed on MAV is 2 degrees. The sensor is light weight less than 5 grams making it suitable to install on any Micro-Aerial Vehicle with low power consumption of 0.32W.

2.1.4 DC MOTOR

The DC motor installed on the Micro-Aerial vehicle receives signal from the Arduino through L293D IC to adjust its speed based upon the operations of the flight. The motor speed is directly proportional to the thrust produced. It is the engine of the MAV.

2.2 INTERFACING COMPONENTS WITH MICRO-AERIAL VEHICLE

2.2.1 LIDAR WITH ARDUINO

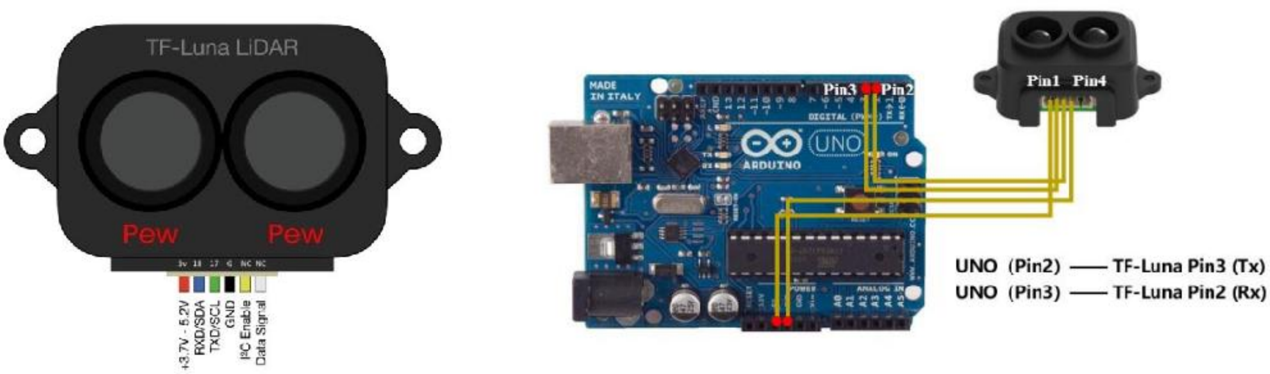

Fig.1 Lidar sensor, Arduino Connections.

2, 3 digital pins of Arduino and Lidar 2, 3 pins are connected respectively for software Serial communication. Fig.1 shows their connections

2.2.2 L293D, DC MOTOR WITH ARDUINO

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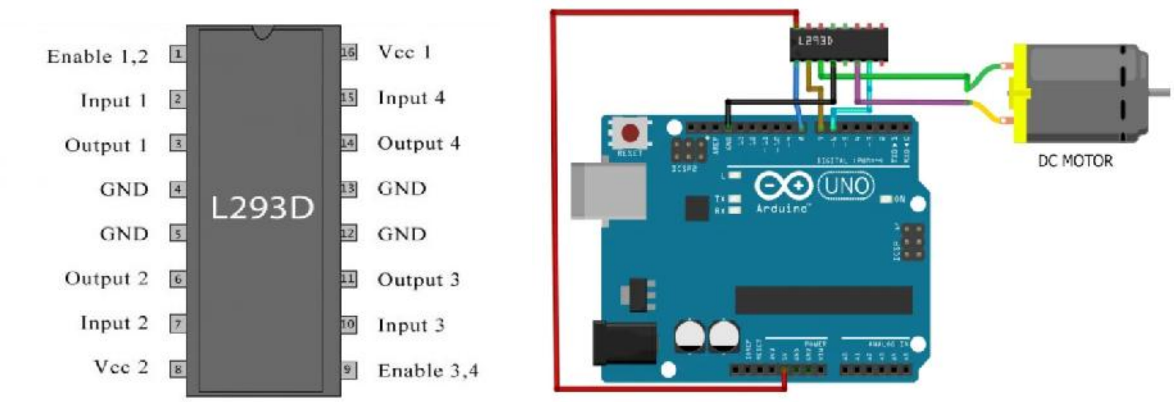

Fig.2 L293D, Arduino Connections.

6, 7, 8 digital pins of Arduino are connected to 7, 2, 1 pins of L293D IC. Fig.2 shows their connections.

2.3 WORKING PROCEDURE

The Lidar (Light Emission and Ranging) Sensor which is used to estimate the distance and the relative velocity of the obstacle is fitted on the Micro-Aerial Vehicle. The Time between Transmitted pulse and received pulse is considered to estimate the distance between the obstacle and the Micro-Aerial Vehicle. The relative velocity of the obstacle moving near the Micro-Aerial Vehicle is estimated based upon the results of distance. The system avoids obstacle after receiving inputs from the different components of the system and gives signals to the flight controller to continue safe flight. The block diagram of working procedure has been shown in Fig.3

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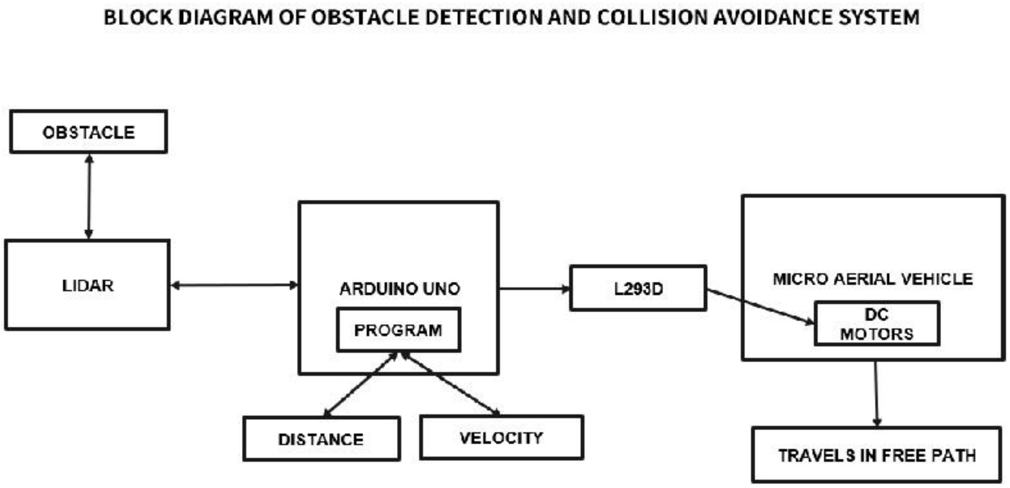

Fig.3 Working of Obstacle Avoidance System

Arduino computes the distance between MAV and obstacle and velocity of the obstacle. With these results Arduino controls the DC motor through L293D. Arduino sends the data of speed of the motor and direction of rotation of the motor to L293D. L293D controls the motor according to the data received. When the obstacle is approaching with some velocity, the speed of the motor increases, increasing the thrust, making MAV tilt backwards and avoiding the obstacle.

3. SOFTWARE

3.1 DISTANCE ALGORITHM

Serial port Communication is the method utilized in Arduino for distance measurement. The serial port communication protocol is defined as 8 data bits, 1 stop bit with no parity check and default baud rate of 115200 bps. The instruction makes changes immediately after sending, but the current setting is not saved and will lose after reboot. “Save current setting ID_SAVE_SETTINGS=0x11 ” must be used to save the change. The full save-current-setting 11s hexadecimal string 5A 04 11 00 is used in this case. Saved data is then used to calculate the distance.

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3.2 VELOCITY ALGORITHM

The basic velocity formula is the rate of change of distance. The function ‘millis();’ returns the number of milliseconds passed since the Arduino board began running the current program. This number will overflow (go back to zero), after approximately 50 days. The default function ‘millis();’ in Arduino has an error of more than 40 milliseconds. Algorithm to find velocity is explained in the below Fig 4

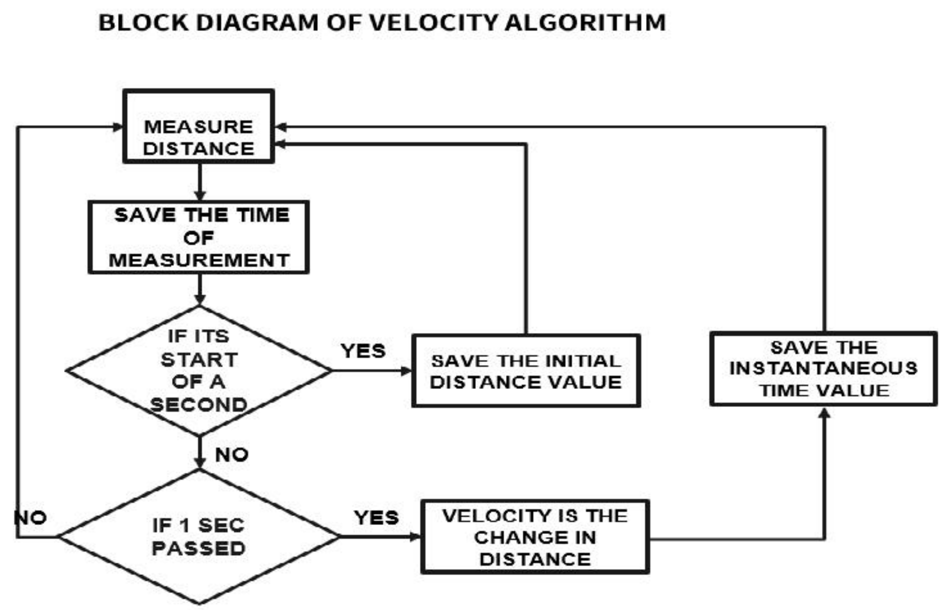

Fig.4 Velocity algorithm block diagram

Since velocity is the rate of change in distance, if the time interval equals one second, velocity equals to change in distance. Algorithm starts with measuring distance. Then, it saves the time of its measurement and initial distance value. Instantaneous velocity is calculated, but not continuously. Between each velocity value derived, has an interval of time of one second.

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3.3 COLLISION AVOIDANCE ALGORITHM

S.No	CONDITION	Digital Motor speed value to L293D
1	Distance less than 15 cm	225
2	Distance is 15cm to 30cm	150
3	Distance is 30cm to 100cm and Velocity is 10cm/s to 100cm/s	150
4	Distance greater than 30cm	100

RESULT AND DISCUSSION:

S.NO	Digital Motor speed value to L293D BEFORE	DISTANCE	RELATIVE VELOCITY OF THE OBJECT	Digital Motor speed value to L293D AFTER
1	50	29cm	10cm/s	150
2	150	12cm	5cm/s	225
3	225	45cm	-25cm/s	50
4	50	6cm	30cm/s	225

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5	225	30cm	-5cm/s	150
6	150	14cm	0cm/s	225
7	225	60cm	-40cm/s	50
8	50	200cm	-60cm/s	50
9	50	120cm	80cm/s	225
10	225	120cm	0cm/s	50

The above table is the result obtained from a random movement of the obstacle keeping the MAV static. All the below Figs are obtained from Arduino IDE software called Serial Plotter.

Two scenarios were tested to know the accuracy of distance between obstacle and MAV and velocity of the obstacle. Results are shown below in graphical format. The below Figures are the graph of indoor experiments with both distance in centimeters, velocity in centimeters per second in the vertical axis and with time on the horizontal axis. Blue line represents the distance graph while the red line represents the velocity graph.Velocity of the obstacle is taken as positive when it is approaching the MAV and it is taken as negative when it is heading away from the MAV.

RAPID MOVEMENTS

MAV is placed in a stationary position and an obstacle is moved rapidly in the field of view of Lidar. Rapid changes in distance are crystal clear in the graph with accurate measurements while the sudden change in velocity has inaccuracy in measurement. However, such rapid changes in velocity in back-and-forth movement are practically impossible to occur in the air.

Velocity is measured periodically every second. Distance changes are not considered during this period of one second. Therefore, the Velocity graph shape is obtained like a digital function graph. Heavy sudden changes in velocity are not possible in aerial vehicles and this algorithm is applicable for collision avoidance systems of an MAV. Collision avoidance algorithm successfully detected the obstacle way before it reached near the MAV and increased the thrust.

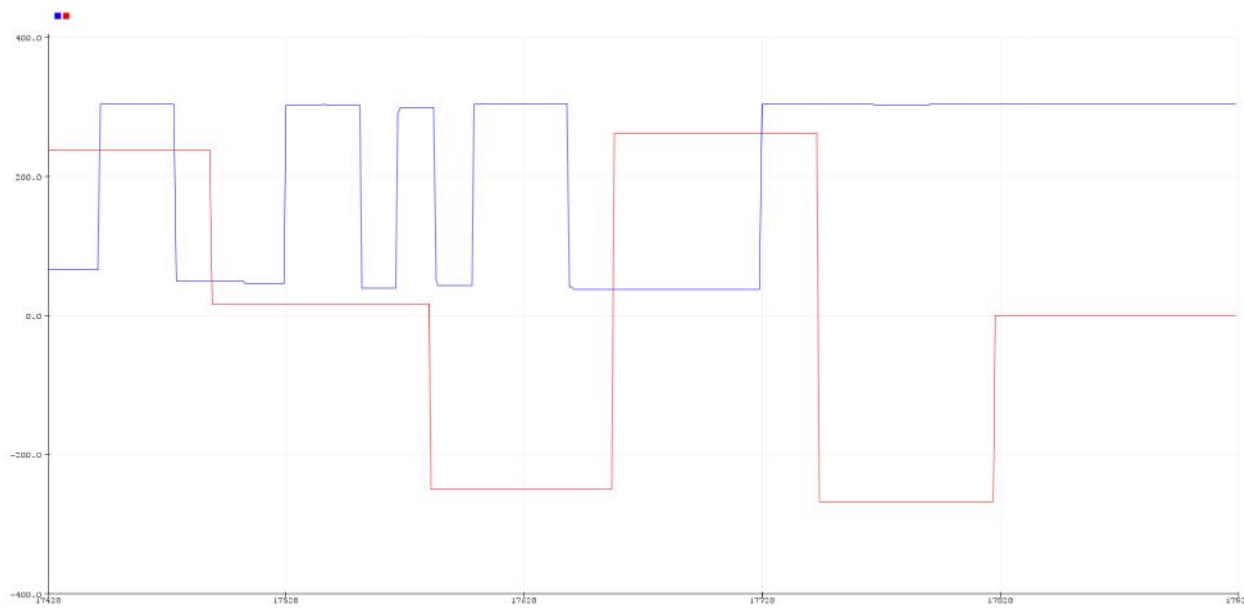

Fig.5 Distance, Velocity vs Time graph

EXISTENT MOVEMENTS

Obstacle is moved with probable velocities in the field of view of Lidar. The below Fig 6 is also a graph with both distance in centimeters, velocity in centimeters per second in the vertical axis and with time on the horizontal axis. Blue line represents the distance graph while the red line represents the velocity graph. Distance measurements are accurate, while the velocity calculations are reliable.

Obstacle is moved away and brought near gradually. When it is moving away from MAV, the distance graph is climbing whereas the velocity graph is dropping down to negatives representing that its moving away. When it is moving near to MAV, the distance graph is declined whereas the velocity graph is climbed to positives representing that it is approaching.

Collision avoidance algorithm successfully detected the obstacle. It increased the thrust when the obstacle was in the avoidance range and decreased the thrust when there is no collision threat.

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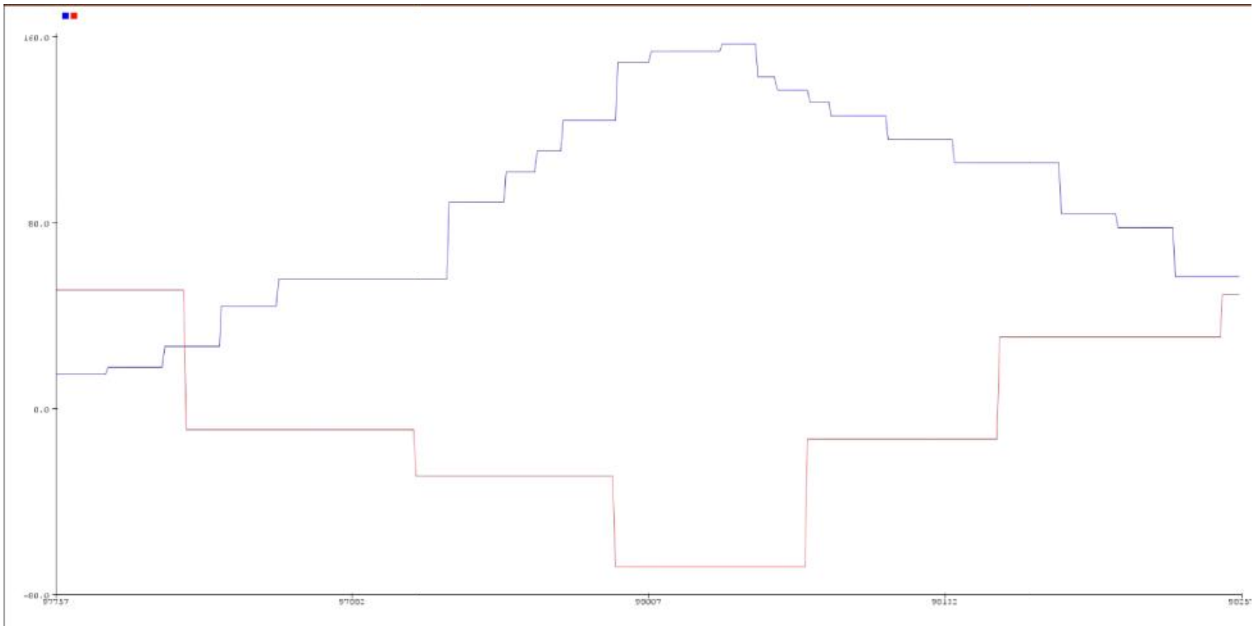

Fig.6 Distance, Velocity vs Time graph

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