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Obstacle Detection with Ultrasonic Sensors and Signal Analysis Metrics

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Abstract

One of the basic tasks for autonomous flight with aerial vehicles (drones) is the detection of obstacles within its flight environment. As the technology develops and becomes more robust, drones will become part of the toolkit to aid maintenance repair and operation (MRO) and ground personnel at airports. Currently laser technology is the primary means for obstacle detection as it provides high resolution and long range. The high intensity laser beam can result in temporary blindness for pilots when the beam targets the windscreen of aircraft on the ground or on final approach within the vicinity of the airport. An alternative is ultrasonic sensor technology, but this suffers from poor angular resolution. In this paper we present a solution using time-of-flight (TOF) data from ultrasonic sensors. This system uses a single commercial 40 kHz combined transmitter/ receiver which returns the distance to the nearest obstacle in its field of view, +/- 30 degrees given the speed of sound in air at ambient temperature. Two sonar receivers located either side of the transmitter / receiver are mounted on a horizontal rotating shaft. Rotation of this shaft allows for separate sonar observations at regular intervals which cover the field of view of the transmitter / receiver. To reduce the sampling frequency an envelope detector is used prior to the analogue-digital-conversion for each of the sonar channels. A scalar Kalman filter for each channel reduces the effects of signal noise by providing real time filtering (Drongelen, 2017a). Four signal metrics are used to determine the location of the obstacle in the sensors field of view:

1. Maximum (Peak) frequency
2. Cross correlation of raw data and PSD
3. Power Spectral Density
4. Energy Spectral Density

Results obtained in an actual indoor environment are presented to support the validity of the proposed algorithm.

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1. Introduction

The term "drone" and the abbreviations "UAV" (Unmanned Air Vehicle) and "RPAS" (Remotely Piloted Air Systems) have entered our vocabulary over the last decade. The defence industry refers to their aircraft as UAV's, while the civil and commercial aviation sector uses RPAS. The visual and print media have adopted the term "drone" to cover all types of unmanned aircraft, from children's toys to aircraft costing millions of euros.

Navigation of these drones in an unknown environment requires the use of many different types of sensors to provide the on board flight controller with data on velocity, position, obstacle distance and orientation. Considerable research has been conducted using LIDAR for range and obstacle detection while on board cameras have been used to implement optical flow as a means of detecting obstacles within the image. Optical sensors are sensitive to light and the use of cameras tends to be computationally expensive, resulting in the use of possible ground stations to aid the on board drone processor. An alternative is the use of ultrasonic sensors which are suitable for close range detection up to ten metres and provides multiple range measurements per second. The advantage of these sensors being that they are inexpensive, have low power consumption and can operate in environmental conditions where other sensors would fail, for example, smoked filled environment. The resolution can be as low as 60 degrees, meaning that they cannot identify the angular location of an obstacle within the sensors field of view as shown in Fig 1.

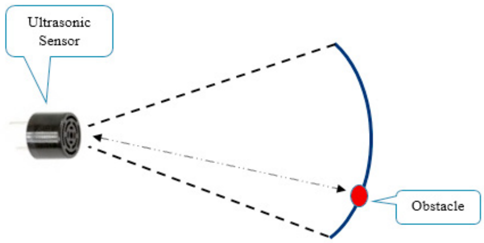

Fig. 1 Sensor field of view

The main contribution in this paper is to examine the raw data received from a number of sonar receivers and how this can be processed to improve the angular resolution for obstacle detection.

2. Related work

The initial development of autonomous systems concentrated on ground vehicles and the use of ultrasonic sensors for obstacle detection and avoidance. Kadogoda et al. (2006) proposed a ground robot using a stepping motor to control a single rotating ultrasonic sensor with a field of view of 300 degrees. Data fusion is implemented using Bayesian combination to reduce the effect of inherent errors such as foreshortening (Murphy, 2004) and specular reflection (Zou et al.,2000) (alternative return paths). The processing of each angular measurement occurs when the robot is stationary, resulting in high latency between measurements making this approach unsuitable for UAV applications. Chen et al. (2013) implemented mapping of the environment with an ultrasonic sensor mounted on an UAV. Using an occupancy grid, each cell in the grid is assigned a probability that the corresponding area is occupied. Updating the grid is a function of the beam width and sensor range, determining which cells are updated and the likelihood of each cell being occupied given previous readings. The confidence for a given cell depends on the number cells that comprise the beam width at the distance returned by the sensor, i.e. the value assigned to a cell is equal to the inverse of the potential grid cells along the width of the beam. Testing was in a parallel corridor, providing an ideal test environment to reduce the effects of specular reflection. The weakness of this system being that the UAV had to move and keep track of its position to improve its confidence in the occupancy of each cell within the grid. This can result in delays in obtaining the flight path solution for collision avoidance. A simple approach adopted by Gageik et al. (2012) for obstacle detection consisted of using a bank of 12 ultrasonic sensors mounted on a ring located