Towards Intelligent Sensor Fusion based Visually Impaired Navigation: An Assistive Technology Framework

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Abstract

This paper presents the development of an electronic navigation framework for blind and visually impaired persons. This proposed approach aims to intelligently fuse the surrounding information sensed via ultrasonic sensors and vision sensors. The intelligent component of the prototype developed would serve in several facets including object recognition and computational performance optimization within the embedded system software. The prototype developed for field testing in indoor as well as outdoor environments would be used as assistive technology for visually impaired. The wearable device developed would provide the feedback via tactile cues. The current status of the research and the future developments are presented in this work.

1. Introduction

There are about 285 million people are estimated to be visually impaired worldwide: 39 million are blind and 246 have low vision that could benefit from some form of aid to help them in their daily lives[1].

Visually impaired persons face constraints in independent mobility and navigation, especially in unknown or dynamic environments. Blind navigation is a cognitively demanding task since blind person does not have access to contextual information, spatial orientation and it requires moment-to-moment problem solving. Researchers attempt to develop humanitarian technology based navigation systems to aid the visually impaired. These navigational aids consist of several types of sensors such as infra-red sensors, ultrasonic sonar sensors, vision sensor, inertial sensors, etc.

A fusion of different sensors which allows the extraction of information which cannot be acquired by a single sensor. Different type of sensor works differently and they have their own strengths and weaknesses. Since one sensor cannot provide all the necessary information, sensor fusion intelligently combines the strength of different sensors to overcome the drawbacks of the other[2, 11].

In this work, an electronic travel aid to navigate visually impaired persons had been proposed. The long-term goal of this resaerch is to create a portable, self-contained navigation aid which makes optimum use of all the sensors for smooth and continuous navigation of visually impaired individuals to travel through familiar and unfamiliar environments. Although sensor fusion combines different sensors and multiple technologies to gain successful navigation over a wide range of environmental conditions, it will be a great challenge [12].

2. Related work

Ultrasonic sensors are designed to generate high frequency sound waves and receive the echo reflected by the target. These are common for target detection and tracking. There are some constraints which limit the accuracy of detecting obstacles by ultrasonic sensors. Sonar device is not suitable to be used by multiple users who travel through the same environment because sonar reflections may interfere with each device's sensor waves[3]. The variance of the temperature, humidity and pressure will affect the response of the sensor. The wide sonar beam causes a poor directional resolution and are often difficult to interpret. Also smooth surfaces at oblique incidence do not produce detectable echoes. An ultrasonic sensor has a limited sensing distance, when compared to most of other sensors. Numerous research have been reported in literature where they have used sonar based obstacle detection [5, 6, 7].

Vision sensors are widely used for detecting the presence or absences of objects or identifying features of detected objects. Compared to other sensory modalities, computer vision can also provide a very rich information of the environment. The major drawback of using vision sensor is, it requires high computer processing power. Some special situations like detection of glass surfaces via cameras are problematic. Also background illumination affects very much on obstacle detection because vision based obstacle detection approaches work well only when there is a good lighting condition. Vision based obstacle detection in visually impaired navigation is also a common research approach [8, 9, 10]

Fusion of these two types of sensors has been considered as an improvement since both vision base and ultrasonic sensor base obstacle detection have their own weaknesses. Sensor fusion is used in many ares such as robotics, GPS and inertial sensor based navigation, Unmanned Aerial Vehicle and etc.

2.1 Robot Navigation and Sensor Fusion

Robotics is a leading branch of engineering, which demands knowledge of hardware, sensors, actuators and programming. For an autonomous mobile robot, sensor fusion is important to perceive its environment. An autonomous robot moves unsupervised. It obtains information of surrounding environments using its sensors and decides its course of action based on that[2].

Use of sensor fusion in robot navigation is an emerging trend.

A quadruped walking robot has been used as a platform to test and demonstrate the development and implementation of a behavior selection based obstacle avoidance algorithm. The obstacle is roughly measured by processing the image acquired through the USB camera, and the ultrasonic sensors are used to complement the visual information in relation to obstacle and to perform the selection of the suitable actions at the right time [4]. Other research had used multiple ultrasonic sensors for intensive observation and image sensor for wide-angle observation in a robot sensing project. Here two kinds of fusion has been implemented; one fuse multiple ultrasonic sensor data and other fuse the two types of sensor data [5]. One of the common approaches of integrated vision-based process for mobile robots that is capable of simultaneously navigating and avoiding stationary obstacles using monocular camera images and moving obstacles are detected with ultrasonic sensors [2]. Also building a map for a laboratory robot by fusing range readings from a sonar array with landmarks extracted from stereo vision images using the SIFT algorithm. [6]. Fusion of the sonar measurements and an updated odometric measurement by using a decentralized information filter to produce optimal estimations of the robot states, thus minimizing the uncertainty in the sensor measurements[7]

2.2 Visually impaired Navigation and Sensor Fusion

Number of attempts on fusion of different sensors in blind navigation can be found in the literature. Fusion of GPS and vision based positioning was used in object-localization and user-positioning [8]. Another research which uses sonar for detecting large and high obstacles, and vision system is to detect small obstacles. One has been stated that the ideal solution is likely to be the use of both a visual, and a non-visual sensor as an input to the Kalman Filter, which should make available the benefits of both[9].

The purpose of this research is to fuse the signals of vision and ultrasonic sensors for obstacle detection in navigation of visually impaired and blind persons.

3. Architecture

Basic design approach can be divide in to three parts. The first part relates to sense the environment using ultrasonic and vision sensors and preprocess them. The next is the fusion module which fuse the signals of both sensors. Finally output of the fusion module is filtered and send to appropriate feedback modules.

Current implementation will be based on several assumptions. Visually impaired navigtor need to detect and avoid both stationary and moving obstacles. Vision sensor is used for detection of stationary obstacle and ultrasonic sensors (ultrasonic sensors have no intrinsic way of distinguishing between moving and stationary obstacles) are used to detect close range moving obstacles [5, 8]. Therefore Detection of moving objects is much more complex than detection of stationary objects. Since the main target of the proposed research is to benchmark the accuracy of sensor fusion with respect to individual sensor modalities. Therefore detection has only confined to identification of stationary obstacles. Proposed electronic travel aid will be initially evaluated in a less obstructive indoor environment. Consider only the local navigation: the surrounding of the visually impaired person is unknown, and sensors are used to detect the obstacles and avoid collision (No specific goal and path is defined)[8]. Sonar sensor distance measurement is calculated under room temperature. It is wise not to be used this hybrid module by more than one user simultaneously under a maximum scanning range of sonar sensors.

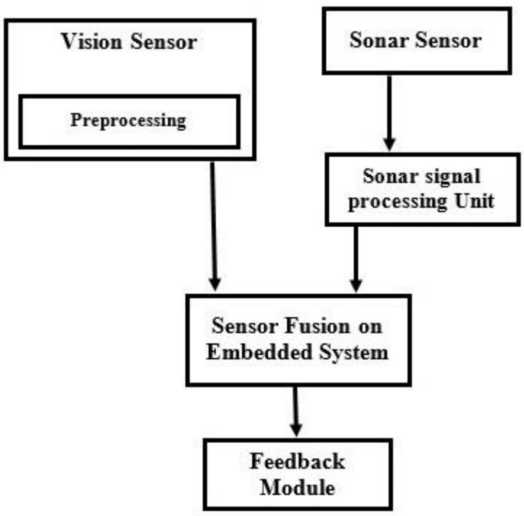

Figure 1: Schematic Diagram of proposed system

3.1 Sub components of the system

Sonar Sensor: Sonar sensor continuously transmit the waves which have with high frequency. When object comes in the path of signal then it will reflected by object and received at sensor receiver. Then signal processing unit calculates the distances based on the time spent waiting for the wave to come back. Then the resulting data is sent back to the sensor fusion module.

Vision Sensor: Images captured by the vision sensor are preprocessed by processing system unit inside the vision sensor. So the vision sensor provides higher level semantic output potentially to the fusion module without overloading its processing unit by sending all of the image data.

Sensor Fusion on Embedded System: This approach combines sensor data from vision and sonar to provide a higher order of functionality. Hence additional processing capability is required due to the increasing complexity of sensor fusion algorithms. Therefore fusion of the sensor data is carried out on a separate processing device.

This research focus on wearable electronic navigation system which should be an efficient travel aid for the visually impaired and blind persons. Light weight, faster response, low power consumption and less hardware are some of the critical factors to be considered when designing wearable electronics. In order to fulfill above factors embedded system is selected as the fusion module instead of PC. Embedded system is dedicated to one specific task which requires less computing power and hardware to perform that dedicated task while PC is designed to run many different types of software and to connect many different external devices. Then preprocessed sonar and vision data are fused at this embedded device by applying fusion techniques.

The viability of the fusion of two sensor data in the sonar signal processing unit itself will be further investigated in future.

Feedback Module: Lastly filter the output signal which is received by sensor fusion module and send that commands to appropriate feedback modules.

The ultrasonic range finder will be used as a sonar sensor for measuring distances. Input sonar signals are processed by microcontroller board. Vision sensor processes the images from the image processor which is built within the vision sensor itself and sends the preprocessed information to embedded system based sensor fusion module. Then fusion module further process-the ultrasonic and vision data.

There are a number of fusion methods available. Probabilistic data fusion method is common which is generally based on Bayes' rule for combining prior and observation information. Theory of evidence, interval methods are some of alternatives to probabilistic methods in sensor data fusion. [11].

The final output of the sensor fusion module is filtered and check whether an obstacle is located in which direction of the user and send commands to relevant vibration motors to generate appropriate levels of vibration.

A pilot study will be conducted prior to the evaluations in order to predict an appropriate sample size and check the feasibility of other evaluation parameters. The evaluation process will continue in an environment which was not seen by the participants before. These tests will be carried out using totally blind and blind folded users. Training on the proposed navigation aid will be given to all participants to familiarize with the system before the evaluation process.

Separate tests will be carried on obstacle detection in visually impaired navigation using sonar sensor based method and vision based method. And the results of these two tests will be compared with the test results of fusion of vision and ultrasonic based obstacle detection approach.

Test results will evaluate based on the user reactions to different obstacles, time taken by each user to complete the navigation process, training sessions that he/ she participate prior to the evaluations and etc.

4. Conclusion and Future Work

This research will address following issues related to sensor fusion based obstacle detection in visually impaired navigation.

Identify the relevant fusion framework to detect obstacles via vision based and the sonar based approaches. Select appropriate multisensory data fusion techniques and fusion algorithms. Optimize the obstacle detection by balancing the load of the two channels (vision based and sonar based approaches). Benchmark the self-adaptive nature of hybrid approach and evaluate it against the vision only and sonar only obstacle detection methods.

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