A Survey on Unmanned Vehicles techniques for Terrain Detection in 3D environment

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ABSTRACT

This survey summarizes current research on unmanned vehicles which are used in terrain detection. Various methods are used for indoor and outdoor terrain detection. Most of the research done in this area is novel and this field is still developing as a program of research. However, the research in this field is necessary even though many existing approaches are effective. The findings consists of various methods and algorithms used; the type of hardware and algorithm used to perform the terrain detection; the benefits of each approach span in the use of various sensors and the way the terrain detection is carried out in each of its applications. For autonomous navigation, the vehicle should be equipped with reliable sensors for sensing the environment, building environment models and following the correct defined path.
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1. INTRODUCTION

An unmanned ground vehicle (UGV) is a vehicle that operates while in contact with the ground and in the absence of a human operator. Applications of UGVs include inconvenient, dangerous or impossible situations where there is absence of human operator. The vehicle has sensors to observe the environment and will make autonomous decisions about its behavior and will forward information to the remote human operator. Unmanned vehicle approach is a new technique for terrain detection which provides a broader aspect for further research. Unmanned vehicles can now observe terrain using various sensors and move ahead to achieve its goal.

2. LITERATURE REVIEW

In the research commissioned by Sebastian Thrun and his team found online method for robust mapping and localization in indoor environments. Moreover, they employed a fast algorithm to generate the 3D model of the indoor environment. Their experimental results illustrated that large-scale environments can be mapped in real-time. Also, their approach was very robust to errors. As a result, much of the literature included in this research is novel and a part of field which is still developing as a program research.

Sebastian's research focused on 3D maps and multi robot mapping. Building of maps in most of the approaches was done incrementally by iterating localization and incremental mapping for each new scan the sensor received. These methods fail when mapping large cyclic environments. A probabilistic method devised which was based on EM could be used for iterative refinement during map construction. A combination of both methods was used to map the cycles in real-time. The research has briefly explained the problem of concurrent mapping and localization; they have also provided an incremental online algorithm to find the solution. For mapping they have given many approaches namely,

- Likelihood Function
- Conventional Incremental Mapping
- Incremental Mapping Using Posteriors
- Backwards Correction
- Multi-Robot Mapping
- 3D Mapping

The results were found in various ways. In the results obtained by the mapping cycle, the robot moved with a pre-specified distance which used localization. The results were accurate and the error cycles were eliminated. Mapping without odometry was another means by which the results were observed. The map generated was less accurate than the one with odometry data. The results of an autonomous robot were observed wherein, the robot could traverse in a rugged terrain, and the error rate would often be as large as 100%. This was due to skid-steering mechanism that the robot used for traversing [1].

In the research conducted by Larry Matthies and team, the obstacle detection by unmanned vehicles was observed. They

have developed a real-time stereo vision system that uses a datacube MV-200 and a 68040 CPU board to produce 256 * 240 pixel range in about 0.6 seconds/frame. This was done in order to sense the terrain type under day, night, and low visibility conditions during off-road navigation. Furthermore, they used the same computing hardware to segregate vegetation and non-vegetation [2].

Larry Matthies have mentioned the algorithm for real-time stereo vision system. Blob coloring algorithm was also used to reject small disjoint regions and regions of bad matches that were contiguous to larger, good regions by making connectivity criterion in the algorithm. Positive obstacle detection was done with the help of simple slope estimation algorithm. Similarly, negative obstacles were also detected using an extension of column-oriented algorithm. Several algorithms were used to make the car work in different conditions. When the vehicle was moving faster the resolution of the image captured had to be higher [3]. Therefore, the mechanisms developed would allow the stereo system to focus attention. Forward looking infrared FLIR imagery, Stereo vision, near infrared imagery were used to distinguish between the various components in the environment such as soil, vegetation whereas, polarization was used to detect standing bodies of water. The speed of the system was 5 to 10 kph over relatively flat surface, cross-country terrain covered with calf-grass and sprinkled with positive obstacles of 0.5 m high and large. They are further extending the process imagery to 512*480 resolution using full frame, non-interlaced cameras. The vehicle would properly detect obstacles at night, day and in other conditions.

The research conducted by Carl Crane described the development and performance of a sensor system that were utilized for autonomous navigation of an unmanned ground vehicle. Four different types of sensors were integrated to identify obstacles in the vicinity of the vehicle and to identify smooth terrain. Slick LMS200 ladar and stereo vision system were the two sensors used. LMS200 transmitted data at 500 kbaud rate whereas stereo vision system utilized 12.5 mm focal length lenses which provide with a horizontal and vertical field view of 50 degrees and 38 degrees, respectively. There were monocular cameras used on the stereo vision cameras to identify traversable terrain. These sensors were used to identify the terrain for traversability and for its smoothness. A common data structure was introduced for use by all sensors called the Traversability Grid.

The obstacle detection was done by various sensors such as the Spinning Ladar that generated a 3D point cloud of the surrounding environment. Stereo vision was used to detect the location of objects in a robot's world. It was capable of giving information about objects, such as color, texture, and patterns that can be used in intelligent systems to classify objects. The terrain sensors consisted of Stationary Ladar that used range data information for terrain mapping and classification. Laser measurement system LMS200 was used for range measurement. Monocular Vision consisted of three stationary cameras that were used to obtain additional information about the terrain. The camera system provided the arbiter with information about the path that the vehicle was traveling on [4].

Anthony Stentz in his research has solved problems related to the autonomous operation of UGV in off-road environments. The perception system was rigorously tested in various environments. The perception system combined laser, camera and proprioceptive sensing elements on both ground as well as air platforms to detect and avoid obstacles in their natural environments. With the UGV's low viewpoint, it was possible to navigate extremely close to the potential hazard before knowing for sure whether or not the path ahead was safe. A system named Flying Eye (FE) which was an aerial vehicle that flew ahead of the UGV to detect difficult obstacles from an ideal, overhead perspective was used. Also, a downward looking sensor was mounted on the vehicle to sense the obstacle at an early stage. The UGV's system consisted of a base ATV, SICK single-axis ladars, a digital color video camera, mechanical bumpers. The Flying Eye (FE) vehicle consisted of a base helicopter retrofitted for fly-by-wire operation, along with perception sensors and computing hardware. The helicopter was equipped with a downward looking stereo vision system to detect obstacles, tag them with position, and radio them to the UGV. The UGV controlled the FE and commanded the FE to clear the path by flying through a series of way points.

The navigation software consisted of two control loops: the Central Nervous System (CNS) and the deliberative autonomy loop. The CNS cycles very quickly provided a basic reflex like function for safeguarding the vehicle. It also monitored the vehicle's bumper for collision, the inertial sensors for dangerous roll or pitch angles. There were two sensing modes namely appearance sensing which includes color cameras and FLIR cameras and geometric sensing that included ladar or FIR stereo system.

The system was tested and the metrics evaluated included the time to travel the courses, the average speed, communication bandwidth, level of remote operator involvement, and number of emergency stops. A large number of emergency stops could indicate too many false negatives. The results found were that the navigation system was capable of detecting and avoiding large positive obstacles, such as trees, rocks, and large bushes; walls and other vertical structures; steep slopes that would cause tip over; and large negative obstacles such as cliffs and deep gullies. Later the perception system was extended to detect and ignore vegetation such as tall grass, weeds, small bushes, and tree limb overhangs [5].

Another sensor that can be used for terrain detection is an Ultrasonic Distance Sensor. Ultrasonic sensors converts

ultrasound waves to electrical signals or vice versa. They transmit and receive ultrasonic signals. They work on a principle similar to that of transducers used in radar and sonar systems, which evaluate attributes of a target by interpreting the echoes to determine the distance to an object. They provide precise, non-contact distance measurements within a 2 cm to 3 m range [6]. Ultrasonic measurements work in any lighting condition, which makes them a better choice to supplement infrared sensors.

3. CONCLUSION

Terrain detection is one of the most important aspects of an Unmanned Ground Vehicle (UGV). This helps the vehicle to move in the environment by detecting obstacles and moving on a specified path. Many researchers have contributed towards detection of obstacles and various techniques are reviewed in this paper. In this survey, a comparison of different sensors is assessed. Noticeable findings are made by different researchers in this area. The existing systems will prove to be accurate enough and productive to study the terrain conditions. All the sensors used by different researchers have their application in specific systems. Other sensors like ultrasonic sensors can also be used in terrain detection. They are very quick and accurate and can be used as a replacement of infrared sensors.

Table: Summary

SR.	HARDWARE	TECHNIQUE	PERFORMANCE
1	Unmanned Vehicle	-Likelihood Function -Conventional -Incremental Mapping Using Posteriors -Backwards Correction -Multi-Robot Mapping -3D Mapping	The results were accurate and the error cycles were eliminated. The robot when traversed in a rugged terrain the error rate would often be as large as 100%.
2	-Forward looking infrared FLIR imagery -FLIR camera	real-time stereo vision system	The system used 256*45 windows of attention in approximately 0.6 seconds/frame.
3	Slick LMS200 ladar -Stereo vision system - LMS200 -Monocular cameras	Traversability Grid	Various sensor systems for obstacle detection were put forth.
4	The Flying Eye (FE) vehicle -Unmanned Vehicle	-	The navigation system was capable of detecting/ avoiding large positive obstacles.

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