Outdoor Terrain Traversability Analysis for Robot Navigation using a Time-Of-Flight Camera

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ABSTRACT

This poster presents an approach for outdoor terrain traversability which mixes 2D data (color information) and 3D information (depth measurements from a time-of-flight-camera) for terrain classification.

The presented methodology classifies all image pixels as traversable or not by estimating for each pixel a traversability score which is based upon the analysis of the segmented color image and the v-disparity depth image.

This approach makes it possible to robustly classify the terrain of outdoors scenes in traversable and non-traversable regions quickly and reliably. Integrated in an autonomous robot control architecture, this enables a mobile agent to navigate autonomously in an unstructured outdoor environment.

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INTRODUCTION

Autonomous robotic systems operating in unstructured outdoor environments need to estimate the traversability of the terrain in order to navigate safely. Traversability estimation is a challenging problem, as the traversability is a complex function of both the terrain characteristics, such as slopes, vegetation, rocks, etc and the robot mobility characteristics, i.e. locomotion method, wheels, etc. It is thus required to analyze in real-time the 3D characteristics of the terrain and pair this data to the robot capabilities.
Time-of-flight cameras have until now not been used for these kind of applications, simply because there were no sensors capable of coping with outdoor conditions, especially due to the interference of solar irradiation. This situation is changing now, with the advent of outdoor-capable sensors. Therefore, we present in this paper an approach for outdoor terrain traversability which mixes 2D and 3D information for terrain classification.

SYSTEM SETUP

Figure 1 shows the Robudem platform which was used as a testbed for the presented algorithms. It is a heavy outdoor robot equipped with a PMDTec CamCube time-of-flight sensor (on top) and a Point Grey Bumblebee stereo camera (in the middle). The time-of-flight camera is mounted in a tilted angle to avoid typical signal modulation problems.

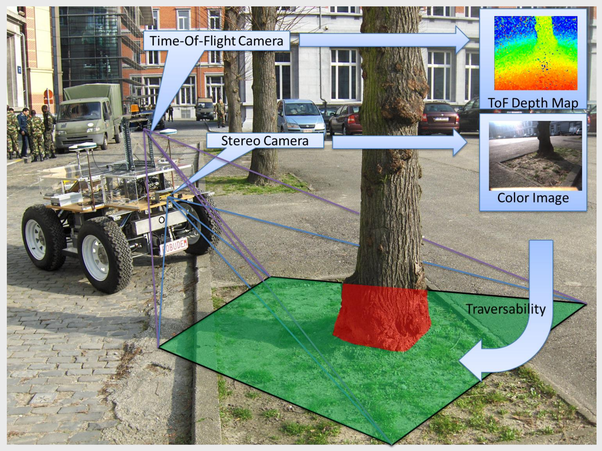

Figure 1. System setup

METHODOLOGY

The methodology for terrain traversability estimation is sketched by Figure 2. A two-way approach is followed:

- From the depth image (Figure 4), a horizontal histogram of depth values is calculated (the so-called v-disparity image [2] as given by Figure 6), and a first estimate of traversable regions is obtained (Figure 7) [1]
- The color image (Figure 3) is converted to the Lab color space and segmented (Figure 5). The median (a,b) value of pixels which are likely belonging to the ground is measured.

At this stage a traversability score is calculated for each pixel. This parameter consists of two components:

- A measure taking into account the color difference
- A measure taking into account the density of obstacle-marked objects in the segment belonging to the pixel

Pixels with a traversability score aboe a dynamically set threshold are marked as untraversable.

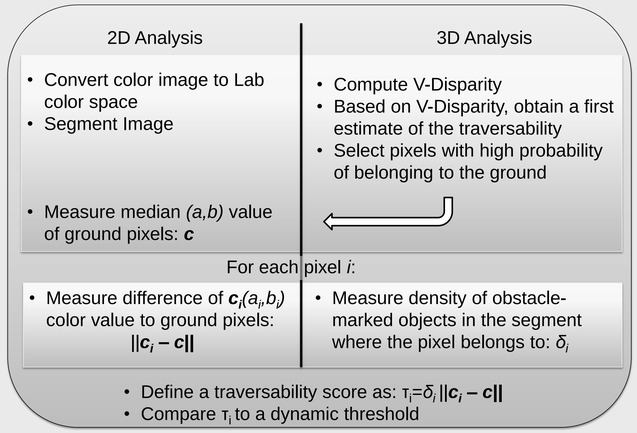

Figure 2. General Methodology

Figure 3. Color Image

Figure 4. Depth Image

Figure 5. Segmented Image

Figure 7. Obstacle Image

Figure 6. V-Disparity

RESULTS

The figures below show the results of the terrain classification algorithm. Obstacles are red, well traversable terrain is green and "suspicious" areas (not enough data) are blue.
It can be noticed that the classification is generally correct, as the obstacles (people, tree, plane) are well-detected.
In the upper left corner of the last image, there are some problems with the classification of the foliage (blue area), which is due to the sensor having difficulties with erroneous reflections on the leaves.

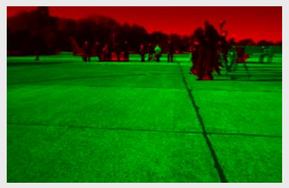

Figure 8. Classification Result

Figure 9. Classification Result

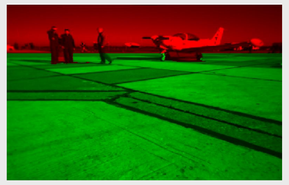

Figure 10. Classification Result

Figure 11. Classification Result

CONCLUSIONS

This poster presented a terrain traversability estimation algorithm based on time-of-flight sensing. This approach makes it possible to robustly classify the terrain of outdoors scenes in traversable and non-traversable regions quickly and reliably. Integrated in an autonomous robot control architecture, this enables a mobile agent to navigate autonomously in an unstructured outdoor environment.

REFERENCES

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2. R. Labayrade, D. Aubert, J. P. Tarel, Real Time Obstacle Detection on Non Flat Road Geometry through V-Disparity Representation, IEEE Intelligent Vehicles Symposium, Versailles, June 2002.