Obstacle detection using stereo vision for self-driving cars

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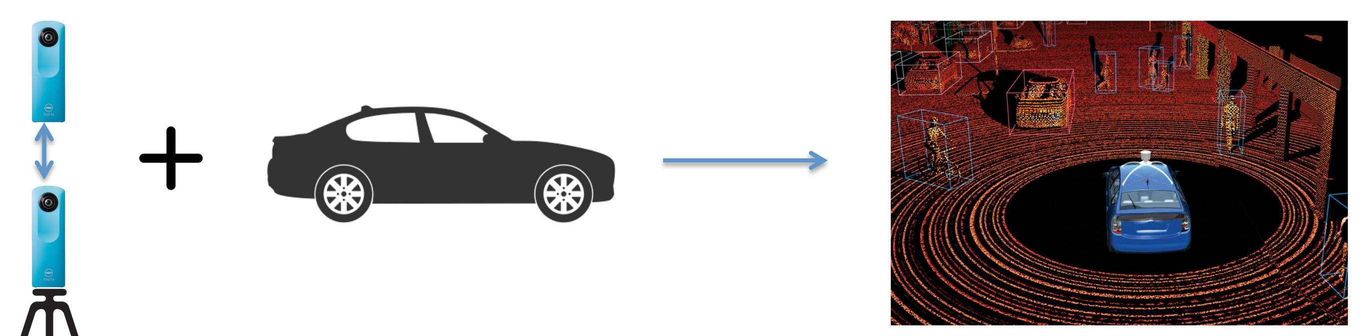
Motivation and Objective

- Perceiving surroundings accurately is essential for autonomous systems like self-driving cars.
- Lidar systems used for perception are expensive. Replace them with inexpensive vision-based systems.

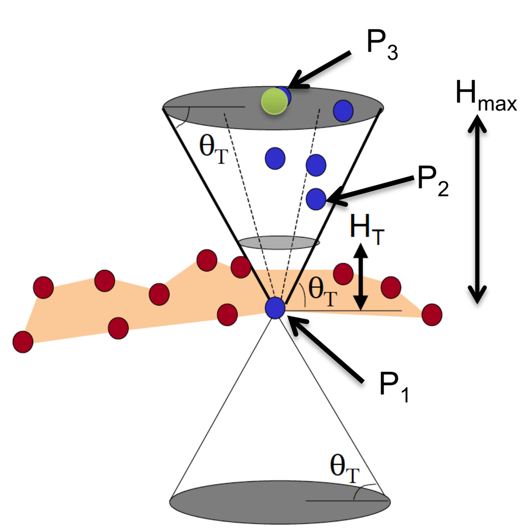


Source: http://www.webpages.uidaho.edu/vakanski/How%20Driverless%20Cars%20Work.html

The objective is to detect obstacles in the surroundings using stereo vision from 360^0 spherical images captured from vertically displaced cameras.

Obstacle detection algorithm

Key idea: Obstacles are points that are at a height from the dominant ground plane.

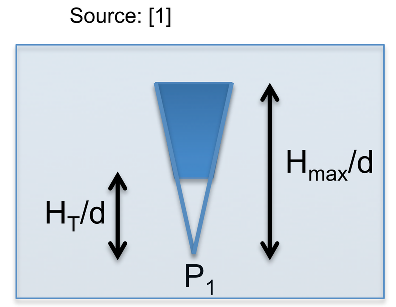


Source: [1]

Definition: Two points P_1 and P_2 belong to the same obstacle and are said to be compatible if:

$H_T < |P_{2Z} - P_{1Z}| < H_{max}$ and $(P_2 - P_1)\bullet(P_3 - P_1)/\|P_2 - P_1\|\|P_3 - P_1\| > \cos\theta_T$

OD algorithm:
- Classify all pixels as non-obstacles
- Scan through all pixels
  - Determine set of pixels, T_P in the projected triangle on 2D image
  - Examine all points in T_P and determine set O_P of points P_i in T_P, compatible with P_1
  - If O_P is not empty, classify all points of O_P as obstacle points.



2D image plane

Process Pipeline

Vertically displaced 360⁰ spherical image pair → **Optical flow → Disparity estimation** → **Depth map generation** →

360^0 by 180^0 spherical panoramas captured using Ricoh Theta camera mounted at two different heights.

Vertical optical flow at every pixel is the disparity value for that pixel in the bottom image.

Trigonometrically transform disparity values to depth values.

Obstacle detection → **Post-processing** → **Polar map for motion planning**

Classifying obstacles from the ground by making use of the relative positions of points in the 3D space.

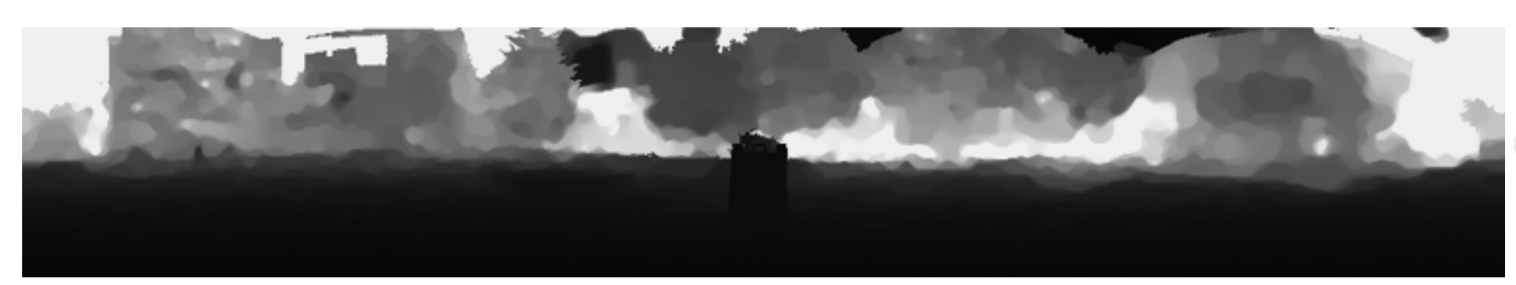
Median filtering and morphological operations to fill small holes in the obstacle map.

Detected obstacle points projected on a 2D plane for motion planning.

Results

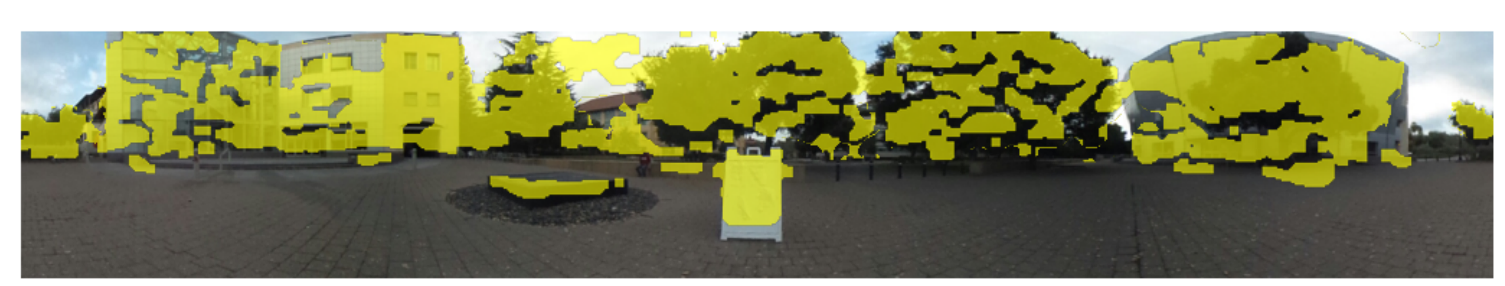
Original lower image: Equirectangular projection (altitude -30^0 to 30^0 and azimuth 0^0 to 360^0) with good mix of obstacles at various ranges.

Disparity map: We observe uniform gradient of disparity along the ground plane, in the bottom half of the image.

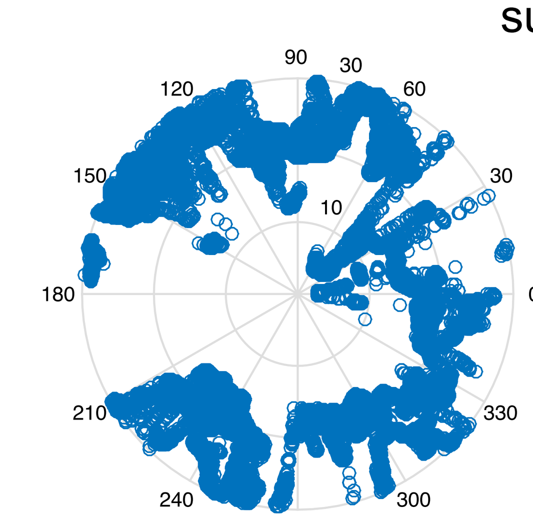


Depth map: Darker regions correspond to smaller depths.

Obstacle map: Obstacles, both closer and farther away, are detected sufficiently well.



Detected obstacles overlaid on the original image



Polar map: The agent is at the center of the map, facing 0^0. The blue points correspond to polar positions of the obstacle points around the agent.

References

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2. Sun, Deqing, Stefan Roth, and Michael J. Black. "Secrets of optical flow estimation and their principles." *Computer Vision and Pattern Recognition (CVPR), 2010 IEEE Conference on*. IEEE, 2010.
3. Bernini, Nicola, et al. "Real-time obstacle detection using stereo vision for autonomous ground vehicles: A survey." *Intelligent Transportation Systems (ITSC), 2014 IEEE 17th International Conference on*. IEEE, 2014.
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