STAIR DETECTION AND MODELLING FROM A WEARABLE DEPTH CAMERA

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Abstract

In this work we propose a method to detect, locate and parametrise stairs with a wearable RGB-D camera. Our algorithm detects if the horizontal planes in the scene are steps of a staircase judging their dimensions and relative positions. With these planes we obtain a scaled model of the staircase with the spatial location and orientation with respect to the subject. Experiments show that the system is able to perform in real-time and works even under partial occlusions of the stairway.

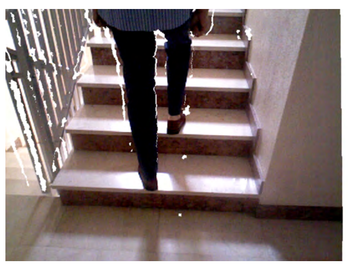
1. Motivation

One of our main interests as researchers is the enhancement of the navigation experience of people with special visual needs (*e.g.* visually impaired).
Stairs are a widespread structure present in most human-made scenarios, whose combination of utility and dangerousness makes them deserving of special attention.

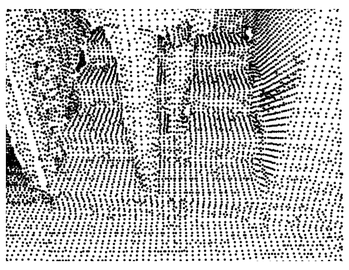
With the help of a chest-mounted RGB-D camera we developed an algorithm to detect and model ascending and descending stairs which was presented in [1].

2. Scene segmentation

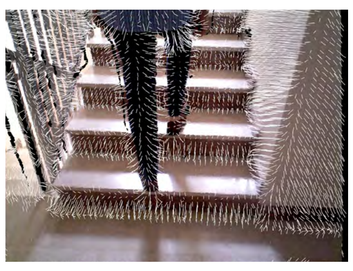
Before detecting stairs, the data from the camera must be segmented in order to classify the planes of the scene. The steps we follow are:



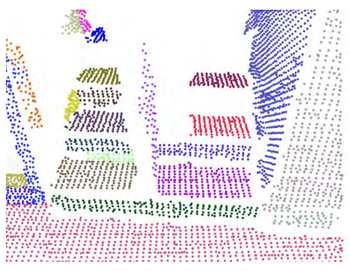
1. Initial point cloud



2. Voxel grid filter

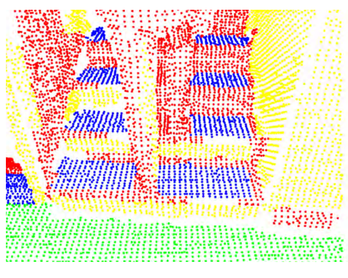


3. Normal extraction



4. Region-growing

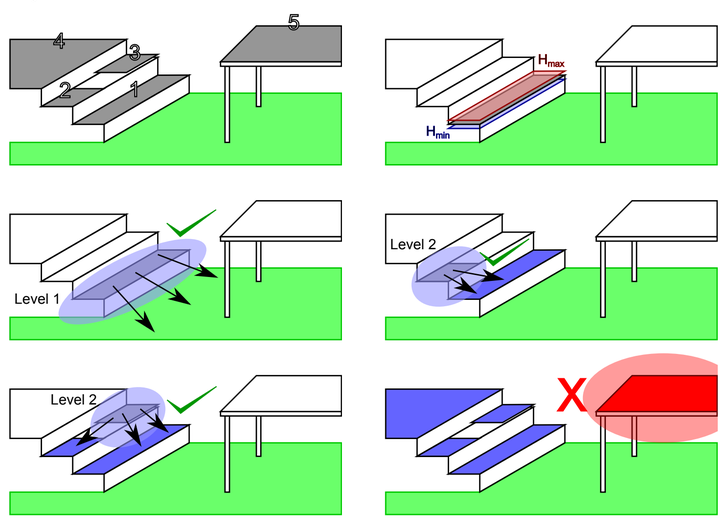
5. Cluster extraction



6. Classification

3. Stairs detection

The relative positions and heights of the horizontal segments are analysed to determine if they form a staircase or not and which step they are.

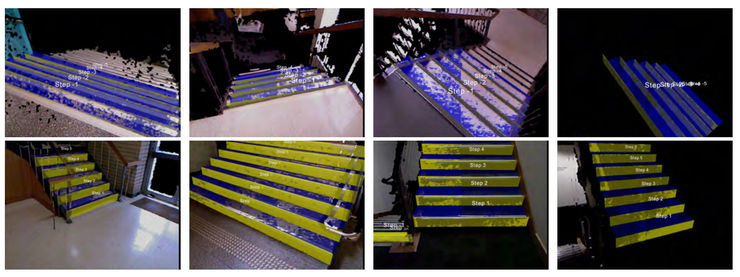


5. Experimental evaluation

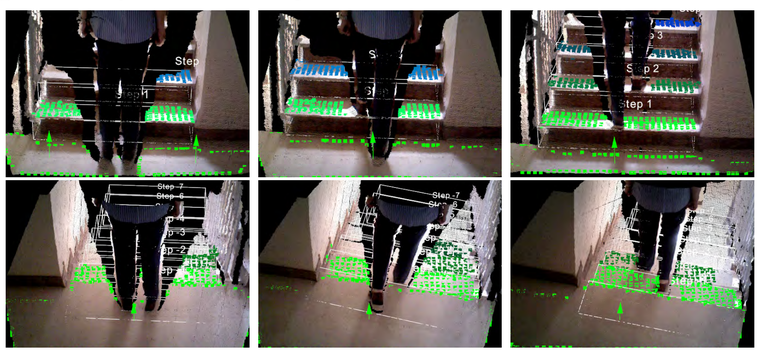
To evaluate the performance of our algorithm in comparison to others we used the dataset from [2].

Evaluator	False negatives	False positives
Tang [2]	5.07%	1.02%
Vlaminck QVGA [3]	0.00%	8.62%
Vlaminck VGA [3]	0.00%	3.45%
Our work [1]	0.00%	0.00%

Detected stairs in some captures of the dataset:

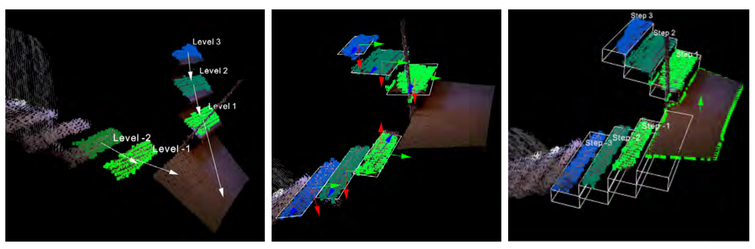


Other images detecting stairs with a person partially occluding the view:



4. Stairs modelling

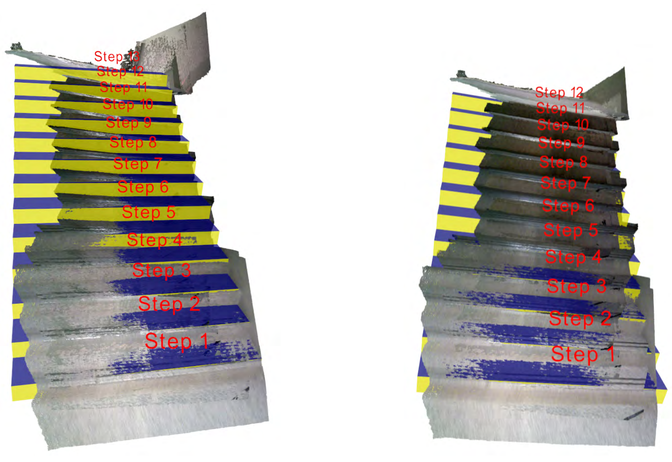
Taking the ordered steps from the previous stage (a), an initial estimation of the stair pose and step dimensions can be obtained from the principal component analysis of the points of every step (b). The final pose is the one that minimizes the bounding rectangle on every step and the dimensions will be the ones that fit a rectangular stair model best given the orientation (c).



(a) (b) (c)

6. Odometry-aided traversal

Additional improvements of the algorithm includes the estimation of the visual odometry [4] to maintain location awareness and to know the relative positions to relevant features in the scene when they are not in the current view.
In the case of stairs, it allows to improve and complete the model of the full staircase and to retrieve any time at which step the user stands. Reciprocally, the current view is used to correct the drift of the visual odometry.



The visual odometry estimation runs at real-time, taking advantage of the GPU. Even combined with the stair detection implementation (average time of 75ms) the whole system is fast enough for human navigation.

Acknowledgment

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References

[1] A., Perez-Yus, G., Lopez-Nicolas, J.J., Guerrero, Detection and Modelling of Staircases Using a Wearable Depth Sensor, in *ECCV Workshops*, 2014
[2] T.J.J., Tang, W.L.D., Lui, W.H., Li, Plane-based detection of staircases using inverse depth, in *ACRA*, 2012
[3] M., Vlaminck, L., Jovanov, P., Van Hese, B., Goossens, W., Philips, A., Pizurica, Obstacle detection for pedestrians with visual impairment based on 3D imaging, in *IC3D*, 2013
[4] D., Gutierrez-Gomez, W., Mayol-Cuevas, J.J., Guerrero, Inverse depth for accurate photometric and geometric error minimisation in RGB-D dense visual odometry, in *ICRA*, 2015