3D Building Reconstruction and Thermal Mapping in Fire Brigade Operations

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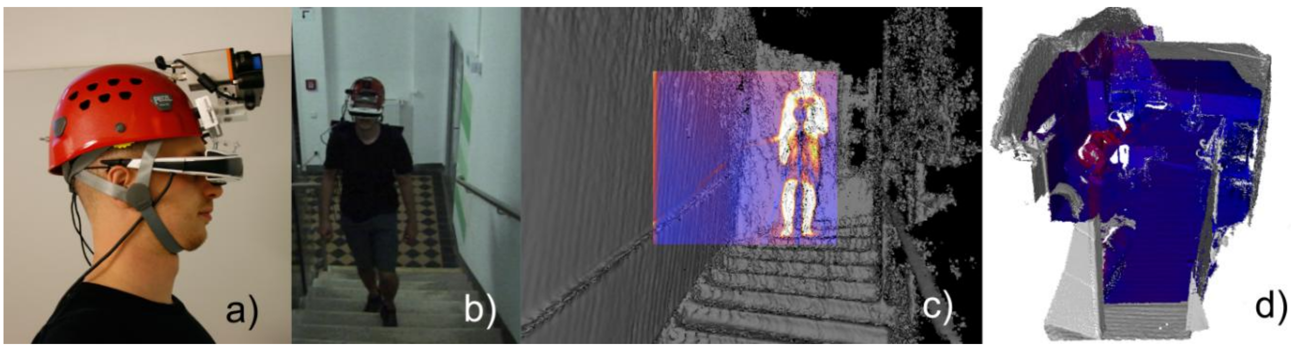

Figure 1: a) Our setup conjoining a depth sensor, thermal camera and head mounted display b) Mobile operation on a notebook. c) Real-time reconstruction of the staircase with thermal image overlay. d) Reconstructed mesh from room structure textured with the images of a thermal camera.

Abstract

Fire fighting remains a dangerous profession despite many recent technological and organizational measures. Sensors and technical systems can augment the performance of fire fighters and increase safety and efficiency during operation. An important aspect in that context is the awareness of location, structure and thermal properties of the environment. This work focuses on the design and development of a mobile system, which can reconstruct a 3d model of a building's interior structure in real-time and fuses the visualization with the image of a thermal camera. In addition, the position and viewing direction of the fire fighter within the model is determined and a thermal map can be generated from the gathered data. This helps an operational commander to provide accurate instructions to his men during a mission. First tests with our system in different situations showed good results, being able to reconstruct different larger scenes and create thermal maps thereof.

Keywords: Real-Time, Dense Reconstruction, Tracking, Thermal Cameras, Volumetric Representation, Augmented Reality, Fire Fighter, Safety.

Index Terms: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities—; I.4.8 [Scene Analysis]: Object Recognition—Tracking

1 Introduction

The safety and efficiency of fire fighters during operation depends to a large degree on knowing their location within a building and the thermal situation. Therefore, tracking their location is an important objective of our system. Additionally it is important for an operational commander to know about the structural context (i.e. building structure) in order to safely direct his men, but 3d models or accurate maps of buildings are rarely available. Our system combines an approach reconstructing the 3d structure of a building [1] with thermal imaging, thereby providing a real-time visualization of thermal properties for the fire fighter as well as thermal maps highlighting fire or human victims for an operational commander.

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2 Setup and Implementation

In our system (Figure 1a) we employ an Asus Xtion Pro as depth sensor and a Xenics Gobi-640-GigE camera for thermal imaging. Either the standard calibration for absolute temperatures (range -20ºC - 120ºC) or the automatic calibration with relative temperature values is applied. For our mobile setup (Figure 1b) we use a notebook with an Intel Core i7-3720, 16 GB main memory and the NVIDIA GeForce GTX 680M with 4096 MB RAM. A Silicon Micro Display ST1080 Head Mounted Display provides visualization.

For real-time dense volumetric 3d reconstruction and pose estimation we use an algorithm based on Kinect Fusion [1] and its extension for large scale environments (KinFu Large Scale) as implemented in the open-source Point Cloud Library (PCL) [2]. The implementation was also optimized for processing on the GPU. We integrated the thermal camera over a customized grabber module in the PCL framework and extended it to create a thermal map instead of texturing with the Kinect's RGB images as in [2]. For that purpose, we have implemented some preprocessing steps for color coding thermal information. The employed lens for the thermal camera offers a smaller field of view than the Asus Xtion, resulting in a relatively small sub-image of the depth reconstruction covered by the thermal camera (Figure 1c). Meshes for the captured environment are generated in an offline process. We calibrate the cameras' intrinsic parameters as well as the extrinsic transformation between the thermal camera and the depth sensor with the MIP Multi Camera Calibration tool [3]. With these parameters and logged camera poses we project the thermal images onto the mesh and generate texture coordinates from the projections as described in [2].

3 Results and Conclusion

In first tests with our system we were able to reconstruct various large scenes like a building entrance, rooms and staircases with a level of detail more than sufficient for the intended purpose. Reconstruction works also in complete darkness, helping the user to navigate in such conditions. Employing calibrated temperatures enabled us to clearly highlight human body temperature in environments with room temperature (Figure 1d) while relative temperatures proved useful in situations with smaller temperature differences (i.e. fine structures) or outside the calibrated temperature range. Reconstruction with thermal imaging showed robust registration of the cameras. Only in situations where the tracking lacked accuracy, misalignment was sometimes caused. Our mobile setup performs reconstruction and tracking at a rate of 12 to 15 frames per second, which is sufficient for interaction but is not fast enough for the intended application yet.

Acknowledgments

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References

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