Interactive Urban Search & Rescue Planning

Support Decision-Making by Visualization-based Analysis

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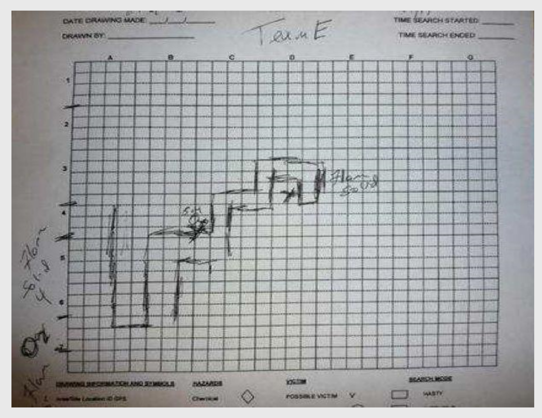
What is Urban Search & Rescue?

Urban Search & Rescue (USAR) is concerned with locating, reaching, rescuing, and stabilizing entrapped victims in urban environments. A possible incident scenario for these rescue operations can be (partially) collapsed buildings. Rescuers have to enter these locations under threat to their own lives and rescue the, possibly severely hurt and immobilized, victims.

The current situation

Initial reconaissance of the collapsed structure is performed by rescuers. The rescuers traverse the emergency site and try to find victims or reach other points of interest.

A supporting rescuer, outside the structure, draws a map of where the rescuers go and where points of interests, victims, or hazards are located based on the information he receives from the rescuers.



Our proposed workflow

Instead of endangering rescuers by sending them into unknown areas with unquantifiable risks, we propose to do the initial reconnaissance using autonomous robots equipped with various measuring devices. Using this data, the rescuers can plan the entry in advance and avoid hazards and rescue victims more efficiently.

Data Acquisition

Advances in sensor technology, alongside computation power, makes it possible for autonomous robots to navigate and map a priori unknown environments reliably. LiDAR scanners on board produce a decent 3D point cloud, which is analyzed in real time.

In addition, we propose to equip more detectors on robots to be able to detect, for example, heart beats or hazardous substances.

Image courtesy of Nagatani, Nishimura, Hada et al. "Redesign of rescue mobile robot Quince"

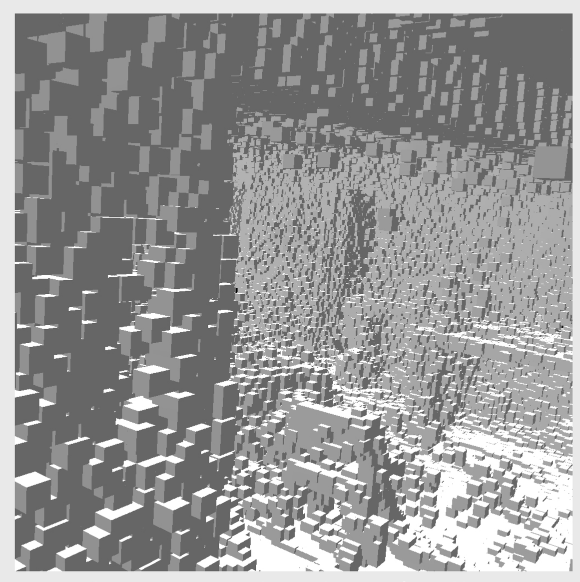
A raw, unstructured point cloud acquisition exhibiting problems with limited occlusion

Rendering

As the acquired data consists of single measurement points (with optional color), limited occlusion is a considerable problem. Moving close to a wall allows the user to see structures behind the wall as there are gaps in the point cloud.

We solve this occlusion problem by spatial binning. The space is quantized and points are assigned to they closest bin. For each occupied bin we render an axis-aligned cube, which can be shaded.

An overview of the dataset acquired at the Fukushima Daiichi nuclear reactor in 2011

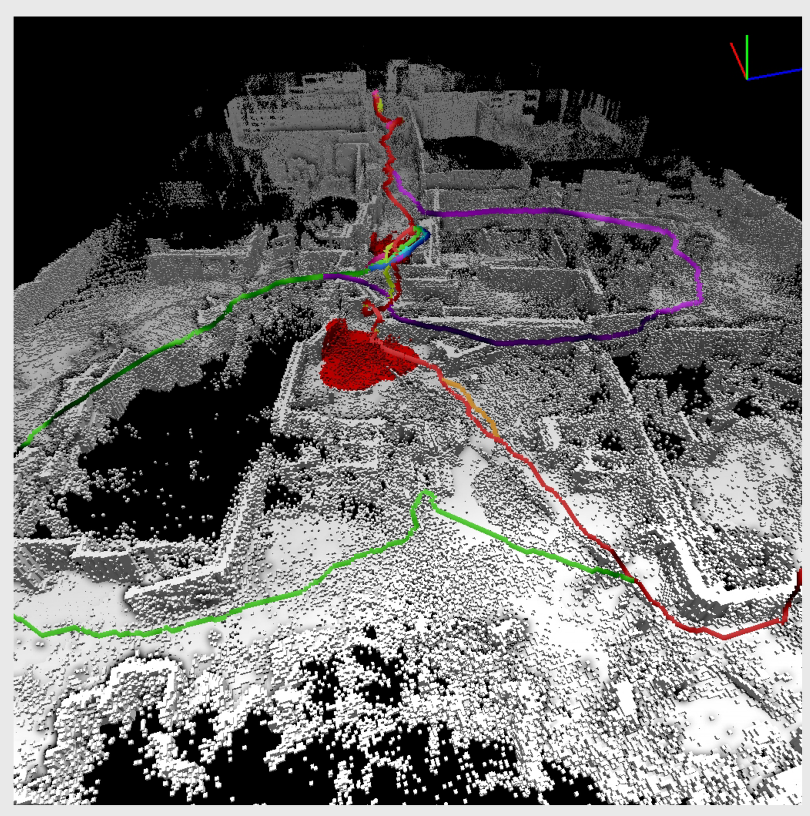


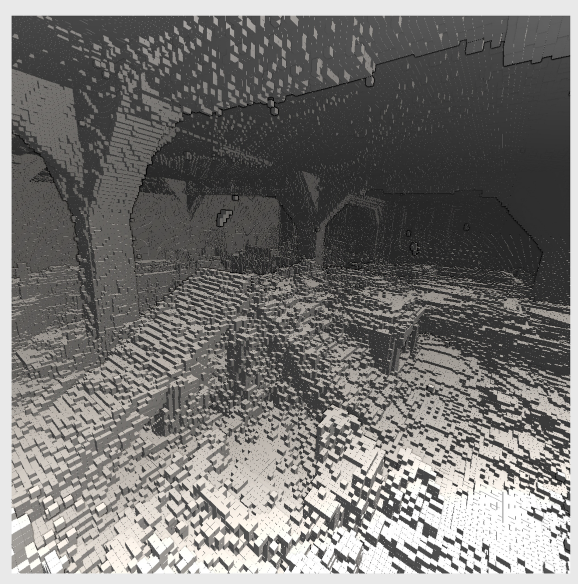
The same scene rendering the axis-aligned bins

Path Computation

To assist the rescuers in selecting a viable path, we compute an ensemble of optimal paths. The path computation is done using a modified A* algorithm, which traverses the bins and finds the optimal path for a specific metric.

The metric is a weighted sum of six submetrics that take into account the distance, the presence of hazards, the surface normal, the available size, and the supporting area. By changing the weights multiple possible paths are computed and the rescuer can make a trade-off based on his experience.

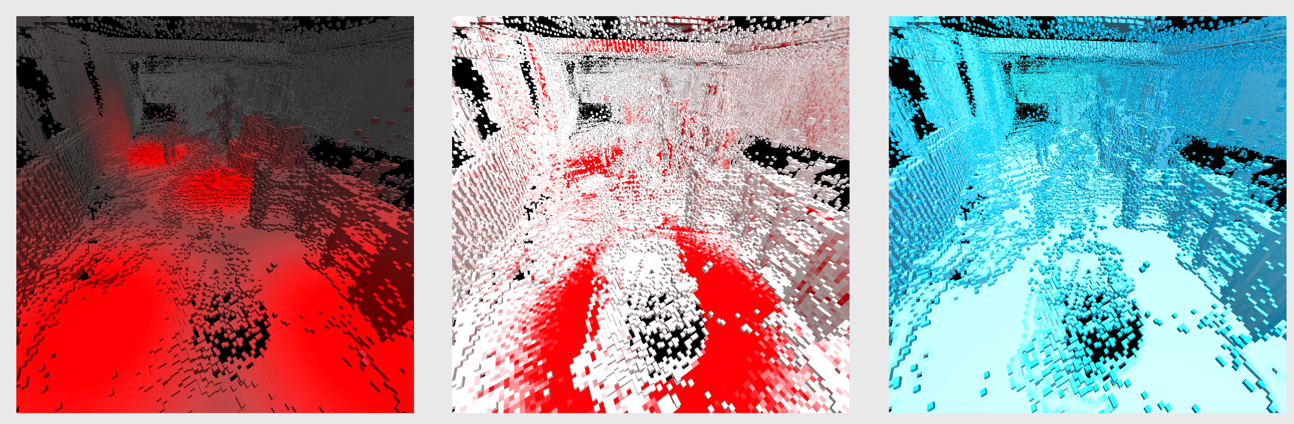




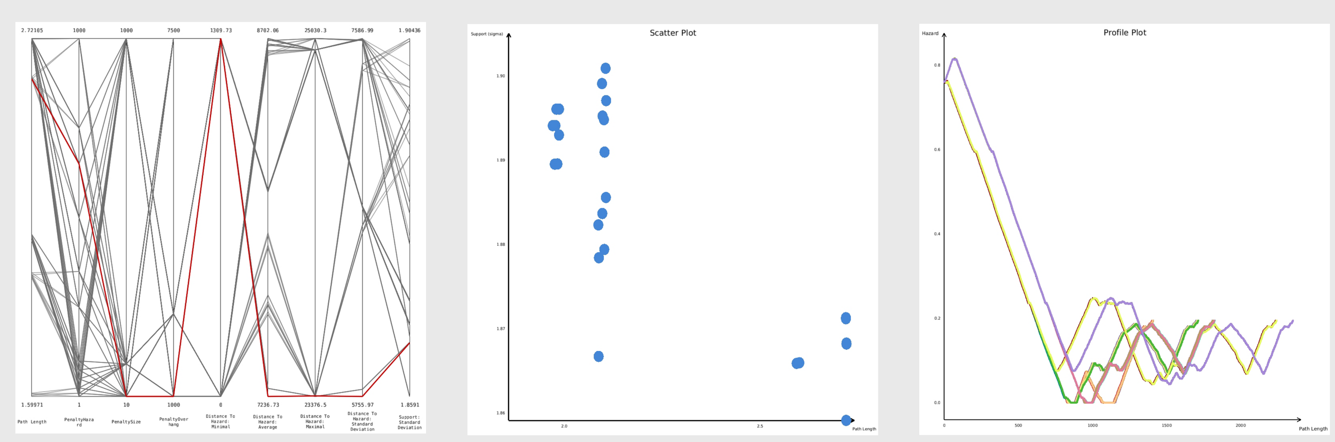
The Bremen rescue arena dataset with 4cm bin size

Decision-Making

The rescuer has to choose between a large number of viable paths to find the optimal trade-off. Optimal in this case means that it should be a short path, but avoid any dangerous areas (hazards, steep inclines and the like). The human has to be in the loop as the data is uncertain and expert knowledge, which is not easily coded, is required. We provide several information visualization techniques to support the rescuer in choosing the optimal path.



Three examples of visualizations showing influences of various submetrics on the final result. From left to right: Distance to closest hazard, bin occupancy, available support area



Three examples of visualizations to select between different paths. The submetric weights create a highdimensional search space

One more thing ... Immersion

By presenting the point cloud in a fully immersive environments, the rescue gains a better spatial orientation. We have adapted our technique to work on a full-dome presentation system as well as supporting stereoscopic rendering techniques.

With the advent of new technologies (for example the Oculus Rift) these technologies will become ever more ubiquitous .

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