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3D printing indoor evacuation plans for visually impaired people

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Abstract:

Evacuation plans are protective and safety elements commonly found in any building, providing information about the user's situation and the shortest and safest route to exit (Al Bochi et al., 2023). Evacuation plans also include self-protection elements such as fire extinguishers, hoses, or fire alarm buttons. To prevent individuals with visual disabilities from facing a risk of exclusion, evacuation plans should be accessible and interpretable for any group. This work aims to reduce the social exclusion risk for individuals with visual disabilities by creating a 3D indoor evacuation plan that accurately represents the reality of a building's floor. The proposed 3D plan is based on 3D LiDAR scanning data as a method to obtain the necessary precise 3D layouts (Oniga et al., 2021). The proposed method is summarized in the flowchart presented in Figure 1.

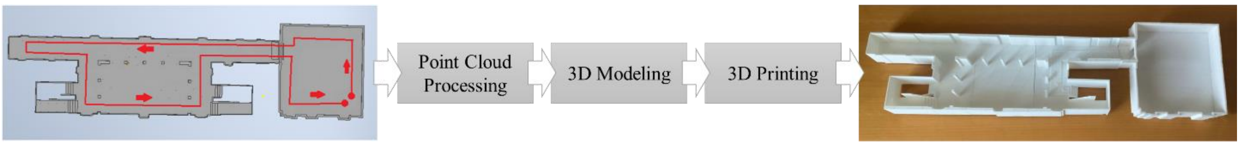

Figure 1. Workflow of the proposed method.

As a case study, the second floor of the School of Industrial Engineering at the University of Vigo was partially utilized. The floor was scanned using a Handheld Mobile Laser Scanner (HMLS) Zeb Go, following a closed-loop procedure. The input point cloud was manually processed to remove outliers, using a Statistical Outlier Removal (SOR) filter, and the ceiling, to create an open area for indoor visualization and hand access.

The processed point cloud was transformed into a mesh through triangulation. The mesh served as the foundation for generating the 3D printing model. The mesh was smoothed and refined to enhance the quality using smoothing techniques and point density adjustments. Subsequently, the model was simplified by removing elements such as closed doors that the evacuation route pass through, as well as furniture. Certain elements, such as stairs and complex areas, were improved through manual modeling. For the creation of the 3D evacuation route, the face corresponding to the floor of solid was selected, and a path of a width smaller than the doors was established, with right angles at direction changes. The route was extruded to a height of 1 mm (Figure 3).

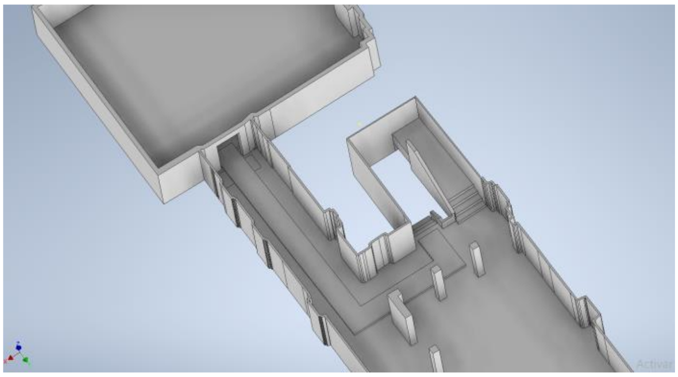

Figure 2. Evacuation route in 3D over the model.

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The adaptation of the model for feasible printing involved editing to ensure realistic. One measure taken in this process was to increase the thickness of the model's walls and floor to provide greater rigidity. Additionally, considering the dimensions of the printing space and the case study, a 1:50 printing scale was selected to maintain the level of detail, and the decision was made to divide the model into various pieces. Tabs were designed to fit together like a puzzle for assembling the different parts (Figure 3). The printer used was an Ultimaker 2. In the end, 10 pieces were printed (Technical Office Room 1, 2, and 3; South Hallways; South Stairs; Central Part; North Hallway 1 and 2; North Stairs 1 and 2). Each piece took approximately 12 hours to be printed.

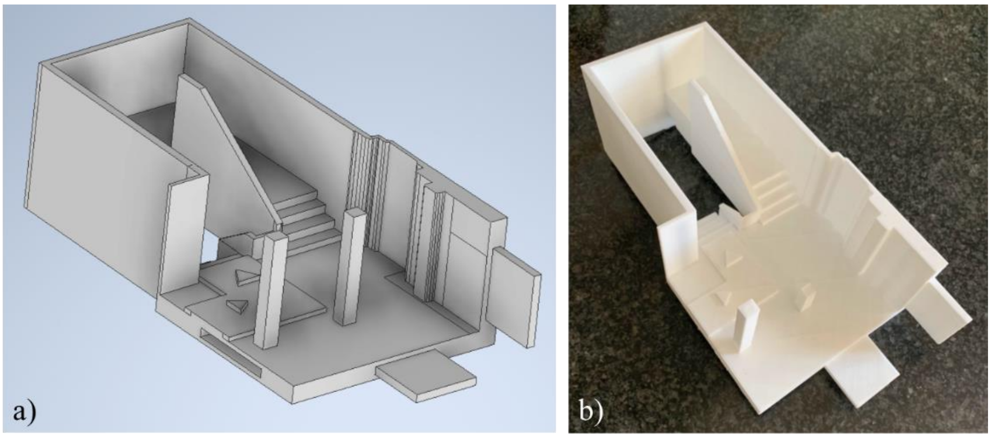

Figure 3. Piece in digital model (a) and printed (b).

The results demonstrated that HMLS LiDAR data acquisition systems are fully valid tools for the creation of a 3D evacuation plan with the accuracy required for a tactile interpretable plan. 3D printing is key to the generation of three-dimensional plans, although the printing time may be too long to produce one single model. Future work will focus on assessing the addition of different textures and testing usability with impaired people.

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