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Automatically generating virtual tours based on dense sets of 360° imagery

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Abstract:

The recent development of consumer-grade panoramic cameras led to new possibilities in creating virtual roundtrips e.g. through museums, cultural heritage or real estate (Radianti et al., 2020). Current approaches for the creation of these tours are based on a manual selection of the image order by the user. This works well for small datasets in the dimension of 10-20 images but becomes very time-consuming for larger amounts of data. We consider large datasets of georeferenced omnidirectional images in outdoor areas and aim to develop an algorithmic approach for automatically eliminating redundant data and creating intuitive connections in between the image locations to enable a natural traversal by the user in the virtual tour. Our goal is to develop a method which is scalable for whole cities or regions while the movement during capturing is not restricted to a network such as the road network.

Our experimental dataset consists of 297 images taken at the scientific farm Campus Frankenforst in Königswinter with high density meaning a typical point distance of a few meters (cf. Figure 1). To get a first understanding of how the results should look like, we developed a tool for visually editing graphs and asked 8 scientific assistants of the Geoinformation group of the University of Bonn to manually draw a reasonable graph which can be used for a virtual tour based on our entire dataset. The assistants were allowed to delete image vertices as they insert edges to create the most intuitive graph. One of the results is displayed in Figure 2. We also asked the participants what criteria they intuitively used to decide when deleting nodes or drawing edges. Deviated from the results we propose three main criteria:

- Visibility: Nodes with a high potential of including vision to multiple important objects (e.g. at crossings, between buildings etc.) are considered more important than other nodes.
- Redundancy: Nodes are considered redundant when having close neighbors. The point density should be consistent.
- Edge differentiation: To reach good usability of the virtual tour, navigational options between images should be clear. Therefore, the angle between edges should be large and the number of incident edges at one node should be limited.

In addition to these graph-related criteria, we also use content-based criteria (Boutell and Luo, 2004) to decide between redundant images. These depend on the lighting conditions, the weather, and capturing time.

Figure 1. Experimental dataset consisting of 297 photos captured at Campus Frankenforst

Figure 2. Manually created graph for a virtual tour based on reduced set of 91 photos

Our method for automatically generating the graph structure consists of three main steps:

1. Clustering: To find and eliminate redundant data, we first calculate the ε-neighbourhood for every node. Secondly, we make use of greedy approaches to approximate a minimum clique cover (Karp, 1972) of the graph. Cliques are used to replace local aggregations of images with similar content by one representative so that the resulting selection of images can be considered as representative for the whole dataset.
2. Filtering: Each clique is supposed to be represented by the most valuable node while all other nodes in the clique are eliminated. We use the proposed criteria to calculate a quality index for each node and keep the one with the highest value.
3. Edge drawing: In the last step, all clique representatives and isolated nodes need to be connected by edges. These are bound to limitations in length, angle between edges, and number of incident edges at one node. Also we exclude edges crossing buildings.

After creating the graph representation of the virtual tour, we can use it together with the underlying data to visualize the tour. To view the panoramas in a browser, we employ the free and open source Pannellum viewer (Petroff, 2019) (cf. Figure 3). The omnidirectional image at the user position is displayed in fullscreen mode allowing to turn in all directions. Links to connected photos are represented by arrows directly in the image. We also included a small map as an overview of the tour allowing the user to jump to a different location.

Figure 3. Screenshot of the virtual tour at Campus Frankenforst, Königswinter

The proposed method allows fast and straightforward generation of virtual tours independent on viewpoint planning in advance. Our integrated criteria for eliminating nodes and drawing edges ensure a user-friendly navigation which is close to human intuition. For evaluating the results in detail, further experimental research is needed through adjusting the criteria or applying visualizations in user studies (Petousi et al., 2023). One promising approach would be to compare the user experiences in manually vs. automatically generated tours based on the same data sets.

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