CS453/553 Scientific Visualization: Term Project

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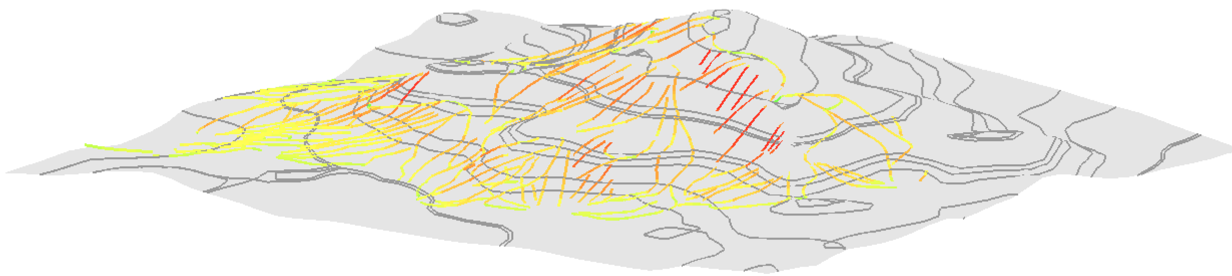

Fig. 1: A 3D screenshot from our ski resort visualization.

1 Abstract

This project focuses on implementing the first stage of the SkiVis [1] framework, which aims to provide skiers with an intuitive and detailed visualization of ski resorts. By representing slopes and lifts as geospatial networks, we seek to explore individual ski slopes based on a variety of characteristics, such as steepness and direction. Unlike traditional panoramic ski maps, this tool provides precise and scaled visualizations that incorporate essential geographical attributes. The implementation includes parsing ski slope data, visualizing routes, and adding color-coded features to highlight slope characteristics, offering skiers a more informed and user-centered approach to route planning.

2 Introduction

Unlike other outdoor activities such as hiking and biking, modern ski routing rarely accounts for user preferences, making it challenging for skiers to discover routes that align with their skills, interests, and conditions. Addressing this gap is crucial to improving the skiing experience.

However, solving this problem is challenging due to several factors. Most ski resorts rely on uniquely designed maps that prioritize aesthetics over functionality. Notably, 86% of these maps employ a panoramic style that emphasizes geographic features but often lacks critical topographic cues necessary for effective navigation. Additionally, these maps frequently omit critical slope data, such as length, width, or trajectory. Another complexity arises from the way slopes are classified. Typically, a slope's difficulty is determined by its steepest segment, even if the rest of the slope is relatively easy. This simplistic classification fails to account for factors such as narrow paths, uphill sections, overall steepness, or compass direction, all of which can significantly impact a skier's experience.

To address these challenges, SkiVis [1] provides a comprehensive platform to visualize ski slopes in a geospatial, topological format, incorporating a variety of detailed slope characteristics. By presenting this information in a clear, scaled manner, SkiVis alleviates the route planning process, empowering skiers with insights that are not readily available through traditional maps. This tool can also benefit snowboarders and sledgers, who share many of the same navigation challenges, by offering detailed information on downhill runs.

In this project, we implement the paper's foundational task (T1) of exploring a ski resort's network of slopes based on defined features. Our work examines individual ski slopes, visualizes them, and adds color-coded characteristics to highlight their various unique slopes. This exploration lays the groundwork for more advanced functionalities, such as preference-based routing and enhanced visual analytics for ski resorts.

3 Previous Work

This project builds upon the publication **SkiVis: Visual Exploration and Route Planning in Ski Resorts** [1], which introduces a comprehensive approach for visualizing and navigating ski resorts through geospatial networks.

Additionally, this project integrates concepts from scalar field topology, as covered in the CS 453/553 course. These foundational techniques have informed our approach to modeling ski slopes and visualizing their unique properties within a scalable and user-friendly framework.

4 Background

In our implementation, we wanted to choose something domestic and closer to home rather than the Austrian ski resort in the paper. Enter Mammoth Mountain, a large ski resort in California featuring a complex network of ski slopes of varying difficulties. Modeling a ski resort in the United States allowed us to use the USGS 3DEP Dataset for topography. We opted for the 1 arc-second dataset which has a reading every 1/3600th degree or approximately every 30 meters. For the ski slopes, or "pistes," we relied on OpenStreetMap data, as suggested in the SkiVis publication [1], to obtain a series of latitude and longitude coordinates for each piste.

The initial topographic geotiff file is 7.5 minute quad which covers about 50 square miles. Using Python scripts and the rasterio Python package we cut this large quad into the area of Mammoth mountain's ski resort. We used to Python to convert this into a PLY file that would be compatible with the C++ scalar visualization code from the first two homework assignments.

After some experimentation we found we had to down-sample the geotiff file using the rasterio Python package to provide reasonable render times for the PLY file. The final aspect of data pre-processing involved querying OpenStreetMap data for the Mammoth mountain area to get the piste coordinates.

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Using this data, we implemented C++ functionalities to produce a scalar topological representation of Mammoth Mountain using the converted PLY file.

Subsequently, we implemented an algorithm to convert the piste coordinates into a more detailed series of quad bisectors. This allowed us to find the gradient of the piste across each quad by using bilinear interpolation to find the scalar value (the elevation) at each point the piste intersects the mesh edges.

These per-quad gradient were used to color code the piste, with red hues representing higher gradient sections and yellow hues representing lower gradient sections. Due to the scope and timeline of the project, we focused on slope as the primary user preference, as it is one of the most influential factors in ski route planning and difficulty assessment [1]. Additionally, we included a 3D interactive view alongside a 2D topological view to allow users to visualize and grasp the directionality, steepness, and navigation of each piste.

We faced several challenges during this implementation. Topographic geotiff files create for large complex PLY files. Mammoth Mountain's topographic map converted into a PLY file took up to 15 minutes to render. This was mitigated by down-sampling the number of vertices for faster rendering. Additionally, finding the bounding box for any given ski resort is a process that we were unable to automate.A complementary challenge was learning geographic information systems programming using the "rasterio" Python package for geotiff data processing, clipping, and down-sampling.

Lastly, OpenStreetMap returned some piste coordinates that fell outside the bounding box for Mammoth Mountain, causing segmentation faults. We resolved this issue by implementing logic to filter out such points, which required debugging and analyzing the problematic files.

5 Results

In our implementation, we highlighted slope as the defining feature of the ski routes. The result was a detailed terrain view of Mammoth Mountain, with multi-colored lines representing different slopes. This visualization allows users to quickly assess the difficulty of individual segments in a piste, offering valuable insights at a glance. The 3D view enhances this experience by showcasing the height of the terrain, allowing users to pan around and explore the landscape from various angles. Additionally, we included zoom functionality to give users a closer look at specific sections of the terrain. Overall, our project demonstrated the potential for user-preference-based navigation in ski resorts, providing a foundational version of the SkiVis tool with essential features for visual exploration and slope analysis.

6 Evaluation

Overall, we are satisfied with our implementation and results. We successfully visualized Mammoth Mountain's ski slopes and terrain in a topological format, incorporating interactive 2D and 3D views that enable users to better understand slope characteristics and navigation paths. Despite challenges, we created a foundational version of the SkiVis concept, demonstrating the feasibility of user-preference-based ski navigation.

Furthermore, we have evaluated our visualizations by comparing the piste routes to the actual trail map. Figure 2 demonstrates how our visualization accurately maps and displays the pistes within the ski network. Additionally, our visualization provides more information than the website by using colored slopes to represent the gradient of the terrain, making it easier for users to understand the difficulty level of each route at a glance.

However, there are areas for improvement. Additional functionality, such as indicating piste slope width, hazard zones, and filters to display specific piste categories (e.g., difficulty levels), could significantly enrich the user experience. Enhancing labeling by providing detailed contextual information—such as piste names, lengths, and popularity—would also make the tool more informative and user-friendly.

Additionally, the algorithm to determine the per-quad gradient of the pistes could be built upon. Rather than opting for a straight line between piste points, the effect of saddles and other singularities could be considered to optimize a skier's path.

Building on these results, we suggest that the original paper could expand its SkiVis tool by incorporating data for more complex ski resort networks and exploring additional use cases. A particularly exciting direction could be the integration of virtual reality, providing users with an immersive and interactive planning experience. These enhancements would further solidify the original paper's foundation and broaden its practical applications.

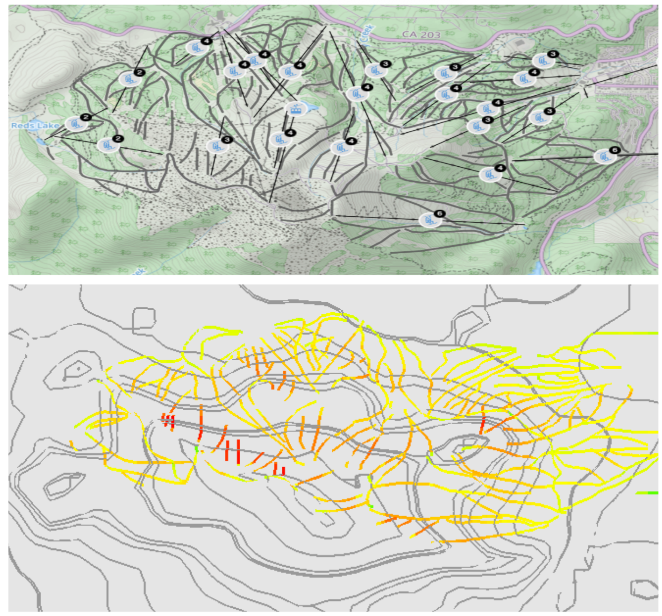

Fig. 2: Comparison of ski resort map to our visualization

7 Division of Tasks

Ziv was responsible for converting geotiff files to PLY files using Python scripts, down-sampling to troubleshoot slow rendering, and also creating text files with XY coordinates to indicate individual piste locations. He also helped Audrey with a C++ algorithm to calculate the scalar value of subsegments between two points and debugged segmentation faults and other miscellaneous errors.

Audrey was responsible for C++ programming. This entailed repurposing Project 2's code to mimic the design and display of the original SkiVis website and also writing functions and data structures to read Ziv's piste files, plot these data points, create lines between them, and color them according to slope through a heatmap. She helped Ziv debug the segmentation faults by testing each piste file to determine troubling data.

Both Ziv and Audrey worked on the proposal, presentation, and final write-up.

8 Conclusions

Modern ski routing methods are complex, non-standardized, and lack navigational support for skiers. The majority of slope maps, while visually appealing, are non-topographical, so it is hard to grasp the scale of these. They also fail to include critical information such as length, steepness, and compass direction. This lack of detailed and user-centered routing solutions poses challenges for skiers, snowboarders, and other resort visitors attempting to plan safe, relevant, and efficient routes.

Our project aims to address this issue by implementing a scalable visualization tool inspired by the SkiVis publication. We used Mammoth Mountain, a major ski resort in California, as a case study. Terrain data was sourced from the USGS 3DEP Dataset using the Digital Elevation Model, while piste data was retrieved from OpenStreetMap. These datasets were converted to relevant file types using Python. We processed the data into a scalar topological representation, mapped pistes onto the terrain, and color-coded them by slope using C++. The implementation features a 2D topological view and an interactive 3D visualization to enhance understanding of piste navigation and slope characteristics.

We successfully generated a visual representation of Mammoth Mountain's topography and complete network of pistes, color-coded by slope steepness. The 3D visualization offered users an intuitive way to explore the terrain and slopes in a correctly scaled platform while understanding characteristics such as directionality, steepness, and proximity to other pistes. The project demonstrated the feasibility of mapping slope characteristics and user-preference factors for ski navigation, achieving a foundational implementation of the SkiVis concept.

Future work includes incorporating additional user-preference features, such as slope width and hazard zones, to enhance the routing experience. Adding a filter functionality to display slopes of a certain type would allow users to further refine their searches based on specific characteristics. Detailed labels for each piste, including statistics such as total length and popularity, could also be implemented to provide users with more comprehensive insights. These additions would make the tool more interactive and informative, further improving its utility for skiers and other resort visitors.

References

[1] J. Rauscher, R. Buchmüller, D. A. Keim, and M. Miller. Skivis: Visual exploration and route planning in ski resorts. *IEEE Transactions on Visualization and Computer Graphics*, 30(1):869–879, Jan. 2024. doi: 10.1109/TVCG.2023.3326940 1, 2