# Visual Exploration of Preference-based Routes in Ski Resorts

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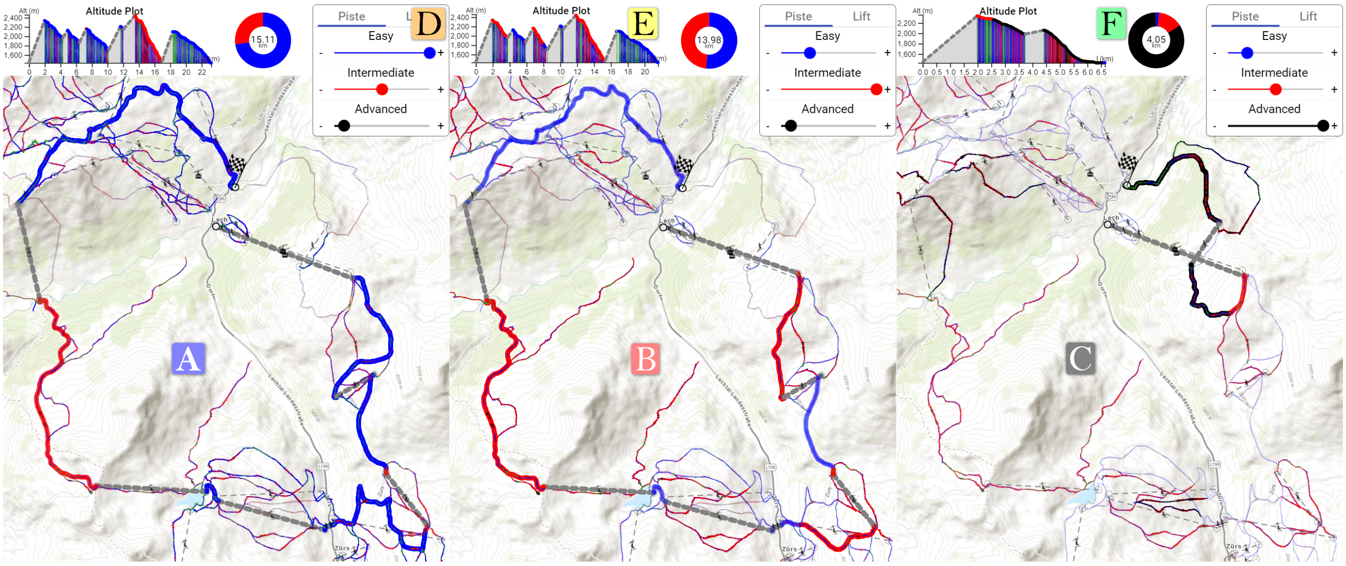


**Figure 1:** *Different suggested routes tailored to user preferences (easy A, intermediate B, or advanced C) for the same start and end location. Preferences can be set by sliders for both pistes and lifts D, and the route is updated dynamically. The altitude plot E provides information about the difficulty, the steepness, and the change in elevation for complete routes. The piechart F indicates the piste difficulty distribution and the center label displays the route length for each or all difficulty levels. The prototype is accessible at https://poster.skirouting.dbvis.de/.*

**Abstract**

*Ski resorts exhibit a variety of available pistes and lifts, to which every skier has intrinsic preferences. While novices tend to favor easy pistes, experts might opt for more advanced pistes. In large resorts, the vast possibilities render manual, optimized routing according to specific piste and lift preferences extremely tedious. So far, existing visualizations of ski resorts lack these routing capabilities.We present a visual analytics interface that allows the user to find an optimal route between arbitrary locations in a ski resort according to individual personal preferences. Furthermore, we encode steepness information along the pistes to expose segments that deviate from the difficulty classification and thus are incompatible with the given user preferences.*

**CCS Concepts**

• ***Human-centered computing*** → *Geographic Visualization;* • ***Network*** → *Routing;*

## 1. Introduction

Pistes in ski resorts are labeled by a color-coded system indicating difficulty. While region-dependent differences exist, the classification into *easy* ●, *intermediate* ●, and *advanced* ● is applied in most European countries. The *Austrian Standards International* defines a piste color standard depending on steepness [Aus16]. Except for a few piste segments, the steepness may not exceed *25%* for blue and *40%* for red pistes. Due to the nonuniform steepness profile of a mountain's topography, pistes occasionally contain more of such exceptional segments - up to a point where the determined difficulty can be questioned on the basis of the underlying steepness. In these cases, skiers are misguided by the prevailing difficulty classification and might choose a route unsuitable to their preference or expertise. Lifts are also classified in different types, most notably *t-bar*, *chair lift*, *gondola*, and *cable car*, the latter two requiring the skier to unfasten their skis. With the ongoing trend of constructing connection lifts to link neighboring ski resorts, the networks of pistes and lifts are becoming more complex to navigate and can possibly

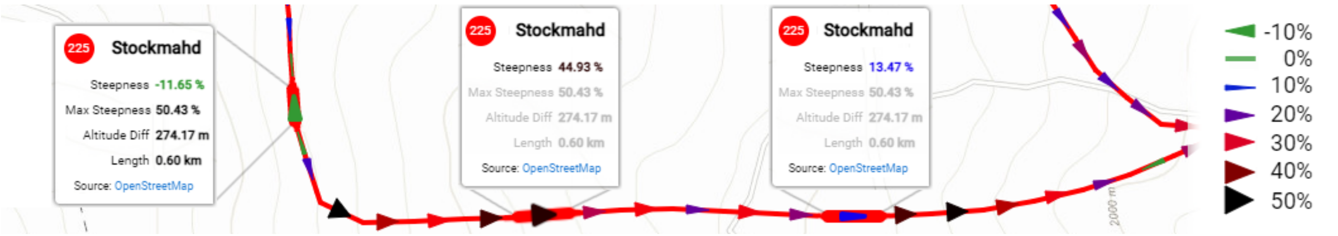


**Figure 2:** *Segment steepness analysis. Even though this piste is classified as intermediate, the overlaid triangles expose an uphill segment (green triangle) as well as steepness values of more than 40% (black triangles). A legend for the triangle steepness is shown on the right.*

overwhelm skiers. While other, similar domains such as bicycle routing already received much attention [Sto12, HZSJ16, SZJH14], routing in ski resorts is a less commonly researched application field, and currently available implementations do not consider user preferences [FHKR21]. Panorama maps are predominantly deployed in ski resorts for visual navigation [Tai10], however, research suggests that the map design is rather influenced by marketing and advertisement objectives than routing purposes [Fie10]. Therefore, the terrain deformation in these maps can introduce misunderstanding and uncertainty [BDM15]. Furthermore, traditional ski maps, even when interactive [Ski22b], suffer from visual flaws such as occlusion, color clutter, or missing indication of piste directions. Similarly, other available map visualizations lack routing capabilities [Por22, FAT22] and piste difficulty information [Bre22, Str22]. The above-mentioned shortcomings of existing ski resort visualizations reveal research opportunities in this field. In this work, we contribute an interactive map visualization that aims to mitigate these drawbacks and is further capable of performing routing between nodes in the network tailored to the preferences of skiers.

## 2. Prototype Design

In contrast to typical ski resort maps, our implementation features a topographic map that is geographically accurate and prevents terrain occlusion. We obtained piste and lift information from OpenStreetMap (OSM), extracted equidistant, 30m length piste segments, and enriched them with elevation information from Amazon Terrain Tiles [Ama22], allowing an altitude difference and steepness calculation. These segments are visualized as lines on the map and colored according to [Aus16], and additionally overlayed by a colored triangle representing the actual steepness of the segment, as displayed in Figure 2. Compared to other simple geometric shapes, triangles allow to indicate route directions, while the opening angle can additionally encode the actual segment steepness in degrees. Thus, easy pistes with small steepness values and little deviation appear smoother, whereas steeper, more difficult pistes have a more rough, uneven appearance. The triangles are colored according to the segment steepness using a continuous color scale loosely based on the introduced difficulty classification, with the addition of coloring values below 5% in *green*, a color used to denote *very easy* pistes in some European countries. Herewith, flat segments and uphill passages are easily detectable. The latter is further emphasized by a 180° rotation of the triangle against the route direction. For an easy visual distinction from the pistes, lifts are visualized as dashed, gray lines including a juxtaposed icon indicating their lift type.
Routing based on Dijkstra's algorithm can be performed by selecting a circular marker placed at every lift station. The preference values for all piste and lift types can be set using sliders, directly influencing both the cost of the route and the opacity of the corresponding objects on the map. The calculated, preference-optimized route is emphasized through an increased width and updates when a preference change occurs. Aside from the map visualization, the prototype provides additional information about the current route, such as the start and end location, the altitude difference, and the total distance in kilometers. Furthermore, a *slope distribution pie chart* that is augmented with the total length of the computed route and an *altitude plot* as illustrated in Figure 1 are included. The upper line in the *altitude plot* indicates the discrete difficulty classification, whereas the area below encodes the steepness for each segment according to the aforementioned continuous color scale, enabling a direct visual comparison and hence exposing discrepant sections.

## 3. Use Case

To demonstrate the prototype's capabilities, we selected the region of *Ski Arlberg*, being the largest ski resort in Austria with a total of 88 lifts and a piste length of 302 kilometers [Ski22a]. Figure 1 shows an exemplary route calculation from *Rüfikopfbahn* to *Schlosskopfbahn* in *Lech*. Even though these lifts are merely separated by 650 meters, the prototype is not capable of considering walking paths and thus enforces the route on pistes. The shortest, most direct route requires the skier to take an advanced, black piste and is therefore avoided for the easy and intermediate option. Given the unidirectional nature of the ski resort, the only alternative is the so-called *White Ring* [Lec22], covering a total of 15.6 kilometers of piste distance for the easy route and transiting the villages *Zürs* and *Zug* respectively before arriving at the *Schlosskopfbahn* back in *Lech*.

## 4. Outlook

For the identification of the most optimal route, the current routing implementation only considers the preferred difficulty of the slope and the lift type from the slider configuration. Since further information such as the steepness, altitude, compass direction, or grooming condition is known, we plan to integrate a multi-objective path optimization approach inspired by [SZJH14] to better tailor the route to the user's preferences. Apart from the capability to navigate between different locations within a ski resort, a closed-loop routing where the start and end locations are identical could be beneficial for planning complete daily routes since usually, every skier returns to the same place he started. This behavior can be modeled as a prize collecting traveling salesman problem (PCTSP) [Bal89].

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