AUTOMATIC PEOPLE DETECTION IN AVALANCHE-CONTROLLED TERRAIN DURING ALL-WEATHER CONDITIONS

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ABSTRACT: Avalanche safety management in release zones, avalanche paths and runout zones is critical for avalanche control work. At the Zermatt-Matterhorn ski resort, avalanche control work has been carried out for many years. Previously, several staff members were deployed to ensure the area was clear of people and guard area access points during control missions. In order to increase public and worker safety and to reduce closure times, we developed a comprehensive area access monitoring system with automatic people detection by radar in real-time. Since 2017, four radars have been continuously monitoring the entry points to the area, which include a ski slope, a road and a hiking trail. The system automatically detects skiers, hikers or cars reliably both day/night and in all-weather. Linked cameras automatically take pictures of detection events that can be used for further information or verification. Access to all detection data, images and camera live views is provided through the secure online data portal via PC, tablet or smartphone. This allows the operator to control the gates and gain a convenient overview of all area entries at any time both in the office and in the field.
The system has been running to the operator's fullest satisfaction and has correctly detected tens of thousands of people since installation.

KEYWORDS: Detection, avalanche control, public avalanche safety.

1. INTRODUCTION

Avalanche control within ski resorts, along transport routes or above settlements requires strict safety management and associated area closures. Closure times should be kept as short as possible and area access should be provided as soon as the area is considered safe. Before artificial avalanche triggering, it is vital to ensure that the avalanche path and runout zone is clear of people. The closure of large (public) areas is challenging and involves closure and guarding of different access ways and user types (e.g. road users, skiers, hikers etc). Additionally, some people tend to ignore closures and enter the zone regardless. To ensure public safety, it is therefore critical to know about the presence of people within and currently entering people into the area.

The ski resort Zermatt-Matterhorn at the famous tourist destination Zermatt in the Swiss Alps, faces this operational challenge. Avalanche control work is carried out at several locations, and includes a section with a ski slope, a road and a hiking trail. The road links the village with the main hydropower plant and hikers, snowshoers and ski tourers use the routes as backcountry access. For many years, the ski field operator performed manual area checks by car, helicopter or on foot prior to avalanche control work. During the missions, guards stationed at the entrance made sure that no one entered the area during control missions. These measures are expensive, labor-intensive or not universally applicable, e.g. helicopter flights are not feasible in bad weather and at night, and physically searching the area may be too dangerous under certain conditions.

In an effort to increase public and operator safety as well as to decrease closure times, we developed a comprehensive area access monitoring system for the ski field operator. The novel system is based on automatic people detection by radar and in real-time at typical area entry points. We present a comprehensive operational monitoring system with real time people detection at the ski field of Zermatt-Matterhorn, using Doppler radars, webcams, alarm functionality and remote-controlled gates, sirens and beacons.

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2. AUTOMATIC DETECTION

Nowadays, various methods for automatic people detection exist, although commonly they are camera-based systems. Conventional cameras lack the option to see in low visibility conditions (bad weather), or at night. While thermal cameras can be used in the dark, they are not suitable in bad weather, particularly during snowfall, as thermal images turn blurry and structures are unrecognizable. In addition, vegetation and rocks in the field of view may interfere with the detection of people. Similar experiences with thermal images were reported by Saurer et al. (2016) who applied infrared radiation thermography (IRT) to identify people in the release zones prior to avalanche control missions.

Unlike camera-based systems, radar works day/night and in bad weather. Radar can see through fog, rain or snowfall and is a reliable tool for diverse purposes. Doppler radars make use of the Doppler-effect and measure the frequency shift of a moving “object”. In natural hazards, several applications of Doppler radars have been reported, e.g. for

- avalanche detection: Doppler radars have been successfully applied for remote avalanche detection in real-time for large areas, including alarm systems for automatic road closures (Meier et al., 2016; Steinkogler et al., 2016)
- rockfall detection: A similar type of Doppler radar was used to detect falling rocks at day/night as well as in all-weather at a notorious rockfall site (Meier et al., 2017).

We present the automatic detection of people with a similar type of Doppler radar as used for the above applications, but with customized detection and analysis algorithms.

2.1 People radar

The Doppler radar is able to detect people, be it skiers, hikers or snowshoers, as well as vehicles, drones or helicopters, in real-time and in all-weather at any time of the day. In this paper, we refer to the detection of a "person" without further distinction, i.e. whether it was a skier or car that entered the area. In a later section, we will deal with the distinction of different detection "objects" and the relevance for the application described here.

Once detected, the radar tracks the person and calculates the person’s position, velocity and direction within its field of view. The maximum detection distance is 1000 m, which amounts to a maximum coverage area of 1 km^2 at a horizontal opening angle of 90° (Geopraevent, 2018).

3. SYSTEM DESCRIPTION

3.1 System setup

We designed a modular system based on detection stations, cloud servers for data processing and an online data portal for data display. The modular system facilitates the option that the system can be easily expanded and upgraded into an alarm system. In principle, the area to be monitored should be permanently monitored for area entrances at four critical points, be it a ski slope, road or hiking trail. In order to test the people detection with the Doppler radar in this setting and to fine-tune our evaluation algorithms, we installed a detection station for winter 2016/17 at Stafel lift station (station d in Fig. 1). The monitoring station consists of a people radar, camera, thermal camera, IR flood lights, data logger and communication device for data transmission.

3.2 System testing and extension

The test period at Stafel lift station was very successful and confirmed that the people detection radar is suitable for this type of application. The radar reliably detected the people on the observed road

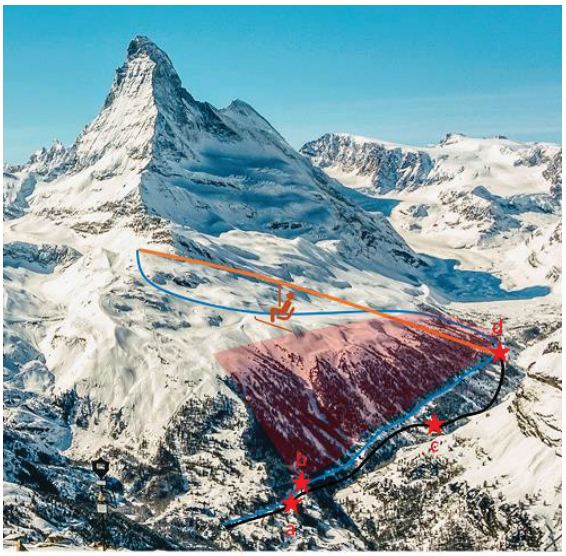

Figure 1: Zermatt’s ski field beneath Matterhorn with the avalanche control area (red), the chair lift (orange), slopes (blue), the road to the hydropower plant (black) and the people detection stations a, b, c & d (stars). The ski field extends to the left in this photo and is not plotted.

section, as confirmed by the camera images. We programmed the radar to trigger the cameras at detection, which then automatically takes a picture (or a series of pictures) of the situation. The camera will do so as long as the radar records a movement of the detected person in the field of view. At night, the system also activates the IR flood light which allows the IR day-night camera to take b/w pictures in the dark. Hence, two types of pictures are generated at each detection event: a color image (at day time) or a b/w image at night as well as a thermal image (at any time). These images have proven very useful for detection verification, where applicable.

In some images, the person detected is difficult or impossible to recognize due to the distance, contrast or visibility conditions (night, weather). The thermal image helped in some cases to provide further information and to locate the person. In bad weather, however, both images could not be used for verification.

As a result of the successful test period, we extended the system with three additional stations including alarm functionality. The stations Bielti ski slope (a), Bielti road (b) and Zmutt hiking trail (c) each consist of a people radar, webcam with IR flood lights, remotely controllable gates, sirens and beacons (Fig. 1).

All stations are self-contained and supplied with grid power. Data is transmitted via optical fiber, and for redundancy, the stations are equipped to transmit data via mobile phone network.

3.3 Alarm functionality

Since people tend to ignore warnings even though they are widely disseminated, we added an active alarm feature. We implemented two gate states: "closure" and "blasting". In contrast to "closure", "blasting" triggers a local alarm if a person is detected despite closed gates. The trespasser is visually and acoustically reminded that their action has been noticed and should encourage them to return.

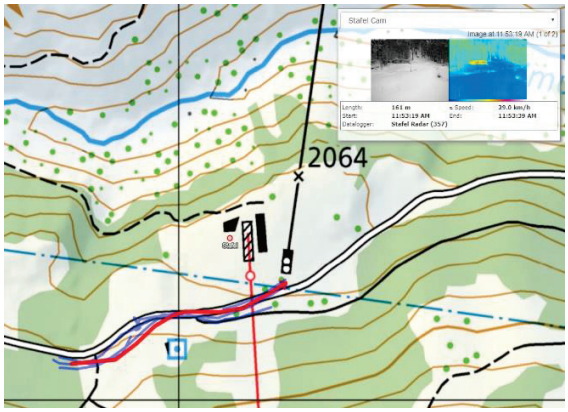

Figure 3: The local area map with detected tracks, day/night camera image, thermal image and additional characteristics of the detection.

3.4 Data portal: overview and map tracker

The individual stations send all data to cloud-servers, where it is processed, validated and visualized in an online data portal. The online data portal is a password-protected platform for authorized users to access any information and control options remotely and at any time. Alarms are processed locally with automatic report to the data portal where they are displayed.

For convenient display of all four stations, we created a uniform view which shows the current station

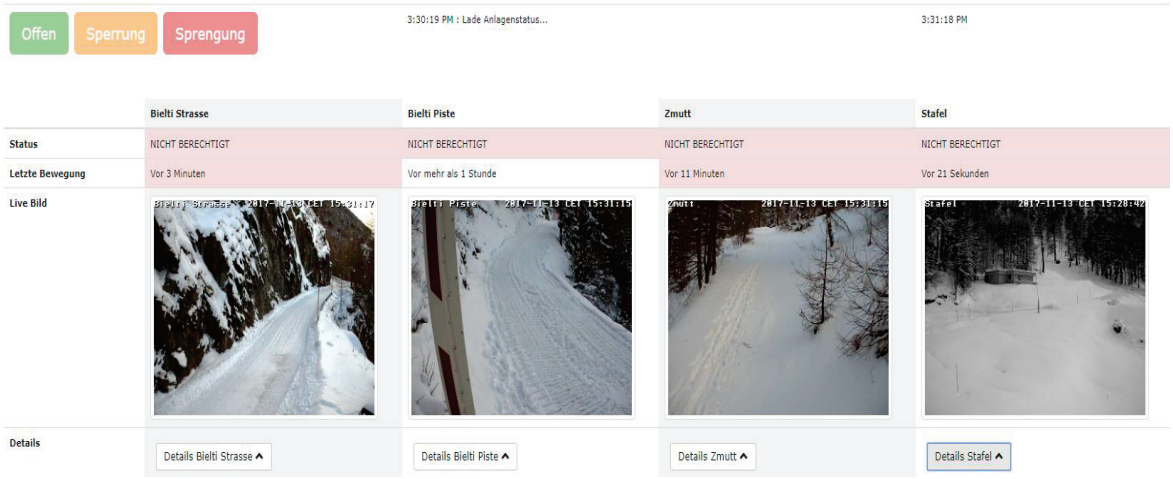

Figure 2: Overview display on the data portal with all four stations and associated status, detection data and camera view. Gate operation is provided via the “details” tab.

status, the last detection and the present camera image for each station (Fig. 2). Authorized users can operate the gates either locally or conveniently by PC, tablet or smartphone via data portal in the station details section. The station overview is visualised in real time, i.e. a detected person is directly visible in the data portal.

Figure 3 shows the map tracker view where real time and archived detection events are displayed alongside with all associated data, e.g. tracks, velocity, direction and the pictures of the day/night camera as well as thermal camera (for the Stafel station). The operator knows where a person has entered the area using the area access history, along with their characteristics to search for the person, if necessary.

4. PRACTICIONER'S EXPERIENCE

The complete system with four operational stations has been in operation since the 2017/18 winter season. This winter was characterized by above-average snowfall and snow depths and caused many (spontaneous) avalanches in the valley of Zermatt. Despite the extreme conditions and associated limitations (e.g. power cuts in Zermatt), the system ran very well and reliably for the most part during this winter. In addition to avalanche control work, the people detection system was also used to close the area at times of high avalanche danger.

Jonas Truffer, Deputy Head of the Search and Rescue (SAR) team Zermatt, is very satisfied with the new people detection system. He says, "the system replaces four workers we previously needed for area checks prior to avalanche control and guarding of entry area points during control operations." He is glad that his employees no longer need to go into the danger zone to make sure it is clear of people. He adds, "this system has allowed us to increase public and worker safety and we have gained an overview of blind spots on the ski slope we did not have before".

Prior to remote controlled avalanche control work, the team members on duty check the data portal for detection data and associated images to find out whether anyone is in the target area. Jonas Truffer points out that the system is very user-friendly via smartphone; the gates can be closed with one click and the camera images provide an insight into the situation on site at any time.

Since the extended system went into operation in November 2017, the system has performed tens of thousands of detections, primarily of skiers, hikers, ski tourers, snowshoers, cars and cyclists. At night though, the system also detected animals, such as mountain hares, foxes and deer. According to the system operators, they do not mind this fact, as the camera images quickly provide information about the detected "object". Automatic distinction between humans and animals is not necessarily trivial, however, we believe it could be improved by masking objects with a small radar cross section that leads to a reduced signal amplitude.

CONCLUSIONS

This paper describes the first automatic people detection system for access monitoring to a critical avalanche area within a ski field. The comprehensive detection system made a major contribution to increase public and worker safety in this area and significantly facilitates the work of the avalanche control and SAR team of Zermatt. With tens of thousands of detections, the people radar has demonstrated that it functions correctly and reliably at any time of the day/night as well as in all-weather. The online data portal provides user access to detection data (images, tracks, direction, characteristics) in real-time as well as live images of all stations conveniently via PC, tablet or smartphone.

CONFLICT OF INTEREST

At Geopraevent we develop, install and run alarm and warning systems for natural hazards. This study was supported financially by the ski field operator Zermatt Bergbahnen AG and the Municipality of Zermatt. Hardware and software design as well as some algorithms were developed, tested and partly funded by Geopraevent Ltd.

As supplier of people detection solutions, we would like to point out that we work solely for the protection of people from natural hazards. We repudiate any connection to military actions and do not support any of these, unless they are associated with the protection of people from natural hazards.

DATA PRIVACY

The collected data is only accessible to authorized people on a secure data platform. During times when the skiing area is open, which the radar automatically detects because of the high people frequency, no pictures are saved for privacy reasons. We do not collect any information about the detected person. Data will not be used for commercial purposes and will not be forwarded to any third party. Data is automatically deleted after three months.

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