

Skiables: Towards a Wearable System Mounted on a Ski Boot for Measuring Slope Conditions

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ABSTRACT

Winter sports like skiing are becoming increasingly popular for both competitive and recreational activities. To minimize the risk of injury, new innovations in skiing equipment have been developed in recent years. However, unexpected slope conditions can still increase risks during skiing. The static categorisation of ski slopes in winter sports resorts does not take into account dynamic changes of difficulty due to high traffic volumes or sudden weather changes. Up to now, efforts have been made to measure the current conditions via satellite imaging or installations on the slope. However, this requires intervention in nature and causes high maintenance costs. To solve these issues we present our preliminary design of a wearable system to let skiers implicitly measure current slope conditions during their skiing experience. Audio and motion data are recorded from a prototype mounted on a ski boot. We show that the data generated by the prototype can be successfully classified with a neural network. We collected data from a skiing activity to demonstrate our concept and discuss the identified challenges in fitting the proposed approach to winter sports equipment.

CCS CONCEPTS

• **Human-centered computing** → *Ubiquitous and mobile computing*.

KEYWORDS

wearable computing, sports, ground classification, skiing

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1 INTRODUCTION

Winter sports have become popular physical activities. The rising number of ski resort visitors by 2019 also resulted in an increasing

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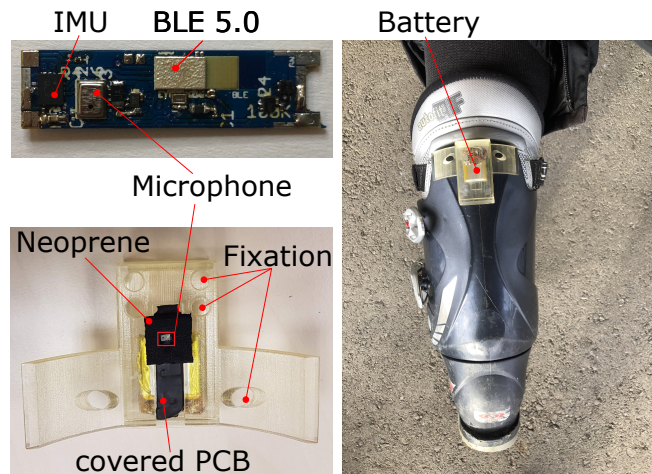


Figure 1: Sensor mounting position and PCB. The vertical mounting prevents meltwater or snow from accumulating in the sensor system. It can be universally attached to any ski boot and does not influence the skiing behavior.

number of beginner skiers [11]. Nevertheless, advances in equipment standards and modernization of ski resorts reduced the number of injuries on the slopes since 1970 [3]. A reason for injuries are underestimated or unexpected slope conditions caused by weather changes or high traffic volumes [1]. An adaptive map that always shows the current slope conditions could help to enhance skiing safety and customize personal route selections also in combination with AR glasses [4].

A continuous monitoring of slope conditions is challenging. So far, winter resorts use static slope difficulty levels, webcams, and weather reports to support skiers' decisions on route selections. Also micro-sensor networks have been deployed in winter resorts, e.g. to measure the effects of global warming or to analyze the avalanche hazard [5, 6, 10, 12]. To determine the dynamic properties of the slopes, many nodes would have to be installed and maintained. Information can also be extracted from time-discrete satellite images [7] or webcams, and drones. However, these cannot provide reliable images in all weather conditions. We present the design of a wearable for letting skiers automatically measure slope conditions. Our prototype, *Skiable*, is mounted on a ski boot and measures audio and motion data to classify the main seven different slope conditions.

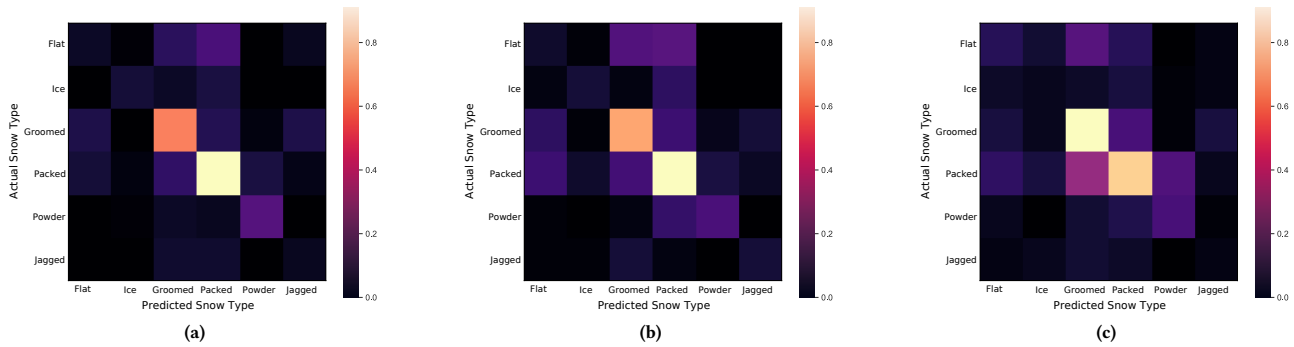


Figure 2: Figure (a) depicts the confusion matrix for the model that was trained with audio and motion data. Figure (b) shows the confusions on audio measurements and Figure (c) visualizes the results when only motion data are applied.

2 SKIABLE

We decided to place our sensory system on the back of the ski boot as shown in Figure 1 on the right. This position is making the sensor unit concealed by the skier’s trousers as well as discreet and protected from external influences. The holes in the housing are used to fixate the prototype with elastic cord. The 8×30 mm PCB consists of a 6-DOF IMU (BMI160) and a low-noise analog microphone (MM034202-1) to measure the features of snow. Similar sensor combinations showed promising results in previous research [9]. The measurements are transmitted via Bluetooth 5.0 (NRF52832) to a smartphone for data collection. We achieve a maximum transmission rate of 15 kHz for audio and 1 kHz for motion on a Huawei P30 smartphone. The 150 mAh lithium-ion battery can power the device continuously for more than twelve hours. To prevent short circuits caused by melting water the entire PCB is coated with a rubber enclosure. The contact microphone is cut out and protected against environmental noise, voices and wind by a 3 mm thick neoprene cover. When mounted, the microphone is pressed onto the ski boot. Thus, sound waves produced by snow frictions can propagate through the ski via the boot to the microphone. In Figure 1 on the left, sensor positions on the PCB are shown in detail.

3 PRELIMINARY TESTS

We made first experiments at the skiing resort “Hoher Ifen” in Kleinwalsertal, Austria on February 18, 2020. Mixed, but mainly sunny weather conditions with temperatures around 0°C (32°F) and a high number of visitors gave us a high diversity of slope conditions. The preliminary results were recorded by two experimenters over a half-day skiing activity. The first experimenter with multiple years of skiing experience attached the Skiable at his ski boot (cf., Figure 1). After connecting a Huawei P30 smartphone to the prototype via Bluetooth, the smartphone was placed in the experimenter’s backpack. Besides audio, gyroscope and accelerometer data, the GPS positions and timestamps were recorded on the phone as well, as on a GoPro action camera mounted on the chest. The camera was aligned so that the snow between and at the ski was recorded. The experimenter rode at normal pace. A second experimenter followed the skier all the time and both discussed and noted down the slope conditions after each run. In total, 45 minutes of skiing were

recorded. The slopes were categorized in flat, ice, groomed, packed, power and jagged snow. The classes were inspired by Müller’s categorization to distinguish biomechanical characteristics in swinging techniques during alpine skiing [8].

4 RESULTS

To classify the recorded data we utilized a deep learning model that we implemented in Python using Keras [2]. It consists of a “Conv1D” input layer with 32 filters, a kernel size of 8, a stride of 1 and the “ReLU” activation function. It is followed by two “LSTM” layers with 64 and 32 units respectively, before reaching the “Dense” output layer with 6 units. We used an “Adam” optimizer with a learning rate of 0.001 and trained 1000 epochs.

The results are shown in Figure 2. The collected video material was used for labelling purposes. We tested differed structures including convolutional layers, spectral data, low-pass filtered sensor measurements, fast Fourier data as well as deeper structures including regularization layers and dropout. The best performance was reached by training the model with raw audio and motion data reaching 0.54 %, whilst the last epoch’s model resulted in an accuracy of 0.50 %. When training the same architecture only with audio data, the model scored a peak accuracy of 49 % while only motion data achieved 44 %.

5 CONCLUSION

This work presented a novel concept of wearables for skiing to increase the user experience and to support ski resort operators. We believe that slope measurements will be increasingly important in the future with the growing impact of global warming. Preliminary tests showed patterns in groomed, packed and powder snow. Due to the limited and unbalanced dataset, we assume that more data must be collected to achieve high accuracies. Furthermore, different and deeper architectures and further preprocessing steps should be tested. Then, in subsequent user studies, the influence of skiers’ route selection and the user experience can be examined. Furthermore it has to be verified if users are willing to share their measured data with resort operators. It must also be clarified how slope conditions can be displayed on maps and whether these information could create swarm effects among skiers.

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