Real-time Snowboard Training System

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Abstract
We present a wireless prototype system for real-time snowboard training. This system can be used to detect common mistakes during snowboarding and to give students immediate feedback on how to correct their mistakes. The project illustrates new ways to assist students during sports training and to enhance their learning experience on the slope.

Keywords
Snowboarding, wearable computing, wireless sensor system, improving sports performance, real-time feedback

ACM Classification Keywords
C.3 [Special-purpose and application-based systems]: Real-time and embedded systems; H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces---Haptic I/O, Voice I/O

Introduction
Learning new sports techniques is often difficult and time consuming. Students need to practice for a long time until they can perform the necessary techniques of a sports domain correctly. In snowboarding, skiing, or surfing, students often receive feedback from their instructor only after they have performed an exercise. Instant feedback from an instructor is less feasible because of the spatial and temporal nature of these sports (Figure 1).

Due to spatial separation on the slope, a snowboarding instructor oftentimes cannot talk to students when they perform exercises incorrectly. Delayed feedback on how to correct and to improve incorrect movements might slow down the trainee's learning pace and increase frustration. This situation is in stark contrast to sports such as tennis, where the instructor can provide real-time feedback and may even physically guide the trainee's arm to demonstrate a correct stroke.

We present a prototype that uses sensors attached to the human body and inserted into the boots that detects mistakes during snowboarding. The system is intended to provide immediate audible or tactile feedback to alert users to incorrect movements and body positions.

Snowboarding instructors can use this system as a tool to automatically supervise and correct their students' mistakes during instruction. Our approach is especially useful when the spatial separation between the instructor and the student is too great to talk or when the instructor cannot focus all of his attention on the student.

In addition to providing valuable assistance to beginners, the system may also be valuable to experienced snowboarders. On difficult slopes, even experienced riders may have difficulty maintaining proper technique. Our system can provide appropriate feedback and help advanced snowboarders to fine-tune their movements and correct their posture.

Figure 1: Two beginners on the slope. The instructor cannot talk to the students to give them feedback on their mistakes.

Related work

In recent years the miniaturization of sensors and computing devices has led to new ideas and research in the area of pervasive and ubiquitous computing for sports and fitness. Some of this interest stems from improving sports performance for elite athletes[1]. Interest in leisure and entertainment has led to products such as the Nike + iPod[2]. Computing technology can also provide incentives to motivate and support fitness in daily life[3].

Michahelles et al. [4] developed a wired system to collect data of a skier's movements. This system does not provide real-time feedback on the slope but can be used off-line by trainers and skiers who want to analyze their performance in downhill skiing.

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[1] http://www.sesame.ucl.ac.uk

[2] http://www.apple.com/ipod/nike

[3] Workshop on Monitoring, Measuring and Motivating Exercise: Ubiquitous Computing to Support Physical Fitness, Ubicomp 2005

Takahata et al. [5] presented a real-time learning environment that uses audio feedback to teach the correct timing of a single karate punch. Kwon et al. [3] developed a real-time motion training system for taekwondo that combines wireless body sensors with video capture. Kunze et al. [2] conducted an experiment to recognize tai chi movements using body-worn gyroscopes and accelerometers. Chi et al. [1] presented a wearable sensing system to support judges in scoring taekwondo sparring matches. The expressive footwear device by Paradiso et al. [6] maps normal gait to pleasant music and gait defects to less pleasant music in real-time.

Interviews with snowboard instructors

We interviewed six snowboard instructors to understand how they teach and to gain more insight into the most common mistakes in snowboarding.

The instructors confirmed our initial assumptions that they cannot observe all students at the same time on the slope and that it is often impossible to give a student instant feedback during an exercise. A student receives immediate feedback only in few cases, for example, when the instructor slowly rides besides a beginner during the first lessons.

The instructors also pointed out that many beginners do not perceive or do not react to immediate feedback while they perform an exercise. Beginners are usually too focused on keeping their balance. This suggested that our system might be more useful for students who already have some experience in snowboarding or for advanced and experienced riders who want to improve their skills.

In summary, all of the interviewed instructors stated that our system could be useful for both instructors and students to improve their skills. They imagined using our system themselves to fine-tune their own movements as well as using the system in their own courses, allowing advanced students to focus on a particular mistake.

Snowboarding basics and mistakes

We will explain in short the basic terms used in the snowboarding domain and how a rider can move his body on a snowboard.

The rider’s feet are fixed to the snowboard and cannot move independently like in skiing (Figure 2). The front foot is closest to the “nose” of the snowboard. The back foot is closest to “tail” of the snowboard. The rider can move his weight to the front foot or to the back foot, cant the snowboard on the “frontside” edge or on the “backside” edge, bend or stretch the legs, and rotate the upper body around the waist in any direction.

The “neutral position” denotes the correct pose of a rider on the snowboard and can be used as a reference to find mistakes during the ride. In neutral position, the weight is central over the board and distributed equally between both feet. The legs and ankles are flexed. This flex acts as a natural suspension to compensate uneven terrain, for example when riding over bumps in the slope. The shoulders and the hips are in line with the feet’s stance on the snowboard. The head is up and the rider looks towards the riding direction.

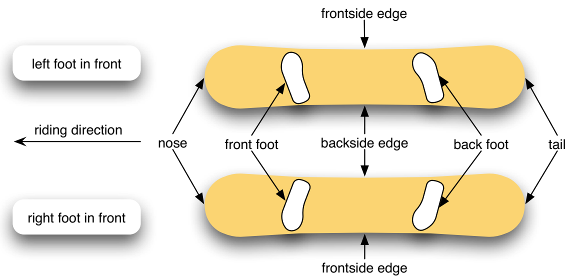

Figure 2: Snowboard stance and terminology

The instructors mentioned three common snowboarding mistakes: Insufficient knee bending, incorrect weight distribution, and incorrect rotation of the upper body. We will briefly summarize these three mistakes.

Insufficient knee bending: Bending the legs helps as a natural suspension to compensate uneven terrain (Figure 3, (a)). Many riders, however, cannot correctly assess if they bend their legs sufficiently or not. They tend to stretch their legs and to bend their upper body downwards from the waist (Figure 3, (b)).

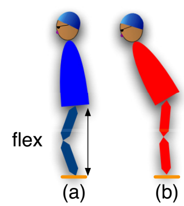

Figure 3: Correct (a) and incorrect (b) knee flexion

Incorrect weight distribution: The rider's weight should be distributed equally between both feet during the ride. But many riders tend to incorrectly lean their upper body towards the tail, especially during a turn. Maintaining correct weight distribution on very steep slopes is difficult even for experienced riders.

Incorrect upper body rotation: The rider's shoulders and the waist should remain in the same plane with the feet's stance during the ride. Yet many riders tend to twist their upper body, which makes it hard to correctly introduce and to perform a turn.

Prototype and implementation

Figure 4 shows our wireless prototype system that senses the rider's motion and posture on the snowboard. We tried to address the three common snowboarding mistakes mentioned above. Our system consists of one Bluetooth Arduino board[4], two Bluetooth Shake SK6 inertial sensor packs[5], two bend sensors and four force-sensitive resistors (FSR). We used a Nokia N70 mobile phone as host device running a Python script to sample sensor data at 20 Hz over the Bluetooth serial port profile. We found no significant overhead in the Bluetooth communication between the sensor boards and the mobile phone.

To address the mistake of insufficient knee flexion, we attached one bend sensor to the back of each knee. The bend sensors measure the amount of knee flexion during the ride. To increase the robustness of the bend sensors, we wrapped each sensor in foam.

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[4] http://www.arduino.cc

[5] http://www.samh-engineering.com

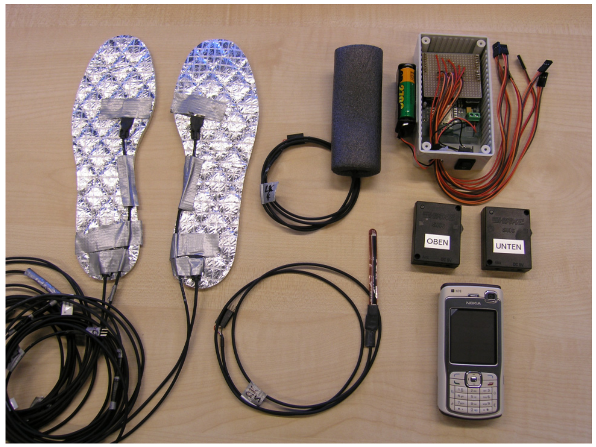

Figure 4: The wireless prototype to sense the rider's motions on the snowboard.

To address the mistake of incorrect weight distribution on the snowboard and to detect if a student rides on the frontside edge or on the backside edge, we inserted two FSRs in each boot. The FSRs measure the amount of force applied by the foot. We placed one FSR sensor under the ball of the foot and one FSR sensor under the heel.

To address the mistake of incorrect upper body rotation we used the digital compass algorithm of the Shake devices to measure the rotation of the rider's upper body relative to the rotation of the snowboard. We attached one Shake device to the lower front leg and another Shake device to the upper body of the rider with hook and loop fasteners.

Pilot study

To test whether our system can sense the most common snowboarding mistakes mentioned above, we conducted a pilot study in an indoor winter sport resort with three snowboarders at advanced beginner level. All three subjects had enough experience to ride down the slope safely. We captured the subjects on video and simultaneously recorded the sensor data using the mobile device.

Before the descent all subjects were instructed to pose on the snowboard in neutral position. The sensor values that we captured in this position serve as a reference to detect mistakes during the descent.

Each subject descended the same part of the slope three times. The distance between the starting point on the slope and the camera was about 60 meters. We chose this distance to simulate a setting that is similar to what snowboard instructors typically observe during courses on the slopes.

To maintain the Bluetooth connection between the sensor boards and the mobile phone, all subjects carried the mobile phone in their pocket during the descent. We experienced no data loss or connection problem during the study.

The off-line analysis of the sensor recordings revealed that it is possible to detect insufficient knee bending and to estimate the weight distribution on the snowboard in real-time merely by using thresholds. For example, the bend sensors revealed that all of our subjects did not flex their legs as much as they did in neutral position before the descent. The necessary software for real-time mistake detection can conveniently run either on the mobile phone or on the microprocessor of the Bluetooth Arduino board. We also found that acceleration during the ride influenced the compass measurements of the Shake devices, thus making it difficult to reliably detect incorrect rotation of the upper body only with a digital compass.

Instructors' opinions

Following our pilot tests, we presented our prototype system for real-time error recognition and the results of our pilot study to eleven snowboard instructors and 28 ski instructors who participated an advanced training course for instructors. One of the snowboarders and three of the skiers were professional instructors who led the course.

The majority of the snowboard instructors (73%) and ski instructors (68%) considered our idea to provide real-time feedback via our system during snowboard and ski training to be potentially very valuable. The other participants mainly questioned whether an automatic system could correctly recognize mistakes during the ride. They argued that without detailed knowledge about the slope it is impossible to distinguish between correct and incorrect movements. For example, in some cases, an instructor needs to see the gradient of the slope in order to assess if a student bends his legs sufficiently or not. While this objection is valid for a subset of all possible mistakes, our prototype system might still be used to detect an incorrect posture or incorrect movements that are independent of the slope's characteristics.

Future work

We are currently improving our prototype system to make it more robust. We also plan to experiment with alternative sensors and their placement on the body, especially to improve detection of incorrect upper body rotation. We further want to compare different modalities to provide real-time feedback for snowboarders. Although audible feedback is straightforward and natural, the noisy environment may make it less useful. The tactile channel could be an alternative way to provide instructions. We ultimately want to investigate how to design patterns of tactile feedback that riders can easily interpret and react to and how real-time error detection and feedback affects the snowboarding and learning experience.

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