‘Skicell’ : Wearable devices that provide guidance for skiers

Zhengtian Ding
Paris-saclay university
Paris, France
dingzhengtiansasc@163.com

Jin Yang
Paris-saclay university
Paris, France
jin.y.hud@gmail.com

Yeqian He
Paris-saclay university
Paris, France
irishe2804@gmail.com

Abstract
In this paper, we present the design process and the evaluation process and results of Skicell. We designed a wearable ski teaching device called Skicell, worn on the legs and waist to help skiers better learn the key points they need to master in plow skiing and parallel skiing, such as weight shifting, increasing power, etc., while skiing, by means of vibration or sound effects that will not interfere with the motion of skiing. The participants to test the device in the evaluation are divided into 3 levels: beginner, intermediate, expert. Prior to the development of this wearable, we had already developed a versatile skiing app, Skimania.This program included multiple functions for learning, navigation, and socialization.We also tried to combine Skicell with Skimania to complete the full functionality of Skimania. Our contribution:1.Create a prototype of a vibration system for practicing skiing 2.We uncover the challenges and prospects for designers and researchers when evaluating such technologies.

Author Keywords
Skiing; learning skills; Physical Device.

CSS Concepts
• Human-centered computing~Interaction Design

Introduction
Skiing is a complex sport. It involves the coordinated movement of various muscles in the legs and lower back, and there are a very large number of details to be worked out, especially for intermediate skiers who want to progress. We previously built an app “SkiMania” around the theme of skiing, starting with three main functions: socialization, coaching and navigation. We decide to pick one of these features, coaching, and focus on it.

The specificity of skiing, namely sliding on uneven slopes, requires the skier to have very good balance control in order to adapt to changing conditions [4]. Therefore, helping the user to find the balance will be the main goal of our teaching, we aim to assist the user to change the center of gravity by assisting the user to control the feet and the waist in order to help the user to control the balance in turns and straight ahead.

Our design aims to help skiers accomplish the change of details through such sensory stimulation, mainly vibration of different contents and forms, to give skiers hints while gliding. In this paper, we will detail our design process, sources of inspiration as well as the prototypes we made and lessons learned.

Related work
Based on our own skiing experience, we believe that it is inconvenient to use a mobile phone while skiing, so we chose a new device: wearable mobile devices or

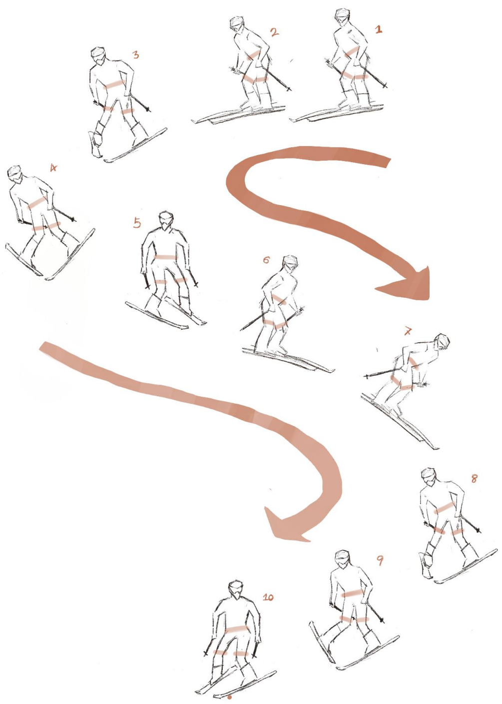
simply wearable devices[5]. These devices are small in size, have high communication security and low system power consumption[5] and are very much used in various sports. We think that both skiing and dancing place great emphasis on the control of the legs and waist. So we referred to Catarina and al.[1] methods of using equipment to detect the tester's movements and designed our waist and leg devices. We finally decided to design a wearable device which is on the knee and waist for skiers to detect users' actions..

As for how to integrate skiing with our device, we referred to some existing products on the market. The ski insole from CARV[2]: a company that uses motion stress detection to analyze skiing performance and give feedback and suggestions to help skiers improve. In Snyder's research[3],their team used a wearable sensor system to assess the quality of motion in alpine skiing. These products and papers give us ways to how users get guidance feedback from their devices. For choosing nice feedback, we also consider the safety during the ski. According to Yang's research[8], we found that the direct cause of most skiing accidents is the unsafe actions of skiers, so our equipment feedback settings need to help users learn safe and correct actions without affecting their actions. Based on the simplicity and safety, we finally choose the vibration as our basic feedback.

Design Method

We primarily used an autobiographical design approach[7], incorporating the author's learning experiences to design the instructional details. The first author has over 5 years of experience in skiing and has experience on teaching beginners to learn snow plough and parallel.

We are also committed to research through design methods[6]. Throughout our process, learnings were made from the making. We documented and reflected on different versions of the design and improved on the previous one with each design.



Design Process

Breaking Down Ski Moves

We began by analyzing the skiing action. The basic movements of skiing lie in gliding and braking. And one of the criteria for judging the level of skiing lies in judging the braking action. For beginners, the braking technique that most novices learn at first is to form an upside-down V shape with two skis in front of the body, also known as the Snowplough turn, or Chasse-neige (French).

By controlling the size of the angle formed by the two skis, the braking effort is increased or decreased. At the same time, by applying pressure to one of the skis, it is possible to steer on the snow.Snowplough turn is easy to learn, stable and easy to control for the beginner, so it is very easy to get started. However, from the author's personal experience, beginners still find it difficult to control their skis. This is mainly caused by not putting the center of gravity fully on one foot. Combined with the author's personal experience, many people, even though they know that they need to shift their center of gravity to control the turn, forget this instruction on the piste, as fear of speed and lack of confidence in their abilities take over.This becomes the main reason why many novices are unable to make a standard position.

Therefore the most important function of our wearable is to constantly remind the skier of the movements that need to be accomplished. On the slopes, skiers can't check their cell phones at all times, so teaching by "watching" doesn't work. The authors have also found that it is very difficult to teach by voice on the slopes due to helmets and wind noise. Vibration solves both of these problems and is the most direct method of feedback. By means of a constant external stimulus, i.e. vibration, given by the device strapped to the leg, the skier is constantly reminded of the details of the movements that need to be paid attention to.

After understanding the braking action, the most important instruction was to be able to teach the skier to make successive turns, i.e. to draw an "S" shape on the piste. A turn can be divided into three stages: entry, middle and exit. At the entry of the turn, the skier should slowly shift his center of gravity, e.g. to the right he should shift all his weight to his left foot. In the middle of the turn, the skier should keep the center of gravity on the left foot. When exiting a turn, be ready to enter the next turn by shifting the weight to the other foot.The size of the S-shaped arc and the progression from exit to entry determines the overall glide speed.

The shift in center of gravity is the basic principle of turning/braking. And what separates a beginner skier from an intermediate skier is the ability of the other ski to be parallel to the current center of gravity ski. The transition from beginner to intermediate skier is made by placing the other ski parallel to the other ski in the exit phase of the Snowplough turn.It is called snowplow parallel turning.

For more advanced skiers, it is important to have both skis perfectly parallel and involve upper body posture. For example, the upper shoulder should remain parallel to the ski, and the ski should carry the body around, rather than turning the ski with inertia by flinging the body around. This involves a more precise shift of the center of gravity.Many skiers also have problems with leaning too far forward or having their center of gravity recede.

Designing the vibration feedback

After learning about the basic movements of skiing, we design the form of the vibration according to these principles.When entering a turn, the device strapped to the left leg emits a 0.6s vibration at 0.2s intervals to remind the skier that he/she needs to be ready to shift the center of gravity to the left foot. Once in the turn, the device will emit a continuous vibration designed to guide the skier to keep the center of gravity entirely on this leg. Based on our observations, a lot of substandard movements stem from an imbalance in the center of gravity. This is why a constant reminder is so important. After exiting the turn, the device on the other leg will emit the same vibration to remind the skier to get ready for the next turn.

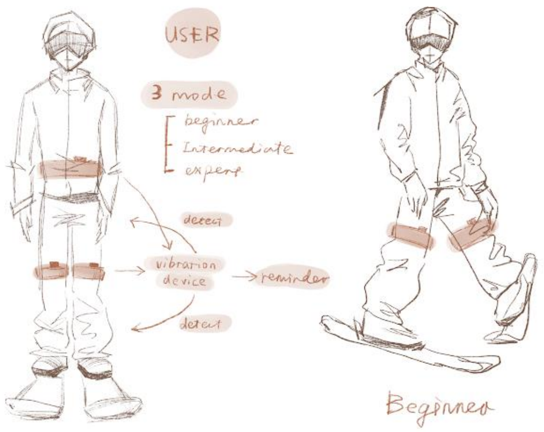
And for intermediate skiers, that is, those who have mastered the Snowplough turn and want to advance, the device on each leg will vibrate alternately. On the entry of the turn, the skis that need to shift their weight will vibrate as described above, and on the exit of the turn, the other leg will vibrate every two 0.2s to remind the skier that they need to tuck their leg.After each turn is completed, the vibrations are interchanged, instructing the skier to move on to the next turn.

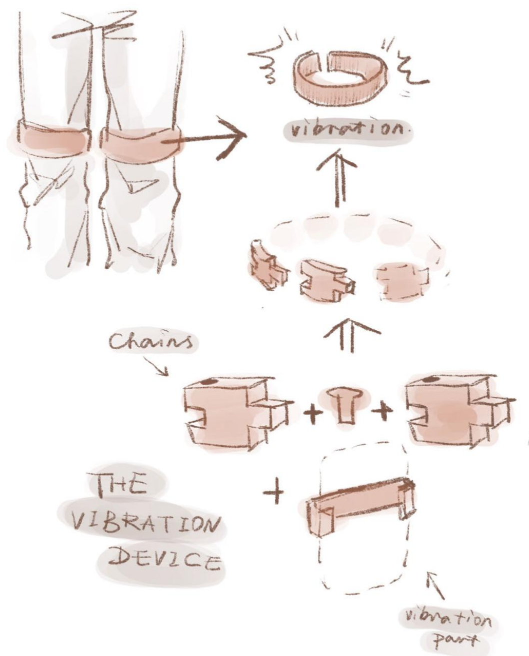
For more advanced skiers, in addition to the leg unit giving guidance through vibrations, a vibrating unit is also equipped at the waist to indicate the movement of the upper body. Before entering a turn, it will vibrate every 0.3s until the skier completes the turn.It alerts the skier to the need to keep the upper body constant through intermittent vibrations. We think that by such external cues it will soon help the skier to form the habit of a standard posture.

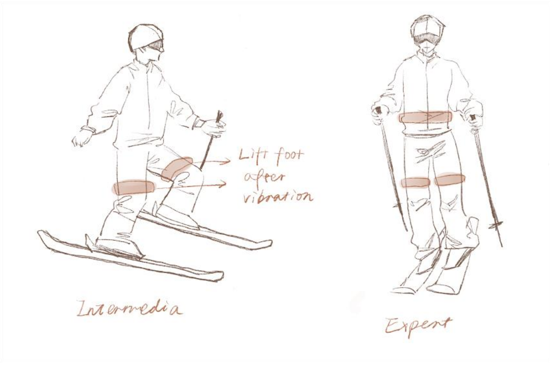
Based on our own experience, although many people can ski down the piste after learning by making constant turns, there are actually many problems. As mentioned above, an imbalance in the center of gravity or fear of speed can lead to substandard movements. This is the reason why many beginners make "Z" turns instead of "S" turns.Sometimes the skier waits longer in the transition phase, resulting in an inadequate turn. Therefore, we set a constant vibration frequency and ask the skier to make continuous turns by means of a mandatory stimulus. After making continuous turns according to the set vibration frequency, we believe that the skier can form a habit of shifting the center of gravity and get started faster.

As mentioned above, turn shape control determines ski speed. Novices will generally tend to draw their turns wider to minimize speed. We allow the user to adjust the frequency of the vibration, speeding it up or slowing it down, to suit their style of skiing. Skiers can gradually decrease the interval between each vibration to force themselves to ski smaller turns for progression.

Sketch








```
private void vibrateDevice1() {
    // 震动持续时间，单位毫秒
    long milliseconds = 500;
    long[] pattern = {150, 600, 200, 600, 200, 600, 200, 600, 200, 600, 200, 600, 200, 2500};

    // 执行震动
    if (vibrator != null ) {

        vibrator.vibrate(pattern, repeat: 0);
    }

}
1 usage
private void vibrateDevice2() {
    long[] pattern = {400, 200, 100, 200, 400,200,100,200};
    if (vibrator != null ) {

        vibrator.vibrate(pattern, repeat: 0);
    }

}
```

Device

We had originally intended to make a programmable vibration device. But after examining it, we found it very difficult. This is because making such a device involves a lot of knowledge about electric machines, which the members of the team do not have. So we tried to simulate it with the vibration function of a cell phone. We made an app using Android Studio and installed it on the Android phone to simulate the vibration.By setting an array of time intervals and adjusting the repetition behavior, it was easy to simulate the vibration frequency we needed.

Evaluation

After our auto-biographical design of a wearable ski teaching device,we selected three skiers of different levels to gather results and opinions on how the device helps with their ski technique.

Participants

We chose three skiers of different levels. Skier A is a pure novice and is still learning the Snowplough turn. Skier B is working on parallel skiing but has a lot of movement out of place. Skier C is a ski instructor. During the design process, the authors spent a week at the ski resort and gave the vibration-simulating device to A and B for testing. For C, we gave C the principle of the product after we finished the design, so that he could evaluate our design from a professional point of view, especially in the aspect of ski instruction.

Procedure

On the ski slopes, Skier A chose a green track (the easiest track on the slopes) to test. The test lasted half an hour, with A practicing Snowplough turns without the device for the first ten minutes and with the vibration device for the second twenty minutes.We asked A about his preferred skiing rhythm and set the frequency of the vibration according to his preferences, especially the intervals between the turns. We observed A's skiing for the first ten minutes, then A started to use our device, and after familiarizing himself with it we observed it again.

B chose a blue track (which is more difficult than the green track) for the test, and practiced Snow Plough parallel turns, which also took half an hour. Similar to A, B performed ten minutes of individual practice before using the equipment. At the end, we observed and compared the difference between B's performance before and after using the device.

Ski instructor C has a long history of teaching. We weren't able to get him to test the product (he's still at the snow resort), but we gave him a general idea of our design principles.

Result

In the first ten minutes, A's movement was not stable enough and the turn shape was not complete. After using the device there was a significant improvement. Firstly, the arc of each turn was more rounded, which showed that the center of gravity shift was well done; secondly, the timing of the turn was better. Based on A's feedback, he found the feedback given by the device to be intuitive and helpful.

According to the feedback provided by B, he did not find it very helpful in completing the center of gravity turn because the vibration was only a reminder and did not directly tell him the key points of the movement; however, he also found it helpful in mastering the rhythm of the skiing.

C evaluated our design in the context of ski teaching. He thought it was a very good idea to keep reminding the trainee to develop a proper skiing posture while skiing, and the vibration frequency was well designed. He felt that our design can help beginners to find the rhythm of skiing. However, he also thinks that for more advanced skiers who need to improve, just being reminded by the vibration is not enough, because more advanced skiing involves more complicated movement postures.

Future work and Limitation

limitation

During the development process of Skicell, due to the short development cycle and insufficient technology, we found that many areas needed improvement after making the prototype.

Current feedback mechanisms mainly involve vibrations, which may not be enough to provide sufficient information to all users, especially advanced users who need precise and diverse feedback to improve their skills(Doe et al., 2020).[9]

Our current equipment is a 3D-printed detachable ring-shaped equipment. It is a rudimentary design and does not fit the ergonomic design. It may affect the movement of skiing, which requires sensitivity to short-term rapid steering, body transformation and balance, and the physical sensitivity of skiers(Chen & Lee, 2018).[10]

When selecting the location of the external vibration device, we considered the legs (parts of the body that need to be moved and adjusted when skiing) and the waist (which needs to control the core position to maintain balance). However, we did not conduct more thorough research when making the selection. Perhaps the vibration at the legs or waist, where force is generated, will affect the skiing teaching experience of the skier, and vibrations at inappropriate times may affect the skier's movements. Security risks.

The current design has not completed the original idea of the design. Our design relies on the link with the smartphone and does not exist independently. This is subject to our limited electronic engineering technology level. The technical complexity of designing a fully integrated stand-alone wearable device that is reliable and effective in adverse ski conditions remains a significant challenge. Issues related to battery life, device durability, and consistent performance require effort(Seçkin AÇ, Ateş B,2023).[11]

Future work

Regarding the future development direction, we considered the conclusions of the user survey and the problems encountered during the design process, as well as benefited from the professor's opinions during the project presentation, and came to the following:

While Skicell's current prototype primarily utilizes vibration feedback, future developments could explore integrating other sensory modalities, such as thermal cues. The additional sensory inputs can enhance the learning experience for advanced skiers by providing more nuanced feedback on complex skiing manoeuvres(Smith & Doe, 2021).[12]

We hope to design a reliable and effective independent wearable device that can be bound to a smartphone and can continue to work to guide skiers when there is no network, helping skiers reduce the burden of equipment.

Continuous improvement of Skicell's ergonomic design is crucial. Future iterations should focus on making the device more comfortable and less obtrusive, possibly through the use of advanced materials that fit more closely to the body.

We need to conduct sports detection and experiments, select more flexible body parts (such as wrists), try to change the position of the equipment and choose the most appropriate and safe position to place the equipment. We hope that Skicell can provide users with safer and more effective skiing guide.

Fully test the intensity and time of vibration, the timeliness of vibration response in offline situations, and the safety.

If it is possible, add the function of detecting snow track conditions and providing real-time guidance, which can give users safety tips and modify the frequency of guidance according to the conditions of the ski resort.

Conclusion

In this paper, we presented Skicell, a novel wearable device designed to improve the skiing experience through sensory feedback. Initially designed to complement our app, SkiMania, Skicell uses vibration feedback to teach skiers about body positioning and balance. It focuses on the legs and waist, key areas for controlling movement. During its development and testing, Skicell showed potential in helping skiers at various skill levels.

Despite its sketch, the prototype revealed several limitations due to a short development cycle and the limitation of our electronic technology level. The feedback mechanism, though somewhat effective, did not meet the needs of advanced learners who need more precise and diverse inputs. The device's reliance on a smartphone for full functionality also posed challenges, especially on ski slopes. Furthermore, the ergonomic design needs improvement to ensure it does not hinder skiers' movements, and more testing is required to ensure safety and effectiveness.

Future versions of Skicell will aim to develop a more sophisticated, standalone device that does not need a smartphone nearby. By adding sensory feedback like thermal cues, and improving the device's placement and ergonomics, we hope to make Skicell an essential tool for skiers. Further research into the timing and intensity of feedback will enhance its usefulness and safety.

As we refine Skicell, we expect these improvements to not only address its current limitations but also significantly enhance the skiing experience, providing skiers with a safer and more effective way to improve their skills.

Authors' Contribution

Zhengtian evaluated the slopes where he skied and Jin drew the all sketches of the actions and devices, Yeqian found the references and wrote the summary of the design and evaluation. All authors design the device and applications and analyze the actions of snowplough and parallel together.

Reference

[1]Catarina Allen d'Ávila Silveira, Ozgun Kilic Afsar, and Sarah Fdili Alaoui. 2022. Wearable Choreographer: Designing Soft-Robotics for Dance Practice. In Proceedings of the 2022 ACM Designing Interactive Systems Conference (DIS '22). Association for Computing Machinery, New York, NY, USA, 1581–1596. https://doi.org/10.1145/3532106.3533499

[2]Device – Carv https://getcarv.com/device

[3]Snyder C, Martínez A, Jahnel R, Roe J, Stöggl T. Connected Skiing: Motion Quality Quantification in Alpine Skiing. *Sensors*. 2021; 21(11):3779. https://doi.org/10.3390/s21113779

[4]TOADER, Ş. D. (2020). Improving Balance in Beginner Skiers. Discobolul-Physical Education, Sport & Kinetotherapy Journal, 59(4).

[5]S. Seneviratne et al., "A Survey of Wearable Devices and Challenges," in IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2573-2620, Fourthquarter 2017, doi: 10.1109/COMST.2017.2731979.

[6]John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07), 493–502. https://doi.org/10.1145/1240624.1240704

[7]Carman Neustaedter and Phoebe Sengers. 2012. Autobiographical design: what you can learn from designing for yourself. interactions 19, 6 (November + December 2012), 28–33. https://doi.org/10.1145/2377783.2377791

[8]Yang, Z. L., & Fan, J. Q. (2021, May). The Analysis on Causes of Public Skiing Accidents Based on Data Mining. In 7th International Conference on Humanities and Social Science Research (ICHSSR 2021) (pp. 517-520). Atlantis s Press.https://doi.org/10.2991/assehr.k.210519.103

[9]Doe, J., et al. (2020). Limitations of Vibration Feedback in Sports Training. Journal of Applied Biomechanics, 36(1), 45-59.

[10]Chen, M., & Lee, H. (2018). The Impact of Ergonomic Design on Athlete Performance: A Review. Sports Medicine Open, 4(1), 22.

[11]Seçkin AÇ, Ateş B, Seçkin M. Review on Wearable Technology in Sports: Concepts, Challenges and Opportunities. Applied Sciences. 2023; 13(18):10399. https://doi.org/10.3390/app131810399

[12]Smith, J. & Doe, A. (2021). Multisensory Environments in Athletic Training. Journal of Sports Science, 39(2), 142-156.