Skill Scoring System for Ski's Parallel Turns

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Abstract: Dynamic posture of sports activity is one of the most important aspects to evaluate the player's skill. Such sports that need evaluation from the objective observation like figure skating and skiing have difficulty in evaluation of skill. The conventional training method for such sports was the feedback of subjective comments from the experts regarding the performance. To overcome this problem, this paper focuses on developing a new training system to give a clear guide for body balance control to the athlete. The system gives scores and messages for raising up the performance skills. It causes improvement of the dynamic posture. This paper introduces a scoring system focusing on the ski's parallel turn. The system automatically scores skill for body balance control regarding three aspects: the tempo at turns of body balance changes between the right and the left, the distribution of body balance, and the angle between the snow slope and the body of the skier. The system has been implemented in an Android smartphone and evaluated the effects of the scoring functions from the three aspects applying to a middle level skier.

1 INTRODUCTION

The skill level of any sports activity relates to the appearance of performance. If a player performs well, the dynamic posture of his performance should be elegant. However, the player is not able to observe himself from multiple aspects, only observation by the third person can bring the judge of the skill level. In some sports, the judge of the skill level is evaluated by the observation. For example, in figure skating, the player is evaluated by judges according to the appearance of the performance. Moreover, skiing is one of the major sports that evaluates appearance during the performance. The qualification tests mainly in Japan, Canada and New Zealand perform examinations to qualify the level of the ski skill by observing the appearance of the performance ((NONSTOP,)). One of the important performance skills is a smooth parallel turn in a gentle snow slope. A major training method for the parallel turn is to hear comments from high skill trainers who have qualified to the trainer license, or to check movies during gliding in the snow slope and to get the comments from the high skill skiers. Thus, it is impossible to train the parallel turn by the skier himself without any objective comments.

Regarding the ski's parallel turn, there exist several engineering analysis of the dynamic posture. For example, a ski robot (Yoneyama et al., 2006) and a simulation-based quantitative approach (Federolf et al., 2010) were performed. These investigated modeling methods of the dynamic posture of skiing. These are not targeted to use it for training. Moreover, another modeling method for the dynamic posture applying accelerometer, magnetic sensor and GPS was also proposed by (Kondo et al., 2013). Including this method, all those advanced researches did not discuss by what the parallel turn becomes elegance. The skiers aim to acquire the skill that maintains elegant and dynamic posture during the parallel turns.

In this paper, we propose a system called *ski trainer* that provides scoring methods for the performance of ski's parallel turn and also provides how elegance the performance is. How elegant is evaluated by the dynamic posture of skier regarding the tempo, the symmetry and the distribution of body balance. The score is calculated based on the actual accelerometer data and feedbacks advices for directing the next step of the training.

In the next section, this paper describes the background and definitions regarding the skill acquisition process of skiing. Section 3 will propose the ski trainer system discussing the methods to score the dynamic posture. Section 4 will show the evaluation of the system regarding the effects and the validity of the

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system. Finally we will conclude the paper and mention the future plans.

2 BACKGROUNDS AND DEFINITIONS

2.1 Training Methods Using Advanced Devices in Sports

It is a very hard process for an athlete to evaluate self-performance of sports by giving scores if there is no guide for the ideal target performance. It is mandatory for a coach or a trainer or an expert player to give comments to the player from the appearance of the dynamic posture. However, the target direction to change the form or posture should be presented by some absolute standard. The best way is to apply standardized values measured by sensors as the guide to reach the ideal dynamic posture.

Advanced technologies in these days implement internet-based communities using small sensor technologies (so called, MEMS) such as a smartphone that is now including accelerometer, gyro sensors and GPS. For example, Otsuka et. al. implemented a social network system (SNS) that provides a community to encourage runners of jogging by the participants in the system (Otsuka et al., 2011). Using position information from GPS of a runner, the system shows an ideal speed and the actual one of the runner. Nike+ (http://nikeplus.nike.com/), which is available in iPhone in these days, is also the similar system that returns the information of the positions during jogging. Adidas' micoach (http://micoach.adidas.com/) is also another system to guide physical threshold of runner's body. It uses heart beat information to guide physical availability of the runner. However, these system shows only how much wrong or how much different from the ideal target values. Therefore the users of the systems can not know how to improve the skill using the information from the systems.

2.2 Training Methods and Qualification for Skiing

In this paper we focus on skiing. There is a skill qualification in Japan, so called *badge test* organized by SAJ (Ski Association of Japan) (http://www.ski-japan.or.jp/). To pass the qualification examination, skiers need to join in a training course and receive comments from the expert trainers. The qualification is mainly decided by the appearance of the performance. The decision of the qualification depends on observations by a few expert trainers during the examination. Therefore, it is hard to standardize the level of the qualification among different resorts or different snow slopes.

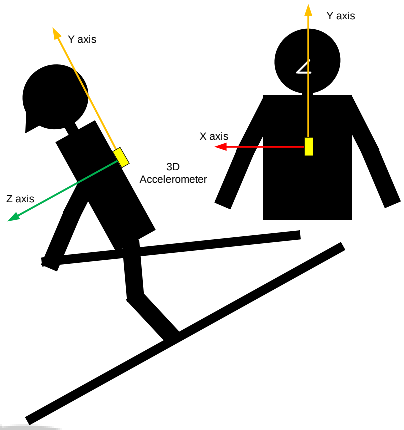


Figure 1: The measurement axis of accelerometer piggy-backed by skier.

In Canada and New Zealand, there are the similar qualification licensing examinations organized by Nonstop (http://www.nonstopsnow.com/). This also causes the same problem as the one of Japan mentioned above.

The training to get good skill for the qualification is mainly to watch the video or to receive comments from the experts. However, it is hard for all skiers to get such guides from experts. Therefore, it is important to implement a system that provides training directions for skiers using absolute values measured from some sensors.

2.3 Discussion

As mentioned above, it is hard for skier by himself to acquire the higher level skill without observing appearance of his performance. Therefore, sensor data brings possibility to train him without any comments from the experts. Such as the systems for jogging discussed above, the similar system is needed for skiing. However, not only sensor grabs the dynamic posture to the skier, but the next step for getting higher skill should be shown by the system. If not, the skier needs the experts' comments again to understand the data from sensors.

In this paper, we will develop a scoring system called *Ski Trainer* based on analyzing data from the skills of experts. Additionally the system will give skier advices to acquire higher skill. The system applies the sensors to acquire the motions of skier and calculates the skill level. Then the system will give the comments to the skier.

We expect the *gamification* effect according to the feedback information from the ski trainer. The skier will try to get higher scores from the system. It promotes the encouragement for the skier to reach higher skill level by showing the score of the current skill and also by giving advices to jump up to the next skill level.

3 SKI TRAINER SYSTEM

3.1 Methods for Scoring

We use an accelerometer to measure performance of skier. We defined the axes of the sensor as shown in Figure 1. We have used data from the accelerometer with three dimensional axis focusing on the three aspects as described below. Here we use 200Hz sampling data for the analysis.

1. Tempo

   When a skier glides in a static tempo, the skier has ability to adapt himself to any snow surface. This means his skill is high if he can follow the tempo. According to this technical aspect, we apply tempo to evaluate the skier's skill.

   When we plot the X axis of the accelerometer values to the vertical axis of a graph as shown in Figure 2, the tempo is calculated by measuring the time distances of crossing points with the horizontal axis of the origin (i.e. X value of accelerometer becomes zero). Let us consider the i-th crossing point $t(i)$ sec. The tempo $T(i)$ is calculated by $(t(i+1)-t(i)) \times 60$ bpm. Here, we apply a threshold condition $T(i) = T + T_H$ when $|T(i) - T| > T_H$ and $T_H \leq T$. This threshold is needed for limiting to the domain of $T(i)$ less than $T + T_H$ because the skier would mistake to turn in a much earlier timing than the target timing. The distribution of the tempo is defined by;

$$\rho = \sqrt{\frac{\sum_{i=0}^{N}\{(T(i)-T)^2\}}{N}} \quad (1)$$

$$M = (\frac{\rho}{T} \times 100) \quad (2)$$

   where $0 < i \leq N$ and T is the target tempo decided by the skier. The score is calculated by $100 - M$. Here, we use $T_H = T$.

   Figure 3 shows an example of calculating $T(i)$ used in the equation above. The upper waves than the horizontal axis of origin show the left side turns. Besides, the lower waves show the right side turns. Figure 3 illustrates the comparison of the tempo graph between a high and a

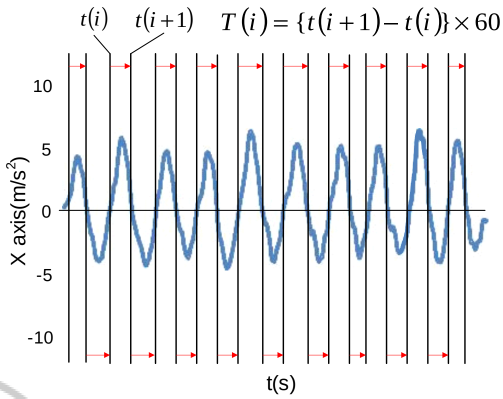


Figure 2: A tempo graph example.

low skill skiers. Figure 3(a) shows the one of a high skill skier with the badge test qualification. Figure 3(b) shows the tempo graph of a low skill skier. Here, each skier defines the target tempo to a suitable one at which he performs parallel turns easily. The high skill skier follows the target tempo, which targets to 60, stably. However, another skier does not follow the target tempo, which targets to 70, at all. Thus, the tempo is one of the important aspects to decide the skill of skier. Using the distribution calculated above, we can represent the score to inform the skier's skill. This means that the skier can know the level with a numerical and absolute value and they can understand what the main target to accomplish is, that is, the skill to glide any slope at a concrete static tempo.

2. Symmetry

   A good balance between the right and the left side during gliding with parallel turn is mandatory for maintaining a good form of skiing. The balance is evaluated by two aspects. One is the ratio of body balance changes between the right and the left sides. We call this the *balance ratio*. Another is the angles of body against the snow slope during turns. We call this the *balance angle*. These are analyzed by the accelerometer's X-Y data mapped to a scatter diagram. Figure 4(a) shows the scatter diagram. The raw data from the accelerometer during parallel turn shapes like a reversed V character. The top of the diagram of Y axis is 9.8 m/s^2, which is 1G. The bottom of it becomes 2G because there does not exist any force from the head to the snow slope more than the gravity as illustrated in Figure 4(a). When we move data to Y direction for 1G (Step 1 in Figure 4(a)) and replace the sign of each Y value of the point (Step2 in Figure 4(a)), it becomes like a V character such

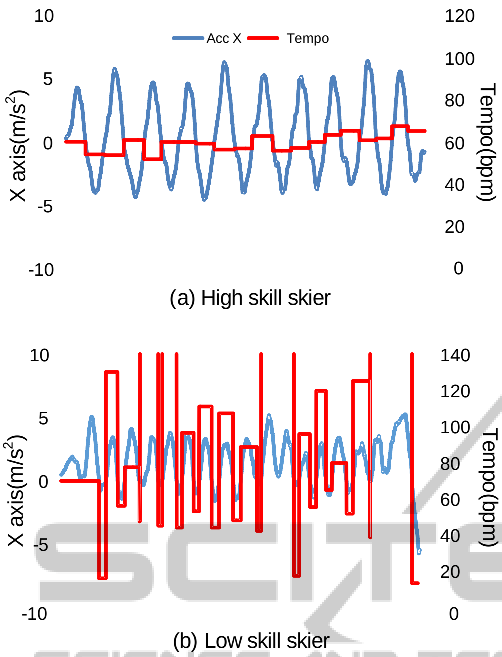


Figure 3: Comparison of tempo between (a) a high skill skier (the upper) and (b) a low skill one (the lower).

as Figure 4 (b). Using this diagram, we decide the scores for the balance ratio and the balance angle. We call this diagram the *symmetry diagram* in this paper.

Regarding the balance ratio, we count the number of points in the diagram separating the right and the left side of the Y axis. If a side of Y axis has a larger number of points, the body balance causes an inclination to the side. If the both sides have the same number of points, it keeps ideal symmetry for the parallel turn that obtains well balance between the right and the left sides of the body. Thus, we score the balance ratio using the equation below;

$$100 - \frac{|L_y - R_y|}{L_y + R_y} \times 100 \qquad (3)$$

where L_y is the number of points in the left side and R_y is the one of the right side of Y axis in the diagram.

On the other hand, the balance angle is calculated by processing an approximated line from the origin of the symmetry diagram of Figure 4(b). How to calculate the line is shown in the APPENDIX section. For example, it shows the lines from the origin of the diagram to the left and the right sides of Y axis as depicted in Figure 4 (b). When the angles of those lines are respectively a_L and a_R,

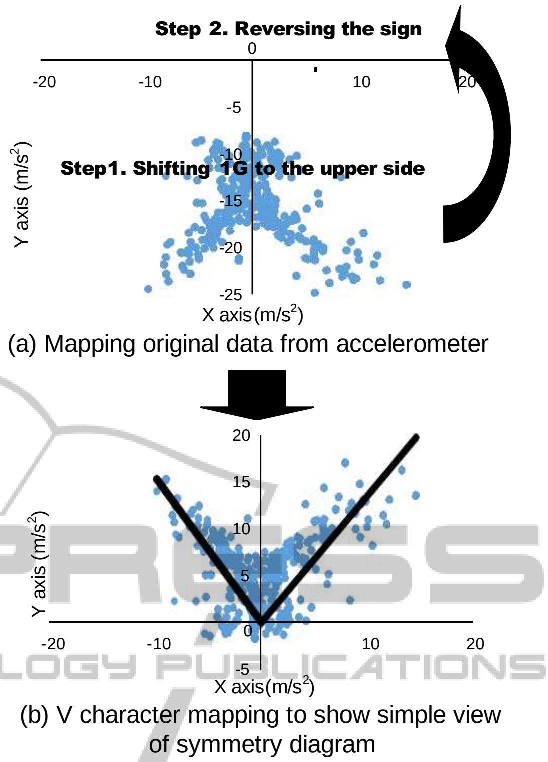


Figure 4: Scatter diagram of a V character mapping X-Y axis of accelerometer data. When we move the data for 1G from the original and reverse the sign of the data regarding Y direction, the shape becomes like a V character.

we calculate the score using the equations below;

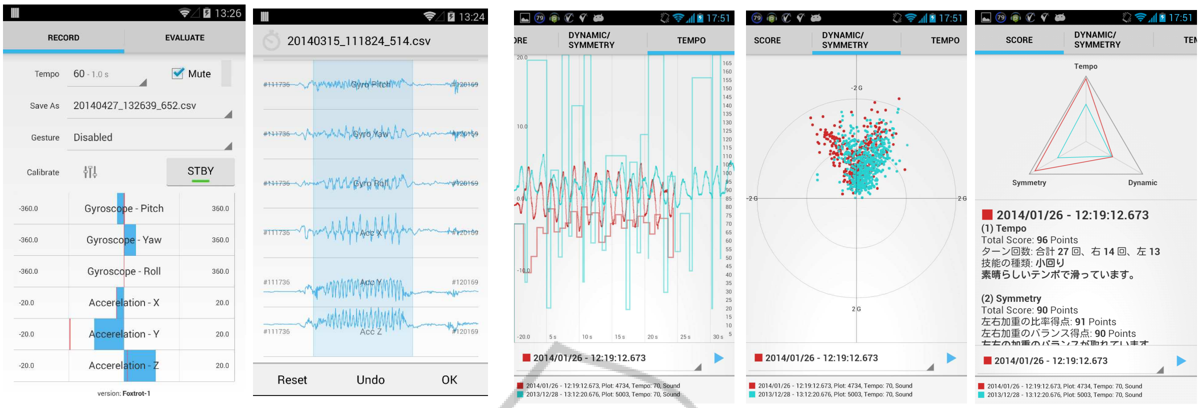
$$100 - 100 \times \left(\frac{|a_L|}{|a_R|} - 1\right), |a_L| \geq |a_R| \qquad (4)$$

$$100 - 100 \times \left(\frac{|a_R|}{|a_L|} - 1\right), |a_L| < |a_R| \qquad (5)$$

If this ratio is more than 100 or less than 50, the score is 0 because it means that the body balance between the right and the left sides varies widely.

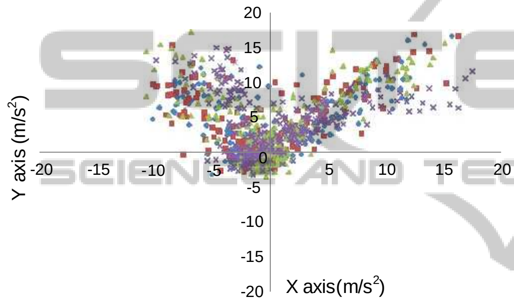
3. Dynamicity

We have experimented with six participants to measure the maximum acceleration to the left and the right side of the body balance. Figure 5(a) shows the symmetry diagram with four time trials of parallel turns performed by a high skill skier. It does not become more than 2G ($9.8\ m/s^2 \times 2 = 19.6 m/s^2$) to the right and the left side. On the other hand, as a comparison, the case of the low skill skier shows that the domain of data between the right and the left sides becomes small as depicted in Figure 5(b). In this case, the appearance of the parallel turns becomes compact and is not elegant. When the acceleration to both

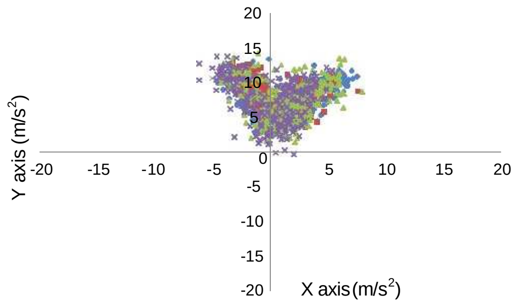


(a) Data recording mode (b) Data selecting (c) Tempo graph (d) Symmetry diagram (e) Score

Figure 6: Screenshots of the ski trainer system implemented on an Android smartphone.



(a) A high skill skier



(b) A low skill skier

Figure 5: Symmetry diagrams of (a) a high skill and (b) a low skill skiers. The force to the right and the left sides never become more than 2G. The data domain in the case of low skill skier becomes small.

sides is maintained largely, the appearance of the parallel turn seems elegant because the angle of the body becomes keen against snow slope and the dynamic body balance is controlled widely. Therefore, we decide the score for the dynamicity to provide a higher score when a larger acceleration is observed from the accelerometer using the equation below;

$$100 - \left(\frac{L_{max} + R_{max}}{2}\right)/19.6 \qquad (6)$$

where the maximum acceleration to the left and the right are L_{max} and R_{max} respectively. This equation calculates an average among L_{max} and R_{max}, and the ratio is calculated by dividing 2G.

Applying the tempo, the symmetry and the dynamicity to the scoring methods, we can evaluate the skier's skill of his parallel turn technique as mentioned above. The tempo shows the ability of the skier if he can adapt himself to the snow surface. The symmetry gives advice to correct skier's turn to obtain it beautiful. The dynamicity brings a factor if he can perform elegant parallel turn.

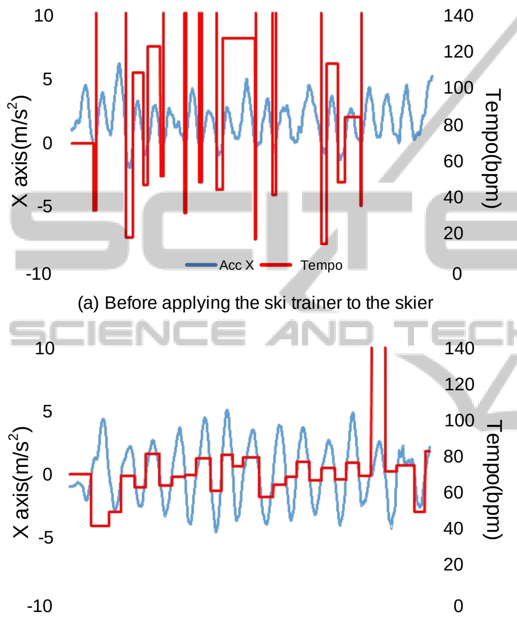
The scoring methods bring a new feature for the training system, which extends the system to output messages used as advices to the skier. We define the messages regarding the scores for the tempo, the symmetry and the dynamicity. When the score of tempo is more than 80, it outputs a message "gliding in a good tempo". If it is less than 40, it outputs "follow the target tempo". When the score of balance angle is 0, it shows a message "inclination is too significant" to the right or the left according to the approximation line in the symmetry diagram. If it is 50 or more, the message "the balance is good" is outputted. When the score of dynamicity is more than 70, it outputs "elegant gliding". If not, it shows "use more side edges to line curves".

Using these three scoring methods and messaging output rules, we implement a system for ski's parallel turn called *Ski Trainer*.

3.2 Implementation

We have implemented the scoring methods discussed above in a smartphone application. The screenshots of the application in an Android smartphone are shown in Figure 6. The application includes the functions below. There are two modes in the application: the *recording mode* and the *analysis mode*. The

Figure 7: Wearing the ski trainer piggybacked by a holster small backpack.



(a) Before applying the ski trainer to the skier

(b) After applying the ski trainer to the skier

Figure 8: Performance comparison regarding the tempo before and after applying the ski trainer.

recording mode saves the accelerometer data to the smartphone. It includes a sound guide function that outputs a target tempo by a metronome sound. The skier performs parallel turn following the sound. Using it as the target tempo, the score for the tempo is calculated.

A screenshot of the recording mode is shown in Figure 6 (a). It includes the accelerometer data and the gyroscope data measured by the sensors equipped in the smartphone. The STBY button starts to record the motion data and saves it in a CSV file stored in the smartphone.

The analysis mode has three steps to show the scores. The first step is to select the interval of the parallel turns as shown in Figure 6(b). This is done by a touch and a drag operation to select the duration of the parallel turns. The ski trainer application has a comparing function among several performances at a time. Therefore, the second step selects data sets

Table 1: Tempo data $T(i)$ before and after applying the ski trainer. The i in the first column corresponds to the sequence number of turns.

i	$T_{before}(i)$	$T_{after}(i)$
1	35	42
2	140	49
3	20	69
...	...	...
23	140	75
...	...	N/A
33	49	N/A
ρ	47.0	9.8
Score	54	90

to evaluate and compare it simultaneously. For example, if a skier wants to compare his performance with the previous ones, this function provides visual comparison methods effectively and he can consider the difference among performances. The final step results the scoring. This has three screens illustrated in Figure 6(c)-(e); tempo, dynamic/symmetry and score, respectively. The tempo screen shows the differences among the target and the actual tempos acquired by performances. The example shows two tempo graphs at a time. The dynamic/symmetry screen shows the symmetry diagram. It represents visually the difference of dynamicity among performances. The score screen shows a triangle where the corners represent the scores of tempo, the symmetry (the average of balance ratio and the balance angle) and the dynamicity respectively. When the score becomes high, the triangle shapes large. The shape of the triangle intuitively informs the skier the lack of skills. The example screen shows the messages in Japanese language mode.

4 EVALUATION

We have asked a middle level skier to use the ski trainer who has 10 year experience of skiing, but who does not have any qualification for any ski licenses. We compare his performance before and after we apply him the ski trainer by comparing twice on two different days. He wear the smartphone in his back as shown in Figure 7 and he heard the target tempo from a noise canceling earphone. Figure 8(a) and Figure 9(a) show the results from the ski trainer on the first trial day of the skier. After considering the messages and graphs outputted from the ski trainer on the second day, his skill level has become higher such as Figure 8(b) and Figure 9(b). It becomes better performance when the score and messages from the ski trainer are applied as advice to him. Let us compare

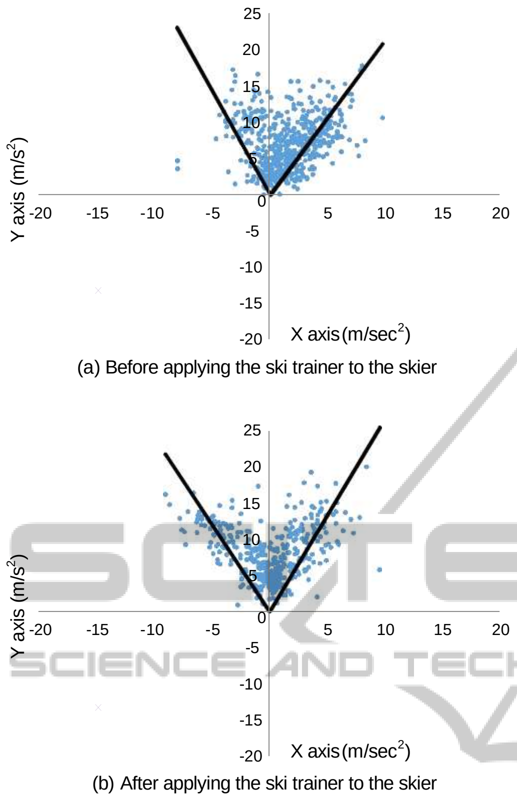


Figure 9: Performance comparison regarding the symmetry/dynamicity before and after applying the ski trainer.

the effect of the ski trainer quantitatively among the tempo, the symmetry and the dynamicity.

- Tempo
  As we can see in Figure 8, the tempo has become stable due to the effort of the skier on the 2nd day. His target tempo is 70. He tried to make the score high following the message from the ski trainer system. Table 1 shows a part of the tempo data calculated from the tempo graph. The score before using the ski trainer was 54. However, he improved his skill to 90. Therefore, we have confirmed that this method provides an effective training to guide the timing related matters of ski's parallel turn. The skier tries to glide any slope by following the target tempo. As the result, the trials raise the skill to turn in any snow environment.

- Symmetry
  Before applying the ski trainer system, the skier tends to use the ski edge in the right side mainly because his dominant leg is the right side. Therefore, the right side of the vertical axis in the symmetry graph of Figure 9(a) includes the larger number of points comparing to the left side. The numbers of the points in the right and the left sides of the vertical axis in the graph are 3658 and 1342 respectively. This result causes the balance ratio a bad result. The score was 54. Moreover, the balance angle shows also inclination to the right side. The angles of the approximation lines are also 2.1 and 2.8 in the right and the left sides of the vertical axis respectively. The score was 67. On the other hand, after the participant skier trained himself to correct his performance referring the symmetry diagram of the ski trainer, the balance between the right and the left side has becomes well. The numbers of the points in the right and the left sides of the vertical axis has become 2597 and 2135 respectively. Additionally, the angles of the approximation lines have become 2.6 and 2.4 for the right and the left sides respectively. Thus, the scores of the balance ratio and the balance angle have become 90 and 92 respectively. According to the observation above, we confirmed that the symmetry diagram provides enough information for considering an inclination to a side, and also it intuitively provides a correct training direction regarding the technique for body balance control.

- Dynamicity
  The symmetry diagram before applying the ski trainer shows that the dynamicity becomes between $9.7m/s^2$ in the right side and $8.0m/s^2$ in the left side. Therefore, the skier's parallel turn has an inclination to the right side, also was very compact (not dynamic). The score of the dynamicity was 45. Due to the score, the symmetry diagram and the messages from the ski trainer, he has become aware of using the both sides of ski edges and has moved his balance largely to the right and the left sides. Then the dynamicity has become $9.4m/s^2$ and $9.0m/s^2$ on the right and the left sides respectively. The score has become 46. Thus, because the acceleration to the side edges has become large according to the advices from the ski trainer, his parallel turn has become more elegant than before although the scores do not change significantly.

As we have discussed in this section, the ski trainer system actually improved a skier's parallel turn. Originally, the training had to be provided by the objective advices from experts by observing appearance of the parallel turn of a trainee skier. On the other hand, our system brought a novel training method by the skier himself using accelerometer data from a smartphone. We also confirmed that the numerical scoring method to the performance, the visual guides and the messages from the tempo graph and the symmetry diagram promotes the self-training. Thus, we conclude that the ski trainer system is effective to training in the ski's parallel turns.

5 CONCLUSIONS

We have designed and implemented a training system using accelerometer on a smartphone for ski's parallel turn. We focused on the tempo, the symmetry and the dynamicity during the parallel turn. Applying the system to a middle level skier, we have a good effect for improving the perspective of his technique. As the next step of this research, we are planning to develop a matching technique to identify the skill level from multiple symmetry diagrams. For example, we will try to match a symmetry diagram to a group of the same diagrams. Then we will design and implement a new system that classifies the skill level to another skier's skill such as an Olympic athlete, and outputs a message such as "Your skill is similar to the gold medalist of this year".

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APPENDIX

The approximation line for the balance angle is calculated using the least squares method. For any accelerometer data of X and Y axis represented by (x_i, y_i) where i is $0 \leq i < N$, we calculate a that makes minimal of;

$$S(a) = \sum (y - ax)^2$$

Because $S'(a) = 0$,

$$\sum xy - a \sum x^2 = 0$$

$$a = \frac{\sum xy}{\sum x^2}$$

The scoring equation for the balance angle uses the data in the right side to calculate a_R and the one of the left side to calculate the a_L. The calculation for the score uses the absolute values of a_R and a_L.