4.2 Reproduction of snow plane using photograph

Assuming that the snow plane is horizontal, the plane apd in Fig. 5 is redrawn in Fig. 6. The angle formed between the line passing through the center of the camera and the center of the photograph and the snow plane is designated as the center angle A_0. The height (distance) H between the snow plane (at the foot of cameraman d) and the camera is measurable. The distance between d and o is designated as L. Designating the distance between o and the front tip and between o and rear tip of the ski as Y_1 and Y_2, respectively, the difference between Y_1 and Y_2 is the length SL of the ski, which is also measurable. If we obtain the positions T_1 and T_2 on the photo plane which correspond to Y_1 and Y_2, respectively, then the values of the corresponding angles B_1 and B_2 will be known. Using the data of H, SL, B_1 and B_2, we obtain the center angle A_0 from the following equations. We also obtain L, and then the triangular pod can be determined. Thus, by knowing the center angle A_0, we are able to determine the position Y on the snow plane using the angle B from an arbitrary position T on the photo plane.

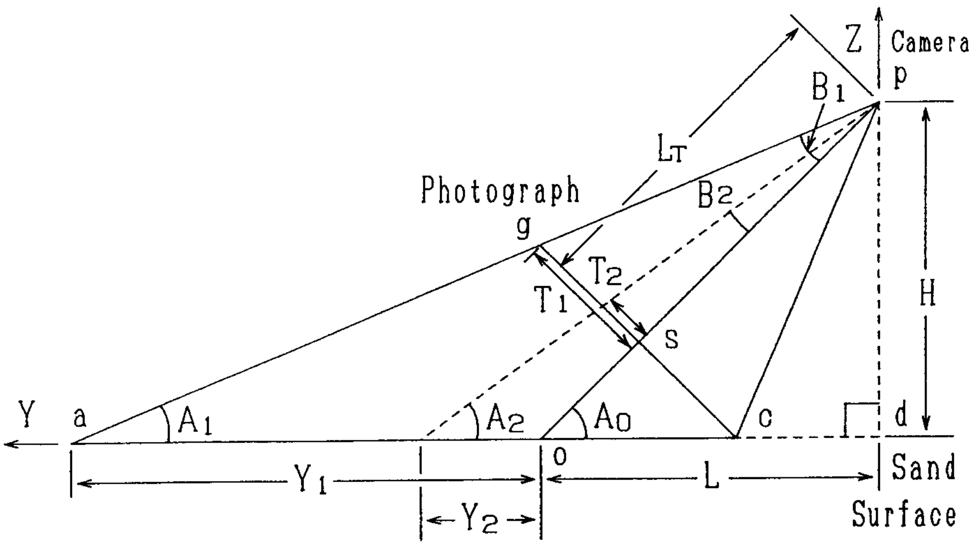


Fig. 6 Snow plane, phot plane and center angle A_0.

$$H/L=\tan(A_0) \quad (1)$$

$$H/(L+Y_1)=\tan(A_1)=\tan(A_0-B_1) \quad (2)$$

$$H/(L+Y_2)=\tan(A_2)=\tan(A_0-B_2) \quad (3)$$

$$L+Y_1=H/\tan(A_0-B_1) \quad (4)$$

$$L+Y_2=H/\tan(A_0-B_2) \quad (5)$$

$$Y_1-Y_2=SL \quad (6)$$

When the ski is not positioned in the direction of ac which is on the centerline of the snow plane ehjq, the calculation process becomes slightly more complex. Readers are requested to refer to ref. 25 in such a case.

Thus, if we can only take photographs of a skier sliding on a snow plane as explained above, then it is possible to draw the loci of the skis on a sheet of paper, as if looking at the loci on the snow plane from a position perpendicularly above them.

5. Moving skier and camera that follows

5.1 Connecting photographs of snow plane

When a camera is fixed and directed towards the sliding direction of a skier, as the skier descends from the left to the right, he quickly leaves the visual field of the camera. When a skier performs short turns, right and left turns can be repeated even in a small visual field. However, when a skier performs long turns, only part of one turn occurs within the visual field. Accordingly, a larger visual field is required. However, if a large visual field of the camera is adopted, the relative size of the skier decreases and detailed motions are unclear. Therefore, it is necessary for the camera to move with the skier. Thus, in photographs taken by a moving camera (Figs. 3 and 8), the skier is always positioned at the center of the visual field. Figure 7 shows the movement of the visual field (i.e., the snow plane ehjq in Fig. 5) of the moving camera. The relative position of the two visual fields is determined from an object K, which is present in both visual fields (ehjq and e'h'j'q'). A series of loci of a sliding ski was produced by connecting such photographs (Figs. 9 and 20). The number of photographs used was a minimum of 10 and maximum of 30. Recently, the number of photographs has increased to approximately 100 because we have used a video recorder. Below, we explain in concrete terms the method of drawing a diagram of a sliding ski using multiple photographs.

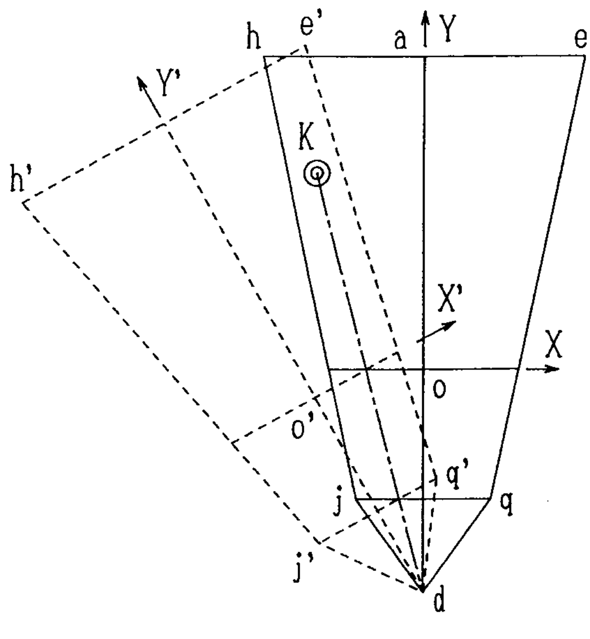


Fig. 7. Connecting snow planes of different visual fields.

Fig. 8. Method of reading coordinates of the skis from the photograph. Skier: Ichino, at Hoonoki-daira Ski Resort, taken on February 4, 1994.

(1) A photograph is glued onto graph paper, as shown in Fig. 8. The coordinates of the corner of the ski and other patterns (objects that are also present in the photograph, K, such as the shadow of bumps and dips on the snow plane) are read from the scale of the plotting paper. The number of coordinates of the ski and objects measured was approximately 10 in one photograph.

(2) The center angle A_0 is calculated by substituting the coordinates of the skis into eqs. (1)~(6). Since two skis are present in one photograph, two values are calculated and average of the two values is taken as the value of A_0. After determining A_0, positions of the patterns present on the same snow plane can be determined.

(3) In 1984, we developed a computer program of approximately 5 kB to obtain A_0 and the position of the ski on the snow plane.

(4) Using the coordinates on the photographs, we obtain coordinates of the ski on the snow plane, and plot them on graph paper to obtain the sliding ski diagram. Skis appearing in different photographs are connected, making use of the coexisting object K.

Figure 9(a) shows the first sliding-ski diagram obtained from the analysis of 8 photographs taken at the Yamada Farm Ski Resort in Shiga Plateau in March 1984. Production of this diagram was very time-consuming and laborious at that time; however, we were greatly impressed by the resulting drawing of the loci of the sliding ski. Figure 9 shows a diagram produced from reanalysis in 1999. Refer to ref. 24 for the figure legend and other information.

5.2 Meaning of parallel turns

The sliding-ski diagram shown in Fig. 9(a) differed from what we had expected of the diagram of parallel turns. According to a ski textbook of the Ski Association of Japan (SAJ), the ski is descending toward the direction of the ski length in the parallel turn. Figure 10 shows a photograph of the parallel turn described on p.60 of the SAJ textbook (1994). We had believed in a parallel turn that the skis are aligned in parallel and the skiers execute a turn while descending in the direction of ski length. When we perform parallel turns on a snow plane, we feel that we make a turn while descending in the direction of the parallel skis.

In Fig. 9(b), there is a difference of 10°~20° between the angle θ showing the direction of descent and the angle δ showing the ski direction. It is not accurate to say that the skier is descending in the direction of the skis. When we first saw Fig. 9 (a), we were unsure whether or not we had made any mistakes in the method of analysis.

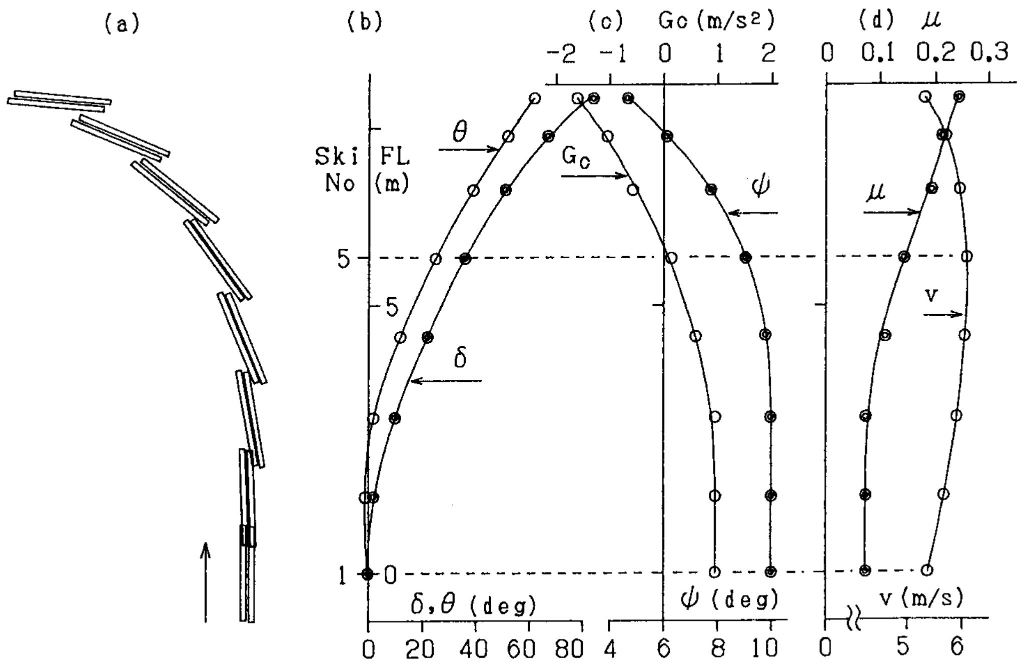


Fig. 9. Uphill turn starting from a straight downhill run; time interval between pairs of skis is 1/4 s. Skier: Ichino, at Yamada Farm Ski Resort, taken on March 28, 1984.

Since then, we have analyzed many parallel turns performed by many skiers, and confirmed that the loci of the sliding skis shown in Fig. 9(a) were correct.

5.3 Logical analysis of ski descent

It is hard to say whether photographs of parallel turns are properly arranged in the SAJ ski textbook. Since the editors of the ski textbook did not logically analyze ski descents as we did, they may not have understood how to arrange photographs of a ski descent in the proper manner. They arranged photographs taken on a 16-mm film sequentially such that the skis turn while descending in the direction of the ski length (parallel direction). Let us arrange the photographs in Fig. 9(a) by various methods. In Fig. 11, the photographs are arranged such that the skis turn while descending in the parallel direction. The scene in front of the skier in each photograph looks discontinuous. In Fig. 12, photographs are arranged such that the background is laterally aligned. While the back end of each pair of skis is arranged to be placed outside the turn in the diagram shown in Fig. 9(a), the front end of Fig. 12 is arranged to be placed outside of the turn. In Fig. 13, drawings are arranged so that the background is vertically and laterally aligned. Figure 13 resembles Fig. 9(a). There is a report in which photographs of the skier are logically arranged;[27] however, in most ski textbooks, photographs of the skier are arranged in a manner similar to those in Fig. 10. Thus, we can see that it is very important to logically analyze ski descents.

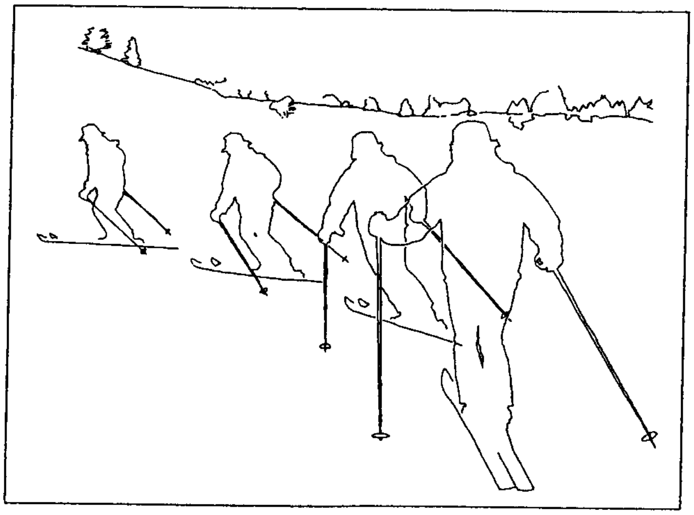
Fig. 10. Diagram showing a parallel turn.

Ski No. 8　6　4　3　2

Fig. 11.　Example of incorrect arrangement of photographs in Fig. 9.

Ski No. 8　6　5　4　3　2

Fig. 12.　Another example of incorrect arrangement of photographs in Fig. 9.



Ski No. 8　6　4　2

Fig. 13.　Example of correct arrangement of photographs in Fig. 9.