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영상처리를 이용한 골프 스윙 자동 분석 특징의 추출

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Feature Extraction for Automatic Golf Swing Analysis by Image Processing

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요 약

본 논문에서는 영상처리 기법을 이용하여 골프 스윙 자동 분석을 위한 특징 추출 방법을 제안하였다. 기존 대부분의 스윙 분석 시스템들이 골프 코치와 같은 전문가가 필요한 반면 제안한 특징 추출 방법을 이용하면 전문가의 도움 없이 중요한 스윙 특징을 추출할 수 있다. 추출한 특징은 어드레싱, 백스윙, 스윙탑, 포워드 스윙, 임팩트, 팔로우쓰루와 같은 키 프레임뿐만 아니라 손, 어깨, 클럽헤드, 발, 무릎과 같은 골퍼의 신체부위와 클럽의 위치까지 포함 한다. 제안한 방법의 효용성을 알기 위하여 스윙영상에 대하여 실험한 결과 제안한 방법이 중요한 골프 스윙 특징 추출에 유용함을 확인하였다.

Abstract

In this paper, I propose an image based feature extraction method for an automatic golf swing analysis. While most swing analysis systems require an expert like teaching professional, the proposed method enables an automatic swing analysis without a professional. The extracted features for swing analysis include not only key frames such as addressing, backward swing, top, forward swing, impact, and follow-through swing but also important positions of golfer's body parts such as hands, shoulders, club head, feet, knee. To see the effectiveness of the proposed method, I tested it for several swing pictures. Experimental results show that the proposed method is effective for extracting important swing features. Further research is under going to develop an automatic swing analysis system using the proposed features.

▸ Keyword : golf swing analysis, feature extraction ,key frame, image processing

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I. Introduction

Like most sports, being a good golfer needs a good swing form and accurate swing analysis. Since a swing occurs in short time, for an ordinary people, it is hard to analyze it with naked eyes alone. Hence, it is becoming more often to use computer aided swing analysis system. A common swing analysis system consists of a computer with cameras and swing analysis software. The cameras are used for capturing 2-dimensional(2D) swing images of side and rear direction from the player. Though 3D motion capture systems can be used for more accurate swing analysis, attaching 3D makers on player's body makes swing itself unnatural and cost is high[1].

Though a few previous systems can generate swing data such as swing speed, weight shift, moment of impact that can be helpful improving swing technique, these data are not enough to be used for analyzing swing accurately. In addition, these systems need user's manual input of various position data in all key frames[2]. We still need more visual data driven system that can automatically generate actual data that we get from used by professional coaches. For example, it'll be more useful if the system can tell the user that "you are doing over backward swing!". Hence, building a golf swing analysis system requires high degree of image analysis and pattern recognition experience. Another difficulty of using previous systems is that they need professional coaches who can use them and the quality of explanations differs depending on teachers. There's no system that can automatically generate these explanation without professional teachers [1].

To automatically generate the explanation, we need information of key frames and visual features in swing. The key frames in swing analysis are address, backward swing, top of swing, forward swing, impact and follow-through. In addition to the key frames, we still need more position and movement information of golfer and golf club in swing. These visual features include position and movement of hands, head, knee, shoulder, club head and shaft. An automatic swing analysis system should be able to support not only key frames but also visual data without aid of human expert.

In Figure 1, I show an entire flow of the proposed feature extraction. From an input swing motion picture, I extract motion area by calculating image difference between all consecutive frames. I extract key feature frames using MBR(Minimum Boundary Rectangle) information of edge and motion difference in consecutive frames. For those key frames, I calculate position and movement features of major body parts and a golf club that are necessary building automatic swing analysis system.

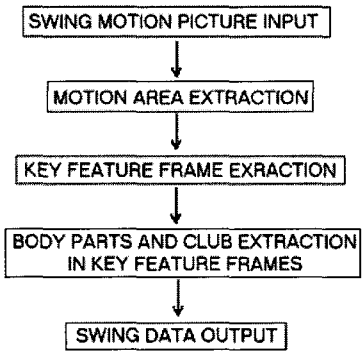


Figure 1. Flow of Feature Extraction in Swing.
그림 1. 스윙에서의 특징 추출 흐름도

II. FEATURE EXTRACTION

2.1 Swing Features

Among many factors that influence on golfer's swing ,including mental factor, I'm focusing on features that can be extracted by visual image processing. These visual features are key frames and position and movement of body parts and club during swing. The key frames are address, backward swing, top of swing, forward swing, impact, and follow-through. Body parts are hand, shoulder, head, knees, feet and movement of these parts affects the whole swing results.

2.2 Extraction of Key Swing Frames

In this part, I explain the extraction method of key swing frames. To know these frames, I first accumulate frame difference between all consecutive frames[3,4]. The accumulated difference image represents all areas where player's motion was occurred. Since all movement of body parts and golf club make the difference, using the motion area makes it easy to extract key frames and body parts. In other words, I only need to focus on the motion areas instead of processing whole areas of the picture. Figure 2 shows an example motion area by a swing. In the figure, all pixels except black background represent motion area.

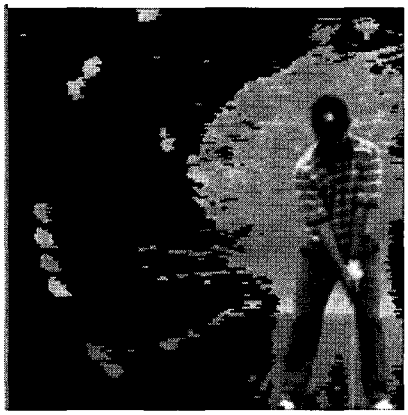
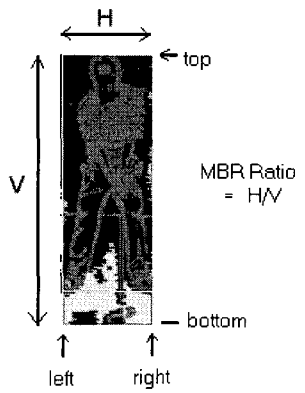


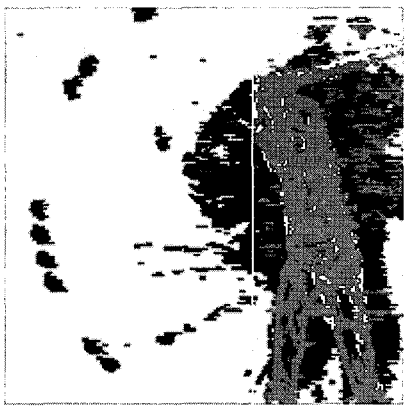
Figure 2. Motion area during swing
그림 2. 스윙시의 모션 영역



(a) motion MBR

(b) MBR in Addressing Frame

(c)MBR in 9 o'clock Backward Swing



(d) MBR in Top of Swing

(e) MBR in Follow-through

Figure 3. Motion MBR and Profile in Key Frames.
그림 3. 키프레임에서의 모션 MBR과 프로파일

In each frame, a MBR that surrounds the player and golf club is used to extract key frames as shown in Figure 3(a). The length ratio of horizontal over vertical line of the MBR shows good information deciding the player's swing stage. For example, the ratio is small in addressing stage as shown in Figure 3(b). When a player is taking backward swing, the ratio begins to increase and the ratio shows maximum value at 9 o'clock backward swing stage as shown in the Figure 3(c). In top of swing, the position of left bounding box in previous stages goes to right side as in Figure 3(d) and has maximum right side value in follow-through swing in (e). Hence, considering the MBR ratio and movement of bounding box greatly helps to extract key feature frames. I also use the color edge information and its projection profile to calculate position of body parts and a golf club[5]. Though there are many edge detection methods, to know edgeness, I calculate RGB difference of the same pixel position in two consecutive frames[6,7]. In the Figure, red pixels inside a MBR area represent edge information in motion area.

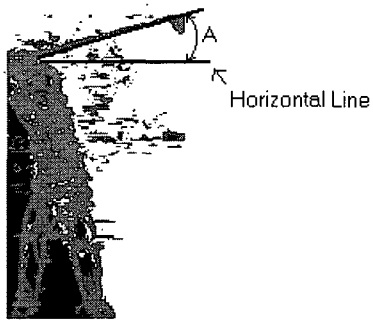
2.2.1 Addressing

Good addressing is important because it affects the direction of ball and other swing characteristics a lot. Addressing frame is a key frame just before the player begins backward swing. Since players make least motion and the MBR ratio is small in addressing , I extract addressing frame by finding the least motion difference frame which has small MBR ratio near 0.3 in the first half part of whole frames. motion difference is measured by counting the changed pixels between two consecutive frames. From an addressing frame, the ball position is extracted using horizontal edge profile.

2.2.2 Backward Swing and 9 O'clock Swing

Many golf professionals say that good backward swing makes good forward swing. Hence, knowing if a backward swing is good is as much important as having a good forward swing. Backward swing frames are all frames between addressing frame and top of swing frame. Motion difference values show the smallest in both addressing and top of swing frame. Among all backward swing frames, 9 o'clock frame is important because it shows a lot about a golfer's swing quality. 9 o'clock frame is a key frame in backward swing when the club head directs to right side and it is located at golfer's waist position vertically. The left side of MBR in addressing frame first goes to left direction till 9 o'clock swing and goes to right direction till top of swing. Hence 9 o'clock swing frame is the frame when the MBR ratio becomes maximum and begins to decrease. In the frame, the position of hands is important because comparing the position of club head and hands gives us good information about cocking timing.

(a) Locating Club Head



(b) Top of Swing and Over-swing

Figure 4. Top of Swing and Locating Club Head
그림 4. 스윙탑과 클럽헤드 위치 찾기

2.2.3 Top of Swing and Detection of Over-Swing

Top of swing frame is the last point of backward swing frames. In top of swing frame, the position and height of club head is important. I extract top of swing as the end of backward swing frames. In proper top of swing, the right side of the MBR does not increase right direction any more and motion difference decrease to the smallest value. In proper top of swing, club head is located right corner of the MBR as shown in Figure 4(a).

Over-swing is one of common problems among amateur golfers. It affects swing timing and cause many problems including behind-swing. Over-swing is generally defined as club head is vertically located below the horizontal line in top of swing. The angle 'A' between a club head and the horizontal line, as shown in Figure 4(b), should be proper and the club head must be located above the horizontal line.

2.2.4 Forward Swing and Impact

Forward swing frames are all frames between top of swing and impact. The position of club head in forward and backward swing frames are important to know if the player's swing plane is good or not. Since swing plane can be seen in rear side image, I don't explain it in this paper. Comparing trace of club head and hands in both forward and backward swing shows good information about the goodness of the swing such as weight shift.

Impact frame is the frame when the club head hits the ball. By looking at the angle the club's face and target direction make, we can see if the swing make a slice or a hook ball. To do this, we need a high speed capture camera solely dedicated to ball position area. In addition, comparing impact frame and addressing frame gives us knowledge of swing quality. Concerning the position of hands and club face, there should be little difference between the two frames. In an impact frame, the MBR ratio has similar value as in addressing frame and motion difference shows big value change. Since I know the ball position, I check the impact frame by checking big motion change just left side of ball position.

2.2.5 Follow-Through and Finish

Follow-through frames are all frames between impact and finish frame. As shown in Figure 3(e), the 3 o'clock follow-through frame has large MBR ratio and the position of right bounding box is located in far right side compared with other key frames. Finish frame is the last frame of whole swing frames. I extract the finish frame by selecting the least motion difference after impact frame. In finish frame, the position of club head and legs are important factors.

2.3 Extraction of Club and Body Parts

To analyze swing correctly, we need more visual data in addition to key frames. Those data include position and movement of club head, hands, feet, head and shoulders in each key frame. For example, the movement of head in key frames show the existence of head sway, that is not desirable. Another data is speed between consecutive key frames. We can calculate the backward swing time by extracting address frame time from top of swing frame time. Too fast backward swing often causes bad forward swing.

Since club head is located at the end of the shaft away from player's body, I extract it using edge information in MBR area. The fact that the club head is always located on edge or corner of the MBR makes it easy to extract the head. Especially, the position of club head in top of swing frame is important to know over swing, as I mentioned in the previous section.

Feet and shoulder positions are needed to know if the stance width

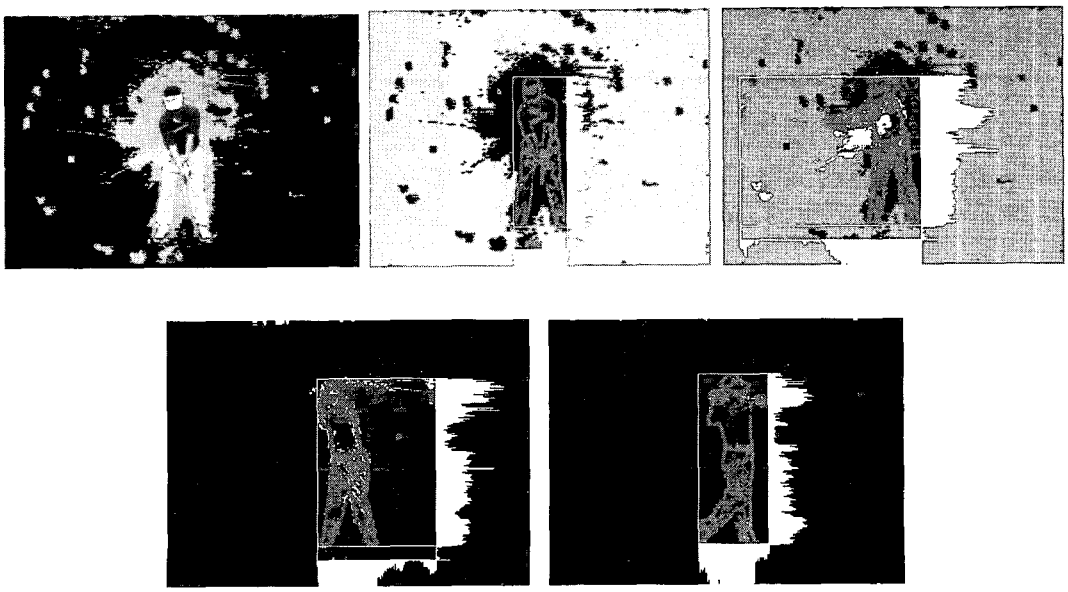


Figure 5. Example of Key frames and MBR extraction.
그림 5. 키 프레임과 MBR 추출의 예.

is proper or not. Stance width is the same as the MBR width in address key frame. While backward swing, feet should not move and position of feet is calculated using horizontal profile from bottom. If the profile size is greater than a threshold value, it is the bottom position of the feet.

Locating head position is also useful because moving head is not good during backward swing. Position of head is extracted using different method on different key frames. For example In addressing and impact key frames, head is always located on top of the player. In 9 o'clock and 3 o'clock swing, head is located in top area of the MBR. In Top of swing, the head is in left top corner of the MBR. By comparing head positions among key frames, we can see the existence of head sway.

III. EXPERIMENTAL RESULT

I tested the proposed method for several swing pictures downloaded from a public golf web site[8]. The resolution of the picture is 320x240 and 15 frame per second(fps). Since the picture is taken using an ordinary camera, the resolution and quality of the pictures is not good.

Key feature frames are extracted well in all pictures. Positions of shoulder and hand are extracted in most key frames except addressing and impact frame. Since I used only side swing images, I can get better result if I combine feature extraction from rear swing image. It is easy to calculate swing speed between consecutive key frames since I know fps and the position of those key frames in picture. In Figure 5, I showed example key frames and their MBRs.

IV. CONCLUSION

In this paper, I proposed an image-based method of swing feature extraction which are needed for an automatic swing analysis. While most swing analysis systems require a professional helper to use them, the proposed method is useful to develop an automatic system that can be used for anyone without a professional. The extracted features for swing analysis include not only key frames such as addressing, backward and forward swing, impact, but also swing speed and important positions of swing objects such as hands, head, shoulder, club head, and feet. To see the effectiveness of the proposed method, I tested it for several swing pictures. Experimental results show that the proposed method is effective for extracting the important swing features. In this study, though I used only side image of player alone, I'll combine both side and rear image features together in future work. Further research is under going to develop an automatic swing analysis system using the proposed features.

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