Analysis of Golf Swings of Varying Skill Level Using Singular Value Decomposition

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1. Introduction Fitting a golfer with a suitable golf club is crucial for enhancing their skills. It is important to consider not only the characteristics of the club but also the golfer's swing [1]. We devised a 3D cooperative action extraction method that uses singular value decomposition(SVD) to analyze cooperative actions in golf swings [2]. In this study, we verify the effectiveness of our swing analysis method using SVD by focusing on differences of golfers' biomechanical kinetics of varying skill level and analyzing the cooperative actions of golfers.

2. Experiment A beginner (mean handicap 58), intermediate (mean handicap 18), and expert(mean handicap 3) golfer were recruited as participants. All three were 172±6 cm and 72±13 kg. Their golf swings were measured using a motion capture system(VICON), and the measurement conditions were the sama as that of Ref. [2].

3. Method The observation matrix $[R_a]$ was constructed using positional data. Then $[R_a]$ was expanded into modes by performing SVD. In this study, we focus on two modes, the top two contribution ratios, and we analyze the swing behavior $[R_2]$ in the first and second modes as expressed by the following equation [2].

$$[R_2] = [R_0] + \sum_{j=1}^{2} \lambda_j \boldsymbol{v}_j \boldsymbol{z}_j^T = [R_0] + \sum_{j=1}^{2} \boldsymbol{w}_j \boldsymbol{z}_j^T \tag{1}$$

4. Results Fig. 1(a) shows the behaviour extracted during typical actions[2]. The difference between the expert and the beginner can be seen in their wrist movements (Fig. 1(a)α_1, α_2), while the difference between the expert and the intermediate can be seen in their chest and knees (Fig. 1(a) β_1, β_2). These differences are represented using a Lissajous figure (Fig. 1(b)) and the postural features of the first mode $\boldsymbol{v}_1$ (Fig. 1(c)). The beginner showed a higher excitation

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of w_1 against w_2 (Fig. 1(b) α_1, α_2) and a smaller absolute amplitude of wrist movement in the X direction compared with the expert(Fig. 1(c) α). These results show that the difference between the expert and beginner is generated by temporal and spatial features. The Lissajous figure of the intermediate was similar to that of the expert, except for a higher chest and knee amplitude in the X direction (Fig. 1(c) β_1, β_2). This shows that any differences between the expert and intermediate is generated by spatial features. Thus, we determined that the differences in skill level can be seen in the modes extracted by SVD.

(a) Stick figures comparing sum of first and second mode swing
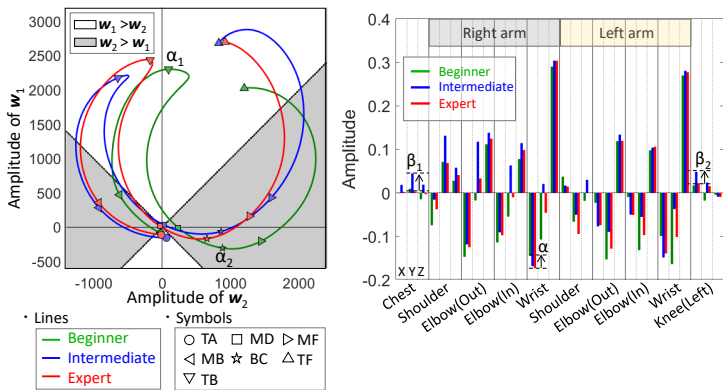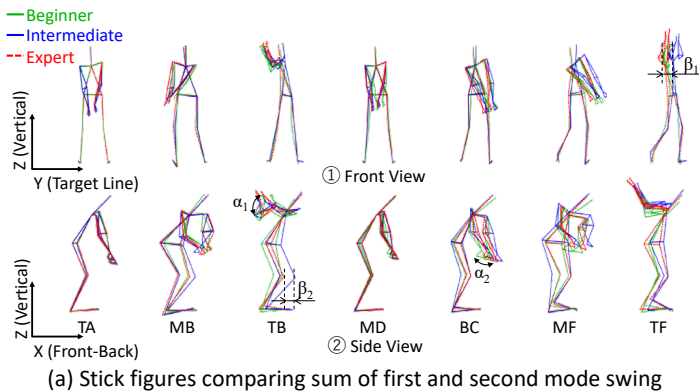
(b) Lissajous figure of w_2 & w_1 (c) Selected v_1 factors

Fig. 1: Results of SVD: (a) Stick figures, (b) Lissajous figure, (c) Selected v_1.factors.

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2. Matsumoto K., et.al. (2020), Proposal of Golf Swing Analysis Method using Singular Value Decomposition, *proceedings* 2020 49:1-7.

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