Supporting Golf Coaching and Swing Instruction with Computer-Based Training Systems

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Abstract. Golf is a popular sport around the world. Since an accomplished golf swing is essential for succeeding in this sport, golf players spend a considerable amount of time perfecting their swing. In order to guide the design of future computer-based training systems that support swing instruction, this paper analyzes the data gathered during interviews with golf instructors and participant observations of actual swing coaching sessions. Based on our field work, we describe the characteristics of a proficient swing, how the instructional sessions are normally carried out and the challenges professional instructors face. Taking into account these challenges, we outline which desirable capabilities future computer-based training systems for professional golf instructors should have.

Keywords: Golf · Swing instruction · Computer-based training systems

1 Introduction

Golf has grown exceptionally in the past decades; today it is played by over 60 million people around the world, being one of the leading sports in terms of total economic expenditure [1]. One of the crucial parts of this strategy game is the swing; an accomplished swing is key for succeeding in this sport [2]. Many amateur players spend a considerable amount of time and effort perfecting their swing, improving accuracy, precision, consistency and distance [2].

Despite the increase of golf tools available in the market and the availability of plenty of materials explaining how to carry out such sequence of movements, novice golf players still find improving their swing skills to be a challenge [3]. Normally, golfers improve their swing through sessions with professional golf instructors using verbal and gestural feedback [3]. Not withstanding the effectiveness of these traditional methods, with the rapid development of sensors, electronics and data analysis techniques, new opportunities open up for making these instructional sessions more effective, combining both guided and self assessment-based methods.

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Advanced computer-based training systems may support both golf instructors and players. On the one hand, golf instructors are required to make fast and accurate observations of the movement patterns and subsequently, guide the player towards a more optimal technique through appropriate coaching sessions [4]. Even if most instructors can quickly highlight the major faults and provide corrective measures, golf instructors typically lack methods to communicate guidance, follow up and administrate the learning process. In a study presented by Schempp et al. [5] regarding the major facets of professional golf instructors, several participants expressed the need to incorporate the use of technology as well as improve on its use during teaching (e.g. *"video and other technologies [could] speed the learning process"* and *"by keeping up with the latest versions of technology I feel I gain an edge in my ability to communicate with my students"* [5]).

On the other hand, coaching sessions can be expensive for amateur golfers and thus, they spend a great deal of time improving their swing movement on their own [3]. However, most of them do not know where to focus their efforts, since it is difficult to identify and modify faults in the complex combination of related movements that constitute a successful swing [3].

These aspects relate to a general area within sports, that is, performance evaluation [6]. Performance evaluation is an essential part of sports and it is concerned with domain modeling and evaluation with respect to such models [7]. Performance improvement guidance is perhaps the least investigated area of computer science within sports. Already in 2006, Barlett [8] argued for the potential of using expert systems and machine learning techniques in sports biomechanics analysis for improvement of performance. Barlett [8], however, concluded that the usage so far is very low. Owusu [7] presents a general model, recognize critique recommend, which can be used for performance improvement in sports. Owusu discusses the use of neural networks and expert systems for recognition and critique, but concludes that very little has been investigated on these topics and especially on the final step of providing recommendations for improved performance.

Both golf instructors and amateur players would benefit from feedback provided by computer-based training systems that use the analysis of sensor and historical data as a basis for their inferences. In order to guide the development of such computer-based training systems for golf instructors, this study addresses the following research questions: (RQ1) how can a good swing be characterized? (RQ2) How is the swing instruction carried out today? (RQ3) What are the challenges and difficulties regarding the instruction process? And, (RQ4) which desirable capabilities should future computer-based training systems for professional golf instructors have to overcome these challenges?

This paper is organized as follows: we first discuss related work summarizing studies describing how golf coaches carry out their instruction and which tools are used for supporting these activities. The research methods employed for answering the research questions are described in Sect. 3 while the results are presented in Sect. 4. The main capabilities of future computer-based training systems for golf instructors are outlined in Sect. 5. Finally, a brief discussion of the study's results and main conclusions are presented in Sects. 6 and 7.

2 Related Work

This section presents a summary of relevant literature related to the work of professional golf instructors, key features of an accomplished swing and tools used as aids for supporting golf training.

2.1 Professional Golf Instructors

Despite the numerous golf instructional books and materials, to the best of our knowledge, publications and formal studies regarding how professional golf instructors carry out their work and their professional practices are very scarce. However, there are three studies that can help us to understand how they assess a golf swing and provide feedback, c.f. [4], and which are the particular skills of golf instructors, c.f. [5,9].

Smith et al. [4] identify the key technical parameters that professional golf instructors associate with a "top level" swing, interviewing and observing sixteen professional coaches. The results show that many coaches determined a successful golf swing from initially observing the "ball flight". Furthermore, many coaches acknowledged that the ball flight was a result of two important parameters, the "club motion" which was affected by the player's "body motion". The descriptors used to characterize these parameters were "consistent", "powerful", "accurate", "simple" and "controlled" with the most prevalent being "repeatable". The authors also highlight that "body motion" was influenced by five intrinsically linked key parameters, i.e., "posture", "body rotation", "sequential movement", "hand and arm action" and "club parameters".

The work presented by Schempp et al. [5,9] focuses in identifying the facets of professional practice monitored by expert teachers in general, i.e. the knowledge and skills expert sport coaches normally examine in order to improve their teaching (self-monitoring). For doing so, they selected expert golf instructors, so the results presented by Schempp et al. [5,9] are relevant in the particular case of golf instructors. A paper-based questionnaire was taken by thirty-one golf teachers (ranked by the Golf Magazine as in the top 100). From the data collected, five themes were constructed that represented the activities and qualities most often monitored by golf instructors: skills (i.e., things teachers do), knowledge base (i.e., things teachers know), personal characteristics (i.e., things teachers are), philosophy (i.e., things teachers believe), and tools (i.e., things teachers use). Even if skills and knowledge were the most important components, teaching tools used in undertaking the task of teaching golf was also highlighted as an area that should be regularly monitored.

2.2 Aid Tools for Golf Coaching and Training

There are multiple systems for swing analysis, but the majority of them provide quantitative data and lack feedback that it is easy to interpret by golf amateurs [3]. In this section, we briefly review systems that not only provide sensor data but

which also give some kind of guidance that can be used by the player to improve his/her skills.

Chun et al. [3] focus their analysis on the wrist movement while performing a swing. The authors describe an autonomous kinematic analysis platform, using the Microsoft Kinect camera system[1], for wrist angle measurement that is capable of evaluating a user's uncocking swing motion (i.e. downswing, see Fig. 2) and providing instructional feedback. According to the authors, the graphical user interface (GUI) provides five types of intuitive feedback: (1) verbal and (2) textual instructions for improving the user's uncocking motion based on the feedback comments and scores defined in a special module embedded in the platform (the generation module), (3) wrist angle sequence visualization using a graph, (4) 2D video and (5) 3D video based on the color and depth data streams captured by the Kinect installed in front of the golfer. A virtual coaching environment for improving the swing is presented in [10]. Using high-speed 3D motion captured data, the visualization and analysis tool identifies faults in a golf player's stroke mechanisms, aligning and comparing the player's swing with players of higher skill levels. From these comparisons explicit instructions on how the player should change their stroke mechanics are visualized in the 3D virtual environment.

There are other works that even if they do not concern golf swing, they can be used as illustrative examples. A simple GUI implemented in Matlab to improve the motor skills for performing a golf putt is presented in [11]. The video of the putt is displayed with quantitative values such as the putt tempo (ratio backswing duration:downswing duration) and score which gives an indication of how close the putt tempo is to the ideal ratio of 2/1.

There are several examples in the literature that present necessary intermediate steps to provide feedback to improve the golf swing, however, they do not present a complete system that provides feedback to players. An example is the work presented in [12], where the challenges associated with the extraction of a highly complex articulated motion from a golf swing video scene is tackled. The authors developed a markerless human motion tracking system that tracks the major body parts of an athlete straight from a sports broadcast video, using a combination of three algorithms.

Commercial solutions for analyzing golf swing are available, e.g. TrackMan, Swing Profile, Swing Smart, Swing Byte 2 or Sky Pro (a comparison of some of these solutions can be read online: http://www.mygolfspy.com/skypro-swing-analyzer-trainer-review/ [Accessed 2015-02-16]); however, to the best of our knowledge, their capabilities for providing feedback are limited.

3 Methods

In order to characterize how professional golf instructors carry out swing instructional sessions, we have conducted empirical work through two primary

[1] Kinect is a line of motion sensing input device (webcam-style) that enables users to interact and control their computer using gestures and voice.

qualitative methods: *participant observation* and *in-depth interviewing* (see [13] for a detailed description of these methods). Participant observation is both an overall approach to inquiry and a data gathering method, where the researcher spends a considerable amount of time in the setting, learning about the daily life there [13]. Qualitative in-depth interviews are much more like conversations, where the researcher explores a few general topics to help uncover the participant's view [13].

Three professional golf instructors participated in this study. All of them have extensive experience in golf coaching (PGA certified) and are active in the field, working at three different golf clubs in the area of Västra Götaland, Sweden. Interviews and participant observations were used to collect data, supported by visuals such as video and photographs (see Fig. 1). For consistency, the two first authors of this paper performed all the interviews and the first author carried out the participant observations.

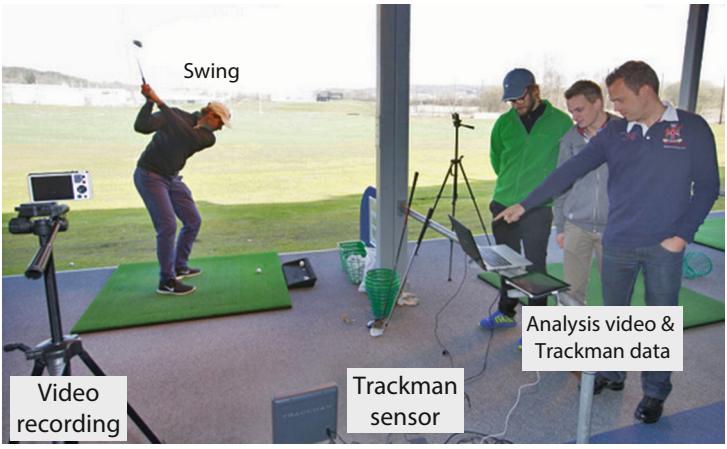

Fig. 1. Swing instruction: video recordings and TrackMan sensors were used to collect data during the field work.

4 Results

This section presents a summary of the data collected during the field work carried out, introducing a description of the swing instruction process, the characteristics of a good swing highlighted by the instructors and a description of current tools and materials used for supporting the instruction process. Broadly, we discuss that it is not easy to provide a unique description of a "good" swing and that it varies very much from player to player. As expressed by the instructors, it is a matter of balancing power and precision, where repeatability normally is a desirable property. Historically, there has not been a unique example of the perfect swing either, and the desired properties of a good swing have evolved as well. We highlight problems associated to, for example, the communication

instructor-player, the need for having a long term learning strategy, the development of repositories of exercises based on empirical evidence and the advantages of developing various types of good swing models that then can be used for providing individual feedback based on the particular characteristics off each player.

Fig. 2. Swing positions. The various illustrations show the golf swing sequence: set-up position (P1), club parallel to ground (P2), left arm parallel to ground (P3), top of the backswing (P4), left arm parallel to ground (P5), club shaft parallel to ground (P6), impact (P7), club shaft parallel to ground on through swing (P8), right arm parallel to ground on through swing (P9) and finish position (P10).

4.1 Proficient Swing and Swing Instruction (RQ1 and RQ2)

This section summarizes how the instruction of a golf swing session is carried out based on our observations. Obviously, it is a challenge to summarize a process that can have large variations from player to player, but the aim of this section is to find those leverage points were support can be provided.

The first session normally starts with a conversation where the golf instructor tries to find out as much as possible about the interests, capacities and goals of the player, a conversation that can vary largely depending on how long they have known each other. During the first training session, the coach asked the player to hit several balls. The instructor looks mainly to the ball flight and the landing positions, i.e. spread, in both length and width. Both the body motion, as well as how the ball is hit are crucial aspects of an accomplished swing. Thus, the ball flight, the body motion and the hit are the focus of the instructors' assessment. As expressed by the instructors, *repeatability* and *consistency* are both required characteristics of a good swing.

What do the instructors look at when assessing a swing? Taking into account the observations carried out and the interviews they mainly look at (1) the ball

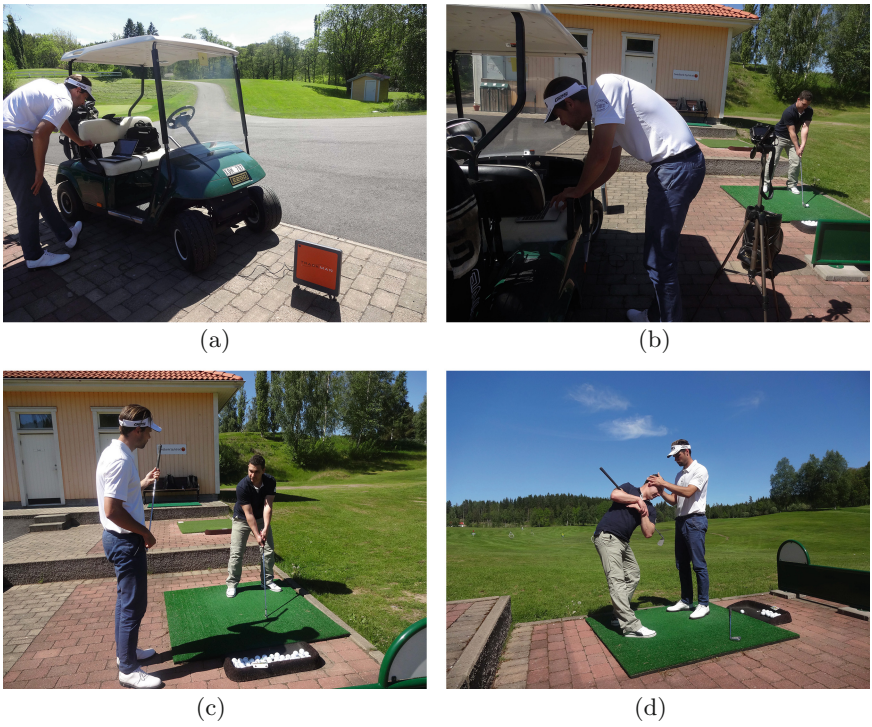

Fig. 3. Illustrations from a swing coaching session from our field work. Figure 3(a) and (b) show the use of tools to support the performance analysis process (TrackMan, camera and computer). Figure 3(a) and (b) exhibit two examples of the traditional means, verbal and gestural, of delivering feedback for performance improvement.

flight, (2) the spread of the ball (both directions), (3) the body motion, (4) the ball hit, (5) the power and (6) the control over the whole process.

While the trainee does several swings, the instructor looks at various aspects of the swing (see Fig. 3). First, they take a look at the ball flight (does it present a similar pattern?, how is the spread of the ball?) and its connection to the ball hit (was the ball hit in the center, on its way up or on its way down?). The hit moment is crucial. If the hit is irregular (new players have larger variation), the instructor looks if the lowest point of hit is at the correct place. However, different body motions can achieve a good hit.

In general, it is desired to have a pure and similar contact with the ball every time (repeatability and consistency). Once the hit is good, the instructor will move forward to other aspects, such as e.g. achieving more power or more control of the ball flight (e.g. curvature).

Support. Broadly, the instruction process consists in observation, feedback and observation again. The trainee carries out several swings, while the instructor

observes and listens (recording with the video camera). The instructor analyzes what happened with the ball and the hit. When improvements are needed, verbal and gestural feedback is provided (sometimes the feedback is provided with the support of the recorded session, showing what is necessary to change and why). After that a new trial phase starts, where the progression is assessed. We would like to note that not only repetitions of the swing were requested; the instructors also proposed several exercises to practice, for example, the body rotation, so the trainee would be aware of its own rotation motion without swinging (which part of the body should rotate around what and which part should not move during the rotation).

The support tools used by the three instructors that were interviewed and observed were mainly, video camera and TrackMan (connected to a computer). The video camera was used to record the swing. The instructor normally employed the video camera to show the trainee the rotation, highlighting the faults or improvement possibilities; the video camera was therefore normally employed as a communication means. The TrackMan radar was used to measure the club and ball parameters. It was used by the instructor for complementing and validating his analysis regarding the ball flight, the hit and the club movement. Other support tools that the instructors mentioned that could be used during the swing training sessions were pressure plates (that measure where the center of gravity is, weight pressure against ground and how does it change over time), impact tape or spray (to see the ball hit), 3D sensors to assess the body movement and several video cameras (to see the body motion from different angles).

4.2 Challenges (RQ3)

The main challenges highlighted by the instructors interviewed involve pedagogical concerns. These pedagogical concerns relate to the adjustment of the teaching situation to the particular characteristics of the player (*"which vocabulary should I use? Which metaphors? Which support tools? How do I explain how and why? How do I explain cause-effect?"*) One of the major pedagogical concerns expressed by the golf instructors was communication. Successful communication and mutual understanding instructor-player is crucial for a fruitful learning process, but not always it is easy to overcome the large age, background, interests, motivational, physiological and psychological differences among the trainees. All the instructors saw communication as a critical skill in golf training.

A clear strategy for learning and achieving training and learning outcomes was identified as problematic to establish by the instructors. The instructors lack means of structuring the learning process, the training outcomes, the content of each session, the pacing and scheduling. These challenges relate also to administrative skills and the lack of appropriate support tools; as it was mentioned, it is hard to keep record of the players, their situation, achievements and expected outcomes.

The last challenge that we frame under pedagogical concerns stressed by the interviewees relate to instructor self-assessment and self-monitoring of

instructors' own practices. Instructors were concerned about their own improvement (*"how do we get better?"*), how do they critically analyze themselves and which factors can improve their performance.

Besides problems related to communication, learning strategies and self-assessment there are other challenges expressed by the instructors, such as, *"are there scientific prove that certain exercises produce certain effects? Can exercises be isolated in blocks? What is the best and fastest way of learning? Which are the most relevant exercises to achieve the desire change? How do we change movement patterns (players underestimate the amount of time that is required to change a pattern)? How do we keep players motivated? How do we ourselves keep motivated and find passion for teaching golf?"*

Regarding the support tools, instructors have expressed their desire of having an integrated platform where body motion, from different angles, images from video cameras and radar data could be analyzed. Moreover, more automatic analysis capabilities over the various types of data that can be collected are required. There are many other sensors that can be used to collect golf-related data, but it is not easy to see how to best use them in a learning context.

5 Future Computer-Based Training Systems (RQ4)

Based on the descriptions given and challenges highlighted in previous sections, we outline which key capabilities (C) future computer-based training systems should have for swing training:

C1. Semi-automatic performance evaluation: the ability of providing performance evaluation, following the model by Owusu [7]: recognize faults, criticize and recommend. Within this capability we group those methods needed to build models from historical data collected from skilled players (swing modeling), compare those models that best fit player's characteristics with actual swings and detect faults. We include here as well the capability of providing recommendations regarding which exercises should be carried out to improve performance.

C2. Interactive analysis: the ability of exploring the golf data interactively, finding patterns, clusters, anomalies, new insights, etc. For doing so, techniques from the areas of data mining (e.g. clustering, decision trees) and visual analytics (e.g. linking, brushing, parallel coordinates) need to be integrated.

C3. Visualization: effective interactive visualization methods that are able to support communication instructor–player. Visualization can be used to depict player's own swing, the swing models of high skill players, compare player's own swing with the models, illustrate improvements (if–then situations), show cause–effect relations, the swing plane, projections, etc.

C4. Data collection and sensor integration: an effective integration or fusion of the various types of data (video, radar, 3D markers, etc.) enables the construction of richer swing models and better swing assessments that

take into account the relations among the interconnected characteristics of a accomplished swing. Here we include as well capabilities for solving the problems associated with the alignment of the various sensors. The integration, for example, of radar data regarding ball flight, club motion, hit with the high speed motion captures of the club and body movements seem crucial for detecting possible flaws and for providing feedback.

C5. Learning strategy: be able to build and administrate a learning and training strategy for each player. This capability should include a library of exercises and their effects based on experimental evidence, mapping training outcomes with most effective exercises. Such capability should not only focus on the individual parts of the game, e.g. swing or putting, but should take into account the complete player's game in order to allow for improvements. Naturally, such capabilities should thus not only take as input the individual parts of the game but should support gathering and analysis of data from all aspects of it.

C.6 Self-assessment: support for instructor's self-monitoring, assessment and improved performance. Furthermore, this capability should include a platform for information sharing for instructors: forums, instruction exchange, golf schools, basic instructor training, experiences, etc.

6 Discussion

This paper presents the results from interviews with golf instructors and observations of golf swing instructional sessions in order to characterize an accomplished swing, describing how the swing instruction is carried out today and which tools are used for supporting this process. The challenges highlighted relate to pedagogical concerns, and were grouped under communication, learning strategy and self-assessment. The characteristics outlined for a good swing in this study match previous research in the area. The swing descriptors *"consistent"* and *"repeatable"* expressed by the instructors interviewed for this study were also mentioned, among others, by Smith et al. in [4] (see Sect. 2.1 for more details on Smith et al.'s work). Moreover, some of the challenges highlighted in Sect. 4.2, communication and self-assessment, coincide with those found by Schempp et al. in [5].

In this paper, we have argued that rigorous scientific research that investigates the effectiveness of various swing exercises to achieve the training outcomes desired is needed. This seems to coincide with the claims by Kelly et al. [10], who state that the amount of rigorous scientific research that has been conducted into golf is surprisingly limited.

In order to compare actual swings with those "good examples" from skilled players (capability analysis outlined in Sect. 5), a set of models based on data collected from such players should be built. Even if limited, there are various examples of modeling the golf swing motion captured by, for example, the Microsoft Kinect, [14,15], where various techniques were used for modeling (Gaussian Mixture Models, Support Vector Machine and Dynamic Bayesian Networks).

Other examples that include swing modeling are presented in [16,17]; while a review of biomechanical models of the golf swing, focusing on how these models can aid the understanding of golf biomechanics and the fitting of golf clubs to individual players is presented in [18].

As highlighted by [19] the design of feedback in the motor skill domain via computer-based training systems is typically led by technology and fails to take into account pedagogical issues. The data collected during our field work showed that many of the challenges encountered in swing instruction are related to pedagogical aspects of the training process: communication, learning strategy and self-assessment. Feedback in golf should consider higher learning aims (not only particular small improvements), and the context of the learning situation. The challenge for computer-based training system's designers is to determine what constitutes effective feedback for athletes in their training [19,20].

7 Conclusions

Despite the increase of golf tools available in the market and the availability of large amounts of data, novice golf players still find improving their swing skills to be a challenge. Traditional methods are still predominant in this field, but new data and visual analysis techniques open up for making these instructional sessions more effective.

Advanced computer-based training systems may support golf instructors in their daily work. In this paper, we have presented an analysis of how the swing instruction process is carried out nowadays, highlighting which challenges are faced that can be leveraged by newly developed computer-based training systems. The major challenges highlighted by the golf instructors that participated in this study were pedagogical concerns related to communication, learning strategy and self-assessment. The results presented in this paper may guide the design and development of such future computer-based training systems for swing coaching.

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