DOI: https://doi.org/10.46354/i3m.2019.vare.004

THE CONCEPT OF AUGMENTED REALITY APPLICATION FOR PUTTING ALIGNMENT IN GOLF

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ABSTRACT
Virtual and augmented reality (VR / AR) applications have successfully overcome the critical part of the Gartner curve. Investments are made and new products entering the economy. However, a very small percentage of society have also heard about AR glasses, mainly linking these with potential identity threats and personal data breaches. The authors dealt with the design of application of AR to improve golf skills by improving the putting technique. The above solution is complicated by requiring complex object recognition, tracking and advanced AR software designing.

Keywords: augmented reality, objects recognition and tracking, intelligent training, Android

1. INTRODUCTION

Modern technologies are becoming a routine component and affects every sector of the economy, as well as the leisure and sports industry. Although golf is quite conservative and also a relatively expensive sport, golf courses are always filled. Golf is becoming more and more democratic and spreading to wider social strata. Historically, the first IT products were allowed to record golf video and use them for training to ensure player error analysis and promotion of the right techniques. Laser-based range finders provided accurate distance detection in the golf course, but the build-up of RFID elements reduced the number of lost balls. For example, GameGolf (Winters 2018), and others, have come up with features to track the golf game by embedding the chips in golf clubs. Then, every swing is recorded in an app on a smart phone that gives data on the player (fairway accuracy, scrambling percentage, green in regulation, etc.).

In its turn, the GPS application allowed the creation of a digital map of the field of play, incorporating elements beyond the boundaries of direct vision, which made it possible to determine the choice of a golf club for a given shot. The player's technical arsenal was complemented by the attraction of Internet resources that provided weather. The emergence of virtual and augmented reality technologies not only created new opportunities for golf training, but also facilitated a real game.

Golf simulators entered the training. With the Indoor Golf Simulator (Winters 2018) it becomes possible to swing with real golf clubs, get stats and yardages on those swings while a simulated golf course or a driving range was projected on the wall. Usually, such a simulator was located in a separate room, which is determined by the safety considerations, as real golf clubs are used. The latest generation simulator PuttView Indoor (Exist Grant 2018) visualizes the ideal putting-line by beam as well as all information for putting practice directly on the green / floor.

Stationary equipment cannot be used on the real golf course, so usually either smart phone or virtual or augmented reality glasses are used.

One example is the VGolf solution (VGolf 2018), where a player sees the golf resort on the virtual reality glasses. The player can simulate the golf game and store data about club speed, orientation, ball velocity, launch angle, trajectory ball spin etc. Similar one is the Aguila Golf Virtual Reality Golf Trainer for Smartphones (Virtual 2018). Águila Golf is a virtual reality-based and mental game designed to walk a golfer through the toughest shots in the game. The golfer can visualize the shot before making it and is immersed in a 360 ° learning environment giving the opportunity to improve strokes through a precise shot evaluation.

Another VR application is the Vuzix-based golf swing monitoring system, where the player can see for himself and control his movements. The camera is placed on the field and simultaneously the video is transmitted to the player's glasses. Motion dynamics can be recorded and repeated to detect errors.

The Live View Golf Plus solution (Golf 2018) is used for training and improvement the skills of players. On the other hand, HoloGolf (Singletary 2018) developed by CapitoliaVR allows the creation of virtual ball movement tracks and assesses the possible movement of the ball on the VR glasses HoloLens screen under certain conditions. The solution can be usable for assessing the situations and playing out different scenarios.

Augmented reality features are often provided by the smart phone. The augmented reality software by Golfscape AR (Golfshot 2018) allows to display a location in the golf resort on the iPhone's mobile phone screen, displaying information on obstacles, holes and distances that are detected using the built-in GPS.

PGA Tour ARkit (LeFebvre 2018) for iPhone allows the golf course to be placed on the table. It allows to watch real-time shot trails appearing on select holes during live competition. It is possible to compare up to four different player shots in a virtual map of six different golf holes.

Golf Scope's (Golfscope 2018) is an iPhone application that uses computer vision to accurately understand the slope, elevation, and distance while putting the ball. It lets you draw the line between the ball and the hole. However, restrictions apply for this application. The player must first take both ball and the target hole for recognition, as the Golf Scopes AR software does not automatically recognize the objects.

However, lately, golf add-ons augmented reality glasses have become more and more popular. Nike (Mallis 2018) patented a set of AR glasses that would give real time analysis, including tracking the speed of the ball, how far the ball is carried and how long it is in the air. The application is programmed to detect the movement of the game ball. The ball is visible through the transparent display area of the glass screen.

2. GENERAL REQUIREMENTS MODEL OF AUGMENTED REALITY APPLICATION

New technologies are emerging as a product of interaction of engineering and society. In digital society practically all the systems are sociotechnical respecting interoperability of both parts – technical and social.

Technical systems usually are closed and determined, but social systems are open and stochastic. The architecture of the system (abstract or physical) is determined by the existence of logical and physical structures and the interaction of these structures.

The logical structure includes requirements, guidelines, algorithms, rules and personalize the particular system, while the physical structure includes hardware and software. The physical structure is the environment for implementation of the logical structure (Aizstrauta and Ginters 2013).

Virtual and augmented reality (VR/AR) solutions are typical sample of sociotechnical system and the same time digital technology.

In 1997 Azuma (Piekarski and Thomas 2003) determined the most significant AR features. It was defined that AR is a combination of real and virtual worlds, and at the same time interaction and activities in the 3D space.

Many of the AR applications have a common core architecture. In addition, many basic components and subsystems can be seen in different applications. MacWilliams, Reicher, Klinker and Bruegge (MacWilliams, Reicher, Klinker, and Bruegge 2004) offered a view on generic AR reference architecture based on the software engineering concepts. The aforementioned model explains the basic functions of AR though views the application of AR as a relatively closed system and involves separate VR functions, for instance, new 3D objects rendering that cannot be an AR attribute.

Modified reference model of AR application (Ginters, Puspurs, Griscenko and Dumburs 2018) involves two interoperable subsystems for visual recognition and voice processing. More detailed the visual recognition model will be discussed.

Visual recognition BPMN2 model comprises some basic activities: identification, recognition, tracking and visualization (see Figure 1).

The system visually identifies five different object types: face, marker, landscape, virtual object and text. All these objects form a common scene or visual layout (Nazemi and Burkhardt 2018). If in the simplest cases, such as the marker type object, the analyzer performs matching patterns in pattern data base, then facial or text recognition is a labour-consuming process, which may require analyzer training using artificial intelligence techniques.

The processed data are visualized on head-mounted display (HMD), replicated to other devices, or become available to other subsystems, including voice processing, since the recognized and / or translated voice content sometimes must be displayed in printed form.

These are the general principles of visual recognition subsystem design, which can be adapted to suit specific AR application requirements.

3. AUGMENTED REALITY ROLE IN PUTTING ALIGNMENT

Below, let's look at AR-based application that can be used in a golf game for putting. The player's task is to hit the golf ball with the smallest number of strokes. If in the initial conditions we assume that the ball is on the green but the relief is even, then the nearest path from ball to hole is a straight line called putting line (PL) (see Figure 2).

To hit the ball the golf club is used which name is putter. The putter centre is usually marked to ease the player's task. The player is in position to simultaneously match the putter and ball centers to the PL, as well as the centre of the hole. Unfortunately, players make mistakes in striking, even at a short distance, but the probability of sampling errors increases significantly over several meters. Of course, the shot force can be controlled only by the player himself, but the AR solution can help point the ball to the hole.

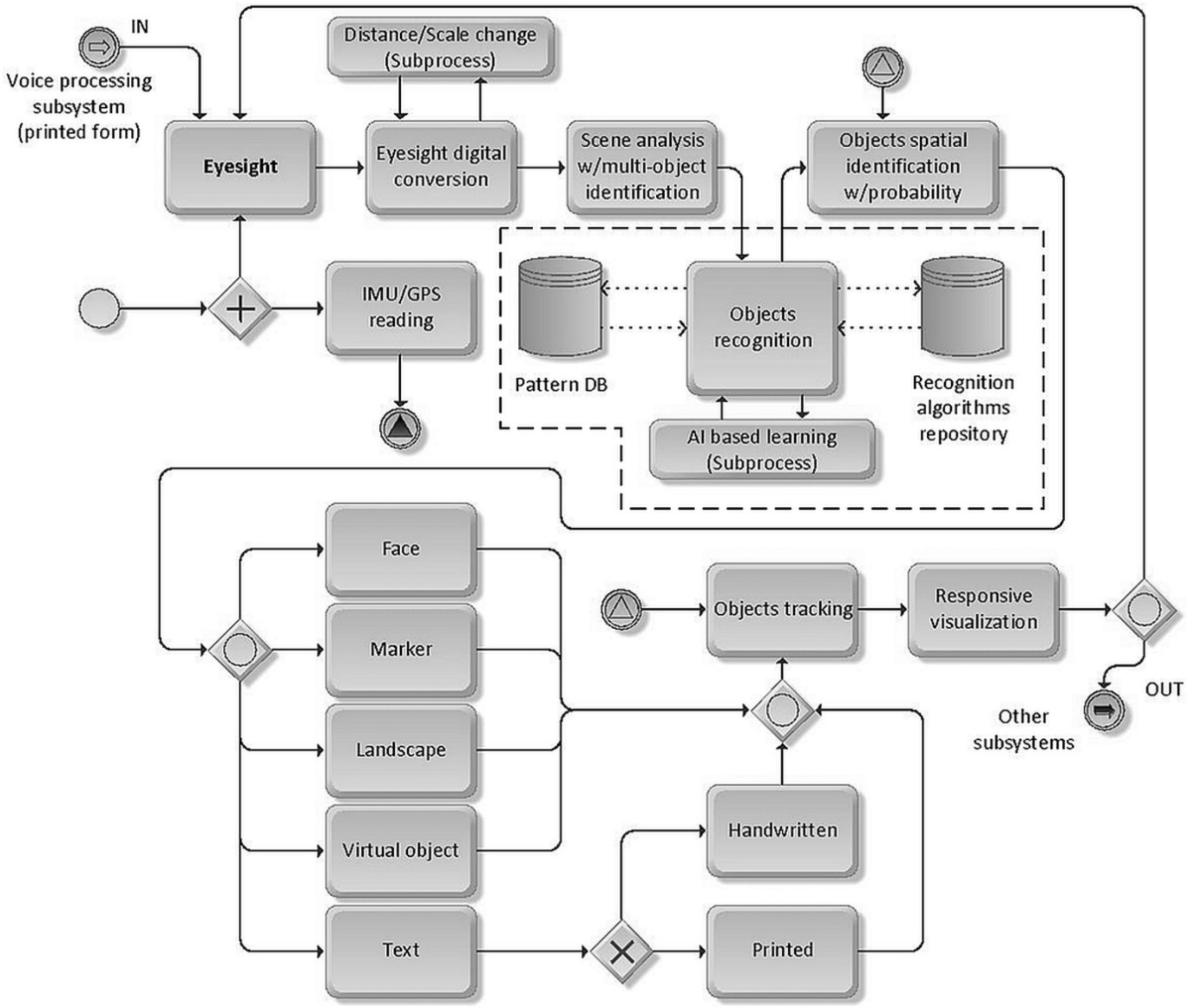

Figure 1: Reference Model of Visual Recognition Subsystem (Ginters, Puspurs, Griscenko and Dumburs 2018)

The player has AR glasses, where the web camera employs two lines on a real green image: putting line PL in red between the ball and the hole, and the X line perpendicular arrow in yellow to the putter centre. The X line owes the direction in which the ball will move if the player hits it from a particular position. If the putter changes the position, the line displacement angle α (1) also changes on the glasses screen:

$$\tan \alpha = (Y_2 - Y_1)/(X_2 - X_1) \quad (1)$$

$$PL^2 = (X_1 - X_2)^2 + (Y_1 - Y_2)^2 \quad (2)$$

As the player receives GPS data from the smart phone, it is possible to graduate the existing eyesight of the camera. Then you can calculate the coordinates of the important points and perform the putter tracking if we assume that the ball does not change its position. The player's task before strike is to stand so that the yellow arrow and red lines will overlap.

As an additional information, the player receives a distance PL measurement from ball to hole (2). This, of course, is not very important, however, an analytical player according to distance can adjust his shot power. Even more these data are gathered for further analysis.

The putting alignment AR software designed in conformity with conceptual model (see Figure 3) runs on an Android smart phone of the player. In fact, there are several parallel processes: Eyeshot coordinates grid computation, Hole data processing and Putter tracking.

After launching the application, putter, ball and holes are recognized. The nearest hole is selected, which is calculated on the coordinates grid map. Putter, ball and hole centers are calculated. Further a X axis yellow arrow is drawn perpendicular to the centre of the putter. And as well as the red PL, connecting the ball with the centre of the hole, is marked. The distance from the ball to the centre of the hole is computed, as well as the displacement angle α is determined. The putter tracking is parallel and real time process. The software operation is cyclical while the equipment is switched on.

The key factor is quality of recognition. The recognition quality is determined by AR software training opportunities. A simple comparison with standard markers in the database is not suitable because this method can only be used for ball recognition.

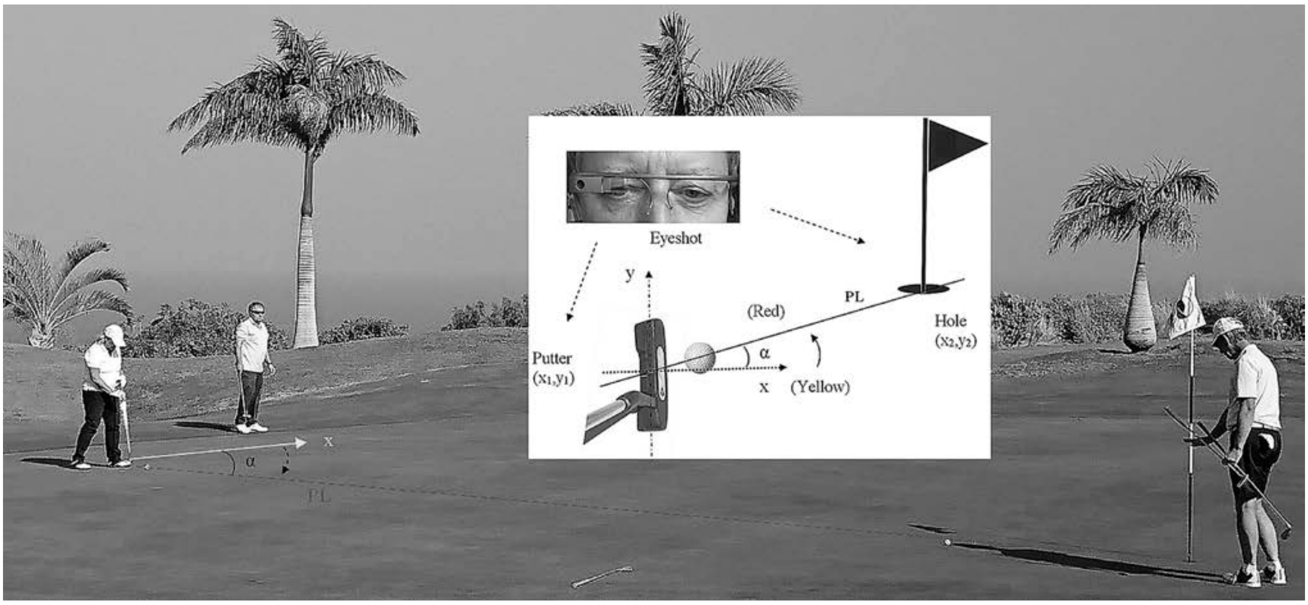

Figure 2: Visual Layout of Putting Eyesight

The hole, of course, is standard and the dimensions are well known, but the viewing distance and the angle of view can be very different. Therefore, the software should be sufficiently intelligent to achieve a correct result. It requires recognition algorithm training using the methods of artificial intelligence. The situation with putter clubs is analogous. Although the putter club is visible in direct sight, unfortunately, contrary to the hole, the shape of the putter is not standardized and is very diverse. The most complicated problem is the determination of the putter centre, which may not be marked on the club. Therefore there is a problem with comparing the appropriate AR marker and a typical image in the database.

Another problem that affects recognition is lighting, because the game can take place at different times of the day, may be shadows, reflections and image can be directly disturbed by the sun's rays. Putting alignment AR software is a local solution and cannot use the cloud services while respecting the fact that not all golf courses have appropriate mobile data coverage.

The player cannot voluntarily move the golf ball, as he has to shoot it from the spot to the green where the ball is located. It's relatively easy to create a demonstrator for the ideal situation, but it's quite complicated to adapt it to the real conditions of the game.

During the golf game, important statistical data are accumulated, and further analysis would help to improve the skills of the game. The accuracy of the shot depends on the distance of the putting, angle, terrain, quality of the green, wind and lighting. The total number of shots depends on the accuracy of each individual shot. The result is also influenced by time spent in game, distance travelled, player experience, resort complexity and other factors (see Figure 4). The above data can be analyzed using semantic methods (Nazemi et al 2015; Nazemi and Burkhardt 2019), which allows to show causal relationships between the essential parameters.

One of the key issues is the choice of appropriate hardware, which must be accessible for wide enough audience. First of all, it's a smart phone that works in the Android environment. However, the choice of AR glasses is rather complicated. The author's study of 2018 (Ginters, Puspurs, Griscenko and Dumburs 2018) identified several popular models that could be used in the AR application of the putting alignment. The models were analyzed using an integrated benchmark model that involved analysis of several technical requirements, such as weight, operating system, WiFi interface, resolution, RAM, additional memory, CPU, Bluetooth, battery capacity and price. Several smart glass models were analyzed: Recon Jet, Telepathy Walker and Jumper, Vue, Moverio BT-200, Jins Meme ES, ODG R9, SED-E1, Google Glass and Vuzix. The authors did not consider the HMD models that did not meet the conceptual requirements and are focused on the implementation of VR functions, such as Oculus Rift VR, Samsung Odyssey, and others. Of these models, only HoloLens (Microsoft 2018) was reviewed.

The choice of appropriate equipment is not straightforward, but it must be concretely grounded. The task does not involve complex and resources consuming procedures, such as face or landscape recognition, therefore a critical resource is neither performance nor resolution. Critically important parameters for putting alignment AR application are weight of glasses, battery capacity and price. The most powerful is the ODG R9 model, however, while respecting the requirements of smart glasses weight limits and sufficient battery resources, it was rejected. It was decided that Google Glass (Digital trends 2018) and Vuzix Blade AR (Statt 2018) are significantly superior in several categories.

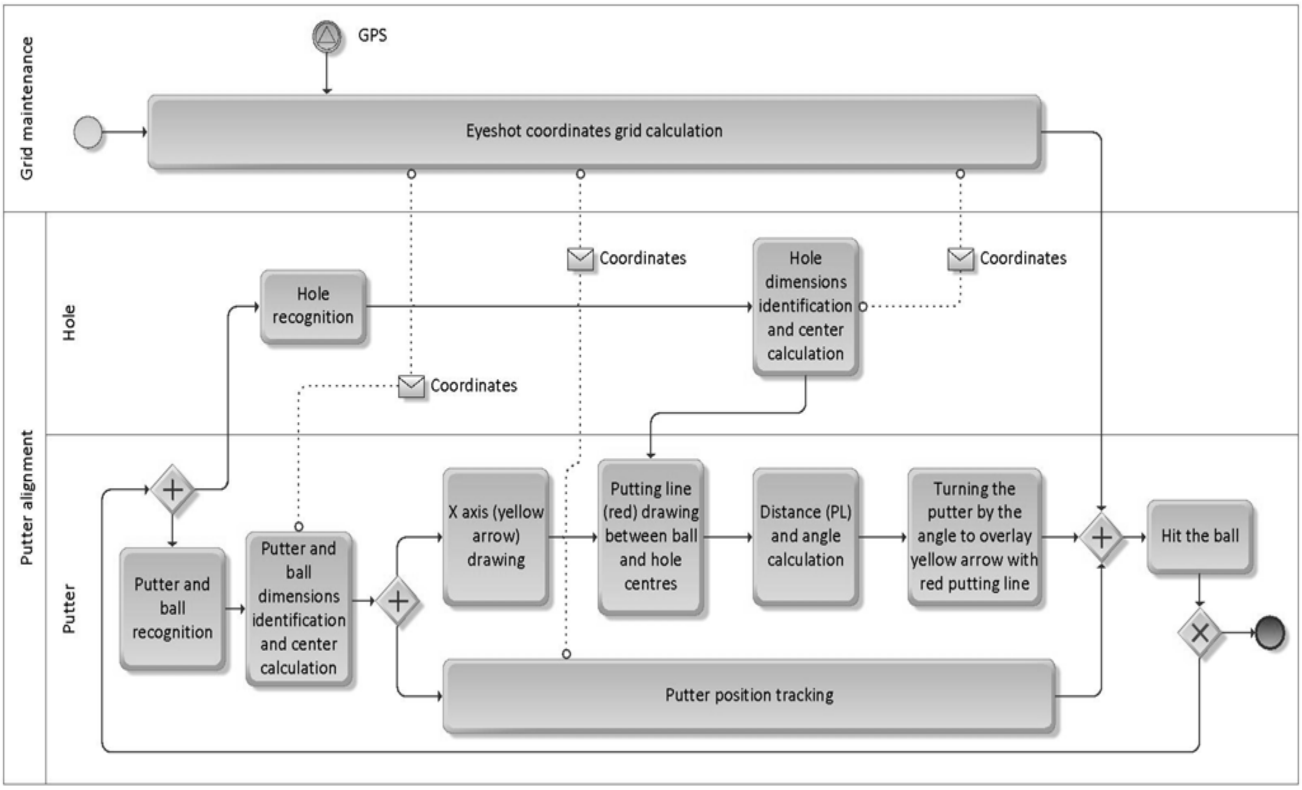

Figure 3: Conceptual Model of Putting Alignment

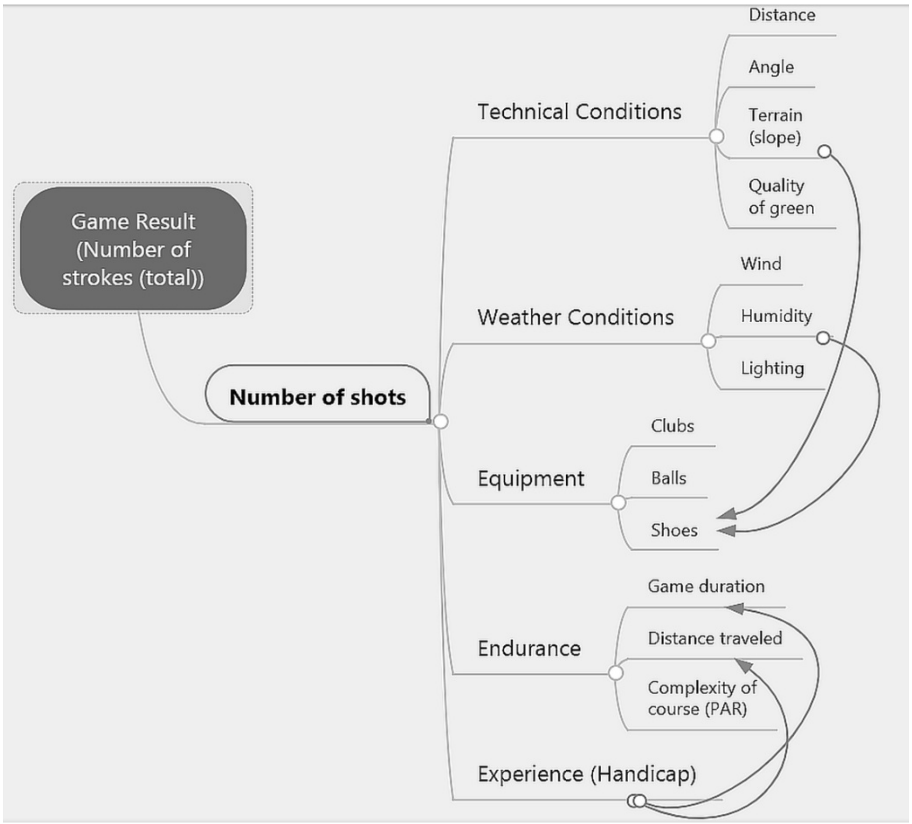

Figure 4: Graph of Essential Factors

The first version of Google Glass Explorer (Google Glass 2018) was released in 2014 (see Figure 5). The headset was criticized due to privacy and safety concerns. The reason was the capabilities to recognize the object and receive up-to-date information about it. Due to public protests, Google stopped the sale of Glass, which was renewed in 2017 when the new Google Glass Enterprise Edition was announced. Practically the main problem was the obvious features of technical surveillance that caused the discomfort of the surrounding persons.

Figure 5: Google Glass vs Vuzix Blade AR

The new Google Glass (Digital trends, 2018) version in 2018 is no significantly different from the Explorer. Additional storage capacity is increased to 32GB, but RAM up to 2GB. Intel Atom CPU performance is higher, but the battery capacity is 780mAh, which could provide 8 hours of operation, of course, depending on the operating conditions. Enterprise edition has GPS/GLONASS support and barometer. Wi-Fi Dual-band 802.11n/ac has a higher performance as the previous one. It has 8 megapixel camera, allowing 720p video recording, a hinge sensor, ambient light sensing and proximity sensor, 3 axis (gyroscope, accelerometer, compass) and a mike with headphone. Except of built-in touchscreen users have control via audio commands. The Google Glass weighs at least 43 grams. However, visually the glasses still remain the previous fashion of surveillance equipment. To reassure the society, Google Glass still places more emphasis on industrial application.

Vuzix Blade AR smart glasses (see Figure 5) (Statt 2018) provides a wearable smart display with a waveguide optics. Finally fashion meets technology in the wearable display arena. The technical parameters and functionality is close to Google Glass, however Vuzix glasses are significantly cheaper. The Vuzix Blade® Smart Glasses received 'Best in Show Overall' Auggie Award at AWE Europe 2018 held in Munich, Germany October 18-19.

In order to properly choose the Google Glass or Vuzix as basic solution for putting alignment AR application the sustainability simulation by IASAM model and state space analysis was done, based on both market information and practical experience (Aizstrauta and Ginters 2013; Piera, Buil, and Ginters 2013). The quantitative values of the evaluation parameters were, of course, subjective, and therefore the overall assessment was subjective. Both solutions were assessed as sustainable and usable for introduction, however Vuzix Blade AR had certain benefits related with equipment fashion, service quality, ownership and also is free of previous faults in public relations.

4. CONCLUSIONS

The golf game is a lovely and democratic way of active recreation without age limits that improve your health. For the beginner it is at least 3 hours and 7-8 km walk, which takes around 150 shots of golf ball. However, the spirit of the competition, which makes you want to play better, is also important.

One of the most significant components that can spoil the results of the game is putting. It is a complicated but rather routine procedure, in which, while maintaining peace of mind, the player must attack a golf ball hole, located a few meters or closer.

The main problem is the proper putting line detection and ball pointing to the hole. The good news is that these skills can be developed as a result of long-term training. But what to do for beginners and players who are not self-confident? The answer is augmented reality applications.

The AR solution offered by the authors allows the player to improve the accuracy of the ball's pointing through tuning the angle between the putter direction and putting line.

One of the most complicated phases of developing an AR solution is an appropriate choice of AR equipment, which must match the specificity of the golf game and also be sustainable. This equipment must not interfere with the player and pay extra attention of other players. So, those can be AR glasses, the design of which would not differ from ordinary sun glasses. In addition, those must be lightweight and comfortable, but the battery must provide several hours of operation. The virtual image must be designed and refreshed in real time, as the player's field of vision moves. Delay in data processing can cause discomfort to the player and affect the game. In addition, the eyesight must be wide enough. The application must be cyclical during the game and must not require any additional action of the player or some data entry. Because computing resources of glasses are limited, the application needs to work on a smart phone, which today, in most cases, works in the Android environment. Today, there are enough options for technical equipment, but sustainability factor is important, as glasses are not cheap. Respecting the above-mentioned functionality, restrictions and technical requirements, as well as sustainability simulation results, the authors given priority to Vuzix Blade AR glasses.

The adaptation of the beta version to real-game conditions may take some time. The main problems are the variety of putters, which affects the recognition of the object. One of the most complex problems is the sensitivity of the object recognition algorithm. A golf hole must be known regardless of whether there is a flag in the hole or not. The shape of the flag as well as the thickness of its stem must be ignored. The golf club must be recognized despite its variety of shapes and the centre of the shot must be calculated and visualized. This can be achieved through adaptive software training using artificial neural networks. Each user is provided with the ability to tune an individual algorithm's sensitivity factor. The quality of the application is also influenced by the peculiarities of lighting and the variable distance to the objects, which complicates the tracking (see Figure 4). The authors' future activities therefore will be devoted to AR software training and other related issues.

ACKNOWLEDGMENTS

The article publication is initiated by FP7 FLAG-ERA project FuturICT 2.0 (2017-2020) "Large scale experiments and simulations for the second generation of FuturICT".

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