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Designing Multimodal Augmented-Reality Approaches in Sports: Collaborative and Competitive Scenarios for Individual and Group-based Outdoor Interaction

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Abstract. This work presents a prototype for a multimodal and augmented (AR) based System designed for individual and joint activities in outdoor sports. Based on the need for social interaction and computer-supported collaborative sports and the decreasing physical activity across all ages, game scenarios for the context of outdoor sports were formulated and implemented with a head-worn multimodal AR interface. The System's innovation, flexibility, and multimodality found the basis for multiple use cases, such as professional and leisure, individual and group contexts. The technical infrastructure allows multimodal experiences while tracking and monitoring data such as movement speed, location, and heart rate. Within several game scenarios, players can cooperatively and competitively challenge themselves and other players to improve their physical activity playfully. This work is an inspiration and orientation for future research, development, and design of gamified AR exercising technologies.

Introduction

Physical activity (PA) has multiplicative health, social, and economic benefits [23], can create connections in many ways, and plays an essential role in many people's everyday life: physical activities have a positive impact on physical and mental health (e.g., [4,6]) and make a valuable contribution to social interaction, participation and individual mobility (e.g., [18,19]).

The use of health-related information and communication technology (ICT) such as exergames [11–15], health applications and wearables [16], as well as digital games and training programs [17] in different domains, has shown to improve activity levels and offer valuable potentials. Recently, virtual and augmented realities (VR and AR) are becoming increasingly visible in the field of health-related ICT and Human-Computer-Interaction (HCI) [3,7,22].

Tying in with new hybrid forms of exercise, as seen in the genre of Exergames and the example of Pokémon Go [1], the field of Computer-supported collaborative sports tries to make use of new technologies by expanding sports experiences through Visual Augmentations [20].

Users of sports games, for example, can receive additional information in real-time and in real-life environments during gameplay and experience a range of innovative forms of activity through augmented reality and mixed reality technologies (MR). AR glasses are already available in cycling, in areas such as movement training and rehabilitation [2] in billiard and table tennis [21], or sport climbing [8].

Prospective research directions refer to the opportunity to use AR more commonly on a recreational level, such as making sports more challenging by designing visual obstacles [21] or enabling the users to manually set their training, as is already the case in Augmented Climbing [8]. The related research stresses the importance of motivational, social, and acceptance factors to support individual and social sports activity [20].

The concepts of immersion and flow have been shown to increase use time and enjoyment and are essential for providing the perfect Sports AR experience [5,9,10]. Similarly, social collaboration and competition prove to have a significant effect on motivation as well as acceptance and desirability of the device [9].

Our work presents an AR-based system to foster physical activity, facilitate social interaction as well as create an innovative interface to access and promote sports and active participation across all ages and abilities. In this paper, we present an ICT-based System aiming to adapt sports activities and combine them with AR approaches and multi-user applications to create new multimodal scenarios in collaborative and competitive individual and social outdoor interactions.

System Overview

The designed and developed System's technical infrastructure consists of several interconnected elements: AR glasses, a smartwatch, and a smartphone allowing different multimodal input and output options (gesture and voice control). Depending on the area of application, the System can be used as a navigation and orientation system (near-real-time positioning) and synchronize movements of multiple players between the real and virtual worlds to support, for instance, the search of geocaches or Bluetooth beacons with audiovisual signals. The System offers more than one output channel (e.g., visual and acoustic) in terms of multimodal interaction. It provides the possibility to use different input modalities, e.g., speech input and touch control. Compared to existing AR interfaces in gaming contexts, the input modalities allow more embedded gameplay. Instead of using additional technical infrastructure such as a phone (e.g., in Pokémon Go), the interface is present in the user's vision and thus directly connected to the natural environment. Similarly, the wearable interface enables the user to move more freely and naturally without holding other technology.

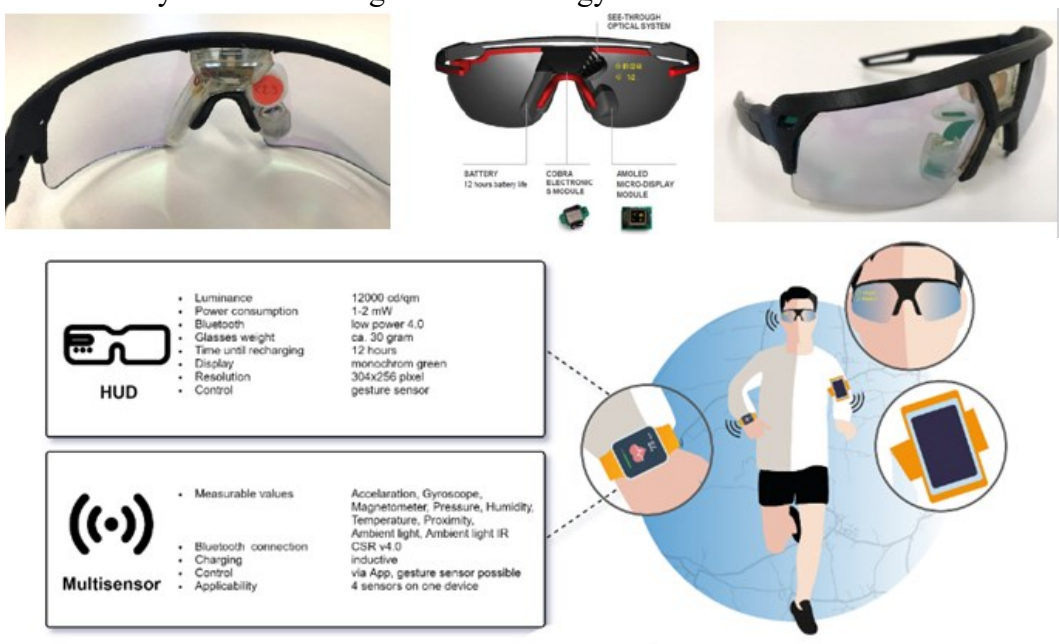

Figure 1: AR glasses with a monochromatic field of view (above) and System components (below)

The System consists of AR glasses and a smartphone application to command the System and store and analyze data (see Figure 1). The System supports multimodal input and interaction options (gesture and voice control in Figure 1) and offers multi-user applications in cooperative AR environments. The smartwatch can share fitness and health information to the application, displayed by the AR glasses, and stored within a cloud-based platform. The data can analyze

and present individual results, share achievements within a group and derive long-term activity trends from strengthening health awareness. The System can consider multimodal input mechanisms and enable two or more (inclusive) user input methods such as speech and gestures.

Multimodal Interaction, Interactive Prototype, and Game Scenarios

The multimodal systems will adapt to the user needs in a context-specific way, allowing them to be used meaningfully. We designed the System to ensure that the user is provided with the best possible combination of available modalities (gesture or interface interaction) to process a specific task before and during the training activities without needing to stop. For this purpose, the development of multimodal interaction fosters accessibility and increases the efficiency and ease of use, and the flexibility of human-technology interfaces. Depending on user skills or preferences and the usage context, different input and output formats are developed, which offer different advantages such as voice or textual chat for communication with other users.

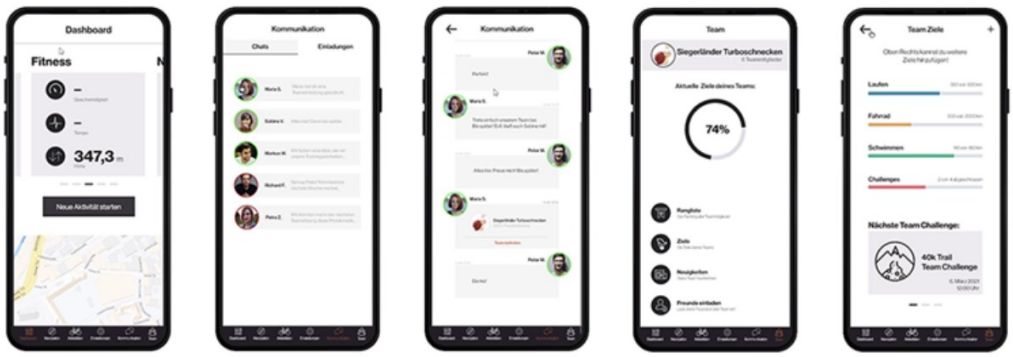

Figure 2: Interactive Prototype of the System Application

The application itself (see Figure 2) is structured like most popular apps many people use daily (such as Instagram and YouTube). The user always sees the current navigation menu at the top. At the bottom, the permanently visible main navigations bar is always accessible, regardless of where the user is and is designed with icons and texts aligned in a row. These elements are the main elements (dashboard, navigation, activities, settings, communication, team) of the application and should be easily accessible for the user to operate through different functions quickly. The control elements were placed where the users would expect them to be for user-friendly operation. Thus, the return arrow is always at the top left. The control elements are displayed uniformly to achieve consistency. The user can communicate with team members and other users in the general chat. The user can invite friends to an existing team or meet for a workout session or challenge.

In the "Team" section, the user can navigate other sub-menu items like rankings, goals, news, and inviting friends. The ranking functionality shows all team members, their rankings, and their points through workouts, challenges, and exercises. Every exercise generates points for the user based on the length and intensity of the workout. In addition, the user can set goals and challenges for the team so that each team member can review and participate in the challenge. The user can also promote different events and share the news with the team in the news section.

The technical infrastructure of the AR interface and app enables a multiplicity of possible game scenarios. The first scenario is called Ghost Run (see Figure 3). When the player can choose between different local routes to record a new time, the System will countdown from five to zero, and the System will track their activity. After completing the run, the player and other players on their team or friends list can see their route's time, pace, distance, and height meters. Suppose a player chooses to race against another player's best time. In that case, the AR interface will show continuous feedback in icons and timings on how the user performs compared to their competitor. After completing the run, the player will get an overview of timings and distances to evaluate how his performance varied in different parts of the route.

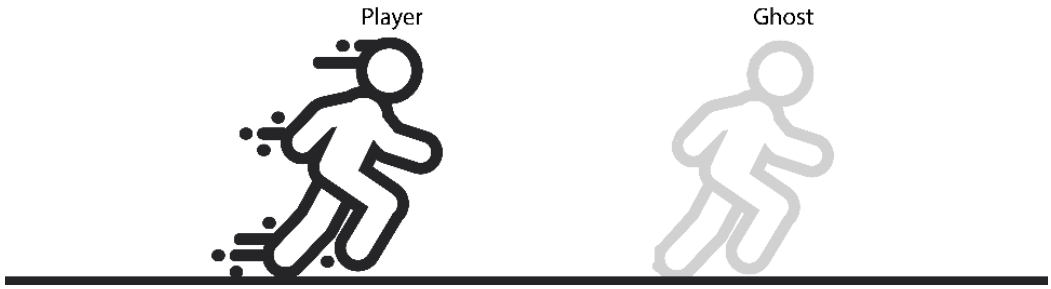

Figure 3: Ghost Run Scenario

The Knockout scenario (see Figure 4) lets players compete against each other synchronously in different regions on classified and comparable routes. The route is split into several segments. The slowest runner of each segment will be kicked out until only one player is left. The AR interface shows the player's current placement compared to the other players. If a player gets eliminated, they get a sound and icon notification. The other players also get notified that they survived the segment.

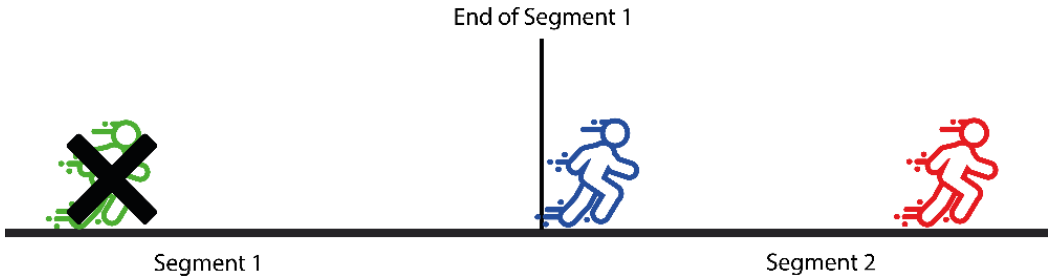

Figure 4: Knockout Scenario

In the Segments scenario (see Figure 5), players compete by running a route separately. The route is split into segments. The player who completes a segment the fastest time wins said segment. When the route is finished, the player that won the most segments wins the challenge. The AR interface shows in which segment the players are in. Every player's segment's time and win will be shown in the post-game lobby.

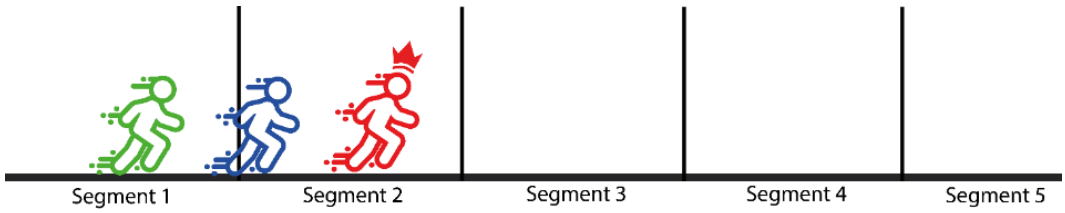

Figure 5: Segments Scenario

The Live Competition scenario (see Figure 6) enables players or teams to compete against other teams. Each player's performance on a route will be tracked and added up to a team score. The AR interface will show the player's and team's ranking compared to the other team. The fastest team wins, and the fastest player on each team gets an additional trophy.

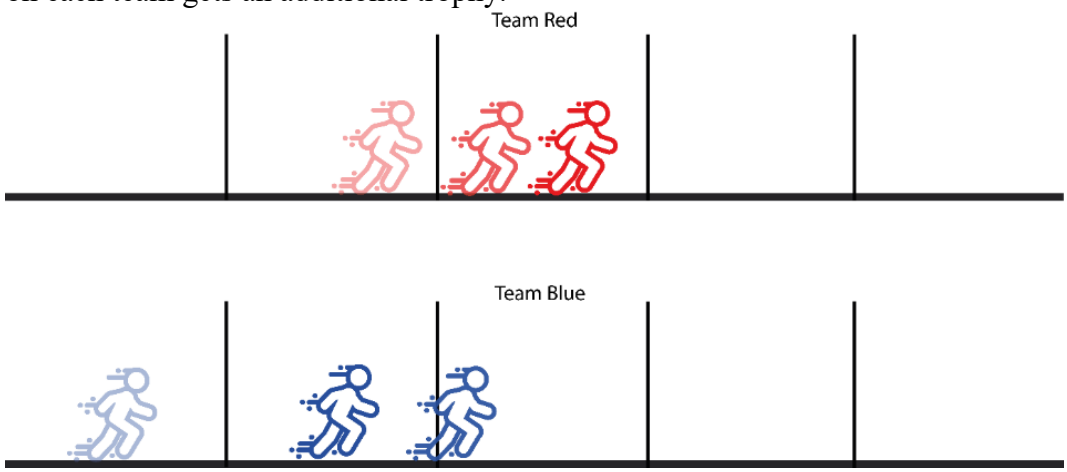

Figure 5: Competition Scenario

Conclusion and Outlook

Our work presents a multi-user and multi-device AR technology intending to make PA more enjoyable. Hence, based on an immersive and multi-user capable AR technology, an innovative, individualizable opportunity of movement training for health promotion is created. These multi-user sports- and exercise-related applications to be developed will be researched concerning their suitability for everyday use and user acceptance of AR systems. Further, their individual physiological and social-emotional effects will be investigated and evaluated in a proof-of-concept. The suggested challenge scenarios serve as a blueprint for other development scenarios such as an AR-based marathon, biathlon, or triathlon or interactive experiences-oriented discovery scenarios at the point of interest, such as AR-supported city tours in urban environments.

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