Use of Augmented Reality in Sport Performance Visualization: Media Tools for Prosumers

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Abstract—**This paper describes a proof of concept demonstrator and a prototype system for sport analytics, as well as data visualization designed for sport event spectators to get more insight on the athletes' performance. The demonstrator highlights fully scalable Augmented Reality (AR) based sport analysis data visualization for engaging consumers and sports fans, and gives them a possibility to become more appealing prosumers. The aim is to combine elements of professional sport event visualization with the crowd generated content and social media communications. The AR sport demonstrator consists of two main parts: a) an AR Sport application, and b) AR Sport HTML5 Web service. The AR Sport application is based on the embedded sensor, which is worn by an athlete to collect acceleration data, and Android software that analyzes movement and produces visualizations about the sport performance. The AR Sport service uses the NUBOMEDIA cloud computing multimedia platform with AR capabilities and augments a user generated video stream with athlete specific overlay data. The spectator can use the AR Sport service via a mobile browser and view the augmented video stream on his/her mobile device.**

Keywords-augmented reality; sport analytics; visualization; multimedia cloud computing

I. INTRODUCTION

Augmented Reality (AR) is a technology for overlaying artificial content to the real world view in real time. The mainstream AR applications have often been mobile device applications targeted for personal use, but, recently, AR applications have also been developed for industrial use and for maintenance and building visualization purposes. There exist fewer applications focusing on utilizing AR for real-time sensor information in specific Internet of Things (IoT) environments, such as in sports analytics, where digital devices are hidden in the environment to enable athletes to provide information on their athletic performance.

The rise of the IoT sensors and IoT environments brings a lot of digital information available for ambient environments, but efficient access to this information requires new type of user interfaces. AR will empower bringing the services and information visualizations of invisible digital world to our sight in real time through our mobile devices. AR can assist the use of digital services and the users in decision-making, being capable of representing the services' information directly in physical environments.

We have developed a prototype of service that is easily accessible and scalable for an audience utilizing IoT sensor data analysis and augmented reality visualization. In Section III, we explain how WebRTC based multimedia communication based on the NUBOMEDIA cloud platform with AR technologies were used in the demonstrator. In Section IV, we explain the functionalities of the AR Sports Web service that allows a sport event spectator to receive visualizations for athlete's performance analysis information augmented on the video stream. The innovation of the system is in visual pairing of the athlete's performance analysis and the AR service request, and in the use of the NUBOMEDIA cloud platform, where rendering of the augmented information for the video stream takes place on the server side. The system enables the real time visualization of the data utilizing the AR technologies, as well as a multiuser scenario in which many spectators can easily receive information about an athlete's performance.

II. STATE OF THE ART

The sports domain has recently started to extensively use sensors both in the amateur and professional level of athletes. There exist numerous solutions for monitoring the personal fitness and sports data from activity and physiological signals. These solutions are mainly used for monitoring and improving individual performance. Advanced sport analytics is using all kinds of data for creating the insights, and analyzing the team and its performance for the benefit of coaching. Visualization of the analytics for a variety of sports is also a well known topic in the research field for team and individual performance [1][2].

Recently, the miniaturizing of the IoT sensors and wireless signal components has also brought the sensors into the equipment, providing very rich data sources for athletic performance analytics. Examples include bats [3], balls [4], and footwear [5].

Personal fitness analysis gadgets [6][7] often display the real time analysis results on the device display or through a smart phone. Additional Web services or mobile device applications are also provided commonly for further analysis and tracking of the athletic performance and achievements

[7]. On the other hand, the IoT sensors that are connected to the sport gear are often used to produce force, position, and acceleration information that is either shown to the person after the action on e.g., a phone's display or reconstructed to the virtual animation of the event [3] [10].

For a long time, broadcasters have augmented visualizations of analytics on the sport feeds to create alluring sports visualizations either of game dynamics or of individual performance. For example, BBC has recently published a web article about these advances [8]. As the sports domain is increasingly interested in innovative and fresh tools for interactive visualization in different contexts and purposes from individual analytics to team performance, the topic has gained wide academic interest [1][2][12][13]. With this technology, we can bring similar informatics to the consumer devices on the sport events and videos. At the same time, the consumer can provide news feed to social media and even to professionals, as they are able to catch the moment with the analytics.

Since there are more data sources available, more attention needs to be paid to real time visualisation of sports data. In addition, developers should study what type of services can be built on top of the emerging technologies. Unifying IoT, AR and sport data analysis will provide a potential to create new services from coaching to engaging the fans of the athletes.

The first AR solutions running on mobile platforms were implemented locally on the client. Until recently, this has been the dominating way to implement mobile AR solutions and one of the well-known bottlenecks in delivery of the AR applications to end users. The WebRTC protocol [11] is changing the playground for multimedia communication systems that have AR capabilities by bringing standardized means of real time video communication to the Web applications. WebRTC allows use of AR services without a need for the installation of special AR-specific software components on a client device. Only access to Internet and HTML5 browser is enough. This tackles one obstacle for AR to become mainstream, as the population of supported devices is extremely large. In addition, this means Web-based development of AR applications is nowadays cost-efficient and it is easy to find expertise. There are also other approaches for Web based AR solutions, for example [14] and [15], but they are using a modified browser to achieve good computational performance for AR tracking.

In addition, requirements for computational power in AR have increased and so it has been natural to distribute the architecture. The advances in development of cloud services and infrastructures have offered solutions for distributed mobile platforms. Many commercial players already use distributed architectures e.g., Vuforia, but this is also an active research topic [16][17], too.

III. SPORT DATA VISUALISATION CLOUD ARCHITECTURE

A. NUBOMEDIA PaaS

NUBOMEDIA is a cloud and PaaS platform supporting development of real-time multimedia applications and a deployment of cloud based multimedia services utilizing WebRTC video communication. The platform provides interfaces that assist development of complex multimedia applications for multiple platforms including HTML5/Javascript, native Android and iOS mobile platforms.

NUBOMEDIA provides interfaces and core functionality for media streaming, processing, PaaS-management, virtualization and load balancing, and an application server for managing users' requests and controls. The platform's interfaces provide a modular structure for the core design and implementation, and tools for developers for using the platform's functionalities in their applications. This paper focuses on the application development capabilities of the platform, especially tailored to support AR visualization of the sport sensor data. The PaaS control functionality and resource management is described in more details in [18].

B. NUBOMEDIA Media Plane

The target of the NUBOMEDIA media plane is to provide comprehensive media streaming and processing capabilities that assist application developers to deploy real-time multimedia communication supporting one-to-one, one-to-many and many-to-many communication models, and processing of the video streams including transcoding, visual content analysis, augmented reality, adding overlay graphics and many other capabilities. The media capabilities are provided by the Kurento media server [19] component of the NUBOMEDIA platform. Kurento is an open source WebRTC media server targeted mainly to provide a Multi-Conference Unit (MCU) for WebRTC based end-user clients. Kurento also supports Selective Forwarding Unit (SFU) operations, but, in this case, many extended capabilities, such as media processing operations, cannot be efficiently utilized. In addition Kurento offers stream management and stream processing for WebRTC clients allowing clients to create different multiparty communication models that application developers can easily embed into their applications.

A particularly interesting feature of Kurento is its pluggable media processing architecture and the capability to manipulate the content of the served video streams. The audio/video stream inside the server can be routed to media elements capable of manipulating or analyzing the content, and thus, providing server side capabilities to provide rich application dependent modifications to the raw A/V streams. The media elements can be chained together. Thus, it is possible to create complex video manipulation processing chains simply by concatenating primitive processing blocks together. The default installation of Kurento contains a basic set of media elements capable of recording, mixing, augmenting, blending, routing and analyzing video streams, for example detecting faces from video streams. Application developers may extend the

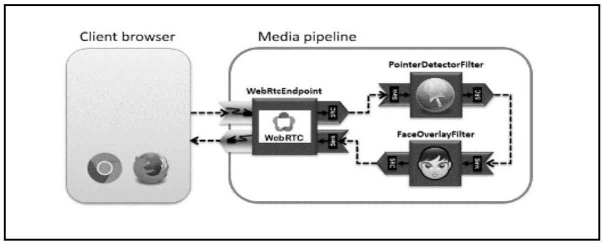

Figure 1. A NUBOMEDIA media pipeline example from Cheambe & al. [18]

media processing capabilities by creating new media elements. The Kurento framework provides a GStreamer based template to assist creation of application specific media elements.

Figure 1 presents a typical set-up for creating a processing and transmission pipeline for a specific multimedia application [18]. WebRTCEndpoints are used to connect the Kurento server to the WebRTC A/V streams that are transmitted between the client and the server. These endpoints can be connected to any media elements for manipulating or analyzing a stream before routing the stream back to the receiving clients. Kurento also offers client libraries for JAVA and Javascript to assist development of Kurento-based applications. It is also possible to control the Kurento server with WebSocket and JSON-RPC in other development environments.

C. Sport data visualization extension for NUBOMEDIA PaaS

The NUBOMEDIA platform provides a comprehensive basis for creation of multimedia communication applications. We extended the NUBOMEDIA capabilities for providing a framework for efficient development of applications that augment image data to video streams and in this way allows visualization of sensor data of athletes for their audience in different kinds of sport competitions. The requirements for such applications include distributed and scalable platform for managing large amounts of audience and athletic related sensor data. The framework supports development of Web based multimedia applications that allow the audience to use their mobile phones' cameras in capturing video streams of athletes and Web browsers in watching of augmented video stream. The augmentation contains measured performance data about the athletes of the sport competition. Depending on the requirements of each specific sport event and properties of the sensor data, the visualization of the performance data may be presented as augmented reality graphics or simple overlay graphics.

IV. Media Tools for Prosumer Prorotype Application

A. Use case of the AR Sports prototype

A long jumper Alan is participating in a local competition. His sport top has an AR marker printed on it and he is wearing an embedded sensor. An Android mobile unit is next to the long jump track and, thus, does not disturb the athlete. Lisa is an enthusiastic fan of long jumping. She is watching the competition and wants to know all the facts. She takes her smart phone out of her pocket and turns on the browser for navigating to the Web page of the AR Sport service. She is pointing the camera at the athlete and the marker on the sport top. The marker is detected by the AR Sport service. Alan makes his jump and, as long as Lisa points the camera at the marker, the analysis of the jump performance is augmented on the video feed and is visible on the screen. Lisa shares the video clip immediately via the social media to celebrate the successful performance of her idol. In addition, Lisa can easily get more detailed information of the different performances, which encourages engaging in sports experience as a fan.

B. Proof of concept instance

The high level architecture of Sport Analysis performance visualization prosumer tool is depicted in Figure 2. The usage of the system is based on two main parts: 1) IoT sport data analysis and visualisation of athletic performances and 2) Use of AR Sports services.

IoT sport data analysis and visualisation of athletic performances is depicted in the upper half of Figure 2. This process collects acceleration data from the sensors, analyses the acceleration data, and creates a visualisation canvas for the athletic performance.

Use of AR Sports services is depicted in the bottom half of Figure 2. The sport spectator launches a mobile browser on his/her mobile device and navigates to the Web page of the AR sport service in the browser. The Web page opens a camera view and transmits the video feed to the NUBOMEDIA server. The spectator can watch the augmented video stream on his/her device or NUBOMEDIA supports distributing the video stream to a larger audience.

The system presented in Figure 2 contains the following components:

Athletes – An athlete will have an AR marker (e.g. a marker that is attached to his/her t-shirt), 3D accelerometer sensors, a mobile device (an Android device) within the Bluetooth range, and the IoT sport data analysis and visualisation application installed to the device that acts as a mobile computation node.

Sport spectators – A sport spectator uses the AR Sport service on a mobile device with a browser (e.g., in a Firefox browser) supporting WebRTC and Web connection to the NUBOMEDIA service through the Web page of the AR sport service. The following paragraphs describe the core parts of the architecture in more detail.

AR Sport application is an Android application that scans available BLE (Bluetooth low energy) devices, which are in our case VTT Tiny Node sensors [21] (in Figure 3) that are used for measuring the athlete's performance. The Tiny Node consists of integrated sensors including 3D accelerometer, pressure, temperature, and humidity sensors. The AR Sport Application allows selecting a desired Tiny Node sensor and for the selected Tiny Node sensor,

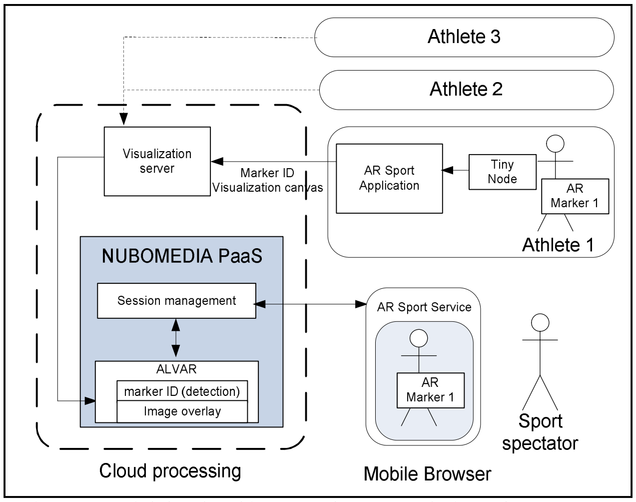

Figure 2. High level architecture of Sport Analysis performance visualization prosumer tool

the application opens a Bluetooth connection. For IoT sport data analysis, the application will first send a message to the Tiny Node for activating collection of acceleration data in the sensor that, in turn, delivers the collected sensor data via Bluetooth for the AR Sport application. The AR Sport application contains analysis and visualisation components. In the prototype, the analysis component uses the acceleration meter data achieved form the Tiny Node sensor. The analysis is performed as follows: recognition of jumps and direction of the jumps by using sliding averages for the x- and y-acceleration data. The jump power is estimated by using maximum vertical acceleration in percentages compared to the best jump of the athlete in the current use session. These values are visualized as depicted on the left in Figure 4. The visualisation shows the direction of the jump (arrow for the jump), name for the athlete, running number for the jump, and power of the jump in percentages compared to the best jump in the use session.

Visualization server receives the produced 2D image visualization canvas by using the HTTP post method. The visualization server handles the connection of AR marker ID and the image that are further passed to the NUBOMEDIA PaaS.

NUBOMEDIA Paas is responsible for real time video service utilising AR capabilities of the VTT *ALVAR* library [20] that supports marker, planar and 3D tracking based tracking, accurate pose estimation, two types of square matrix markers, and recovering from occlusion. An example of an ALVAR marker is depicted on the left in Figure 3. The NUBOMEDIA service detects the AR marker from a video stream coming from sport spectator's device, and pairs the information of corresponding AR marker with the visualisation of the athlete's performance and augments the image on the video stream. An example of the visualization of acceleration data, video stream from AR Sport Service and augmentation is depicted in Figure 4.

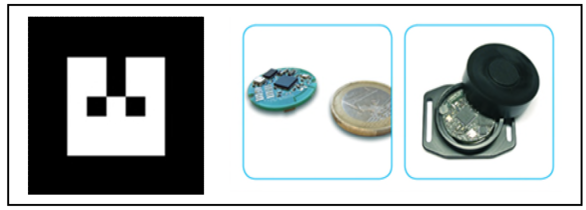

Figure 3. Example of ALVAR AR marker on the left and VTT Tiny Node sensor on the right.

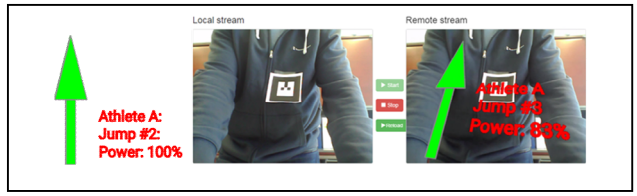

Figure 4. Visualization example of AR Sport Application

The sport spectator can access the analysed performance results through the Web page of the *AR Sport service*. When (s)he access the Web page, the camera of the mobile phone is turned on and the video is streamed to the NUBOMEDIA server by using the HTML5 camera interface input and WebRTC streaming. The Web page is created by an application server that also initializes the AR processing chain in the Kurento media server. The NUBOMEDIA service analyses the video stream and when an AR marker is identified, the NUBOMEDIA service renders a corresponding visualisation canvas of the athletic performance over the video stream and sends the stream back to the browser.

The current prototype implementation assumes that there is only one athlete with a marker and performance visualization that is overlaid on the AR marker. In the future, the system should be extended to use multiple AR markers on separate athletes as the system is capable of visual tagging and pairing of multiple athletes. As each AR marker can be uniquely identified and mapped to the ID of the Tiny Node sensor of an athlete, the corresponding data can be overlaid on the each individual AR marker or an another AR tracking target. In the current implementation, the augmentation is placed on the top of the marker and can be seen only when the marker is visible in the video stream. As the athlete moves, this could become a problem when the marker is out line of sight, but this could be avoided by developing more sophisticated service and user interface. For example, the marker can be used as a trigger for starting the augmentation of the athlete's performance information. In addition, another problem could arise from multiple markers on the camera view as multiple visualizations in the video stream would not be reasonable on a small screen. In this case, the spectator could be given control for choosing the athlete on the display the athlete whose information will be augmented and the system would visualize one performance at the time.

V. Conclusions

This paper describes the AR Sport demonstrator system that utilizes NUBOMEDIA PaaS for multimedia application development. The AR Sport service identifies the athlete and his/her sensor based on an AR marker and connects the visual tag with the visualization canvas created by the IoT sport data analysis software on an Android device. The sport event spectator is able to see the analysis results on the top of the athlete in an augmented reality video stream in real time. The demonstrator showcased that we can create cloud based AR services for sport events for creating totally new type of engaging experiences for the enthusiastic fans. The increasing number of sensors worn by athletes will provide new opportunities to offer visualization applications for the spectators, and it creates a possibility to consumers, such as sports fans, to become more interesting prosumers in sport events. The linking of the information allows tagging of video streams with local sensor data and also with additional information, such as an athlete name, nationality, ranking etc. Future plans include enhancing the user interface based on wider testing and integration of advanced performance analysis on the AR Sport application.

Acknowledgement

This work has been funded by EU- NUBOMEDIA (FP7-ICT-2013-1.6., GA-610576) project and VTT's internal Productivity with Internet of Things research program.

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