# GIS AND GPS BASED PHOTOREALISTIC REALTIME SIMULATIONS FOR TV PRODUCTION

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***Abstract***

*Outdoor sports television broadcasts often require additional information besides the video images to enhance the understanding of the status of the competition. A realtime photorealistic simulation of the ongoing event based on the localization provided by a GPS and the terrain information in a GIS is proposed in this paper. The system developed is based on the high performance graphic toolkit OpenSceneGraph for the generation and rendering of the simulation in realtime. It also considers the adaptation of the output for broadcasting and streaming without requiring any special hardware what makes it affordable also for tight budget producers.*

*Keywords*: TV broadcasting, Virtual Reality, GIS, GPS, Digital Video.

## 1. INTRODUCTION

Sport event broadcasting often needs to enhance the information obtained by production cameras. Outdoor sport events are not easy to be covered by cameras due to the big extension they can take and non-passable areas they may take place. Therefore, expensive solutions as hiring special vehicles such as helicopters, boats or quads are usually taken. Nonetheless, they cannot always offer the views so that the users could understand exactly what is going on. There is a need for new technology solutions for low budget productions or sport events with non reachable locations by the cameras.

The solution presented in this paper produces a 3D photorealistic simulation in real time that can be broadcasted so as to offer unachievable views or best competition understanding views. Our system is based on GPS information of each participant and terrain information taken from a GIS. But, apart from simulations, it can also supply further information such as the distance to the finishing line, the geographic interest points of the nearby, the terrain profile of the competition and so on.

## 2. SPORTS EVENT BROADCASTING

Outdoor sports broadcasting has specific requirements that differ from other outdoor television productions:

- The action covers a vast area

  Most of the sports competition that take place outside a stadium such as bike races, marathons, sailing or golf extend over a vast area. This makes more difficult the continuous visual tracking of the participants without the hiring of special vehicles to carry the cameras as helicopters, boats or quads.

- The points of interest (participants) may do large displacements

  When the displacements of the participants are very large, it is not easy for the cameras to take the best views that help the watchers to keep track of the competition development. Moreover, it is highly probable that there will be unreachable locations due to the relief of the terrain or the conditions of the roads.

- Required graphics are specific to each sport and need realtime updates

  For proper coverage of sporting events can not miss a complete graphics module which reports the updated status of the competition, intermediate results, developments of the participants, incidents, times, etc. Several systems for graphics and character insertion exist, but apart from very specific and expensive systems, low cost production systems provide limited graphic capabilities not enough to cover a sporting event.

These specific features turn sport events into costly television productions in terms of the required widespread deployment and the need of expensive resources. Yet, both broadcasters and sponsors are aware of the great audience sports competitions have. Therefore, they are interested in new production paradigms for their broadcasting in order to enhance the quality of the content and ensure profitability.

Virtual reality techniques have been first used in sports broadcasts for overlaying virtual advertising. Virtual advertising is the use of high-power computers to place still or video images into live video broadcasts in real time so that they look as if they are part of the original scene. Television exposure is the advertisers' most important benefit of any small advertisement, for which they sometimes pay millions of dollars per season. There exist expensive solutions that require a profound calibration process to produce accurate and realistic virtual elements for live broadcasts such as the products offered by VizRT[1]. However, current low-cost graphics hardware has proved to perform well in countless applications for realtime rendering [1]. The combination of low-cost hardware with image analysis for automatic calibration has arisen more affordable and flexible approaches concerning virtual reality overlaying.

Apart from virtual advertising, computer vision techniques can help the sports broadcasters to illustrate, analyze and explain the competition by the generation of images and graphics that can be incorporated in the broadcast. This provides visual support to the commentators [2] and enhances the comprehension of the audience. There also exist some approaches that, aided of image analysis, segment people or balls from the background and estimate their 3D position in realtime (e.g. tennis Hawk-Eye [3] unpublished [4 ] or Viz Arena[1]).

In this paper an approach for outdoor sports events simulation in realtime is described. The real localization of the participants is taken from GPS devices and a 3D scenario is built based on GIS layers (elevation data and ortophotos) in order to obtain a photorealistic view. There are some sports like bike races, marathons, triathlons, rowing races or rallies where the awareness of the geographic localization of the images, the relative position between the participants or the distance to the finishing line helps to understand the status of the competition. Furthermore, this GIS based simulation framework can also estimate and publish elevation related information such as the degree of the slope, covered distance, distance between participants and so on.

## 3. GIS AND GPS BASED FRAMEWORK

The realtime photorealistic simulation requires the development of a high performance graphic application. On one hand, the 3D scenario composed of participants and 3D terrain objects must be defined. On the other hand, the rendering of the scenario according to the view point selected must be carried out. The rendering is a time demanding issue since it is the computational process of generating an image from 3D information. A terrain object itself contains a great amount of polygons that the rendering process should manage. Thus, the graphic application needs to be designed on top of selected graphic toolkits for speeding up the rendering task.

The core of the framework is based on OpenSceneGraph[2], an open source 3D graphics programming platform. It is widely used on virtual reality environments due to its support for many performance increasing features like OpenGL support, view fustrum, small feature and occlusion culling, multi threading and database optimization. The definition of the scenario and the rendering engine have been developed on top of it, in fact, different plugins or modules have been developed around OpenSceneGraph core to ensure a better compliance with the requirements of the framework.

The process starts loading a digital elevation model (DEM) and ortophoto based pre built 3D terrain object. Although the great size of the entire model, paged database and level of detail performance techniques enable the platform dealing with all the polygons in realtime. The terrain object is the base of the selected sports scenario and participants and other related objects are loaded on top of it.

For a realtime positioning of the participants in the 3D scenario, a GPS reading driver has been developed. It decodes the raw sentence coming from the participants and performs a world to local coordinates´ conversion in order to place

[1] http://www.vizrt.com/

[2] http://www.openscenegraph.org

their equivalent virtual models inside the 3D scenario. Additionally, buffering and low pass filtering techniques have been introduced to avoid displacement flickering when GPS glitch or small data blackouts happen.

A virtual camera is also defined whose six degrees of freedom can be manipulated from a production interface. This can be controlled from diverse implementations, being the joystick and midi tables the most common ones. This way, the production director can choose the viewpoint that best fits the understanding of the audience. The director takes the control of the camera as if it were a helicopter. Moreover, predefined points of view can be prepared beforehand and switch between then in realtime as if they were independent camera inputs.

If required, additional graphics can be overlaid to the scenario with the aim of enhancing the watchers' understanding of the competition. It is possible to superimpose a road map coming from a GIS-vector layer, extrude 3D buildings from a shape file or display custom geometries to represent the distance differences between two participants or their trajectory trails.

Finally, the scene graph engine processes all the geometry and layers to render the output. This is a costly computational process, so in order to achieve the results in realtime some optimization tasks are carried out in the GPU. View fustrum culling defines the volume visible by the virtual camera and discards all the elements that laid outside, as they will not be visible in the final image. In this same manner, occlusion culling handles the polygons that are occluded because they get behind other opaque objects, and small feature culling gets rid of the objects that do not contribute to the final image because they are very small in comparison with the surrounding objects.

Once the final rendered image is ready, it is necessary to link with the corresponding output module. Broadcast module is the responsible of adapting the signal properties to match the standard broadcast specifications. This is accomplished through a SDI card (Blackmagic DecLink Studio[3]) that features a PCI Express connection port to manage the bandwidth required in a HDTV emission. Technically, it is important to accelerate the data transference between the GPU and the SDI card. That goal has being achieved by an advanced OpenGL method called Pixel Buffer Objects (PBO). It is used to render the output to an intermediate frame buffer and then asynchronously move this data to the SDI video card.

On the other hand, the streaming module relies on FFmpeg libraries to encode the output to be transferred via web. Render To Texture (RTT) method is used to blit the final image into a texture and then it is split into several blocks to encode to H264 using multithreading in a streaming compatible MPEG-4 [5] format.

The relationship between all the described modules of the presented framework is synthesized in **Error! Reference source not found.**.

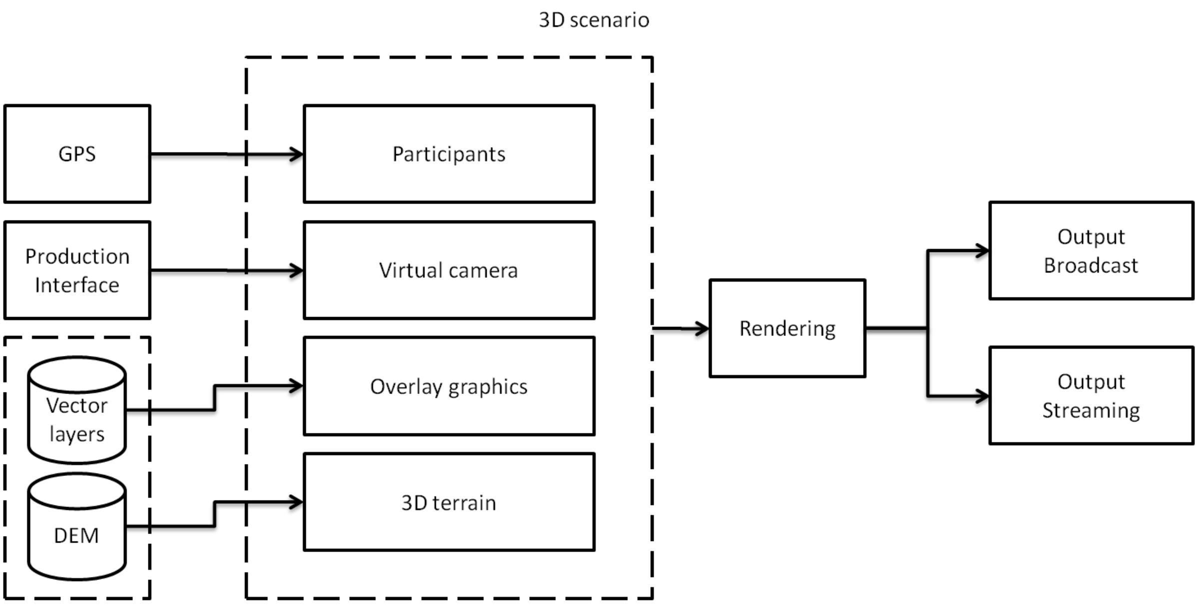



*Fig. 1 Architecture of the sports event simulation and broadcasting in realtime.*

[3] http://www.blackmagic-design.com/

## 4. SETTING UP AND RESULTS

The described system was designed to generate realtime outdoor sports simulations so different competitions were selected to test and validate its performance in real broadcasting environments. The sports must have taken place in vast areas, a GPS-based localization system for the tracking of the participants had to be feasible and the local broadcaster (public television of the Basque Country, EiTB[4]) needed to have interest in producing it.

With the aim of validating the platform in aquatic environments were selected regattas. Rowing races are a pretty followed sporting event in the Cantabrian Sea. For terrestrial environments, running and bike races where selected due to their having the largest audience in the region. The Behobia-SS[5] half marathon, the Tour of the Basque Country and the Bilbao Triathlon[6] were the chosen competitions.

The localization system was provided by G93 Telecomunicaciones[7] (microwave link services for TV and sports) and it consisted of a GPS device and a transmitter. Sometimes the GPS sentences were sent to the ground station through the wireless communication technology General Packet Radio Service (GPRS). At other times, they were multiplexed with the images of the video cameras and sent by OFDM (Orthogonal frequency-division multiplexing) radio link. On all occasions, the GPS sentences were updated every second at the ground center. However, television viewers had a perception of continuous participants movement thanks to the algorithm implemented to predict the movements the participants made during that time. This algorithm is adaptive, in other words, it takes into account the participants' previous positions, speed and orientation [6].

### 1. Rowing race

Rowing races are commonly broadcasted aided by a helicopter. However, the pictures that the helicopters take do not always correctly show the boats' relative positions (Fig. 2). This time proved to be of much help the realtime simulation system since the virtual cameras provided views which helped the understanding of the competition more than the physical cameras' views (Fig. 3).

The additional information added also provided highly relevant information. The channels are regulated in the competition and the organizers place beacons on the sea marking the start and end of each boat's lane [6]. Drawing the lanes in the virtual scenario improved the understanding of the competition. These lanes were also labeled with their respective dynamic boats' name for their better identifying.

The complete localization device that included the GPS and the transmitter was mounted on the stern of each boat.

### 2. Marathon

This setup was prepared for the 47th Edition of the Behobia-San-Sebastian, a race with 25000 participants. Two motorbikes equipped with a video camera and a GPS receiver transmitted the images and position information to the central unit through a - radio link. These motorbikes followed the head of the race and the chasers so both groups could be displayed on the simulation.

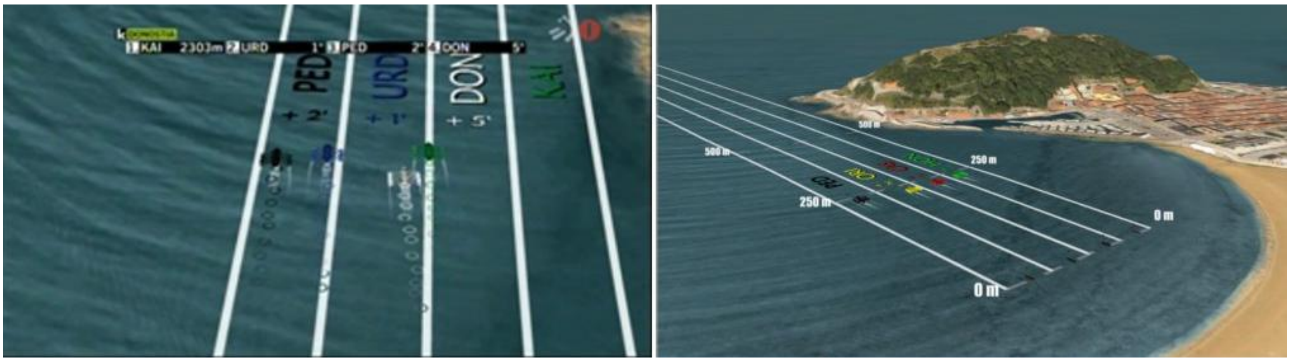

*Fig. 2 Images captured from a helicopter in a rowing race.*

[4] http://www.eitb.com/

[5] http://www.behobia-sansebastian.com

[6] http://www.bilbaotriathlon.com

[7] http://www.g93.es/




(a) (b)

*Fig. 3 Some views created by the system, in (a) the output after being broadcasted is shown.*

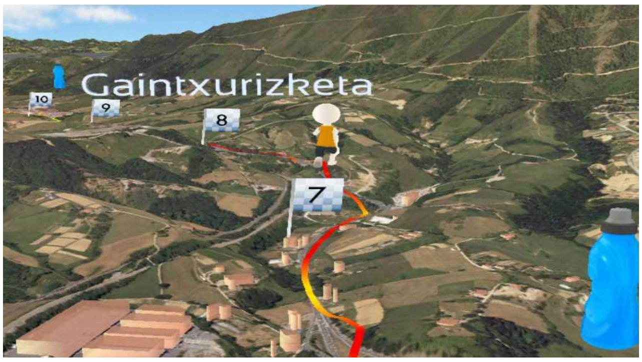



*Fig. 4 Realtime simulation of the marathon event.*

Fig. 5 Realtime simulation of the triathlon event.

The additional information designed for the marathon consisted in overlaying objects on top of the terrain 3D-model that helped the interpretation of the localizations (Fig. 4): the race route with different colour scheme to represent the variations in the relief, the most characteristic interest points (race's kilometric points, provisioning points, etc.) and main village names. On the other hand, an altimetry chart was also generated based on a DEM and previously generated race route vector layer where the positions of the participants were shown in realtime.

## 3. Bike cycling and triathlon

Using a similar setup like in the previous case, two new competitions had been broadcasted: the Tour of the Basque Country 2011 and Bilbao's triathlon. Once again, two motorbikes equipped with a video camera and a GPS receiver transmitted the image and position information of the followed competitors and at the swimming stage a catamaran was also used for that purpose. The virtual terrain included an overlay with the race's route and kilometric points, but this time the 3D objects representing the participants could be switched in realtimedepending on the competition's stage (swimming, cycling or running) (Fig. 5).

## 4. Results

In all three implementations, the system worked perfectly in realtime and the output signal was integrated on the professional platforms in order to broadcast live. The public television of the Basque Country (EiTB) has been making use of it in the broadcasting of these sports from 2006 to 2011. It confirms that the described system is a valid application for enhancing outdoor sports broadcast and in addition it complies with all the image requirements of video broadcasting standards.

The usability of the system to broadcast other sports would require the adaptation of the localization system to keep track of the real position of the participants along with the redefinition of the 3d scenario: new 3d objects for representing the participants and new designs for the specific additional information to be shown.

The GPS-based localization system used in the testing was too heavy to be carried by runners or cyclist. The weight was mostly owing to the transmitter. Yet, there exist lighter GPS devices that can be accessed via internet without the need of heavy transmitters. This solutions would provide more accurate positioning, will not require motor-vehicles with a GPS to follow the participants and more participants could be tracked.

## 5. CONCLUSIONS

In this paper a complete realtime photorealistic simulation framework used for sports event broadcasting has been described. The system includes the entire value chain of a television production: data capturing, processing, video generation and publication of the output. The most outstanding features that make it suitable for the nowadays needs of television producers are the lack of high hardware requirements and the realtime behaviour. The obtained results have been validated by the integration of the system in the public television of the Basque Country (EiTB) at row racing, bike racing, triathlon and marathon broadcastings from 2006 to 2011.

The use of GIS has enabled both the photorealistic view of the realtime simulation and accurate information concerning the status of the event. Direct access to the elevation information and vector layers about the trajectory of the competition permit computing this accurate status information. They also permit designing more realistic interaction of the virtual participants with the terrain object.

The system has been used to improve outdoor sports events broadcasting since it can provide views of the event that enhances the comprehension of the competition and can add additional information to the simulation. Yet, it can also be used as the unique system for broadcasting far or unreachable areas when hiring special vehicles to carry the cameras cannot be afford due to the tight budget of the production.

GIS and navigation systems (GPS in this case) can be used for realtime virtual geographic environment generation covering the needs of knowledge areas far from cartography or environmental analysis. In this paper an approach for sports production has been presented but other areas such as weather, cultural heritage or e-learning would also benefit from their usage.

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