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Using 3D and information visualisation to improve perception and facilitate situation awareness

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Abstract

CSIR engineers are developing a 3D viewer library called Sentience3D. The goal is to aid users and developers of simulations in building the visualisation tools they need to achieve the required level of situation awareness in their virtual environment simulations. The library makes use of open source building blocks and is itself moving towards a Lesser General Public Licence (LGPL). Online or offline simulation traces are used to populate a virtual environment similar to Google Earth with 3D representations of all the simulation entities. The virtual environment is then visually augmented with additional information such as entity relationships and model state.

Having an adequate level of situation awareness is very important for decision makers in fields such as aviation, air traffic control, and military command and control. It is, however, of equal importance to have a high level of situation awareness when attempting to make sense of and use complex simulation traces and results. This paper and the accompanying poster describe the long-term vision for 3D visualisation, some use cases and the design of Sentience3D. Instances of impact in the domains of the current SANDF and international clients are also presented.

1.Introduction

1.1 Background

The 3D visualisation capability has been gaining momentum within the CSIR defence domain for many years. At DPSS Optronic Sensor Systems (OSS) the possible use of 3D visualisation to present simulation outputs was realised in the early 2000s. OSS performed many engagement simulations where an infrared missile is launched towards an aircraft equipped with countermeasure flares. Visualising the engagement using only 2D plots of missile and aircraft positions proved difficult. An initial 3D visualisation tool called "Flight Path Viewer" was constructed using the then current Silicon Graphics (SGI) Open Inventor toolkit. The visualisation was very basic, e.g. the ground plane was represented by a rectangle, but it allowed the user to step to a certain time point in the simulation and get an idea of the 3D relationship between the objects in the scenario.

Development of Open Inventor did not progress much during the following years and newer technologies became available. The OpenSceneGraph project, which is a scene graph programming interface on top of OpenGL, was identified as a new open source project that provided the tools needed to create a richer 3D environment. The "Flight Path Viewer" evolved into a new tool called "SimPathView" that exploited some of the features of OpenSceneGraph. The tool provided the same basic functionality, that is, stepping through a scenario in time and moving around the 3D scene, but now allowed a 3D terrain to be placed into the visualisation. The terrain helps to orientate the user in the scene and also provides some idea of scale when viewing the scene.

"SimPathView" was a tightly integrated single-purpose tool, but it was apparent that the infrastructure it was built upon could be used in other projects, at least in DPSS and possibly also in the CSIR at large. At the time various competency areas in DPSS were doing simple 3D visualisation of their simulation traces and results. The DPSS Command, Control and Information Warfare (CCIW) competency area had some requirements for visualising their Ground Based Air Defence Systems (GBADS) simulation. In 2000 CCIW built an early viewer based on the EON SDK. In 2001 they started making use of a viewer supplied by ThoroughTec. In 2004 another in-house effort resulted in Cyclops 1.0 being built by CCIW. Among the other competency areas, at least RADAR and Electronic Warfare (RADAR & EW) and Aeronautic Systems (AS) were also doing simple OpenGL-based 3D visualisation.

During 2004 the Ground Based Air Defence Systems (GBADS) simulation group (CCIW) expressed the need for an updated 3D viewer component to be used as part of their simulation offerings. The lessons learnt during the construction of "SimPathView" and Cyclops 1.0 were used to eventually build a 3D viewer library called "CyclopsViewer" for Cyclops 2.0. The new library was not a stand-alone application, but rather a collection of high-level tools and objects that could be used by external applications (e.g. Cyclops 2.0). This allowed the viewer component to be used in a new version of "SimPathView" in multiple other viewers and virtual operator/equipment consoles in CCIW and AS as well as RADAR & EW.

A need to use the viewer component in external DPSS contracts emerged during early 2009. Given its long history and the multiple funding streams contributing to the CyclopsViewer, it was difficult to form a clear picture of the rights and permissions associated with the viewer. It was therefore decided to create a new project from scratch, this time with a clear licence and terms of use. Thus the "Sentience3D" project was born. The growth of OpenSceneGraph, related geo-spatial libraries and new open source building blocks greatly eased the design and implementation of the new viewer component.

Currently, Sentience3D provides an interactive virtual environment with real-world terrain and Geographic Information System (GIS) support. Online (while the simulation is running) and offline simulation traces may be used to populate this environment with representations of all the simulation entities. The virtual environment is usually further augmented by additional information such as entity relationships and entity states.

1.2 **Scope of the paper**

This paper and the accompanying poster describe the long-term vision for 3D visualisation, use cases, the design of Sentience3D and instances of impact in the domains of SANDF and international clients. It is a follow-up on papers presented at the 2007 Afrigraph conference [1], the 2009 Fall Simulation Interoperability Workshop [2] as well as a ScienceScope article [3].

1.3 **Structure of the paper**

Section 1 presented the background and scope of the paper. Section 2 gives a selection of visualisation use cases. Section 3 goes into some of the details of the library architecture. Section 4 then gives examples of impact-generating uses of the library. Sections 5 and 6 finally present the conclusion and some ideas on future work.

2.Visualisation use cases

As mentioned, Sentience3D is the latest collaborative effort with a renewed drive to create an open source and easily accessible visualisation toolkit. For the purpose of this paper, the three simulation types differentiated by the United States Defence Modelling and Simulation Office (US DMSO) are used. These are:

- Live simulation – Real operators using instrumented and dummy equipment in the real world.
- Virtual simulation – Real operators using simulated equipment in a synthetic environment.
- Constructive simulation – Simulated operators using simulated equipment in a synthetic environment.

These simulations are usually run either for the purposes of training or for doing controlled experiments during research and development. Regardless of the type of simulation being run, the instrumented equipment and environment capture data that may be used during analysis.

The main goal of the viewer library is to help developers of simulations in the building of visualisation tools. These tools are often needed to achieve the required level of situation awareness in a synthetic environment. Situation awareness is about the perception of environmental elements, the comprehension of the meaning of these and the ability to extrapolate their status into the near future. The library therefore targets the improvement of the perception of the simulation traces and results. Visualisation is used to augment the natural ability of the user, developer or client to follow the simulation traces and then analyse the results. Using such visualisation involves more of our senses and appeals to our natural ability to understand spatial relationships.

The visualisation library has been found to be useful as a visual verification and validation aid by modellers, as a platform for generating experimental stimulus and as a simulator in its own right used in playing out simulation runs to deduce or infer new knowledge. 3D visualisation is also an effective communication tool to present live, virtual and constructive simulations to decision makers, clients and the public. When a user or client is able to intuitively follow the simulation traces, it immediately instils credibility of the simulation results. Three simulation use cases are presented below.

2.1 **Visualising simulation traces**

The first use case is visualising simulation traces. This may be done offline or online, as the visualisation software does not interact with the simulation. Examples of offline visualisation of constructive simulations are shown in Figures 1 and 2.

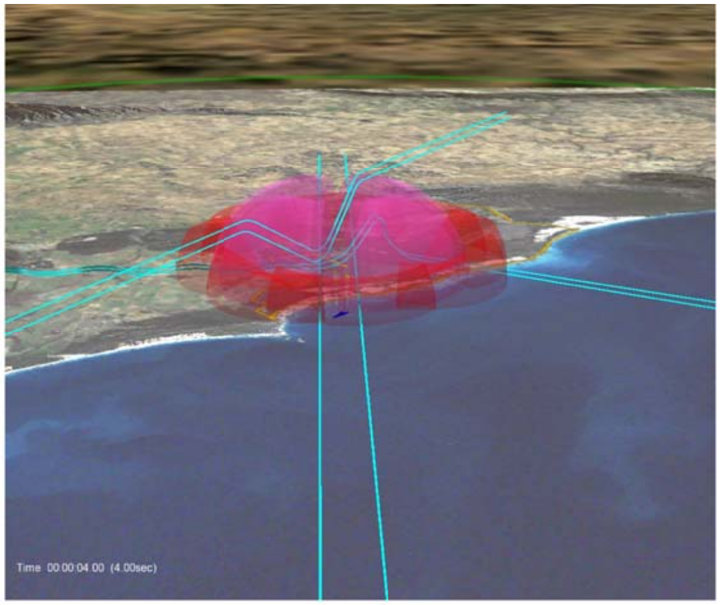

Figure 1: Overview of a GBADS battery (DPSS, CCIW – Command & Control simulation group)

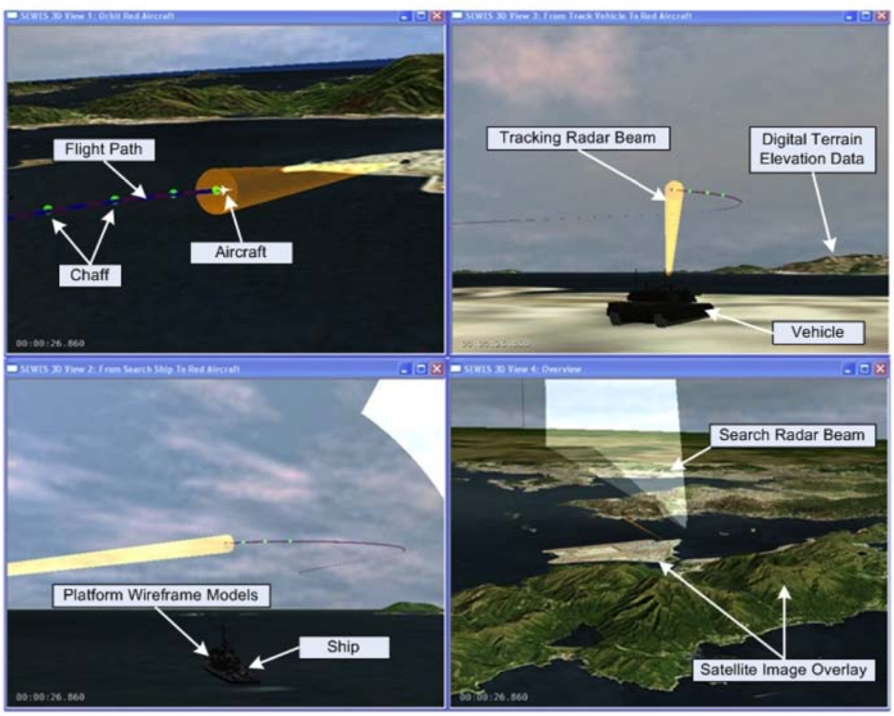

Figure 2: Overview of an electronic warfare simulation (DPSS, RADAR & EW – SEWES simulation group)

2.2 **Interacting with a live or virtual simulation**

The second use case of visualisation is an online visualisation tool that can manipulate and interact with the simulation. Examples of these are mock-ups of 2D equipment consoles and 2D/3D scenario planning tools. A 2D map view interface which is part of a virtual simulation is shown in Figure 3.

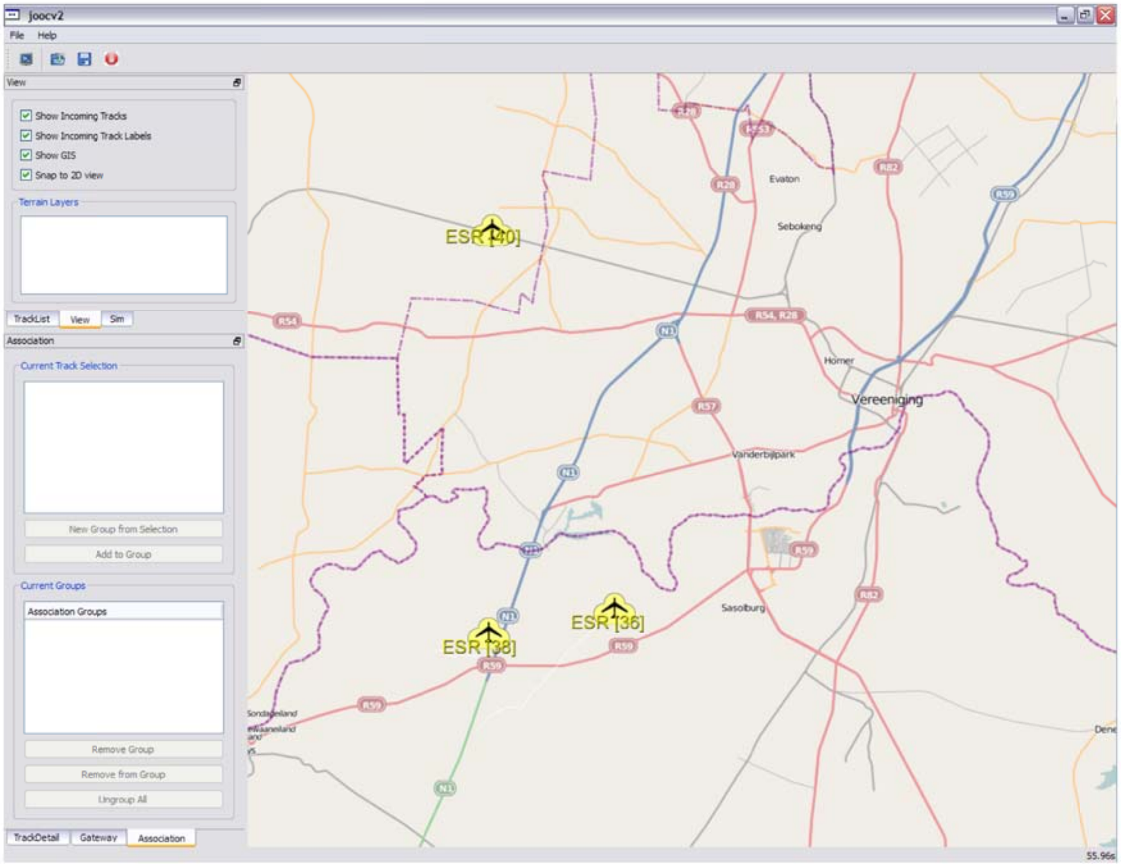

Figure 3: A 2D map view interface (DPSS, CCIW – Command & Control simulation group)

2.3 **Augmenting live and virtual simulation**

The third use case is augmenting the available information during a live scenario (such as a field exercise) with a 3D view of the situation. During a surveillance deployment 3D visualisation might be used to show a real-time bird's-eye overview of the situation indicating the state (e.g. position, orientation and field of view) of all systems on a realistic 3D terrain with the relevant GIS features. Figure 4 shows a 3D overview of a sensor field of view in a live simulation during development of a pedestal pointing and tracking system. The pedestal's position and orientation is geo-aligned with the 3D terrain and a GIS layer.

Figure 4: An overview of a live simulation during the development of a pedestal sensor system (DPSS OSS – Image Processing group). The yellow cone is the camera's field of view and the camera image is shown on the left

3.Sentience3D design

In this section the Sentience3D architecture is discussed with regard to the client interface, the command queue and the client-viewer synchronisation mechanism.

3.1 **Interface**

The Sentience3D library uses a layered design to separate the application from the underlying implementation. Each layer effectively augments the library interface, but contains only logic that is relevant to the particular interface wrapper. The innermost C++ interface provides low-level object-oriented methods for using the Sentience3D library. This is a powerful and flexible interface, but its use is typically limited to C++ applications.

From the start though, a high-level ANSI C interface wrapper was designed as part of the library. The reason for the C interface is because it is still much easier to integrate a pure C library into a variety of programming languages. Specifically, Matlab integration was a high priority for the library and Python integration simplifies prototyping and testing of library features.

The C interface operates at a very high level of abstraction. Objects are created using unique names and the parameters required for their construction. The names are then used to refer to objects when they need to be manipulated, e.g. translated to a specific location on the earth.

Ultimately the C interface translates commands into C++ calls in the library, but the extra level of indirection had some additional benefits. Two of these, namely streaming of commands and simplified synchronisation, are discussed in the following sections.

3.2 **Command streaming**

During the prototyping stage of the library, the idea of using a command queue was investigated. Basically, all commands from a user of the library is placed into a queue and the commands can potentially be streamed over a communication channel such as a local area network. Logging and replaying of user commands then also become a simple matter. The network option allows the viewer to run on a remote, possibly stand-alone, PC and in this way not to interfere with a running user simulation. Logging of user commands also makes debugging of the library and user applications easier.

The open sourced Google protocol buffers library was found to be a good fit for the command queue and streaming. The Sentience3D C interface commands are translated into protocol buffer messages on one side and the messages are then translated into C++ calls on the other side. Sending of messages over a network and logging them were therefore simplified by using Google's protocol buffers library.

3.3 **Simplified synchronisation**

A user simulation and the 3D viewer can exist as separate applications or as separate threads of execution in a single application. The use of the C interface and protocol buffers allowed easier synchronisation between the user code and the Sentience3D library. Protocol buffer messages can contain other messages, which makes it possible to create a large message containing all updates that the user considers atomic, e.g. all object updates that occur at a specific time step in the simulation. Synchronisation is required in order to ensure per frame consistent data visualisation.

On the user side the messages are buffered until a complete atomic group is constructed, the completed messages are placed into a queue and the viewer extracts messages from the queue and can be certain that a single large message constitutes an atomic update while requiring minimal locking of resources. The message queue can be a local queue between threads or it can be a network queue between distributed applications.

The visualisation library was also designed with cross-platform use in mind. Only cross-platform components are used as building blocks and the use of the protocol buffers allows the visualisation tool and the simulation to be hosted on different operating systems as required.

4.Results

This section presents a selection of projects in which 3D visualisation is making an impact. The SimPathView tool built by DPSS OSS has already been mentioned. It has been used in infrared (IR) countermeasure evaluation and optimisation to visualise and analyse the simulation traces of a high fidelity one-on-one constructive simulation. This was done for the South African Air Force (SAAF).

In DPSS CCIW, the Cyclops 2 GBADS Viewer has been used in support of the Virtual GBADS Demonstrator (VGD). VGD is a system-of-systems level constructive and virtual simulation for doing controlled experiments during the various phases of the system life cycle. CyclopsViewer has also been used for the construction of human-machine interface mock-ups for simulated equipment. Recently Sentience3D has also been used for similar applications and currently supports many visualisation and analysis tools within the Command and Control (C^2) enterprises.

In DPSS RADAR & EW, both the CyclopsViewer and Sentience3D libraries have been used in support of SEWES (Sensors and Electronic Warfare Engagement Simulation). SEWES is used by international and local clients.

DPSS AS (with the support of CCIW) has also used CyclopsViewer to build visualisation tools for their FRT (Faster than Real Time) simulation of aircraft tactics against ground threats. The FRT simulator was delivered to an international client. AS also developed the Gripen Tactics (GT) air-to-air mission planning and tactics evaluation tool with CCIW for the Gripen aircraft. The tactics tool was delivered to the SAAF.

Sentience3D is also currently being used to augment live simulations and even operational deployments of a Wide Area Surveillance Project (WASP) in DPSS OSS. A Stand Alone Tracker (SAT) and HeliKite surveillance platform is currently under development and will similarly use 3D for visualisation and analysis.

During the development of Sentience3D we were able to reciprocate by contributing our development efforts back into the open source building components such as OpenSceneGraph. We have already submitted improvements to OpenSceneGraph's database pager, compilation processes under Linux and OSX, the terrain intersection interaction and terrain construction process. We have also submitted additional features and example code which have been included in the trunk distribution.

5.Conclusion

3D visualisation has been shown to make an impact on the way simulation is done. Specifically, visualisation is used to:

- Verify model implementations during development.
- Present simulation results to clients such as the SANDF.
- Improve situation awareness during live exercises by making use of geo-aligned maps, terrain elevation data and other visual cues.

Having Sentience3D open source allows the library to be used by a wider community which may then contribute the expertise it has gained back into the library. It is currently being funded, developed and used by various groups within the CSIR in an iterative agile fashion to quickly respond to users' needs. As mentioned, it makes use of open source building blocks and is itself moving towards a Lesser General Public Licence (LGPL). The user may therefore build commercial applications without having to pay licencing fees.

1.Future Work

The long-term vision for the visualisation capability is to add more GIS functionality and improved support for live data and sensor displays. Improved GIS support adds visual cues and intuitive visualisation of geo-aligned information to aid in improving situation awareness. Support for efficiently incorporating live information streams from sources such as cameras and search radars is cardinal to advanced 2D and 3D visualisation and virtual equipment displays.

2.References

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3.Acknowledgements

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