ANALYSIS OF WITNESS STATEMENTS USING 3D VIRTUAL REALITY CITY RECONSTRUCTION AFTER THE ENSCHEDE FIREWORKS DISASTER, MAY 2000, THE NETHERLANDS

Wouter Brokx and Mark van Persie
National Aerospace Laboratory NLR
P.O. Box 153
8300 AD Emmeloord
The Netherlands
brokx@nlr.nl
http://remotesensing.nlr.nl

KEY WORDS: 3D, virtual reality, modelling, analyses, city modelling, disaster, reconstruction

ABSTRACT

On Saturday 13th May 2000, an explosion in a fireworks factory killed 22 people and destroyed over 500 houses over an area of 35 hectares in the centre of Enschede, The Netherlands. In the largest investigation ever performed by the Dutch Police Force and the Justice Department there was a growing need for a visual environment for reconstruction and analysis of the events that took place on the day of the disaster. NLR created a 3D Virtual Reality environment of the destroyed quarter for reconstruction and analysis of witness statements using a wide range of commercial software visualisation tools and GIS. The witnesses were able to confirm and detail their statements of the event. The flexibility of the virtual reality environment easily enabled corrections to the model and adjustments to the statements. After integration in a Virtual GIS and line-of-sight analysis of the 25 selected witness statements, the location of where the first firework started according to the witnesses could be calculated. The analysis software produced is based on least-squares. The model was used in numerous visual presentations and national television broadcasts, including the visualisation of the results presented by the investigating committee.

1 CONTEXT

After alarm calls about incidental firework at the fireworks factory S.E. Fireworks, located in a residential area, and arrival of the Fire Brigade, the situation rapidly worsened. Forty five minutes after the first call, the central bunker complex and 16 containers with firework fully exploded. Twenty two people were killed and 950 persons got injured. An area of about 35 hectares with more than 500 houses was destroyed.

Soon after the disaster that took place 13th May 2000, a large investigation was started by the Police, the National Government (the investigating Committee Oosting) and the Justice Department. Within this framework it appeared that there was a growing need for a geo-spatial reconstruction of the exact situation before the explosion. The Remote Sensing department of the National Aerospace Laboratory was asked to generate a three dimensional computer model of the Roombeek quarter, just North of the centre of Enschede. The first objective was to use the model for support and analyses of the statements made by witnesses who had observed certain events from different directions. Other objectives of the model were reconstruction of the different events before, during and after the explosion, and presentation of the final results of the investigation.

Figure 1. Aerial photograph of the Enschede fireworks precincts

The most important model requirement was to provide the witnesses with a realistic view of the situation, so that they could revive the events as they happened that day. Secondly, the model had to be geometrically accurate to enable the combination of results and the calculation of the optimal position of the observed events. Due to destruction of the quarter, both adequate photo material for building texture mapping and geometrically accurate site plans were largely unavailable. This made the construction of the model challenging and difficult.

2 MODEL CONSTRUCTION

An inventory of all information available showed that a digital two dimensional GBKN database (Large Scale Base Map of The Netherlands) was available in polygon vector format with outlines of the roads and buildings. Furthermore, a stereo aerial photo pair of the exact same day (!) was available, which was scanned at a resolution of 60 cm (Figure 1). Also, recent as well as older photographs and video imagery were available.

In phase one, a relatively simple 3D model was constructed based on the aerial photographs, not accounting for building textures, and the image processing software ERDAS. The aerial photographs were worked out using the photogrammetry options of the Orthomax module. The building heights were digitised with the StereoAnalyst module, after which an accurate ortho-photo was computed for the area. Within the VirtualGIS module the ortho-photo was draped over the digital elevation model incorporating building heights. The result gave a good first impression of the disaster area before the explosion and made it possible to do geometrical measurements and line-of-sight analysis. However, the situational awareness of the model was limited due to the lack of real-world textures on the sides of the buildings.

Figure 2. A 3D visual reconstruction of the central bunker complex surrounded by containers at the SE Fireworks premises, Enschede, The Netherlands

Therefore, a more realistic 3D Virtual Reality model of the area was required to include building textures. This was realised using the Evans & Sutherland software RAPIDsite. Each building was modelled using the footprint from the GBKN vector map, and the heights measured in the aerial stereo-model. Textures for the buildings were obtained from available photographs and video screen dumps. Textures for trees, cars, fences and other objects were taken from existing object databases or constructed by hand from photographs.

The resulting final model was very realistic and had good geometric accuracy. The RAPIDsite software provided model displaying and navigating as well as flexible adjustments to the model. However, there was no functionality for extended geometrical analyses. The geometric quality of the model was in the same order of magnitude as the GBKN for position, with maximal errors of 0.3m. The maximal errors for heights related to the quality of the aerial stereo-model were 1.6 m. The quality of the textures was highly dependent on the quality of the available photographic material.

3 WITNESS STATEMENT ANALYSIS

After completion of the model the Dutch Police Force was assisted during the sessions with the witnesses of the first firework. Presented on a big screen, the witness was asked to state the exact position at time of the observation in the 3D model. If necessary, the interactive model was easily adjusted on indication of the

witness with trees, fences, cars, etc. The witness was asked to pin-point the exact position of the observed events, and this viewing line was marked and saved in the model by placing red viewing lines with a perpendicular scale-bar indicating the positional accuracy of his observation.

From the 25 selected witness statements the most likely starting position of the event had to be determined. Analysis software was developed where the witness positions, the directions of observation and inaccuracies could be specified in X, Y and Z dimensions. Also weights for witness quality aspects - as specified by the police - could be incorporated. Based on these inputs, probabilities for the presence of the optimal position were computed for each grid cell in an area around the event (Figure 3). Probabilities are based on the sum of the weighted quadratic distances of the observations to the grid cell. A high probability (in black) corresponds to the most likely position of the first firework. Since this has not been recorded and there is no evidence left to be found, this is an important contribution to the reconstruction of the events that have taken place.
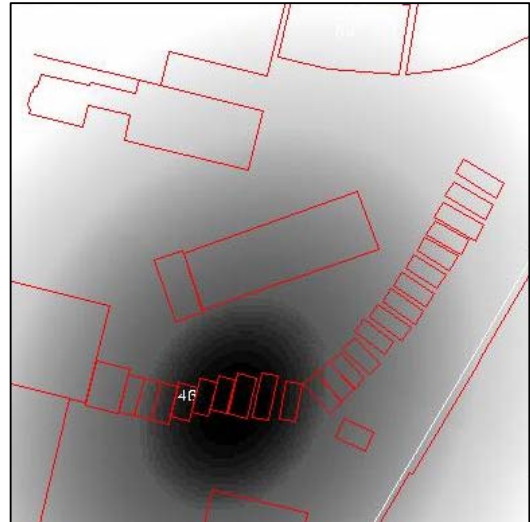

Figure 3. The result of the least-squares analysis on the 25 witness statements, with a high possibility in black. This image is simulated and does not correspond to real data.

4 CONCLUSION

The 3D visualisation was a successful aid to supporting the witness procedure, and witnesses stated that the model helped them to relive the events and accurately pin-point the direction of observation. Based on the recorded witness positions, lines of sight and their accuracy it was possible to calculate the origin of the first fireworks as being observed. The results of these analyses were used as part of the investigation and as possible evidence in court of justice.

The 3D model was used as input to a simulation of the explosion, produced by the Dutch National Forensic Institute. Also, video clips of the model were rendered and integrated into the final audio-visual presentation of the governmental investigation of the fireworks disaster by the Oosting Committee (Oosting et al.), which was broadcast on national television. The reconstruction of a 3D Virtual Reality environment for visualisation and analysis of witness statements has proven to be a successful integration of 3D visualisation and geo-spatial analysis of geo-information.

Figure 4. A 3D visual reconstruction of the central bunker complex surrounded by containers at the SE Fireworks premises.

REFERENCES

Evans & Sutherland Computer Corporation, 2000. E&S RAPIDsite User's Guide, USA, ISBN 902101-200D.

Oosting, M., 2001. Eindrapport 'Commissie onderzoek vuurwerkramp'onder voorzitterschap van Mr. Dr. M. Oosting, Enschede/Den Haag d.d. 28-02-2001.

ERDAS, 1999. Imagine OrthoBASE 8.4 Tour Guide, USA.