

RAPID MAPPING OF THE 3D URBAN ENVIRONMENT

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ABSTRACT:

The United Kingdom Armed Forces face an increasing requirement to accurately and rapidly map the 3D urban environment in order to support a wide range of activities including active engagement of forces, counter terrorism and peace keeping measures. The challenges faced by the UK Forces have resulted in a diverse range of mapping requirements that may overlap or differ significantly. This in turn has generated a wide customer base. The initial requirement of this study was therefore to capture this complex and fragmented situation, to define the needs and information requirements of urban data users and to bring together the relevant active work programmes to meet these needs. A plethora of photogrammetric and remote sensing software tools are available to generate, render and analyse 3D urban models. Thus a second requirement was to perform a review of applicable software tools, identifying their suitability for application to defence tasks. The final aim was to assess the current capability within the UK user community to generate 3D urban datasets, determining the tools used and whether there are any obvious gaps in capability that can be quickly and easily filled. This study gives an overview of the current activities addressing urban mapping, as well as exploring the sources of urban mapping information. This examination of existing capability, available solutions and future UK military requirements will help to shape future developments within this field by advising UK procurement and research programmes for future years.

1. INTRODUCTION

It has been recognised that future warfare is likely to occur in urban areas. Military operations are becoming increasingly short term with the opposition usually having a significantly lower capability, known as an asymmetric threat. Conflict often occurs in urban areas where reduced forces can have more impact, for example the use of snipers in buildings. Counter terrorism operations often occur in urban regions where terrorists have more cover and places to hide. The increasing proportion of people living in towns and cities has caused expansion of urban areas, with recent surveys suggesting that urbanisation is increasing worldwide. Thus it follows that there will be an expansion of military operations in urban areas.

Military operations are becoming increasingly varied with traditional operations in denied areas now decreasing and activities such as peacekeeping and stabilisation becoming more common, as seen in Kosovo and Bosnia. Operations in accessible areas give the opportunity to create more detailed three dimensional 3D models using airborne Light Detection and Ranging (LIDAR) or ground survey techniques.

Preparation for operations in denied areas may involve the use of Virtual Reality (VR) or 3D models to allow activities such as mission rehearsal and scene familiarisation. Being able to visualise the battle-space prior to deployment can give commanders the advantage of knowing what to expect and

identify possible areas of risk. The models can also be used to plan access routes and provide pre-operation orientation.

Homeland defence is another key application of 3D urban modelling, with models of major UK cities being developed to aid in counter terrorism activities. These requirements differ from previously mentioned operations, as the preparation time can be variable. Models of high risk targets can be modelled in advance, but it may still be necessary to produce data at short notice if an unexpected area is attacked.

3D modelling and VR arrived on the public market a few years ago. The commercial sector have been the primary driving force behind this new technology, exploiting it for games and entertainment, advertising and media business. The defence community has seen these new developments as useful, but not essential, with needs, risks and trade-offs (speed of production versus accuracy and reality) not clearly defined.

There are many different types of 3D visualisation from prismatic building block models, which extrude blocks from 2D building footprints to fully rendered volumetric CAD models. Different types of functionality are associated with different types of model, for example, some offer analytical functions, others are generated for aesthetic appreciation.

Although there is now significant technology to create 3D models, a fundamental question that needs to be addressed is whether these models offer more to the military user than traditional 2D maps. A 3D model is simpler to interpret due to its

similarity with the image seen by the human eye. Changes in elevation are clearer as contour lines and spot heights need not be interpreted. Intervisibility can be assessed and more detailed surface information can be displayed, such as entrances to buildings and height of windows. The ability to fly around objects in real time offers the opportunity for increased situational awareness.

However, a potential disadvantage of using a 3D model is that it may not be realistic, surface colours and textures may have to be inferred, vegetation, such as trees, have to be representative from a limited library. The speed of production must be considered since detailed 3D models can take a significant time to generate, as well as the amount of extrapolation, such as assuming the rear of a building to be the same as the front. As with 2D maps, issues such as currency and ensuring the models are up-to-date still apply. Issues of how to serve 3D and VR data need to be explored. One option is to use web servers to allow distributed, secure and fast access to large centrally held 3D models over a network. New technologies are being developed that allow users to access an image of the models without having to download terabytes of data. The type of viewer used by the end user also needs to be considered, with issues cost, ease of use, maintenance and functionality to be considered.

In parallel with developments in 3D modelling and visualisation, there have also been significant developments in sensing systems that can rapidly collect the 3D data required to generate urban models. Techniques such as rapid capture with terrestrial laser scanning have allowed large datasets to be collected within a small time-scale and this does not require excessive processing time in order to produce models. On a larger scale, airborne LIDAR can be used to collect data over a city at good accuracies and resolution. These laser surveying systems are routinely used to generate 3D models for civil engineering projects.

2. METHODOLOGY

To investigate these issues and relevant technology developments in the creation, exploitation and visualisation of 3D urban models, a study was recently performed on Rapid 3D Urban Modelling.

The project initially performed an assessment of the end user community for 3D urban data and defined their information requirements. This was completed by targeted visits to organisations such as the Defence Geographic Centre (DGC) and Geographic Engineering Group (GEG). Questionnaires were used to obtain product specifications such as scale, coverage, feature set and timeliness issues. It was important to define the level of information required by the user, whether it be a basic Digital Terrain Model (DTM) or a detailed 3D model and the time frame of requirement. The visualisation level was also considered, from full scene rendering with illumination effects or just simplified objects. Production capability was also assessed such as data sources, timeliness and software used.

The next task was to determine the government sponsors of work in this field and to capture their main objectives. This was

achieved by personal communication with research co-ordinators and evaluation of tasking orders.

A review was then undertaken of software tools that could be used to generate, render and visualise 3D urban data, covering both commercial software packages and academic research developments. Information is a key part in providing 3D urban data and therefore the next step was to provide an overview of the available information sources that can be exploited.

3. OUTCOME OF STUDY

The study found that there were numerous users of urban data within the defence community. Homeland defence activities are very rapid as information is often required urgently. Presently, Ordnance Survey (OS) data and military mapping data is used alongside survey data from total stations. Recently, terrestrial laser scanning was being tested for future implementation as it offers the opportunity for rapid data capture from longer ranges, a major advantage in anti-terror operations.

It has been suggested that 3D models of high-risk areas could be created and stored for future use. Sites of high security value and high risk public events in London, for example, require security reviews, frequent contingency planning and constant updating in the light of new requirements or changes to the environment. The ability to walk through and view the area in different conditions could save recurring costs of survey visits. Changes to physical security measures such as fences, barriers, lighting and patrol frequency can be modelled easily. The study found that there was a need for 3D mapping although simplified models with little rendering would be sufficient for many site orientation applications where accuracy was not a paramount requirement.

Soldiers use 3D mapping at Brigade and Company level, with activities such as mission rehearsal, scene familiarisation and mission planning. Specific applications include route analysis, location of observation posts, identification of potential obstacles, building access, collateral damage prediction, containing and isolating combatant forces, creating buffer zones, restoring essential services, evacuation of groups of people and gathering information. This group requires accurate models with high levels of visualisation at short time scales. It would be unrealistic to build a model of locations to support planning of urban operations when time duration of operations cannot be foreseen beyond a few weeks. However, for urban areas where a long time presence is expected, or where operations might be expected to recur over a period of time, the development of an urban model could be a worthwhile investment for planning and to assist in situational awareness. It was found that in practical terms, additional information would be required with the 3D model to achieve maximum utility. For example, building usage (residential, commercial, military, police), construction details (cladding, material, thickness) and significance (cultural, medical, educational, religious) would add value to a model.

For some operations, it was found that users appreciate feature annotation, such as heights of window sills and simple presentation as there is not sufficient time to use complex

viewers. Absolute accuracy is not required for site orientation, as an operation would not be mounted on the basis of the model alone. With these types of models, bandwidth is a limitation on product transmission into theatre. Improved compression, bandwidth or viewers could overcome this limitation. Again, currency and closeness to reality must be considered.

Models are also generated to aid in blast analysis. Metre-level accuracy is required with very simplified rendering. The models are generated on request without the requirement for rapid time scales. Helicopter operations to provide air to ground support could be improved by knowledge of heights of buildings from 3D models and other vertical structures such as pylons and viaducts.

A review of the main software packages that could be used for producing and using 3D mapping or models was performed. Canoma is used to produce 3D models of small areas. The drawbacks of this package are that it needs perspective within photographs and it does not use a DTM, allowing large errors to be present in the models over steep terrain. SO CET SET is used for modelling wider areas as well as extracting individual buildings from stereo imagery for applications such as modelling conference centres for Party Political Conferences. Photo Modeller Pro is currently being used for applications such as modelling military equipment. ESRI's ArcGIS and ERDAS IMAGINE are used for quicker production.

Three specific packages were considered in more depth, Luminova rendering tools, the Urban Tactical Planner (UTP) and Enable3D.

Luminova is a computer visualisation and 3D modelling tool which outputs photo-realistic models of scenes. The models are produced quickly and a shadow analysis tool is used for extraction of elevation from mono-imagery and a surface characteristics library is used for texture. The models produced are artificial and therefore texture is not extracted from imagery. A variety of input sources are available, including satellite and airborne optical imagery and Synthetic Aperture Radar (SAR). Luminova has properties suitable for generating VR models for mission rehearsal as well as modelling new systems currently in the procurement cycle. Overall, Luminova is a powerful package that produces very detailed models with illumination and shadowing present but issues of compliance with reality and currency need to be addressed.

Urban Tactical Planner (UTP) is an operational planning tool intended to support Military Operations on Urban Terrain (MO UT) and was developed by US Army Topographic Engineering Centre (TEC). It facilitates the rapid visualisation of key aspects of the urban environment, for example hospitals, schools and forests. UTP runs on ArcView 3.0 or ArcExplorer and is designed for rapid dissemination on a CD. UTP is a simple program with predefined views which assist the user in exploring the data. It allows further information such as photographs, building plans and video clips to be hyperlinked, giving added information. Overall, UTP is simple to use and provides significant contextual information. The hyperlink capability and perspective views enhance the product and it appears to be a suitable product for planning military activities and providing orientation.

Enable3D is a 3D visualisation service provided by QinetiQ. It takes two-dimensional GIS data and transforms the data into an interactive virtual model. The main input formats are OS MasterMap data, VMap and UVMMap. Enable3D prepares data for TerraVista, which produces the 3D model. Assumptions are made about the visual appearance of structures, for example a rectangle on a 2D map is a row of terraced houses and all of the houses are assumed to be the same. Although Enable3D produces aesthetically pleasing results, the models are not true to reality, therefore limiting their usefulness, but they do have the advantage of being quick to produce.

The study also addressed problems surrounding the use of 3D models for military applications. A main consideration is the variation in requirements depending on the user. Issues such as detail, accuracy, scale, processing time and 3D model size/coverage varies depending on the user and the application. Time issues may be critical in a counter terrorism operation but of less importance than accuracy when used for mission planning and scene familiarisation. Mission rehearsal may require a larger 3D model than a weapons system. However, some users wanted accurate models that were true to reality rather than highly rendered models that made assumptions about the area, perhaps implying that areas not covered by imagery should not be rendered. It was found that detailed models, if realistic, are easier to interpret and interact with and thus could be useful for mission planning and familiarisation. The issue of currency also has to be considered, as the models need to be up to date, for example if a building has been damaged it should be re-modelled.

The main UK government provider of 3D data is DGIA. DGC produce a wide range of geospatial mapping products to international standards for Defence use only, although 3D urban models are not part of the standard product ranges. It was found that DGC urban map production comprises only a small percent of their production volume, with only a small number of requests for urban maps. This may be due to lack of requirement or customer appreciation of production time, cost and difficulty.

The method of data capture available may affect the end product. Airborne LIDAR, airborne photography and vehicle borne laser scanning are some of the possibilities. As new technologies are developed, improved survey tools may be available for rapid data collection. QinetiQ have developed an Airborne Topographic LIDAR System (ATLAS) which is a fast, accurate terrain mapping and visualisation tool with an absolute 3D accuracy of 5cm RMSE (150m flying height). As other systems become available they can be evaluated for future use.

The study concluded with an assessment of the gaps between requirements and capability, with recommendations on how to improve the current situation.

4. CONCLUSIONS

To summarise, this project found that the UK Armed forces have the ability to map small areas such as a building of interest to an adequate level of detail. There is a requirement to produce 3D models of large urban areas, but no universal method is currently

being used. Issues of accuracy, scale, time, currency, amount of detail and methods of data capture require ongoing research and development. Industry offers new developments in visualisation and rendering software and data collection methods such as LIDAR that have the potential for offering armed forces with enhanced urban information.

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