In-situ Refinement Techniques for Outdoor Geo-Referenced Models Using Mobile AR

Thuong N. Hoang[1] and Bruce H. Thomas[2]

Wearable Computer Lab – University of South Australia

ABSTRACT

We present a set of techniques to perform in-situ refinements on simple geo-referenced models using mobile augmented reality systems. The refinements include affine transformations to the model and surface feature additions, including high detail concave and convex features. The techniques employ pinch gloves and a single-point laser rangefinder augmented with an orientation sensor as input devices. Finished models can be exported for use with other geospatial applications. The proposed techniques are intended to be an effective and elegant approach to enhancing outdoor models using mobile augmented reality.

KEYWORDS: 3D modelling, geo-referenced models, outdoor AR.

INDEX TERMS: H.5.2 [Information Interfaces and Presentation]: Graphical User Interfaces—Input Devices and Strategies; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

1 INTRODUCTION

This paper extends our investigations into outdoor 3D modelling within the domain of augmented reality (AR). Mobile AR systems in an outdoor environment are confronted with the challenge of precise manipulation of data (which is essential in desktop-based modelling solutions), but provide a richer visualisation with abundant in-situation context information. This paper presents a set of techniques to perform refinements on existing geo-referenced models by employing a mobile augmented reality system. The techniques comprise intuitive in-situ affine transformations and real time surface feature additions, including concave and convex features. Affine transformations adjust the position, orientation, and size of the model, while surface feature additions enhance the model details. Both techniques aim to improve the truthful representation of the corresponding real world artefact. The refinement process we follow is to import 3D models representing physical buildings from Google Earth, perform refinements on the models with outdoor AR techniques, and export the models back to Google Earth.

Geo-referenced Google Earth models representing real world buildings are the main concern of this paper. These models are constructed on a desktop computer as polygonal objects containing GPS coordinates of the real world counterpart, using Google SketchUp. These models tend to be simplistic and lack height information because they are based on aerial imagery. The two techniques presented in this paper are used to refine these models on our Tinmith mobile wearable augmented reality backpack system. Our wearable computer system employs thumb tracked pinch gloves as the main input device, and we extended this input capability with a handheld 3DOF orientation tracked single-point laser rangefinder (OSPLR). There are two main advantages of employing an OSPLR over a two dimensional laser ranger. The OSPLR is much smaller and lighter, thus making the device more suitable for a wearable computer system. Secondly, the single point device allows the user to accurately scan over a small sub-portion of the structure. This allows the user to model only the sections of the structure required.

The key contribution of our techniques is the usage of an OSPLR to construct highly detailed surface features of outdoor buildings using mobile AR. Instead of generating high density 3D point clouds, our techniques only require the range data at the key features. A second benefit of our techniques is a complete system for refinements of 3D models with an immersive mobile AR wearable computer system to provide in-situation visualisation of the real world buildings, from various viewpoints, increasing the accuracy of the finished model.

2 BACKGROUND AND RELATED WORK

There have been a number of investigations into the use of mobile augmented reality for modelling. Baillot et al. [1] developed a set of techniques for creating and maintaining physical models using mobile computers. A user employ the techniques to specify vertices in space, by either entering known measurements via keyboard, or creating intersection points between a selection ray and a plane or a line segment, then to connect those vertices in order to create polygonal models of physical buildings.

Instead of using 3D points as the fundamental modelling entity, Tinmith-Metro techniques [2] define a series of infinite planes to delimit the boundaries of 3D models in space. Each of the infinite planes is created by the user sighting along a real world surface, and all the planes are combined together to form a solid object. Complex objects with concave shapes can be constructed using Constructive Solid Geometry (CSG) operations.

Wither et al. [3] employed a single point laser scanner to calculate the required distance and orientation for the placement of textual annotations on physical objects, as well as to separate foreground objects for occlusion. Whereas our techniques utilise an OSPLR for the modelling process itself.

There are several limitations to the modelling approaches mentioned above. Construction by specifying vertices with intersection methods or known measurements of the environment is a time-consuming process. On the other hand, the use of infinite planes and CSG in Tinmith is not suitable for precise modelling of fine detailed features, as the system has limited sensing of range information relative to the user. Whereas SketchUp lacks the AR in-situation visualisation of real world objects.

3 INSITU MODELS REFINEMENT

Our techniques introduce the use of an OSPLR to the Tinmith wearable AR system. The device acts as a 3D cursor. When the OSPLR is active, the device ranges from the user to a location that

1) ngocthuong@gmail.com
2) Bruce.Thomas@unisa.edu.au

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reflects laser light back to the device. The distance and 3DOF orientation allows a virtual *laser point*, in the form of a coloured sphere, to be placed in 3-space relative to the user. Because the coloured sphere is placed within the Tinmith graphical coordinate systems, the spheres' are an accurate reflection of 3-space points for modelling activities.

The modelling process consists of the following steps: 1) Import a geo-referenced polygonal model of a real world building from SketchUp into Tinmith; 2) Perform affine transformations to correctly align the model to its real world counterpart; 3) Perform surface feature additions to model using an OSPLR; 4) Export the refined model. After the improvement process, the exported model can be viewed in Google Earth.

3.1 Affine Transformations

Affine transformations combined with the visualisation capability of mobile AR system allow the user to correctly position, orientate, and scale the model against its real world counterpart. Tinmith supports these transformations using image plane techniques, employed to rectify, for example, the height of the model created with SketchUp using only aerial imagery. Figure 1 depicts a user aligning the model to real world building.

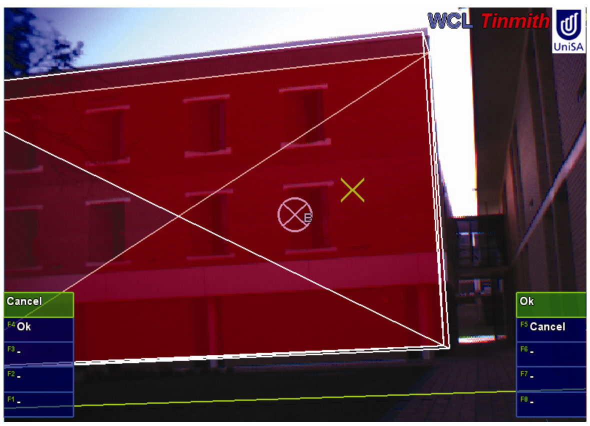

Figure 1. Affine transformations

3.2 Surface Feature Addition

By employing an OSPLR, surface feature addition techniques allow finer details of the external surfaces of the physical world structure to be modelled in-situ. Given that the user's GPS position and the orientation of the OSPLR is known, this combined device can be employed as an absolute 3D cursor into the physical world.

Applying this approach, the user starts modelling a feature of the real world building by pointing the OSPLR at the corners of the feature. The user fills in the feature, say a door alcove, with additional points defined by the OSPLR, created in an order such that a triangle strip is constructed, see Figure 2. The user is able to visualise the position of the new point as a 20 cm sphere placed at the end of a vector defined by the 3DOF orientation and distance measurement from the OSPLR. We observe a 10cm error using the rangefinder in outdoor tests. We assume the OSPLR is 50cm below the centre of the image plane, as the relative distances from the GPS sensor and OSPLR is not actively sensed. A top and bottom cap polygons are automatically added to create a semi-enclosed polygonal part resembling the real world feature. The user can control what areas receive a dense grouping of triangles simply by adding more points where needed. A number of possible triangle segmentation algorithms could be employed; our current algorithm is very simple to allow for experimentation with our new 3D cursor device. In the future, we will investigate different triangulation algorithms to for more optimal results.

Figure 2. Constructed feature using triangle strips

Once the density of the polygons is at the desired level, the user then points the glove operated 2D cursor towards the surface of the model that the feature is to be attached. The user then selects either *Concave* or *Convex* from the pinch glove menu, to bind the feature part onto the model. A concave feature is appended to the building by applying the Constructive Solid Geometry operation of *intersection*, whereas a convex feature uses the *union* one.

Common approaches of modelling using 2D array laser rangefinder, such as [4], often apply the same level of details for all modelling areas, and require a separate post-processing phase. Our techniques support selective modelling, in which the user controls the point density of different sub portions of the object. Thus, denser point cloud can be used for the portions that require high details and sparse point cloud for other unimportant ones. The polygonal model is automatically constructed in-situ, without separate post-processing. This approach is simpler, faster, and more mobile than a traditional 2D laser scan point cloud solution.

4 Conclusion

In conclusion we have presented a set of techniques to perform in-situ refinements to outdoor 3D models using mobile AR. We employ the current image plane techniques in Tinmith, and a single-point laser rangefinder augmented with 3DOF orientation sensor. The augmented rangefinder acts as an absolute 3D cursor and allows the user to construct polygonal models resembling real world features. This approach proposes an elegant and effective use of a laser rangefinder, which is more suitable for mobile AR than a traditional 2D laser scan point cloud solution.

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