

interactive 3d modelling in outdoor augmented reality worlds



Research Thesis for the Degree of Doctor of Philosophy

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Abbreviations and Definitions

1394	IEEE Standard 1394, also referred to as Firewire or i.Link [IEEE95]
2D	Two Dimensional in XY
3D	Three Dimensional in XYZ
AAAD	Action at a distance, first defined by Mine [MINE95a]
ACRC	Advanced Computing Research Centre at UniSA
AGD66	Australian Geodetic Datum 1966 [ICSM00]
AGD84	Australian Geodetic Datum 1984 [ICSM00]
AR	Augmented Reality
CIS	School of Computer and Information Science at UniSA
COTS	Commercial Off The Shelf
CRT	Cathode Ray Tube (technology used in television and monitor displays)
CSG	Constructive Solid Geometry
DGPS	Differential GPS
DIS	IEEE Standard 1278, the Distributed Interactive Simulation protocol [IEEE93]
DOF	Degrees of Freedom ([X, Y, Z] for position, [θ , ϕ , φ] for orientation)
3DOF	Three degrees of freedom, only three measurements, such as only orientation or position tracker information
6DOF	Six degrees of freedom, information about orientation and position, a complete tracking solution
DSTO	Defence Science Technology Organisation, Adelaide, South Australia
ECEF	Earth-Centred Earth-Fixed Cartesian coordinates, in metres [ICSM00]
Evo	Evolution or version number
FOV	Field of View, the angle of the user's view that a head mounted display or camera can cover
GLONASS	Russian Federation, Global Navigation Satellite System (Global'naya Navigatsionnaya Sputnikovaya Sistema in Russian)
GPS	US Department of Defence, Global Positioning System
HMD	Head Mounted Display
HUD	Heads Up Display
ITD	Information Technology Division (located at DSTO Salisbury, Adelaide)
IPC	Inter-Process Communication
LCD	Liquid Crystal Display

LOD	Land Operations Division (located at DSTO Salisbury, Adelaide)
LLH	Latitude Longitude Height spherical polar coordinates [ICSM00]
LSAP	Land Situational Awareness Picture System
MR	Mixed Reality
NFS	Sun Microsystems' Network File System [SAND85]
OEM	Original Equipment Manufacturer
RPC	Sun Microsystems' Remote Procedure Calls
RTK	Real-Time Kinematic (centimetre grade GPS technology)
SERF	Synthetic Environment Research Facility (located at DSTO Salisbury, Adelaide)
SES	Scientific and Engineering Services (located at DSTO Salisbury, Adelaide)
STL	Standard Template Library (for the C++ language)
SQL	Server Query Language
Tinmith	This Is Not Map In The Hat (named for historical purposes)
UniSA	University of South Australia
USB	Universal Serial Bus
UTM	Universal Transverse Mercator grid coordinates, in metres [ICSM00]
VE	Virtual Environment
VR	Virtual Reality
WCL	Wearable Computer Lab at the University of South Australia
WIM	Worlds in Miniature [STOA95]
WIMP	Windows, Icons, Menus, and Pointer
WGS84	World Geodetic System 1984 [ICSM00]
X	The X Window System
XML	Extensible Mark-up Language

Summary

This dissertation presents interaction techniques for 3D modelling of large structures in outdoor augmented reality environments. Augmented reality is the process of registering projected computer-generated images over a user's view of the physical world. With the use of a mobile computer, augmented reality can also be experienced in an outdoor environment. Working in a mobile outdoor environment introduces new challenges not previously encountered indoors, requiring the development of new user interfaces to interact with the computer. Current AR systems only support limited interactions and so the complexity of applications that can be developed is also limited.

This dissertation describes a number of novel contributions that improve the state of the art in augmented reality technology. Firstly, the augmented reality working planes technique gives the user the ability to create and edit objects at large distances using line of sight and projection techniques. This technique overcomes limitations in a human's ability to perceive depth, and requires simple input devices that are available on mobile computers. A number of techniques that leverage AR working planes are developed, collectively termed construction at a distance: street furniture, bread crumbs, infinite planes, projection carving, projection colouring, surface of revolution, and texture map capture. These techniques can be used to create and capture the geometry of outdoor shapes using a mobile AR system with real-time verification and iterative refinement. To provide an interface for these techniques, a novel AR user interface with cursors and menus was developed. This user interface is based around a pair of pinch gloves for command input, and the use of a custom developed vision tracking system for use in a mobile environment. To develop applications implementing these contributions, a new software architecture was designed to provide a suitable abstraction to make development easier. This architecture is based on an object-oriented data flow approach, uses a special file system notation object repository, and supports distributed objects. The software requires a platform to execute on, and so a custom wearable hardware platform was developed. The hardware is based around a backpack that contains all the equipment required, and uses a novel flexible design that supports simple reconfiguration.

Based on these contributions, a number of modelling applications were developed to demonstrate the usefulness of these techniques. These modelling applications allow users to walk around freely outside, and use proprioception and interactions with the hands to control the task. Construction at a distance allows the user to model objects such as buildings, trees, automobiles, and ground features with minimal effort in real-time, and at any scale and distance beyond the user's reach. These applications have been demonstrated in the field to verify that the techniques can perform as claimed in the dissertation.

Declaration

I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text.

Wayne Piekarski

Adelaide, February 2004

Dr Bruce Thomas – Thesis Supervisor

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Most importantly of all, I would like to thank my mum Kris, dad Spishek, brother Arron, and my grandparents for supporting me for the last 25 years. My family also helped me build some of the early backpack prototypes in the garage, making an important contribution to the project. It is through their encouragement and care that I have made it through all the steps to reach this point in life, and I couldn't have done it without them. When my dad bought me a Commodore 64 when I was a little boy, who would have thought I would have ended up here today? My family has always taken care of me and I love them all very much.

In summary, I would like to thank everyone for putting up with me for the last couple of years. I believe that this dissertation has made a real contribution to the field of computer science and I hope that everyone that reads this dissertation finds it useful in their work. It has been a fun journey so far, and I look forward to catching up with everyone and having lots of fun and good times, because that is the most important thing of all.

Now it is time to catch up on some sleep and have a holiday! (Well, not really - there is still plenty of other work to do now)

Regards,

Wayne Piekarski

Adelaide, February 2004

Inspiration

“Another noteworthy characteristic of this manual is that it doesn't always tell the truth ... The author feels that this technique of deliberate lying will actually make it easier for you to learn the ideas. Once you understand the simple but false rule, it will not be hard to supplement that rule with its exceptions.”

Donald Knuth, from the preface to The TeXbook

“If you do choose to use a computer, beware the temptation it offers to let manuscript preparation displace composition. They are two separate activities, best done separately. Hyphenation and exposition are at war with one another. Pagination vies with content. The mind busy fretting over point size has no time left over to consider clarity. If you need a break from the ardors of composition, try the time-honored ones like poking the fire or baking bread. They smell good, and they don't give you any illusion that your paper is making progress while you indulge in them.”

Mary-Claire van Leunen