Mobile Computing

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Das Mediennutzungsverhalten der Menschen hat sich in den letzten Jahren stark intensiviert und gewandelt. Die Kombination aus der raschen Verbreitung mobiler Endgeräte und der Einführung neuer Dienste jenseits der reinen Sprachtelefonie führt zu einer Fülle neuer Möglichkeiten sowohl für Konsumenten als auch für Anbieter von Mobilfunkdiensten. Im Rahmen der Schriftenreihe werden herausragende Arbeiten aus dem breiten Forschungsfeld des Mobile Computing publiziert. Darin werden unter Einhaltung wissenschaftlicher Methoden Problemfelder aus der Praxis bearbeitet und Lösungsansätze vorgestellt. Das Hauptaugenmerk liegt neben der Entwicklung technologischer Artefakte auf der Ausgestaltung ökonomisch sinnvoller Geschäftsmodelle und der Nutzerakzeptanz solcher Systeme.

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Mobile Augmented Reality for Human Scale Interaction with Geospatial Models

The Benefit for Industrial Applications

Foreword by Professor Dr. Dieter Schmalstieg

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RESEARCH

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Foreword

Augmented Reality (AR) has recently become recognized as an emerging new medium. A broad audience today is interested in AR applications such as personal navigation, marketing or games. However, the history of AR applications in an industrial context goes further back. This field of application is currently reaching a turning point that marks the productive deployment of AR in the field.

You are holding the dissertation of Dr. Gerhard Schall in your hands, which deals with the use of AR systems for industrial applications in wide outdoor environments. Such an AR system requires at least three significant components: a model of the environment in which the system should be deployed, a real-time capable method for tracking the human user and an ergonomically acceptable mobile hardware setup. These three are the core topics of this book.

Maybe the most important of the three topics is the geospatial model that is suitable for AR applications. This implies that the model allows both localization from and visualization of the model data, which requires novel structures for the model data. Moreover, the model must be measured from scratch or converted from existing sources; both cases require appropriate processing method. Ultimately, the AR system must support the user in a better way than hitherto possible with conventional maps. A key achievement of the work described in this book is the systematic development of technology that addresses these requirements.

The first part of the book is concerned with two kinds of model creation. Models of large indoor environments are acquired using a mobile robot equipped with a computer vision system. Data from outdoor underground infrastructure databases is transcoded into 3D models.

The second part of the book describes the design and crafting of handheld AR systems relying on tablet computers. The AR device is held with both hands and has suitable ergonomic properties for outdoor work of engineers.

The third part of the book deals with outdoor 3D tracking. A hybrid tracking system is presented, which integrates GPS, compass and inertial sensor with a visual orientation tracker. Using sensor fusion, improved robustness and precision can be achieved.

Overall, this book points into new directions concerning outdoor AR for industrial applications. It can be assumed that AR is soon going to be an important medium for presenting geospatial information in-situ, i.e., directly at the task location where engineers work.

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Why do I write about augmented reality topics? Probably the major reason is my intense interest in the potential of AR and the joy of exploring new technologies. Even more important, I hope that mobile and handheld augmented reality can be further enhanced and find adoption in real-world scenarios. I foresee new ways of interacting using augmented reality as a user interface as well as new and changing fields of application.

The topic of this thesis is tied to several fields of research thus it is highly interdisciplinary. Topics from wearable computing, pervasive and ubiquitous computing will be mixed with more specialized fields like virtual and augmented reality technology. There are simply too many topics related to the theme of this thesis – this makes it impossible to explore all possible topics fully. Hence, wherever possible, sources for further reading are provided to overcome possible gaps and to serve the reader when there is more interest in a specific topic.

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Abstract

Augmented reality (AR) is intended to present new and more meaningful interfaces to users. At the same time there is a trend towards more realistic representation of real-world information as computing devices are becoming more pervasive than ever. Mobile AR has left the research lab and demonstrated its educational, social and economical potential. This thesis contributes to the research with several novel tracking approaches and a set of tools for creating content for AR applications.

One necessity for successful AR application is accurate and robust tracking of the user's position and orientation (pose). This thesis covers several approaches to achieving robust and accurate tracking for AR. A marker-based hybrid tracking system using ultra-wideband and inertial sensors for indoor environments is described. Furthermore, the thesis presents a multi-sensor fusion approach for combining differential data from the global positioning system, inertial sensor data as well as pose estimations with a visual tracker.

Another integral part of an AR application is the computer graphic content. Only non-manual modeling approaches can fulfill the need for larger areas and more complex content. Data sources such as geospatial information systems can be exploited for the creation of content. Following this vision, this thesis presents a content modeling approach describing a transcoding pipeline which generates models for AR by taking advantage of the rich data stored in geospatial databases. The models contain visual and non-visual information for the dual purpose of visualization and tracking.

There is a close relation between the content and the applied tracking approach. In particular, the coordinate systems of both methods need to fit together to achieve properly registered overlays. The approaches developed are applied in several mobile AR applications, among them an industrial application for registered visualization of subsurface infrastructure. Various tools, for example a virtual redlining annotation feature, are described and expert interviews are provided. In addition, evaluations from real-world test sites are presented. The thesis concludes with a summary of and reflection on the status quo, including a road map of open issues for further research.

Kurzfassung

Augmented Reality (AR) ist ein User-Interface-Paradigma, das virtuelle und reale Informationen verschmelzen läßt. Die Überlagerung der realen Umgebung mit virtuellen Informationen mit interaktiven Frameraten wirft eine Reihe von Themen auf. Diese beinhalten unter anderem die Forschungsgebiete der Erzeugung von 3-D-Modellen für AR und der Positions- und Orientierungsbestimmung (auch Tracking genannt) des mobilen Benutzers.

Um diese Probleme zu behandeln, befasst sich diese Arbeit mit der hochgenauen, robusten und stabilen Positions- und Orientierungsbestimmung. Für den Einsatz im Inneren von Gebäuden sowie im Freien wird eine Reihe von hybriden Techniken vorgestellt, die unterschiedliche Sensoren, wie Intertialsensoren, Magnetometer, Ultrawideband, differentielle GPS-Empfänger und Kameras intelligent integrieren. Alle präsentierten Techniken sind geeignet, ihren jeweiligen Zweck erfolgreich zu erfüllen.

Weiters befasst sich diese Arbeit mit der Erzeugung von größeren und komplexen 3-D-Modellen für AR, die auch kontextuelle Informationen enthalten. In diesem Zusammenhang ist eine manuelle Erzeugung der Modelle nicht zielführend. Daher präsentiert diese Arbeit einen Modellierungsansatz basierend auf einem Transcoding-Verfahren, welches auf effiziente und automatische Weise prozedurale 3-D-Modelle aus Daten von geographischen Informationssystemen generieren kann. Die erzeugten Modelle enthalten neben der Geometrie auch kontextuelle Informationen, die für interaktive Visualisierungen als auch für die Positions- und Orientierungsbestimmung verwendet werden.

Zusätzlich müssen die Koordinatensysteme der 3-D-Modelle und Trackingsysteme zueinander registriert werden, um die virtuellen Modelle passend der realen Welt in 3-D überlagern zu können. Die vorgestellten Methoden wurden in mehreren AR-Hardware-Prototypen, welche eigens dafür experimentell entwickelt wurden, eingesetzt. Am Beispiel der AR-Visualisierung von unterirdischer Leitungsinfrastruktur im industriellen Umfeld werden mehrere Werkzeuge zur Visualisierung und mobilen Benutzer-Interaktion vorgestellt. Das Potential von mobiler AR wird in Interviews mit Experten und Außendienstmitarbeitern, die im Rahmen von Feldtests und Benutzerstudien die AR-Prototypen getestet haben, bestätigt.

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