Instantreality — A Framework for Industrial Augmented and Virtual Reality Applications

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Abstract

Rapid development in processing power, graphic cards and mobile computers open up a wide domain for Mixed Reality applications. Thereby the Mixed Reality continuum covers the complete spectrum from Virtual Reality using immersive projection technology to Augmented Reality using mobile systems like Smartphones and UMPCs. At the Fraunhofer IGD the Mixed Reality Framework instantreality (www.instantreality.org) has been developed as a single and consistent interface for AR/VR developers. This framework provides a comprehensive set of features to support classic Virtual Reality (VR) as well as mobile Augmented Reality (AR). The goal is to provide a very simple application interface which includes the latest research results in the fields of high-realistic rendering, 3D user interaction and total-immersive display technology. The system design is based on various industry standards to facilitate application development and deployment.

Keywords

X3D, Semantic Modeling, Computer Vision based Tracking, Mobile Systems

1 Instantreality VR System

The instantreality framework is a high-performance Mixed-Reality (MR) framework that provides a comprehensive set of features to support classic Virtual-Reality (VR) and advanced Augmented Reality (AR) equally well. In this context, the term “mixed reality” describes the fusion of the virtual and real worlds as follows:

- Within Virtual Reality scenarios the user interacts with 3D digital objects in

Fig. 1 Immersive experience of machine construction with instantreality

real time (see Fig. 1). Using stereoscopic projection systems and multimodal interaction devices, the user is completely immersed in a virtual world.

- Augmented Reality (AR) describes the real-time overlay of our real environment with digital information. A typical Augmented Reality System includes a mobile computing unit, a video camera —which captures the user's environment — and a head mounted display for visualising the superimposed digital information.

The instantreality framework has been developed in close cooperation with the industry and supports various ISO/ECMA standards. It includes the latest research results in the fields of high-realistic rendering, 3D user interaction and total-immersive display technology. In Virtual Reality particular instant reality addresses the following topics:

1.1 Clustering and Distributed Rendering

In Darmstadt instantreality drives the high-immersive stereo projections system HEyeWall 2.0. This tiled display integrates 24 (6 × 4) DLP stereo projection systems and thus offers a resolution of 8400 × 4200 pixels (see Fig. 2). The system uses 48 PCs for parallelized rendering. Using colour calibration and geometric adjustment

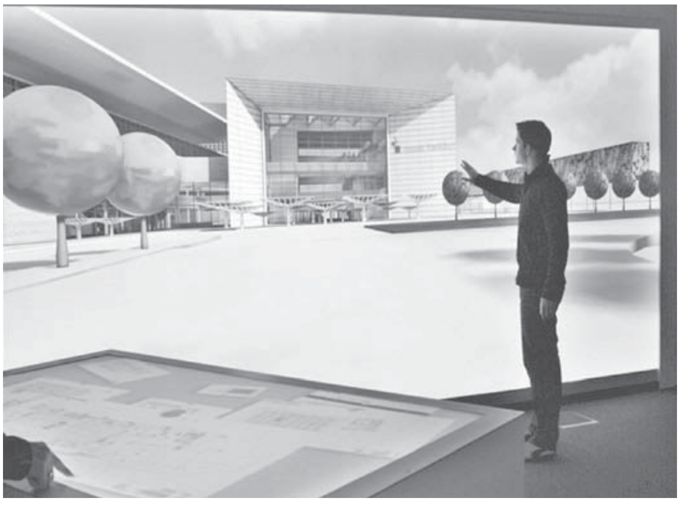

Fig. 2 HEyeWall 2.0 — tiled stereoscopic Virtual Reality display

homogeneous and edgeless pictures are rendered. The modular system can be scaled arbitrarily. Consequently, a wide range of projection resolutions and shapes is possible. With this technology, our customers are able to visualize their 3D models, sketches, and processes in real-time on the HEyeWall.

Thereby, the instant**reality** software framework includes various optimisation methods to exploit all available hardware resources and to reach global application specific runtime goals:

- Cluster-based Rendering
  Different sort-first/sort-last algorithms balance the rendering load for every cluster-node in real-time [1]. The method scales almost linear and is not fixed to the number of CPUs/GPUs. The algorithm allows increasing the overall cluster performance by increasing the number of render-nodes.
- Multi-Resolution Datasets
  Instant**reality** can create and manage multi-resolution datasets for points, meshes and volume datasets. This allows the system to control the overall render performance to reach global application goals like a minimal frame rate.

1.2 Semantic Modelling

With the Geometric Modelling Language (GML) developed at the Institute of Computer Graphics and Knowledge Visualization at Graz University of Technology high-level semantics have been included into the modelling process [2]. Thus, 3D-Modells are not only defined with geometric primitives like points and triangles but sequences of operators and parameters are used to describe structures and repetitive forms. Using this technology different instances of a generic 3D-Modell class can be generated by just modifying specific parameters (see Fig. 3). The GML has been included into the instant**reality** framework and this yields a high potential for interactive design applications.

Fig. 3 Modelling different instances of a wheel rim using the Geometric Modelling Language

1.3 Interactive VR with Multi-touch

Multi-touch technology is one of the most interesting research fields in today's Human-Computer-Interface area. By now, this kind of technology is just the basis for a lot of new techniques in the way we are working with computers. Thereby, Multi-touch interaction can be both, interacting with more than one or two fingers simultaneously, as well as working collaboratively in a multi-user scenario. The multi-touch technique has been integrated into instantreality and it is very promising since it allows people to interact seamlessly with what they see by simply touching it [3]. A multi-touch with a typical size of 150×90 cm has been developed and it is used for 3D-visualisation, navigation and interaction (see Fig. 4). In this implementation the projection unit is embedded inside the table. A wide-angle optic and a mirror system create a clear and high-resolution image on the table's surface. An optical touch-sensing method tracks the user's fingers using computer vision techniques. The multi-touch table's acrylic sheet is illuminated by infrared light. As the refractive index of acrylic is higher than the refractive index of air, light does not escape but is subject of total internal reflection. Whenever an object comes close enough to the surface, the total reflection is hindered; light therefore dissipates and illuminates the object. This would also illuminate a fingertip touching the surface and a camera trained on the table's surface can now capture the resulting light blobs from fingers. The blob detection processes the recognition of bright spots in the image, which results in a set of 2D images showing fingertip positions. Blob tracking assigns a unique ID to each blob and tracks this blob from frame to frame.

Fig. 4 Interaction with virtual world using the multi-touch-table

2 Instantreality AR system

Computer-supported information and communication systems play a decisive role in shaping our work and leisure time. Not only can new technologies for human-machine interaction be found in the workplace, they are also opening up numerous new fields of application. Augmented Reality plays a major role in this context. With this technology, digital information can be superimposed upon our real environment. The AR systems are characterized by the following characteristics:

- **Mobility:** Augmented Reality technology is particularly well-suited for mobile applications. For example, it can be used to support the targeted work of an assembler in a large factory hall (see Fig. 5) or to realize an information system for tourists to be used outdoors.
- **Real-time capability:** The digital information is always superimposed on the real objects in real time — that is, the Augmented Reality system supports the continual alignment of virtual and real objects.

- **Relation to context:** Information is visualized through superimposition on real objects. This ensures that the relationship between computer-generated objects and the real 3D scene is clear.
- **Intuitiveness:** The objects which are displayed consist primarily of graphic animations which guarantee that information is transmitted in a way that is easy to understand and independent of language.
- **Interactivity:** Innovative interaction paradigms which go beyond mouse/keyboard entry support the necessary mobility (the user has to be able to move freely over a large area) as well as agility (the user must be able to act freely with both hands).

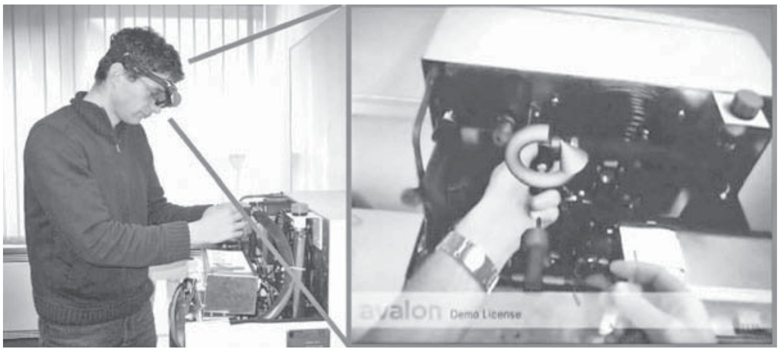

Fig. 5 Augmented Reality for the support of a service technician

2.1 Robust and Markerless Tracking

A special challenge in the development of Augmented Reality systems lies in the realization of adequate and robust tracking methods. The tracking system is used to identify and register the exact position and orientation of the user. In order to create such a solution, a hybrid, markerless tracking method has been developed that is based on the following data sources:

- **Live video data streams:** The live video data is recorded with a miniature firewire camera. This camera takes color pictures with a resolution of 640×480 pixels at a frequency of 30 Hz.
- **Inertial sensors:** The inertial sensors register accelerations in a translatory direction and velocities in a gyratory direction. Orientation in the earth's magnetic field is also registered (compass sensor). The data is exported at a very high frequency of around 100 Hz via a USB interface. The camera and sensors are combined in a tracking box, and the electronics are merged. The recorded data is correlated with the video grabber (interface in the computer for reading camera images), creating a synchronized data stream of video images, linear accelerations, angular velocities and orientation in the earth's magnetic field which serves as input data for the tracking software.

The tracking system is realized algorithmically by imitating the human sense of orientation [4]. Priority is given to processing the visual information, though in cases of bad lighting or high acceleration, the inertial systems come to the fore. For processing the visual information, the live images from the video camera are processed in real time. Features are extracted from the images which make it possible to identify characteristic features in the real environment (landmarks). These landmarks are identified by using point and edge detectors (see Fig. 6).

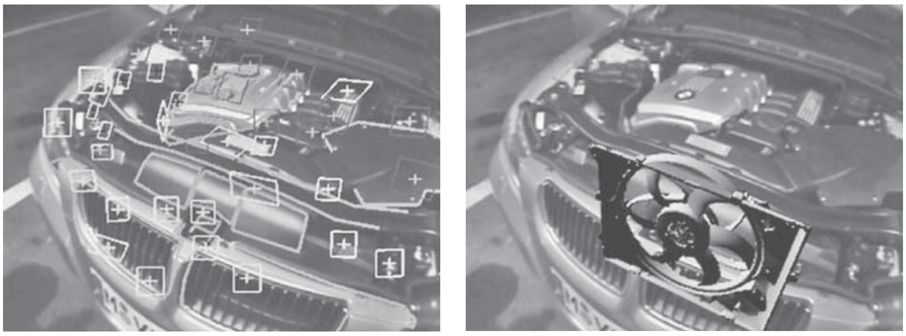

Fig. 6 Markerless tracking using natural feature tracking (left: Feature point and edges, right: AR visualisation)

With the help of the landmarks that have been identified in the two-dimensional camera images, the position of the camera is reconstructed in three-dimensional space. Epipolar geometry techniques are used to do this. Landmarks are either set in relation to previous video images (frame-to-frame tracking), or they are correlated with a digital 3D model of the real environment. The digital 3D model of the environment is created in a preprocessing stage on the basis of 3D CAD models of buildings or machines, for example. Inertial sensors support this image-based tracking method. The assumed pose (position and orientation) of the tracking unit can be predicted by analyzing the measured motion path of the tracking unit. This estimated pose is the starting point for the image-based tracking algorithms. The inertial sensors are also evaluated if no landmarks are detected in the camera images. The problem with using inertial sensors, however, is that measurement errors can accumulate, since they are not absolute poses which are registered here, but rather relative movements. For this reason, the poses determined using the inertial sensors are continually corrected with the help of the absolute pose results from the image-based tracking.

2.2 Augmented Reality Embedded Systems

Virtual Reality is often linked to technically most demanding installations whereas the intended platforms for Augmented Reality are mobile devices like PDAs or UMPCs (see Fig. 7). So, downscaled Augmented Reality systems have been developed that support different lightweight devices even on embedded operating systems. Consequently, the rendering component is based on the OpenGL ES standard. OpenGL ES supports the display of three-dimensional computer graphics on mobile end devices [5]. Building on this, a scene graph is developed with which the 3D objects can be structured and managed. The scene graph is compatible with the X3D standard.

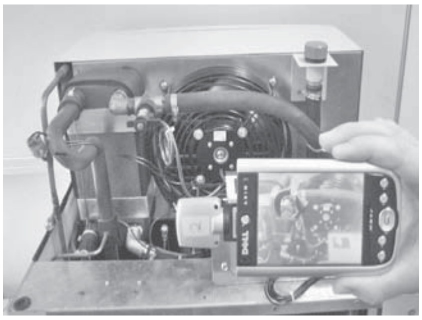

Fig. 7 AR-maintenance support system running on the PDA

3 Conclusion

Instantreality covers the complete domain from Virtual Reality to Augmented Reality applications. Thus, Computer Vision based tracking can be used for VR applications or VR simulations can be combined with real captured environments, to mention only two examples. This fusion of CV and CG includes the simulation of consistent illumination in Augmented Reality applications as well as colorimetric measurements to support colour-confident rendering. The instant**reality** framework provides a complete set of tools and plug-ins to ease the integration of different data sources as well as the application development and deployment:

- **Integration:** Plug-ins for the most common digital content creation tools (e.g. Maya, 3DMax) enable the application developer to integrate 3D data very efficiently. Data Importers for the Framework can directly read and process the most common CAD data formats (JTOpen, Catia5, Catia4, Step, STL etc.).
- **Composition:** A special runtime environments allow the developer to integrate and compose data from different sources. The system includes various plug-ins to enable the developer to create any type of application logic and behaviour by defining components, component relations and component processing units. A nifty event and script debugger ease the development process.
- **Deployment:** Various server and middleware systems can be utilized to deploy the final applications on a wide number of hardware platforms. The server and services communicate using standard ZeroConf mechanisms to ease the installation and service process.

The system design includes various industry standards to ease the development and application service process [6]: OpenGL 2.0 (Khronos Group), GLSL (Khronos Group), Collada (Khronos Group), CG (NVIDIA corporation), X3D (ISO/IEC 19775:2004), ECMAScript (ISO/IEC 16262:2002), JAVA (Sun corporation), SOAP (W3D SOAP V1.2), ZEROCONF (IETF Zeroconf WG). All system components are available on a wide number of hardware and software platforms: Windows 2000/XP/Vista, Windows CE, Linux32, Linux64, Mac OS X, IRIX, SunOS.

References

[1] Roth M, Rieß P, Reiners D (2006) Load Balancing on Cluster-Based Multi Projector Display Systems. In: Joaquim Jorge, Vaclav Skala (eds) Proceedings of the International Conference in Central Europe on Computer Graphics WSCG, Plzen

[2] Berndt R, Havemann S, Settgast V, Fellner D (2008) Sustainable Markup and Annotation of 3D Geometry. In: Ioannides, Marinos et al (eds) Proceedings of the 14th International Conference on Virtual Systems and Multimedia, Limassol

[3] Jung Y, Keil J, Behr J, Webel S, Zöllner M, Engelke T, Wuest H, Becker M (2008) Adapting X3D for Multi-touch Environments. In: Spencer, Stephen N. (eds) Proceedings of the 13th International Symposium on 3D Web Technology, Los Angeles

[4] Bleser G, Stricker D (2009) Advanced Tracking through Efficient Image Processing and Visual-inertial Sensor Fusion. Computers & Graphics 33(1): 59–72

[5] Rieß P, Stricker D (2006) AR On-demand: A Practicable Solution for Augmented Reality on Low-end Handheld Devices In: Müller S, Zachmann G(eds) Proceedings of the 3. Workshop der GI-Fachgruppe VR/AR, Aachen

[6] Behr J, Dähne P, Jung Y, Webel S (2007) Beyond the Web Browser - X3D and Immersive VR. In: Proceedings of the IEEE Virtual Reality 2007, IEEE Symposium on 3D User Interfaces, Charlotte

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