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VIRTAINER: Technologies for the Virtual Interaction with Groups of Objects in Ordered Stacks: Application to Storage Container Terminals and Warehouses

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Abstract

The interactive exploration of virtual environments is a problem area relevant to a wide range of applications, key among them the monitoring of industrial processes. This project aims to contribute to resolving the problems surrounding the visualisation of large data volumes subject to specific placement, as are stacks of shipping containers in a maritime terminal or merchandise in a large warehouse. This visualisation should be interactive so that the user might make decisions in real-time, and it should represent the data sets in real-time to be able to know the state of the system at any moment. The virtual environment defined as such can be utilised for investigation into user-environment interaction, covering fundamental aspects such as navigation, query of information associated with geometric elements or collaboration among distinct remote users.

Keywords: CAD Model, Real-Time Rendering, Virtual Environment, Augmented Reality.

1 Description of the Project

This Section describes the goals of the project, the physical and human resources employed to achieve those goals, and the schedule of the project's tasks.

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1.1 Project Goals

This project has two main goals, the basic research in methods of processing and visualization of stacked objects and the development of new techniques of suitable communication person-computer to these methods. The response times of visualization will be improved substantially according to the following **features of the data**:

- Most of them are boxes that form stacks ordered on the ground. The stacks, possibly of different sizes, form arrays of object's blocks.
- There are mobile objects that move on the streets, the gaps between the stacks, or over the stacks (fly over).
- The number of boxes is of so big that it is impossible, at the present time, to render them interactively on a low cost graphical processor.
- The visualization must be oriented towards the understanding of the data more than to represent the reality faithfully.
- The container yard may contain other objects like trees, signals or buildings, which are not the main target of the visualization.
- We will be handling outdoor and indoor scenes, thus, the conditions of illumination will vary throughout the day.

The **general goals** of the project can be summarized as follows:

- To improve the rendering times of ordered 3D structures in interactive and distributed applications.
- Exploitation of the coherence to improve the methods of reducing the number of graphical objects sent to the graphic pipe.
- To try different human-computer interfaces of virtual reality for process supervision or environment exploration.
- To test methods of augmented reality in the industrial process of storing in stacks.
- To integrate the previous techniques in distributed information systems.
- To apply the know-how to the problem of the three-dimensional representation of a container terminal.

Each one of these goals can be further refined as follows:

Improvement of Rendering Times

- Modeling geometric structures with 3D array spatial organization.
- Development of efficient traversal algorithms for the structures modeled.

- To study and develop methods of substitution of geometry by images. To apply level of detail techniques based on images.
- To study and develop specific multiresolution models for stacked structures.
- To study the possibility of using non-photo-realistic rendering techniques to improve the rendering times. To experience their applicability.
- To achieve real time rendering of scenes of stacked objects, using a combination of different techniques.
- To develop network transmission protocols for simultaneous rendering of the model on different displays.

Exploitation of the Coherence

- To develop simple methods of stack selection depending on the position of the observer
- To apply occlusion techniques to the removal of hidden objects.
- To develop specific visibility algorithms for stacked structures.
- Removal of hidden faces due to occlusion by the same matrix.
- Preparation of anticipated views like pre-computed visual structures for the acceleration of the visualization.
- To study methods for maze rendering and their applications.

Virtual Reality

- Development of a software system for virtual reality applications.
- Validation of the software with available devices: HMD, tracker, 3D mouse, etc.
- Construction of a stereoscopic projection of our own design.

Augmented Reality

- To study and propose user location methods in outdoor environments and along his/her line of vision.
- To match the image of a real object with the location of a virtual object.
- To present information about the object of interest in mobile devices.

Integration in Distributed Systems

- To obtain a model distributed among different environments and accessible to multiple users.

- To broadcast the changes to the model to the distributed enviroment at acceptable rates.
- To study the feasibility of using standards to take advantage of the constructed renderers.

Application to Storage Centres

- To apply the proposed data structures to stacks of containers stored in a container terminal.
- To construct an interactive 3D application, using our techniques for rendering and operative supervision of machinery and trucks in the container yard.
- To test the constructed virtual reality system on the supervision application.
- To set up a prototype system of augmented reality to evaluate the possibilities of integration with the industrial processes.
- To enable the distributed rendering of the industrial process.

According to these objectives, at the end of the project we would like to have the following **software and hardware systems**:

- A general purpose library to handle a scene graph with OpenGL rendering and directed at the manipulation of virtual reality devices.
- A set of techniques, methods, data structures and specific algorithms oriented towards the real time visualization of 3D array structures in distributed environments.
- An 3D application for the supervision of the container yard of a marine terminal.
- A framework for the of transmission of changes and models over the network in distributed environments.
- An stereoscopic projection workbench of our own design.
- A prototype of portable augmented reality system.

1.2 Available Resources

The participant groups have worked in projects funded by the European Union, the Spanish Government, the Valencian State Government and by private organizations. Those projects are aimed at the development of techniques for rendering acceleration. These can be applied to the construction of graphical interfaces for industrial process monitoring. The main references that support this research are:

- Development of a navigation module for the company Maritima Valenciana. The work began with an initial agreement between the Polytechnic University of

Valencia and Maritima Valenciana, which was followed by a FEDER-CICYT (1FD97-2158-C04-01) project with a contract associated to the company. The results of this research mean an important technological innovation in the container terminal of Valencia's harbour. The rendering system is 2D and uses OpenGL display lists for the visual management of the data.

- Development of general purpose software for Virtual Reality applications (Xplora). This software constructs a scene graph with OpenGL support. We have tested the software with a HMD, a tracking system and other 3D interaction devices. We have also completed modules for dual projection with temporal and spatial multiplexing, texture management, levels of detail and selection. The system is stable and has been published in the OpenGL repository.
- Research and development of potential applications of virtual environments to teaching and to management within the University. We have developed a prototype of a virtual environment for Computer Graphics teaching and a multi-user virtual prototype of the Jaume I University accessible through the Internet (financed by the foundation Caixa-Castello' Bancaixa, P1.1B2000-21).
- Research and development of methods that use occluders to accelerate natural scene rendering in agricultural environments (projects GV97-TI-05-42 and TIC99-0510-C02-01).
- Comprehensive research in general multiresolution models, based on triangle strips and triangle fans (TIC99-0510-C02-01 TIC2001-2416-C03-02, the latter in cooperation with the University of Gerona and the Pompeu Fabra University).
- Development of specific multiresolution models for particular objects, like those generated by procedural systems (projects GV97-TI-05-42 and TIC99-0510-C02-01).

We intend to apply the knowledge acquired to adapt our tools to the interactive rendering of ordered structures suitable for some of hierarchical or array organization. Our purpose is to develop novel topics using Augmented Reality as support for decision making or methods for component selection and multiresolution. We also want to work on Virtual Reality systems (using both projection systems and HMD), advancing in the capabilities of browsing, querying and collaboration of users in virtual environments.

The human and material resources that support this research are made of the research teams and the laboratories of the Computer Graphics Group of the Jaume I University of Castellón and the Computer Graphics Group of the Polytechnic University of Valencia. Two researchers of the University of Vigo have also participated in the project. As for infrastructure, we have planned the use of a Virtual Reality projective system acquired with a FEDER grant at the Jaume I University.

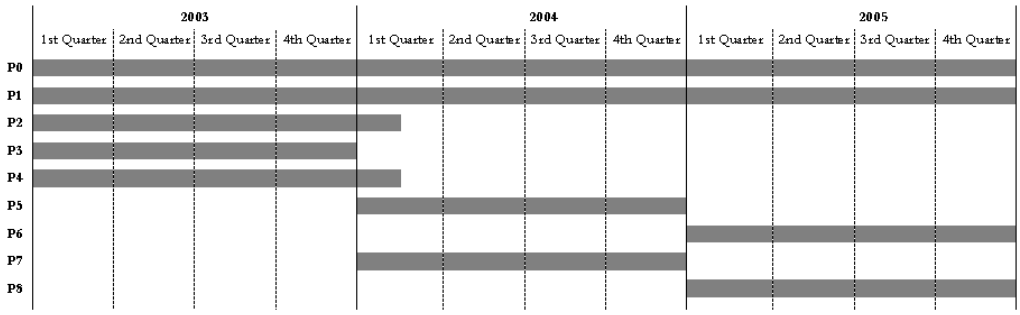
1.3 Project Schedule

The tasks involved in the project are:

- P0 Coordination.
- P1 System specification.
- P2 Rendering acceleration techniques.
- P3 Geometry simplification techniques.
- P4 Interaction techniques for virtual environments.
- P5 Interactive renderer.
- P6 Stereoscopic projection system.
- P7 Virtual and augmented reality support software.
- P8 Augmented reality support devices.

Task P1 is devoted to the analysis of the project's goals, a survey of existing solutions and the specification of the hardware and software to develop. Tasks P2, P3 and P4 are devoted to the definition of models and algorithms that will be implemented on an interactive renderer in task P5. Tasks P6, P7 and P8 refer to the development and integration of tools and techniques applied to advanced interfaces for querying Virtual and Real Environments. Although in the initial project specification a detailed division of these packages in tasks was made, in this report we only address those tasks that have made relevant accomplishments.

The schedule of tasks is shown in the following figure:



2 Project Milestones

Until the moment for emitting the present report the project has been developed according to the initial forecasts. We have completed the tasks associated to the modelling and to the visualization acceleration techniques (Package of tasks P2), to the modelling and geometry

reduction techniques (Package of tasks P3) and to the modelling and virtual environments interaction techniques (Package of tasks P4). The efforts of the project have been focused mainly on the following tasks:

- T23, T24 y T25 Acceleration techniques for rendering.
- T26 Non-photorealistic rendering.
- T33 Multiresolution polygonal modelling.
- T34 Image-based techniques (impostors).
- T44 Contextual system data modelling.
- T45 Contextual data integration.
- T46 Interaction techniques based on location and context.

In these packages of tasks the following milestones have been reached:

- Development of a realistic rendering system that integrates different acceleration techniques like selection and deletion, occlusion or path selection.
- Development of a non-photo-realistic visualization system with different styles.
- Accomplishment of exhaustive comparative between different multiresolution models, based on polygons and base in strips as well.
- Implementation of several multiresolution models.
- Development of techniques for the substitution of geometry by images (impostors). Dynamic update of impostors.
- Design and construction of a reduced model of a terminal of stacked objects in a laboratory.
- Accomplishment of an exhaustive study of the different techniques of interaction with a CAD model based on the view (position and direction of observation).
- Integration of contextual data and development of a prototype query system of the data based on the view.
- Development of techniques for the abstraction of geometric information from a set of images.

The obtained intermediate results in these tasks have been used like input for the combination of techniques (tasks T27 and T35). The obtained conclusions and the selected methods are used in the package of tasks P5 for the integration of the developments made in an interactive viewer. In this package of tasks the following works have been made:

- Design and implementation of the data access modules, the logical representation modules, and the geometric and visualization modules.
- Integration with the asynchronous system of communications Score.

- Integration on the platforms of open code OpenSceneGraph and OpenTracker.
- Synchronization by means of software technology coming from multiple renderers.
- Design of the architecture for the simultaneous execution of several viewers with different cameras (making of cabins).
- Integration with wireless interaction devices.
- Visualization on HMD.
- Improvement of the scene update loops.
- Outdoor scenes illumination
- Adaptation of the techniques to terminals of stacked objects
- Integration with mobile devices

Finally, we have made progress some tasks tied to the P7 package on software support to the Virtual and Augmented Reality. In this package of tasks the following works have been carried out:

- Realization of an exhaustive comparative between location techniques of the observation (hardware sensors and vision based systems).
- Development of a observer location system based on marks.
- Integration of software on an open code library (AR Toolkit).
- Test and validation with different camera models and different markers.

At the moment of emitting this report there are some tasks left related to the packages P5 and P7 which are in phase of development, like the network visualization sharing (T55 task) or the integration of the techniques in a commercial visualization software (tasks T53, T74 and T75).

As final result of our activities the following milestones have been reached:

- **Dynamic simulation of a containers terminal in real time**. The visualizer gathers events from the process and updates the position of the objects. The data base corresponds with a real data base yielded by one of the collaborating companies. The visualization allows interactive movement of the camera, stereoscopic view, integration with external devices of interaction and mosaic of cameras.
- **Prototype of query system of contextual information associated to a stacking.** We have developed a system based on the location of the observer using marks in the scene. The system allows superposing a virtual model of the stacking to the original image, to select an object of the stack and to accede to its associate information. The prototype is functional in laboratory, and is necessary to migrate to the outside to be able to apply it in real workplaces of stacking.

3 Result Indicators

This Section includes some indicators of the relevant of the results obtained so far during the development of the Project.

3.1 Publications

Until the moment of issuing the present report, the project has produced intermediate results susceptible to be published. These results have appeared in different forums of recognized prestige, national and international as well. Next the main publications related to the project in this period are enumerated:

- 1 international journal paper [1]
- 1 national journal paper [2]
- 5 papers in series "Lecture Notes in Computer Science" [3] [4] [5] [6] [7]
- 8 international conference papers [8] [9] [10] [11] [12] [13] [14] [15]
- 3 national conference papers [16] [17] [18]

It is important to emphasize that, along with the publication of partial results, the project has been presented in the Spanish Congress of Computer Graphics, in the Industrialist Track in Eurographics and in the Latin American Symposium of Graphical Computation SIACG'2004.

3.2 Personnel in Training

At the moment of starting the project, the participant groups of investigation had several research assistants. Some research fellows have been incorporated to both subprojects. Until the moment they have delivered the following research works related to the project:

- *Detección de características singulares en conjuntos de objetos apilados*, 3 credits research work, Program "Métodos Informáticos Avanzados", Universitat Jaume I, 2004
- *Anotación de características en sistemas de Realidad Aumentada basados en marcas*, 9 credits research work, Program "Métodos Informáticos Avanzados", Universitat Jaume I, 2004
- *Explotación del hardware gráfico para acelerar la visualización de geometría*, 6 credits research work, Program "Métodos Informáticos Avanzados", Universitat Jaume I, 2004.

The coordinated subproject of the Universitat Jaume I has received a research fellow from FPU program, who will make her doctoral Thesis in topics related to the location of the viewer in open outdoor environments.

3.3 Technology Transfer

The companies Marítima Valenciana, Cecopesca and Feicopesca participate like observant organizations interested in the utilization of results. The participation of the Marítima Valenciana company takes shape in the industrial infrastructure lending to the project. More concretely, we have planned to use the terminal of the port of Valencia to make the field tests of the Augmented Reality system.

3.4 Collaboration with Other Research Groups

The Department of Computer Languages and Systems of the Jaume I University has been maintaining for some years relations with the Department of Computation of the Oriente University in Santiago of Cuba. The collaboration has as main target the formation of 10 professors of the Oriente University. At the moment, these 10 professors are attending the doctorate program "Advanced Computer Science Methods" at the Jaume I. The visits in both senses are been financed by means of specific actions promoted by the Jaume I University and scholarships of the Spanish Agency of International Cooperation.

The present project has allowed to integrate by means of a scholarship to a professor from the O.U., who will make the research of her doctoral thesis in the topics related to the project, specially in the development of a functional prototype for the augmented reality in the yard of containers. Integration in the project of this professor opens doors to new collaborations between both departments in the scope of the present research. In this line, relations with the Group of Computer Vision of the Jaume I University have started.

On the other hand, during the last year, research fellow from FPU program assigned to the project, has made a research stay in the Technical University of Graz, Austria. The Image-based Measurement Group)of the University of Graz has wide experience in the development of systems of tracing for the location of the observer, as much based on hardware sensors as well as based on vision. The collaboration of the research fellow has been focused in the accomplishment of different tests from exactitude in different tracing systems, and the collaboration has been satisfactory for both parts.

3.5 International Project Grants

Recently, the main researcher of the project and some members of the research team have been incorporated to the project:

Game Tools: Advanced Tools for Developing Highly Realistic Computer Games
VI European Program, Priority 2, Information Society Technologies
Specific Targeted Research or Innovation Project
Contract nº 004363

The participation of the research team in this project is focused in following topics:

- Use of multiresolution models.
- Development of visualization acceleration techniques.
- Advanced interfaces in video games: stereoscopic views and Virtual Reality.

All of these topics are closely related to the present research project.

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