PC-based stereo visualization tools for aviation virtual reality projects

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ABSTRACT

Virtual reality is a new way to enhance the human interaction with a simulator or another man-machine system. Synthetic environment of virtual reality provides new possibilities of human activity due to the use of various sensor channels. Stereo visualization provides human immersion to virtual space and is the important feature of virtual reality. The investigations of technical and programming tools for stereo visualization of highly accurate and detailed 3-D models of objects and the terrain with geo-specifically placed objects like buildings, roads, forests and other special landmarks are discussed. Hardware includes liquid crystal shutter glasses and Intel Pentium computer with standard monitor. Use of original photogrammetric and rendering software under MS Windows provides very realistic "walk-through" and "fly-over" simulations. These tools are cheaper than ones oriented to powerful workstations. The examples of animations and virtual spaces with designed for airplane pilot training 3-D site models of real scenes are demonstrated.

Keywords: digital site model, virtual reality, simulation.

1. THE FEATURES OF VR SYSTEMS FOR AVIATION PROJECTS

The aviation industries have long understood the importance of simulation and training. The current trend for increased technological complexity and shorter avionics hardware life spans require simulators that are flexible, upgradable, and networkable. This allows remote simulation without having to transport trainees to the simulation site. Networking is also needed in group simulations which are more realistic than single-operator ones. Virtual reality (VR) is flexible, upgradable, and networkable technology, therefore it ideally matches the needs of aviation simulation[1,2,3]. To decide the project problems VR hardware-in-the-loop simulation provides the researcher the possibility

- to use only cockpit panel and control sticks during simulation;
- to test avionics in various modes of flight;
- to analyze the ergonomic issues of man-machine interaction;
- to train the operators (pilots) before the appearance of a certain vehicle;

The aviation training puts on the VR systems some specific demands:

- the simultaneous indication of exterior space and command data;
- the high speed visualization;
- the more-detail visualization of exterior objects on small distances;
- the realistic sound generation.

It is necessary to take into account that the stereo visualization has the sense only for detailed objects represented by a lot of polygons. If the object is represented as one polygon the human brain hasn't the ability to estimate its depth. So the

problem of stereo visualization is actual for some special flying modes such us low-height flight, helicopter against tanks fighting, reconnaissance, etc.

2. NECESSARY TOOLS TO BUILD VR AVIATION SIMULATORS

To build aviation simulator based on VR technologies it is necessary to realize some program tools that decide following problems:

- scene restoration based on airborne and spaceborne photos;
- creation of database of mesh scenes, mesh objects and textures;
- real time rendering;
- animation (optional);
- interaction with objects and scene.

The full decision of these problems is possible if we use special workstations such as Helava DPW 770 and Evans&Sutherland ESIG-4000 and EiSIEST. This variant including software cost exceeds 1.5 billion USD. If we take into account the nowaday functional equality of highend Windows NT Pentium based PC and lowend Silicon Graphics stations and the plans of Intel Corp. to provide 10X increase in 3D performance for PC users in 1999 year, we can insist that the use of PC-compartible computers has good perspectives in VR area. Of course, this variant doesn't permit to realize a full spectrum of aviation simulator tasks, but in this case the cost/effectiveness feature is very attractive. The cost of PC-based computer with special software doesn't exceed 15000 USD.

There are some program systems intended to decide the problems above:

- ERDAS digital photogrammetric system;
- PARADOX and Oracle database tools;
- Autodesk 3DStudio rendering and animation system;
- CrystalEye, SimulEye or Kasan 3D MAX stereo visualization software for LCD goggles;
- Autodesk Cyberspace Developer Kit for virtual space construction and providing with interaction.

Each above system decides only one problems and it doesn't provide the creation of aviation VR simulator software as united program under one operating system.

3. OUR VERSION OF VR TOOLS FOR PC

The photogrammetric part of our programming system is considered in this volume[4]. Here we discuss the part connected with database constructing and rendering. The system permits to store and to edit a set of objects' models, located on terrain model, as well as to generate the 3-D image on a computer display for any chosen points of view. The system works under management OS Windows 95. A special LCD glasses are necessary for viewing of a stereo images.

3.1. The system structure:

The system consists of following main modules:

- Processor of the initial information
- Editor of a orthoplan (graphic editor)
- Program of a stereo image generation
- Library of conditional designations
- Library of 3-D objects and textures

The processor of the initial information transforms files with the terrain description in formats DXF, ASC, etc, in a format of the graphic editor. The processor makes a surface triangulation and simulated objects matching to it.

The graphic editor provides wide opportunities for viewing and editing of the simulated surface plan:

- mesh relief editing;
- new objects intrusion;
- the characteristics of existing objects changing;

- a choice of a stereo image parameters;
- the determination of a set of points of viewing in a form of a "flightover' trajectory.

The graphic editor uses library of conditional designations for display object content of a surface structure . All data, used by graphic editor, are stored in a kind of objects, that permits to make surface scaling and change of their parameters without distortions.

The library of objects is a database of possible objects and their conditional designations in the graphic editor. The sample given from library is executed by the graphic editor and stereo visualization program. The modification in a database is executed by the specialized librarian program.

3.2. Classification of simulated objects and their representation

The terrain description in terms of a 3-D modeling system is reduced to the surface description and to the description of objects located on it. The objects are divided on "flat" (for example a wood, field, lake), "linear" (roads, rivers, pipelines) and "dot" (separate buildings, trees, bridges).

The initial relief data are stored in files of formats DXF and ASC. The processor of the initial information carries out filtration of the redundant information (deletes points lying in one plane), builds a Delone triangulation and assigns a special code (surface attribute) for each received polygon . The code of a polygon corresponds to a code of flat object, which places on this polygon. At addition of new flat objects initial triangulation is supplemented. Thus, the flat objects are connected to the description of a relief. On a code of a polygon the program determines its kind on a orthoplan (graphic editor finds the appropriate information in library of conditional objects) and on a stereo image (the generator of a stereo image uses the library of 3-D objects and textures).

The description of linear objects is reduced to the description of its code, width and broken line as a set of points. There are no information about heights of points of a broken line, since it is determined from heights of polygon, through which this broken line passes.

The description of dot objects is reduced to the description of their codes, coordinates of centers, parameters of scaling and orientation. The library of conditional designations and library of 3-D objects and textures store the information on abstract dot objects. The graphic editor and generator of a stereo image execute geometrical transformations of coordinates of library object for rendering of a conditional designation and stereo image of a particular sample of object.

3.3. Library of 3-D objects and textures

The library of objects and textures contains the description of standard elements, used at construction of terrain plans. Such description contains a identification code of object, its name, conventional image for 2-D plan and reference on a file with the description of 3-D of a kind of object (as a rule, file in the DXF format).

At entering of object into a terrain plan on its name (or code) from library the conventional image of object and its size dimensions is extracted, then positioning of object on a terrain and scaling for reduction in conformity of the sizes of real and library objects is made. These parameters (name, file of the 3-D description, coordinate on a terrain and scale multipliers) are transmitted then in the program of 3-D modeling and rendering.

The texture descriptions of rendering object can be stored either in a BMP-file or to be defined during 2-D orthoplan editing. At change standard texture a file of the description of unique object is created and the reference on it is transmitted in the 3-D modeling program, instead of the reference on initial (standard) file.

3.4. Structure of a 3-D scenes database.

The information required for 3-D scene rendering and reception of help information is stored in a database. The data are organized in a kind of the tables and are sorted out for acceleration of access. To control and keep the integrity of data the references are established between the tables (see fig.1,2).

The model of a scene consists of objects that occupy limited area in 3-D space. The location of particular object on a terrain is defined in the coordinates of its matching point (X,Y,Z) and the corner of turn (Alpha) in table ***OBJECTS***. The field ***Layer*** from this table specifies a fitting of object to a layer.

To avoid repetitions at storage of typical objects (buildings, trees and etc.), the real objects on a terrain are set through references on unique objects from library ***OBJCT_LIB***. The object in this library has only number ***NUM_OBJCT_LIB***, type of object ***Id_Type*** and linear size of object ***L***, the analysis of which allows to remove excessive detailed elaboration at the rendering of small-sized objects.

The object is determined by the list of flat convex polygon belonging to it ***POLYGONS***. Some real objects on a terrain or some records in table ***OBJECTS*** can have identical values of fields *NUM_OBJCT_LIB*, i.e. can be defined by the same polygon.

The fields *TEXTURE* and *MTRL* are the references on the unique numbers of records in tables ***TEXTURES*** and ***MATERIALS*** that contain information about textures and materials of a polygon surface.

The polygon is determined by the list of units from the table ***VERTICES***. If the number of units in each polygon is fixed, the references on appropriate can be arranged directly in table ***POLYGONS***: VRTX1, VRTX2, VRTX3. (see fig.1). For any number of units in each polygon intermediate table ***PLGN_VRTX*** is necessary, in which number of the vertex in the polygon ORDER and the reference pairs on the number of polygon NUM_PLGN from table ***POLYGONS*** and the number of vertex NUM_VRTX from table ***VERTICES*** are stored (fig.2). The condition of fixed number of the VERTICES in polygon is not strong restriction, and nowadays the version of database without ***PLGN_VRTX*** is realized (fig.1).

Tables ***GROUPS*** and ***INFO_GROUP*** are intended for organizing the object groups and storing the information about each group. The objects are independent, the sets of facet and nodes of various objects are not crossed.

The information on cameras and sources of light is stored in tables ***CAMERAS*** and ***LIGHTS***.

There are special tools to execute the automatic control at integrity of data in database (Referential Integrity property with cascade updating of records). These connections are marked by arrows on fig.1 and fig.2. For example, the connection between the fields VRTX1, VRTX2, VRTX3 in table ***POLYGONS*** and NUM_VRTX in ***VERTICES*** makes impossible the removing of the vertex so long as there is a reference on it in any polygon. Besides the change of the unique number of vertex Num_VRTX in ***VERTICES*** causes the automatic change of the numbers in VRTX1, VRTX2 and VRTX3 from ***POLYGONS***.

The database is intended for filling, storage, support and sample of data, necessary for rendering of 3-D scenes. The data can be as local, as client-server. At filling and editing of a database the integrity of data automatic control is executed.

The extraction and transfer of data is executed as reply to the inquiry of the visualization program with the help of a video data server VSERVER made out in the kind DLL. The polygon extraction for object rendering in a concrete space volume is made in some stages:

1. The analysis of a fitting of object to a given layer (or layers), location of a object matching point and its size (fields X, Y, Z, OBJECTS) permits to reject those objects, which do not belong to a considered volume.

2. For the other objects those polygons are chosen only, at which the first vertex falls in a considered volume.

As a result of the inquiry the list of polygon and vertices is formed. To reduce frequency of loading of a textures at rendering, the list is ordered on objects and further on textures, i.e. next in the list are the polygons with the identical numbers of objects and textures.

The inquiry of the accompanying descriptive information about object or group of objects is made from tables ***GROUPS*** and ***GROUP_INFO***. A type of the information (text, audio, video) specifies the field Id_Type, the information is contained in the field Info.

As a result of the inquiry the vertex, and, hence, and object, which is closest to a considered point (or to a beam, directed to this point from point of view) is determined. This inquiry is multistep and reasonably complex, but time of its processing is not so crucial, as at preparation of data by video server.

At the first stage the objects inside of which specified point falls are defined. Then all VERTICES in polygons belonging chosen objects in view of their real terrain location are sorted out, and vertex, polygon and object, for which distance up to a point is minimum, are defined.

The procedures described above are realized on Delphi 2.0 and permit to work as with local data, as in client-server technology. The specified approach is reasonably flexible concerning a format of storage of data, as far as the reference to different sources of data is based on the concept of drivers. To the present time in Delphi there are drivers for local Dbase, PARADOX and server InterBase, Oracle, Sybase, Informix, MS SQL-Server technologies.

The 3-D scene rendering program **3dviewer** communicates with the program of a standard rendering (OpenGL, 3DR, DirectX) via visualizator made out in the kind DLL (**builder**). The scene are stored in a database, attended by video data server (**Vserver**). **Vserver** is made out in the kind DLL and serves as **builder**, as 3dviewer.

3.5. Stereo driver for OS WINDOWS 95.

The stereo driver is intended for viewing of the stereo images on a PC-display. Main stereo driver function is synchronous switching of video pages and LCD cells of stereo goggles.

The driver works under OS WINDOWS 95 on the basis of a interface of applied programming (API) DirectDraw and supports all standard Windows video modes (at 4 Mb video RAM - up to 1024 õ768 õ16 in two-page non interlaced and 1240 õ1024 õ24 in interlaced modes). API DirectDraw provides hardware independence of stereo driver and its use in techologies based on DirectDraw, for example for stereo TV watching. To plug stereo goggles it is necessary the availability of one free port COM1-COM4, LPT1-LPT2 depending on a type of stereo goggles. In case of connection to LPT1 or LPT2, the availability of one free connection COM1-COM4 for maintenance of synchronization in the modes MODE2, MODE3 is in addition required. The driver is written as the virtual driver of Windows, established and configured with the help Drivers item from Control Panel, and contains functions, ensuring synchronization with signal of return course of beam and switching of video pages and control codes of stereo goggles. Following modes of synchronization are supported:

- MODE1-synchronization on a signal of a return course of a beam from a video adapter. This MODE is not supported by all video adapters.

- MODE2-synchronization with the help of temporary labels-interruptions, generated by a COM port. This mode is supported always when there is the availability of free COM port.

- MODE3-synchronization on a signal of a return course of a beam from a monitor cable. This signal arrives on a input of COM-port and produces the interruption synchronous with display cadre scanning. Additional hardware connection and availability of free COM port are required.

From the point of view of productivity and reliability the modes MODE1 and MODE3 are more preferable.

The mode of page switching with program cadre frequency growing (minimum 25%) from nominal, i.e. up to 90-110 Hz, is used to provide stereo effect. Also it provides the best combination of rendering speed, image quality (in comparison with Kasan 3D MAX goggles) and high cadre scanning frequency (in comparison with SimulEyes goggles) on standard hardware.

4. EXAMPLES OF AVIATION IMPLEMENTATIONS

To illustrate the effectiveness of the system we developed some simulations of aviation modes. Fig.3 represents the simulation of low height helicopter flight over village Litvinovo (Moscow Region). The mesh model of scene is made

from aerial photos by our original software system PISoft 3DL and rendering is made by our software with the using of real textures of house walls. Fig.4 represents the real attack maneuver of Sukhoy-37 with the target in Litvinovo.

5. CONCLUSION

PC is the enough powerful platform to create VR aviation simulators for separate modes of flight. The merit of this choice is low cost and accessibility for wide range of users. Such simulators can be used for pilots training and plane systems' analysis on the project stage.

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