Context-Aided Visualization of Volumetric Data[1]

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Abstract

The paper discusses the concept of context-aided visualization and its implementation in the Visualizer system. Visualizer supports presentation of 3D distributions of physical characteristics (e.g. temperature or air velocity) along with the surrounding objects. This approach provides highly informative visual presentation of environments of human inhabitation. Visualizer application areas are architecture, air conditioning and heating systems, urban planning, landscape design, design of cooling systems in technical devices, computers, etc.

Keywords: Scientific visualization, visualization of volumetric data, scalar and vector fields.

1. INTRODUCTION

The purpose of scientific visualization is to provide better understanding of a process or phenomenon under investigation. For example, the FlowVision system [1] uses the interactive animation for analysis of complex 3D fluid flows. In the VisAEffect system [2], the Motion Map texture method with cyclic animation is exploited for visualization of 3D flows in natural objects. In [3], the marker traces and triangulation methods help in presentation of cores enclosing complex reciculation zones in studies of 3D air flows. A representative gallery of visual presentations in studies related to various scientific and technical problems can be found also on the web site [4]. The visualization approaches in the above examples are aimed to provide an insight to the nature and peculiarities of the research subject.

The purpose of the visualization task discussed below is somewhat different. It deals with presentation of climatic and other characteristics in environments of human inhabitation, such as temperature distribution in an apartment. Here the primary point is evaluation of the generic level of comfort and amenity of the environment while subtle nuances of distributions being presented may be of secondary interest. Therefore, the focus of visual conception for this task differs from that of the "classical" scientific visualization. A proper approach should provide a combined presentation of the environment including its appearance and microclimate or, possibly other characteristics related to quality of the inhabitation area (e.g. acoustics or illumination). Such an approach named *context-aided visualization* was implemented in the Visualizer system. Visualizer supports presentation of spatial distributions of scalar and vector characteristics (temperature, humidity, air velocity, etc.) in their physical environments – interior of a building, a city district or country estate, passenger section of a bus, etc. Visualizer also proved to be useful in technical application areas such as design of cooling systems in computers, lamp design and others.

The rest of the paper is organized as follows. Section 2 presents illustrations of Visualizer applications. In Section 3, the currently implemented features are considered. Section 4 is devoted to implementation issues and section 5 outlines future prospects of Visualizer development. The conclusion summarizes state of the work and discusses its current and potential application areas.

2. EXAMPLES OF CONTEXT AIDED VISUALIZATION

The examples in this section illustrate the currently implemented Visualizer features. The distributions presented in the images were calculated with Flow simulation program [5] and visualized with Inspirer simulation program [6] which part the Visualizer is.

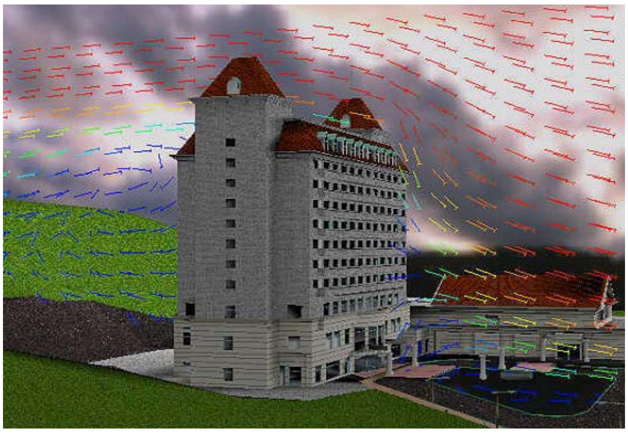

Figure 1: Air flow around a building.

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[1] The version of the paper with color illustrations can be found on http://www.keldysh.ru/pages/cgraph/publications/cgd_publ.htm

Figure 1 presents the image of a building with air flow around it. The arrows show directions of air motion; the absolute values of air velocity are represented by colors of the arrows. Presentations of this kind can be helpful in town planning – for example for choosing a protected from wind place for a children's playground.

Figure 2: Temperature distribution in a car.

The purpose of the presentation in Figure 2 is to demonstrate effectiveness of air conditioning in a car. Distribution of temperature in a car is presented on a vertical section plane with semitransparent color fringes.

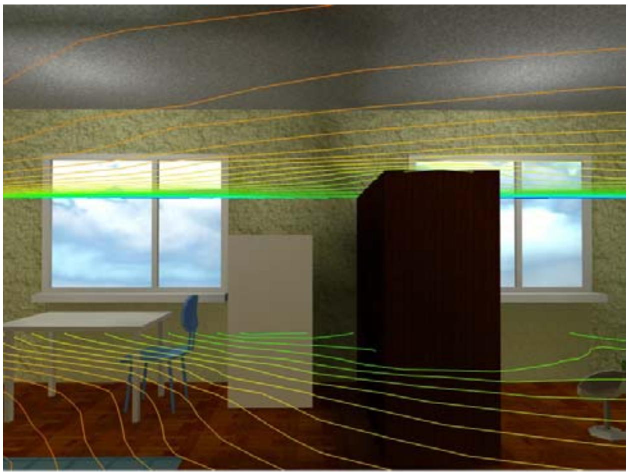

Figure 3: Temperature distribution on two section planes in a living room.

Figure 3 shows temperature distribution in a living room simulated under given outdoor weather conditions. The distribution is displayed on two horizontal section planes, which provide better understanding of temperature variation within the volume of the room.

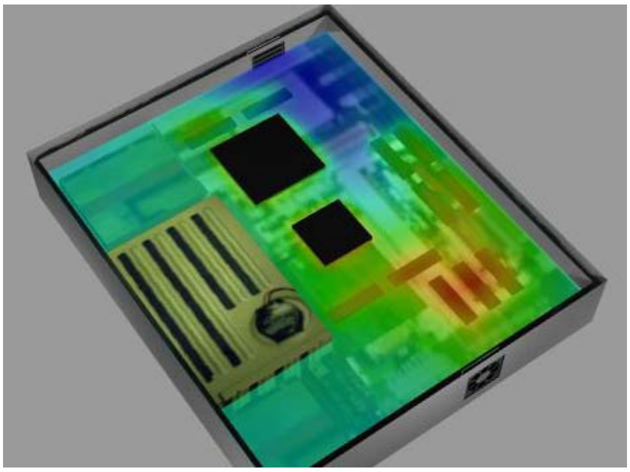

Figure 4: Temperature distribution inside a computer notebook.

Figure 4 exemplifies application of Visualizer in design of a cooling system for a computer notebook. The figure shows the color fringes presentation of temperature distribution on the horizontal plane inside the notebook.

3. VISUALIZER FEATURES

3.1 Visual Forms of Data Presentation

Visualizer supports presentation of scalar, 3D and 4D vector fields specified on a regular or irregular spatial grid.

For scalar fields, the following visual forms are provided:

- isolines;
- color fringes;
- isolines with color fringes;
- isosurfaces.

The first three forms can be shown in one section plane, in a series of parallel planes, or on three orthogonal planes. The latter is useful for example in presentation of temperature distribution near a corner of a room.

For 3D vector fields the supported visual forms are:

- variable length arrows all having the same color;
- constant length arrows whose color is used for presentation of vector length.

4D vector fields (for example, air flow velocity and temperature) are presented with variable length arrows whose color corresponds to the value of the fourth component.

3.2 Presentation Data Sets

Visualizer can use arbitrary volumetric data obtained as a result of simulation or measurements. It also has a built-in solver Flow [5] that simulates air flow velocity and temperature distribution in a scene under given boundary conditions and heat transfer/radiation attributes of scene objects. Flow supports simulation of atmospheric processes with both laminar and turbulent regimes of air flow.

In general, a source data set can contain multiple components (up to 20 are currently supported). Visualizer allows loading of multiple source data sets, possibly produced with different solvers.

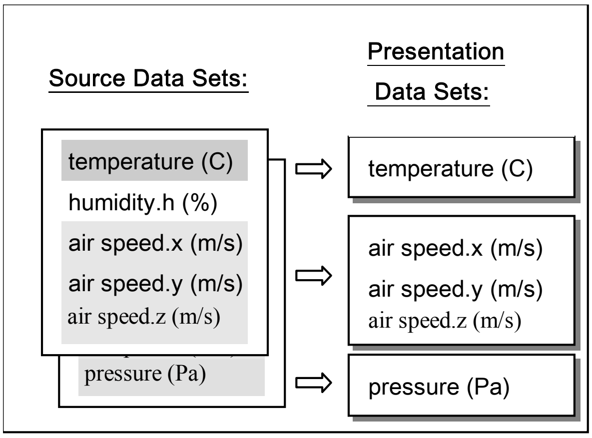

Figure 5: Definition of presentation data sets.

The user can define *presentation data sets* consisting of one, three, or four components from the currently loaded source data sets (figure 5).

3.3 Presentations

For each defined presentation data set, the user chooses one of available visual forms. A pair (data set, visual form) is called *presentation*. It is possible to specify multiple presentations for the current scene that will be visualized all together in the environment of the scene.

Visualizer provides a flexible interactive user interface that allows definition of presentations and their options, such as color palette, transparency, wireframe/smooth shading, and animation parameters. Section planes can be defined interactively or by direct specification of position and orientation. The currently defined presentations can be saved to a file for use in subsequent sessions.

The *value query* feature allows the user to query scalar or vector values of the spatial data at specific locations by picking points on visualized presentations.

3.4 Animations

Visualizer supports spatial and time-driven animation of presentations.

In spatial animation, a presentation plane (e.g. color fringes image) moves along the user specified trajectory with optional rotation about the coordinate axes. In the simplest case, the plane moves just along its normal vector. Spatial animations provide better understanding of how the characteristic under investigation varies in 3D space.

The time-driven animation can be used if source data contain information about variation of a distribution with time. Visualizer can prepare and replay a sequence of images presenting the data distributions during the specified time interval at a given rate.

4. IMPLEMENTATION ISSUES

Visualizer is implemented as a module of Inspirer [6] - a computer graphics system for architectural applications. Inspirer supports physically accurate lighting simulation and realistic visualization of indoor and outdoor scenes under artificial or natural (daylight) lighting conditions. This is an important prerequisite for producing veritable and convincing presentations in Visualizer.

The user loads and displays the “environment” scene with general Inspirer instruments. In Visualizer, he/she loads the needed data sets, defines presentations and views resultant images.

4.1 Volumetric Data Adapter

Preparation of presentation data sets is implemented in a separate component named Volumetric Data Adapter (VDA). A source data set is presented in a text form; it consists of a header and a body. The header contains information about the total number of components, their names and units. It also includes specification of the data set domain and the grid. The body of a data set is just an ordered sequence of component values in all nodes of the grid.

VDA provides interactive user interface for loading source data sets and selection of components to be used in presentations (see section 3.2). It extracts the requested components and makes them available to Visualizer.

4.2 Context-Aided Visualization

Implementation scheme of context-aided visualization of spatial data distributions in Visualizer is shown in figure 6.

Each presentation is processed by a presentation geometry generator (PGG), which generates the *presentation geometry* in the form of polylines (isolines, arrows) or triangle mesh (isosurfaces, color fringes planes) with appropriate color attributes. Different visual forms are generated with specific PGGs. The generator of isosurfaces uses the algorithm described in [7].

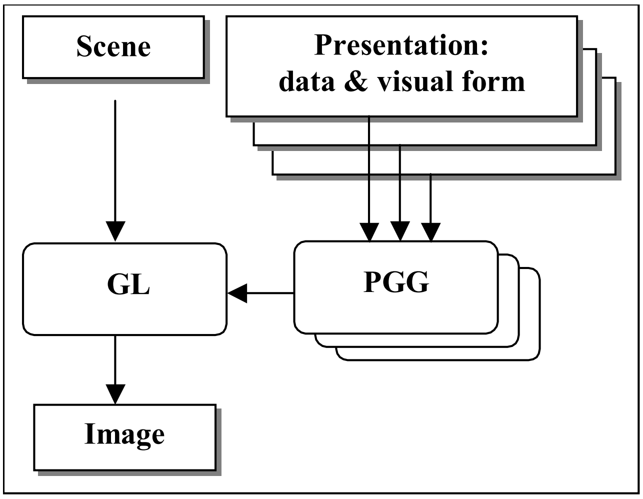

Figure 6: Implementation of context-aided visualization.

The presentation geometry is then transferred to the Inspirer graphics library (GL) that displays it along with the base scene. It should be noted that the geometry for each presentation is visualized via a different channel, so individual presentations can be dynamically hidden or restored.

For an animated presentation, a series of presentation geometries is generated and replayed at a user request.

5. FUTURE PROSPECTS

Architectural solutions used in Visualizer implementation provide a good perspective for its evolvement. The most obvious direction of further developments is adding more visual forms and options of data presentation – marker traces, moving particles, probably some kinds of textured presentations, etc. This can be done by implementation of corresponding PGGs.

An interesting idea is introduction of a sensor shape in visualization of scalar fields. Usage example of this approach is visualization of a human body shape with color fringes presentation of temperature distribution on its surface. This allows a viewer to see how a grown up, or a child (or a home creature) will feel in the environment being presented – under given outdoor weather conditions, heating and air conditioning options. As a next step, animated sensor-driven presentations might be implemented, - as an example, a presentation of a scalar or vector field on a human body shape moving around an apartment.

Figure 7 illustrates a possible approach[2] for implementation of context-aided visualization of volumetric data with a sensor. The approach implies development of additional "sensor-driven" PGGs – one for each visual form (isolines, color fringes, arrows). The PGG should input the triangle mesh of the sensor shape selected by the user and map the source volumetric data onto the vertices producing appropriate presentation geometry.

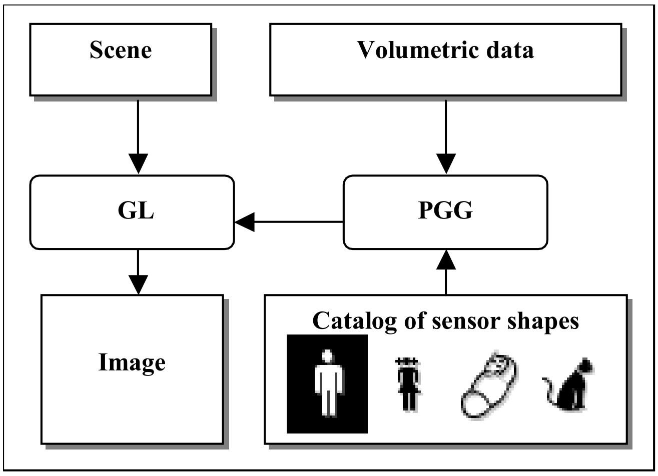

Figure 7: Implementation of sensor-driven visualization of volumetric data.

Other possible development direction is implementation of more solvers and support for external solvers. Use of additional solvers will require development of converters for import of external data to the file formats used by Visualizer.

6. CONCLUSION

Visualizer was implemented in the Computer Graphics Department of Keldysh Institute of Applied Mathematics as a tool for visualization of spatial data distributions in environments of human inhabitation such as an apartment, a hospital, a transport vehicle, a city district or a country estate. The main intention of this approach is to provide a generic impression on the amenity and comfortableness of the environment through presentation of both the appearance and physical characteristics related to living or working conditions – temperature, humidity, air flow velocity, soundproofing, illumination, other ecological characteristics. The major application areas of Visualizer are architecture, design of heating and air conditioning systems, city planning, landscape design, etc.

Being highly informative, Visualizer presentations can serve as a decision making aid in a variety of practical situations. It is important that the presentations can be addressed as to specialists, as to other audiences, such as officials, businessmen, potential buyers of an apartment or a country house.

Growing requests posed by human beings to their inhabitation environments will apparently cause an increased demand for presentation tools of this flavor.

It should be stressed also that usability of context-aided visualization, in general, goes beyond the application areas mentioned just above. For example, Visualizer was applied with success in design of cooling systems in computer notebooks, in building industry applications (prediction of destructive influence of weather factors on building constructions), in lamp design, and other technical areas. We believe that the conception of context-aided visualization can be helpful also in other branches of science and technology.

7. REFERENCES

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[2] This implementation does not imply recalculation of the given temperature distribution with respect to heat emission properties of the sensor itself.