

3D Visualization of UCG Process

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ABSTRACT

The paper presents the aspects of 3D graphics utilization in the visualization of underground coal gasification (UCG) process. Data gathered during the process as well as achieved by the mathematical modelling describe a three dimensional structure of the georeactor where the process takes place. Proper visualization of this information is crucial for better understanding of the process and further possibilities of its development and practical usage. Therefore, a dedicated software tool was developed to support the visualization of the data. This program enables visualization of the data in user friendly environment which supports the monitoring of process during each stage. It is developed with application of XNA technology in C#.NET. The system overview with possible applications is presented.

Keywords

visualization, 3D graphics, UCG process

1. INTRODUCTION

The energy requirements of modern world are constantly increasing. Though renewable energy sources are one of the most promising, they are still in a minority in the market. It seems the fossil fuels are going to play the most important role for the predictable future [Col06, Sha09]. Unfortunately, these energy sources are hardly environmentally friendly. One of the crucial environmental aspects is CO₂ emission, which is believed to be a cause of climate changes. Therefore it is necessary to adopt fossil fuel usage, with the view of environmental impact reduction while preserving energetic efficiency. The underground coal gasification (UCG) is recognized as one of such promising technologies [Bhu13, Bia08].

The UCG goal is to convert underground coal seam into flammable gas, which can be further used as an energy source. The coal deposit is usually accessed by system of wells (Figure 1). At minimum two wells are required: one for injecting processing gases into

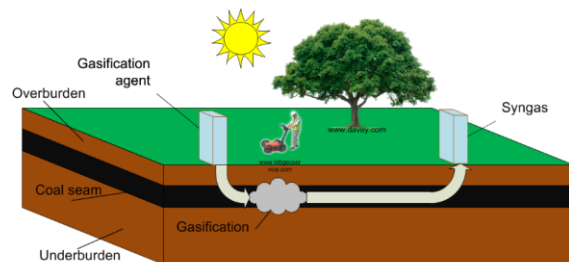


Figure 1 Underground coal gasification process scheme

reaction zone (injecting well or injector) and one for acquiring and removal produced gases (production well or producer). The two wells are connected by gasification channel. Gasification channel forms the zone, where entire process takes place. The gasification process is complex and involves several physicochemical phenomena [Col06, Zog13]. Among many others the most important are: gaseous phase chemical reactions, surface chemical reactions, pyrolysis, water evaporation, transport of mass and energy (also in porous media). As the result of the processes several chemical individuals are formed, the thermal energy is produced, consumed and transferred, the geometry of gasification channel is modified. All that processes influence quality of produced syngas.

The UCG process is recognized as complex and not fully understood, which makes its controlling

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a difficult task. On the other hand, syngas quality and stability of its parameters in time are crucial for industrial utilization. Therefore, further research are absolutely necessary. Several research projects have been set up worldwide. Two main pathways are taken: experimental and modeling. In both of them huge amounts of data are gathered. Their analysis can be much more effective if the data are presented to the scientist in appropriate, readable and effective way. Because of that, the project aimed at UCG process visualization system development has been started. As the UCG data describe the process state in time and space it was assumed that 3D graphic will be the proper tool for visualization. The most important parameters of UCG process are spatial placement, shape and time development of solid – gas interface, spatial and temporal distribution of gaseous phase fluxes, temperature and concentrations of gaseous chemical species: hydrogen, carbon monoxide, carbon dioxide, methane, oxygen and many others. The application of 3D computer graphics for UCG process data visualization is presented. The class structure of the developed software is described along with achieved results.

2. VISUALIZATION TECHNIQUE

The UCG originating data describe how values of several chosen quantities varied in time in the vicinity of georeactor. The term ‘georeactor’ is used to describe a selected space, containing gasification channel, the cavern and coal in which gasification process takes place. Regardless of data origin – measurements or simulation – they always have similar structure. Firstly, each of measurements or calculations is bound to its location – a set of 3 coordinates (x,y,z) which identify a point in 3D space, where the value was calculated (measured). In case of modeling results, used in the work described in the article, the points locations are defined by georeactor spatial discretization (numerical grid). The point may, or may not be uniformly spread in the space. In the case of numerical modeling there are usually few thousand of points in which the values are calculated. During measurements, the number of measurement points hardly exceed few hundreds. Therefore the simulation data were used for visualization development and testing. During the simulation the data are calculated in well-defined time intervals, which allow prediction of georeactor state evolution in time. Summing up, it may be stated that:

- there are up to several thousand points in which parameters’ values are determined,
- there are few (usually 10 to 20) parameters, which values are determined

- there is full set of data (values of each parameter in each point) determined in few hundreds discrete time intervals.

It was assumed that visualization of UCG data should allow:

- visualization of at least two parameters simultaneously,
- observing varying parameters’ values in time,
- visualization of each point with tools for selecting which part of data should be presented to the user.

Visualization of UCG process should base on its nature. As the georeactor vicinity is represented by set of data defined within 3D space, selection of 3D computer graphic is straightforward. Investigation of UCG process requires analysis of at least three parameters:

- changes of gasification channel shape and size in time, which is strictly connected with effectiveness of ongoing process,
- temperature field in gasification channel, coal bulk and on the surface separating gaseous and solid phase,
- selected chemical compounds concentrations in gasification channel and coal bulk.

All mentioned data are expected to change in time during UCG process. Simultaneous visualization of selected values is highly desirable, as it gives the researchers possibility to investigate probable interactions between parameters. The gasification channel is de facto defined by surface separating solid and gaseous phases. The shape of the surface and its placement in the space inform of changes in gasification channel. Therefore, use of triangulated 3D surface was chosen for gasification channel representation. Other data (temperature and concentrations) have point rather than surface nature. Nevertheless, combined visualization of few selected parameters as a 3D objects gives an opportunity to present each of parameter using different feature of the object (color, height, rotation, etc.). It was accepted that 3D primitives as simple polyhedrons will be used for their visualization. Total visualization will present a set of 3D objects placed in 3D scene and animated according to passed time.

It was assumed, that in each of the points defined by numerical grid a graphical 3D object will be placed. The object color, size, proportion and rotation speed are used for presenting values of selected parameters. The primitives (cone, cube, tetrahedron etc.) or complex 3D model can be used for values representation (3D objects). For example, let’s

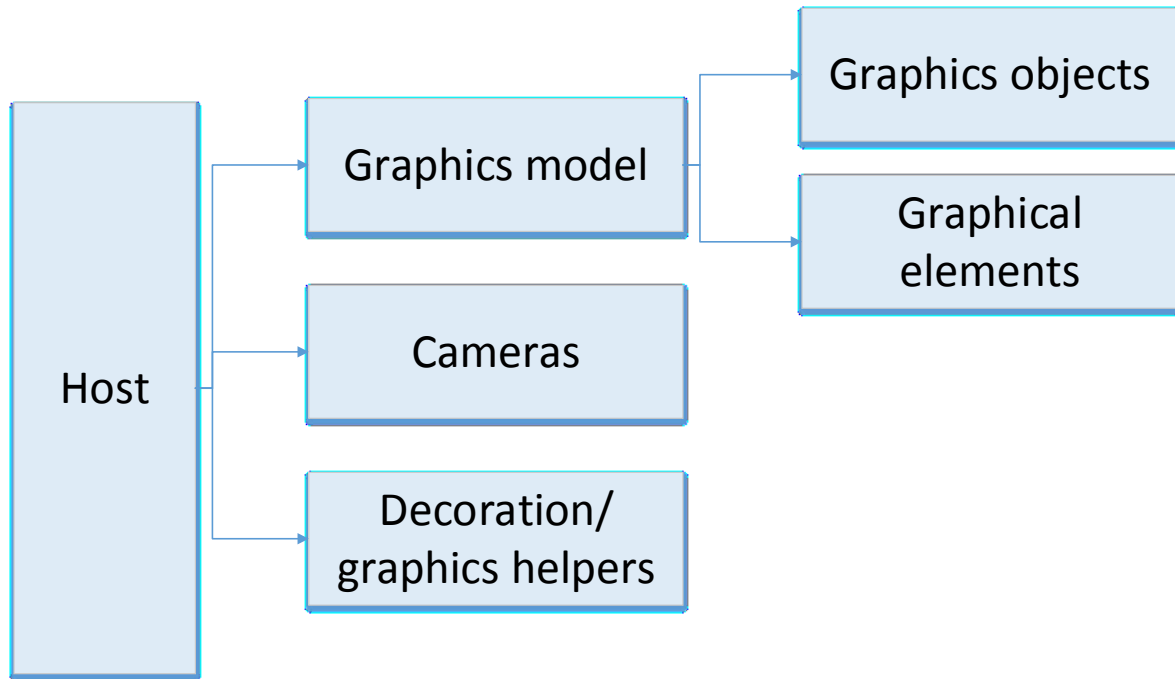


Figure 2 Concept of UCG visualization system

choose a tetrahedron as a 3D object used for visualization. Its color can be used for representing temperature, size for hydrogen concentration and rotation for pressure. It is also possible to change sizes in selected directions, but because of readability it is usually better not to exceed 3 or 4 parameters' visualization at the same time.

Visualization of values variations in time is relatively straightforward – each time interval (time step) is in fact bound to one set of parameters values. It is sufficient to display the sequence of following visualizations as time passes.

The design of software for UCG data visualization was prepared with a view of flexibility and easiness of further enhancements. Special attention was also paid to the efficiency.

The overall software construction consists of six components (Figure 2):

- a **Host** component,
- a **Graphics Model** component,
- set of **Graphics Objects**,
- set of **Graphical Elements**,
- a **Cameras** component,
- a **Decoration/graphics helpers**

The responsibility and role played by each of the elements are presented in following paragraphs.

Host component represents a platform on which whole visualization system is built. The role of host component is to ensure the way of communication between other components. The component takes care of all other necessary components and objects creation and initialization. It is responsible for visualization time span management. The component holds graphic context, which is used by other components for drawing their part of visualization. The Host component repetitively call contained components to update themselves and to draw themselves with use of provided graphical context.

Graphics Model represents a visualization of selected simulation result. It holds information of state of visualization (still, animated, etc.), simulation time and current frame. The frame idea supports visualizing time advance in visualizing model. It is an analogue for movie frame in UCG visualization software. It was assumed that each simulation provides data for several hundreds of frames, which are used for animated visualization. The role of graphical model is to synchronize the simulation time and appropriate frame number. Apart from Graphics Objects, Graphical Model holds Graphical Elements – a special kind of visualized data presenters.

Graphical Elements are used for visualizing the effect of data transformations, which, by its nature, are not bound to grid points. As an example the surfaces showing distribution of selected constant value of parameter, a plane with values map of selected parameter and so on.

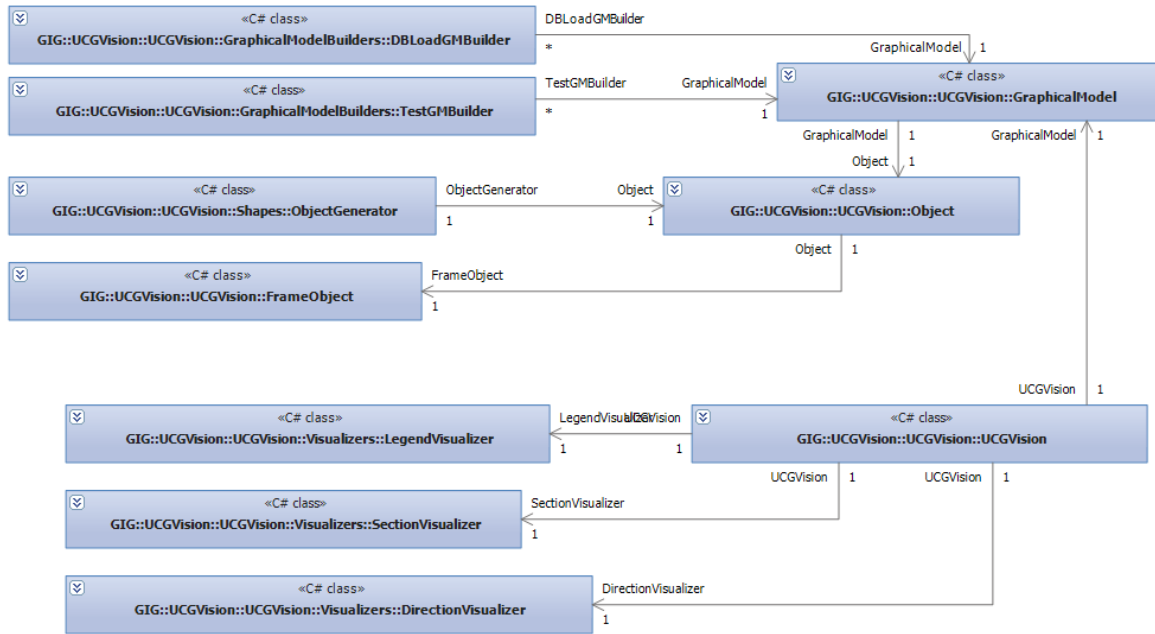


Figure 3 Static class diagram of UCG visualization system

Graphics Object represents a set of data which has to be presented along with objects responsible for visualizing them in selected way. The Graphic Object data are bound to collection of frames. Graphic Object holds a visualizer – object capable of presenting data for selected frame. As visualizers can be easily changed it is also easy to change the way the UCG data are presented.

Cameras provide the user view of visualized 3D data. The system presents to the user part of the data which is visible from the selected camera. Software define 5 cameras – 4 still targeted at the visualized space and one movable. The movable camera can be moved in the space in the same way as in FPS (First Person Shooter) games. It allows making close-ups as well as seeing the visualized data from different perspectives.

Decoration/graphics helpers are used for showing UI elements such as legend, directions markers, guiding planes and so on. All this elements do not really belong to visualized data but helps user to appropriately understand what is visualized and helps him to navigate in the space. As some of the helpers need information from graphical model, there is a host which is responsible to set up required communication.

Implementation of 3D graphic visualization software is very difficult without help of appropriate graphic library. The considered library should ensure a level of abstraction between graphic hardware and developed application. There are two solutions widely used in graphic software development:

DirectX and OpenGL. Both support programmer with similar features, though they differ in portability and integration with operating system. OpenGL is known to conform with open source standard and is available on several operating systems. On the other hand DirectX is non questionable leader in graphic software development on Windows machines. As it is not portable, it can be better integrated with the operating system and gives more control to programmers. Usually DirectX solutions have better performance on Windows machines, allow better multithreading operations utilization and provide COM object oriented interface. Taking under consideration, that the visualization software is dedicated to run Windows operating system, the DirectX was chosen as a base, but with help of higher level XNA Game Studio 4.0 library. The XNA Game Studio is a managed code library dedicated to 2D and 3D game development. It wraps DirectX API and presents it to the user with high level, easy to use class model. The software was written in C# programming language, Microsoft Visual Studio was used as IDE.

The program structure (most important classes) are presented in Figure 3. The UCGVision class is a Host component for applications. It holds references to GraphicalModel object (visualized data representation), LegendVisualizer, SectionVisualizer and DirectionVisualizer objects. The three last objects belong to Decoration/graphic helpers. The GraphicalModel holds collection of references to Object class objects. The Object holds collection of FrameObject (frame representations). All objects are

5. ACKNOWLEDGMENTS

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6. REFERENCES

- [Bhu13] J Bhutto A.W., Bazmi A. A., Zahedi G. Underground coal gasification: From fundamentals to applications. *Progress in Energy and Combustion Science*, 39, pp. 189 – 214, 2013.
- [Bia08] Białecka B. *Underground Coal Gasification (Podziemne zgazowanie węgla). Podstawy procesu decyzyjnego*. Główny Instytut Górnictwa, Katowice 2008.
- [Col06] Collot A-G. Matching gasification technologies to coal properties. *International Journal of Coal Geology*, 65, pp. 191–212, 2006.
- [Nur14] Nurzyńska K., Janoszek T., Iwaszenko S. Modelling Test of Cavity Growth During Underground Coal Gasification Process Using CFD Method. 2014 International Conference on Information Science, Electronics and Electrical Engineering (ISEEE 2014), April 26-28, 2014, Sapporo City, Hokkaido, Japan (in press).
- [Sha09] Shafirovich E., Varma A. Underground Coal Gasification: A Brief Review of Current Status. *Ind. Eng. Chem. Res* Vol. 48, pp. 7865–7875, 2009.
- [Zog13] Żogała A., Kabiesz J., Iwaszenko S. Czynniki wpływające na skład chemiczny i wartość opałową gazu uzyskiwanego w procesie podziemnego zgazowania węgla. *Przegląd Górniczy* nr 6/2013, pp. 89-95, 2013.