

An E-Learning Course on Scientific Visualization

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Abstract

In this paper we present an e-learning course on scientific visualization. Based on over ten years of teaching experiences in this field, we have created a multimedia online course which we use as additional material for our lecture. The course will be made publicly available so that not only our students but all people interested in the field of scientific visualization can benefit from the materials we have prepared. In the course important visualization techniques and algorithms are discussed. The main goal is to lay the fundamentals for future specialists and researchers in the field of scientific visualization.

Categories and Subject Descriptors (according to ACM CCS): I.3.0 [Computer Graphics]: General K.3.1 [Computers and Education]: Distance Learning

1. Introduction

Recent news from space research about projects like "The Sun in 3D" [Nat07] once more remind us of the fact that scientific visualization gets more and more important. Everyday data sets generated by e.g. medical research institutes and automotive industry become larger and larger. To analyze and interpret such data sets in acceptable time, appropriate visualizations are needed. So there is a strong need to propagate the necessary knowledge on scientific visualization to a broader audience than just a handful of specialists. Therefore in this paper we present a multimedia e-learning course on scientific visualization. We have already introduced this course as additional teaching material for our lecture on scientific visualization. The e-learning course is provided to our students as substitution for a textbook. A preview version of this course is publicly available at <http://wwwvis.informatik.uni-stuttgart.de/~taras/scivis.html>.

In the following chapters we firstly introduce some related work strongly influencing our work (chapter 2). Then we describe why we have decided to create a web-based course instead of an ordinary script or textbook (chapter 3). After that we illustrate the structure and the different elements of the course (chapter 4). Furthermore we give some insights in the technical implementation (chapter 5). At the end we describe some of our experiences with the created course (chapter 6) and give an outlook on future works (chapter 7).

2. Related work

In [RWE04] Martin Rotard, Daniel Weiskopf, and Thomas Ertl presented a curriculum for scientific visualization derived from ten years of teaching experiences in this field. One problem that was pointed out in their paper was the lack of an established textbook that could be used for the lecture. The structure of the e-learning course presented in this paper is very closely related to the discussed curriculum.

The department Graphical-Interactive Systems at the Wilhelm Schickard Institute for Computer Science of the Universitaet Tuebingen created a quite huge repository of applets illustrating several algorithms and experiments related to computer graphics and visualization [DW07b] [DW07a]. We inserted links to these applets at appropriate positions in our e-learning course. Another collection of applets that we integrated into our e-learning course is provided by the Department of Computer Science of the Brown University [DB07].

The described e-learning course was created with the help of tools and concepts developed by the Metacoon team, whose aim is to design a fully accessible e-learning platform which can be used by universities as well as schools and companies [Met07].

In [FEJ03] Frederico Figueiredo, Dena Eber, and Joaquim Jorge presented a repository for online computer graphics educational materials - CGEMS. The aim of CGEMS is to

- Introduction
 - What is visualization?
 - History
 - Examples
 - Related Fields
 - Further Reading
- The Visualization Process
 - Definitions of Visualization
 - The Visualization Pipeline
 - Sources of Error
 - Visualization Scenarios
- Data Acquisition
 - Data Sources
 - Data Representation
(The Domain, Data Structures, Data Values, Data Classification)
 - Time Dependency
- Interpolation and Filtering
 - Voronoi Diagrams and Delaunay Triangulation
 - Univariate Interpolation
 - Differentiation on Grids
 - Interpolation on Grids
 - Interpolation without Grids
 - Filtering by Projection or Selection
 - Fourier Transform
 - Sampled Signals
 - Reconstruction and Frequency Filtering
- Basic Mapping Techniques
 - Diagram Techniques
 - Function Plots and Height Fields
 - Isolines
 - Color Coding
 - Glyphs and Icons
 - Multiple Attributes
- Volume Visualization
 - Introduction
 - Classification
 - Segmentation
 - Volumetric Shading
 - Numerical Computation of the Gradient
 - Direct Volume Rendering
(Ray Casting, Texture Based Volume Rendering, Shear Warp Factorization, Splatting, Equation of Transfer for Light, Compositing Schemes, Non Uniform Grids)
 - Indirect Volume Rendering
(Contour Tracing, Surface Fitting Techniques, Cuberille Opaque Cubes, Marching Cubes & Tetrahedra, Slicing, Contour Propagation)
- Vector Field Visualization
 - The Vector Calculus
 - Characteristic Lines
 - Arrows and Glyphs
 - Mapping Methods Based on Particle Tracing
 - Numerical Integration of Ordinary Differential Equations
 - Particle Tracing on Grids
 - Line Integral Convolution
 - Vector Field Topology
 - 3D Vector Fields
- Tensor field visualization
 - Diffusion Tensors
 - Glyphs Basic Mapping Techniques
 - Hue Balls and Lit Tensors
 - Hyperstreamlines and Tensorlines
- Visualization of High Dimensional Data

Figure 1: Structure of the e-learning course.

build up a platform supporting the exchange of educational materials between computer graphics educators all over the world. We plan to contribute to this repository in the future.

Gitta Domik et al. created online materials on a curriculum for visualization [Dom07]. This curriculum mainly concentrates on basic knowledge like human perception issues which are thought in the basic course "Graphical-Interactive Systems" at our institute. The materials described in this paper focus on topics directly related to the visualization process which is introduced in chapter 7.1 of [Dom07]. Besides the curriculum, [Dom07] provides a very valuable survey of visualization courses worldwide.

In 2006 Helen Wright published a new textbook on scientific visualization [Wri06] which gives a practical introduction to scientific visualization but does not deal in depth with the topics discussed in our materials.

3. Why a web-based course and no ordinary textbook?

At first glance it may seem strange that we decided to create a web-based course instead of a textbook or script. But there are some good reasons for preferring a web-based course.

From our teaching experiences we know that it is very helpful for students if theoretical contents are illustrated by

animations, videos or applets. Ordinary textbooks or scripts do not have any capability for providing such contents. It is obvious that this is not just our experience. There are web pages of other institutes listing quite a big number of applets illustrating different visualization algorithms [DW07b] [DW07a] [DB07].

As one goal of our web-based course was to serve as a starting point for students interested in visualization we integrated links to those existing contents at suitable positions in our course. This already leads to another reason for developing a web-based course. As education in visualization is a relatively young field of interest new teaching materials are created almost every day in different parts of the world. A web-based visualization course gives us the possibility to integrate all these materials dynamically so that students do not need to waste much time searching for appropriate materials. Furthermore as our course is integrated in an e-learning platform it provides many features supporting self-studying.

Last but definitely not least, with a web-based course we have much more possibilities to provide disabled students with the same knowledge as able-bodied ones.

4. Course structure

Unsurprisingly, the overall structure of the course is similar to the curriculum of the related lecture. During the development of the materials for the course we slightly redesigned the curriculum presented in [RWE04]. We decided to strengthen the parallelism to the visualization pipeline (see figure 1). This shall help students to keep track of the complex topics.

The course starts with an introductory page for the course itself, summarizing the topics of the course, its educational goals, and needful prerequisites. As the course should foster different strategies of self-studying we furthermore provide an outline map of the whole course, showing the dependencies of the different chapters (see figure 2). This outline map will be further refined in future versions of the course.

The first chapter of the course introduces the field of scientific visualization itself. The intention of this chapter is to motivate students getting a deeper insight in visualization rather than providing detailed knowledge. Therefore at the beginning it provides a really short definition for the term visualization followed by some facts about the history and some motivating examples. Furthermore it briefly presents some related fields of visualization. At the end some references to related books, proceedings and journals are given. In the second chapter the fundamental concept of the visualization pipeline is introduced and different visualization scenarios are presented. The following chapters discuss topics relevant for the different processing steps of the visualization pipeline - data acquisition, interpolation and filtering, mapping techniques, and rendering.

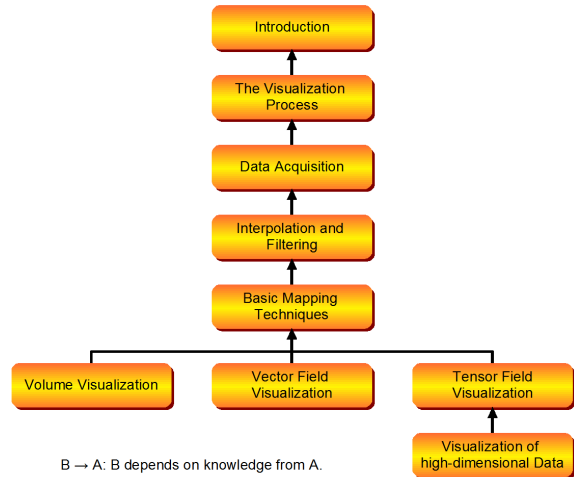


Figure 2: Outline map of the e-learning course.

Each of the course's chapters begins with a short introductory section which motivates the topic and clarifies the objectives of the chapter. After that the subsections are introduced. The main part of each chapter is, of course, ordinary textual content (including tables, lists, and formulas). Depending on the kind of content - e.g. definition, example, summary - the text is formatted differently in font, layout, color etc. Thus students can easily identify the different parts. Furthermore it loosens the text.

At suitable positions additional content which supports the knowledge transfer is inserted, e.g. visualizations, schematic drawings, links to applets, and exercises. Each chapter ends with some questions helping students verifying if they have reached the objectives of this chapter. As the course is not a strictly guided course these questions can additionally be used for repetition. At the moment the questions are simply listed without providing the answers. In future versions of the course whole self-study tests following the QTI specification [qti06] will be inserted.

5. Technical implementation

In the following sections we briefly describe the underlying system of our course, the way the course materials are created, and ways of accessing the materials.

5.1. Underlying system

The described e-learning course is built upon the conceptions of the Metacoop platform [Met07]. We have chosen this platform as one goal of the developers is to create a fully accessible e-learning platform. For example font sizes can be adjusted by the user independently from the browsers configuration, authors are encouraged to provide a detailed

description for every image, and, when using the newest version of the Metacoön server environment, formulas are rendered as MathML [W3C03] if the browser supports this. Another reason for choosing Metacoön were the well developed authoring tools.

5.2. Creation of course materials

The textual content of the course is written in OpenOffice [Sun07]. By installing a plugin provided by the Metacoön team, styles for the different parts of the course are inserted (see figure 3). Using these styles it is easy for the author to make sure that for example a description for every image is supported. To upload the materials to the Metacoön server the OpenOffice document is transformed to an XML document complying with the Metacoön format. Together with all the other contents of the document (including images, simulations, animations, and audio files) the XML file is packed in a compressed archive. The transformation and the packaging are performed by a transformation program provided with the Metacoön plugin.

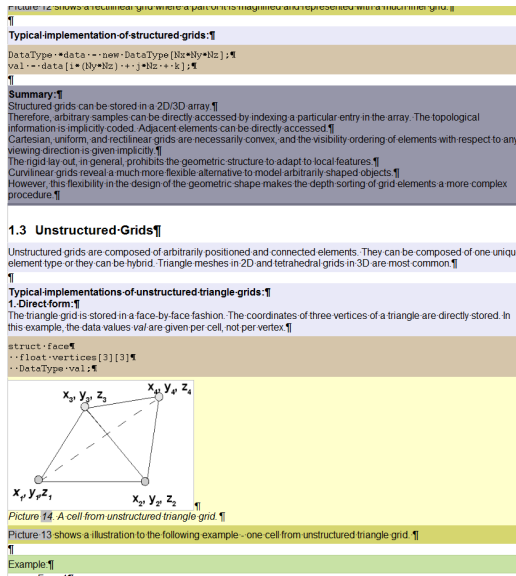


Figure 3: Extract of the OpenOffice sources of our e-learning course (illustrating the different styles)

One goal of the Metacoön system was to support the creation of web-based courses in collaboration of several authors. Therefore the content of the course should be split up into small learning modules which than are edited by different authors. Of course, each module should form a well defined unit. The different modules can be uploaded to the e-learning platform through a special web interface which provides an easy to use versioning tool. Furthermore this interface provides features to arrange the different parts of the course to one well structured course with different

sections, subsections and so on. From this arrangement the course navigation is created automatically.

5.3. Ways of accessing the course materials

The course materials can be accessed in three ways.

The intended way is to use the course in combination with the whole e-learning platform. Thereby students are provided with many well established e-learning features. For example sections can be marked as "understood", and important topics can be added to a list of favorites. Furthermore the platform offers forums and chats to support the communication between students and tutors, as well as possibilities to make additional materials like assignments and related code fragments available to the students. Also the electronic submission of solutions is supported.

Another way to access the course is by directly calling its start page at <http://wwwvis.informatik.uni-stuttgart.de/~taras/scivis.html>. The advantage is that no login is needed and so the course is available to everyone who knows this link. Unfortunately, when using this way of access no e-learning features are available.

The third way of access is to download the PDF document of the course which can easily be generated in the authoring interface of the Metacoön platform. So also offline learning is supported in a good way.

6. Experiences with web-based offerings

Since several years our institute has provided students with additional materials and information over the internet. Our experiences show that online materials like the described course are well accepted by students and should be extended. Students use the materials to prepare for lectures and exams. Often students get motivated to visit a certain lecture by informing themselves about the discussed topics with the help of online materials. So it is advisable to present lectures on the internet as well as possible.

Since the described materials are relatively new, we cannot provide a detailed study on their impact on the exam results of students using these materials. But a first small survey showed that our students are glad being provided with materials more detailed than the slides of the lecture but less extensive than textbooks specialized to only a couple of the lecture's topics. Some students who already used the materials for their exam preparations, gave us convincing feedback. So we are expecting positive results for the evaluation at the end of the this year's course.

7. Conclusion and future work

In this paper we have presented a multimedia e-learning course on scientific visualization, discussing important visualization techniques and algorithms. The course is already

used by our students as additional teaching material for our lecture. Currently we plan to make the course publicly available.

In the future we will continue our work on the described course to keep it up-to-date. We will develop and integrate even more multimedia content and extend the supporting features for self-studying. Furthermore we will integrate the course directly into our lecture and the related exercises. We will investigate possible ways of content improvement in direct cooperation with our students, e.g. by establishing a Wiki. Also the accessibility of the course will be further improved.

Moreover we will investigate methods to realize e-learning environments in Second Life [Lin07]. Especially scientific visualization provides many topics which could be much better demonstrated in a 3-dimensional environment than in a 2-dimensional one. Besides we believe that it would be very appealing for students.

8. Acknowledgements

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