A Breadth-First Approach for Teaching Computer Graphics

G. Domik and Frank Goetz
University of Paderborn
Computer Graphics, Visualization and Image Processing
{domik, frank.goetz}@uni-paderborn.de

Abstract
Two themes of computer graphics, namely computer-generated color and computer-generated visualization, are introduced in a teaching/learning tool using a breadth-first approach. The breadth-first approach provides a holistic view of the topics to teach, aids in interdisciplinary teaching and is equally motivating to male and female students. The breadth-first approach has now been used for several years and we can also report on evaluations of the teaching/learning tool.

1 Introduction

1.1 Breadth-First

The breadth-first approach was suggested as one of three possible approaches to teach computer science by the computer science computing curricula 2001 [CC 2001]. It can also be used to teach individual courses or topics. The idea here is to start with a holistic view of each topic to teach (breadth) and undermine it with an application; then use depth to the level the students are ready for. The first part (breadth) provides overall understanding of the topic on an entry level. The application should give extra motivation to learn more about this topic. The second part (depth) can differ for different kinds of students (e.g. CS (computer science) students versus media studies students. If a topic is prepared breadth-first, then the breadth part of the course can be simultaneously taught to interdisciplinary students, something we do more and more in computer graphics. Here is a list of advantages for a breadth-first approach:

- CS students get a holistic view of a topic before they learn about more complicated details
- CS students can then move on to any depth-level
- students of other disciplines learn of the importance of a topic through the goal of the application
- students of different backgrounds can be taught together at the breadth-level
- all students are being taught the same "language" to describe a topic
- application oriented approaches are motivational to both men and women

We developed an educational tool named "SIMBA – Computer Pictures" to teach *computer generated color* and *computer generated visualization* via the breadth-first method. The tool and the courses are further described below. We have used SIMBA to teach *computer generated color* for the last four years as part of our introductory computer graphics course and in an interdisciplinary course "Creativity and Technology" where we taught both CS students and media studies students. We will report on both the tool SIMBA and our experience in using it to teach in this paper.

1.2 Facts about our University

The University of Paderborn [www.uni-paderborn.de] in Germany hosts 14,000 students in five different faculties. The Department of Computer Science is part of the Faculty of Electrical Engineering, Computer Science and Mathematics and grants degrees of Bachelor, Master and PhD of Science in Computer Science. Courses on Computer Graphics, Visualization and Image Processing and advanced seminars in these areas are being offered to CS students. The department of Media Studies is part of the Faculty of Cultural Studies. The Media Studies curriculum leads to a Master of Science in Media Studies.

1.3 Interdisciplinary Teaching in Computer Graphics

This is not our first course in Computer Graphics and Image Processing for students outside our faculty. An earlier example of such a course is described on the course website wwwcs.upb.de/cs/ag-domik/bildverarbeitung/bic-vl-ws0001/index.htm, where Media students participated in a course called "The Digital Image". The emphasis there was on teaching/learning methods for manipulating digital images rather than on the current technology. The underlying idea was that fast changing technology must be grasped by its meaning not by its use of short-lived software systems. In the project part of this course (click on "Project" on course Web Site) the Media students developed an augmented reality system with the help of two upper level computer science students on the basis of the ARToolkit [BK99]. The results were very encouraging and the plan was born to further the connection of CS and Media students.

In a sabbatical during 2001, Gitta Domik had the chance to observe interdisciplinary courses at the University of Colorado at Boulder, specifically the course "Technology for the Community" by Professor Elizabeth Jessup and other courses of the Technology, Arts and Media (TAM) program. These and other highly successful Boulder projects strengthened the idea of offering more interdisciplinary courses at Paderborn.

2 The tool SIMBA

SIMBA is an educational tool based on multimedia concepts to teach and learn key concepts of Computer Science. Its goal, and at the same time its difference to other similar tools, is that it is broken down into key concepts (inside modules) rather than into lecture size. SIMBA was developed within a time frame of three years by several German universities sponsored by the German government [SIMBA04]. "SIMBA – Computer Pictures" (originally: SIMBA- Computerbilder) [SD03] of which we report here, is only a small part of the teaching/learning tool SIMBA, namely the only one conceptionalized with a breadth-first approach and the only one specifically developed for teaching graphics courses. From now on, to save space, we will refer to "SIMBA-Computer Pictures" simply as "SIMBA".


Figure 1: *wwwcs.upb.de/cs/ag-domik/SIMBA enters SIMBA. Click e.g. on "Computer-generierte Visualisierung" and enter "simba" as username and "computerbilder" as password.*

Two key concepts of teaching computer graphics were developed as two different modules for SIMBA: computer-generated color and computer-generated visualization (see [wwwcs.upb.de/cs/ag-domik/SIMBA] and Figure 1). Only

computer generated visualization has a translation of its presentation slides into the English language. Unfortunately the many interactive applets of computer generated color can therefore only be used by German speaking students and lecturers. A third module – "Digital Image Processing" ("Digitale Bildverarbeitung") exists in parts and will not be further discussed here.

Each of the modules is presented to the student in two dimensions: in *breadth* and *depth*. *Breadth* means that all methods that are necessary to understand the key concept are explained in a horizontal menu. *Depth* means that for each method or technique, while being explained, there are more difficult levels revealed in a vertical menu. An example for computer-generated color is depicted in Figure 2.
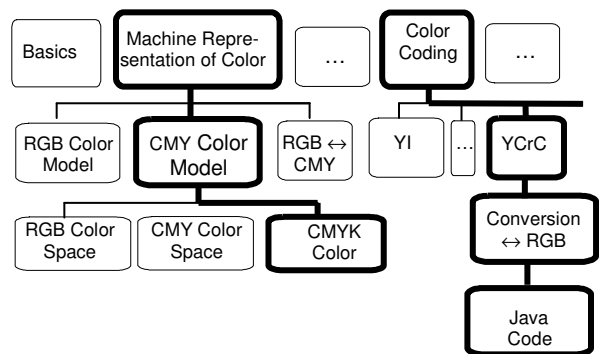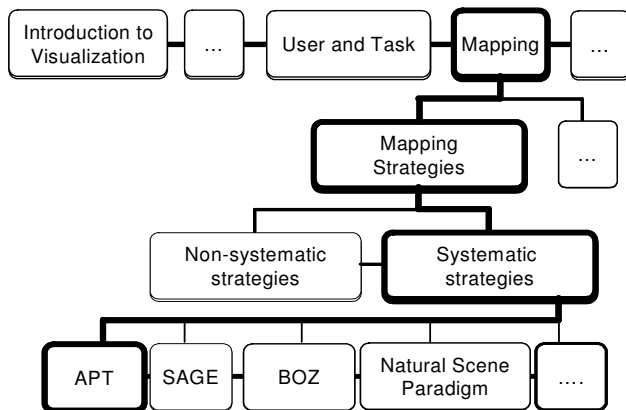

Figure 2: *SIMBA shows topics of breadth (here the example of computer-generated color) in its horizontal axis and depth in its vertical axis.*

The breadth of the topic is represented by the six different themes (Basics, Machine Representation of Color, Perceptual Color Models, Color Coding, Color Standards, Machine Representation of Images) describing computer-generated color and runs from left to right. By clicking on any one of these themes, e.g. "Color Coding", this subtopic is explained on an easy-to-understand level (e.g. on "Color Coding" we are referring to the need for splitting up a TV signal into independent black-and-white and color information to serve both color and black-and-white TV sets – a historical reason), while additionally a deeper level of information becomes visible, in this case "YIQ", "YUV" and "YCrCb". Selecting "YCrCb" reveals information on the content of the three channels Y, Cr, Cb in relation to the human visual system and the RGB color model. Only one level deeper ("Conversion") the method of conversion between RGB and YCrCb is revealed. Again, while showing the matrix of conversion, another level of depth is opened to the user and a Java code sample for the conversion can be studied. Each click reveals information that can be understood without going into more depth, though a full and deep understanding of the key concept can only be evolved by going through all levels in breadth and depth. In our case, e.g. Media students would be led through all breadth topics but only CS students would be led through all breadth and depth topics.

The second example of SIMBA is computer generated visualization. Figure 3 shows the breadth of the topic

(divided into the eight main themes as suggested in [Dom00]). By clicking on any one of the themes, e.g. "mapping", this subtopic is explained and additionally a deeper level of information becomes visible, in this case "mapping strategies", "problems in the mapping process" and "visual context". Selecting "mapping strategies" reveals information on "systematic strategies" and "non-systematic strategies". Again, while informing on systematic strategies, another level of depth is opened to the user and e.g. information on APT (A Presentation Tool, [Mackinlay 1986]) can be studied.

Figure 3: *SIMBA shows topics of breadth (here the example of computer-generated visualization) in its horizontal axis and depth (for example on APT, a systematic mapping strategy developed by [Mackinlay 1986]) in its vertical axis.*

It is interesting to note here, that it is very hard to divide a key concept into independent breadth levels, without increasing depth when going from left to right. In the case of computer-generated visualization much effort of a subcommittee of the SIGGRAPH Education Committee [Dom97] has gone into developing independent themes and the results were quite satisfying. In the case of computer-generated color the success was inferior and for insiders of computer-generated color it is easy to note a slight increase of depth in the breadth dimension on that module.

Each module has a motivational application to explain the value of this concept to the "real world". E.g. visualization is motivated by the environmental issue if and where to build high-risers in a (really existing) valley. This question is to be decided by using visual representations of the terrain and environmental parameters such as wind speed, direction and humidity (see Figure 4).
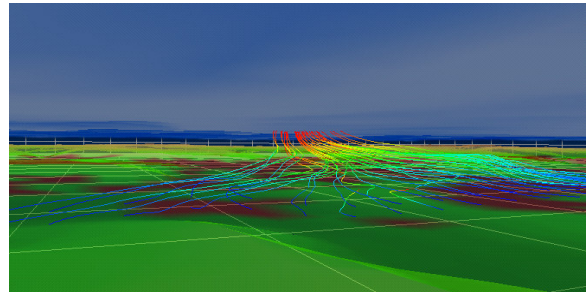
Figure 4: *Visualization of a valley and some of its environmental parameters.*

With this application it is easy to explain and understand that visualization goal, mapping strategy selected, or individual abilities and goals of the viewer influence the effectiveness of a picture. The students are being motivated to learn more about these themes in order to generate expressive and effective images.

Computer-generated color is motivated by showing and explaining visualization presentations using color as a key visual attribute. Additionally, we motivate by discussing some of the wide spread user interfaces for color selection that are often not clear to interpret (e.g. what does a hue of "21" mean in the Microsoft Word color editor?). By asking more detailed questions about this much used editor we have found that the curiosity to know more about how to create colors is being peaked. During our evaluation (chapter 4) we found that while our first application (real world problem) is motivating to men and women alike, our second motivation (technical aspects) is stronger favored by male students.

Additionally to the breadth and depth arrangements, SIMBA is very rich in interactive elements, but these are not further discussed in this paper.

3 Use of SIMBA to teach "Creativity and Technology"

The module "color" of SIMBA is being used to teach color to our computer science students in the introductory course of computer graphics. However, it is of more interest to see, if SIMBA is indeed a tool to use for interdisciplinary courses. Here we will report on a sequence of courses "Creativity and Technology" that were held at the University of Paderborn, Department of Computer Science. The students were either in the Master Program of the Computer Science Department (further referred to as "CS students") or studying towards a Master in Media Studies (further referred to as "Media students"). The goal was to have students of different disciplines work on the same project. In order to be able to communicate with each other, though coming from a different knowledge background, the students needed a common "language". This was accomplished by using the same multimedia tool (SIMBA) to teach both kinds of students, but teaching them at different levels of depth.

We expected new ideas for visualizations by mixing the less technical, but highly creative Media students with our CS

students. Also, we expected different ideas from the new gender mix, as our CS courses are male dominated whereas our media courses are well gender balanced.

3.1 The CS Side of Learning

Participating CS students signed up for a two semester project course "Creativity and Technology" that met for six hours every week during semesters. This included lectures (on computer-generated visualization using the SIMBA tool, on creativity and computing and on other topics), a seminar (on 3D Web Technology) and project work. The prerequisites to take part in the project group were two courses in computer graphics. Therefore students had a solid grasp of the rendering process, raytracing, radiosity, and volume rendering, color, and some understanding of texturing and animation.

The project that evolved over the two semesters was a client-server based tool for remote visualization based solely on open source technology [GD03]. In order to challenge the display on the remote clients, the visualization process was intended for large, complex data. A suitable data set that modelled the area of a 10 km x 10 km terrain, including simulated data of wind direction, pressure, humidity, and temperature for each defined volume position in space over the terrain and over time was used as a test set (Figure 5).

Nine CS students participated in the project group.

Figure 5: *The openVisaar System (developed by CS students) depicting the same terrain as in Figure 4.*

3. 2 The Media Side of Learning

Media students had no prerequisites to fulfil. Forty students participated in the course that was also called "Creativity and Technology". The main content of the lectures was "computer-generated visualization" following the SIMBA tool, but not to the depth of CS students. Computer-generated color was also taught from the SIMBA tool, again in full breadth but limited depth. The lecture on "Creativity and Computing" was held in the same form as for CS students,

following scientific articles in [CACM02] to better understand how creativity can be supported by a computer system.

Media students also learned to use Maya (by Alias), Flash and Shockwave (both by Macromedia) in the lab. Using this software (or any other software they were knowledgeable of) students were trained to develop expressive and effective visual representations for complex data sets keeping in mind specific visualization goals.

"Creativity and Technology" for Media students ran for one semester, parallel to the second semester of the CS project course named identically.

3.3 Working Together

Working together started after a mid-term test for Media students. CS students presented visualizations of the complex, environmental data set. Also, CS students specified some specific visualization goals for this data set: e.g. a town council using this data set to decide

- where to place a high-riser,
- or where to place a dump site

Together CS and Media students discussed which visualization elements should be developed over the remainder of the course. CS students and Media students had the advantage of speaking the "same language" when speaking of the system to be developed: "expressive and effective" had the meaning defined by Mackinlay (1986); the influence of viewer abilities or the influence of the visualization goal was well understood on both sides. From here on CS students and Media students would meet and work together over new visualizations. Examples of joint developments are shown below: Figure 6 shows a glyph for multivariate data on wind parameters designed by Media students, and Figure 7 shows the terrain with these new elements in the openVisaar Tool.
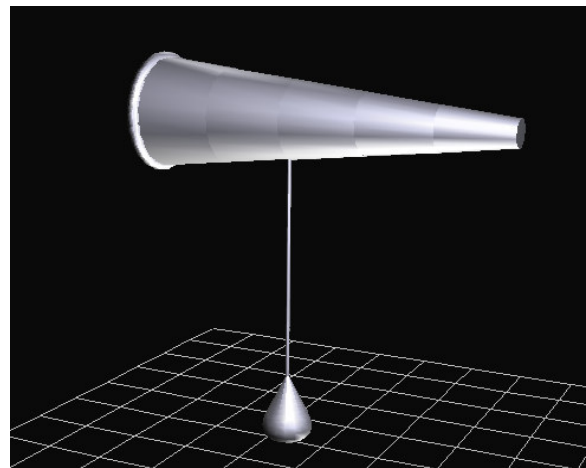
Figure 6: *Glyph for multivariate data on wind parameters designed by Media students: colors and size of wind tube and drop are parameter driven.*
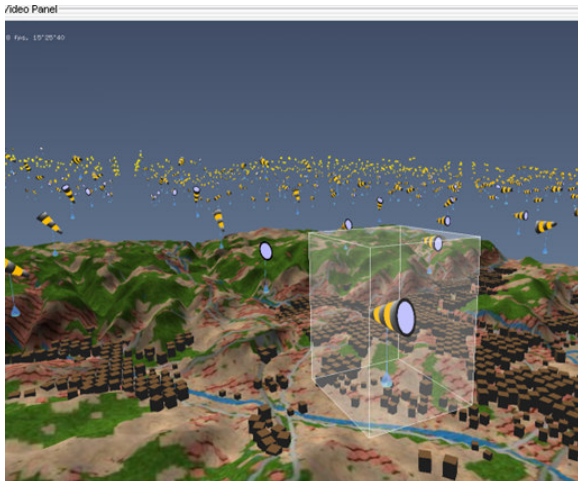
Figure 7: *openVisaar with glyphs designed by Media students.*

4 Performed Evaluations

In a qualitative way we could observe an effective communication between the two groups. Key words on visualization, color and other system issues were equally understood on each side. We did not quantitatively evaluate the value of the courses "Creativity and Technology". However, SIMBA which we used in teaching these courses was evaluated in the setting of a large computer graphics course [Tig04], of which some factors are summarized here.

The study was conducted with 84 (mainly) CS students (70 male, 12 female; 2 did not reveal their gender). More than 90% of students found, after using the tool, that specifically the interactive elements were helpful to enhance their understanding. 70% found the modules motivational. Also 70% improved strongly of the breadth and depth order in the menus. The same amount of students (70%) declared that it became clear to them by the application why the topic is relevant to their studies. Technical problems using SIMBA were named by 73% of women and 25% of men. Among these problems were incompatibilities of SIMBA with Linux or a slow Internet access from home.

5 Conclusions

We have developed a breadth-first approach for our educational tool SIMBA. It offers a gender and discipline independent motivation for our students. We could also report on the successful use of SIMBA teaching an interdisciplinary course "Creativity and Technology" for CS and Media students. The evaluation of SIMBA proved our theory that breadth-first approaches are useful even for our technically oriented clientele of CS students.

References
[BK99] BILLINGHURST, M. AND KATO, H: Collaborative Mixed Reality, *Proc. International Symposium on Mixed Reality. Mixed Reality--Merging Real and Virtual Worlds*, Yokohama, Japan (1999) 261-284.

[CACM02] Creativity and Interface, a series of papers in the *Communications of the ACM,* Vol 45, No. 10, (2002) 88-126.

[CC2001] Computing Curricula 2001: www.computer.org-portal-cms_docs_ieeecs-ieeecs-education-cc2001-cc2001.pdf

[Dom00] DOMIK, G.: Do We Need Formal Education in Visualization? *Visualization Viewpoint. IEEE Computer Graphics and Applications*, Vol. 20, No. 4 (2000).

[Dom97] DOMIK, G., BAKER, P., GRINSTEIN, G., HEWETT, T., MCGRATH, M., OWEN, S.: ACM SIGGRAPH Curriculum for Visualization On-Line Document, www.uni-paderborn.de/cs/vis

[GD03] GOETZ, F. AND DOMIK, G.: Remote and Collaborative Visualization with openVisaar, *Proc. of The 3rd IASTED International Conference on Visualization, Imaging, and Image Processing,* Benalmádena, Spain (2003), pp. 902-907.

[Mac86] MACKINLAY, J.: Automating the Design of Graphical Presentations of Relational Information, *ACM Trans. on Graphics,* Vol. 5, No. 2, (April 1986) pp 110-141.

[SIMBA04] BMBF-Verbundprojekt SIMBA: Schlüsselkonzepte der Informatik in multimedialen Bausteinen unter besonderer Berücksichtigung der spezifischen Lerninteressen von Frauen, July 2001 – May 2004, http://www.die.informatik.uni-siegen.de/simba/

[Tig04] TIGGES, A.: Evaluation des Lernmoduls "Computergenerierte Farbe" des SIMBA-Teilprojektes "Computerbilder", Universität Dortmund, Lehrstuhl Hochschuldidaktik (2004).