Computer Graphics for Information System programmers

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Abstract

An introductory computer graphics course is always a challenge. It is even more so if computer graphics is an additional component to a general computer science degree. In this instance, it is really important to discuss which computer graphics topics are relevant for tomorrow's programmers and engineers who are going to work mainly in Information Systems developments and data management software. The objective of this this paper is to consider what should be taught to future professionals who, not being directly involved in the development of specific computer graphics applications, will possibly need to use computer graphics in their developments. We will describe how this objective can be achieved by a carefully selected set of programming assignments.

Categories and Subject Descriptors (according to ACM CCS): Computers and Education [K.3.3]: Computer Science Education—Computer Graphics [I.3.3]: General—

1. Introduction

The continuous evolution of computer graphics makes this subject a very difficult one to teach. This task is really complex in any specialised computer graphics course due to the necessity of constantly updating materials and frameworks. That is not easy in the context of a general computer science degree either. This paper will address the problem of teaching computer graphics in a framework where computer graphics is just one component, generally only one or two modules, in a standard computer science or other IT degree.

In such a case, when training general computer science professionals and programmers, it is essential to take into account what computer graphics elements will be truly important in their future work. Consequently, what theoretical knowledge should be taught and what practical skills should be covered depend on the development field they will mainly be involved with.

We will show that Information Systems (IS) and data management software are the most important activity areas and why some traditional teaching approaches are not necessarily the most convenient ones in such a context.

2. What applications will our students develop?

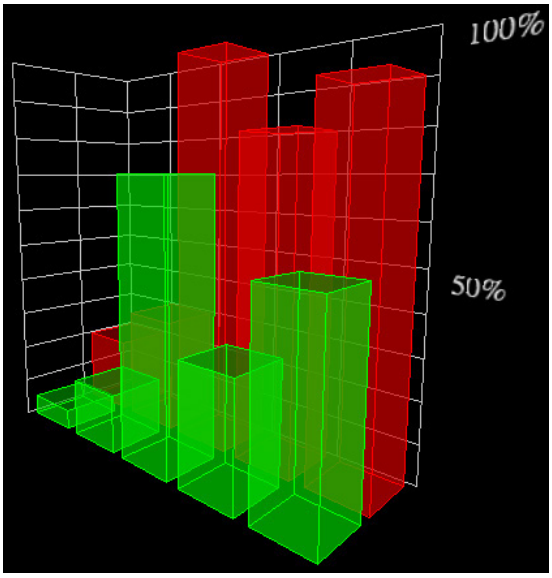
Although it is very well-known that IS and data management software are the most demanding computer science fields, we decided to explore what the current work activity is in our country.

It is not easy to know exactly in which fields our students will be using their programming skills, but it is possible to get an approximated idea by studying information about current trends in computer science jobs.

After analysing information from an important Spanish source [ali], it was proved that data management and IS are the most demanded fields. And that fact can also be contrasted with identical results with other international websites focused on job searching such as `dice.com` and `indeed.com`.

Our students are in the third year of a three-year computer science degree. Computer graphics is a one-semester subject, three hours a week, half theoretical lectures and half laboratory work.

As stated before, the most common applications our students are going to develop are mainly database front-ends, data analysis and management. Therefore, we realised that our current approach, based on standard computer graphics curricula, although mostly valid, was not able to provide them the specific and important elements for their future work as we will show later on.



In the first programming assignment, the student has to develop a simple application that visualizes bar and pie charts in 2D an 3D. Data visualization is very important in IS.

Figure 1: *Assignment 1. Statistical data visualization.*

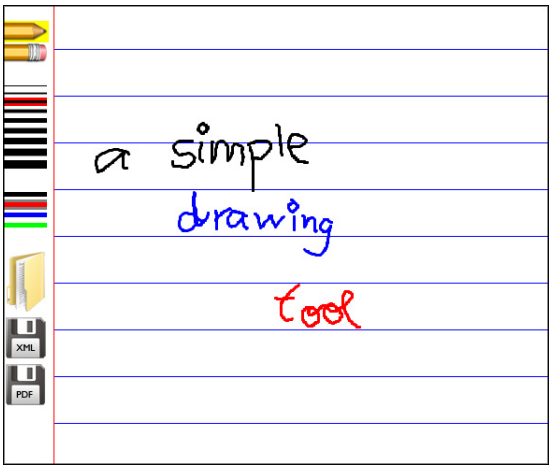
3. Computer graphics for IS and data management software

As stated before, our objective was to reconsider the contents of a computer graphics subject with the following context:

- It is the only computer graphics subject in a general computer science degree.
- Although some students might eventually be involved in the development of specific computer graphics applications in the future, the common situation is more likely to be very different, i.e, the main part of them will work in IS and data management software.
- We want to provide practical skills that could really help them in their common future tasks.

Consequently, an important step in order to adjust the contents of the subject is to determine what computer graphics skills are those normally used in this kind of applications. With our own professional background, and an important feedback from former students of ours, the following necessary computer graphics techniques arose:

- Modeling and visualizing statistical and analytical data. In any kind of data management application, the necessity of showing different charts, in either 2D or 3D, is really very important and frequent. Although the programmer is always able to find some kind of external utility or API to do so, it is always very convenient to be able to develop a customised chart visualization tool to fit with any particular requirement.
- Basic image processing and visualization. Image visualization and manipulation are very common in almost any application and quite frequent in IS environments. Our students should be familiar with image formats, how to open and visualize them and basic operations in order to manipulate them. Pixel access and modification are very interesting issues to be covered by any programmer.
- Basic modeling, visualization, selection and manipulation of 2D vector data. It is not only interesting to visualize a bar chart for instance, it is also required to allow the user to select either a label, a particular bar or any of the elements of the chart. Therefore, picking techniques, in 2D or 3D, are also something that has to be considered.
- Cartographic data and geographic information. GIS applications and related data are becoming more and more popular. Map retrieving and visualization are essential in lots of applications. The popularity of GPS-capable mobile devices and phones allows a new range of applications that are very common in the market. In order to work with this kind of information, vector 2D and 3D data and images are essential again, as well as coordinate system transformations.



In the second assignment, the students have to develop a simple drawing application. Interaction skills are the essential objective.

Figure 2: *Assignment 2. A free drawing application.*

A common feature to the majority of IS applications is data visualization, also known as data graphics. Recent works in this field [Tuf01] [Fry08] assert the correctness of our previous list, where bar, line, stacked area, pie and ring charts, scatter plots, time series, tree and graph diagrams, among others are some of the frequent elements in current data-based applications.

Taking into account the previous information, some important issues arose as essential requirements in our redefinition of our computer graphics module:

- In this type of data-based applications, a high level API is always going to be used if available. Thus, an OpenGL approach is, in our opinion, probably out of scope with our non-specialised students. There are probably better options than OpenGL, such as the `processing.org` framework for instance [RF06]. A high level API that, without loosing flexibility is more appropriate to the profile of our students [LPSBMTCF09].
- 2D is still much more important than 3D in data management applications. Therefore, a comprehensive study of a 2D API should be covered, without ignoring the 3D graphics basis.
- Tangential areas such as image processing and interaction are sometimes essential in the development of IS applications. Basic image processing techniques are important in order to allow the students to open and manipulate images. Interaction, although sometimes covered by specific subjects, is a basic key in the development of GUI.
- Rendering techniques, lighting, visibility, shaders and other more advanced topics are worth knowing but, perhaps, only from a theoretical point of view. Laboratory work should not be focused on these issues since they seem not to be especially useful to our students.
- Basic modeling, visualization and interaction are the most interesting computer graphics skills when developing general IS and data management software. Animation, advanced rendering and others can be postpone to more specialised courses.

Although these conclusions were taken considering our university scope and the future framework of our students, we do believe that they can also be applied to other institutions and, in general, when training computer science engineers and programmers which main activity is focused on IS developments.

4. What was wrong with our previous approach?

Firstly, we will describe our subject in order to understand the problems we have found in the training of our students. The subject (one semester) is divided into two different activities: theoretical lectures and laboratory work.

In the theoretical part of the subject (2 hours per week) we cover the following computer graphics topics:

1. Introduction and history of computer graphics.
2. Basic principles of interactivity.
3. A global vision of the graphics pipeline.
4. 2D geometric transformations.
5. 3D basic principles.
6. 3D geometric transformations.
7. Projection.
8. Visibility.
9. Lighting and Shading.

In the laboratory work the students had to solve an assortment of programming assignments that were focused in the development of several little applications:

1. A basic 2D application were some geometric transformations were applied to an input model.
2. A 3D object modeling tool.
3. A 3D visualizing tool with flat and Gouraud shading.
4. Animation of a 3D scene.

The theoretical knowledge provided to our students, future computer engineers and programmers, has to be horizontal and comprehensive. Only in this way can they be prepared, in our opinion, for any future workplace. Consequently, we consider that any change to the computer graphics curricula should be better if oriented towards the laboratory work.

The programming assignments they were solving so far were more influenced by our own activity as computer graphics professionals and researchers rather than the future framework of our students. Therefore, they were misaligned with their needs.

If the computer graphics foundations are covered from a theoretical point of view, it is more convenient to design a set of assignments that are going to be similar to the kind of problems our students will probably face.

Although different approaches [SW04] [Dav07] [GMGM06], and with satisfactory results, have been proposed for laboratory work and practical learning, our proposal was to design a well-oriented body of programming assignments with the following characteristics:

- Focused on current IS and data management and its visualization.
- Comprehensive enough, from a computer graphics point of view, to fit with any different student needs.

5. A new set of programming assignments

Basic modeling, visualization and interaction are the main pieces of a collection of five programming assignments. Their objective is to force the student to solve some of the problems they will probably face when applying computer graphics in their future activity.

With a low-medium level of complexity, they explore the common problems when managing and visualizing data. However, these assignments are not only focused on visualization, since basic modeling techniques and interaction are also covered.

Another important consequence of solving these assignments is that they are also valid as a training element whenever the student has to deal with other computer graphics applications.

We will now briefly describe each assignment focusing on the computer graphics techniques and skills they mainly cover. The complete description of these assignments can be found at `www.processing.tk`.

Assignment 1. Statistical and analytical data visualization

Description: From a multi-dimensional table with general data, visualize this data as a bar and pie charts in 2D and 3D. See figure 1.

Justification: As stated before, data visualization in general is an essential key in a lot of data processing applications and IS. After detecting some problems with this kind of techniques in our students, we decided to design an assignment with the main objective being the visualization of statistical information. They have to do it in a 2D and 3D environment. With the 2D part, they finally become familiar with basic 2D primitives. In the 3D part of the assignment, they have to learn how the model/view matrix becomes a powerful mechanism in the 3D modeling of a scene. In any case, they eventually assimilate how important geometric transformations are when transforming between coordinate systems.

Computer graphics main areas: Modeling and visualization.

Computer graphics specific skills:

- Use of basic 2D and 3D primitives.
- Transformation of coordinate systems (from world-real units to screen coordinates).
- Use of model/view matrix and its use in transforming between different coordinate systems.

Assignment 2. A simple 2D drawing application

Description: Development of a simple 2D drawing application tool, with a vectorial storage model and XML export. See figure 2.

Justification: A simple 2D drawing application is a perfect practical exercise. Students have to define a dynamic data structure for vector information storage and to, sometimes, face their first GUI. Working with mouse events and buttons force them to use a graph of states. Implementing a delete tool is also the perfect situation to introduce 2D picking techniques and some geometrical concepts, (distance from a point to a segment, vector cross product). They also realize how difficult a selection tool could be in a visualization application.

Computer graphics main areas: Modeling, visualization and interaction.

Computer graphics specific skills:

- Modeling 2D vector data and how to serialise this information.
- Efficient visualization of 2D vector data.
- Basic GUI development (mouse event handling, buttons and a state graph).
- Basic interaction with 2D vector data since the selection of elements is required (2D element picking). Distance from a point to a segment.

Assignment 3. Calculating the histogram of an image

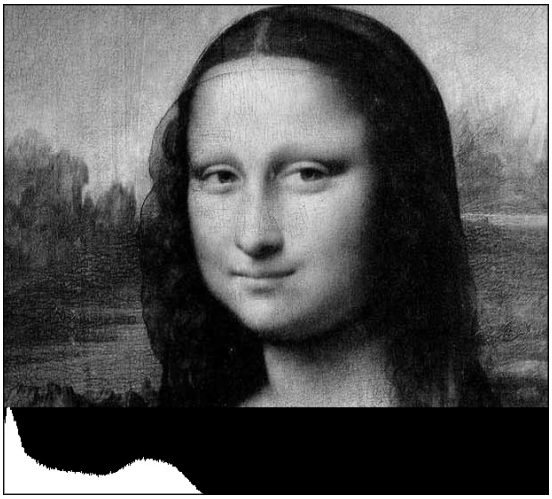
Description: Calculating the histogram of an input image and its graphics representation. See figure 3.

Justification: Open and visualizing images are natural tasks in a lot of applications. In our opinion, it is essential that our students were able to work with pixel level operations. A simple problem, the histogram of an image, is a perfect activity to put into practice these skills. Additionally, the visualization of the histogram, improves our students ability of working with data visualization.

Computer graphics main areas: Visualization.

Computer graphics specific skills:

- Basic image processing techniques.
- Image formats and files.
- Pixel access functions and basic image manipulation.
- 2D data visualization (histogram).



In the third assignment the histogram of an input image has to be calculated and represented. Basic image processing and manipulation techniques are necessary.

Figure 3: *Assignment 3. Calculating the histogram of an image.*

Assignment 4. Map retrieval and visualization

Description: Interaction with a Web Map Service (WMS) in order to get a cartographic image from its bounding box, with zooming and panning. See figure 4.

Justification: Zooming and panning in data visualization are techniques that often cause a lot of problems to our students. The objective of this assignment is to improve their geometric transformation knowledge and its use in transformations between coordinate systems. Cartographic maps are becoming very popular in a lot of applications and they provide a perfect workbench for this assignment. The development of a simple Web Map Service (WMS) client is not difficult as, just with an http request, an image is retrieved. However,

working with geographic coordinates and screen coordinates in a zooming/panning environment, will test students in their practice of geometrical transformation basis.

Computer graphics main areas: Visualization and interaction.

Computer graphics specific skills:

- Image visualization.
- Zooming and panning by terms of geometrical transformations.
- Model/view matrix and its use in transformations of coordinate systems.

In the fourth assignment, a simple Web Map Service client has to be implemented.

Figure 4: *Assignment 4. Retrieving cartographic images from a WMS.*

Assignment 5. 3D real-time terrain rendering

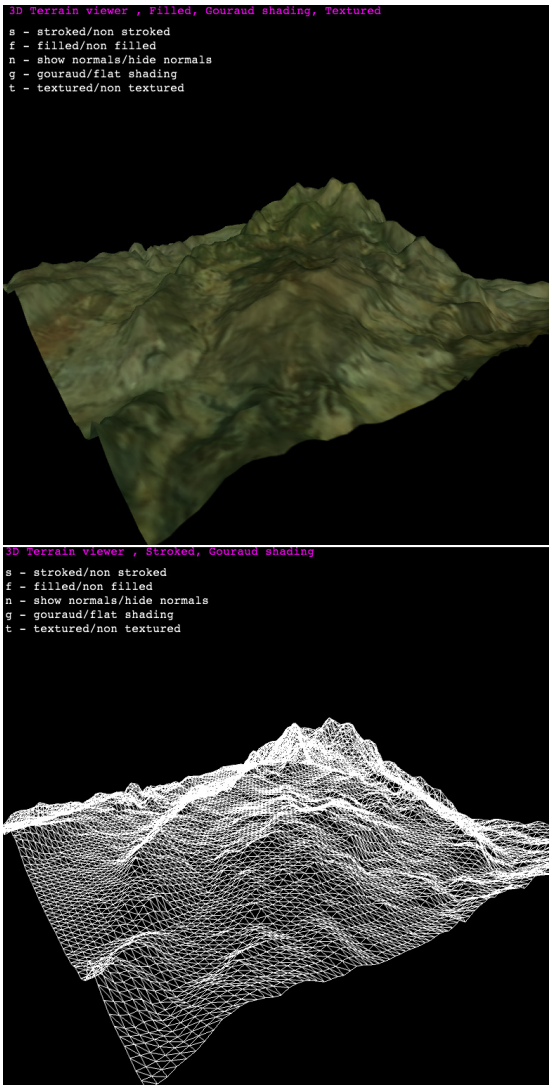
Description: 3D real-time visualization of a small area of terrain from its ortho-photography and DEM (Digital Elevation Model). See figure 5.

Justification: Again, cartographic information is used in this last assignment. In this case the input are two images, an ortho-photo and a DEM. With the DEM, students explore how a triangular mesh can be generated. With the ortho-photo, they learn the very basic texturing techniques. The visualization of the result, textured and wire-framed, allow them to explore basic 3D visualization concepts. Changing the point of view using a trackball model, introduces them to the use of a model/view matrix in the development of an object browser.

Computer graphics main areas: Modeling, visualization and interaction.

Computer graphics specific skills:

- Basic image manipulation.
- 3D displacement modeling from an input image (DEM).
- Basic interaction with a 3D model (trackball based visualization).
- Basic lighting techniques.
- Basic texturing techniques (ortho-photo).



The last assignment is the most complex one. Using two images, the students implement a simple 3D terrain viewer.

Figure 5: *Assignment 5. 3D real-time terrain visualization.*

6. Results

Our motivation in order to change our computer graphics course was generated by some recent problems we noticed in our students:

- A motivation shortage.
- An important deficiency in their general fundamentals.
- What they don't directly do, it is likely they won't be able to do.

Although it is difficult to evaluate the benefits of any change, very subjective actually, after two years of a gradually introduction of this new approach, the majority of our students expressed they were more satisfied with their laboratory work and considered it much more useful than our previous alternatives.

7. Conclusions

In our opinion, when training computer engineers, a strong theoretical foundation is always required. Computer graphics main topics are important to be comprehensively covered. However, laboratory work could be more flexible.

With our current context where the majority of our students will be working in IS and data management software fields, it is with the laboratory assignments where we have a perfect opportunity to align our subject to the framework our student needs.

A well-thought collection of programming assignments have been presented in this paper, specifically designed to match the common set of developments a data management programmer usually carries out. These assignments are general enough to also match other requirements, being also appropriate for those students who might work in the development of applications more directly focused in the computer graphics world. With this new collection of assignments, our students are more prepared for the common tasks they will face in their professional future.

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