

2D Computer Graphics

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I. INTRODUCTION

Computer Graphics (CG) is a vast, important, and popular discipline. In Computer Science, over 90 percent of the undergraduate curricula have an optional CG course. The 2D aspects of CG such as vector primitives, 2D curves, halftoning, and 2D transformations are important in creating 2D content. Acquisition and reproduction of 2D content also requires knowledge of the **Image Processing (IP)** discipline. These aspects are of major importance since most of the content created, acquired, reproduced, and visualized is 2D. Yet, in typical CG courses, 2D CG and IP are only briefly presented since the focus is on 3D.

This paper deals with 2D computer graphics wholly. 2D computer graphics is a computer based generation of digital images mostly two dimensional models such as 2D Geometric models, text, etc. This paper comprises of application that consists printing and drawing techniques such as typography, cartography, etc. It is the two dimensional image not just representation of real world objects but an independent artifact with added semantic value because they give more direct control of image than 3D computer graphics. This paper deals with desktop publishing, engineering and business kind of domains. 2D graphics will be rendered at different resolutions to suit different output devices. 2D computer graphics is based on vector graphics devices. This paper also involves postscript language and X Window system protocols as important landmarks.; [Larrondo-Petrie et al. 1994; Cunningham 2002], it is typically presented in an introductory course that concentrates on 3D [Wolfe 1999; Hitchner et al. 1999]. Such a course also has to deal with IP, since the main goal is image synthesis. It also has to deal with HCI since the user interacts with the 3D objects. Despite the link between CG, IP, and HCI, 84 percent of the introductory courses are typical 3D CG courses that spend most of the time on 3D topics.

There are so many topics to cover in an undergraduate Computer Science curriculum that it may be appropriate to cover some parts of CG with another discipline. At the present time, only 3 percent of the courses on CG introduce it together with IP. This paper argues that this percentage should significantly increase.

II. CG AND IP COURSE

The CoGIP course presents particular topics of traditional CG and IP courses. Obviously it cannot cover all the material of the traditional courses, but it presents topics that form a coherent view of the two disciplines. Here is a list summarizing the topics it covers:

- perception** human visual system, sensation of color
- color** models, transformation (brightness, contrast, gamma, etc.), composition (alpha blending, mathematical, etc)
- sampling** pixels, quantization, aliasing, and antialiasing
- acquisition and reproduction** digital camera, scanning, printing, displaying, halftoning
- vector primitives** ellipses, rectangles, polylines, curves, etc.
- rasterization** mid point, scan conversion, painter's algorithm
- filling** boundary and floor fill
- image filtering** filterin in the spatial domain (blur, sharpen, median filter, etc.) and in the frequency domain

transformations affine homogenous coordinates, composition
Content creation heavily relies on the use of computers. The visual representation of information in technical talks and reports, data visualization, and user interface uses text but also heavily relies on graphics and images. Common 2D content tools² such as Photoshop R are increasingly powerful. Mastering these tools goes through understanding the theory behind the algorithms.

Images can be captured with digital cameras and various other devices. Appropriate knowledge of the limitations of the different types of acquisition is essential to creating quality content. Given quality content, creating a reproduction on different media is a challenge. For someone who does not understand how our eyes perceive the final images, it is difficult to select an appropriate solution since they involve different costs and different output quality.

III. RELATIONSHIPS BETWEEN CG AND IP

This section presents the theoretical relationships between CG and IP. These relationships strengthen the logic of combining these two disciplines in a single course. Table 1 presents the basic relationships between CG and IP. Images is the predominant relationship,

Computer Graphics	Shared / Related	Image Processing
synthesis	image	processing
rendering	volume	filtering thresholding
	perception color sampling	
antialiasing supersampling		aliasing filterin
	texture filterin forward-reverse	image 2D
texture mapping	mapping	transformation
animation	morphing	image

Table 1: Relationships between topics shared by CG and IP. The classification is a tool for comparison, not a strict classification and whereas CG can be viewed as a process that happens while (or before) the images are created, IP happens after an image is available to process. How the human eye perceives colors, how colors are represented in digital forms, and how vector graphics are sampled to be displayed on a monitor are few examples of aspects of these topics that are common to CG and IP.

Many topics are advanced topics in one of the CG and IP disciplines (Table 2). Shading and projection are basic topics in CG, but they relate to advanced IP topics of shape from shading and stereo vision. Contrast enhancement and image compression with wavelets are basic topics in IP, but they relate to advanced CG topics of High Dynamic Range Imagery (HDRI) contrast enhancement and multiresolution surface editing with wavelets. Other topics are advanced in both CG and IP, such as texture analysis and synthesis, and 3D reconstruction from images.

In introductory CG courses, topics such as curves and transformations are first introduced in 2D and then extended to 3D. While these 2D topics may have little to do with IP, they fit well in the 2D context of images. Table 3 presents CG topics that are appropriate for a CoGIP course and their extension to 3D. It shows that bringing

Computer Graphics	Shared / Related	Image Processing
shading		<i>shape from shading</i>
image synthesis	projection	<i>stereo</i>
<i>HDRI mapping</i>		contrast
<i>multiresolution surfaces</i>	wavelets	image compression
<i>synthesis</i>	texture	<i>analysis</i>
	<i>3D reconstruction</i>	

Table 2: Relationships between CG and IP topics that are advanced topics in one of the two disciplines. The advanced topics are highlighted in italics.

Computer Graphics	Related	CoGIP
3D & surfaces	curves	2D
3D & projection	transformations	2D
3D, more degrees of freedom	animation	2D
polygon, sphere, torus, etc.	primitives	2D vector
scan-line	vector to raster	mid point
wireframe / smooth shading		contour / interior

Table 3: 2D CG topics that are moved from the traditional introductory CG course to the CoGIP course.

the same topic from 2D to 3D is not a trivial extension.

IV. DISCUSSION

To be able to create quality 2D content, mastering the 2D CG and IP disciplines is important. Typical introductory CG courses focus on the 3D aspects and don't provide adequate knowledge of topics such as the difference between vector and raster graphics and how vector graphics are rendered to raster representation, halftoning techniques, color models, and filling algorithms. The proposed 2D CG and IP CoGIP course is not intended to replace the typical introductory course that focusses on 3D, but to provide an alternative that should gain more attention since computer scientists often have to deal with 2D content.

The CoGIP course is interesting for students, since it presents the theory that governs how they perceive the world and how digital images are approximate views of the real world. It also presents how images and 2D graphics can be created, edited, and reproduced to deliver quality results that correspond to different constraints.

The close relationship between the CG and IP disciplines allows an easy integration of both. Since they require similar background knowledge, presenting them together does not put additional constraints on the target audience. They also provide an interesting platform on which to build advanced courses such as vision, object recognition, 3D CG, and animation.

The CoGIP course also presents some challenges. A first practical challenge of such a proposed course is that there is no appropriate book that covers both disciplines in sufficient detail. CG books lack important IP topics such as the Fourier transform while IP books lack important CG topics such as curves. The GTI410 course³, which is a practical academic example of a CoGIP course, relies on chapters extracted from various books that cover the required topics.

The topics covered in the course, even though there is no doubt they are related, can seem too independent. Raster and vector graphics, and 2D CG and IP may seem unrelated opposites. An approach to bring the topics closer together uses assignment topics (Table 4) balanced between 2D CG and IP, as well as vector and raster graphics.

Topic	CG/IP	Vector/Raster
Color models	both	both
Filling	CG	raster
Filtering	IP	raster
Curves	CG	vector
Transformations	CG and some IP	vector and some raster

Table 4: Assignments of the GTI410 CoGIP course and how they relate to 2D CG and IP as well as vector and raster graphics.

The *J2DCG*⁴ framework was developed to allow 2D CG and IP to be coded in a single application. The framework does not present a working system, such as an image editing package, but gives a context in which algorithms are implemented with little programming effort. The framework design is thus focussed on ease of modification not efficiency or rigorous object-oriented design.

V. CONCLUSION

This paper discusses the importance of mastering many CG and IP topics to be able to create quality 2D content. It describes the CoGIP course, identifies the theoretical and practical relationships between CG and IP, the benefits and drawbacks of the CoGIP course, and possibilities of advanced courses. It also presents a framework for assignments and specifies assignment topics to cover many of the main aspects.

The CoGIP course is obviously not the only appropriate way to teach CG. Further study of particular programs such as Computer Science, Computer Engineering, Electrical Engineering, Software Engineering and Information Technology is required to better identify when a CoGIP course is an appropriate replacement of the traditional 3D CG introductory course.

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