CoGIP: a Course on 2D Computer Graphics and Image Processing

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1 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 briefl presented since the focus is on 3D.

This paper proposes a course on 2D CG and IP as an alternative way to introduce CG. These two disciplines have strong theoretical relationships which can be easily exploited in a single course. In this sense, our main contributions are: (1) the description of a course on 2D CG and IP; (2) the identificatio of the relationships between CG and IP; (3) the identificatio of the benefit and the drawbacks of the proposed course; (4) an open source framework to create assignments and example topics for assignments.

As a basis to the work presented in this paper, undergraduate Computer Science curricula[1] were looked at with a focus on the type of courses: traditional 3D CG, advanced CG, mixes of CG, IP, and **Human-Computer Interaction (HCI)**. Even though CG can be introduced in many ways [Brown et al. 1988; 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 significantl increase.

2 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 floo fill

image filtering filterin in the spatial domain (blur, sharpen, median filte , *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 tools[2] such as Photoshop® 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 fina images, it is difficul so select an appropriate solution since they involve different costs and different output quality.

3 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		aliasing
supersampling		filterin
	texture filterin	
texture mapping	forward-reverse mapping	image 2D transformation
animation	morphing	image

Table 1: Relationships between topics shared by CG and IP. The classificatio 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 firs introduced in 2D and then extended to 3D. While these 2D topics may have little to do with IP, they fi 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

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[1] The current set of information can be accessed at http://profs.logti.etsmtl.ca/epaquette/cgcourses/

[2] PhotoShop is a trademark of Adobe Systems Incorporated.

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

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.

4 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 filli g 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 firs practical challenge of such a proposed course is that there is no appropriate book that covers both disciplines in sufficien detail. CG books lack important IP topics such as the Fourier transform while IP books lack important CG topics such as curves. The GTI410 course[3], 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.

[3]GTI410 in the IT program of ETS, http://www.etsmtl.ca/

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 efficien y or rigorous object-oriented design.

5 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, identifie the theoretical and practical relationships between CG and IP, the benefit and drawbacks of the CoGIP course, and possibilities of advanced courses. It also presents a framework for assignments and specifi 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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[4]http://j2dcg.sourceforge.net