Digital Media in Computer Science Curricula*

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ABSTRACT

"Digital media" is one of those unfortunate terms that means different things in different contexts. This difficulty of definition – along with its association with art, communication, architecture, and film – puts digital media on the margins of traditional computer science curricula. This paper reviews the types of digital media programs current in higher education; proposes a curriculum model for digital media instruction that is firmly grounded in computer science at the same time that it interfaces easily with digital art; and describes specially-designed course material that serves the interdisciplinary need while preserving the rigor of the computer science discipline.**

Categories and Subject Descriptors

K.3.2. [**Computers and Education**]: Computers and Information Science Education – *curriculum*.

Keywords

digital media, multimedia

1. INTRODUCTION

Digital media exists only implicitly or marginally in the computer science curricula at most universities. Topics within the realm of digital media are often treated in graphics, image processing, network, or programming courses, but in most of the computer science programs we reviewed there was no explicit digital media course or track. Full-fledged digital media programs often exist as areas of emphasis within art or communications departments, or they are interdisciplinary or independent departments in their own right.

The variety of perspectives from which digital media is approached reflects the different sizes, emphases, and demographics of the universities' programs. No single approach is right for all universities, and we do not mean to suggest that digital media rightfully belongs only within the computer science curricula.

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Still, there is some resistance in computer science to finding any place for digital media at all. The sad truth is that among computer scientists, digital media suffers from the stigmas of being variously-defined, largely application-driven, and perhaps worst of all, popularized. But given the rise of student interest, the prevalence of multimedia in widely ranging work environments, and the expertise that computer science has to offer the discipline, we would be remiss in failing to consider the place of digital media in computer science education. Courses in digital media can round out a computer science program, integrating theory and practice in an area that is motivating to students and giving students the advantage of highly marketable job skills.

In this paper, we discuss the various interpretations of digital media in higher education, propose a paradigm easily accommodated by existing computer science programs without requiring wide curriculum revision or new degree programs, and describe the curriculum material we have developed to support our paradigm.

2. DIGITAL MEDIA, VARIOUSLY DEFINED

We define digital media for the computer science context as the study of image, sound, and video processing; interactive multimedia development; and advanced web programming. By our definition, this study is based on the mathematical and scientific underpinnings of digital media and aims towards a working knowledge of the related programming languages, development platforms, and communication environments.

Digital media has other definitions in other contexts, however, and it is instructive to consider what goes by this name outside of computer science. Existing programs in colleges and universities around the world align digital media with art, communications, architecture, or computer science. Degree programs can exist in any of these departments, or the courses can be offered from a separate department or as interdisciplinary endeavors.

The summary below is based on a detailed report compiled by the authors, available as WFU Technical Report 2003-2 [4]. The report gives a complete list of the digital media-related courses offered at 50 universities with well-regarded computer science programs (based on an NAGPS survey [3]) and 20 liberal arts colleges (based on *U.S. News & World Report*'s 2004 ranking). Other programs of note and programs outside the U.S. have been added to the list. The digital media courses are distributed around computer science, computer engineering, art, architecture, music, English, and communications departments. We summarize by

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describing each type of program and citing example universities which follow the model under discussion. Programs that vary in their proximity to traditional computer science are included for the purpose of giving an accurate picture of what digital media has come to mean in higher education.

Digital media courses sometimes arise within communications departments, where the word "media" is interpreted in the journalistic or mass communications sense. While the emphasis is usually on an analysis of digital media communication, courses in interactive multimedia, graphic design, and digital video for broadcast or film can be included. (Examples: UC-SD, UNC-CH; U. of Wash.; Digital Media Communication at St. Mary of the Woods College; and Castleton College's BS in Communication, with concentration in Digital Media.)

Digital media courses with an emphasis on media production can evolve from traditional communications departments into their own programs or departments. In such programs, courses range from the standard application-driven courses in image, sound, and video processing to those involving media culture and criticism. (Examples: U. of Penn.'s Digital Media Design interdisciplinary CS/Comm. program; Ireland's Cork Institute of Technology BA in Multimedia as an option within their Media Communications Depart.).

Digital media courses within art departments generally focus on graphic design; 2D and 3D imaging, modeling, and animation; interactive multimedia programming; digital photography; and digital video. Some digital media/art programs are closely aligned with film studies and production. The programs can exist as separate departments or even independent schools or institutes. The emphases in digital media/art programs can vary among aesthetics and graphic design; production; and theoretical or critical analysis. (Examples abound. Digital art courses programs are present in most universities. Schools with a special focus on digital art/media include the San Francisco Art Institute's Center for Digital Media; The Expression Center for New Media; the Media Design School in New Zealand, and the Art Institutes' programs and numerous campuses throughout the U.S.)

Digital media courses appear within architecture programs as well. Courses in CAD and 3D modeling and visualization represent the most typical association between architecture and digital media. (MIT Media Lab's program in Media Arts and Sciences is part of MIT's School for Architecture and Planning. The program includes master's and doctoral degrees as well as a Media Arts and Sciences Freshman Year program, all of which include basics of computational media design and research experiences in the Media Lab. See also U. of Washington's Center for Digital Arts and Experimental Media, and Advanced Studies in Digital Media within Cornell's Architecture Department.)

A number of independent and/or interdisciplinary programs in digital media have emerged in recent years. The CREAT program at the University of Central Florida exemplifies the kind of interdisciplinary program that can grow out of a collaboration among computer science, art, film, music, and English departments. (It was, by the way, developed by a computer scientist.) CREAT, which stands for Consortium for Research and Education in the Arts and Technology, offers BA and BS degrees in digital media, with the options of focusing on Computing for Media (most closely related to computer science), graphic design (art-related), Internet and Interactive Media (Web design, e-commerce, and game programming), Computer Animation, Digital Music, or Writing for the Media.

The Rochester Institute of Technology has designed a similar program that brings three tracks together in their Center for Digital Media – a BA in Fine Arts in New Media Design and Imaging; a BS in New Media Publishing; and a BS in Information Technology/New Media Emphasis. Students take a common core curriculum that includes coursework in graphic design, programming, photographic imaging, video, and publishing. As is the case with other programs described in this section, the goal is to bridge the "intellectual and cultural devide" between the arts and sciences.

Carnegie Mellon's Entertainment Technology Center offers a Master's degree in Entertainment Technology, jointly conferred by the School of Computer Science and the College of Fine Arts. Equal numbers of art and engineering students are accepted into the program and work together on team projects [2].

In London, the Thames Valley University's Media and Digital Arts program also has an interdisciplinary nature with a choice of tracks, but leaning more toward art and communication than toward computer science. Their BA in Digital Arts focuses on art, design, and technology, though with little traditional computer science. The alternative BA in Media Arts takes a more analytical view of communication and creative media.

The University of Bremen in Germany offers a degree in digital media firmly grounded in computer science and engineering and enhanced with courses in theory and analysis, art and design, human-computer interfaces, and applications. As opposed to choosing a "track", students work through a 3-year program taking courses from all areas.

The University of Florida's Digital Worlds Institute attempts to weave digital media into existing computer science curricula. Students are required to take typical computer science subjects and prerequisites – calculus, physics, linear algebra, data structures, programming languages, etc. – along with drawing, sculpture, digital art, digital production, and a variety of electives in art, music, film, aesthetic computing, and so forth. The Institute offers either a BA or a BS in Digital Arts and Sciences.

3. THE PLACE FOR DIGITAL MEDIA IN A "TRADITIONAL" COMPUTER SCIENCE PROGRAM

The examples above indicate that digital media is, under various umbrellas, a growing and thriving field of study at the university level. However, one striking observation we made in our review of programs was the very small number of digital media courses and programs in relatively small liberal arts colleges. We see two main reasons for this.

First, digital media as a discipline is not considered part of the mainstream of traditional computer science curricula. In the Steelman Report of ACM SIGCSE's Curricula 2001, digital media does not figure as a "core topic" [1]. Some (but not all) of its important topics are scattered within other subject areas. We show this correlation in Figure 1.

Second, small schools don't have the luxury of specialized programs in all their students' areas of interest. Somehow, digital media has to be woven into existing programs, but given its interdisciplinary nature, where does it rightfully belong? We would argue that it *is* possible to include digital media in a traditional computer science program – even a small program in a liberal arts college – that perhaps this is one of the best places for such a course, given the interdisciplinary-friendly environment of liberal arts schools. A feasible strategy in most schools is to offer a small number of digital media courses and coordinate an inter-departmental program. At our university, a simple solution has been to coordinate a major in computer science with a minor in art, or vice versa. The art component is concentrated on digital art and photography. This plan requires no widespread curriculum reform or degree approval; it requires only that the two departments be careful in scheduling of courses without conflicts.

Topics for Proposed Digital Media Course or Courses

Fundamentals
multimedia data representation and file types
data compression
data transmission, bandwidth issues
standardization organizations

Image Processing
sampling, quantization
resolution, bit depth
color representation, details on color models
display devices and color gamuts
mathematics of dithering
mathematics of anti-aliasing
compression algorithms -- Huffman code, LZW compression, run-length encoding, and jpeg compression
discrete cosine transform
advanced topics in scanning and digital photography
advanced topics in photographic processing
vector graphics, drawing, and painting programs

Audio Processing
sampling
quantization, non-linear quantization
manipulation of waveforms
Nyquist theorem
audio compression
file format
industry standards
audio filters and transforms, e.g. Fourier transform
advanced topics in capturing and editing sound files
MIDI

Video Processing
analog vs. digital video
digital TV, HDTV, digital cable
video display devices
industry standards
digital data transmission, bandwidth issues
data compression
mpeg
storage media
VBR techniques
capturing and editing digital video
digital video transmission
live and streaming video
fixed vs. dynamically varying bandwidths
video conferencing

Multimedia Programming
visual and event-driven programming
frame-based animation
advanced use of scripting languages, OOP and non-OOP
3-D modeling and animation
GUIs

Web Programming
Web programming languages and tools
interactive multimedia file delivery on the Web

Digital Media Topics Extracted from Computer Curricula 2001, Appendix B

Programming Languages (PL)
PL1. Overview of programming languages (core)
- Scripting languages

Net-Centric Computing (NC)
NC1. Introduction to net-centric computing (core)
- Networked multimedia systems

NC4. The Web as client-server computing (core)
- Support tools for Web site creation and Web management

NC7. Compression and decompression (elective)
- Analog and digital representations
- Lossless and lossy compression
- Data compression: Huffman coding and the Ziv-Lempel algorithm
- Audio, image, and video compression and decompression
- Timing, compression factor, suitability for real-time use

NC8. Multimedia data technologies (elective)
- Sound/audio, image/graphics, animation/video
- Multimedia standards (audio, music, graphics, image, video, TV)
- I/O devices (scanners, digital camera)
- MIDI keyboards, synthesizers
- Storage standards (Magneto Optical disk, CD-ROM, DVD)
- Tools to support multimedia development

Human-Computer Interaction (HC)
HC1. Foundations of human-computer interaction (core)
- Human performance models: perception, movement, and cognition

HC5. Graphical user-interface design (elective)
- Multi-modal interaction: graphics, sound, haptics
- 3D interaction

HC7. HCI aspects of multimedia systems (elective)
- Information retrieval and human performance (Web search, graphics, sound)
- HCI design of multimedia information systems

Graphics and Visual Computing (GV)
GV1. Fundamental techniques in graphics (core)
- Simple color models (RGB, HSB, CMYK)

GV2. Graphic systems (core)
- Raster and vector graphics systems
- Video display devices

GV4. Geometric modeling (elective)
- Polygonal representation of 3D objects
- Parametric polynomial curves and surfaces

GV5. Basic rendering (elective)
- Image synthesis, sampling, and anti-aliasing

GV7. Advanced techniques (elective)
- Color quantization

GV8. Computer animation (elective)
- Keyframe animation, scripting systems

Information Management (IM)
IM13. Multimedia information and systems
- Applications, media editors, and authoring
- Streams/structures, capture/represent/transform, spaces/domains, compression/coding
- Real-time delivery, QoS, A/V conferencing, video-on-demand

Figure 1. Correlation of digital media topics with SIGCSE's Computer Science Curricula 2001.

In computer science, we offer a digital media course covering the fundamentals in image, sound, and video and multimedia programming. Specific topics are listed in Figure 1. An advanced digital media course is also underdevelopment. Other courses relevant to students specializing in digital media are graphics, image processing, and special-topics courses like multimedia networks. We also offer half-semester electives covering advanced web programming and 3D modeling and animation. Art courses include three levels of digital art and three levels of digital photography.

It could be argued that a digital media course in a computer science degree program is simply redundant, since so many of the topics are covered in graphics, networks, human-computer interaction, and general programming. But the advantage to centralizing the material in a digital media course is that the concepts can be better motivated in that specialized context. For example, the importance of compression is clear when students have to choose a compression algorithm and then see how their choice affects the quality of their multimedia work. The application of Fourier transforms can be illustrated in sound processing. Experiments in network communication can be based upon the transmission of the students' own multimedia productions. The geometry of color models and comparative color gamuts can be made relevant through a comparison of digital images in print and on a variety of computer monitors. Digital media brings together theory and practice, science and skills, in a way that interests and excites students. The possibility that these topics might be repeated in a graphics or networks course need not be viewed as a disadvantage, since reinforcement of learning in different contexts is a sound pedagogical practice.

4. INTEGRATED CURRICULUM MATERIAL FOR DIGITAL MEDIA AND DIGITAL ART

To support our interdisciplinary digital media program, we have developed curriculum material that integrates computer science-based digital media and digital art. Our grant-supported curriculum development project is premised on the idea that the study of digital media – whether it is looked at from a computer scientist's or from an artist's perspective – is based upon a central body of information. There are certain fundamentals that students from either camp must understand. We call this basic body of knowledge the digital media "primer." Branching from the primer in either direction are the "advanced modules" in computer science and art. For computer science, the advanced module ensures that the digital media course goes beyond application programming. The advanced art module, on the other hand, delves into graphic design, aesthetics, and human perception.

The natural medium for this course material is electronic. The learning modules – text-based chapters, programming exercises, and interactive demos – are Web-accessible, and an e-book version is under development. For each chapter of the primer, more in-depth coverage is provided as appropriate in one or both of the advanced modules. Hyperlinks in the margin of the text show where a student can find additional information on a topic.

Interactive demonstrations and exercises are an important element of our curriculum material. For the primer, we attempt to make the exercises intuitive and base them on simple real-world experiences and concepts. The CS module, on the other hand, is more mathematical and analytical in nature, and thus the demos are geared towards visualization of the complex mathematical models and algorithms. Examples from the first two sections – the Background and Image Processing sections – serve to illustrate this approach.

The concepts of analog vs. digital representations of data, sampling, and quantizing are illustrated by means of an analogy that allows the students to monitor a puppy's first year of growth. Through the interactive demo, the students weigh a puppy on an analog scale and record its weight as a discrete number – quantizing. They then must decide the frequency of weighing the puppy – sampling. The effects of quantizing and sampling become apparent as students are allowed to see, graphically, the results of their choices.

The concept of an image histogram is also demonstrated in an interactive tutorial. (See Figure 2.) This exercise shows the students how changing the shadow, highlight, and midtone values affects a simple 6-gray-level image's brightness and contrast. The values can be adjusted by means of sliders, and the histogram changes in response. The tutorial also allows the student to experiment with the sliders and observe the tonal changes in sample photographs. Immediate text feedback about further improving the brightness and contrast of the photograph is given to the students for each adjustment the student has made.

Figure 2. Histograms and photographic adjustments

In the CS module, interactive demos are particularly useful in explaining the geometric representation of color spaces. One demo demonstrates the distortion of the RBG color cube into the HSV hexacone. The demo allows the students to rotate the 3D color cube any time. This graphical correlation of the the two color models in 3-dimensional space helps the students understand the algorithm for color space transformation, which may later be one of their programming assignments.

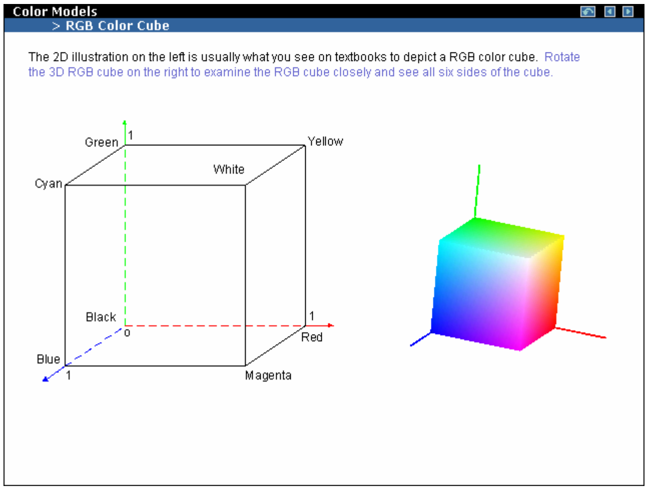

Figure 3. Moving through the RGB color cube

Below is a not-exhaustive list of additional learning modules and programming exercises already available for use:

Primer

- Fundamentals of Digital Imaging (text-based chapter)
- Effects of Varying Bit Depth (interactive)
- Effects of Undersampling (interactive
- Tonal Range Adjustment in Scanning (interactive)
- Printing Resolution: DPI vs. PPI (worksheet)
- Making Sense Out of Megapixels (worksheet)
- Fundamentals of Digital Audio (text-based chapter)
- Capturing Digital Sound (interactive)
- Video Examples of Levels of Compression (video)
- Video Interlacing (video)
- Understanding Timecodes (video)

Computer Science Module

- Digital Imaging (text-based chapter)
- Dithering (programming exercise)
- Huffman Encoding (programming exercise)
- Convolution Masks (interactive)
- Convolution Masks (programming exercise)
- LZW Compression (programming exercise)

Art Module

- Pegboard Analogy for Image Resolution (interactive)
- Optimal Color Mixing in Pointillism, Dithering, and Inkjet Printing (interactive)
- Metering Emulation (interactive)
- JPEG Compression Artifacts (worksheet)
- Choosing Among JPEG, GIF, and PNG (worksheet)
- Understanding and Applying Curves (interactive)

This material is freely available at the authors' website, http://digitalmedia.wfu.edu.

5. ON-GOING WORK

The curriculum material is being used with computer science and art students at Wake Forest University. It is also being tested at the University of Central Florida in two large sections of a Principles of Digital Media course. In the spring of 2004, the material will be used at in a course at Winston-Salem State University. Plans are also underway to use the material in faculty development courses for high school teachers.

Interesting and unexpected spinoffs have resulted from the interaction between computer science and the arts at our university. Computer science students are currently collaborating with the local Alban Elved dance company in the production of a performance entitled "Fibonacci and Phi." (See http://www.albanelved.com.) Students will be writing poems and creating multimedia versions of these poems illustrated with their own digitally-enhanced photographs and drawings to be projected on a screen behind the dancers. They are also generating fractals and 3-D animations to coordinate with the dancers' movements.

Our goal is to show that by coordinating Computer Science/Art courses and using coherently interrelated course material, it is possible to incorporate a well-integrated and rigorous digital media track into existing computer science and art departments without complicated curriculum revision or new degree programs. Digital media is a relevant, useful, and interesting elective for computer science majors. When taught with both rigor and creativity, it can bring mathematical concepts and classic algorithms to life at the same time that it gives students experience that will be valuable in many job markets. In schools where a full-fledged separate digital media program is not feasible, digital media can find a place in the computer science program and a relationship with digital art that serves student interests well. This is a topic that is of interest to computer scientists, and with this paper we hope to initiate fruitful discussions at the SIGCSE 2004 conference.

6. REFERENCES

[1] Computing Curricula 2001, Computer Science Volume, December 15, 2001 http://www.acm.org/sigcse/cc2001/.

[2] Schell, Jesse. Entertainment Computing : Shaping an Entertaining Future at Carnegie Mellon. *IEEE Computer*, August 2003, pp. 96-98.

[3] The 2000 National Doctoral Program Survey, National Association of Graduate-Professional Students, http://survey.nagps.org/index.php.

[4] Y.L. Wong, J. Burg, and V. Strokanova. Digital Media in Undergraduate Computer Science Curricula: Updated and Detailed Report. Wake Forest University Technical Report 2003-2, September 2003.