A Media Computation Course for Non-Majors

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ABSTRACT

Computing may well become considered an essential part of a liberal education, but introductory programming courses will not look like the way that they do today. Current CS1 course are failing dramatically. We are developing a new course, to be taught starting in Spring 2003, which uses *computation for communication* as a guiding principle. Students learn to program by writing Python programs for manipulating sound, images, and movies. This paper describes the course development and the tools developed for the course. The talk will include the first round of assessment results.

Categories and Subject Descriptors

K.4 [**Computers and Education**]: Computer and Information Sciences Education
; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems

General Terms

Experimentation,Design

Keywords

Multimedia, programming, non-majors

1. ISSUES WITH CURRENT INTRODUCTORY CS COURSES

Computer science departments are not currently successful at reaching a wide range of students who are taking introductory computer science. The evidence for this statement includes international studies of programming performance [10], declining retention rates [5], and failure rates sometimes as high as 30% [17]. In particular, participation of women in computer science is dropping. Studies suggest that computing courses are seen as overly-technical and avoiding relationships to real applications [9], and are frankly boring and lacking opportunity for creativity [1].

At Georgia Institute of Technology ("Georgia Tech"), all students are required to take an introductory course in computing, including programming skills. The traditional course is undoubtedly one of the most unpopular courses on campus, especially among those *not* in explicitly computing-related fields. While this is certainly a problem for the College of Computing at Georgia Tech (where the course has its academic home), it points towards a larger problem for the field.

Alan Perlis in April 1961 made perhaps the first argument that programming should be part of a liberal education for *all* students. If Calculus is the study of *rates*, and that's important enough to be part of the liberal education, then so should computer science. Perlis argued that computer science is the study of *processes*, which is certainly relevant to even more fields than those concerned with rates. The argument has been echoed and strengthened over the intervening years—by Seymour Papert arguing for a programming as a way of learning about learning [13][14], to Andrea diSessa's arguments for "computational literacy" as a critical component of many fields [3]. As long as non-CS-majors have such a dislike for computing, the hope is diminished for computer science as an accepted part of a liberal education and for computing generally to meet its potential for intellectual impact across the range of disciplines, not just in computational science and engineering.

We are developing a new course *Introduction to Media Computation* around a theme of *computation for communications*. The premises and core concepts of the proposed course are:

- All media are being published today in a digital format.
- Digital formats are amenable to manipulation, creation, analysis, and transformation by computer. Text can be interpreted, numbers can be transformed into graphs, video images can be merged, and sounds can be created. We call these activities *media computation*.
- Software is the tool for manipulating digital media. Knowing how to program thus becomes a communications skill. If someone wants to say something that her tools do not support, knowing how to program affords the creation of the desired statement. If she understands what her tools are doing, she may become a more adept practitioner, and more capable of transferring knowledge between tools.
- Core computer science concepts can be introduced through

media computation. We introduce these concepts as answers to questions that the students naturally develop when working with the media programs. For example, programs can get large and cumbersome. Abstraction is our tool for managing program complexity and allowing programs to become even larger yet more flexible. However, computing has limitations. There are some programs that cannot complete in our lifetime, and knowing that these limitations exist is important for technological professionals.

This paper describes the course, its approach, and the technological materials being developed for it. The presentation will also include results of the pilot course evaluations.

2. CURRENT STATE IN DEVELOPMENT OF "INTRODUCTION TO MEDIA COMPUTATION"

CS1315 Introduction to Media Computation was offered for the first time in Spring 2003 to a pilot class of 120 students. We will iterate on the course during Summer 2003 and implement at a full-scale in Fall 2003, with two sections of 120 students and three sections in Spring 2004.

Our learning objectives are:

- Students will be able to read, understand, and make functional alterations to small programs (less than 50 lines) that achieve useful communications tasks. Note that this is a very different goal than being able to write 50 lines from scratch. We see these students as developing *tool building* skill, not *software development* skill.
- Students will appreciate what computer scientists do and the key concerns of that field that relate to students' professional lives.
  - Students will recognize that all digital data is an encoding or representation, and that the encoding is itself a choice.
  - Students will understand that all algorithms consist of manipulating data, iteration (looping), and making choices — at the lowest level, these are choices about numbers, but we can encode more meaningful data in terms of those numbers.
  - Students will recognize that some algorithms cannot complete in reasonable time or at all.
  - Students will appreciate some differences between imperative, functional, and object-oriented approaches to programming.
  - Students will appreciate the value of a programming vs. direct-manipulation interface approach to computer use and will be able to describe situations where the former is preferable to the latter.
- Students will be able to identify the key components of computer hardware and how that relates to software speed (e.g., interpretation vs. compilation)
- Students will develop a set of usable computing skills, including the ability to write small scripts, build graphs, and manipulate databases – not necessarily using the common tools, but in a manner that exposes concepts and enables future learning.

We have developed (and are continuing to develop) a set of course notes and lecture slides that support the course. Overall, the course is designed to meet the "Imperative First" CS1 general structure and requirements in the new ACM/IEEE Computing Curriculum 2001 [2]. The order of media covered in the course is arranged to correspond to an increasing level of complexity in data structures.

- A sound is an *array* of *samples*.
- A picture is a *matrix* (two-dimensional array) of *pixels*.
- A directory structure (of media files, to process many files with a single recipe) is a *tree* of files.
- A movie is an *array* of *matrices* (frames, as pictures).

The media thus serve as a way of visualizing and making concrete (and interesting, we believe) the programs that the students are writing. Once the students are writing programs of increasing complexity, we introduce the ideas of algorithm complexity, object-oriented programming, and recursion as techniques for managing that complexity.

The syllabus for the course walks through each media type, with some repetition of concepts so that conditionals and loops can be re-visited in different contexts. Here's a rough description of the syllabus.

- Week 1: Introduction to the course and the argument for why media computation. Introduction to variables and functions, in the context of playing sounds and showing pictures.
- Weeks 2–3: Pictures as a media type, including psychophysics (why don't we see 1024x768 dots on the screen?), looping to change colors with a simplified **for** loop (Figure 1), conditionals to replace specific colors, then indexing by index numbers to implement mirroring, rotating, cropping, and scaling.
- Weeks 4–6: Sound as a media type, including psychophysics (how human hearing limitations make MP3 compression possible), looping to manipulate volume (Figure 2), then indexing by index numbers to do splicing and reversing of sounds (Figure 3). Include discussion of how to debug and how to design a program, as those issues arise. One lecture on additive and FM sound synthesis.
- Week 7: Text as a media type: Searching for text, composing text, reading text from a file and writing it to a file. An example program parses out the temperature from a downloaded weather page.
- Week 8: Manipulating directories. Manipulating networks, including making the temperature-finding program work from the "live" Web page. Introduction to HTML.
- Week 9: Discuss media transitions. Moving from sound to text and back to sound again. Using Excel to manipulate media after converting it to text.
- Week 10: Introduction to databases: Storing media in databases, using databases in generating HTML.
- Week 11: Movies: How persistence of vision makes animations and movies possible, generating frames using the various techniques described earlier in the semester.

```
def greyScale(picture):
  for p in getPixels(picture):
    intensity = (getRed(p)+getGreen(p)+getBlue(p))/3
    setColor(p,makeColor(intensity,intensity,intensity))
```

Figure 1: An example Jython program using our API to convert a picture to greyscale

```
def normalize(sound):
    largest = 0
    for s in getSamples(sound):
        largest = max(largest,getSample(s) )
    multiplier = 32767.0 / largest

    print "Largest sample value in original sound was",  largest
    print "Multiplier is", multiplier

    for s in getSamples(sound):
        louder =  multiplier * getSample(s)
        setSample(s,louder)
```

Figure 2: An example Jython program using our API to normalize sounds to a maximum volume

- Week 12: "Can't we do this any faster? Why is Photoshop faster than Python?" Introduction to how a computer works (e.g., machine languge), and the difference between an interpreter and a compiler. Algorithmic complexity and the limits of computation.
- Week 13: "Can we do this any easier?" Decomposing functions, modularity, and functional programming (map, reduce, filter, and simple recursion).
- Week 14: "Can't we do this any easier?" Introduction to objects and classes.
- Week 15: "What do other programming languages look like?" Brief overview of JavaScript and Squeak.

We developed the course in a collaborative process with a board of faculty advisors from across campus and a team of undergraduate and graduate students developing materials. We have been using both on-line and face-to-face forums to gather input on the course (`http://coweb.cc.gatech.edu/mediaComp-plan`). Both student and faculty feedback has been very positive.

3. TECHNOLOGICAL SUPPORT FOR THE COURSE

The language for the course is Python (`http://www.python.org`). Python is a popular programming language used today by companies including Google and Industrial Light & Magic. It's most often used for Web (e.g., CGI script) programming and for media manipulation. Python was specifically developed to be easy-to-use, especially for non-traditional programmers.

The specific version of Python that we are using is Jython (`http://www.jython.org`). Jython is an implementation of Python in the popular programming language Java. Anything that one can do in Java (e.g., servlets, database programming via JDBC, GUI programming via Swing) can be done in Jython. Jython *is* Python—learning one is the same as learning the other.

We chose Jython in order to enable cross-platform multimedia manipulation. We have written a set of Java classes that encapsulate the kind of multimedia functionality that our examples require, as well as a set of Jython classes that provide a simple and useful API to those functionalities. The API was designed based on existing literature on challenges that students find in learning to program, e.g., we allow set-based manipulation of samples and pixels before more complex and general iteration structures are learned [11][12].

Our API allows for access to the samples that make up sounds and the pixels that make up pictures.

- Figure 1 is an example program using our API that converts a picture object to greyscale. It computes the intensity of a given pixel by averaging the red, green, and blue components, and then replaces the color of that pixel with a gray pixel (red, green, and blue components the same) with the same intensity. Notice that the loop in this example is phrased as a set operation—essentially, "for every pixel p in the pixels of the given *picture*, do...." Some research on novice programming suggests that this is a simpler concept to begin with, as a way of easing into iteration [11].
- Figure 2 is a program that normalizes sounds to a maximum volume, by searching for the largest sample, computing a multiplier so that that sample would reach the maximum amplitude, and then multiplies all samples in the sound to raise the amplitude of the overall sound. We continue to use the simpler form of iteration here, but using multiple loops—an increase in complexity.
- Figure 3 takes a filename, then returns the sound in that file in reverse. Here, we use a more conventional `for` loop, with explicit indices in order to copy the array elements correctly.

We have also created a set of tools to support the students' tasks in this course. Our first and immediate need

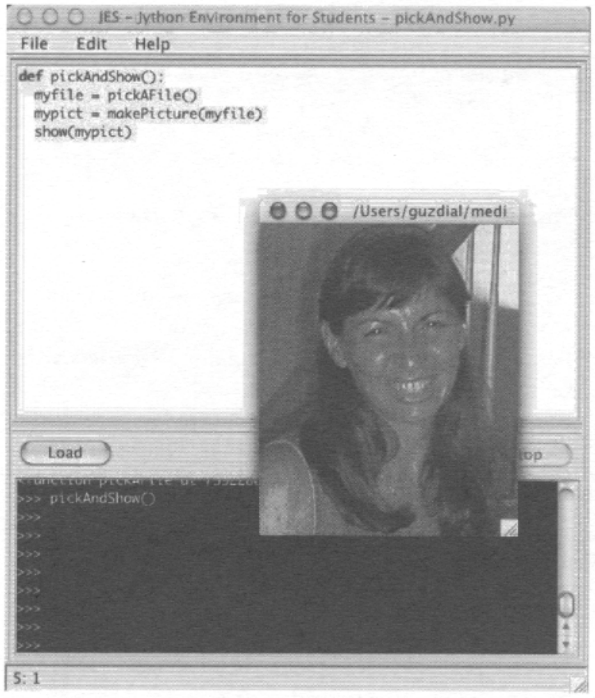
```
def backwards(filename):
  source = makeSound(filename)
  target = makeSound(filename)

  sourceIndex = getLength(source)
  for targetIndex in range(1,getLength(target)+1):
    sourceValue = getSampleValueAt(source,sourceIndex)
    setSampleValueAt(target,targetIndex,sourceValue)
    sourceIndex = sourceIndex - 1

  return target
```

Figure 3: Return the sound in the file backwards

was for some kind of development environment. Jython is a new language [15], so most developers simply use plain text editors, or make do with Python or Java development environments. We believe that non-CS major freshmen require more support. A team of undergraduate senior design students created our tool for students, *JES (Jython Environment for Students)* as a simple editor and program execution IDE (Figure 4). JES runs identically on Windows, Macintosh OS X, and Linux systems.



```
def pickAndShow():
  myfile = pickAFile()
  mypict = makePicture(myfile)
  show(mypict)
```

```
>>> pickAndShow()
>>>
>>>
>>>
>>>
>>>
>>>
>>>
>>>
```

Figure 4: JES: Jython Environment for Students, with a graphics example running

We also realized that our students would need to visualize and explore media and to prepare media for use in their programs. For example, students want to look at sounds using a variety of visualizations, record their own sounds, investigate the RGB values in pictures of their choosing, and burst MPEG movies into folders of JPEG frames for ease in manipulation. By using their own media, we make the student programming assignments into a creative activity, and thus, make it more attractive to women and others dissuaded by the stereotype of computer science as non-creative [9][16]. Another team of undergraduate students have modified the media tools in Squeak [4][6] to create cross-platform media exploration and manipulation tools (Figure 5).

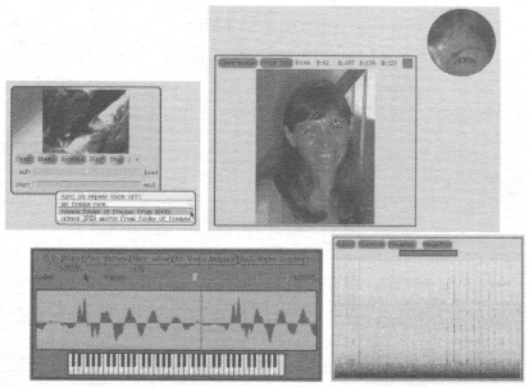


Figure 5: MediaTools: Movie tools (ul), image tools (ur), sound editing (ll), and sound views such as a sonogram (lr)

We used our CoWeb collaboration tool to support a collaborative experience for students in the Media Computation course. The CoWeb has been used successfully in a variety of classes, including computer science. By encouraging students to share their creative artifacts via the CoWeb, we further erode the perspective of computer science as a loner, non-creative activity. Further, we used the CoWeb to support student help-seeking, e.g. asking questions about the multimedia assignments. Such support may be critical to the success of the project. A factor analysis considering a range of variables influencing CS1 success, with completion as an outcome variable, suggests that comfort asking questions is the most critical factor for succeeding in CS1 [18]. Findings suggest that Web-based collaboration tools encourage much greater participation and comfort than in-class questions [7][8].

4. ASSESSMENT RESULTS SO-FAR

Our retention results have been quite positive. 120 students enrolled for the course, 2/3 female. Only two students withdrew from the course.

We have been using initial, midterm, and final surveys to get impressions from across the course. We have used the same surveys at the same time with a section of our traditional CS1. On the midterm survey, 97% of the students in the Media Computation course agreed with the statement "Are you learning to program?" compared with 88% in our traditional CS1 course. When asked what students like about the class, the students affirm that we're succeeding at creating a course that students recognize its applicability, even among non-CS majors: (All of the quotes below are from female students.)

- "I like the feeling when I finally get something to work."
- "Very applicable to everyday life."
- "I dreaded CS, but ALL of the topics thus far have been applicable to my future career (& personal) plans– there isn't anything I don't like about this class!!!"
- "When I finally get a program to work like I want it to."
- "The professor answers questions in class and online and is concerned about our success in the class. He also seems to understand that most of us are not engineers and most likely won't do straight programming in the future- just the way of thinking is important."
- "Collaboration! If I can't figure it out, I can ask for help."

When we ask students "What is something interesting, surprising, or useful that you learned?" we found that students were buying into the relevance of the course and even finding the computer science interesting (again, all female respondents):

- "The most useful things I have learned are the basics about computers and pictures/sound. I think when we learn HTML–that will be interesting and useful to real life applications."
- "Just general concepts about programming. It's pretty logical, sort of like in math, so it's understandable."
- "Programming is fun and ANYONE can do it!"

5. SUMMARY AND FUTURE DIRECTIONS

We believe that programming and computation will become part of a general, liberal education, but computing courses will have to change to make this happen. We are exploring a media computation approach that we feel will appeal to a liberal arts major, while still retaining a focus on programming. Our assessment explores how well these students learn, but also how motivated they are. A key question for us is whether these students will have a continuing interest in learning about computation, a critical goal of any introductory course.

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