Pepperdine Computer Science Courses on iTunes U

2013 Innovation in Technology and Learning Grant Case Study

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Introduction

This is a case study from the 2013 Innovation in Technology and Learning Grant established by the offices of the Provost and the Chief Information Officer, and administered through the Technology and Learning department. The case study consists of two parts — Project Description and FCPX Specifications.

The following section describes the work done before receipt of the grant. The next section describes the scope of this grant and the work done under its funding. The last section gives reflections on lessons learned and makes a few recommendations for those with an interest in pursuing similar projects.

The second part of this report titled FCPX Specifications is an appendix that documents how we used the features of Final Cut Pro X (FCPX) software to produce the lecture videos. It is intended for those who wish to use the same development environment for lecture capture to integrate lecture slides and computer demonstrations into the final movie.

Background

The following table shows the computer science courses the author had recorded and posted on iTunes University before the awarding of the grant. Each lecture is 50 minutes with a total of 170 lectures.

Course	Recorded	Lectures
Math 220, Formal Methods	Fall 2010	40
Math 221, Discrete Structures	Spring 2011	40
CoSc 320, Data Structures	Fall 2011	52
CoSc 330, Computer Systems	Spring 2012	38

Apple provides two types of content delivery, Collections and Courses. Students view and download iTunes U Collections from the iTunes Store in the iTunes app on a Mac or Windows computer. They can also access them via the iTunes Store app in iOS.

During the first year of lecture recording, Collections were the only option available on iTunes U. Collections are good for one-time events but have limitations for packaging the ancillary materials for a course, such as syllabi, slides and assignment notices.

After the first year of recording, Apple provided Courses to overcome the limitations of Collections. The best features of iTunes U Courses are accessible only to iOS mobile devices that have the free iTunes U app installed. The interface is designed for convenient navigation between lectures, slides, and other course materials. Students with Windows computers can view all the content of Courses with a Web browser interface, but the navigation is not so seamless. The lectures provided with Collections were converted to Courses, and all the above courses are now in the Courses format.

To post a lecture on iTunes U is a three step process.

- Record the lecture.
  Computer science lectures typically incorporate slides and computer demonstrations. We learned quickly that it is not feasible for the camera operator to focus on the projection screen in front

of the classroom to capture the content of the slides and demos. The image quality is simply too poor. Consequently, capturing a computer demo is accomplished with video capture software on the instructor's laptop.

- Compose the lecture.
  After each lecture, the video recording is downloaded to a computer and imported into a video editing program. All the slides from the lecture and any demo footage are also imported into the program. The editing software composes all the elements into a 50-minute movie that can be uploaded to iTunes U.

- Post the materials.
  iTunes U Course Manager is a web-based tool for instructors who want to post materials to an Apple Courses course. When you setup a course you must choose whether your course will be self-paced or in-session. All courses for this project are self-paced. In addition to the lecture, you can post PDF versions of lecture slides, assignments, links to web pages, and papers.

The most crucial decision we had to make was the choice of the video editing software. After some experimentation, we decided on Final Cut Express as the program to edit the lectures. The other options we considered were iMovie and Final Cut Pro 7. iMovie comes free with the Apple operating system but was too limited in its feature set. Final Cut Pro 7 was too expensive at $1,000. We settled on Final Cut Express, the consumer version of Final Cut Pro 7, with a price of $200.

Funding for the above project was provided by the Natural Science Division and the office of the Provost. Fixed costs included the video camera and two 2-TB USB external drives. One external drive can store all the raw footage and the composed video for all four courses. The second drive is used as backup housed at a separate location from the first.

Recurring costs are student salaries for video recording the lectures and composing the lectures with the editor software. For recording, we draw from our own students in the major who have previously taken the course being recorded. Depending on the complexity of the lecture, *i.e.* the number of slides and demos, it takes between one and two hours to compose a single 50-minute lecture.
work, some courses were composed by student workers and some were composed by the instructor. The instructor did the organization and posting to the iTunes U site.

Scope of this grant

With the recent release of Final Cut Pro X (FCPX), Apple has consolidated their video editing product line. They still offer the free iMovie application for consumers but have dropped the mid-range Final Cut Express altogether. In conjunction with the consolidation they reduced the price of Final Cut Pro from $1,000 to $300. While this price is more than the previous price of $200 for Final Cut Express, it seems reasonable given that FCPX is a full professional product.

Unfortunately, lectures for the four courses produced by the prior work were all rendered with the now-discontinued Final Cut Express. Going forward, it is necessary to render all the new course lectures with FCPX. For maintenance purposes, if any of the previous lectures need to be changed they should be re-rendered with FCPX.

This grant has two objectives — to re-render the previously recorded lectures in FCPX and to record two new computer science courses. The table below shows the work accomplished under the grant. Two

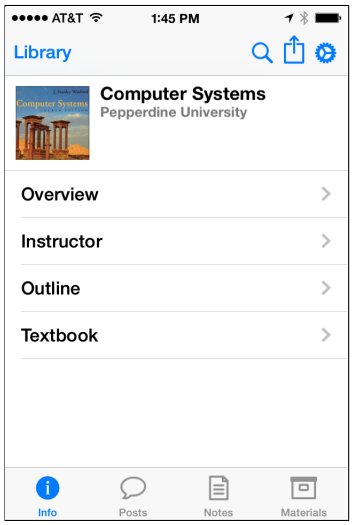
new courses were recorded over the 2013–14 academic year with a total of 82 lectures. One legacy course was re-rendered with FCPX with a total of 40 lectures. At the termination of the grant, we had not yet composed all the lectures for the two new courses for iTunes U. However, we are on track to complete the composition and post CoSc 450 in time for student use this Fall 2014 and likewise for CoSc 425 by Spring 2015.

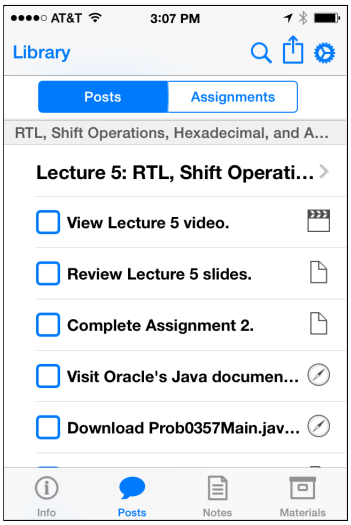
Course	Date	Action	Lectures
Math 220, Formal Methods	Fall 2010	Re-rendered	40
CoSc 450, Programming Paradigms	Fall 2013	Recorded	51
CoSc 425, Computer Organization	Spring 2014	Recorded	31

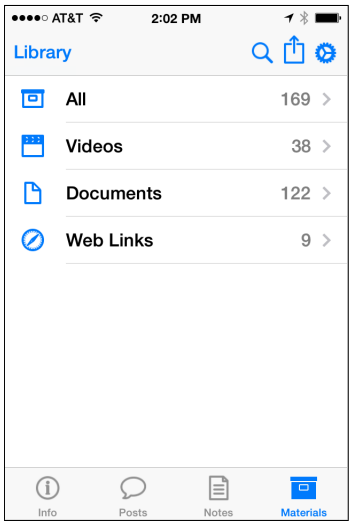
In addition to student salaries, funding for the grant was used to purchase the FCPX software and a 6-TB RAID hard drive system with Thunderbolt 2 connectivity (PROMISE Pegasus2 R4).
item will prove especially valuable going forward, as it allows us to consolidate raw footage and rendered files for all six courses onto one drive. It is also proving to be a time saver during the composition and rendering process because of its high speed.

The iTunes U experience

The screenshots in this section are from an iPhone. iTunes U content on an iPad is similar but more accessible because of the iPad's larger screen size. The iTunes U app provides four interface screens — Info, Posts, Notes, and Materials. The screenshots below show the Info, Posts, and Materials screens for the Computer Systems course. The Notes screen (not shown) allows students to take notes on the course, the video lectures, and the book.





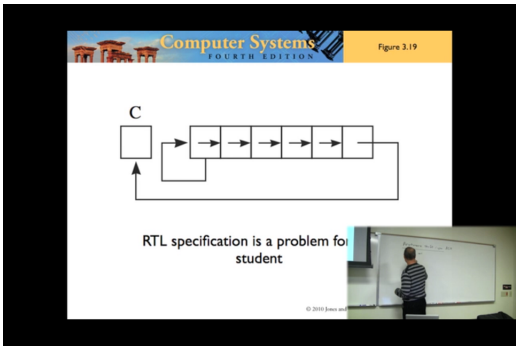


Organization of each Pepperdine computer science course is modeled after the popular Stanford iOS development course on iTunes U. As seen in the middle screen shot above, each post is organized around

a video lecture, and provides ancillary material for that lecture such as lecture slides, homework assignments, Web links, and downloads. The Materials screen (above right) consolidates access to all the course materials on one screen.

The following screenshots are from a Computer Systems lecture. Parts of the presentation (below left) show the instructor explaining concepts at the white board. Students are not asked to work at the board and so need not fear being recorded. The audio of classroom discussion is captured, which gives the offline viewer a sense of the classroom experience.

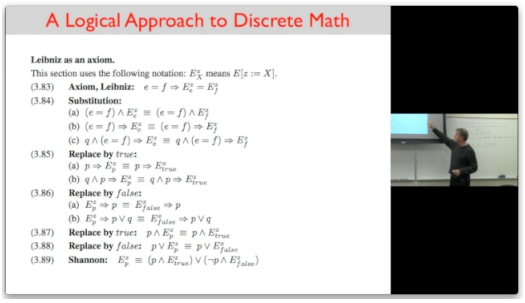


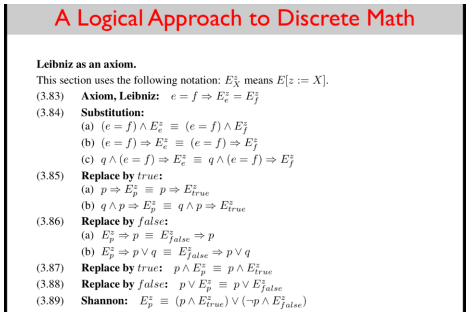


When the instructor refers to a slide on the projection screen, the camera person continues to focus on the instructor. During the composition of the final movie the slide is integrated into the scene using picture-in-picture (PiP). The screenshot (above right) shows the instructor in the embedded video in the foreground with a higher quality image of the slide in the background.

This figure shows an unfortunate characteristic of our previous work. Namely, the foreground picture of the lecture obscures part of the slide. The overlap is not consequential when the overlapped portion of the slide does not obscure any content. Frequently, however, it does so as shown in the above figure.

The following screen shot (below left) is from the course we re-rendered as part of this grant and shows how we corrected the problem. The PiP is now designed so that the slide is flush left in the view rectangle and the lecture PiP is flush right with no overlap. The appendix of this report, FCPX Specifications, documents this process for incorporating this PiP design in a lecture capture movie.





Even with the higher quality image of the slide in the movie, the ultimate resolution of the slide is limited by the resolution of the movie. iTunes U also permits viewing of PDF images with a resolution limited only by the native resolution of the viewing device. The above right image shows the slide viewed as a PDF image and is higher quality than the same slide rendered in the movie. The post for each lecture includes all the slides in PDF format for that lecture.

Another improvement in the lecture capture process under this grant is an improved intro clip. The following image on the left is the intro clip used in all the previously recorded and rendered lecture videos. It has a simple fade in of the text with no sound. The new intro clip on the right provided by the University is a moving panorama of the campus with a pleasant sound track and a fade in of the text. All re-rendered and newly composed lectures use the new and improved intro.





Reflections

What follows are some personal observations, reflections, and lessons learned from this project.

- Lecture quality
  I continue to be amazed at how much a course can be improved when I know that it will be recorded. I have been teaching some of these courses for decades and always prided myself that I improved the course each time I taught it.

  However, knowing that a lecture can be viewed at will by anyone on the Internet is a quantum jump in motivation. Before each lecture, I found myself analyzing my delivery as I had not done before. One big improvement was the increased quality in my slide presentations. For another example, I would research a little history on the topic and weave in an interesting tidbit. Although quality is largely subjective, I believe the quality of all the courses I capture for iTunes U is substantially improved over what it had been before.

- Going paperless
  Posting a course on iTunes U requires *all* materials to be available electronically. As the universal document standard is PDF, which is supported well in iTunes U and on mobile devices, all course documents were converted to that standard. All lecture slides are posted in PDF format. All papers from the literature are provided with a link to the PDF. I no longer provide any paper to my students except for the paper exams. Even the syllabus is delivered electronically.

  Going paperless is environmentally friendly. But beyond that, it is beneficial to students and instructors. Because all documents are online they are always available to any student anywhere anytime on their mobile devices or personal computers. All papers are now graded with PDF markup and returned electronically.

- Student benefit
  Students benefit in several ways that were not anticipated. One of the original motivations for lecture capture was to help a student athlete who had a practice schedule that conflicted with the

course schedule. Since then, several student athletes have taken advantage of the online lectures to resolve schedule conflicts. This coming Fall semester a basketball player will use the online course recorded under this grant for just that purpose.

Recently, a growing number of regular students use the online lectures to resolve course scheduling conflicts. On an individual basis, we will approve a student to enroll in a computer science course and permit the student to be absent from the lecture on the days that the conflicting class meets.

International Programs students benefit from the online lectures the same way. Some computer science students have been able to study overseas who would not otherwise have been able to do so without the online lectures. Those students follow the same schedule as the Malibu students, hand in their homework assignments electronically, and take advantage of office hours via Skype. IP has been cooperative in supplying a proctor for the exams, which are scanned and returned to me for grading.

One unanticipated benefit is for the in-class students. A common apprehension is that classroom attendance will suffer if the lecture is available outside the classroom. My experience is to the contrary. Not only does attendance not suffer, students who attend the lectures in person find value in the online lectures as well. Students review the lectures, sometimes before the in-class lecture and sometimes after. Students comment that they like the ability to pause and repeat segments of the presentation that are highly technical.

Another unanticipated benefit for the in-class students comes from the availability of the online lecture slides. Some students access the slides during the lecture and take notes on them electronically as they participate in the lecture.

- External recognition

  Because an iTunes U course can be viewed by anyone outside the Pepperdine community, it serves as a model of the academic program and its curriculum. A well-crafted course will, therefore, enhance the reputation of the program and the institution. Some prominent institutions with this philosophy are Stanford, Harvard, and MIT.

  I am occasionally contacted by viewers of my courses, thanking me for the content and complementing me on the computer science program. One talented individual even worked through the Math 220 and Math 221 courses on iTunes U and contacted me about his progress.
  he has contributed to an on-going research project, the Equational Deductive System for Linear Temporal Logic originally funded at Pepperdine by a Tooma grant. I never anticipated such a development before embarking on this project.

- Course selection

  The payoff for providing some courses on iTunes U is greater than that for others. As a considerable amount of effort must be expended to capture the lectures in a course, a higher benefit will accrue to a course whose content will change little from year to year.

  Of the previously-recorded courses, Math 220, Math 221, and CoSc 330 have remained the most stable. The content of CoSc 320 has varied the most and is now somewhat out of date. The materials for the courses CoSc 425 and CoSc 450 recorded under this grant were revised extensively in preparation for the recording. It is anticipated that they will be stable for quite some time.

- Recommendation

  Because I believe so fervently in the benefits that technology can have on education, and because my area of expertise is highly technical, I expended the time and effort to provide these courses on iTunes U. The project described in this Case Study, however, is not a model of how Pepperdine should accomplish course capture in the future.

  It is not reasonable to expect an instructor to have the technical expertise to record every lecture of a course, expend two hours of additional time per lecture to render the lecture into a movie, and then to organize and post all the materials on iTunes U Courses. However, given the right incentive for the instructor we could have more courses offered on iTunes U as described in this Case Study.

  Even though the process is labor-intensive, most of the labor can be done by talented students. With the right training, each 50-minute course lecture would require four hours of student time — one hour to record, two hours to render, and one hour for setup, teardown, and downloading from camera to computer. A three-hour course typically has 40 lectures to be recoded, which totals 160 student hours per course. A typical work week for the student would be 12 hours to capture the lectures of a three-unit course. Incentive for the instructor could be a small grant or release time for the effort to organize the course and post the materials on iTunes U Courses.

  Fixed costs are not that great. The FCPX software is $300, the high-capacity RAID system for storing the six courses described in this Case Study is $1,500, and a suitable camcorder can be had for less than $1,000. The biggest fixed expense would be a Mac with Thunderbolt 2 connectivity. The cost of all these items could be amortized over many courses.

  My recommendation is to implement a standing program for lecture capture providing the above support for the instructor. The program could start small, experimenting with one or only a few courses in the beginning, gradually building up in-house expertise, and expanding the program as experience dictates.

The work described in this project is on-going. In the future, we plan to finish composing and posting the two new courses whose recorded was funded by this grant. Data Structures will have changed substantially by then, so it would be good to re-record that course. On the hardware side, we would like to acquire a second RAID system for backing up the projects in a physically different location from our primary drive.

We gratefully acknowledge the previous support of the Natural Science Division and the Provost's office, and the support of Information Technology for the grant that made possible the continuation of this project. Kevin Miller, Librarian for Digital Curation and Publication, provided valuable support in setting up the iTunes system.

Introduction

This appendix is intended for those who are interested in posting course lectures on iTunes University as described in the Project Description part of the report. Posting a course on iTunes U is a three step process — recording the lecture, composing the lecture with a video editing program, and posting the materials. Recording the lecture is straightforward. Posting materials to iTunes U is a little more involved, but there is much good documentation for how to organize, prepare, and upload course materials.

The most difficult part of lecture capture is learning how to use Final Cut Pro X (FCPX) to edit and render the lecture. This document shows how to incorporate presentation slides and computer demonstrations into the raw video to produce a movie that can be uploaded to iTunes U. The problem is not that the process is difficult to perform. The problem is that FCPX is a large program with many features, voluminous documentation, and many Web tutorials on how to use all those features. We had to wade through a lot of irrelevant material to learn how to perform the few tasks necessary for composing a lecture video. This appendix is a how-to manual on the process.

Video recording the lecture

A student worker was hired to video record the lectures. The camera was a Canon VIXIA HF21 Dual Flash Memory Camcorder. The file format for the camera output was 1080i HD, 1920×1080 pixels, which matches the standard $16 : 9 = 1.777$ aspect ratio for posting video on the Internet.

For audio, we used a Sennheiser G3 Evolution wireless microphone ENG Camera/Lavalier set, G band (566–608MHz). It is important not to rely on the builtin mic of the camera because of its poor quality.

While recording a lecture, the camera should always focus on the instructor and should zoom in on whatever the instructor writes on the board. The camera should never focus on the screen. Instead, slide images of higher quality are incorporated into the video composition with a picture-in-picture (PiP) of the instructor discussing the content of the slide.

iTunes University

To create a course on iTunes U you upload materials using a web browser at Apple's course manager site.

https://itunesu.itunes.apple.com/coursemanager/

It only requires a personal Apple ID, which is free. To publish the course on iTunes U requires coordination with Pepperdine's Librarian for Digital Curation and Publication, who is Pepperdine's liaison to Apple.

The most important hard limit that you must observe is a file upload size of 1 gigabyte (GB). The following guidelines will produce lecture videos with a file size of about 850MB, or 85% of the maximum allowed file size, for every 60 minutes of content.

Software/Hardware system

When the original recordings were made, three software options were available from Apple — iMovie designed for home use, Final Cut Express for more features but less than professional quality, and Final

Cut Pro 7 for professional use. We started with iMovie, but soon abandoned it for Final Cut Express for its feature set.

The bad news is that in the intervening years Apple has abandoned both Final Cut Express and Final Cut Pro 7 and replaced them with one professional product, Final Cut Pro X (FCPX). Furthermore, the new FCPX file format is incompatible with Final Cut express. The good news is that the price is $300 from the Apple app store, which is a significant price reduction from the previous full professional product price of $1,000. We are currently recomposing the lectures into FCPX and recommend it for composing lecture videos. Consult the FCPX documentation for the hardware requirements of FCPX.

For storage, we use the PROMISE Pegasus2 R4a 6-TB RAID hard drive system with Thunderbolt 2 connectivity. It can be configured at several different RAID levels. It comes with a default configuration of RAID level 5, which is a good configuration for both reliability and speed for this project.

Final video resolution and format

There are three common aspect ratios for video. They are, in order of increasing width, $4:3 = 1.333$ for many YouTube videos, $16:9 = 1.777$ for wider screens appropriate for mobile devices, and 1.85 for commercial movies.

For lecture presentations, it is desirable to have the presentation slide at full size and the video in a small rectangle (PIP) adjacent to and not overlapping it. Hence, we rejected $4:3$. We briefly considered 1.85, but no mobile device screens or computer monitors are this wide, so we would lose vertical resolution and the content would display with black horizontal bars above and below the screen image. Therefore, we recommend $16:9$.

The complete compositing specifications are as follows. For the audio encoder:

- Sample rate: 44.100kHz
- Channels: 1 (mono)
- Bits per sample: 16
- AAC encoder quality: high
- Data rate: 128 Kbps

For the video encoder:

- File format: MPEG-4
- File extension: `mp4`
- Image size: 640×360
- Codec type: H.264
- Video compression: H.264 baseline profile
- Frame rate: 30 fps
- Key frame interval: 30

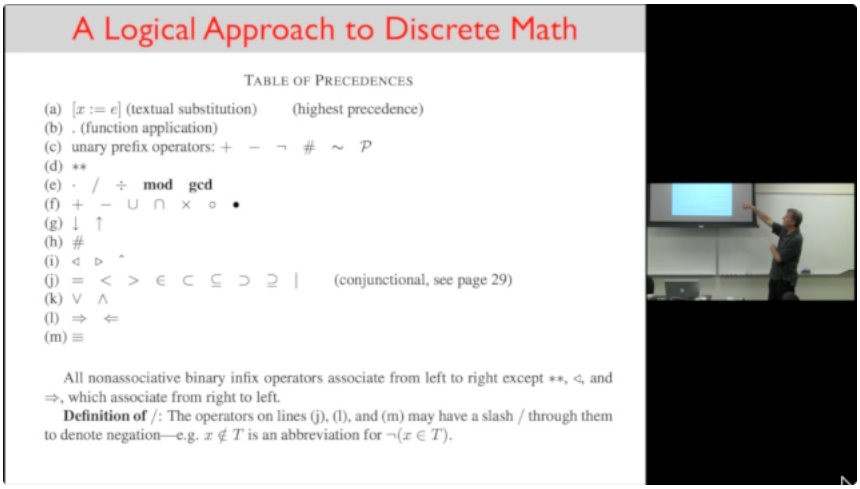
- Bit rate: 1,696 Kbps

To make these settings in FCPX requires yet another program, Compressor, which costs $50. You use Compressor to create encoder settings that FCPX uses. As you will not need Compressor for any other purpose than to create the setting one time, you can get a trial version of Compressor and use it only for that purpose. Alternatively, I have made the settings file available here for download.

`http://www.cslab.pepperdine.edu/warford/640x360-MPEG-4.setting`

Lecture slide resolution and format

Instructors typically have lecture slides in either PowerPoint or Keynote format. The most common aspect ratio for both applications is $4:3 = 1.333$, which is narrower than the video ratio of $16:9 = 1.777$. So, when a slide displays in the video there will always be vertical black bars beside the slide image. With no PiP, the slide is in the center with black bars on both sides. With PiP on the left, the slide is on the right with one black bar on the left containing the PiP. With PiP on the right, the slide is on the left with a black bar on the right.



To get your slides into FCPX you must export them from PowerPoint or Keynote into the proper format. FCPX handles TIFF, which is a lossless compression format, better than it handles JPEG, so TIFF is the format you need. Not all applications export to TIFF and some that do, do not allow you to set the resolution. The best for us was a two-step process — first convert to pdf and then to TIFF.

Guidelines for exporting to pdf are:

- Export slides, not Slides With Notes
- Do not check any Options. For example, do not Add borders around slides.
- Select Best image quality

Guidelines for exporting to TIFF are:

- Open the PDF file in Apple's Preview application.

- Export the images to TIFF (menu File → Export...)
- Select a resolution of 72 pixels / inch.
- Check Get Info on the resulting TIFF file to verify that the resulting image is 800×600.

The reason for exporting at 72ppi is that the final video is rendered at 72ppi. It must therefore compress the TIFF image when it composes the video. We experimented with higher resolutions including 150ppi, which is Preview's default export setting. The resulting files are extremely large and waste disk space with no improvement in quality. The only time you would need an export setting greater than 72ppi is if you want to zoom in on your TIFF image within FCPX. In such a case you would export at 144ppi, which will quadruple your file size. As you will most likely display your slides full size without zooming, you should export them at 72ppi.

When you export a file with multiple PDF documents to TIFF, the resulting file will contain multiple TIFF images. We use the utility software TIFF Splitter from Winsome Technologies to split the single file into individual files with one file per image before importing into FCPX.

FCPX project organization

The latest version of FCPX uses a new flexible library system to manage the content for composing a movie. There are three parts to the system — libraries, events, and projects. Here is our recommended organization for lecture capture.

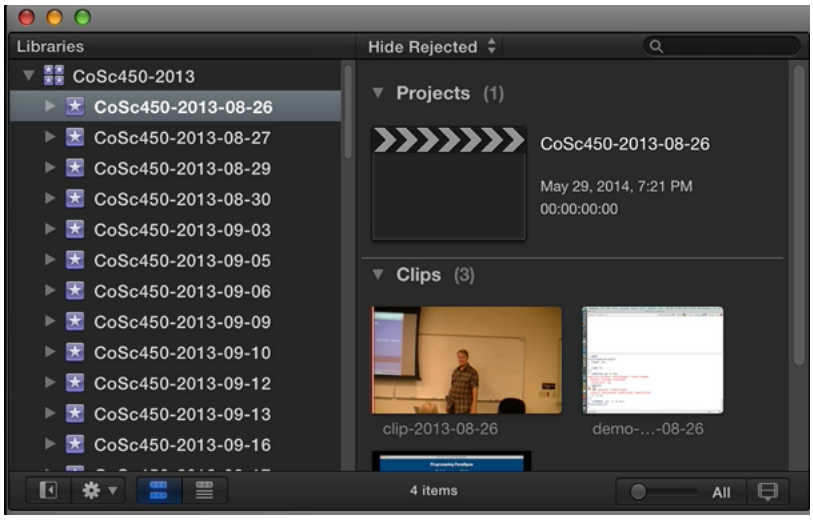
- Libraries
  We recommend one library for one entire course. Our naming convention is to uniquely identify the course in the name of the library. For example, the course CoSc 450 that was recorded in 2013 has a library name of `CoSc450-2013`.

- Events
  Libraries contain events. We recommend storing three kinds of events in the library.

  - lectures
    There should be one event for each lecture. Our naming convention is to uniquely identify the lecture in the name of the event. For example, the course that was recorded on August 26, 2013 has an event name of `CoSc450-2013-08-26`. Each lecture event should contain (a) the raw footage for that lecture, (b) a project for the final movie, and if used (c) the screen-captured demo used in that lecture. We uniquely identify the name of the raw footage by date. For example, the raw footage recorded on August 26, 2013 is named `clip-2013-08-26`.
  - slides
    This event consolidates the TIFF slide images imported into FCPX. If there is a large number of slides for the course, you can organize them into several events.
  - intro-outro
    This event contains the intro and outro clips provided by Pepperdine for the beginning and ending scenes of the final movie.

- Projects
  In FCPX there is one project per final movie. For lecture capture, there will usually be one movie per lecture. So, we create one project in each one of the lecture events. The name of the project is the same name of the event that contains it.

Following is a screenshot of FCPX showing the organization described above.



FCPX composition techniques

We have produced two video tutorials showing the FCPX techniques we used for lecture capture as described in this report.

http://www.cslab.pepperdine.edu/warford/lecture-capture-1.mp4
http://www.cslab.pepperdine.edu/warford/lecture-capture-2.mp4

The tutorials show how to set up a new project, how to place the intro clip, how to color-correct that ugly orange hue in the above image (an occasional error that happens when the recording camera has a bad setting), how to incorporate a PiP slide image, how to incorporate a computer demo, and how to insert fade-in/fade-out transitions between scenes.