REALSIMPLE Project at CCRMA
Progress Reports

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Abstract

This document contains the technical progress reports for the REALSIMPLE project at CCRMA, in reverse chronological order by quarter. It also contains pointers to all online materials posted to date.

1 Final Progress Report, Fall Quarter, 2007-2008

1.1 Julius Smith

Julius did the following:

- Wrote an introductory tutorial[1] on developing virtual musical instruments and effects using the Faust language and Pure Data program environment, among others.
- Wrote materials[2] for advanced laboratory assignments on developing virtual electric guitars and associated effects in the Faust language. This material will be extended and ported into specific laboratory assignments during winter quarter (for Music 420).
- Worked with Nick Porcaro on porting virtual electric guitars from SynthBuilder to the Synthesis Tool Kit (STK).
- Ported laboratory subprojects to the Connexions project at Rice University. The automatic translation tools are working very well, and only a handful of bugs are awaiting attention from the Connexions technical staff. The required ZIP file for uploading a RealSimple project to Connexions can be created in any subproject by changing to its directory and typing "make tralics". (Tralics is the LaTeX to XML converter used by Connexions.) A significant added

*Work supported by the Wallenberg Global Learning Network

[1] `http://ccrma.stanford.edu/realsimple/faust/`

[2] `http://ccrma.stanford.edu/realsimple/faust_strings/`

value associated with the port to Connexions is that for the first time all mathematics will be rendered online as MathML (Math Markup Language). This means math can be copy/pasted into other applications such as Mathematica like normal text. (In contrast, online math on the CCRMA website is handled using bit-map images and ALT text containing the original LaTeX expression.)

- Developed example usage of the transfer function measurement toolbox developed for the project last year.
- Submitted an eight-page paper on selected results from the quarter to the Linux Audio Conference (and it has been accepted). This paper is largely a condensation of [1].[3]

1.2 Nick Porcaro

Nick is a professional software engineer hired part time to port valuable SynthBuilder packages to the Synthesis Tool Kit (STK) (C++) used by the project. Porting efforts this quarter were focused on patches pertaining to virtual electric guitars and supporting software.

1.3 Nelson Lee

Created an online reader that steps students through the theory behind the advanced virtual stringed instrument labs. The reader is comprehensive, in that references to papers, other online resources as well as the RealSimple labs are linked to give a coherent story of the technology. The intent of such a reader is to offer students a complete, yet condensed presentation of the methods and theory used in physically modeling stringed instruments, so that together with the advanced labs, students develop a solid theoretical and application-oriented foundation of the field.

2 Progress Report, Summer Quarter, 2006-2007

There was no funded activity on this project during the summer quarter.

3 Progress Report, Spring Quarter, 2006-2007

3.1 Edgar Berdahl

Edgar did the following:

- Created the virtual flute lab.
- Created the transfer function measurement toolbox.
- Documented the transfer function measurement toolbox with real example measurements.
- Attended a Wallenberg teleconference with Sweden
- Made slides for the ASA presentations

[3] http://ccrma.stanford.edu/realsimple/faust_strings/

1. Combining physical REALity with SIMulations in Pedagogical Laboratory Experiments
2. Collocated proportional-integral-derivative (PID) control of acoustic musical instruments
3. Estimating the state of a one-dimensional waveguide

- Traveled to ASA, spread the word about RealSimPLE, and gave the three presentations
- Took pictures of Uwe Hanson's musical acoustics demos (see realsimple/doc/images/ASA_SaltLakeCity)
- Aided in final polishing process by adding dictionary entries, proofing/editing labs, and making a wish list
- Reformatted the tree of lab dependencies from the ASA presentations so that it would fit well on the front web page.
- Used the map HTML tag to link the nodes of a DAG of lab dependencies to the appropriate labs

3.2 Nelson Lee

The following were accomplished:

- Testing at Lynbrook High School was carried out. A demonstration using the monochord and RealSimple electric guitar was used. Data was collected to determine the efficacy of the labs in an actual high-school environment.
- A focus group was created to discuss strengths and weaknesses of RealSimple's current approaches and content.
- A Lab for excitation extraction from recorded tones was created. The lab became the final lab in Music 421.
- A tutorial on excitation extraction was created (ICMC07)
- A tutorial on the acoustics of the gypsy guitar was created (ISMA07)

4 Progress Report, Winter Quarter, 2006-2007

4.1 Ryan Cassidy

Ryan worked on the following:

- Created a lab experiment on auditory filter banks, with a study of various auditory spectrograms generated by different human vowel sounds.
- Wrote a lab experiment covering various paradoxes and illusions in psychoacoustics.
- Created a lab experiment teaching human vocal tract acoustics, including an experiment using a computer-driven vocal tract model.
- Submitted an extended summary of work on efficient time-varying loudness modeling for (hopeful) publication at an electrical engineering conference.

- Gave a CCRMA DSP Seminar presentation on optimized loudness modeling for musical psychacoustics.

4.2 Edgar Berdahl

Edgar worked on the following:

- Edgar wrote MATLAB scripts for generating Internet-ready traveling wave animations. Centered around these animations, Edgar created a traveling waves laboratory assignment.[4] Edgar also created a vibrating string animation for the RealSimPLE main page.
- Providing a complement to the monochord laboratories, Edgar wrote an assignment on monochord simulation using a digital waveguide. Besides explaining the basic theoretical underpinnings, the digital waveguide model laboratory assignment[5] allows students to adjust the model's parameters in real-time while listening to the output.
- Edgar created a further laboratory assignment on the Proprtional-Integral-Derivative (PID) control of acoustic musical instruments. In the PID control laboratory assignment,[6] students learn the theory for a simplistic model and test the theory on a digital waveguide model.
- To help further disseminate RealSimPLE project output, Edgar wrote three submissions to the 153rd Meeting of the Acoustical Society of America, to be held in Salt Lake City, Utah. The submissions were accepted and are scheduled to be presented in three lectures covering 1) the philosophy of the RealSimPLE project and a report on project output, 2) PID control of acoustic musical instruments, and 3) state estimation of a vibrating string.
- On February 16th, Edgar held a Digital Signal Processing (DSP) Seminar at Stanford University on the state estimation of a vibrating string.
- Edgar also compiled code on the CCRMA network for using flext to embed STK instruments in `pd`externals. Please see the tutorial on embedding STK instruments in Pure Data externals.[7]

4.3 Nelson Lee

- Introduced Synthesis Toolkit (STK) for students to easily synthesize their own virtual instruments
  - A lab that introduces the concepts and paradigms in the programming platform STK.
  - A lab that introduces lattice ladder filters in the realm of digital reverb.
  - A lab that implements two landmark models of reverberation in the digital effects community. Gives students a solid understanding of the underlying physics behind reverb as well as how it is approximated in the digital/virtual world.

[4]http://ccrma.stanford.edu/realsimple/travelingwaves/
[5]http://ccrma.stanford.edu/realsimple/waveguideintro/
[6]http://ccrma.stanford.edu/realsimple/pidcontrol
[7]http://ccrma.stanford.edu/realsimple/stkforpd/

  - Lab that allows a student to implement time-varying effects. Teaches students the fundamentals behind such effects, namely the Doppler effect, and giving students opportunities for implementing their own Leslie speaker and flanger, both of which have had a significant impact on music in the last 50 years.
  - A lab that introduces the basic virtual/physical model of a guitar. Students get to implement their own electric guitar using the STK. Furthermore, the lab steps students through how overdrive and distortion/feedback occurs in both the physical and the virtual worlds.
  - Acoustic Guitar lab that expands on the Electric Guitar lab by introducing two planes of vibration for a string and a different excitation signal, a measured body response of an actual acoustic guitar.
  - A lab that implements a piano. The significant difference between this lab and the acoustic guitar lab is the introduction and application of dispersion.

- Lectures Supporting Theory Portions of New Labs Created
  - Lecture explaining Delay Line interpolation created to further accomodate time-varying effects lab.
  - Lecture discussing digital reverb created.
  - Delay line and Variable Delay Line Effects lectures created to explain theory behind reverb and time-varying effects labs.
  - Lectures discussing the Wave Equation and how it has been digitized to a delay-line-loop has been created.
  - Body Factoring lecture discussing impulse response decomposition and re-implementation created.
  - Commuted Synthesis lecture supporting acoustic guitar lab created.

- Introduced labs used to analyze data and design parameters for models using Matlab/Octave
  - Matlab was used to compute decay times and fitting filters for implementing such decays for implementing components in a virtual guitar and a virtual reverberator.
  - Spectral Analysis was also introduced and well explored in labs analyzing body-factoring and substitution in the acoustic guitar lab.

- Institutional Review Board (IRB) protocol approved for study in progress with partnering high school (Lynbrook High School, San Jose, CA)
  - Integration into curriculum already begun for high school Physics Honors.
  - Experiment with control group to occur beginning of April

5 Progress Report, Fall Quarter, 2006-2007

5.1 Ryan Cassidy and Edgar Berdahl

During the fall of 2006-2007, Ryan and Edgar worked on the following:

- Ryan spear-headed the installation and debugging of a Javascript form system for use in conjunction with the RealSimple monochord laboratory (with help from Alex Medearis, an undergraduate research assistant).

- Edgar created a laboratory for investigating the role of a harmonic's contribution to the sound of a plucked string. For instance, a recording of an electric guitar is made to sound more like that of a clarinet by approximately removing the even-numbered harmonics and attack transients.

- Ryan created a lab involving psychoacoustics and loudness, which steps students through the creation of a state-of-the-art loudness model using freely-available computer software.

- Edgar updated the first monochord laboratory in several ways. He increased the refresh rate of the spectrogram in the Pd patch. Edgar then added a description of the energy decay behavior of a lightly-damped harmonic oscillator. Edgar modified the Pd patch so that students could estimate the energy decay time of the string pluck that they measure in the lab. Finally, Edgar modified the graphics files so that they would not cause the PDF files to have large file sizes, yet they would still have appropriate resolution and visual appearance in the PDF file and on the website.

- Together, Edgar and Ryan created a new monochord-based lab, in which a known weight was used to provide tension on the chord. While Edgar was primarily responsible for building the new monochord prototype, Ryan handled the lab write-up and computer software for the lab in Pd, a freely-available computer music program. Both Edgar and Ryan were involved in testing the lab with the new prototype, and making appropriate modifications. This lab allows students to test hypotheses based on facts obtained from physical properties of the apparatus.

- Ryan presented two RealSimple works at the 152nd Meeting of the Acoustical Society of America, held in Nov. 2006 in Honolulu, HI. The presentations emphasized the pedagogic benefits of our RealSimple web site lab activities, as well as a state-of-the-art method developed by Nelson Lee for the modeling of acoustic guitar strings.

6 Progress Report, Summer Quarter, 2005-2006

During the summer of 2005-2006, the CCRMA RealSimple team consisted of

- Alex Medearis, engineering undergraduate going into his senior year (20 hours per week)
- Ryan Cassidy, advanced PhD/EE graduate student (10 hours per week)
- Julius Smith, Stanford co-PI (half a day per week, on average)

6.1 Alex Medearis

Alex's tasks were as follows:

- Build a monochord test bench following the KTH monochord assembly instructions,[8] developed previously during the REALSIMPLE planning grant.

[8] http://ccrma.stanford.edu/realsimple/mono_inst/

- Interface the monochord to a PC sound card.
- Test the sound card on a PC running Windows XP in JOS's CCRMA office, following the KTH soundcard set-up instructions,[9] also developed previously during the planning grant.
- Interface monochord and sound card with Pure Data (Pure Data (`pd`)[10]) software, following and extending the KTH soundcard set-up instructions.
- Help design lab experiments using the monochord and `pd` software on the PC.

Alex performed extremely well on all of his assigned tasks. He proved to be a motivated, efficient, and hard working engineering student, with excellent problem-solving talents. The monochord is working well and was used to create example waveforms and spectra in our newly developed monochord laboratory assignment.[11]

Availability of "Max Lab" at CCRMA was very good over the summer, so it has not yet been necessary to purchase the planned equipment for the small electronic and acoustics laboratory in JOS's office. However, the monochord and PC are now installed in JOS's office, making the nearest screwdriver two floors away. We therefore expect to acquire the planned equipment next year during the full grant.

Our experience building the monochord revealed that it required significant time and effort to construct, considerably more than we feel can be reasonably expected of busy high-school physics teachers. To address this, Alex investigated possible sources of molded plastic parts (especially the main piece for holding the string and sensors). The hope is that with such parts the monochord can be more quickly assembled in kit form, or perhaps sold to teachers fully assembled. The costs of making the mold is high (starting at $2000, based on Alex's investigations to date). However, the per-unit cost is low. It seems plausible therefore that the REALSIMPLE project could make 100 or so of these units and sell them directly from KTH and CCRMA to interested teachers around the world, at an affordable unit cost. An alternative is to coordinate the physics class with an earlier shop class!

6.2 Ryan Cassidy

Ryan Cassidy's tasks for the summer were the following:

- Help Alex as needed.
- Translate KTH monochord assembly instructions from Word to LaTeX format.
- Translate KTH soundcard set-up instructions from HTML to LaTeX format.
- Help design lab experiments using the monochord and `pd` software on the PC.
- Help write up a monochord laboratory assignment[12] (in LaTeX) for the RealSimple website.

Ryan's performance was also excellent. Ryan is a seasoned engineer with a knack for pedagogy.

[Any issues needing discussion?]

In summary, we could not have hoped for a better team for this summer's activities at CCRMA.

[9] http://ccrma.stanford.edu/realsimple/soundcard_test/
[10] http://crca.ucsd.edu/~msp/software.html
[11] http://ccrma.stanford.edu/realsimple/lab_inst/
[12] http://ccrma.stanford.edu/realsimple/lab_inst/

6.3 Julius Smith

JOS tasks this summer, in addition to project oversight/management/communications, included the following:

- Investigate the status of tools for porting LaTeX to CNXML.[13]
- Help design lab experiments using the monochord and `pd` software on the PC.
- Help write up the monochord lab assignment.
- Provide technical and administrative support.
- Develop the RealSimple website and source repositories.

At the present time, there are no complete automated software tools for converting LaTeX to CNXML, as needed for the Connexions[14] website. We have therefore decided, for the time being, to disseminate REALSIMPLE work products on the CCRMA website in both HTML and PDF formats, using substantially the same terms of license (Creative Commons License 2.5[15]) as materials on the Connexions website. This license allows anyone to perform the necessary conversions for contributing REALSIMPLE work products to the Connexions or any other website.

The principal technical barrier to generating CNXML from high-level source is the creation of MathML (Math Markup Language) from high-level source (LaTeX in our case). A macro package is under development by Michael Kohlhase and others that will enable LaTeX authors to specify semantic information in their mathematical formulas (in addition to the information needed for display, as is already provided by LaTeX). Such enhanced LaTeX source is called "semantic LaTeX". From this source, one can generate PDF files as usual, but also CNXML, which enables advanced Web applications such as searching of math formulas and copy/pasting formulas into symbolic mathematics applications such as Mathematica. Our present conversion from LaTeX to HTML, on the other hand, renders most formulas as embedded images in the HTML, making mathematics a "second-class citizen" relative to text in the context of Web documents. While we feel MathML is valuable long term, using it now was deemed too large a task for our project at present. We will continue to monitor developments.

The first monochord laboratory assignment[16] has been written and posted on the website. It contains what we consider to be appropriate beginning elementary experiments with the monochord.

Near the end of the summer quarter, all source materials for the REALSIMPLE project at CCRMA were consolidated into a Subversion[17] source-control directory, from which project members (and ultimately anyone) can obtain a working copy of the source tree using the Subversion `svn` program. Software was written for conveniently generating the website automatically from the consolidated source tree, including automatically generated download-links for PDF versions, etc. This software was an adaptation of software developed over the years by JOS for his CCRMA website.

7 Spring Quarter, 2005-2006

There were no funded activities on REALSIMPLE at CCRMA during the spring quarter.

[13] http://beta.cnx.org/technology/cnxml/
[14] http://cnx.org/
[15] http://creativecommons.org/licenses/by/2.5/
[16] http://ccrma.stanford.edu/realsimple/lab_inst/
[17] http://subversion.tigris.org/

8 Winter Quarter, 2005-2006

In Winter quarter, Nelson Lee worked on

1. tutorial animations in Flash
2. porting LaTeX to CNXML format

Nelson's initial Flash animations and Connexions[18] test modules are listed in the following two subsections below.

CNXML[19] format is used by the Connexions project at Rice University, which is one website where we plan to host our final teaching materials for global accessibility. LaTeX is a standard word-processing language for the mathematical/scientific community, and Julius has four relevant on-line books written in this format, parts of which will be ported into the planned teaching materials.

At the beginning of the quarter, Nelson and Julius met for a couple of hours with Cammy Huang-DeVoss at Wallenberg who generously gave us an in-depth look at how she developed animated visualizations and other teaching aids, primarily in Flash. We discussed our overall goals and how they might best be accomplished. We obtained invaluable input and orientation from Cammy. In particular, it was this meeting that convinced us that Flash was the right choice of animation technologies at present.

Since the focus of the planning grant is to prototype an acoustics laboratory assignment on vibrating strings using the proposed technology, Nelson's initial Flash projects were concerned with simulating vibrating strings in various ways. These animations will be utilized in the "theory background" section of the string laboratory assignment under development. Much of the theory background section will be adapted from the text for Music 420 ("Signal Processing Models in Musical Acoustics"). Several of the figures in this text would be far clearer if animated, and so two were chosen as initial Flash simulation targets. They are listed in §8.1 above, and serve their intended purpose beautifully.

The flash animations developed this quarter have already been used satisfactorily for in-class demonstrations in Music 420. The ability to animate traveling waves on a string, pause the animation, discuss what is happening, and resume to the next point of discussion, is extremely valuable for teaching purposes.

In addition to these "theory background" animations, we plan to construct animations corresponding to specific experiments in the lab assignments under development. In the animations, one can see very clearly what theory predicts, and the student can then check these predictions experimentally, and look for the effects seen in the theoretical simulations. Computer simulations can also be used to check especially difficult measurements in the experimental set up. Even for simple measurements, the theoretical simulation can be used to check the student's recorded observations, alerting the student to recheck when something appears to be out of range. The simulation can check the student's results even when there are free parameters in the experiment such as the precise striking point along the string. In particular, the computer can independently estimate the striking point from the recorded waveform in order to check that it agrees with reported measurements.

Nelson also spent a significant portion of his time investigating how to most efficiently port LaTeX to the Connexions CNXML format. Nelson joined the development team for that project and tested its current functionality. He also made a couple of small test modules at Connexions and

[18] http://cnx.org/

[19] http://beta.cnx.org/technology/cnxml/

an example course. (A "course" at Connexions is a sequence of "modules".) In view of the level of effort already under way in the Connexions project on porting LaTeX to CNXML, we decided in early February to postpone work on the LaTeX translation front and work more on laboratory animations development. Nelson continued to receive assistance from Cammy Huang-DeVoss in that effort.

We are hoping that by this summer, when we plan to finalize the prototype web site, the LaTeX-CNXML translation tools will be in a reasonably usable state, so that we will not need to do a lot of development ourselves. However, based on discussions with Connexions developers, Julius plans to write a Perl script that maximally automates the conversion of LaTeX source to sTeX ("semantic TeX") source, which is the first step in the semi-automatic translation to CNXML, as presently designed.

Finally, in preparation for laboratory development work, we are starting to build a small electronics & acoustics laboratory in Julius's CCRMA office (Knoll 306). Initial purchases planned include an oscilloscope and basic tools for testing and constructing electronic circuits, as well as tools needed for building the acoustics laboratory set-up specified by the KTH team. In addition, a laptop computer was purchased to support Nelson's work on the project.

8.1 Flash Visualizations Developed Winter 2005-2006

- Struck String Lab[20]
- Moving String Termination[21]
- Traveling Wave Decomposition[22]

8.2 Connexions Test Modules Developed Winter 2005-2006

- Test Course[23]
- Traveling-Wave Animation[24]
- Moving String Termination[25]

9 Fall Quarter, 2005-2006

There were no funded activities on REALSIMPLE at CCRMA during the fall quarter.

10 Bookmarks

Below are some of the valuable pointers regarding Flash we obtained from Cammy Huang-DeVoss and Lee Brimelow at Wallenberg:

- `http://search.devx.com/search.cfm?q=flash&a=1&f=1&s=0&sa.x=0&sa.y=0`
- `http://www.kirupa.com/developer/mx/usingtext.htm`

[20] http://ccrma.stanford.edu/~jos/rsadmin/StruckStringSampleLab.swf
[21] http://ccrma.stanford.edu/~jos/rsadmin/LREndApp.swf
[22] TravellingWaveApp.swf
[23] http://www.cnx.org/content/col10341/latest/
[24] http://www.cnx.org/content/m13521/latest/
[25] http://www.cnx.org/content/m13522/latest/

- http://www.flashkit.com/index.shtml
- http://flashmx2004.com/forums/
- http://www.oddcast.com/sitepal/?&affId=36734&bannerId=0&promotionId=2375
- http://www.digitalcuriosity.com/
- http://levitated.net/daily/index.html
- http://www.actionscript.cl/
- http://www.uncontrol.com/
- http://www.arseiam.com/index2.htm
- http://yugop.com/

Connexions Book Marks:

- Connexions: http://cnx.org/
- Connexions community discussion regarding LaTeX to CNXML conversion: http://beta.cnx.rice.edu/communities/Community4.

References

[1] J. O. Smith, "Making virtual electric guitars and associated effects using Faust," Dec. 2007, http://ccrma.stanford.edu/realsimple/faust_strings/.