Signals and Systems: Casting it as an Action-Adventure rather than a Horror Genre

Roberto Togneri, Sally Male

Dept of EEC Engineering,
University of Western Australia

The unit: ENSC3015 Signals and Systems

Outline

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The Problem

What We Did

Did It Work?

Conclusions

- The core content:
  - Signals and Systems: Basic Concepts and Properties
  - Continuous-Time Systems and the Laplace Transform
  - Discrete-Time Systems and the Z Transform
  - Continuous-Time signals and the Fourier Series and Transform
  - Sampling from Continuous to Discrete Time
  - Discrete-Time Fourier Analysis
- The core outcomes:
  - Understand time-domain techniques and apply transform-domain techniques to analyse system responses and characteristics
  - Understand the importance of Fourier analysis, the important properties, and the problem of sampling when analyzing the spectral characteristics of signals

Aim: Identify the problems in the student engagement, implement our solutions and evaluate findings from a 2016 custom online student survey and 2013-2017 institutional unit feedback

The problem with: Convolution

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- “*The graphical procedure discussed here appears very complicated and discouraging at first reading. Indeed, some people claim that convolution has driven many electrical engineering undergraduates to contemplate theology either for salvation or as an alternative career* (IEEE Spectrum, March 1991, p.60)”
- Convolution needs to be visualized and then graphically presented, but that is too qualitative (can’t assess in an exam / test environment). However it is the graphical procedure which best describes the concept and power of convolution.

The problem with: Complex Numbers

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- The *phase response* where you need to know which quadrant you are in (calculator fail: beware of [$\tan^{-1}$])

- All roads lead to Euler: $e^{j\theta} = \cos\theta + j\sin\theta$

- When is it i? And when is it j?
- What is s? What is z?

- Going along the infinite $s = j\omega$ axis or around the $z = e^{j\Omega}$ gives me the frequency response
- I can relate to $\omega = 2\pi f$ what the heck is digital frequency Ω?

The problem with: Discrete-time Sinusoids

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- $\cos(\omega_0 n) = \cos((\omega_0 + 2\pi)n)$
  but $\omega_0 \neq \omega_0 + 2\pi$, my head hurts!

- $\cos(3\pi n)$ is periodic but $\cos(3n)$ is not, but aren't all sinusoids periodic?

- As I increase frequency I come back to the same frequency / system response when I get to 2π, I remember an episode from Star Trek about this, but wasn't that science **fiction**?

The problem with: Fourier Analysis

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- How can you have a –ve frequency? I can ignore it but I can't remove it (since some operations may move it to the +ve frequency side and then we can "see" it)? Yep clear as mud!
- What is that 2 doing there and why don't I see it when f=0?
- If I view the duality property with a mirror will that help?
- Or should I use the mirror to understand the even symmetric / odd symmetric property for real signals?

The problem with: Sampling

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- So you sample and have less of the original signal and yet we now have an infinite spectrum of replicas and an infinite bandwidth?
- Surely if you undersample there is no way to recover the signal or is there?
- So when I take the FFT everything is periodic and half of what I get I can throw away? Help!
- I don’t believe you, surely a Hamming window distorts the data whereas the rectangular window doesn’t?

The problem with: Notation and Solutions

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- The i vs j for complex numbers is just the tip of the iceberg
- Is it $X(j\omega)$ or $X(\omega)$? And then we have $X(e^{j\Omega})$ and $X(\Omega)$, and please don't remind about frequency F which is only between 0 and 1 (or was it -0.5 to 0.5).
- You mean I can use the same convolution integral using time when using frequency (or I understand why you convolve time functions but why do you convolve spectra)?
- One of the better textbooks (Lathi) adopts unusual notation

The problem with: it has it all!

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- Mathematics:
  - Laplace and Fourier transform theory with a dash of Z transforms and sampling
  - Did somebody mention random signals? (thankfully no, not yet anyway)

- Computer Science
  - Algorithms and programming: using MATLAB just to get going let alone serious algorithm development for DSP efficient implementations

- And the applications
  - Circuits and Systems, at least that makes the Laplace transform easy
  - Digital Systems, nothing to do with gates and logic, real z-transform DSP here
  - Control and Communications, the next chapter on the Laplace and Fourier

The Standard Delivery

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Activity	Comment
2 hour lecture / week	recorded lectures emphasising key concepts demonstrated on tablet PC and GUI demos
2 hour practice class / week	tutorial practice class with student peer facilitators, followed by formative class test assessment (worked exercises)
3 x 3 hour laboratories	pre-lab and in-class assessment of three labs (Introduction MATLAB/Simulink, Using Simulink for CLTI and DLTI, Using MATLAB for Fourier Analysis)
2 hour final exam	summative assessment (worked exercise)

We are not the only ones!

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- Educational MATLAB GUIs (http://dspfirst.gatech.edu/matlab/)
- Magnitude Response Learning Game (http://www2.spsc.tugraz.at/people/bgeiger/MRLT/index.html)
- JHU Signals and Systems Demonstrations (http://pages.jh.edu/~signals/)
- Signals and Systems Concept Inventory (http://www.signals-and-systems.org/)

What we did: Lecture Material

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- Improve quality of lecture notes
  - Self-contained ; highlight key concepts ; worked examples
  - Consistent layout and presentation which links across chapters
  - Include only the “hallmark” textbooks (Oppenheim, Haykin and Lathi) and make references to the relevant sections
  - Check, correct and update regularly
- Concept Quizzes
  - In preparation for each class test select multiple choice quizzes from the signals and systems concept inventory were shown during lecture breaks → **we need more of these!**
- Tutorial exercises and solutions
  - Be sure the tutorial solutions are correct!

77 % found the lecture material the most useful resource

What we did: Student Peer Facilitators

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- Peer Facilitators
  - Three MPE students were employed to interact with students in the class as required while the tutor went through selected tutorial questions
- Working through solutions
  - Solutions were worked through “live” on a tablet with explanations along the way as to the why and how (you don’t get this with PDF solutions)
- Hold the tutorial the hour before the class test
  - Go through remaining questions relevant to the class test
  - Allow students to study in their groups, ask the peer facilitators or just simply quietly revise for the test.

79% found the peer assisted tutorials more accessible than traditional tutorials
59% found the practice class before the class test helpful

What we did: Formative Class Test Assessment

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- 6 class tests throughout semester (every other week)
  - More regular assessment than a single mid-term test
  - Helps students pace through the material
- The class tests were optional
  - The class test mark is compared with the final exam, and only the better of the two is used in the final assessment
    - Students who miss the class test (for whatever reason) are not penalized
    - Students who do poorly are not penalized (but their "failed" attempt will provide necessary feedback on what to expect and what they need to improve)
    - Students who do well are rewarded (so there is a good reason to participate, do well in the class test, better than in the exam, and it is included)

82% preferred the regularly spaced class tests to the one mid-term test
82% preferred the optionally assessed class tests to compulsory assessment

What we did: In-class Lab Assessment

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- Labs 1 and 2
  - Standard simulation / exploration of concepts for systems and signals
  - Rewritten to make more relevant
  - Scheduled to be aligned with lecture delivery
  - Assessment by pre-lab (individual), in-class (group) and lab report (group) to provide better balance (assessed before, during and after the lab)
- Lab 3
  - Analysis and Design lab (practical!)
  - No lab report: only pre-lab and in-class

82% found the assessment was fair and provided the required motivation
79% found the labs a useful resource in assisting understanding

- From 2018
  - *All labs no lab report*: only pre-lab and in-class; more efficient for students and staff
  - *More effective assessment*:
    lab demonstrator randomly asks students in group to explain and show

What should have worked: GUI Demos

- GUI Demos available from Learning Management System (LMS)
  - Educational MATLAB GUIs
- GUI Demos deployment
  - Demonstrated in class during lectures

67% didn’t access the GUI Demos and of those that did was 50/50 between finding them useful or not sure

- Demos are engaging/interactive so why the fail?
  - Most demos have limited interactivity
  - Not tied to any assessment
- How to make Demos more useful
  - Gamification → LMS integration
  - Assessment → LMS integration / students need a tablet running demo during test

Students Unit Reflection Feedback (2013-2017)

Year	Response N (%)	LRAS μ (σ)	OGEE μ (σ)
2013	28 (36%)	2.68 (0.89)	2.82 (0.66)
2014	44 (44%)	2.84 (0.95)	2.84 (0.88)
2016	53 (42%)	3.53 (0.77)	3.47 (0.74)
2017	42 (33%)	3.29 (0.85)	3.29 (0.91)

Students' Unit Reflection Feedback Response from 2013 to 2017 (1: *Strongly Disagree* to 4: *Strongly Agree*).
LRAS: Learning Resources were Adequate for Study in the unit;
OGEE: Overall, Unit was a Good Educational Experience.

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Students Unit Reflection Feedback (2013-2017)

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- In 2015 there were problems with the delivery of the unit and the student feedback was not representative
  - In fact it was quite bad!
  - It was bad because an external lecturer was hired without the necessary supervision and mentoring support

The human / people factor

Support for the lecturer, the unit co-ordinator, the facilitator, the lab demonstrator cannot be understated, **teaching staff need to have the resources to care and engage with the students' learning not just about the teaching of it**.

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Student Comments: What we did right

- “Overall I felt the unit was very well put together, there was an abundance of learning resources which helped enhance my understanding of some of the topics. I am a particular fan of how the class tests are structured (i.e. if you do better in the exam that will be the mark which you receive) as it gives me a better opportunity to consolidate my knowledge as well as get regular exposure to exam like questions.”

- “having the peers, "panic" tutorials (cramming before the test) and the optional tests was great! I hope more units introduce them”

- “The content is certainly difficult, however, with the tutorials being done in class with demonstrations really helped with understanding the material during the lectures, and not having to rewatch and struggle to understand the unit”

- “I have really enjoyed this unit, the best part about it has been the lab work as it makes the content seem like it is applicable to the real world.”

Students comments: To be improved

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- “Reduce the content as 6 optional tests, 3 labs, 1 exam, tutorial classes plus lecture classes are too much for students to handle, please consider we also have other units to study/research/work on project as well.”

- “Labs were helpful but if grouped with the wrong people very frustrating (a few people I was paired with asked to copy my pre-lab and teach them how to use MATLAB). If possible make them slightly shorter, but individual reports.”

- “Maybe provide more of a reason to use the demos, or as way to include them throughout the course so as to help with understanding the theoretical sections.”

Lab Demonstrator Interview (2018)

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- *Lab reports issues*:
  - out of class marking (higher costs),
  - online group report submissions (more admin),
  - groups were allowed to finish outside of class hours (inconsistent),
  - dysfunctional groups (unfair marking),
  - possible plagiarism (reuse previous report)

→ Get rid of lab reports!

- *Creative thinking* on how to upgrade existing pre-lab and in-class assessment. This is what the lead lab demonstrator did:
  - A more rigorous assessment of the pre-lab, which became necessary to do the lab during the in-class, each member of the group had to take responsibility
  - *Bonus*: Improved group dynamics when a random member would be picked to explain and demonstrate; group members coached each other so any one student would be able to answer
- *And the Irony*: In 2018 the labs were made more challenging, and students performed even better

Enhancing the Learning

- GUI Interactive Demos (visual and animated, how can students use these better?)
- More “live” worked examples (so students can learn how to approach answering a question)
- More concept / sketch questions (not just crank the handle)
- More practical application questions (albeit simplified)
- More concept multiple choice questions (which get students to think)

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- There is just so much we can do: achieving the balance
  - More hands-on labs?
  - More on-line MCQ quizzes?
  - More problem based learning?
  - Keep the class test/exam exercise questions?

- Signals and Systems changing the focus
  - *Too much content, too theoretical, too much to do* (main issues students identified) needs to be presented as so many exciting things we can do, the theory is so empowering/fascinating and I want more to do, this is fun!
  - *Too much content* → **?**jettison obscure content which is cute and interesting but ultimately rarely used → **!**Provide as supplementary material
  - *Too theoretical* → **?**just present the key equations and steps and avoid the confusing abstraction and curious relationships → **!**Fundamentals are important but they should be simplified, emphasized and demonstrated