Encl: Additional information for Activity Report

I understand that the School of Computer Sciences needs an annual activity report.
I am submitting my current file as an interim report, with the understanding that I may add/revise/elaborate in my full report, to be provided at the end of my current teaching term (W16).

0. General.

I was on sabbatical from Jan 1 to December 31, 2015. During this time I remained in Waterloo and continued my research on Wind Turbines and Infra sound. I maintained regular meetings with my graduate students, and with my colleagues on campus.

In Fall 2015 I was cross appointed to Systems Design Engineering (September 1, 2015 to August 31 2018).
The cross appointment was sponsored by my colleague, John Zelek.

1. Research

Publications
J. Vanderkooy and R. Mann. "Measuring Wind Turbine Coherent Infrasound". Wind Turbine Noise 2015, INCE/EUROPE, Monday 20th April to Thursday 23rd April 2015. Glasgow, Scotland.

Public Lecture, Undergraduate Computer Science Club
Title: "Infrasound is all around us"
Date: Thursday July 9, 2015, 6pm
Location: MC4060
http://csclub.uwaterloo.ca/media/Infra%20Sound%20is%20All%20Around%20Us

Funding
Title: "Infrasound measurement, analysis and synthesis"
School of Computer Science, University of Waterloo
$12,000, one time "seed grant" for support of undergraduate research assistants and/or coop students.
Application letter (28 July 2015, attached)

Funding
Title: "Infrasound measurement, analysis and synthesis"
Office of Research, University of Waterloo.
$10,000, one time "seed grant" for purchase of "Research Infrasound Source"

from Kevin Dooley Inc.
Application letter (28 September 2015, attached)

2. Teaching

Funding
Equipment purchase for teaching.
Item: Qty 10 National Instruments myDAQ USB data acquisition system.
Course: CS489/W16 "Computational Sound".
School of Computer Science, University of Waterloo. ($2500 CAD total)

Curriculum
New course CS489 "Topics in Computer Science".
"Computational Sound", first offering W16.
Undergraduate Information Session. (DC1302, 28 Oct 2015).
Video of presentation
https://cs.uwaterloo.ca/%7Emannr
/15Oct28%20Computational%20Sound%20Demo%20R.Mann.mp4
Current enrollment, 37 students.
Lecture notes, student projects and live class video to follow in the full report.

3. Service.

Advocacy: Wind Turbines

- Media release (Nov 11, 2015). My research on infra sound and wind turbines. (PDF).
- Public comments to: "Health Canada and Wind Turbines: Too little too late?" Carmen Krogh, R Y McMurtry. Canadian Medical Association Journal (CMAJ) Blogs. November 28, 2014. (Four comments total, from November 29, 2014 to December 6, 2015.) http://cmajblogs.com/health-canada-and-wind-turbines-too-little-too-late/
- Professor denied access to Health Canada wind turbine data (Wind Concerns Ontario, May 20, 2015)

- Select Committee on Wind Turbines - Parliament of Australia. Submission #408, May 3, 2015 (PDF).
- In the News: [The Australian] Canadian research boosts Cooper's case on turbines (University of Waterloo, Monday, March 9, 2015)
- Canadian research boosts Cooper's case on turbines. (The Australian, February 24, 2015)
- Invited Lecture: Carmen Krogh. "Harm from Wind Turbines: What Has Been Known for Decades". Wed 7 May 2014. 3:30pm. DC1302 (Davis Center). University of Waterloo. Abstract. Webcast (via "livestream.com"). Slides (pdf).

September 28, 2015

Professor George Dixon
V.P. Office of Research
Needles Hall 1013
University of Waterloo

Dear Professor Dixon,

I am writing to ask you for urgent funding for my research in infra sound and in particular, infra sound from Industrial Wind Turbines. At this point I must also beg your indulgence on a rather long letter which I feel is necessary to convey my interest in this research, the path I have taken to this point, and my vision for going forward.

I first became aware of health issues related to wind turbines after reading the paper "Adverse health effects of industrial wind turbines" in Canadian Family Physician journal in May 2013 (link).

I was surprised to find no specifications or guidelines for infra sound (low frequency noise, below the range of human hearing) from Industrial Wind Turbines. Acoustics experts were reporting infra sound, but their concerns were being dismissed by the Ontario Ministry of the Environment and Wind energy proponents. On March 20, 2014 a speaker at Public Health Ontario dismissed the impacts of infra sound, yet failed to provide any measurements to justify this conclusion (link).

In November 2014, Health Canada reported that there was no evidence of health impacts associated with wind turbines, yet failed to report their infra sound measurement data supporting this conclusion (link). I contacted the health Canada person responsible for commissioning this study (Dr. David Michaud) on several occasions requesting their raw data, measurement methods, Etc. and offering to share the results of my own research. I was met with delays, referral to other departments, and finally refusal. I would be glad to share this chain of correspondence, but the end result was that I had to file a freedom of information request which is currently in process.

Since August 2013, I have been working with colleagues (Physics, University of Waterloo) to record and measure infra sound from wind turbines. Infra sound measurement is challenging because wind turbines do not operate at a fixed speed. Further, we needed a way to isolate a single wind turbine from other turbines and from (random) wind noise. Our method uses an optical telescope fitted with a photo detector to obtain reference blade passage periods, recording these together with the microphone infra sound signal. Using signal processing we are able to isolate the infra sound from a single turbine. We have successfully measured infra sound from several different individual turbines in Ontario.

We presented our results at Wind Turbine Noise 2015, INCE/EUROPE, in Glasgow, Scotland in April of this year. A copy of the paper is available on my web page (link).

My interest going forward is research dedicated to the following:

1 Develop the best possible methods and systems for measurement of infra sound in general and specifically that generated by Industrial Wind Turbines.

2 Develop methods and standards for analysis of information gathered both in our lab and in conjunction with other interested researchers.

3 To emulate infra sound in a lab setting to a documented duplicate of that generated by wind turbines.

4 Enable future testing by others, with appropriate medical training and ethics approval, on humans with the goal of establishing safe exposure levels.

I submitted a research proposal (document attached) to the School of Computer Science. I am pleased that my chair has provided student funding for this project. He was unable however to provide equipment funding, in particular, approximately 10 K needed to purchase the device needed to emulate infra sound, a key component of this research.

By way of explanation this is a device developed by a new Canadian company that sees a market for both emulating and mitigating infra sound in a variety of settings such as HVAC systems, transportation vehicles, Etc. They have scheduled one of their first production units for me which is due for delivery on Oct 9th. This underscores my funding urgency as if I cannot buy this unit I may have to wait considerable time before other orders are filled and I am able to get a unit from a subsequent production run.

I am appealing to your office directly for 10 K of seed funding such that I can seize the opportunity to acquire the necessary equipment and begin this research project. Subsequently with some initial research and preliminary results in place an NSERC or other government grant in the next round of applications will be appropriate.

I do appreciate your considering my request for the cost of this equipment which is so critical to the initial research.

Yours Truly

Richard Mann

Attached: Research Proposal, "Measurement, Analysis and Synthesis of Infra Sound"

28 July, 2015.

Dear Mark,

As I mentioned last week, I am requesting funding for my research in infra sound.

As the use of many forms of new technology and it's inevitable proximity to human users grows, we are seeing an increasing number of cases where humans are being exposed to infra sound with little concern for, or awareness of, potential health effects.

I believe there is a unique opportunity to put the university at the center of this issue, and help shape a field of study which is just beginning to evolve. I would very much like to see our department play a pivotal role in research, publishing, and defining this evolution.

I have included a brief research summary and budget below. Please let me know if you require any additional information.

Thanks,

Richard

"Measurement, Analysis and Synthesis of Infra Sound"

Infra sound refers to sound waves below the range of human hearing (20 to 20000 Hz). Infra sound comes from a number of natural phenomena including weather changes, thunder, and ocean waves. Common man-made sources include heating and ventilation systems, industrial machinery, moving vehicle cabins (airplanes, trains, cars), and energy generation (wind turbines, gas plants).

While low frequency noise and infra sound are known to impact human health, there are no standards for infra sound exposure. In most cases, low frequency sound is simply ignored. Sound level readings are typically in "dBA", decibels A-weighted. A-weighting is based on (averaged) curves of human hearing sensitivity, which fall off sharply at low frequencies. Low frequency noise and infra sound, in particular, are largely unstudied.

My research to date has focused on wind turbines. For this project I will broaden my research to multiple sources of infra sound, thereby increasing the potential for multiple research partners, interest from multiple groups and industries, sources of funding, etc. This broadening of scope will also have a multiplier effect on establishing data bases and measurement standards, which are now lacking and which our department can have a significant role in helping to establish.

The specific aim of this project is to: 1. record infra sound from man-made and natural sources, 2. characterize the signals, and 3. reproduce the complete sound, both audible and infra sound, under controlled (laboratory) conditions. All data will be made available to the research community.

Progress

1. Infra sound recording and measurement.
I have constructed a measurement system consisting of G.R.A.S. 40AZ infra sound microphones (0.5 to 20000 Hz), an Infiltec INFRA20 micro barometer (0.05 to 20 Hz) and a Honeywell silicon pressure sensor (0-15 psi). Combining these signals will provide the full sound spectrum (from 0 to 20000 Hz). Signals are captured with National Instruments data acquisition hardware using Labview software. A number of sources have already been recorded.

2. Characterization of infra sound.
Current work is based on the narrow band Fourier transform of the signal. In joint work (John Vanderkooy and I) we measured infra sound from wind turbines. These techniques will be extended to consider a variety of other infra sound sources.

3. Synthesis of infra sound.
To generate infra sound we will use an infra sound transducer device designed by Kevin Allan Dooley Inc. The RSI-10 system is an infra sound transducer device and associated amplifier-control unit, designed to develop infra sound pressures within a controlled space, based on an arbitrary analog signal input. The full power frequency response of the system is from ~0.2 Hz to ~ 40 Hz. An optional PS-09 pressure sensor feedback module will also be assessed. This sensor can provide a method of closed loop pressure control of the control space or alternatively, analog pressure signals may be provided as feedback from user supplied infra sound microphone or pressure sensing system (+100 mV /Pa signal recommended). The goal of this stage will be to ensure that the device performs within its specifications so as to provide a dependable base for further research.

Budget

A. Student support.
Projected workload, one student per term for three terms, starting Fall 2015. I plan to hire undergraduate students via part time and/or Co-op positions. Students will develop software and hardware, take measurements, and perform analysis.

B. Equipment.
RIS-10 "Research Infra Sound Source" $7899.99 USD + HST.
The RIS-10 (Kevin Allan Dooley Inc.) is a volumetric infra sound source based on an electromagnetically controlled axial compressor. The flow magnitude and direction (into the control volume or out of the control volume) as well as the frequency of variation are determined based on the infra sound pressure requirements set by the analog input signal.

References:

J. Vanderkooy and R. Mann. "Measuring Wind Turbine Coherent Infrasound". Wind Turbine Noise 2015, INCE/EUROPE, April 20-23, 2015. Glasgow, Scotland

Research Infrasound Source (RIS-10)

I first became interested in infrasound in May 2013 after reading a paper by Carmen Krogh dealing with adverse health effects caused by Industrial Wind Turbines. Infrasound refers to sound waves below the range of human hearing. Infra sound comes from a number of man-made sources including HVAC systems, industrial machinery, moving vehicle cabins, and energy generation (wind turbines, gas plants).

I was surprised that very little study had been done on this subject and the effects on humans. What information has been published has largely been ignored by both governments and the wind industry. While low frequency noise and infra sound are believed to impact human health, there are currently no standards for infra sound exposure. In most cases, low frequency sound is simply ignored.

I began researching ways to record infrasound and in joint experiments with a colleague at Waterloo we developed a method of isolating infrasound from a single wind turbine and measuring it free from the "clutter" of other turbines, wind noise Etc.

Our work was presented at the INCE/EUROPE Wind Turbine Noise conference in Glasgow, Scotland, in April, 2015.

I have been fortunate to have recently received approval of seed funding from both the School of Computer Science and Office of Research such that I will be able to purchase the necessary equipment and hire student research assistants allowing this research to go forward.

The focus of my research is as follows.

1 Develop the best possible methods and systems for measurement of infrasound in general and specifically that generated by Industrial Wind Turbines.

2 Develop methods and standards for analysis of information gathered both in our lab and in conjunction with other interested researchers.

3 Create infra sound in a lab setting to a documented duplicate of that generated by wind turbines and other man made devices.

4 Enable future testing on humans, by others with appropriate medical training and ethics approval, with the goal of establishing safe exposure levels.

5 Share the results of this research with others in the scientific community.

The number of manmade sources of infrasound continues to grow among us and the health and safety of individuals presently appears to be secondary to profit in the proliferation of these products. It will be of great benefit to society if we can establish safe levels of infrasound exposure and evolve associated emissions standards.

Richard Mann

University of Waterloo

November 11, 2015

THE AUSTRALIAN

Canadian research boosts Cooper's case on turbines

GRAHAM LLOYD THE AUSTRALIAN FEBRUARY 24, 2015 12:00AM

ACOUSTICS expert Steven Cooper has expanded his legal action to include vocal wind farm advocate Simon Chapman, as independent research was produced to support the findings of high-level infrasound at Cape Bridgewater in Victoria.

The Australian yesterday reported Mr Cooper was considering legal action against the ABC's Media Watch and its portrayal of him and his research on the effect of the Pacific Hydro wind turbines on local residents.

Participants in the Cape Bridgewater study, which was designed and financed by wind farm company Pacific Hydro, are considering joining the legal action against Professor Chapman over published comments which questioned their integrity.

Professor Chapman, from the University of Sydney completed his PhD on "Cigarette Advertising as Myth; A Re-Evaluation of the Relationship of Advertising to Smoking".

He has argued that health complaints by some residents living near wind farms are the result of psychological concerns rather than physical impacts.

In an article published on The Conversation website and highlighted by Media Watch, Professor Chapman said the six residents involved in the study "rush to their diaries to report 'sensations' when they are cued by audible changes in the sound?".

"No chance of any collusion in such a study when these six would all know each other, and half actually lived together," he said.

"If this dog's breakfast of a study means anything, it provides support for the nocebo hypothesis; those with pre-existing anxiety and antipathy to the turbines, when cued by audible sound from those turbines, record 'sensations' on cue."

But Mr Cooper said the findings of the Cape Bridgewater study did not focus on audible noise and that the infrasound that was recorded was inaudible.

He said residents were able to record changes in "sensations" which matched changes in the wind turbine operations which were measured separately. For the majority of the observations of high sensation severity, there was no change in the noise.

The Cooper study results have been hailed as significant by some of the world's leading acoustic experts but not accepted as proving a cause and effect relationship by Pacific Hydro.

Mr Cooper has received further support for his work at Cape Bridgewater from computer scientists in Canada who have been working to record sub-audible noise or infrasound from wind turbines since 2013.

Richard Mann, at the University of Waterloo in Ontario, said scientists there had arrived at a similar position to Mr Cooper despite working in a different way.

"Our results show that wind turbines emit a characteristic pulsation (change in barometric pressure) that repeats with every blade passage," Professor Mann said.

"This is consistent with the infra sound 'signature' you have reported."

The Waterloo University research did not consider health effects from wind turbine infrasound. But Professor Mann said: "I join the many scientists and experts worldwide requesting a thorough investigation of wind turbine noise."

Sunday May 3, 2015.

Dear Senators,

I am a professor at the University of Waterloo in Canada. I have been working on Wind turbine noise since 2013.

Infrasound measurement is challenging because wind turbines do not operate at a fixed speed. Further, we need a way to isolate a single wind turbine from other turbines and from (random) wind noise.

My colleague and I have developed a method to do this, and have just presented our research in Glasgow, Scotland. The citation is:

J. Vanderkooy and R. Mann. "Measuring Wind Turbine Coherent Infrasound". Wind Turbine Noise 2015, INCE/EUROPE, Monday 20th April to Thursday 23rd April 2015. Glasgow, Scotland. Link: http://www.cs.uwaterloo.ca/~mannr/WTN2015.pdf

We use an optical telescope fitted with a photodetector, aimed at the turbine. Each time a blade passes through the field of view, brightness changes are detected, and recorded along with the input sound. Infra sound is found by averaging the input sound over repeated blade passes, thereby identifying infra sound from an individual turbine.

Wind turbines emit a characteristic infra sound pulse (air pressure change) that repeats with every blade passage. Infra sound was first reported for wind turbines, as early as 1979. Some people claim that newer turbine designs removed the infra sound problems of the older designs. Our measurements show that is not true. Infra sound pulses are still present in modern turbines.

Numerous researchers report infra sound disturbances from wind turbines, including the "infra sound signature" recently reported by Steven Cooper at Cape Bridgewater. I also note that two other papers presented in Glasgow, working independently, reported similar infra sound.

There appear to be no government regulations on infra sound. Further, governments are not even measuring infra sound levels. I am advocating that governments and wind companies acknowledge the known health impacts of infra sound, determine safe exposure levels, and establish proper measurement standards.

Additional information:

I recently learned that Health Canada has collected extensive measurements of wind turbine noise, including infra sound, as well as wind turbine operational data, Link: https://www.wind-watch.org/documents/analysis-modeling-and-prediction-of-infrasound-and-low-frequency-noise-from-wind-turbine-installations/

Repeated requests to Health Canada, either to work together, or to study the data independently, have been denied. Accordingly, I have filed an "access to information" request, listed below.

A-2015-00042: Wind Turbine Noise and Health Study. MG Acoustics was contracted by HC to study infra sound. Request all correspondence between HC and MG. Also request all raw data collected by MG for this contract. This includes all microphone, microbarometer, vibration, weather station, and turbine operational data (turbine orientation, RPM, power output, wind speed at turbine, etc). Note: Informal request made to David Michaud (March 2, 2015), redirected to Stephen Bly (March 9, 2015), and ultimately rejected by Stephen Bly (March 24, 2015)

Sincerely,

Richard Mann
Associate Professor (Computer Science)
University of Waterloo
Waterloo Ontario
Canada

"Measurement, Analysis and Synthesis of Infra Sound"

Richard Mann, University of Waterloo, November 3, 2015.

Infra sound refers to sound waves below the range of human hearing (20 to 20000 Hz). Infra sound comes from a number of natural phenomena including weather changes, thunder, and ocean waves.
Common man-made sources include heating and ventilation systems, industrial machinery, moving vehicle cabins (airplanes, trains, cars), and energy generation (wind turbines, gas plants). While low frequency noise and infra sound are known to impact human health, there are no standards for infra sound exposure. In most cases, low frequency sound is simply ignored. Sound level readings are typically in "dBA", decibels A-weighted. A-weighting is based on (averaged) curves of human hearing sensitivity, which fall off sharply at low frequencies. Low frequency noise and infra sound, in particular, are largely unstudied.
My research to date has focused on wind turbines. For this project I will broaden my research to multiple sources of infra sound, thereby increasing the potential for multiple research partners, interest from multiple groups and industries, sources of funding, etc. This broadening of scope will also have a multiplier effect on establishing data bases and measurement standards, which are now lacking and which our University can have a significant role in helping to establish.

The specific aim of this project is to:

1. Record infra sound from man- made and natural sources.
2. Characterize the signals.
3. Reproduce the complete sound, both audible and infra sound, under controlled (Laboratory) conditions.

All data will be made available to the research community.

Infra sound recording and measurement.

I have constructed a measurement system consisting of G.R.A.S. 40AZ infra sound microphones (0.5 to 20000 Hz), an Infiltec INFRA20 micro barometer (0.05 to 20 Hz) and a Honeywell silicon pressure sensor (0-15 psi). Combining these signals will provide the full sound spectrum (from 0 to 20000 Hz). Signals are captured with National Instruments data acquisition hardware using Labview software. A number of sources have already been recorded.

Characterization of infra sound.

Current work is based on the narrow band Fourier transform of the signal. Results for Wind turbines are reported in [1]. These techniques will be extended to consider a variety of other infra sound sources.

Synthesis of infra sound.

To generate infra sound I will use an infra sound transducer device [2]. This device and associated amplifier-control unit, is designed to develop infra sound pressures within a controlled space, based on an arbitrary analog signal input.
The full power frequency response of the system is from ~0.2 Hz to ~ 40 Hz. A pressure sensor feedback module will also be assessed. This sensor can provide a method of closed loop pressure control of the control space or alternatively, analog pressure signals may be provided as feedback from user supplied infra sound microphone or pressure sensing system (+100 mV /Pa signal recommended). The goal of this stage will be to ensure that the device performs within its specifications so as to provide a dependable base for further research.

Student opportunities.

One student per term for three terms, starting fall 2015. I plan to hire undergraduate students via part time and/or Co-op positions. Students will develop software and hardware, take measurements, and perform analysis.

References.

1. J. Vanderkooy and R. Mann. "Measuring Wind Turbine Coherent Infrasound". Wind Turbine Noise 2015, INCE/EUROPE, April 20-23, 2015. Glasgow, Scotland

2. Research Infrasound Source (RIS-10). Kevin Allan Dooley Inc.

University of Waterloo

Richard Mann

Associate Professor
Department of Computer Science
University of Waterloo

mannr@uwaterloo.ca
DC2510 (Davis Center)
Voice: (519) 888-4567 x33006
Fax: (519) 885-1208
Driving directions to Waterloo
Campus map

Teaching Winter 2016

Course discussion/notes/slides on Piazza here.

"Computer Sound and Audio"

- Course number: CS489/CS689 ("Topics in Computer Science", Note: Section #001)
- Lectures: W/F 16:00--17:20, PAS 1229. First lecture Wed 6 Jan, 2016.

Note: If you have not registered yet, feel free to attend and contact me after lecture.

More details below...

- Evaluation:

  Undergraduate: 60% assignments, 40% term project.
  Graduate: 40% assignments, 60% research project.

- Prerequisite(s): Scientific Computation (CS370, or equivalent). Matlab experience an asset.

  The course will provide a self contained introduction to sound processing by computer. The course will have a strong practical focus. Students will be encouraged to explore various hardware and software platforms for audio.

  This is a project based course. Undergraduates will do a term project and complete a final report, in the area of their choice. Graduate students will take on a larger project and write it up as a research paper.

  Introductory material will be covered in lectures, demonstrations, and assignments.

  The course will begin with a brief introduction to human hearing, acoustics and electronics. We will then cover analog to digital and digital to analog conversion, followed by time and frequency domain analysis of signals (Fourier transform).

  Given this foundation a number of practical problems will be studied, including: Sound analysis (time frequency and wavelet representation), sound synthesis (amplitude and frequency modulation) and System identification (measure frequency response of circuits, microphones, speakers).

  Optional topics (lecture and/or project material) include: Digital signal processing (z-transform), audio compression (MP3), digital audio hardware and software systems, and acoustics simulation.

  Lectures and assignments will be provided in Matlab (or Octave). Students may complete assignments as well as their projects on the hardware/software of their choice.

- Undgraduate information sesssion presentation (October 28, 2015). Video presentation (mp4 file). Slides from presentation (pdf).

Research

Announcement (Nov 3, 2015). I am pleased to announce that on Oct 25, 2015, University of Waterloo (Office of Research and School of Computer Science) has approved funding for my research in Infra sound. Research details are provided here (PDF).

Note: Accepting applications for undergraduate research assistants (part time (starting W16) and full/time co-op (starting S16)). Areas of interest: Embedded computing, Computer Audio, and/or Electronics. Feel free to contact me for details.

Research interests

- *Computational vision (high-level vision, motion understanding, event recognition)*
- *Computational hearing (acoustics, speech, music, signal processing)*
- *Perception and Learning*
- *Artificial Intelligence*
- *Industrial Wind Turbine Noise (audible and infra sound)*

Publications

Latest work: J. Vanderkooy and R. Mann. "Measuring Wind Turbine Coherent Infrasound". Wind Turbine Noise 2015, INCE/EUROPE, Monday 20th April to Thursday 23rd April 2015. Glasgow, Scotland.

News (Wind Turbines):

- Media release (Nov 11, 2015). My research on infra sound and wind turbines. (PDF).
- Professor denied access to Health Canada wind turbine data (Wind Concerns Ontario, May 20, 2015)
- Select Committee on Wind Turbines – Parliament of Australia. Submission #408, May 3, 2015 (PDF).
- In the News: [The Australian] Canadian research boosts Cooper's case on turbines (University of Waterloo, Monday, March 9, 2015)
- Canadian research boosts Cooper's case on turbines. (The Australian, February 24, 2015)
- Invited Lecture: Carmen Krogh. "Harm from Wind Turbines: What Has Been Known for Decades". Wed 7 May 2014. 3:30pm. DC1302 (Davis Center). University of Waterloo. Abstract. Webcast (via "livestream.com"). Slides (pdf).

Teaching

Current course: "Computer Sound and Audio"

- Course number: CS489/CS689 ("Topics in Computer Science", Note: Section #001)
- Lectures: W/F 16:00--17:20, PAS 1229. First lecture Wed 6 Jan, 2016.

Previous Courses

- CS484/684 - Computational Vision (F11, W13)
- CS886 - Perception as Bayesian Inference (W10)
- CS787 - Computational Vision (W03, F04, W07)
- CS486/686 - Introduction to Artificial Intelligence (S02)
- CS498Q/698Q - Computational Vision (W00, W01, W06)
- CS251 - Digital Design and Architecture (W01, W02, W04, W05, F05, F06, F10, W11, F12)
- CS134 - Principles of Computer Science (S00)

Links

Industrial Wind Turbines

Software Available

Useful Links

Contact Information

Past

Images

Some notes from Audio course CS489 Winter 2016 (Piazza)

Encl: Piazza notes from one lecture. Note: Latex formulas scrambled in Email, but should work somewhere (?). Web browser?

CS489/W16 Lecture 04. Friday 15 Jan 2016

Comments: Office hours, project expectations.

Demonstration: FRITURE Software

Friture.org <http://friture.org> (Thanks to a student for the link.)

Multiplatform (Windows, Mac, Linux).

Realtime spectrum spectrum analyzer and Sonogram (they call this "2D spectrum").

Can also generate sine waves, sweeps, white and pink noise.

Question: Latency of display? Can this system Save data to disk reliably as it runs? It would be great to capture data for (offline) analysis by Matlab, or add measurement "plug ins" to this software.

Details:

User interface is "Pane/Panel/Tile" type, with "docks" for various instruments. This is similar to commercial sound software I have seen, very easy to use. It does everything we need for measurement, all with a very nice interface.

It is written in Python. Scientific computation is done via Scipy --> Numpy --> MatPlotLib

MatPlotLib is a complete open source implementation of Matlab, including plotting.

Float performance of Python is very good, but needs to be measured, compared to commercial products such as Matlab and Labview.

The audio is done via "Port Audio". The standard interface can be used on Mac, Win, Linux. Question: Latency in Linux vs Windows and Mac.

If anyone wants to do "open source" projects, this is the place to go!

Outline

Today's Lecture:

- Sine waves and sound synthesis.
- Demo Pasco 9307 Fourier Synthesizer

Next week:

- Matlab DFT

Assignment #1

Part a) Fourier Synthesis (out today)

Part b) Matlab DFT (out next week)

Pasco Fourier Synthesizer, circa 1973.

Manual PDF <https://fys.kuleuven.be/pradem/PDF_files/Fourier_Pasco.pdf>

Waves and Frequencies

Sine wave.

$$\cos(\theta)$$

INSERT FIGURE HERE

Pure tone (sine wave)

$$x(t)$$ is the (continuous) signal as a function of time.

$$x(t)= a \cos (2\pi ft)$$

$$a$$ is amplitude, $$f$$ is frequency ("Hz", "Hertz", "cps") cycles per second, and $$t$$ is time (seconds).

Example: 440 Hz pure tone (denoted $$A_4$$ in musical notation).

INSERT FIGURE HERE

Sum of phase shifted sine waves

(Fourier Series)

$$x(t) = \sum_{k=1}^{K}{a_k \cos (2\pi f_k t + \phi_k)}$$

ϕ_k is phase shift of wave k (in radians).

Special case: Frequencies are integer multiples of f_1, the fundamental frequency. This is called a harmonic series. Harmonic series result from vibrating strings and vibrating columns of air (organ pipes) and many other processes.

General case: Frequencies f_k are not related by integer multiples.

Components could come from independent sound sources, or from single sources that have inharmonic components.

For example, percussive instruments. Resonant frequencies of rods and bars have resonances at

$$f_k = a(k+ 1/2)^2 f_1$$.

where a is a constant dependent on the physical dimensions.

CITATION

Example Square wave at frequency f_1.

$$x(t)=\cos (2\pi f_1 t) + 1/3 \cos (3 \times 2\pi f_1 t) + 1/5 \cos(5 \times 2\pi f_1 t) \ldots$$

Other waveforms can be generated with:

1. Even vs odd harmonics vs all harmonics

2. Different phases.

- Replace cosines with sines (ie., $\phi_k = \pi/2$).

- Randomize phases

3. Vary weights of harmonics. For triangular wave replace weights $a_k = 1/k$ with $a_k = 1/k^2$.

Homework

1. Experiment. Write a program to create a mono WAV file (44.1kHz, 16 bit) to emulate the settings of the Pasco 9307 Fourier Synthesizer.The simplest program will take the settings from constants, and produce a short length (say ten seconds) of data. You may develop a GUI if you

like (in a language of your choice), but that is not necessary for this assignment.

The fundamental frequency is $$f_1=440 Hz$$.

The signal consists of the fundamental plus nine (9) harmonics.

Magnitudes are $$a_k$$ are continuously adjustable (between 0 and 1).

Phases $$\phi_k$$ can be set to $$[0, \pi/2, \pi, 3\pi /2, 2 pi]$$.

Recall that $$\phi=0$$ are cosines and $$\phi=\pi/2$$ are sines.

Experiments.

Produce one wave file for each case. (All waves are at 440Hz.)

1. Generate a square wave

2. Generate a triangular wave

3. Generate a "sawtooth" wave.

$$x(t)= (t-\left \lfloor \frac{t}{T} \right \rfloor)$$ where $$T=1/f_1$$ is the period.

Reference: Wikipedia Sawtooth Wave <https://en.wikipedia.org/wiki/Sawtooth_wave>

Animated GIF, constructing a sawtooth wave.
https://en.wikipedia.org/wiki/Sawtooth_wave#/media/File:Synthesis_sawtooth.gif

2. Mathematics.

Write the Fourier series for a square wave and for the sawtooth wave above.Both series have odd harmonics, and both harmonics fall off as $$1/k$$.

Show how to construct a square wave from the sum of two (time shifted) sawtooth waves.

You can show this either with a picture, or with algebra.