Designing Undergraduate Instruction in Music Informatics

Martin McCrory, candidate for M.S.

Indiana University School of Informatics
Department of Music Informatics
Chris Raphael, Advisor

May 1, 2009

Abstract

With the continuing advancement of technology, we see many new technological tools being developed that help us create and experience music, this development being referred to by many as "Music Informatics." It is critical for our institutions of higher learning to foster the understanding of this development process so that musicians can harness this advancing technology for real musical benefit. Unfortunately, instruction in Music Informatics is limited to a sprinkling of graduate courses around the nation.

To that end, I have designed a 15-week undergraduate survey course that focuses on four main topics relevant to Music Informatics. This no-programming course is marketable to virtually any academic institution of higher learning with a music program, and can be taught by any professor with a minimum of background in music and technology.

Acknowledgements

My partner, Lana Muniz, for being supportive of me for these long two years, and for also being super smart and awesome.

My parents, Joanne and Elliott McCrory, for Skypeing in to the presentation today all the way from Switzerland! Also, for being the kindest, most loving parents anyone could ask for.

My Music Informatics advisor, Chris Raphael, for providing extensive counsel on the multitude of ways to teach Music Informatics topics, as well as giving me guidance throughout the entirety of my Capstone.

My Instructional Design advisor, Ron Haynes, for his advice regarding research methods, survey methods and instructional design in general.

Donald Byrd, whose materials for several of his graduate level Music Informatics course I studied copiously (and "borrowed" from a few times, thanks Don!).

Joan Middendorf, for teaching a wonderfully useful course on designing curricula for the college campus, from which I consulted extensively.

Christian Briggs, who let me use his classroom as a laboratory for developing my instructional designs entirely too often.

Marty Seigel, who not only helped me feel at home in the Informatics department, but also taught a great first semester Intro to HCI course that still sticks with me in many ways today.

My fellow Music Informatics graduate students, with whom I've taken many classes, had many discussions, and discussed countless ideas related to this project.

Section 1: Project Summary

For this research project, I have:

- Designed a 15-week, upper-level undergraduate course covering topics that many consider to be "Music Informatics" (MI) topics.
- Used several different forms of analysis and research methods to determine exactly how best to design this course.
- Created course materials for instructors and students to use in the course.
- Constructed and taught sample lessons to demonstrate the course environment.

Section 2: What is Music Informatics?

When conceiving of this project, I realized that the concept of Music Informatics is not well defined. Even highly experienced members of the field disagree on the details of what exactly Music Informatics is! It became clear to me that I would have to come up with a definition of Music Informatics that I could use as a springboard to narrow my focus for the entire project.

So, here is my initial definition of Music Informatics:

> *"Music Informatics describes the use of Information Technology to address issues raised by music performers, composers, theorists, researchers, listeners and anyone else who interacts with music in some way."*

This definition is broad, and in theory includes a wide range of topics that may or may not be taught in my course. However, it gave me a place to start. Some key elements of this definition:

The use of Information Technology is a vital component of this definition. There are many applications of technology in general to Music, but it is Information Technology in particular that forms the basis of all study of Music Informatics. An audio recording of a piece of music isn't Music Informatics in and of itself, but the process of compressing the recording into MP3 format without losing much sound quality is very much relevant to Music Informatics.

Music Informatics affects anyone who interacts with music in some way. This includes all of the groups I mentioned, as well as many others that I didn't list. With the continuous advancement of technology, and musicians' desire to innovate and continuously improve their crafts, it is natural for musicians of all kinds to turn to technology to shape their music.

However, I knew that if I wanted to have a working definition of Music Informatics, I would need to become more specific with my thoughts. After consulting with Subject Matter Experts and researching the topics covered in Indiana University's graduate Music Informatics program, I arrived at a more specific definition of Music Informatics:

Music Informatics is figuring out how to use new technological developments to make music more readily understood and accessible. Some topics that, in my opinion, fall under the "umbrella" of MI include:

1. *Music representation and visualization*
2. *Music Information Retrieval--using a database to store metadata and/or actual music content, and the efficient and relevant retrieval of this information*
3. *Digital Copyright laws and how they affect music creation/consumption today*
4. *Creating technology to aid in music performance-digital instruments, automatic accompaniment systems, etc.*

This definition pinpoints four target areas of study that my previous definition left vague. Going beyond the point of "who is involved in Music Informatics," this current definition moves toward a discussion of "what topics fall under the umbrella of Music Informatics?"

However, at this point, my definitions of these four target areas are necessarily vague. I had a general idea of what sorts of things could be included in each area of study, but these ideas were based solely on my personal experience in Music Informatics. I determined that it would be best to learn more about these target areas at a later time, when I could do more research and arrive at more informed conclusions about these areas of study.

Section 3: Predispositions

At this point in the project, all I had to guide my project were some predispositions I had about Music Informatics based on conjecture. These predispositions included:

Music Informatics skills will have increasing relevancy and importance as time moves forward. I could easily see that the increasing use of IT around me was not restricted to YouTube, Facebook, etc. Musicians are increasingly utilizing IT to better perform, create, store and understand music.

Many schools teach a few subjects that fall under the umbrella of Music Informatics. This was evident from my discussions with peers and experiences taking Music Technology classes at the University of Illinois, as well as my experiences here at IU and my discussions with my peers at my schools and other schools as well.

Few schools teach many subjects that fall under that umbrella, and fewer still call it Music Informatics. The four topics I mentioned earlier are divergent on a certain level. Also, I certainly had never heard of anyone learning "Music Informatics" before attending IU, and a quick Google search for "Music Informatics" didn't turn up very many hits outside of IU webpages.

Music Informatics skills are attainable for someone entering the business world after completing their undergraduate education. All that is required of that someone is some computer science knowledge (programming, etc) and knowledge in the specific areas of Music Informatics in which he or she is interested.

Many music professors (and some other non-music professors) would be able to teach a Music Informatics course. Teaching the course would require a high level of experience with Information Technology, including perhaps computer programming, but many musicians (especially in academia) are becoming more and more knowledgeable on these sorts of topics.

Section 4: Needs Analysis

4.1 Summary of Needs Analysis

After cataloguing these predispositions, I needed to determine the specific need of my instruction. My methodology consisted of doing the following: I

- Created personas,
- Conducted exploratory research,
- Surveyed my target learner audience,
- Surveyed potential course instructors and
- Consulted with Subject Matter Experts.

Personas are a way of envisioning my target audiences by actually creating fictitious learners and instructors to serve as focal points for my thoughts. The students are all assumed to be enrolled in my course, and the instructors are all assumed to be teaching my course. Here are the personas I created:

William Flesh is a 19 year old Junior at the University of Michigan. Bill studies Music Technology and is currently picking up a business minor. Bill has extensive experience producing music on computers, having arranged music since the age of 11 and having used software to digitally "mix" music for six years. He has some theory and composition experience, primarily limited to two theory courses he took Freshman year and some amateur composing using said computer software. Bill has not done any computer programming outside of certain skills in various music programs that some may consider programming (a Visual Basic-like interface). Bill uses new media frequently, both in his schoolwork and his daily life. He has a YouTube, Facebook and Wikipedia identity that he checks up on frequently. He has posted some of his musical creations on YouTube, with his most popular video receiving over 20,000 views.

Bethany Lincicome is a 21 year old Senior at Northwestern University. Bethany is an extremely accomplished cello player, having earned the assistant principal chair in the University Orchestra earlier this year. She has been playing cello since the age of 6, and is preparing auditions for the top-tier orchestras around the country upon her graduation in May. Bethany is interested in expanding her musical knowledge beyond her strong music theory skills, and has a particular interest in how she can use music technology to benefit her career over the next few years. She has "everyday" computer experience, including web browsing, word processing, and watching videos on YouTube, but no programming experience.

Ryan Cabrera is a 20 year old Senior at the University of Illinois. Ryan is a Music Education major with a choir emphasis, and sings Tenor in the Concert Choir. He did very well in his required Music Theory courses, and even took a theory elective (20^{th} century music theory)! He also excelled in his conducting classes, and has some music production experience as well. One of Ryan's primary interests these days is figuring out how he can use music technology in his classroom when he graduates. Though not having any computer programming experience, Ryan uses his computer very frequently, and often contributes to his YouTube channel, which consists primarily of cute videos of his kittens, and gets thousands of views each week.

Eugene Wie is a 24 year old 2^{nd} year graduate student at the University of Wisconsin-Madison. Eugene studies Music Technology, and is two years into a five year PhD program. Eugene is one of the two TAs assigned to the course (it wasn't his first choice of teaching assignments) under Professor Moriarity. Also, everyone is teaching the course for the first time. Eugene got his B.A. in Music Theory from Knox College in Illinois, where he decided to change his focus to Music Technology for his graduate studies. As a result, he has a strong background in all aspects of Music Technology heading into teaching this course. However, though aware of many "Music Informatics" topics, he will be teaching this course by "flying by the seat of his pants," going off of the instruction the head Professor gives him, some secondary research as he progresses through the semester, and through learning while his students learn.

Stephen Mediate is a 37 year old Assistant Professor in Music Informatics at Indiana University. Professor Mediate has been teaching at IU for six years, previously having taught Music Business at an East Coast school for four years. He Professor Mediate's degrees are in Computer Science (B.S.) and Music Business (PhD). Professor Mediate is completely knowledgeable on all Music Informatics topics, having taught all of these subjects at one time or another throughout his career. However, this will be the first time he has combined all of these topics into one course, so assembling course materials out of his old course notes may be tricky. Most of his courses are graduate courses, this will be the first time in six years he's had to teach an undergraduate course.

Maria Ochoa is a 47 year old Associate Professor holding a joint faculty position in computer science and music business. Possessing a working knowledge of music theory, Professor Ochoa primarily teaches courses in the computer science department. Most of her courses are undergraduate courses, so she is comfortable with the younger undergraduate demographic. Many of her classes use new media elements, and Professor Ochoa is quite comfortable incorporating new teaching methods and materials into her curriculum without extensive forethought. She will require a staff to teach the course, and as such will choose TAs with musical experience to offset her deficiency in musical knowledge.

4.2 Exploratory Research

4.2.1 Exploratory Research Summary

With my personas in mind, I determined that I needed to find out more about how Music Informatics topics are taught at the University level. I decided my exploratory research would consist of:

- Investigating the Informatics, Music Technology and other related concepts at various universities (limited to Big Ten institutions for practical reasons),
- Comparing the multidisciplinary music/technology programs and courses offered at these institutions,
- Determining if certain MI topics were or weren't being taught in these classes,
- Determining if universities had the resources to teach an MI course, if none existed and
- Determining the specific need for MI instruction.

4.2.2 Results from Exploratory Research

The results from my exploratory research were as follows:

- Indiana University has the only Music Informatics graduate program in the Big Ten. No universities offer an undergraduate Music Informatics major.
- No universities currently offer a Music Informatics course for Undergraduates (Indiana used to, taught by Donald Byrd).
- However, many universities (five of the eleven Big Ten universities) offer graduate or undergraduate courses in what they call "Music Technology."
- All of the Big Ten universities (except for Michigan St.) have "Informatics" programs, with the most common specialties being Bio or Medical Informatics.
- Three Big Ten universities (UIUC, UM, Purdue) offer undergraduate majors in "Informatics."
- Schools with particularly good resources for studies involving music technology include Indiana, IUPUI , Minnesota, Penn State and Northwestern.

4.2.3 Insights from Exploratory Research

From my exploratory research, I developed the following insights:

Many universities could, in theory, offer a Music Informatics course. It would seem that many of the large Big Ten universities have the personnel expertise to teach topics in Music Informatics. Additionally, many of these universities have large enough music programs that there could perhaps be demand for a technical elective in a music theory/performance/education curriculum.

I still need to determine if there is a specific need at these schools for this course. My exploratory research did not lead me to any specific conclusions. I am still working off of conjecture at this point, as I have not conducted any in-depth research, performed an extensive context analysis, or interviewed any of my two target audiences (instructors and students).

I still need to determine the exact specifications of the course. I have a vague idea that my course will incorporate the four elements outlined in my earlier definition of Music Informatics, but I am not sure how I will accomplish this. Also, the contents of my course will be partially dictated by the specific needs that the course instructors and participants have.

I need to learn more about my two target audiences: the students and the instructors. All of the above points boil down to this insight, and my project really cannot go further until I determine the specific needs that potential course instructors and students have.

4.3 Surveys

4.3.1 Summary of Surveys

To learn more about my two target audiences, I designed two surveys:

- Potential learners (upperclass Music Theory/Music Technology/Music Business students)
- Potential instructors (tenured Music faculty)

The surveys were hosted on Surveymonkey.com from January 22-March 22. Each was 17 questions in length, and took an average of 4 minutes to complete. The surveys contained similar questions in a similar format.

4.3.2 Student Surveys

Unfortunately, I did not receive enough responses from students to generate any statistically significant results.

4.3.3 Instructor Surveys

I sent out 110 surveys via e-mail to music instructors (primarily music theory, composition and technology instructors) at all eleven Big Ten universities. I received 31 responses, for a 27.2% positive response rate.

Here are the questions that were asked in the instructor survey:

1. Firstly, do you agree with my definition of Music Informatics? [the definition I gave was largely similar to the definition I presented earlier in this paper]
2. For how many years have you been teaching music-related courses at the undergraduate level?
3. What music-related courses do you currently teach?
4. What music-related courses have you taught in the last 5 years?
5. Do any of the music-related courses you teach or have taught in the last 5 years include any instruction on any sort of music technology?
6. For these courses or units, please describe your instructional materials. Did you create your own instructional materials? Did you use materials that were provided to you with little modification? Or did you use some pre-existing materials to augment your own instructional materials?
7. For these courses or units, did you ever use any “new media” to teach?
8. For these courses or units, did your students ever do any computer programming?
9. For these courses or units, was there ever a time where you felt your students were particularly ENGAGED in the material?
10. For these courses or units, was there ever a time where you felt your students were particularly DISENGAGED in the material?
11. I would be able to learn the basics of a computer programming language if I needed to do so for a course that uses programming as a tool to better understand music. (Strongly Agree 1 2 3 4 5 Strongly Disagree)
12. I usually put together the instructional materials for the courses I teach. (Strongly Agree 1 2 3 4 5 Strongly Disagree)
13. If all of the instructional materials were provided to me, I would be willing to teach a Music Informatics course even if the material is slightly out of my “comfort zone”. (Strongly Agree 1 2 3 4 5 Strongly Disagree)
14. I think there is interest at my school in a course that teaches students how to use technology to:
    a. create and perform music in interesting ways.
    b. categorize, classify and organize music.
    c. better understand music.
15. I would feel comfortable teaching a course that teaches students how to use technology to:
    a. create and perform music in interesting ways.
    b. categorize, classify and organize music.
    c. better understand music.
16. Lastly, how old are you?
17. What is your gender?
18. Do you have any comments or parting words?
19.

Detailed results from this survey are available at http://www.martinmccrory.com/capstone/survey_summary.xls .

4.3.4 Insights from Surveys

- I need to slightly re-think my specific definition of Music Informatics (to more accurately reflect the state of affairs with regard to digital instruments).
- Creating in-depth instructor materials may be a waste of time.
- **Instructors that do know programming are sometimes willing to incorporate programming into their courses.**
- **Instructors that do NOT know programming absolutely will NOT include programming in their courses, and are reluctant to learn even a simple programming language if it is required for the course that they teach.**
- Young music theory instructors generally know most of the subject material related to Music Informatics.
- Older music theory instructors may not be the best candidates to teach a Music Informatics course.
- Some (but not a lot) of music theory courses use technology to the extent that this course would.
- Instructors generally believe that there would be interest at their university for a Music Informatics course.

Section 5: Computer Programming

At this point in my research, I decided that students in this course should not be required to do much in the way of computer programming. This decision has prompted vigorous debate with my Music Informatics colleagues. Many are against the removal of computer programming for the following reasons:

- Music Informatics is a rigorous scientific course of study, and doing computer programming encourages a rigorous scientific approach to the subject.
- Much of what Music Informaticians do in the "real world" is computer programming, so a course that teaches this should reflect that.
- Doing computer programming allows for students to "learn by doing" and personally experience the tools they've been studying.

However, I decided that including computer programming in what is essentially a survey course of Music Informatics would bring up more problems than it would solve:

- Doing computer programming in a Music Informatics course would either (a) require a few weeks of time set aside to learn the programming language/environment (b) require a prerequisite of a computer science course that few members of my target audience would have taken.
- In the "real world," developers learn new programming languages and environments frequently, and often these environments have specific development characteristics that are virtually impossible to teach in a generalized course.
- Sometimes, it is difficult to use programming to "learn by doing," as often the main message of an assignment gets lost in a myriad of technical challenges that a student faces during the programming process.
- Including programming in the course curriculum limits the instructors who can teach the course.

Finally, leaving out programming from a Music Informatics course still allows for a deep level of thought and discourse on the subject:

- Students can still experience programming through the use of "plain English" algorithms, or the use of pseudocode. Often, this is a more direct way to "learn by doing," as the technical issues with programming are completely bypassed in order to get right to the core issues of the assignment.
- There are other ways to demonstrate scientific rigor in the course besides computer programming, such as using the Scientific method to compare existing algorithms.
- Lastly, and perhaps most importantly, **Learning how to think at a high level about the theory of Music Informatics is more important than learning some programming environment "halfway."** Students will eventually learn the technical tools they need to do their job in the "real world." However, teaching students how to think critically and creatively about Music Informatics subjects is a universal skill that can be used in any job after the course is complete.

Therefore, students in this course will not be required to do any formal computer programming or learn any formal programming languages or environments. Students will, however, be required to use pseudocode at times to write algorithms, study existing code and point out flaws/characteristics and perhaps interact with programming environments on a limited level during select case study exercises.

Section 6: Context Analysis

6.1 Learners

From the survey information, I determined that my learners generally will consist of:

- Music students (music theory or music technology, with some performance/history/ed taking the course as an elective)
- Technology students with an interest in music taking the course as an elective

I also reinforced my idea that a Music Informatics course should be directed at learners who come to the course with a music background (and perhaps minimal computer experience), rather than having a CS background (and perhaps minimal musical training). Generally speaking, basic computer concepts are all that's necessary to learn Music Informatics topics at a surface level. However, a deep understanding of music is required to fully comprehend many Music Informatics topics, and this level of depth is not often seen among CS students.

To illustrate the above idea, the notion that "music is made of notes" is something that any music student can easily comprehend. However, someone with no formal musical training will not understand this concept. To have them understand this concept would likely require an inordinate amount of classroom time that could be better spent teaching topics more relevant to Music Informatics.

Additionally, the converse of the above example (telling a music student something like "a Bubble Sort operates with an efficiency of $O(n^2)$" is something that can be explained to a music student with a basic grasp of technology without too much trouble.

6.2 Instructors

Generally, the instructors for the course will be:

- Music theory/technology professors (though this is not completely certain, as I only surveyed Music theory/technology professors), or
- Possibly business/computer science professors with an interest in music.

Regardless of the department in which they are employed, the instructor likely knows some computer programming. A key component of the data derived from the surveys is that instructors strongly prefer to be very comfortable with the material they teach, and a course that incorporates any computer programming (even on a low level, such as analysis of algorithms) would likely be taught by an instructor who has experience in this field.

However, it is not a requirement that the instructor be completely versed in every facet of a particular programming language to teach the course. Much more important is that the instructor understands the Music Informatics issues thoroughly, and that they understand how these issues fit into the big picture of Music Technology issues facing musicians today.

6.3 Classroom

Classrooms in which this course is taught should be small, to accommodate the small class size. Students may find that having the class in a computer lab, with internet-equipped workstations available, may be helpful to learning. However, instructors should devise a way to encourage students to use the computers for only class-appropriate activities (i.e. NOT Facebook) during class.

Section 7: The Course

7.1 Course Summary

The course lasts 15 weeks, consisting of an overview, four technical units and a conclusion. Each technical unit tackles a specific topic that falls under the "umbrella" of Music Informatics. In each unit, learners either give a group oral

presentation or write a short paper (see section 7.2). At the end of the overview and conclusion, a practical exam takes place (see section 7.2).

7.2 Course Deliverables

7.2.1 Essay Exams

There are two essay exams, one each at the beginning and end of semester. Both exams are problem-based, and ask students to address real-life Music Informatics issues.

Students are graded on the depth of their response, the validity and logicality of their solution. The first exam is graded "easier," like a homework exam—its purpose is to give the instructor a sense of the student's prerequisite knowledge, strengths and weaknesses, as well as to form groups for the oral presentation. The second exam is graded "harder," like a true final exam. Students are expected to synthesize information from the relevant technical units, come up with unique and deep solutions to the problems given, and to argue their points with ferocity and logic.

7.2.2 Group Oral Presentation

The class is divided into four groups (one for each technical unit). Each group gives a presentation in one of the units. For example, Group A gives a presentation in Unit 2, Group B gives a presentation in Unit 3, etc. Groups and units are assigned by the instructor. The topic of the presentation is the students' choice related to the Unit in which the presentation was assigned. A grading rubric for the oral presentation can be downloaded at http://www.martinmccrory.com/capstone/rubric.pdf.

7.2.3 Unit Papers

In the three units in which a student's group is not giving an oral presentation (and excluding the overview and summary portions of the course), students will asked to write 750-1250 word essays that offer a solution or prototype model to a real-world Music Informatics problem related to the Unit in which the paper was assigned.

7.2.4 Case Study Readings and Exercises

Students will do case study readings and/or exercises for almost every class period. Readings may come from online or printed sources. Exercises may be watching videos on YouTube, playing with Flash applications, viewing sheet music, or anything relevant to the unit. These case studies serve to illustrate relevant and interesting examples of the material discussed in class. There will be approximately 26 case studies.

7.3 Course Syllabus

The complete course syllabus can be downloaded at http://www.martinmccrory.com/capstone/syllabus.pdf.

Appendix A: Sample Lessons

A.1 Introduction to Music Genre Classification (Week 7)

A.1.1 Instructional Objectives

The objectives of this lesson are to:

- Allow students to explore how humans classify music
- Expose the student to the creation of algorithms for automatic genre classification

By the end of the lesson, students should be able to:

- Label specific, musically valid reasons why they personally classify music into genres
- Describe at least one method a computer may use to perform genre classifications

A.1.2 Lesson Overview

Students first perform manual genre classification, in the following manner:

- Each student is given a matrix, with each row representing a genre and each column representing a candidate song (for an example matrix, see Appendix 2).
- Each candidate song is played.
- Students mark which genre (only one genre per candidate song) the student feels best represents the candidate song.

After the marking period, the genre classifications for each song are tallied on the board. The instructor leads students in a discussion of the following concepts:

- Why did you classify the song into this genre?
- What specific features in the music led you to this decision?
- Why is there disagreement with this song (if there is disagreement among the students)?

Lastly, the instructor should lead students in the following discussions:

- How might a computer classify music into genres?
- Could a computer use the same lines of thinking that you did when classifying music into genres?
- How could a computer perform automatic genre classification? Would it be at all like how we just did it?
- Can you think of circumstances in which it would be useful for a computer to perform automatic genre classification?

A.2 Copyright Laws and their affect on music creation/consumption (Week 10-11)

A.2.1 Instructional Objectives

The objectives of this lesson are to:

- Inform students of what current and former copyright laws in the U.S. are (relating to music)
- Have students create and defend a stance on certain issues relating to Intellectual Property rights

By the end of the lesson, students should be able to:

- List what some of the current copyright laws are in the U.S.
- Describe the Digital Millenium Copyright act and at least two ways that the DMCA affects the creation and consumption of music
- Define “fair use”
- List at least three ways in which filesharing systems affect the creation and consumption of music

A.2.2 Lesson Overview

The lesson begins with a hands-on group exercise, to establish a baseline of copyright treatment over time:

- The classroom splits up into several groups.
- Each group takes 10 minutes and researches the state of copyright laws (in the U.S.) during a given time period.
- The time periods are: {beginning of time-1849, 1850-1960, 1960s, 1970s, 1980s, 1990s, 2000-2005, 2006-present}
- After the deliberation, the smaller groups report back to the larger group with their findings

Next, the instructor gives a short lecture on the current state of copyright laws in the U.S.:

- Summary of important copyright legislation in the past 3 centuries
- Sonny Bono act of 1998
- How these legislations affect how works available for consumption today are held in copyright

Group discussion on the following topics:

- Digital Millenium Copyright Act—what it is, how it affects music creation/consumption
- Fair Use—what it means and how fair use restrictions affect creativity (example: scrambled hackz)
- Digital Rights Management—what it is, some common examples, and how DRM affects music creation/consumption
- Filesharing/P2P networks—some examples of common filesharing systems, how they affect music creation/consumption

A.3 Introduction to Audio Music Visualization (Week 5)

A.3.1 Instructional Objectives

The objectives of this lesson are to:

- Introduce students to audio-based forms of music visualization
- Teach students how sound waves propagate through air
- Instruct students how to combine basic sine waves to create new sound waves

By the end of the lesson, students should be able to:

- Name the three basic forms of audio-based music visualization
- Describe how sound moves through air, and how a time/amplitude representation precisely describes this movement
- Combine sine waves (using an online tool) to create special sorts of waves (square/sawtooth wave, approximations of traditional acoustic instruments)

A.3.2 Lesson Overview

The lesson starts with a summary of the three "basic" forms of audio visualization:

1. Time-domain visualization (domain: time, range: amplitude)
2. Frequency domain visualization (domain: frequency, range: amplitude)
3. Piano roll visualization (domain: time, range: frequency)

The lesson today focuses on the time-domain visualization. Firstly, the instructor starts with a simple overview of how sound works:

- Sound forms when the air around us becomes displaced in a certain fashion.
- If the air is displaced with enough "force" (a high enough amplitude) and does so repeatedly enough for us to perceive it, we hear a sound via our ears.
- Some examples of things that can create this displacement: a stereo speaker vibrating back and forth, a string on an instrument vibrating up and down, our vocal chords displacing air via a similar vibration, etc

Next, the instructor correlates how sound is formed to the visualization:

- In a simple sound wave [no harmonics], the air vibrates up and down at a constant rate until the source of the vibration stops vibrating the air. (example: speaker playing A440 at a constant rate).
- If you were to "tag" a specific molecule of air with a locator beacon, and mark its position relative to the ground, you'd notice that, during the vibration, it "bounces" up and down at a periodic rate—the number of Hz (cycles per second) at which the sound was created!
- The time-domain visualization captures this "bounce"—the domain illustrates how long it takes the "bounce" cycle to complete (period) and the rance illustrates how high it bounces (amplitude).

Next, the instructor describes how these simple waves are "combined" to form more complicated waves:

- Unlike the visual world, where two objects can't be in the same place at the same time, sound waves *can* combine to form new and more interesting sounds!
- Our ear can hear multiple sound waves at the same time, and our brain combines them into one sound. We can harness this ability of our brain to create more complicated sounds.
- Imagine that, instead of one speaker oscillating the air at a constant rate, you have a large number of speakers, each one tuned to a different frequency, each one oscillating the air at a constant (but different) rate. This allows for many new sounds to be created.
- Certain frequencies (related to the lowest frequency being heard, usually called the "fundamental") are special. Particularly, frequencies that follow what's known as the "overtone series" (basically even multiples of the original frequency) can be used to create unique "timbres" (a musician's word that describes the difference in tone quality between two sounds of identical frequency).

Lastly, to illustrate these last few points, the instructor directs students to an online tutorial that allows students to create sound waves by choosing harmonics, their amplitudes, and their "phase" (when they turn on and off). The URL to this tutorial can be found at: http://www.falstad.com/fourier/.

Appendix B: Sample Essay Questions

1. Your elderly aunt Irma is considering buying a computer for the first time. Irma is a music aficionado, lives on the Upper West Side of NYC, and has been attending musical performances at Lincoln Center for years. She has an extensive record collection and a 20-year-old record player with which to enjoy her music. She claims she's buying the computer "for the internet" and "to check on my grandkids," but you know better. You know that her musical experiences are all about to change, as well. Explain to Irma, in simple but conceptually accurate terms, how the way she experiences music will change if she purchases her laptop. Write your answer in dialog form.

2. You are a sales consultant hired by a local record store (NOT a big chain like Borders). Their sales have fallen 30% over the past 18 months, and your job is to find out why. Of course, you know why—mp3 downloads, legal and illegal—are to blame. However, there are likely some other factors at play here. Give a full report to the store manager, detailing exactly why his record store is failing and what she can do to get her store back on track. If you need specific details about the store, make them up.

3. You want to start a music social networking site. You want its functionality to include things such as the ability to listen to, share, rate, tag, sort, store and discuss music, create, share, rate and store playlists, and give artists a chance to showcase their musical talents. Technically speaking, how do you think you could accomplish this? If you are not familiar with the specific technological tools that you'd use to perform a task (say, implement a metadata-based social music tagging system), explain in loose terms what your tools would accomplish, and how, in theory, they'd accomplish them. Use pseudocode in instances where you are describing how an algorithm may work.

4. You are a distinguished professor, specializing in information science at a Big Ten university. Music has always held an interest for you, and you believe that today's technology has a lot to offer in terms of improving the way we can understand and manipulate music and sound. You want to encourage other technologically-minded academics to develop new tools to accomplish these goals. How would you go about doing this? Explain in detail what steps you'd take, what systems you'd use, and what your end result would look like.

5. You are a lawyer defending a high-profile music producer, who is charged with multiple counts of copyright violation. In private counsel with you (meaning, he has NOT testified to this yet), he has informed you that he did sample other musician's works, but most of them were only small, barely recognizable snippets of the original. This is a high profile case, with the potential to shape the way future music copyright law cases are litigated. Explain your defense strategy. How can you convince a jury that your client should not be indicted under current United States copyright law? Is he completely innocent? Or is he probably guilty, but perhaps the jury should take pity on your client? Include responses to predictable counterarguments and appeals to what you feel is morally right.

6. You are a senior software engineer at a large company that specializes in multimedia software production. You are working on a large-scale consumer-oriented audio editing and manipulation suite (such as Cubase). Propose a design for a new type of music visualization that you believe would add functionality to this suite. Justify why this design is worth incorporating, and outline, in broad strokes, the technical characteristics of this visualization. Try to propose a design that doesn't already exist ☺

7. You work for the Nowhereville Symphony Orchestra, a nonprofit orchestra with an aging clientele. You have a good computer programming background. You propose to your boss an idea that you believe will attract a younger audience to NSO concerts—free, live streaming of concerts, as well as archived access to low-fidelity audio recordings of NSO performances! Your boss says that it's a great idea and wants to know more. Explain to him why you feel that this is a good idea, why it will work, and how you'd go about implementing it.

8. Continuing with the above question, you are the boss's wife, who is a professor of Music History at Nowhereville University. You overhear the previous interchange, and you're not as thrilled as your husband (the boss) about the idea. What's wrong with this idea? Could it be implemented with a few changes, or is it fundamentally flawed? Why?