MAT 399/599 Syllabus

Semester:	Spring 2018
Course title:	Computation and Modeling of Head-Related Transfer Functions
Instructor:	Professor Matt Klassen
Email:	mklassen@digipen.edu
Phone:	(425) 895-4423
Office hours:	M-Th 2:00-3:00, or by appointment
Course Web Page:	http://azrael.digipen.edu/MAT399
Time/Place:	lectures: T,Th 9:00-9:50 in Hokusai, lab: Mon 1:30-4:30 in Mathews

GUEST SPEAKERS:

Thursday, January 25, 9:00 am: Brian Schmidt, DigiPen, *"HRTF measurement with the dummy head, and HRTF implementation for games"*

Thursday, February 1, 9:00 am: Hannes Gamper, Microsoft, *"HRTF measurement and modeling"*

Tuesday, February 20, 9:00 am: Ethan Geller, Epic Games, Lecture I: *"DSP for HRTF overview: ITD extraction, linear phase conversion, and CB/diffuse field smoothing"*

Thursday, February 22, 9:00 am: Ethan Geller, Epic Games, Lecture II: *"Design patterns for making an HRTF spatialization API"*

Tuesday, February 27, 9:00 am: Ethan Geller, Epic Games, Lecture III: *"What spatial audio might look like in the next 5 years: personalization and channel agnostic audio engines and processing"*

Thursday, March 1, 9:00 am: Ravish Mehra, Oculus Research *"Data-driven approaches to HRTF personalization"*

Tuesday, March 13, 9:00 am: Barnabas Bede, DigiPen *"Introduction to Neural Networks and Machine Learning"*

Thursday, April 5, 9:00 am: Michael Berg, Unity *"HRTF and Audio Engine Frameworks"*

MATERIALS:

Reference Materials: (not required)

Head-Related Transfer Function and Virtual Auditory Display, by Bosun Xie.

A Digital Signal Processing Primer, by Ken Steiglitz.

Immersive Sound: The Art and Science of Binaural and Multi-Channel Audio, edited by Agnieszka Roginska and Paul Geluso.

The Technology of Binaural Hearing , Jens Blauert, editor.

Spatial Hearing, by Jens Blauert.

Virtual Auditory Space: Generation and Applications, by Simon Carlile.

The Fourier Transform and its Applications, by Brad Osgood (Stanford online notes for EE 261)

Immersive Audio Signal Processing, Sunil Bharitkar and Chris Kyriaskakis

BACKGROUND MATHEMATICS:

MAT 200 (Calculus II)

WEB PAGES AND MOODLE:

The Moodle page for MAT399 will contain a link to the course web page. The web page is the central repository for all course documents, including homework assignments. Updates to homework will be posted on the web page only. Scores for quizzes, homework, exams, and projects, will be posted through perl scripts on the course web page.

The Moodle page will be primarily used for chat, forums, and for submission of projects.

COURSE DESCRIPTION:

This course explores the mathematical properties and various implementation details of Head-Related Transfer Functions (HRTF's). HRTF's encode into a signal processing filter the auditory cues which are essential to sound localization in 3D space by the human head, and particularly the outer ear, or pinnae. Such functions are essential in the implementation of binaural audio for virtual and augmented reality.

Topics include: transfer functions in signal processing, 3D sound and human auditory system, measurement of HRTF, physical acoustic modeling of HRTF, interpolation of HRTF, virtual auditory display, binaural synthesis, filter design and approximation of HRTF.

In addition to these applied mathematical subjects, we will have hands-on projects which include: measurement of single-point HRTF's in the DigiPen Sound Lab using binaural microphones, comparison of these HRTF measurements with known databases of HRTF's, simple software implementation of interpolation of HRTF's for binaural synthesis.

COURSE GOALS AND OBJECTIVES:

1) Students will learn the basic definitions and algorithms associated to HRTF.

2) Students will become familiar with the procedure of measurement for HRTF in the sound lab.

3) Students will use both the measurement and definitions of HRTF to compute and model HRTF for various implementations, including audio for VR and AR.

EXAMS:

There will be a midterm exam given during regular class hours, and a final exam.

Calculators are allowed on quizzes and exams.

GRADING:

Midterm Exam	20%
Homework	20%
Final Exam	20%
Projects	40%

Grades will be determined based on total course percentage. Percentage scores will determine letter grades according to the scale: (in the worst case)

A	93 – 100
A-	90 – 92.9
B+	87 – 89.9
B	83 – 86.9
B-	80 – 82.9
C+	77 – 79.9
C	73 – 76.9
C-	70 – 72.9
D	60 – 69.9
F	< 60

ACADEMIC INTEGRITY:

Academic dishonesty, or cheating, occurs when a student represents someone else's work as their own, or assists another student in doing so. This can happen on exams, quizzes, homework, or projects. Academic dishonesty also may occur when a student uses any prohibited reference or equipment in the completion of a task. For example, the use of a calculator, notes, books or the internet when it is prohibited. Plagiarism is a common form of academic dishonesty. This can take the form of copying and pasting exerpts from the web, and representing them as original work. The type and severity of any occurence, as well as the legitimacy of any claim of academic dishonesty, will be judged by the instructor and the disciplinary committee. All students are asked to help in promoting a culture of academic integrity by discouraging cheating in all forms.

PROJECTS:

The full description of the programming project can be found on the course web page. Submission of projects should be in a zipped folder which contains source and executable and which can be uploaded on the Moodle page.

Project work will include both sound lab recording of HRTF's and software implementations.

DISABLED STUDENT SERVICES:

Students with physical, psychological or learning disabilities that affect their ability to perform major life activities associated with this class may be eligible for reasonable accommodations under the Americans with Disabilities Act. If you have a documented disability please contact the Disability Support Services office to arrange for accommodations for this class.

TENTATIVE WEEKLY TOPICS:

Week	Dates	Topics
1	Jan 8 - 12	Review of transfer functions, complex plane, frequency response and magnitude reponse functions.
2	Jan 15 - 19	Spatial sound and human auditory system. Localization cues: interaural time difference (ITD), interaural level difference (ILD), spectral cues.
3	Jan 22 - 26	Definition of HRTF, time and frequency domain versions. Localization one or more sound sources, stereophonic law of sine, precedence effects.
4	Jan 29 - Feb 2	Binaural recording, synthesis, and virtual auditory display. Room acoustics.
5	Feb 5 - 9	Continuous and discrete linear time-invariant (LTI) systems, system transfer functions.
6	Feb 12 - 16	HRTF measurements, principles and design. Excitation signals. Speaker and microphone placements.
7	Feb 19 - 23	HRTF equalization, signal generation and processing, quality and errors, far-field HRTF databases.
	Feb 26 - Mar 2	Near-field HRTF measurements, time and frequency domain features of HRTF, minimum phase.
8	Mar 5 - 9	Evaluation of ITD and ILD, spectral features of HRTF, physical spectral cues and spectral notches.
9	Mar 12 - 16	Spatial symmetry for HRTF, distance perception cues, symmetry of ITD
10	Mar 19 - 23	Spring Break
11	Mar 26 - 30	Spherical head model for HRTF: far-field calculations, interaural localization cues.
12	Apr 2 - 6	Snowman model for HRTF, numerical techniques, boundary element method. HRTF filter models and approximation, FIR vs IIR, frequency warping.
13	Apr 9 - 13	Spatial interpolation and decomposition of HRTF, principle component analysis (PCA), spatial basis functions, sound-field signal mixing.
14	Apr 16 - 20	Customization of HRTF, binaural reproduction through headphones, binaural reproduction through loudspeakers, crosstalk cancellation.
15	Apr 23 - 27	Final Exams