

MUS_TECH 348

3D Sound and Spatial Audio

Syllabus

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The Goals of this Class:

- To acquaint each participant with the techniques and applications of 3D sound and spatial audio.
- To enable each participant to understand the literature of 3D sound. This literature spans a wide range of fields and borrows terminology from many disciplines.
- To provide each participant some practical experience with 3D sound in a way which is relevant to their individual area of study. Participants in the class may come from a wide variety of backgrounds spanning multimedia studies to hearing science to computer science. Each person will have the opportunity to do a project related to their own field and interests.

Textbook. Readings In 3-D Sound and Spatial Audio. Course packet is available at Quartet.

Assignment: 3-D Sound Notebook

Over the span of the course, you will construct a notebook that reflects the knowledge you have acquired. The Notebook should both capture the evolution of your experience in the class and represent a summary of what you have learned.

Each person comes to this class with a unique background. One function of the Notebook is to be a vehicle for you to construct a representation of what you have gathered from this course in a way that is relevant to you. This assignment also puts the course's emphasis on your process of integrating information from lectures and readings. The Notebook ought to be an information resource you can keep after the class is over. The Notebook assignment also asks that you take time to reflect on the nature of your learning experience in the class and seek to relate the class to your everyday experience.

Work on the Notebook should be accumulative. This assignment preferences consistent day-by-day, week-by-week work. Don't even think about putting it off. Get started today.

Grade. The course grade will be based **entirely** on the notebook.

Format. The Notebook text must be created with a word processing program that enables the various sections to be expanded incrementally. Be sure to back up your files onto separate disks.

Organization. Your notebook must contain the following sections:

I. Summary of the Class Topics as presented in Lectures, Readings, Discussions, etc. Write a summary of the topics covered in the class. Every topic is supported by class lectures and readings. Imagine that you are writing this for yourself in the future or for someone like yourself. Synthesize the information into a whole and construct an organized summary of the material. (Do not simply include your lecture notes! Do not forget the readings!) Organize your text by topics like the "Schedule of Topics" and use subject headings and subheadings to help organize the material. (Do not include lecture dates or general impressions of lectures!) Write full sentences and complete paragraphs. (Do not write sentence fragments and constantly make lists.)

II. Project. A project of your design depending on your own area of specialization. For most people this will probably be a research paper on a topic of 3-D sound related to their own interests. For people with a background in synthesis, it could be an application or demonstration. For people in the creative arts, this might also be a creative work. A project proposal should be included in the notebook when it is reviewed by the instructor during the 3rd to 4th weeks. All project proposals require the approval of the instructor. A draft version of the project should be included when the notebook is turned in during the 6th to 7th weeks.

III. Diary. Personal reflections (at least one for every week) that capture the evolution of your subjective reactions to and ideas about the topic. Include here any reflections you have on your learning process, ways in which the class impacts your day to day thoughts and experiences, ideas for alternative things to do, etc. This is also the place to provide feedback to the instructor on how well the course is serving you. Organize the Diary by the date of the entry.

Review by Instructor. The Notebook will be collected for review and comments by the instructor in the 3rd to 4th weeks and the 6th to 7th weeks.

Final Version. The Final Version is due: **Monday, March 13, by 9am.** Don't be late and don't ask for an extension. Turn it in.

Turning In Your Notebook. Turn in your Notebook at room 112 of the Music Administration Building. This room is the departmental office for the Music Studies Department and is located near the main stairway entrance. There will be a large box in the office for holding the projects. Projects should be included with your Notebook.

Picking Up Your Notebook. Notebooks will be available for pickup in room 112.

Schedule of Class Topics

Week 1 Introduction to Acoustics and Psychoacoustics

Lecture: Sound Waves, Frequency, Decibels, Fourier Analysis, Intensity vs. Loudness, Frequency vs. Pitch, Spectrum vs. Timbre, Time Domain vs. Frequency Domain

Readings:

Everest, F. Alton. (1994) "Fundamentals of Sound" Chapter 1 from Master Handbook of Acoustics, McGraw-Hill, New York.

Everest, F. Alton. (1994) "Psychoacoustics." Chapter 2 from Master Handbook of Acoustics, McGraw-Hill, New York.

Week 1-2 Physical Acoustics of Directional Hearing

Lecture: Interaural Intensity Difference (IID), Interaural Time Difference (ITD), Head-Related Transfer Functions (HRTF), HRTF Measurements

Readings:

3D Working Group of the Interactive Audio Special Interest Group 3DWG of the MIDI Manufacturers Association. (1998) "3D Audio Rendering and Evaluation Guidelines, version 1.0" "3D Audio Primer," pp. 2-15.

Kendall, Gary S. (1995) "A 3-D Sound Primer: Directional Hearing and Stereo Reproduction." *Computer Music Journal*, 19(4), introduction and "Physical Acoustic Perspective," pp. 23-31.

Kanana, Yuvi, Philip A. Nelson, Maurice Petyt, Sunghoon Choi (1999). "Numerical Modelling of the Transfer Functions of a Dummy-Head and of the External Ear." *The Proceedings of the AES 16th International Conference*, Rovaniemi, Finland, pp. 330-345.

Algazi, V. Ralph, Richard O. Duda, and Dennis M. Thompson (2002). "The Use of Head-and-Torso Models for Improved Spatial Sound Synthesis." *Paper 5712, The 113th AES Convention.*"

Week 3-4 Psychoacoustics of Directional Hearing

Lecture: Lateralization, Externalization, IID/ITD, HRTFs, Monaural vs. Binaural, Localization Blur, Front/Back Confusion, Head Movement, Testing and Evaluation

Readings:

Kendall, Gary S. (1995) "A 3-D Sound Primer: Directional Hearing and Stereo Reproduction." *Computer Music Journal*, 19(4), "Psychoacoustic Perspective," pp. 31-33.

3D Working Group of the Interactive Audio Special Interest Group 3DWG of the MIDI Manufacturers Association. (1998) "3D Audio Rendering and Evaluation Guidelines, version 1.0" "3D Audio Evaluation Guidelines," pp. 16-24.

Blauert, Jens. (1974) *Spatial Hearing*, trans. John S. Allen, MIT Press, Cambridge MA. Excerpt from Chapter 2, pp. 36-50.

Wightman, Frederic L., Kistler, Doris J. (1989) "Headphone simulation of free-field listening. I: Stimulus synthesis." *J. Acoust. Soc. Am.*, 85(2), 858-867.

Wightman, Frederic L., Kistler, Doris J. (1989) "Headphone simulation of free-field listening. II: Psychophysical validation." *J. Acoust. Soc. Am.*, 85(2), 868-878.

Martens, William L. (2003). "Perceptual Evaluation of Filters Controlling Source Direction: Customized and Generalized HRTFs for Binaural Synthesis." *Acoustical Science and Technology*, 24 (5), 220-232.

Begault, Durand R. (1991) "Challenges to the Successful Implementation of 3-D Sound." *J. Audio Eng. Soc.*, 39(11), 864-870.

Week 5-6 Headphone and Stereo Loudspeaker Reproduction

Lecture: Binaural Recording, Equalization, Head-tracking, Externalization, Intensity Stereo, Precedence Effect, Digital Filtering and Convolution, Efficiency: Data Reduction and Computational Shortcuts, Crosstalk Cancellation, Transaural Reproduction

Readings:

Kendall, Gary S. (1995) "A 3-D Sound Primer: Directional Hearing and Stereo Reproduction." *Computer Music Journal*, 19(4), "Reproduction of 3D Sound," pp. 36-44.

- Sunier, John. (1986) "A History of Binaural Sound." *Audio*, March, 1986, pp. 36-46.
- Bauer, Benjamin B. (1961) "Phasor Analysis of Some Stereophonic Phenomena," *J. Acoust. Soc. Am.*, 33(11), 1536-1539.
- Schroeder, M. R. and Atal, B. S. (1963) "Computer Simulation of Sound Transmission In Rooms." *IEEE Int. Conv. Record*, 7, 150-155.
- Begault, Durand R. (1994) Excerpt beginning with "Implementing HRTF Cues" from "Chapter Four Implementing 3-D Sound." pp. 135-168 from *3-D Sound for Virtual Reality and Multimedia*, Academic Press, Cambridge, MA.
- Durlach, N. I., Rigopulos, A., Pang, X. D., Woods, W. S., Kulkarni, A., Colburn, H. S., and Wenzel, E. M. (1992) "On the Externalization of Auditory Images." *Presence*, 1(2), 251-257.
- Gardner, William G. (1995) "Transaural 3-D Audio." M.I.T. Media Laboratory Computing Section Technical Report No. 342, July 20, 1995.
- Gardner, William G. (1997) "Head Tracked 3-D Audio Using Loudspeakers." *Proc. 1997 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics*, New Paltz, NY.

Week 6-7 Environmental Sound I: Reverberation

Lecture: Reverberation and Reverberation Time, Artificial Reverberation, Image Model, Doppler Shift, Subjective Evaluation of Concert Halls, Occlusion

Readings:

- 3D Working Group Interactive Audio Special Interest Group 3DWG of the MIDI Manufacturers Association. (1999) "Interactive 3D Audio Rendering Guidelines, Level 2.0" pp. 1-10.
- Schroeder, M. R., Gottlob, D., and Siebrasse, K. F. (1974) "Comparative study of European concert halls: correlation of subjective preference with geometric and acoustic parameters." *J. Acoust. Soc. Am.*, 56(4), 1195-1201.
- Rasch, R. A. & Plomp, R. (1982) "The Listener and the Acoustic Environment" from the *Psychology of Music*, edited by Diana Deutsch, Academic Press, New York.
- Schroeder, M. R. (1962) "Natural Sounding Artificial Reverberation." *J. Audio Eng. Soc.*, 10(3), 219-223.
- Chowning, John M. (1971) "The Simulation of Moving Sound Sources." *J. Audio Eng. Soc.*, 19(1), 2-6. [This printing taken from *Computer Music Journal*]
- Kendall, Gary S. and Martens, William L. (1984) "Simulating the Cues of Spatial Hearing in Natural Environments." *Proceedings of the 1984 International Computer Music Conference*, Paris.

Week 7-8 Environmental Sound II: Spaciousness, Precedence and Distance

Lecture: Interaural Crosscorrelation, Spaciousness, Decorrelation, Distance Perception, Precedence Effect Revisited

Readings:

- Kendall, Gary. (1995) "The Decorrelation of Audio Signals and Its Impact on Spatial Imagery." *Computer Music Journal*, 19(4), 71-87.
- Griesdinger, David (1999). "Objective Measures of Spaciousness and Envelopment." *The Proceedings of the AES 16th International Conference*, Rovaniemi, Finland.
- Martens, William L (1999). "The Impact of Decorrelated Low-Frequency Reproduction on Auditory Spatial Imagery: Are Two Subwoofers Better Than One?" *The Proceedings of the AES 16th International Conference*, Rovaniemi, Finland.

- Gardner, M. B. (1968) "Historical background of the Haas and/or precedence effect." *J. Acoust. Soc. Am.*, 54, 1243-1295.
- Zahorik, Pavel (2002). "Auditory Display of Sound Source Distance." *Proceedings of the 2002 International Conference on Auditory Display*, Kyoto, Japan.

Week 8-9 More Multi-Loudspeaker Considerations

Lecture: Localization with Multiple-Loudspeakers, Ambisonic recording and reproduction, Encoding and Decoding Multi-channel Audio,

Readings:

- Pulkki, Ville (2001) "Localization of Amplitude-Panned Virtual Sources II: Two- and Three-Dimensional Panning." *J. Audio Eng. Soc.*, 49(9).
- Gerzon, Michael A. (1985) "Ambisonics in Multichannel Broadcasting and Video." *J. Audio Eng. Soc.*, 33(11).
- Jot, Jean-Marc, Lacher, Veronique and Pernaux, Jean-Marie. (1999) "A Comparative Study of 3-D Audio Encoding and Rendering Techniques," from *The Proceedings of the AES 16th International Conference*, Rovaniemi, Finland, pp. 281-300.
- Bosi, Marina (1999). "High Quality Multichannel Audio Coding: Trends and Challenges." *Proceedings of the AES 16th International Conference*, Rovaniemi, Finland.

Week 10 Presentation of Projects by Class Members