Wavelets and Signal Processing with Applications

EE 6391-002, CRN-20326
Fall 2022

Syllabus

Department of Electrical & Computer Engineering
The University of Texas at El Paso, El Paso, Texas 79968, USA
R. von Borries
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Contents

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Monday, August 22, 2022

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1 General Information

- **Course ID:** Individual Studies, EE 6391-002, CRN-20326
- **Time:** Friday, 5:30 pm to 8:10 pm
- **Lecture Room:** Engineering Building E324
- **Prerequisites:** Discrete-Time Signals and Systems EE 4383
- **References:** (1) C. S. Burrus, R. Gopinath, and H. Guo. *Wavelets and Wavelet Transforms*. OpenStax-CNX, 2015. http://cnx.org/content/col11454/1.6/ [BGG15]; and (2) S. Mallat. *A Wavelet Tour of Signal Processing: The Sparse Way*. Elsevier Science, 3rd edition, 2008 [Mal08]
- **Computational Software:** `Matlab`® [uMa] [uMb] and `Mathematica` [Mat]
- **Instructor:** von Borries – `rvonborries@utep.edu`
- **Office:** Engineering Building 313
- **Office Hours:** MW 6:00 pm to 7:00 pm (room 313 or Blackboard)
  F 4:00 pm to 5:00 pm (room 313 or Blackboard)
- **Version:** Monday, August 22, 2022

2 Description

Wavelets and Signal Processing with Applications is a doctoral level *Individual Studies* course implemented to enhance both (1) research expertise on wavelets and signal processing; and (2) research collaboration between UTEP and Sandia National Laboratories with application in the power systems area (e.g. detection and localization of faults in electric power lines).

3 Textbook and Numerical Computation Software

Wavelets and Signal Processing with Applications has two required resources: (1) the textbook by C. S. Burrus, R. Gopinath, and H. Guo. *Wavelets and Wavelet Transforms*. OpenStax-CNX, 2015. http://cnx.org/content/col11454/1.6/; (2) the textbook by S. Mallat. *A Wavelet Tour of Signal Processing: The Sparse Way*. Elsevier Science, 3rd edition, 2008 (available at UTEP's library); and (3) the software `Matlab`® for numerical computation and visualization developed by The MathWorks, Inc. [uMa, `Matlab`® on MathWorks].

4 Course Topics

1. Fourier Domain [Mal08, Chapter 2]
   (a) Linear time-invariant filtering: impulse response, transfer function
   (b) Fourier integrals: in $\mathbf{L^1}(\mathbb{R})$, in $\mathbf{L^2}(\mathbb{R})$
   (c) Properties: regularity and decay, uncertainty principle, total variation
   (d) Two-dimensional Fourier transform
2. Discrete-time Signals and Systems [Mal08, Chapter 3]
   (a) Sampling analog signals: sampling theorem, aliasing
   (b) Finite signals: circular convolution, discrete Fourier transform
3. Introduction to Wavelets [BGG15, Chapters 1, 2]
   (a) Wavelet transform: scaling, translation, Haar scaling functions and wavelets
   (b) Continuous wavelet transforms: continuous-time and continuous-scale
   (c) Discrete wavelet transforms: discrete-time and discrete-scale
4. Multiresolution Analysis [BGG15, Chapter 3]
   (a) Signal spaces: multiresolution analysis, scaling functions, wavelet functions, discrete-wavelet transform
   (b) Parseval's theorem
   (c) Examples of discrete wavelet expansions

5. Filter Banks and Discrete Wavelet Transform [Vai93, Chapter 4], [BGG15, Chapter 4]
   (a) Basic multirate operations: upsampling, downsampling, filtering, interpolation, decimation, building blocks, polyphase representation, multistage implementations
   (b) Wavelet analysis: from fine scale to coarse scale
   (c) Wavelet synthesis: from coarse scale to fine scale
   (d) Input coefficients
   (e) Multiresolution versus time-frequency analysis
   (f) Periodic versus nonperiodic discrete wavelet transforms
6. Frames [BGG15, Chapter 5]
   (a) Bases: orthogonal, biorthogonal
   (b) Frames and tight frames
7. Properties of Scaling and Wavelet Functions [BGG15, Chapter 6]
   (a) Scaling functions: time-domain and frequency-domain necessary conditions, sufficient conditions
   (b) Wavelet functions: properties
   (c) Examples
   (d) Iterating the filter bank
8. Regularity and Moments [BGG15, Chapter 7]
   (a) Regular scaling filters
   (b) Vanishing wavelet moments
   (c) Daubechies' wavelets
9. Applications [Mal08, Chapter 11]
   (a) `Matlab`® toolbox
   (b) Wavelet denoising: signal denoising, image denoising
   (c) Detection and localization of faults in electric power lines
   (d) Compressive sensing

5 Evaluation

Based on activities developed by the student, under instructor guidance, including: active participation in classroom discussions, lecture assignments with classroom summary presentations, mathematical detailed description of main concepts, and scientific programming of several small projects.

6 Grading

$A = 100 - 90\%$, $B = 90 - 80\%$, $C = 80 - 70\%$, $D = 70 - 60\%$ and $F = 60 - 0\%$.

7 Attendance

Class attendance is mandatory and will be monitored. Any student with more than two unexcused absences will be dropped out of the EE 6391.

8 Textbooks and Related References

[BGG15] C. S. Burrus, R. Gopinath, and H. Guo. *Wavelets and Wavelet Transforms*. OpenStax-CNX, 2015. http://cnx.org/content/col11454/1.6/.

[Coh95] L. Cohen. *Time-Frequency Analysis*. Prentice Hall, Upper Saddle River, NJ, 1995.

[Dau92] I. Daubechies. *Ten Lectures on Wavelets*. SIAM, Philadelphia, PA, 1992. CBMS-NSF Regional Conference Series in Applied Mathematics.

[Mal08] S. Mallat. *A Wavelet Tour of Signal Processing: The Sparse Way*. Elsevier Science, 3rd edition, 2008.

[Mat] Mathematica. Wolfram Research, Inc. https://www.wolfram.com/mathematica.

[Mey93] Y. Meyer. *Wavelets: Algorithms and Applications*. SIAM, Philadelphia, PA, 1993. Translated and Revised by Robert D. Ryan.

[OS89] A. V. Oppenheim and R. W. Schafer. *Discrete-Time Signal Processing*. Prentice Hall, Upper Saddle River, NJ, 1989.

[OV16] A. V. Oppenheim and G. C. Verghese. *Signals, Systems and Inference*. Pearson, New York, NY, 2016.

[uMa] https://www.mathworks.com/help/matlab/getting-started-with-matlab.html. Matlab® documentation.

[uMb] https://www.youtube.com/user/MATLAB?feature=watch. Matlab® tutorials.

[Vai93] P. P. Vaidyanathan. *Multirate Systems and Filter Banks*. Prentice Hall, 1993.

A Calendar

EE 6391, F 5:30 pm to 8:10 pm

August

M	T	W	R	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

2022

September

M	T	W	R	F	S	S
			1	2	3	4
	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

2022

October

M	T	W	R	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

2022

November

M	T	W	R	F	S	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23			26	27
28	29	30				

2022

December

M	T	W	R	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

2022

- ☐ **Labor Day, UTEP Closed**
  September 5, Monday
- ☐ **Course Drop/Withdrawal Deadline**
  October 28
- ☐ **Thanksgiving, UTEP closed**
  November 24 to 25