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Teach-Ware: Signal Processing Resources at Connexions

Please send suggestions for Web resources of interest to our readers, proposals for columns, as well as general feedback, by e-mail to Dong Yu ("Best of the Web" associate editor) at dongyu@microsoft.com.

In this issue, "Best of the Web" presents signal processing education resources available at Connexions (http://cnx.org). Connexions is a platform and environment for scholars to collaboratively develop and rapidly publish educational materials on the Web. It is based on a new approach to education that seeks to provide a place where everyone in the world can freely share knowledge, and it provides equal access to all people via tools that permit everyone ranging from university professors to school children to post and update knowledge in one place.

There are three general categories of users: 1) students, who use Connexions to access information online, to prepare for their classes and review the class materials; 2) authors, who enter content into Connexions in document files called modules; and 3) instructors, who build courses as documents created by linking related modules together in a specific order.

The materials published are typically organized in small modules that can be connected into larger collections and used in different courses and contexts. Instructors can further customize content by overlaying their own set of links and annotations. All the contents published on Connexions are free to use and reuse under the Creative Commons (http://creativecommons.org/) "attribution" license.

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Connexions may be browsed by subject or searched using keywords directly from the Connexions content page. They can also be discovered from generic search engines. At the time of this writing (3 November 2008), there are a total of 7,047 reusable modules woven into 399 collections. These include 496 modules for arts, 83 modules for business, 307 modules for humanities, 1,417 (35 collections) modules for mathematics and statistics, 3,440 modules (234 collections) for science and technology, and 612 modules for social sciences. Due to the large number and broad range of fields, we will not be able to cover all resources available. Instead, we will sample material to give readers a sense of what is available.

Among hundreds of collections in the category of science and technology, we found a few dozen of them with relatively rich contents including:

- audio localization
- array signal processing
- digital communication systems
- digital filter design
- digital signal processing
- elements of detection theory
- estimation theory
- fast Fourier transforms
- frequency and music
- freshman engineering problem solving with MATLAB
- fundamentals of signal processing
- image coding
- gravitation fundamentals
- methods for voice conversion
- multirate signal processing
- principles of object-oriented programming
- seismic imaging
- signals and systems
- speech signal analysis
- statistical learning theory
- statistical signal processing.

For example, in the collection of audio localization, the material covers the following practical aspects of the topic:

- audio localization problem motivation and goal
- beamforming theory
- design decisions for audio localization implementation
- MATLAB simulation of audio localization
- hardware implementation for audio localization
- software implementation of audio localization
- results and discussion on audio localization
- conclusions on audio localization project
- appendix for audio localization project.

Both theory and applications are covered with the content appropriate for classroom presentation, and with proper Matlab codes and illustrations.

The collection of fast Fourier transform, which is cross-listed in the category of mathematics/statistics and science/technology, has particularly detailed coverage of the topic, with the following table of contents:

- Preface: Fast Fourier Transforms
- Introduction: Fast Fourier Transforms
- Multidimensional Index Mapping
- Polynomial Description of Signals
- The DFT as Convolution or Filtering
- Factoring the Signal Processing Operators
- Winograd's Short DFT Algorithms
- DFT and FFT: An Algebraic View
- The Cooley-Tukey Fast Fourier Transform Algorithm
- The Prime Factor and Winograd Fourier Transform Algorithms

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- Implementing FFTs in Practice
- Algorithms for Data with Restrictions
- Convolution Algorithms
- Comments: Fast Fourier Transforms
- Conclusions: Fast Fourier Transforms
- Appendix 1: FFT Flowgraphs
- Appendix 2: Operation Counts for General Length FFT
- Appendix 3: FFT Computer Programs
- Appendix 4: Programs for Short FFTs

Similarly, among the collections in the category of mathematics and statistics, we found a number of interesting ones with good content, including matrix analysis, random processes, functions, state-space systems, collaborative statistics, and statistical learning theory. The matrix analysis collection gives particularly rich content, as reflected by the following list of topics (subtopics omitted):

- Matrix Methods for Electrical Systems
- Matrix Methods for Mechanical Systems
- The Fundamental Subspaces
- Least Squares
- Matrix Methods for Dynamical Systems
- Complex Analysis 1
- Complex Analysis 2
- The Eigenvalue Problem
- The Symmetric Eigenvalue Problem
- The Matrix Exponential
- Singular Value Decomposition.

Some more advanced topics are also available in the category of mathematics and statistics, such as statistical learning theory. Excellent and detailed materials have been created in this collection, including:

- basic elements of statistical decision theory and statistical learning theory
- elements of statistical learning theory
- the introduction to classification and regression
- the introduction to complexity regularization
- an example of the use of sieves for complexity regularization in denoising
- plug-in classifier and histogram classifier
- probably approximately correct (PAC) learning
- Chernoff's bound and Hoeffding's inequality
- classification error bounds
- error bounds in countably infinite spaces
- complexity regularization
- decision trees
- complexity regularization for squared error loss
- maximum likelihood estimation
- maximum likelihood and complexity regularization
- denoising II: adapting to unknown smoothness
- nonLinear approximation and wavelet analysis
- Vapnik-Chervonenkis Theory
- the Vapnik-Chervonenkis inequality
- applications of VC bound
- lower performance bounds for estimators.

All resources (i.e., collections and the modules) can be readily accessed by visiting http://cnx.org/ and by clicking the "Content" tab. Unless otherwise noted, the resources are free. This resource list is also available by convenient point and click on the *IEEE Signal Processing Magazine* Web site. From the "Contact Us" tab on the Web site http://cnx.org/, one can find descriptions of the philosophy of Connexions, FAQ, media news (including a recent *New York Times* article describing the changing textbook marketplace and the role of online services providing free and low-cost alternatives), as well as numerous papers and presentations about Connexions from seminars, conferences, and meetings.

Connexions is different in many ways from other open education projects. For example, it has content from all over the world in a growing variety of languages, not just materials from one specific school or university (e.g., versus MIT OpenCourseWare, http://ocw.mit.edu). It also collects materials to support a wide range of education from K–12, community college, university, continuing education, to industrial training. Further, rather than from top down like many other open education projects, Connexions is organized from bottom up and everyone is free to join and take charge.

Connexions also serves somewhat different purposes from Wikipedia. Let's use a specific scenario. If one is interested in learning basic elements of music, a search on the Web gives the Connexions collection in http://cnx.org/content/col10218/latest/ (created by a part-time music teacher). This collection gives rather comprehensive explanations of the subject suitable for any age, with suggested activities for introducing each useful concept to children at early elementary school level. The course may be used by instructors not trained in music, with all necessary definitions and explanations included. Information on the same subject from Wikipedia is more meager.

With Connexions, one can not only find and use relevant materials, but also easily create them. Several small, self-contained, chunks of information called modules can be created and then joined into a collection to form a course, book, report, or survey. A module can contain only text, or be made more interesting by adding tables, images, sounds, and videos. Modules are stored in a markup language to facilitate reuse and portability. On the Web site http://cnx.org/help/ModuleInMinutes, one can find three basic steps to create a Connexions module: 1) get an account and log in to the personal workspace; 2) create content either from scratch using an online editor or convert it from a Microsoft Word document; and 3) publish the content. Steps are also given to create a collection from existing modules.

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