TEACHING WAVELETS WITH JAVA ON THE INFORMATION SUPERHIGHWAY

Haitao Guo, Jan E. Odegard and C. Sidney Burrus

ECE Department, Rice University
Houston, TX 77251-1892

ABSTRACT

One of the most exciting new developments on the information superhighway is the Java language of the Sun Microsystem. Java is portable, powerful, and network-aware. This paper presents some ideas and experiments on teaching wavelets and signal processing using Java. The URL for our wavelets applets is `http://www-dsp.rice.edu/edu`.

1. INTRODUCTION

Wavelet theory is a young field whose emphasis has increased tremendously in recent years. Although more and more books [8, 1, 2, 3, 12, 13, 14] and courses are devoted to this subject, the mathematical concepts used in wavelets theory can be rather difficult to learn. It is even harder to understand its relation with multirate digital signal processing, and to apply wavelet theory to real applications. There are several software toolbox available for wavelet-based signal and image processing, e.g. rice-wavelet-toolbox [15] from Rice University, Wavelab [18] from Stanford University, wavelet toolbox in Khoros [19], uni-wave [17], UNICODER [16] from university of Wisconsin. But some of them require Matlab or Khoros to run under, and they require costly installation and maintaining, especially across several platforms. They are excellent tools for research, but not for beginners who want to learn wavelets for the first time.

On the other hand, wavelet theory is related to multiresolution analysis [7] which has very intuitive meaning, and can be effectively shown visually. Many other aspects of wavelet theory can also be show graphically, e.g. time-scale contents of the signal, the tree structure of the wavelet packet transform. Thus a hand-on graphical tool would be very valuable for teaching wavelet theory.

The Internet has become an increasingly important channel for information distribution. Many impressive experiments have been conducted on remote teaching using the Internet and the World Wide Web [9, 5, 6, 10].

The Java language of Sun Microsystem is one of the most exciting new development on the information superhighway. Java is portable, compact, powerful, and network-aware. People can load your Java program (applet) over the network, and run your Java program on their PCs or workstations. The only requirements are a Java-enabled browser (e.g. Netscape 2.0) and some kind of connectivity to the Internet. Java also provides powerful yet simple graphic user interface (GUI), and network support. These make Java an ideal language for teaching wavelet theory on the information superhighway.

In this paper, we first give an overview of Java, showing why it is suitable for network distributed teaching. Then we present some ideas and experiments on teaching wavelet theory using Java.

2. WHY JAVA?

Java is a network-aware language superficially resembling C++, but much smaller and more compact and cleanly designed. It's an unlimited-extent language with garbage collection like Lisp, but with static type checking. It includes lightweight processes (threads) as a native facility and has powerful network-security features. The ability to safely pass around code objects probably represents the most significant advance in WWW technology since the first release of Mosaic. As a language Java is,

Simple Java has the bare bones functionality needed to implement its rich feature set. It does not add lots of syntactic sugar or unnecessary features. So Java is easy to learn and use. Java has builtin garbage collection and bound check for array data. Thus it is also safer to use.

Object-Oriented Almost everything in Java is either a class, a method or an object. Only the most basic primitive operations and data types (int, for, while, etc.) are at a sub-object level. It is easy to reuse codes in Java.

Platform Independent Java programs are compiled to a byte code format that can be read and run by interpreters on many platforms including Windows 95, Windows NT, SunOS, Mac, and Solaris.

The data types are also platform independent. The floating-point type `float` and `double`, representing single-precision 32-bit and double-precision 64-bit format IEEE 754 values and operations as specified in IEEE *Standard for Binary Floating-Point Arith-*

This research is supported in part by TI, BNR, and Texas ATP grant.

metic, ANSI/IEEE Std. 754-1985 (IEEE, New York). So we are guaranteed to have the same result on different platforms, which is important for signal processing applications.

Applets Java applications can be embedded in HTML documents (called applets), and automatically executed by the Java interpreter when the documents is received. This capability allows for the developments of interactive applications over the network.

Network Aware Java is designed for the Internet. We can use Java to access anywhere on the Internet. For example we can load data directly from other machines on the Internet which we have `ftp` or `http` access to. We can even load programs from other site, thus facilitates cooperation.

High Performance We have test pure numerical applications like the FFT, the program in Java is about 10 times slower than native C, but still fast enough for applications like demonstration and teaching. Several company and people are working on just-in-time (JIT) compilation of Java code to native code. One day Java will be compilable on the fly to code that rivals C++ in speed.

Client Side Application Java runs on the client side. So it does not use the processing power of the server. It is especially good for remote teaching, since many students may use the server at the same time. Before Java, people have to relay on *Common Gateway Interface* (CGI) for interactive application. Not only server has to do all the processing, the response time is poor because all the requests and responses have to go through the network.

3. WAVELETS APPLETS

We teach wavelet by providing a set of Java programs (applets). They have similar graphical user interface. Students can choose different signals and wavelets from the menu. They can also load their own data. Students are asked to click or drag mouse in the left figure window, and observe the result in the right figure window. Many options can be chosen from the menu to control the representation of the results in the right figure window, e.g. time domain representation, frequency domain representation.

Here we describe some of the wavelets applets we designed.

3.1. Wavelets and Scaling function

Wavelets and Scaling functions are related by two scale recursive equations. This applet demonstrates the relationship among wavelets and scaling functions on different scales and at different translations.

3.2. Wavelet-based Multiresolution analysis

This applet demonstrates the wavelet-based multi-resolution analysis. Students are encouraged to click in the input figure to choose the subspace, and watch the projection in that subspace shown in the display figure. Students can either inspect wavelet spaces (W spaces) or scaling spaces (V spaces). A snapshot is shown in Figure 1.

3.3. Pick Your Wavelets

This applet demonstrates the parameterization of the scaling coefficients. All the length-6 wavelets can be parameterized by two free parameters from $-\pi$ to π. The students are encouraged to click or drag the mouse in the left-hand figure to adjust those two parameters, and watch the wavelet and/or scaling function change in the right-hand figure. For classical wavelets, students can pull down the Wavelets menu, and locate the parameters in the plane. A snapshot is shown in Figure 2.

3.4. Denoising via Wavelet Thresholding

Noise Reduction via Wavelet Thresholding is a powerful method [4]. This applet demonstrates this technique. The students can choose the signal and noise, and adjust the threshold, then see the result instantly. A snapshot is shown in Figure 3.

3.5. Wavelet based Signal Compression

Wavelet has been prove to be a powerful tool for data compression [14]. This applet demonstrates this aspect. The students can choose wavelet and signal they want to compress. They can adjust the quantization levels, and study the rate-distortion characteristics of wavelet-based signal compression algorithms. We have implemented one dimensional version of the embedded zero-tree wavelet compression algorithm [11].

4. SUMMARY

The Java language is portable, powerful, and network-aware. We developed a suite of applets on teaching wavelets and signal processing using Java on information superhighway. We encourage interested readers to try them, and we welcome feedbacks on its performance.

The current URL for our wavelets applets is <`http://www-dsp.rice.edu/edu`>.

REFERENCES

[1] A. N. Akansu and R. A. Haddad. *Multiresolution Signal Decomposition, Transforms, Subbands, and Wavelets.* Academic Press, San Diego, CA, 1992.

[2] C. K. Chui. *An Introduction to Wavelets.* Academic Press, San Diego, CA, 1992.

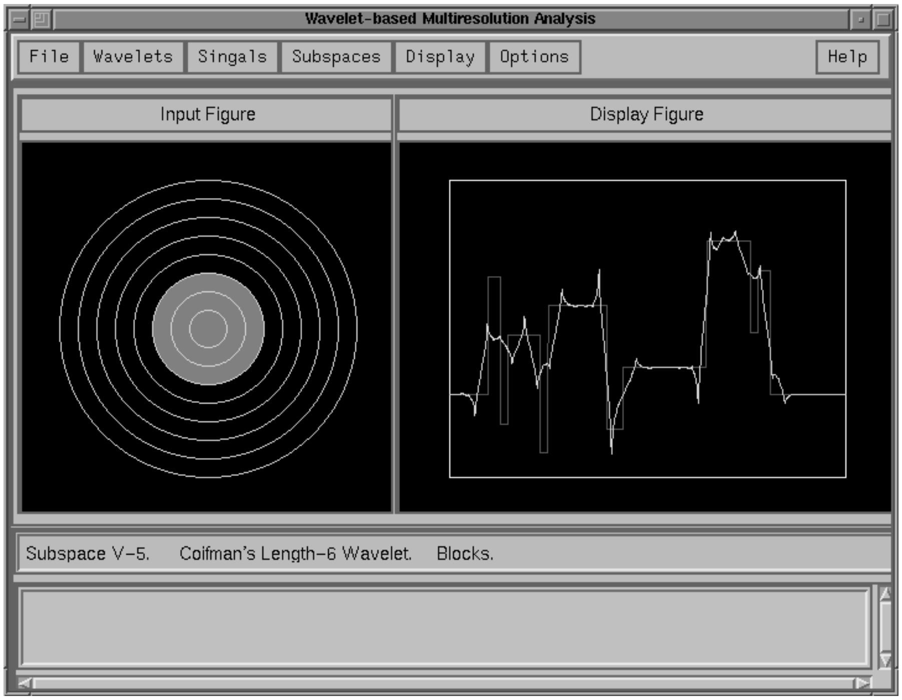

Figure 1: The snapshot of the applet – Wavelet-based Multiresolution analysis

Figure 2: The snapshot of the applet – Pick Your Wavelets.

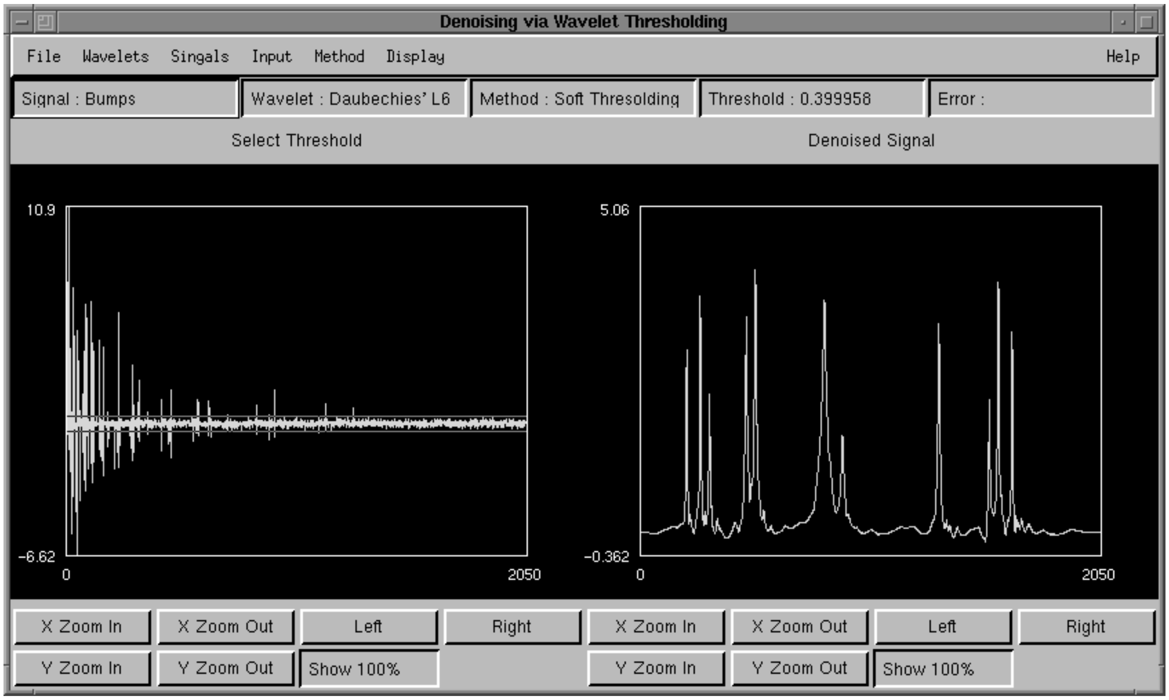

Figure 3: The snapshot of the applet – Noise Reduction via Wavelet Thresholding

[3] I. Daubechies. *Ten Lectures on Wavelets*. SIAM, Philadelphia, PA, 1992. Notes from the 1990 CBMS-NSF Conference on Wavelets and Applications at Lowell, MA.

[4] D. L. Donoho. De-noising by soft-thresholding. *IEEE Trans. Inform. Theory*, 41(3):613–627, May 1995.

[5] D. M. Etter, G. C. Orsak, and D. H. Johnson. Distance teaming experiments in undergraduate DSP. In *IEEE Proc. Int. Conf. Acoust., Speech, Signal Processing*, pages II1109–1112, Atlanta, GA, May 1996. IEEE.

[6] Don H. Johnson. The signal processing information base: A road to electronic information exchange. In *IEEE Proc. Digital Signal Processing Workshop*, pages 139–141, Yosemite, CA, October 1994. IEEE.

[7] S. Mallat. A theory for multiscale signal decomposition: The wavelet representation. *IEEE Trans. on Pattern and Machine Intelligence*, 11(7):674–693, 1989.

[8] Y. Mayer. *Wavelets: Algorithms and Applications*. SIAM, Philadelphia, 1993.

[9] J. H. McClellan, R. W. Schafer, J. B. Schodorf, and M. A. Yoder. Multi-media and world wide web resources for teaching DSP. In *IEEE Proc. Int. Conf. Acoust., Speech, Signal Processing*, pages II1101–1104, Atlanta, GA, May 1996. IEEE.

[10] G. C. Orsak. Teaching signal processing on the information superhighway. In *IEEE Proc. Digital Signal Processing Workshop*, pages 131–134, Yosemite, CA, October 1994. IEEE.

[11] J. M. Shapiro. Embedded image coding using zerotrees of wavelet coefficients. *IEEE Trans. SP*, 41:3445–3462, 1993.

[12] G. Strang and T. Nguyen. *Wavelets and Filter Banks*. Wellesley-Cambridge Press, Wellesley, MA, 1996.

[13] P. P. Vaidyanathan. *Multirate Systems and Filter Banks*. Prentice Hall, Englewood Cliffs, NJ, 1992.

[14] M. Vetterli and J. Kovacevic. *Wavelets and Subband Coding*. Prentice Hall, Englewood Cliffs, NJ, 1995.

[15] Rice wavelet toolbox. Electrical and Computer Engineering, Rice University. `http://www-dsp.rice.edu`.

[16] Unicoder. Multirate Signal Processing Group. University of Wisconsin - Madison. `http://saigon.ece.wisc.edu/~waveweb/QMF/software.html`.

[17] Uni_wave wavelets toolbox. `http://www.tsc.uvigo.es/~wavelets/uvi_wave.html`.

[18] Wavelab. Statistics Department, Stanford University. `http://playfair.Stanford.EDU:80/~wavelab`.

[19] Wavelet toolbox in khoros. `http://www.khoral.com`.