Web-Enabled Physiologic Signal Processing and Analysis

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INTRODUCTION

The WFDB (WaveForm Data Base) Software Package is open-source software that includes a large set of applications for physiologic signal processing and analysis, based upon a common library of subroutines for reading and writing digitized signals and annotations of those signals. PhysioNet, the US NIH-sponsored Research Resource for Complex Physiologic Signals, has made several thousand such recordings freely available via the World Wide Web. The combination of our WFDB library with the World Wide Web Consortium (W3C) libwww libraries permits applications to act as HTTP clients that can read input from web servers such as PhysioNet as well as from local disk files.

METHODS

The WFDB software has been developed over many years, beginning in the early 1980s to support our studies of long-term electrocardiograms and other physiologic signals. The applications thus include highly specialized algorithms such as QRS (beat) detectors in addition to general-purpose tools for tasks such as sampling frequency conversion. To web-enable the WFDB library, we created a set of wrappers for the standard C I/O library, and an object we called a NETFILE. The application programming interface used by the wrappers is identical to that of the standard C I/O functions, except for the use of NETFILE pointers in place of FILE pointers. The wrapper for the file open function sets the file type (local or remote) member of the NETFILE object it references, and it and the other wrappers invoke either a standard C I/O library function or an analogous function from libwww, according to the file type. We then replaced the WFDB library's I/O function calls with calls to the wrappers. The resulting software is portable across all of the popular platforms (including GNU/Linux, Mac OS/X, MS-Windows, and all versions of UNIX).

Applications that use the WFDB library locate their inputs by searching for them in an ordered list of locations that can be modified by the user in the same manner as the command execution path. Users of WFDB software can keep local copies of frequently-used files, and arrange for others to be retrieved from PhysioNet or other web servers, simply by including both disk directories and web addresses in the search path.

RESULTS

Between 600 and 900 PhysioNet visitors download the WFDB Software Package each month from the PhysioNet master server. Between 15% and 20% of all data downloaded from PhysioNet each month are retrieved not by web browsers, but by WFDB applications. Over 80 web-enabled WFDB applications are currently available. One of the most useful of these is WAVE, an application providing a virtual chart recorder with interactive facilities for annotating signals and for signal processing and analysis using external WFDB plugins. Cooperating WAVE processes running on networked systems can maintain synchronization while interacting with users at each location.

DISCUSSION AND CONCLUSION

Web-enabling the WFDB Software Package has allowed us to provide researchers with an alternative to downloading and local storage of lengthy recordings from PhysioNet and other web servers, and has stimulated new collaborative analyses of physiologic signals and time series by geographically dispersed researchers. This software, which is freely available in source form from http://www.physionet.org/, can be of particular value in telemedicine, where the centers for data collection, storage, and interpretation may be distant from each other.

Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng CK, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* 101(23):e215-e220 [Circulation Electronic Pages; http://circ.ahajournals.org/cgi/content/full/101/23/e215]; 2000 (June 13).