

WaveForm DataBase Toolbox for MATLAB and Octave

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- 1 MATLAB, Octave, and the WFDB Toolbox
 - Origins of MATLAB and Octave
 - What are the advantages of using MATLAB/Octave ?
 - User community
 - What is the WFDB Toolbox for MATLAB/Octave?
- 2 Getting Started
 - Installation
 - Exploring the toolbox
 - Getting help
 - PhysioNet Tools (Alpha)
- 3 Future work
- 4 Getting involved

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Origins of MATLAB and Octave

MATLAB

- MATrix LABoratory (MATLAB).
- Developed by Cleve Moler in the 1970s.
- Purpose: teach matrix theory at University of New Mexico.



Origins of MATLAB and Octave

Octave

- Octave is an open source (GPL) project that is similar to MATLAB
- Developed by John W. Eaton in 1988 for chemical reactor design course
- Named after his professor, Octave Levenspiel



What is MATLAB/Octave ?

Characteristics of the language

- Scripting language (not strongly typed), biased towards high precision numerical computations:
 - $x=1$ (defaults to 64 bit double)
- Integrated development environment with debugger & compiler
- Heavy use of linear algebra libraries

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What are the advantages of using MATLAB/Octave ?

Outline

- Language syntax and libraries suitable for applying signal processing and linear algebra techniques
- Graphics
- Highly portable and very well documented
- Strong user community

What are the advantages of using MATLAB/Octave ?

Language syntax and libraries

- Very concise and intuitive syntax for developing linear algebra and signal processing algorithms:

$$y = Ax$$

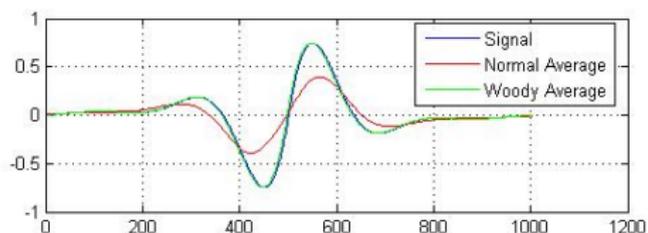
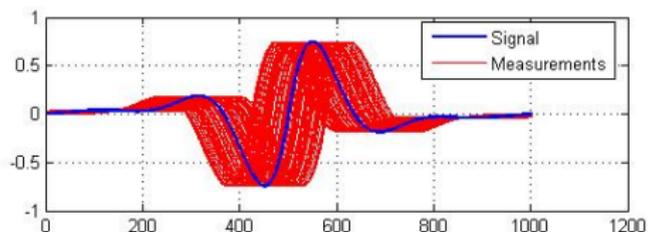
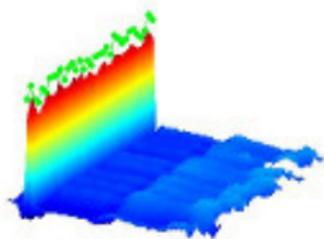
$$x = A \backslash y$$

- Libraries for filter design, wavelets, control systems, neural networks, image processing, statistics ... etc
- Ideal for quickly developing, testing, and cross validating

What are the advantages of using MATLAB/Octave ?

Graphics

- Easy to use and well documented graphics library



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- Used by students, researchers, government, and industry
- Academic textbooks (Over 5k books in Amazon)
- Active forum, magazine, developer blogs, and code repository (MATLAB Central)
- Ranked 14th most popular programming language (tiobe.com)

MATLAB/Octave User Community

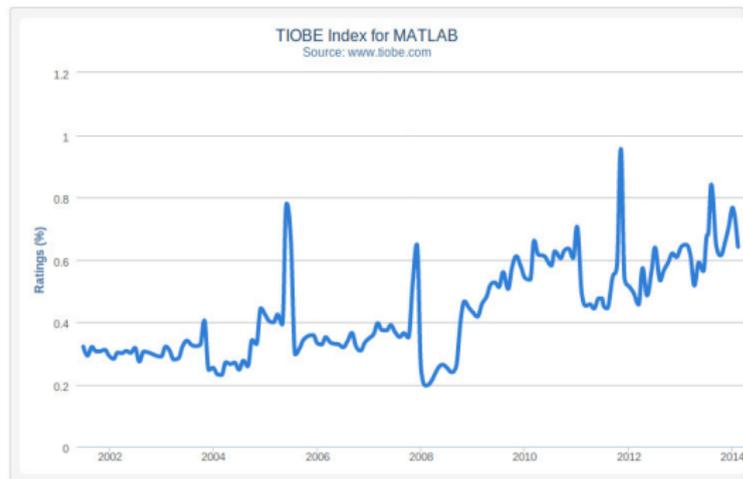
TIOBE Index : Ranked 14th

- Increasing trend in user base
- Ahead of: PL/SQL, Scala, Lisp, and R

Some information about MATLAB:

📈 Highest Position (since 1993): #14 in Feb 2014

📉 Lowest Position (since 1993): #29 in Aug 2011



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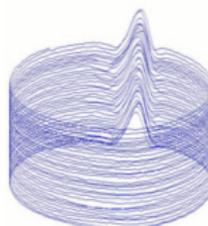
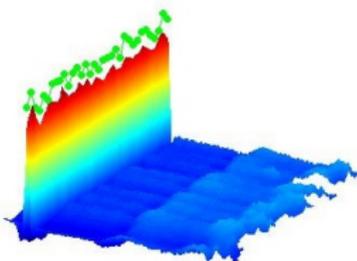
WFDB Toolbox for MATLAB/Octave Described

Description

- MATLAB/Octave/Java functions for accessing and processing physiologic signals in the formats used by PhysioBank databases



Current release: version 0.9.6.1
Last updated February 10, 2014 (see the [change log](#))



- [Quick Start](#)
- [Toolbox functions](#)
- [Acknowledgments](#)
- [Community Forum](#)

The WFDB Toolbox for MATLAB and Octave is a collection of functions for reading, writing, and processing physiologic signals and time series in the formats used by [PhysioBank databases](#) (among others). The Toolbox is compatible with 64-bit MATLAB and [GNU Octave](#) on GNU/Linux, Mac OS X, and MS-Windows.

When using any of these functions in your work, please look at the help for that function to see how to cite the original publication and authors.

In addition, please cite the following paper in any publications that make use of this toolbox:

WFDB Toolbox for MATLAB/Octave Described

Contributors

Contributors:

Sahar Alkhairy, Fernando Andreotti, Joachim Behar, Thomas Brennan, Eudald Bogatell, Gari D. Clifford, Michael Craig, Mohammad Ghassemi, Li-wei Lehman, Erina Katsumata, Sara Mariani, Louis Mayaud, Bla Merela, Benjamin Moody, George Moody, Shamin Nemati, Bryann Tripp, Daniel J. Scott, Ikaro Silva, Gabriel Squillace



www.against-the-grain.com

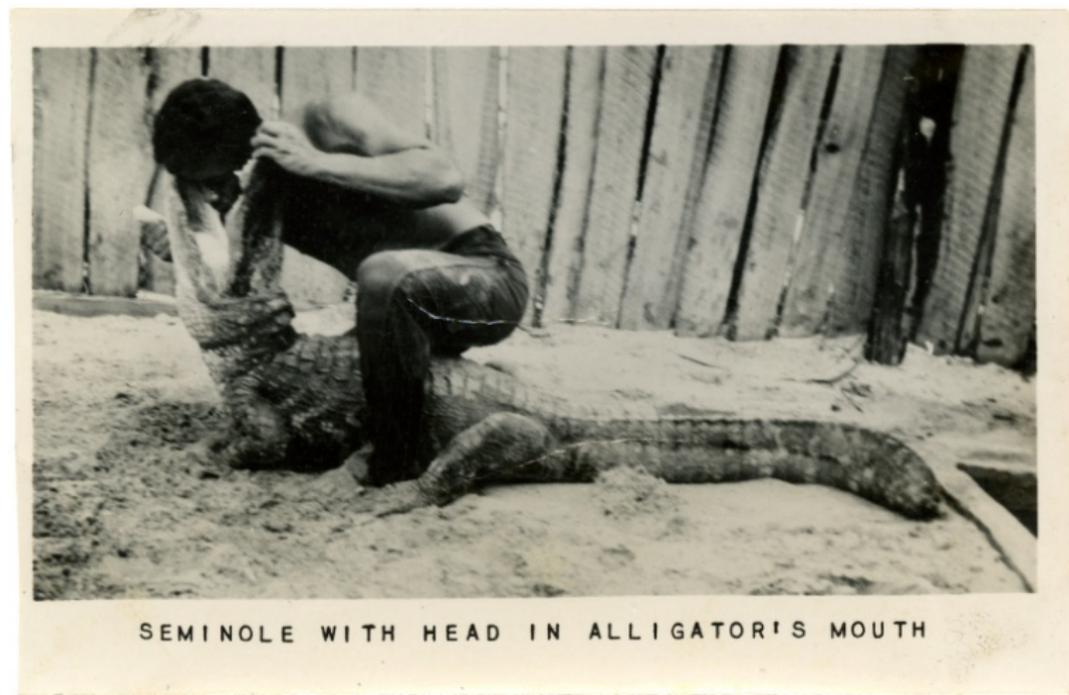
WFDB Toolbox for MATLAB/Octave Described

General Information

- Beta release 0.9.6.1 (February 10, 2014)
- 31 M-functions
- Provides access to over 3 TB of physiological signals
- Interface to LightWave (annotation visualization tool)
- Multicore processing at JVM level (alpha)
- Unit tested on 64-bit Windows, Mac, and Linux

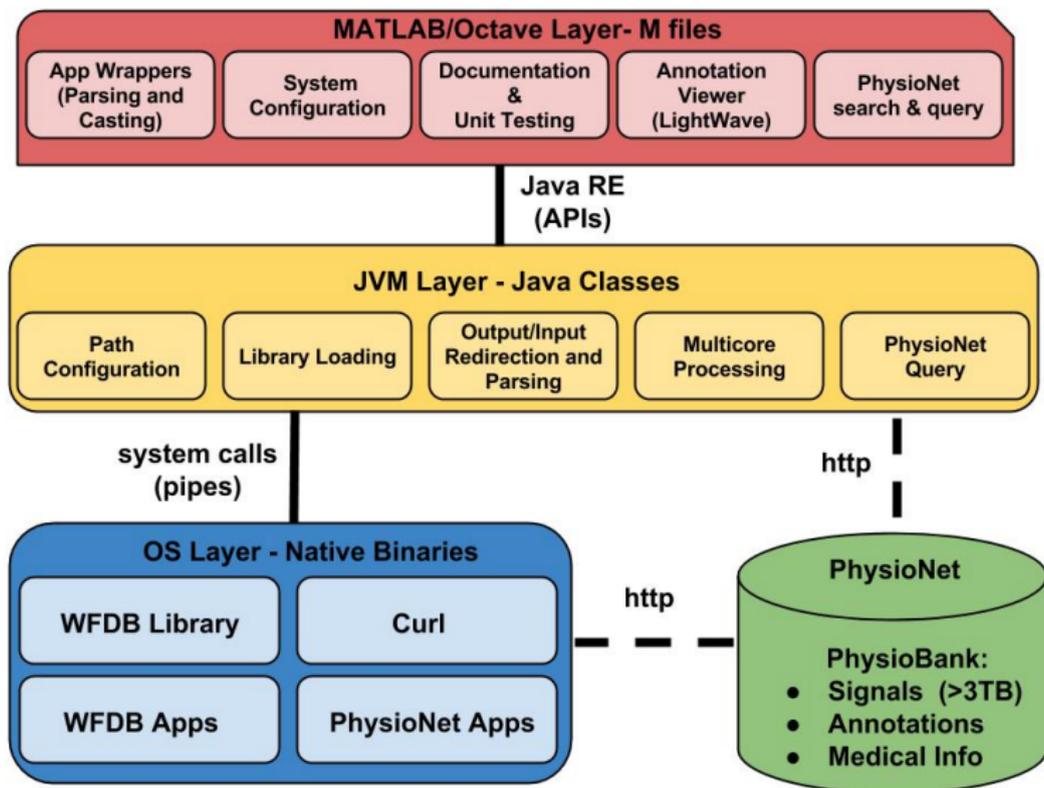
How is the WFDB Toolbox is built?

Let's take a look inside



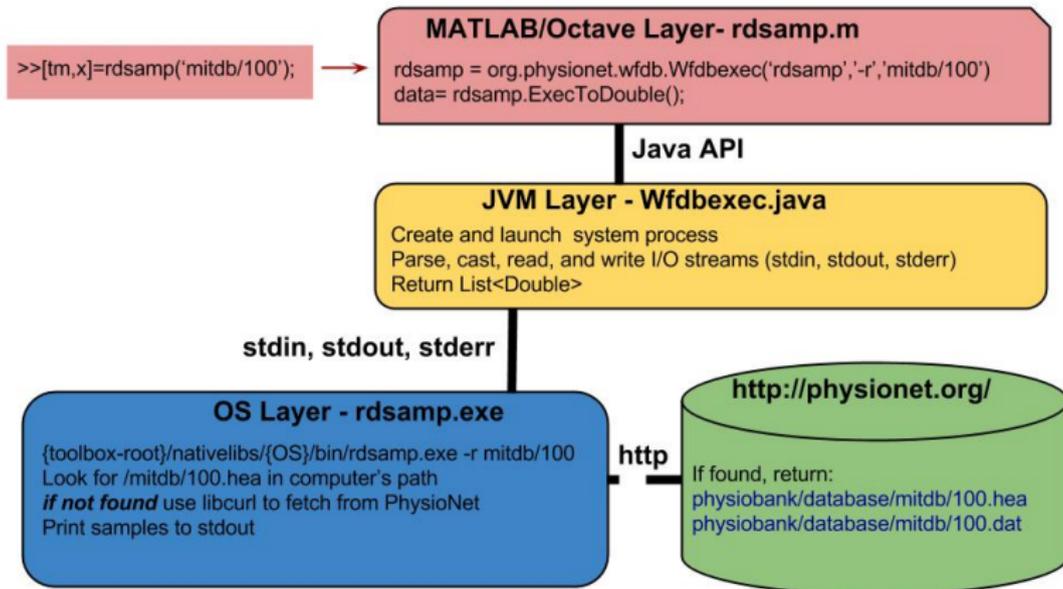
How is the WFDB Toolbox is built?

Structure of the WFDB Toolbox



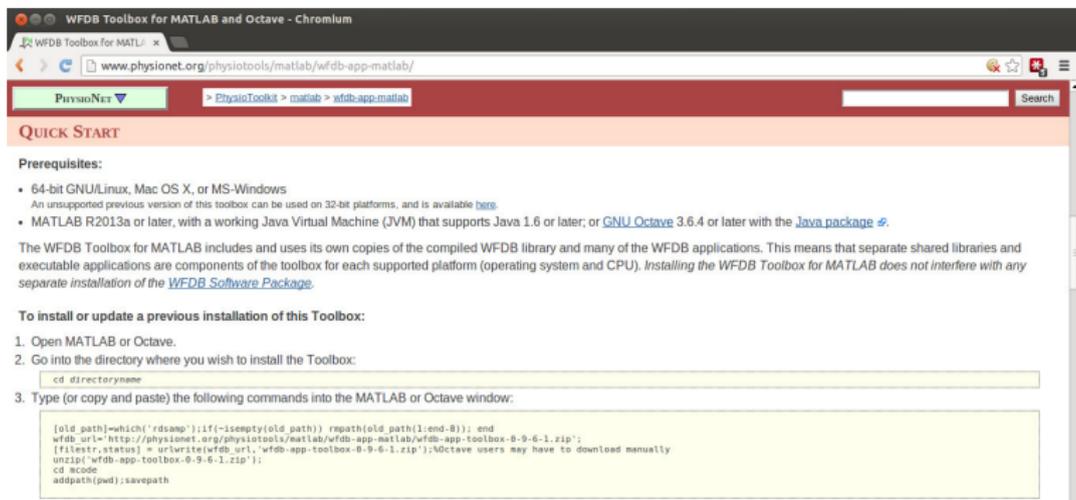
How is the WFDB Toolbox is built?

Example



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www.physionet.org/physiotools/matlab/wfdb-app-matlab/



The screenshot shows a web browser window titled "WFDB Toolbox for MATLAB and Octave - Chromium". The address bar shows the URL www.physionet.org/physiotools/matlab/wfdb-app-matlab/. The page has a navigation bar with "PhysioNET" and a breadcrumb trail: "PhysioToolKit > matlab > wfdb-app-matlab". Below the navigation bar is a "QUICK START" section.

Prerequisites:

- 64-bit GNU/Linux, Mac OS X, or MS-Windows
An unsupported previous version of this toolbox can be used on 32-bit platforms, and is available [here](#).
- MATLAB R2013a or later, with a working Java Virtual Machine (JVM) that supports Java 1.6 or later; or [GNU Octave](#) 3.6.4 or later with the [Java package](#).

The WFDB Toolbox for MATLAB includes and uses its own copies of the compiled WFDB library and many of the WFDB applications. This means that separate shared libraries and executable applications are components of the toolbox for each supported platform (operating system and CPU). *Installing the WFDB Toolbox for MATLAB does not interfere with any separate installation of the [WFDB Software Package](#).*

To install or update a previous installation of this Toolbox:

1. Open MATLAB or Octave.
2. Go into the directory where you wish to install the Toolbox:

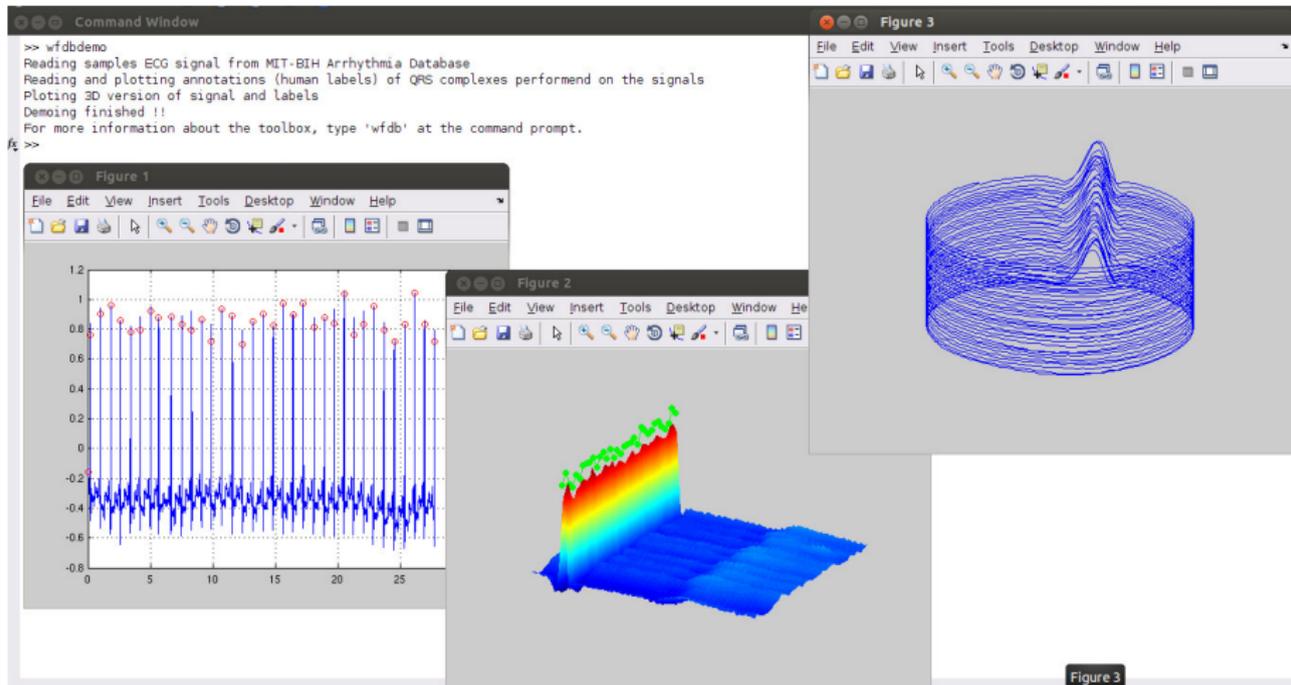
```
cd #directoryname
```
3. Type (or copy and paste) the following commands into the MATLAB or Octave window:

```
[old_path]=which('rdscmp');if(~isempty(old_path)) rmpath(old_path[:end-8]); end
wfdb_url='http://physionet.org/physiotools/matlab/wfdb-app-matlab/wfdb-app-toolbox-0-9-6-1.zip';
[filestr,status] = urlwrite(wfdb_url,'wfdb-app-toolbox-0-9-6-1.zip');%Octave users may have to download manually
unzip('wfdb-app-toolbox-0-9-6-1.zip');
cd mcode
addpath(pwd);savepath
```

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Exploring the toolbox

Demo



Exploring the toolbox

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```
Command Window
>> wfdb
WaveForm DataBase (WFDB) Toolbox
Version 0.9.6.1

Last Updated February 10, 2014

This is a set of MATLAB functions and wrappers for reading, writing, and processing
files in the formats used by PhysioBank databases (among others).
The WFDB Toolbox has support for reading public PhysioNet databases directly from
web. This feature allows your code to analyze a wide range of physiological
signals available from PhysioBank without the need to download entire
records and to store them locally. This toolbox is distributed under the LGPL
license (see LICENSE.txt file in this directory). For more information about the
toolbox please go to: http://www.physionet.org

Table of Contents (TOC)
-----
ann2rr - Extract a list of intervals from an annotation file
bxb - ANSI/AAMI-standard beat-by-beat annotation comparator
sdr - Derives a respiration signal from an ECG signal
ecgppuwave - Estimation of QRS and P waves from ECG signals
qrs - Estimation of QRS from ECG signals
lomb - Estimates power spectrum using the Lomb periodogram method
mat2wfdb - Writes a MATLAB variable into a WFDB record file
maprecord - Performs multithreaded concurrent annotation or processing of WFDB records
mrqann - Merge annotation files
msentropy - Multi scale entropy estimation
physionetdb - Get information about all of PhysioNet's available databases and signals
rdann - Read annotation files for WFDB records
rdmimic2wave - Searches MIMIC II matched waveform records within a clinical time range
rdsamp - Read signal files of WFDB records
score2013 - Scores entries to the PhysioNet 2013 Fetal ECG challenge
sortann - Rearrange annotations in canonical order
sqrs - Finds the QRS complexes of a WFDB ECG record signal
```

Exploring the toolbox

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```
Command Window

To credit this toolbox, please cite the following paper at your work:

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
[http://circ.ahajournals.org/cgi/content/full/101/23/e215];
2000 (June 13).
PMID: 10651218; doi: 10.1161/01.CIR.101.23.e215

In addition, some of these functions use binary executables compiled
from open-source third-party code contributed to PhysioNet. When using
these functions on your work, please look at the help for that function
in order find out how to credit the original paper and authors.

For questions, contributions, and feedback please contact us at:

wfdb-matlab-support@physionet.org

Or join our community at:
http://groups.google.com/forum/#!forum/wfdb-app-toolbox

The source code for the native libraries used in this toolbox can be obtained from PhysioNet under
the GNU GPL agreement.

Original contributors of open source native code that is available at PhysioNet
are credited in their respective MATLAB wrappers. In addition, the
following people contributed to the development or testing of
the MATLAB wrappers and the JVM interface:

Sahar Alkhairy
Joachim Behar
Eudald Bogatell
Jonas Carlsson
Gari D. Clifford
Michael Craig
```

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```
>>doc
```

```
%Browse to -> Supplemental Software
```

Supplemental Software

File Edit View Go Favorites Window Help

Search

Contents | Search Results

- WFDB Toolbox Toolbox
 - Functions
 - WFDB Toolbox Web Site
 - FAQ
 - Forum
 - Database List
 - Release Notes
 - License
 - DEMOS

For a detailed list of changes see the repository Log at:
<http://code.google.com/p/wfdb-app-toolbox/source/list>

0.9.7 (TBA)
Fixed issues when reading data stream with warning messages. Added data integrity check in RDSAMP.

0.9.6.1 (February 10, 2013):
Minor bug fixes with JAR files loading libraries.

0.9.6 (February 6, 2013):
Added support to GNU Octave version 3.6.4 (requires Octave Java package). Added single, and fixed point, and higher precision options to RDSAMP. Added a system wide WFDB path configuration to WFDBLOADLIB. The default search is now the current directory, {WFDB_HOME}/database, and <http://physionet/physiobank/database>. So databases can be stored in a single centralized location on the user's machine ({WFDB_HOME}/database). Added the function WOODY (average with alignment), and HTML help files.

0.9.5 (December 6, 2013):
Updated native libs to WFDB 10.5.22. Added WFDBEXEC (runs WFDB native commands in their native API and by a system call through the JVM), EDR, GORS, MSENTROPY. Added framework for users who want to run their own custom version of the WFDB native binaries. Any user who can successfully compile and run WFDB executables on their system should be able to use most functionality of this toolbox provided that they install the binaries in the /jcode/nativelibs/custom directory (see README for details). Added WFDB and WFDBCAL environment variables and ability to set and change them. Added system wide debugging information and variable to allow configuration of maximum network waiting time (default = 1 second).

0.9.4.3 (06 November 2013):
Fixed libcurl and path issue.

0.9.4.2 (05 November 2013):
Added more diagnostic information and fixed some issues with using spaces in Windows directories.

0.9.4.1 (04 November 2013):
Fixed library path issues with Windows systems.

0.9.4 (01 November 2013):

Supplemental Software

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WFDB Toolbox Toolbox

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 - bxb
 - ecgpuwave
 - edr
 - getwfdbClass
 - gqrs
 - lomb
 - maprecord
 - mat2wfdb
 - mrgann
 - msentropy
 - mxm
 - physionetdb
 - rdann
 - rdmimic2wave
 - rdsamp
 - score2013
 - sortann
 - sqrs
 - sumann
 - tach
 - wabp
 - wfdbdesc
 - wfdbexec
 - wfdbloadlib
 - wfdbtest
 - wfdbtime
 - wfdbtool
 - wfdbupdate

fx WFDB Toolbox Toolbox Functions ann2rr

MATLAB File Help: ann2rr [View code for ann2rr](#) [WFDB Contents](#)

ann2rr

function varargout=ann2rr(varargin)

[RR,tms]=ann2rr(recordName,annotator,N,N0,consecutiveOnly)

Wrapper to WFDB ANN2RR:
<http://www.physionet.org/physiotools/wag/ann2rr-1.htm>

Reads a WFDB record and Annotation file to return:

RR
 Nx1 vector of integers representing the duration of the RR interval in samples.

tms
 Nx1 vector of integers representing the beginning of the RR interval in samples.

Required Parameters:

recordName
 String specifying the name of the record in the WFDB path or in the current directory.

annotator
 String specifying the name of the annotation file in the WFDB path or in the current directory.

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Exploring data bases

Printing database list

```
Command Window
>> physionetdb
adfecgdb      Description: Abdominal and Direct Fetal ECG Database
              URL: http://physionet.org/physiobank/database/pbi/adfecgdb
aftdb        Description: AF Termination Challenge Database
              URL: http://physionet.org/physiobank/database/pbi/aftdb
aami-ec13    Description: ANSI/AAMI EC13 Test Waveforms
              URL: http://physionet.org/physiobank/database/pbi/aami-ec13
ahadb        Description: AHA Database [sample excluded record]
              URL: http://physionet.org/physiobank/database/pbi/ahadb
apnea-ecg    Description: Apnea-ECG Database
              URL: http://physionet.org/physiobank/database/pbi/apnea-ecg
bpsrrat      Description: Blood Pressure in Salt-Sensitive Dahl Rats
              URL: http://physionet.org/physiobank/database/pbi/bpsrrat
capslpdb     Description: CAP Sleep Database
              URL: http://physionet.org/physiobank/database/pbi/capslpdb
challenge/2009/test-set-a
              Description: Challenge 2009 Test Set A
              URL: http://physionet.org/physiobank/database/pbi/challenge_2009_test-set-a
challenge/2009/test-set-b
              Description: Challenge 2009 Test Set B
              URL: http://physionet.org/physiobank/database/pbi/challenge_2009_test-set-b
challenge/2010/set-a
              Description: Challenge 2010 Training Set A
              URL: http://physionet.org/physiobank/database/pbi/challenge_2010_set-a
challenge/2010/set-b
              Description: Challenge 2010 Test Set B
              URL: http://physionet.org/physiobank/database/pbi/challenge_2010_set-b
challenge/2010/set-c
              Description: Challenge 2010 Test Set C
              URL: http://physionet.org/physiobank/database/pbi/challenge_2010_set-c
challenge/2011/sim
              Description: Challenge 2011 Pilot Set
              URL: http://physionet.org/physiobank/database/pbi/challenge_2011_sim
```

Exploring data bases

Database list webview

Command Window

```
>> physionetdb([], [], 1)  
>>
```

Web Browser - http://physionet.org/physiobank/database/DBS

Location: http://physionet.org/physiobank/database/DBS

adfecgdb	Abdominal and Direct Fetal ECG Database
aftdb	AF Termination Challenge Database
aami-ec13	ANSI/AAMI EC13 Test Waveforms
ahadb	AHA Database [sample excluded record]
apnea-ecg	Apnea-ECG Database
bpsrrat	Blood Pressure in Salt-Sensitive Dahl Rats
capspgdb	CAP Sleep Database
challenge/2009/test-set-a	Challenge 2009 Test Set A
challenge/2009/test-set-b	Challenge 2009 Test Set B
challenge/2010/set-a	Challenge 2010 Training Set A
challenge/2010/set-b	Challenge 2010 Test Set B
challenge/2010/set-c	Challenge 2010 Test Set C
challenge/2011/sim	Challenge 2011 Pilot Set
challenge/2011/set-a	Challenge 2011 Training Set A
challenge/2011/set-b	Challenge 2011 Test Set B
challenge/2013/set-a	Challenge 2013 Training Set A
challenge/2013/set-b	Challenge 2013 Test Set B
chbmit	CHB-MIT Scalp EEG Database
chfdb	BIDMC Congestive Heart Failure Database
chf2db	Congestive Heart Failure RR Interval Database
crisdb	CAST RR Interval Sub-Study Database
ctu-uhb-ctgdb	CTU-CHB Intrapartum Cardiotocography Database
cuadb	CU Ventricular Tachyarrhythmia Database
earndb	Evoked Auditory Responses in Normals
edb	European ST-T Database
eegmldb	EEG Motor Movement/Imagery Dataset
engdb	Examples of Electromyograms
erpbc1	ERP-based Brain-Computer Interface recordings
fantasia	Fantasia Database
gaitdb	Gait in Aging and Disease Database
gaitmdd	Gait in Neurodegenerative Disease Database
gait-maturation-db/data	Gait Maturation Database
meditation/data	Heart Rate Oscillations during Meditation
iafdb	Intracardiac Atrial Fibrillation Database
ltafdb	Long Term AF Database
ltstdb	Long Term ST Database
ngbdb	MGH/MF Waveform Database
mimicdb	MIMIC Database
mimicdb/numerics	MIMIC Database Numerics
mimic2cdb	MIMIC II Clinical Database Public Subset

Exploring data bases

Printing & Downloading signals

```
Command Window
>> record_list=physionetdb('mitdb');record_list(1:10)' %Get record list from database 'mitdb'

ans =

'mitdb/101'
'mitdb/101'
'mitdb/102'
'mitdb/102'
'mitdb/103'
'mitdb/103'
'mitdb/104'
'mitdb/104'
'mitdb/105'
'mitdb/105'

>> [tm,signal]=rdsamp(record_list{1}); signal(1:10,1)%Read first record from the database

ans =

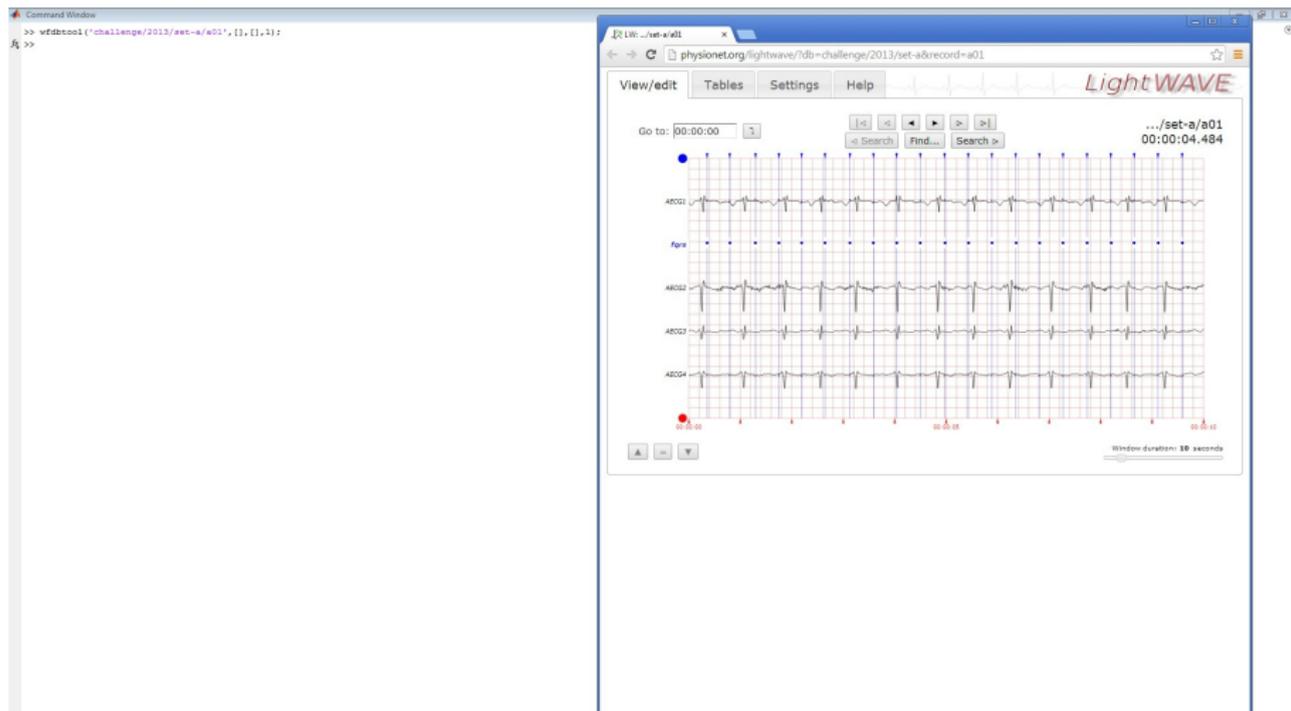
-0.3450
-0.3450
-0.3450
-0.3450
-0.3450
-0.3450
-0.3450
-0.3450
-0.3450
-0.3300
-0.3200

fg >> physionetdb('mitdb',1);%Download entire database
```

Calling LightWave

Displaying data in LightWave (Alpha!)

```
>>wfdbtool('challenge/2013/set-a/a01', [], [], 1);
```



Future Work

Near Horizon

- Adding unit testing, documentation, tutorial
- Improving JVM performance and memory efficiency
- Testing on MATLAB 2014a, Octave 3.8, WFDB 10.5.23, and Java 1.8
- Dropping support to MATLAB 2013a and Java 1.6

Future Work

Long term development

- Read/write user annotation from LightWave
- Upload & download data from PhysioNetWorks
- Have a parallel and distributed computing framework using Hadoop
- Document and release Java API
- Suggestions ?

In conclusion

Ways to get involved

- Use the toolbox and submit open-source code to PhysioNet
- Join the community:
www.physionet.org/physiotools/matlab/wfdb-app-matlab/
- Report any bugs, fixes, and enhancement requests:
wfdb-matlab-support@physionet.org