LALApps — LSC Algorithm Library Applications

Contact: Jolien Creighton jolien@gravity.phys.uwm.edu

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Authors

Patrick Brady
Duncan Brown
Jolien Creighton
Isabel Leonor
John T. Whelan
Mark Stephen Williamsen
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Chapter 1

How to get, build and use software for the LSC Data Grid

1.1 Getting and installing the software

We describe the installation of LAL and LALAPPS for use in gravitational-wave data analysis. These packages are under active development at the present time and the latest functionality is available only from CVS. These instructions assume a standard RedHat installation including development tools.

1.1.1 Installation of required development tools

A useful installation of LAL and LALAPPS requires FFTW, the FRAME and METAIO libraries. Pre-compiled versions of these libraries are available as RPM's from

http://www.lsc-group.phys.uwm.edu/lal/rpms/

The binary versions

- fftw-2.1.3-2lal.i386.rpm 28-Aug-2003 17:35 810k
- frame-6.08-1lal.i386.rpm 28-Aug-2003 17:35 464k
- metaio-4.13-1lal.i386.rpm 28-Aug-2003 17:35 24k
- stow-1.3.3-1lal.i386.rpm 29-Aug-2003 12:27 29k

are compiled on RedHat7.3 and RedHat 9.0 architecture, but should work on other versions of RedHat. Download the RPM's, log in as root on your computer, then type

```
rpm -Uvh fftw-2.1.3-2lal.i386.rpm
rpm -Uvh frame-6.08-1lal.i386.rpm
rpm -Uvh metaio-4.13-1lal.i386.rpm
rpm -Uvh stow-1.3.3-1lal.i386.rpm
```

Watch for error messages. If everything installs correctly, skip to Sec.1.1.3, otherwise continue through the following steps.

If the binary RPM's do not work for some reason or your particular O/S is not supported, the source RPM's are also available at the LAL web site. Download
### 1.1 Getting and installing the software

**fftw-2.1.3-2lal.src.rpm**  28-Aug-2003 17:35  810k
**frame-6.08-1lal.src.rpm**  28-Aug-2003 17:35  464k
**metaio-4.13-1lal.src.rpm**  28-Aug-2003 17:35  24k
**stow-1.3.3-1lal.src.rpm**  29-Aug-2003 12:27  139k

To your computer. As root, type

```
rpm -Uvh fftw-2.1.3-2lal.src.rpm
rpm -Uvh frame-6.08-1lal.src.rpm
rpm -Uvh metaio-4.13-1lal.src.rpm
rpm -Uvh stow-1.3.3-1lal.src.rpm
```

Watch for errors. If this fails, there is a major problem: e-mail lal-discuss@gravity.phys.uwm.edu. If it succeeds, as root

```
cd /usr/src/redhat/SPECS
rpm -ba fftw.spec
rpm -ba frame.spec
rpm -ba metaio.spec
```

```
cd /usr/src/redhat/RPMS/i386
rpm -Uvh fftw-2.1.3-2lal.i386.rpm
rpm -Uvh frame-6.08-1lal.i386.rpm
rpm -Uvh metaio-4.13-1lal.i386.rpm
```

Watch for errors at every step. If you encounter a problem: e-mail lal-discuss@gravity.phys.uwm.edu. If it succeeds, then you can go ahead to the next stage. Later versions of the RPM software require `rpm` to be replaced by `rpmbuild`.

#### 1.1.2 Configuring your environment

While developing, we recommend that you install the LAL and LALAPPS somewhere under your home directory. If you follow the instructions below, the LAL and LALAPPS libraries will be in `$LALPREFIX/lib`; the documentation in `$LALPREFIX/doc`; the header files in `$LALPREFIX/include`; the binaries in `$LALPREFIX/bin`. The environment `$LALPREFIX` should be set to the absolute path where you want to install these things. For example, user `patrick` might put the source code in `/home/patrick/src` and set `$LALPREFIX` to `/home/patrick`.

To make the appropriate binaries accessible to you, check that your path is set correctly. It is also useful to add environment variables for the CVS servers. If you have a lal CVS login, change `anonymous@gravity.phys.uwm.edu` to `your_user_name@gravity.phys.uwm.edu` in the environment variables below. If you are using `bash`, add the following lines to your `.bash_profile` file

```
export LALPREFIX=${HOME} # <---- Change this as appropriate
export PATH=${LALPREFIX}/bin:${PATH}
export LALCVS=":pserver:anonymous@gravity.phys.uwm.edu:/usr/local/cvs/lal"
```

If you are using `csh` or a derivative, add the following lines to your `.cshrc` file

```
setenv LALPREFIX $HOME
setenv PATH $LALPREFIX/bin:$PATH
setenv LALCVS ":pserver:anonymous@gravity.phys.uwm.edu:/usr/local/cvs/lal"
```

These environment variables must be set before running anything, so it is a good idea to log out and log back in again before continuing. **Note:** With libtool version 1.4.2, or greater, there is no need to have the `LD_LIBRARY_PATH` environment variable set. Library paths are hard coded into the libraries using the `-rpath` compiler option. This is the correct way to do this, using `LD_LIBRARY_PATH` is incorrect.
1.1. Getting and installing the software

1.1.3 LAL

In the following commands, remember \texttt{LALPREFIX} is the absolute directory path where you want to install the LAL library. If \texttt{LALPREFIX} does not exist, you must create it:

\begin{verbatim}
mkdir $LALPREFIX
\end{verbatim}

Then create the directory into which you wish to put the source files for LAL and LALApps:

\begin{verbatim}
mkdir $LALPREFIX/src
\end{verbatim}

The LAL software is maintained in a CVS repository – CVS stands for Concurrent Version-control System which is tool to allow multiple developers to manipulate the same software, merging differences and identifying conflicts between changes if they arise. Obtain the LAL package from the CVS repository as follows:

\begin{verbatim}
cd $LALPREFIX/src
cvs -d $LALCVS login
\end{verbatim}

At this point, you will be asked for a password. The password for the \texttt{anonymous} user is \texttt{lal}. If you have your own username, use the password that you have been given. The version of LAL that is checked-out is identified by the argument to the \texttt{-r} option in the commands below. The HEAD tag checks out the current development version. If you want to check out a released version, replace the \texttt{HEAD} tag by \texttt{release-X-Y} where \texttt{X} and \texttt{Y} are integers which identify the release version number as \texttt{X.Y}.

\begin{verbatim}
cvs -d $LALCVS checkout -rHEAD lal
\end{verbatim}

You have now obtained the latest development version of LAL.

\textbf{Build and Install}

To build and install the LAL software suite,

\begin{verbatim}
  cd $LALPREFIX/src/lal
  ./00boot
  ./configure --prefix=$LALPREFIX \ 
    --enable-frame --enable-metaio \ 
    --enable-static --disable-shared \ 
    --with-extra-cflags=-g
  make
  make check
  make dvi
  make install prefix=$LALPREFIX/stow_pkgs/lal-howto
\end{verbatim}

\begin{verbatim}
  cd $LALPREFIX/stow_pkgs
  stow lal-howto
\end{verbatim}

This completes the installation and testing of LAL.

1.1.4 LALApps

In the following commands, remember \texttt{LALPREFIX} is the absolute directory path where you want to install the LALApps binaries. We assume that you have followed the build instructions for LAL and that the directories \texttt{LALPREFIX} and \texttt{$LALPREFIX/src} exist.

Obtain the LALApps package from the CVS repository as follows:
1.1. Getting and installing the software

```bash
cd $LALPREFIX/src

cvs -d $LALCVS login

At this point, you will be asked for a password. The password for the anonymous user is lal. If you have your own username, use the password that you have been given. The version of LALApps that is checked-out is identified by the argument to the -r option in the commands below. The HEAD tag checks out the current development version. If you want to check out a released version, replace the HEAD tag by release-X-Y where X and Y are integers which identify the release version number as X.Y.

cvs -d $LALCVS checkout -rHEAD lalapps

You have now obtained the latest development version of LALApps.

Build and Install

To build and install the LALApps suite,

```bash
cd $LALPREFIX/src/lalapps
./00boot
./configure --prefix=$LALPREFIX \
  --with-extra-cppflags="-I$LALPREFIX/include" \
  --with-extra-ldflags="-L$LALPREFIX/lib" \
  --enable-frame --enable-metaio \
  --enable-static --disable-shared \n  --with-extra-cflags="-g -static"
make
make check
make dvi
make install prefix=$LALPREFIX/stow_pkgs/lalapps-howto
cd $LALPREFIX/stow_pkgs
stow lalapps-howto
```

This completes the installation and testing of LALApps.

Note that if you are building lalapps on a machine with Condor installed and wish to run in the standard universe, append the option --enable-condor to the configure for lalapps before you type make. The lalapps executables will then be linked with condor_compile and checkpointing will be available.

1.1.5 Updating LAL/LALApps

Since LAL and LALAPPS are constantly being improved, you will eventually want to update the versions you have installed. These instructions give you come guidance on the process. As you become a more experienced developer, you will develop your own tricks for making this more efficient. To do a complete update:

1. Update the source code on your computer

```bash
cd $LALPREFIX/src/lal
make cvs-clean
cvs update -Ad
cd $LALPREFIX/src/lalapps
make cvs-clean
cvs update -Ad
```
2. Remove the old versions

```bash
    cd $LALPREFIX/stow_pkgs
    stow --delete lal-howto
    stow --delete lalapps-howto
```

3. Repeat the **Build and Install** instructions for LAL and then LALAPPS, but **change the prefix argument** to **make install**. For example, if you compiled on 28 August 2003, you might want to use

```bash
    make install prefix=$LALPREFIX/stow_pkgs/lalapps-030828
    cd $LALPREFIX/stow_pkgs
    stow lalapps-030828
```
Chapter 2

LALApps utilities

Several utilities (macros, global variables, and functions) are provided to assist in writing programs in LALApps, and for maintaining a standard look-and-feel. This chapter describes these utilities and concludes with the listing of an example program.
2.1 Header *lalapps.h*

Provides utilities for writing programs for LALApps.

Several macros, global variables, and function prototypes are given that will assist in writing LALApps programs, and will aid in maintaining a standard look-and-feel.

To use these utilities, include the header *lalapps.h* and make sure the program links to the object *lalapps.o*. 
2.1. Header lalapps.h

2.1.1 Function set_debug_level

Name

set_debug_level — sets the LAL debug level

Synopsis

#include <lalapps.h>
extern int lalDebugLevel;
int set_debug_level( const char *s );

Description

The function set_debug_level sets the LAL debug level to a value determined by the string s, which can be an absolute debug level (a string representing an integer) or a string of LAL debug level flags. Allowed flags are:

- **NDEBUG**
  No debugging information is printed and memory debugging code is disabled.

- **ERROR**
  Error messages are printed.

- **WARNING**
  Warning messages are printed.

- **INFO**
  Information messages are printed.

- **TRACE**
  Function call tracing messages are printed.

- **MEMINFO**
  Memory allocation information messages are printed.

- **MEMDBG**
  Debugging of memory allocation routines is enabled but no messages are printed.

The following pre-defined composite levels are available:

- **MSGLVL1**
  Equivalent to **ERROR**.

- **MSGLVL2**
  Equivalent to **ERROR | WARNING**.

- **MSGLVL3**
  Equivalent to **ERROR | WARNING | INFO**.

- **ALLDBG**
  All debugging messages are printed.

If the argument to set_debug_level is NULL, then the string stored in the environment variable LAL_DEBUG_LEVEL is used. If this environment is not defined, or if no flags or values are specified in the string, the debug level is set to 0, which is equivalent to **NDEBUG**. (This is also the default value for lalDebugLevel unless it is set to some other value.)

For example, the statement
2.1. Header lalapps.h

```c
set_debug_level( "ERROR | INFO" );
```

will set the debug level so that error and information messages are printed (but not warning messages). Another example is the statement

```c
set_debug_level( "2" );
```

which would set the debug level to 2 (warning messages are printed).

**Return Value**

The return value is the (integer) debug level that is assigned to `lalDebugLevel`.

**Environment**

`LAL_DEBUG_LEVEL`

Default LAL debug level string to use.
2.1.2 Function **clear_status**

Name

`clear_status` — clears the LAL status structure after a failed LAL function call

Synopsis

```c
#include <lalapps.h>
extern const LALStatus blank_status;
int clear_status( LALStatus *status );
```

Description

Clears the LAL status structure and iteratively frees attached any linked status structures. This is to be used after a failed LAL function call to restore the status structure to a useable form. The structure `blank_status` contains a blank status structure that can be used to initialize a status structure in the program.

Example

The following program calls a routine `LALFailUnlessNegative` twice, once with a positive argument (which causes the routine to fail) and once with a negative argument (which causes the routine to pass). The function `clear_status` is used to clean up the status structure after the failure and the constant structure `blank_status` is used to initialize the status structure.

```c
#include <lalapps.h>
#include <lal/LALStdlib.h>
extern const LALStatus blank_status;

void LALFailUnlessNegative( LALStatus *status, INT4 n )
{
    INITSTATUS( status, "LALFail", "$Id$" );
    ATTACHSTATUSPTR( status );
    ASSERT( n, status, 1, "Non-negative n" );
    if ( n > 0 )
    {
        TRY( LALFailUnlessNegative( status->statusPtr, n - 1 ), status );
    }
    DETACHSTATUSPTR( status );
    RETURN( status );
}

int main( void )
{
    LALStatus status = blank_status;
    LALFailUnlessNegative( &status, 5 );
    clear_status( &status );
    LALFailUnlessNegative( &status, -2 );
    return status.statusCode;
}
```
2.1.3 Macro **RCSID**

Name

RCSID — set the RCS Id variable

Synopsis

```c
#include <lalapps.h>
#ifndef RCSID
#define RCSID( id ) static volatile const char *rcsid = (id)
#endif
```

Description

RCSID sets the static (i.e., internal-linkage) variable rcsid to the RCS Id string, $\text{Id}$, which is given as the argument `id`. The string $\text{Id}$ is expanded by RCS to contain the identification of the source file along with its revision number. For example:

```c
RCSID("$\text{Id}$");
```
2.1.4 Macro PRINT_VERSION

Name
PRINT_VERSION — prints the LALApps version of the program

Synopsis
#include <lalapps.h>
static volatile const char *rcsid="$Id$";
#ifndef PRINT_VERSION
#define PRINT_VERSION( program )
   fprintf( stderr, PACKAGE " %s version " VERSION "\n$s\n", program, rcsid )
#endif

Description
PRINT_VERSION prints the version information for program in a standard format, along with the RCS Id information. For example, for the program lalapps_hello, the version information

   lalapps hello version 0.1
   $Id$

is printed with the command lalapps_hello -V. The source code to print this is

   PRINT_VERSION( "hello" );

Note that PRINT_VERSION requires the string variable rcsid to be set.
2.1.5 Macro **LAL_CALL**

**Name**

**LAL_CALL** — call a LAL routine and handle any errors

**Synopsis**

```
#include <lalapps.h>

extern int vrblvl;
extern int ( *lal_errhandler )( LALStatus *stat, const char *func,
                                 const char *file, const int line, volatile const char *id );
extern lal_errhandler_t lal_errhandler;

static volatile const char *rcsid="$Id$";

#ifndef LAL_CALL
#define LAL_CALL( function, statusptr )
   { (function),lal_errhandler(statusptr,#function,__FILE__,__LINE__,rcsid)}
#endif
```

**Description**

**LAL_CALL** executes the LAL function **function** and executes the error handler **lal_errhandler**, which examines the status structure **statusptr** to see if an error occurred. Typically the error handler will return with value 0 if there was no error; otherwise it will print a trace of the execution stack and then perform a specific action. The action performed depends on the error handler, which can be set to one of the following:

- **LAL_ERR_DFLT**
  The default error handler (same as **LAL_ERR_ABRT**).

- **LAL_ERR_ABRT**
  Raises **SIGABRT** if there is an error.

- **LAL_ERR_EXIT**
  Exits with the returned status code if there is an error.

- **LAL_ERR_RTRN**
  Returns the status code.

Note that **LAL_CALL** requires the string variable **rcsid** to be set.

**Return Value**

If **LAL_CALL** returns (rather than terminating execution), the return value is equal to the status code returned by the LAL function.

**Example**

The following example program illustrates the use of **LAL_CALL**. The routine **LALInvert** is called incorrectly twice. The first time the division by zero error is caught. The second time, the unexpected null pointer error is not caught and the default error handler aborts the program.

```
#include <stdlib.h>
#include <lalapps.h>
#include <lal/LALStdlib.h>

RCSID( "$Id$" );
```
extern int vrblvl;
extern const LALStatus blank_status;

void LALInvert( LALStatus *status, REAL4 *y, REAL4 x )
{
    INITSTATUS( status, "LALInvert", rcsid );
    ASSERT( y, status, 1, "Null pointer" );
    if ( input == 0 )
    {
        ABORT( status, 1, "Division by zero" );
    }
    *y = 1 / x;
    RETURN( status );
}

int main( void )
{
    LALStatus status = blank_status;
    REAL4 x;
    int code;

    vrblvl = 1;

    lal_errhandler = LAL_ERR_RTRN;
    code = LAL_CALL( LALInvert( &status, &x, 0 ), &status );
    if ( code == 2 )
    {
        puts( "division by zero" );
        clear_status( &status );
    }
    else if ( code )
    {
        exit( code );
    }

    lal_errhandler = LAL_ERR_DFLT;
    LAL_CALL( LALInvert( &status, NULL, 1 ), &status );

    return 0;
}
2.2 Source hello.c

This is the source code for the program lalapps_hello:

```c
#include <stdio.h>
#include <unistd.h>
#include <lalapps.h>
#include <lal/LALStdlib.h>
#include <lal/LALHello.h>

RCSID( "$Id: hello.c,v 1.1 2002/01/16 19:11:33 jolien Exp "$ );

#define usgfmt \ 
  "Usage: %s [options]\n" \ 
  "Options [default in brackets]:\n" \ 
  "  -h print this message\n" \ 
  "  -V print version info\n" \ 
  "  -v verbose\n" \ 
  "  -d dbglvl set debug level to dbglvl [0]\n" \ 
  "  -o outfile use output file outfile [stdout]\n"

#define usage( program ) fprintf( stderr, usgfmt, program )

extern char *optarg;
extern int optind, opterr, optopt;
extern int vrbflg;

int main( int argc, char *argv[] )
{
  const char *program = argv[0];
  const char *outfile = NULL;
  const char *dbglvl = NULL;
  lal_errhandler_t default_handler;

  LALStatus status = blank_status;
  int code;
  int opt;

  /* parse options */
  while ( 0 < ( opt = getopt( argc, argv, "hVvd:o:" ) ) )
    {
      switch ( opt )
        {
        case 'h':
          usage( program );
          return 0;
        case 'V':
          PRINT_VERSION( "hello" );
          return 0;
        case 'v':
          vrbflg = 1;
```
break;
case 'd':
    debugv = optarg;
    break;
case 'o':
    outfile = optarg;
    break;
default:
    usage( program );
    return 1;
}
if ( optind < argc )
{
    usage( program );
    return 1;
}

/* set debug level */
set_debug_level( dbglvl );

/* try to call LALHello; catch error LALHELLOH_EOPEN */
default_handler = lal_errhandler;
lal_errhandler = LAL_ERR_RTRN;
code = LAL_CALL( LALHello( &status, outfile ), &status );
if ( code == -1 && (status.statusPtr)->statusCode == LALHELLOH_EOPEN )
{
    fprintf( stderr, "warning: couldn't open file %s for output"
              "(using stdout)\n", outfile );
    clear_status( &status );
    lal_errhandler = LAL_ERR_EXIT;
    LAL_CALL( LALHello( &status, NULL ), &status );
}
else if ( code )
{
    exit( code );
}
lal_errhandler = default_handler; /* restore default handler */
LALCheckMemoryLeaks();
return 0;
2.3 Python Module pipeline

This module contains objects that make it simple for the user to create python scripts that build Condor DAGs to run code on the LSC Data Grid.

2.3.1 Functions

s2play(t)
Return 1 if t is in the S2 playground, 0 otherwise

2.3.2 Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>author</strong></td>
<td>Value: ‘Duncan Brown <a href="mailto:duncan@gravity.phys.uwm.edu">duncan@gravity.phys.uwm.edu</a>’</td>
</tr>
<tr>
<td><strong>date</strong></td>
<td>Value: ‘$Date: 2003/10/01 08:46:06 $’</td>
</tr>
<tr>
<td><strong>version</strong></td>
<td>Value: ‘1.18’</td>
</tr>
</tbody>
</table>

2.3.3 Class AnalysisChunk

An AnalysisChunk is the unit of data that a node works with, usually some subset of a ScienceSegment.

Methods

__init__(self, start, end)
start = GPS start time of the chunk. end = GPS end time of the chunk.

__len__(self)
Returns the length of this AnalysisChunk in seconds.

__repr__(self)
dur(self)
Returns the length (duration) of the chunk in seconds.

end(self)
Returns the GPS end time of the chunk.

start(self)
Returns the GPS start time of the chunk.

2.3.4 Class AnalysisJob

Describes a generic analysis job that filters LIGO data as configured by an ini file.
Methods

```python
__init__(self, cp)
cp = ConfigParser object that contains the configuration for this job.
```

```python
calibration(self, ifo)
Returns the name of the calibration file to use for the given IFO. ifo = name of interferomener (e.g. L1, H1 or H2).
```

```python
channel(self)
Returns the name of the channel that this job is filtering. Note that channel is defined to be IFO independent, so this may be LSC-AS_Q or IOO-MC_F. The IFO is set on a per node basis, not a per job basis.
```

```python
get_config(self, sec, opt)
Get the configuration variable in a particular section of this jobs ini file. sec = ini file section. opt = option from section sec.
```

### 2.3.5 Class AnalysisNode

pipeline.CondorDAGNode  

```python
AnalysisNode
Contains the methods that allow an object to be built to analyse LIGO data in a Condor DAG.
```

Methods

```python
__init__(self)
Overrides: pipeline.CondorDAGNode.__init__
```

```python
get_end(self)
Get the GPS end time of the node.
```

```python
get_ifo(self)
Returns the two letter IFO code for this node.
```

```python
get_input(self)
Get the file that will be passed as input.
```

```python
get_output(self)
Get the file that will be passed as output.
```

```python
get_start(self)
Get the GPS start time of the node.
```

```python
set_cache(self, file)
Set the LAL frame cache to to use. The frame cache is passed to the job with the –frame-cache argument. file = calibration file to use.
```
2.3. Python Module **pipeline**

<table>
<thead>
<tr>
<th>set_end(self, time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set the GPS end time of the analysis node by setting a –gps-end-time option to the node when it is executed. time = GPS end time of job.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>set_ifo(self, ifo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set the channel name to analyze and add a calibration file for that channel. The name of the ifo is prepended to the channel name obtained from the job configuration file and passed with a –channel-name option. A calibration file is obtained from the ini file and passed with a –calibration-cache option. ifo = two letter ifo code (e.g. L1, H1 or H2).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>set_input(self, file)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add an input to the node by adding a –input option. file = option argument to pass as input.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>set_output(self, file)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add an output to the node by adding a –output option. file = option argument to pass as output.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>set_start(self, time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set the GPS start time of the analysis node by setting a –gps-start-time option to the node when it is executed. time = GPS start time of job.</td>
</tr>
</tbody>
</table>

Inherited from CondorDAGNode: __repr__, add_parent, add_var_arg, add_var_opt, job, set_log_file, set_name, set_retry, write_job, write_parents, write_vars

2.3.6 Class CondorDAG

A CondorDAG is a Condor Directed Acyclic Graph that describes a collection of Condor jobs and the order in which to run them. All Condor jobs in the DAG must write their Codor logs to the same file. NOTE: The log file must not be on an NFS mounted system as the Condor jobs must be able to get an exclusive file lock on the log file.

Methods

<table>
<thead>
<tr>
<th><em>init</em>(self, log)</th>
</tr>
</thead>
<tbody>
<tr>
<td>log = path to log file which must not be on an NFS mounted file system.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>add_node(self, node)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add a CondorDAGNode to this DAG. The CondorJob that the node uses is also added to the list of Condor jobs in the DAG so that a list of the submit files needed by the DAG can be maintained. Each unique CondorJob will be added once to prevent duplicate submit files being written. node = CondorDAGNode to add to the CondorDAG.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>set_dag_file(self, path)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set the name of the file into which the DAG is written. path = path to DAG file.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>write_dag(self)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write all the nodes in the DAG to the DAG file.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>write_sub_files(self)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write all the submit files used by the dag to disk. Each submit file is written to the file name set in the CondorJob.</td>
</tr>
</tbody>
</table>
2.3.7 Class CondorDAGError

exceptions.Exception

pipeline.CondorError

CondorDAGError

Methods

Inherited from Exception: __getitem__, __str__
Inherited from CondorError: __init__

2.3.8 Class CondorDAGJob

pipeline.CondorJob

CondorDAGJob

A Condor DAG job never notifies the user on completion and can have variable options that are set for a particular node in the DAG. Inherits methods from a CondorJob.

Methods

__init__(self, universe, executable)

universe = the condor universe to run the job in. executable = the executable to run in the DAG.

Overrides: pipeline.CondorJob.__init__

add_var_arg(self)

Add a command to the submit file to allow variable (macro) arguments to be passed to the executable.

add_var_opt(self, opt)

Add a variable (or macro) option to the condor job. The option is added to the submit file and a different argument to the option can be set for each node in the DAG. opt = name of option to add.

Inherited from CondorJob: add_arg, add_condor_cmd, add_ini_opts, add_opt, get_stderr_file, get_stdout_file, get_sub_file, set_log_file, set_notification, set_condor_file, set_stdout_file, set_sub_file, write_sub_file

2.3.9 Class CondorDAGNode

Known Subclasses: AnalysisNode

A CondorDAGNode represents a node in the DAG. It corresponds to a particular condor job (and so a particular submit file). If the job has variable (macro) options, they can be set here so each nodes executes with the correct options.

Methods

__init__(self, job)

job = the CondorJob that this node corresponds to.

__repr__(self)
### 2.3. Python Module **pipeline**

#### add_parent(self, node)

Add a parent to this node. This node will not be executed until the parent node has run successfully. node = CondorDAGNode to add as a parent.

#### add_var_arg(self, arg)

Add a variable (or macro) argument to the condor job. The argument is added to the submit file and a different value of the argument can be set for each node in the DAG. arg = name of option to add.

#### add_var_opt(self, opt, value)

Add a variable (macro) options for this node. If the option specified does not exist in the CondorJob, it is added so the submit file will be correct when written. opt = option name. value = value of the option for this node in the DAG.

#### job(self)

Return the CondorJob that this node is associated with.

#### set_log_file(self, log)

Set the Condor log file to be used by this CondorJob. log = path of Condor log file.

#### set_name(self)

Generate a unique name for this node in the DAG.

#### set_retry(self, retry)

Set the number of times that this node in the DAG should retry. retry = number of times to retry node.

#### write_job(self, fh)

Write the DAG entry for this node’s job to the DAG file descriptor. fh = descriptor of open DAG file.

#### write_parents(self, fh)

Write the parent/child relations for this job to the DAG file descriptor. fh = descriptor of open DAG file.

#### write_vars(self, fh)

Write the variable (macro) options and arguments to the DAG file descriptor. fh = descriptor of open DAG file.

### 2.3.10 Class **CondorDAGNodeError**

```
exceptions.Exception
  pipeline.CondorError
      CondorDAGNodeError
```

##### Methods

- **Inherited from Exception:** __getitem__, __str__
- **Inherited from CondorError:** __init__
2.3.11 Class CondorError

exceptions.Exception → CondorError

**Known Subclasses:** CondorDAGError, CondorDAGNodeError, CondorJobError, CondorSubmitError

Error thrown by Condor Jobs

**Methods**

_init_(self, args=None)

Overrides: exceptions.Exception._init_

Inherited from Exception: __getitem__, __str__

2.3.12 Class CondorJob

**Known Subclasses:** CondorDAGJob

Generic condor job class. Provides methods to set the options in the condor submit file for a particular executable

**Methods**

_init_(self, universe, executable, queue)

universe = the condor universe to run the job in. executable = the executable to run. queue = number of jobs to queue.

add_arg(self, arg)

Add an argument to the executable. Arguments are appended after any options and their order is guaranteed. arg = argument to add.

add_condor_cmd(self, cmd, value)

Add a Condor command to the submit file (e.g. a class add or environment). cmd = Condor command directive. value = value for command.

add_ini_opts(self, cp, section)

Parse command line options from a given section in an ini file and pass to the executable. cp = ConfigParser object pointing to the ini file. section = section of the ini file to add to the options.

add_opt(self, opt, value)

Add a command line option to the executable. The order that the arguments will be appended to the command line is not guaranteed, but they will always be added before any command line arguments. The name of the option is prefixed with double hyphen and the program is expected to parse it with getopt_long(). arg = command line option to add. value = value to pass to the option (None for no argument).

get_stderr_file(self)

Get the file to which Condor directs the stderr of the job.
get_stdout_file(self)
Get the file to which Condor directs the stdout of the job.

get_sub_file(self)
Get the name of the file which the Condor submit file will be written to when write_sub_file() is called. path = path to submit file.

set_log_file(self, path)
Set the Condor log file. path = path to log file.

set_notification(self, value)
Set the email address to send notification to. value = email address or never for no notification.

set_stderr_file(self, path)
Set the file to which Condor directs the stderr of the job. path = path to stderr file.

set_stdout_file(self, path)
Set the file to which Condor directs the stdout of the job. path = path to stdout file.

set_sub_file(self, path)
Set the name of the file to write the Condor submit file to when write_sub_file() is called. path = path to submit file.

write_sub_file(self)
Write a submit file for this Condor job.

2.3.13 Class CondorJobError

| exceptions.Exception  | pipeline.CondorError | CondorJobError |

Methods

Inherited from Exception: _getitem_, __str__
Inherited from CondorError: __init__

2.3.14 Class CondorSubmitError

| exceptions.Exception  | pipeline.CondorError | CondorSubmitError |


2.3. Methods

Inherited from Exception: __getitem__, __str__
Inherited from CondorError: __init__

2.3.15 Class ScienceData

An object that can contain all the science data used in an analysis. Can contain multiple ScienceSegments and has a method to generate these from a text file produced by the LIGOtools segwizard program.

Methods

__init__(self)

__getitem__(self, i)
Allows direct access to or iteration over the ScienceSegments associated with the ScienceData.

__len__(self)
Returns the number of ScienceSegments associated with the ScienceData.

__repr__(self)

make_chunks(self, length, overlap, play)
Divide each ScienceSegment contained in this object into AnalysisChunks. length = length of chunk in seconds. overlap = overlap between segments. play = if true, only generate chunks that overlap with S2 playground data.

read(self, file)
Parse the science segments from the segwizard output contained in file. file = input text file containing a list of science segments generated by segwizard.

2.3.16 Class ScienceSegment

A ScienceSegment is a period of time where the experimenters determine that the interferometer is in a state where the data is suitable for scientific analysis. A science segment can have a list of AnalysisChunks associated with it that break the segment up into (possibly overlapping) smaller time intervals for analysis.

Methods

__init__(self, segment)
segment = a tuple containing the (segment id, gps start time, gps end time, duration) of the segment.

__getitem__(self, i)
Allows iteration over and direct access to the AnalysisChunks contained in this ScienceSegment.

__len__(self)
Returns the number of AnalysisChunks contained in this ScienceSegment.

__repr__(self)
### 2.3. Python Module `pipeline`

Add an AnalysisChunk to the list associated with this ScienceSegment. start = GPS start time of chunk. end = GPS end time of chunk.

**add_chunk**(self, start, end)

**dur**(self)

Returns the length (duration) in seconds of this ScienceSegment.

**end**(self)

Returns the GPS end time of this ScienceSegment.

**id**(self)

Returns the ID of this ScienceSegment.

**make_chunks**(self, length=0, overlap=0, play=0)

Divides the science segment into chunks of length seconds overlapped by overlap seconds. If the play option is set, only chunks that contain S2 playground data are generated. If the user has a more complicated way of generating chunks, this method should be overridden in a sub-class. Any data at the end of the ScienceSegment that is too short to contain a chunk is ignored. The length of this unused data is stored and can be retrieved with the `unused()` method. length = length of chunk in seconds. overlap = overlap between chunks in seconds. play = only generate chunks that overlap with S2 playground data.

**start**(self)

Returns the GPS start time of this ScienceSegment.

**unused**(self)

Returns the length of data in the science segment not used to make chunks.

#### 2.3.17 Class `SegmentError`

`exceptions.Exception`  

```
SegmentError
```

**Methods**

```
__init__(self, args=None)
```

Overrides: `exceptions.Exception.__init__`

Inherited from `Exception`: `_getitem__`, `_str__`
Chapter 3

LALApps programs

This chapter describes the programs that are part of the LALApps package.
3.1 Program **lalapps_hello**

**Name**

*lalapps_hello* — prints “hello LSC!”

**Synopsis**

```
lalapps_hello [-h] [-V] [-v] [-d dbglvl] [-o outfile]
```

**Description**

*lalapps_hello* prints “hello LSC!” to the screen or to an output file.

**Options**

- `-h`
  
  Print a help message.

- `-V`
  
  Print the version information.

- `-v`
  
  Verbose output.

- `-d dbglvl`
  
  Set LAL debug level to `dbglvl`.

- `-o outfile`
  
  Write the output to file `outfile`.

**Debug levels**

The LAL debug level can be specified as an integer or as a string of flags:

- **NDEBUG**
  
  No debugging information is printed and memory debugging code is disabled.

- **ERROR**
  
  Error messages are printed.

- **WARNING**
  
  Warning messages are printed.

- **INFO**
  
  Information messages are printed.

- **TRACE**
  
  Function call tracing messages are printed.

- **MEMINFO**
  
  Memory allocation information messages are printed.

- **MEMDBG**
  
  Debugging of memory allocation routines is enabled but no messages are printed.

The following composite levels are available:
3.1. Program `lalapps_hello`

**MSGLVL1**
Equivalent to **ERROR**

**MSGLVL2**
Equivalent to **ERROR | WARNING**

**MSGLVL3**
Equivalent to **ERROR | WARNING | INFO**

**ALLDBG**
All debugging messages are printed.

For example, the command

```
lalapps_hello -d "ERROR | INFO"
```

will set the debug level so that error and information messages are printed.

**Environment**

**LAL_DEBUG_LEVEL**
Default LAL debug level to use.

**Author**
Jolien Creighton
3.2 Program **lalapps_animate**

**Name**

*lal_animate* — produces an animated display showing the time series output of a selected channel in a lower window, and a simultaneously calculated FFT power spectrum in the upper window

**Synopsis**

```
```

**Description**

*lal_animate* produces an animated display showing the time series output of a selected channel in a lower window, and a simultaneously calculated FFT power spectrum in the upper window. The output from this program must be piped into the graphing program *xmgr*.

**Options**

- **--help**
  
  Print a help message.

- **--channel name**
  
  Name of frame channel

- **--duration secs**
  
  How many seconds to look at

- **--epoch sec nsec**
  
  Starting epoch

- **--framedir dirname**
  
  Directory containing frame files

- **--highpass freq attenuation**
  
  High-pass filter parameters

- **--numpts npoints**
  
  Points per graph to display

**Example**

To run the program, type:

```
lalapps_animate --channel H2:LSC-AS_Q --framedir ./h1 --numpts 16384 \  --epoch 693768272 0 --duration 1 --highpass 300 0.01 | xmgr -pipe
```

This will search in directory ./h1 for frame files containing the channel H2:LSC-AS_Q and pipe the data starting at 693768272 GPS seconds and 0 GPS nanoseconds to xmgr in segments containing 16384 points until 1 seconds of data has been reviewed. The data is highpass filtered to above 300 Hz with an attenuation of 0.1; the output is shown in Fig. 3.2

**Author**

Bruce Allen and Patrick Brady
Figure 3.1: Example of output from `lalapps_animate` program

![Spectrum](image1.png)

![IFO output](image2.png)
3.3 Python Module \texttt{inspiral}

Classes needed for the inspiral analysis pipeline. This script produced the necessary condor submit and dag files to run the standalone inspiral code on LIGO data.

3.3.1 Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>author</strong></td>
<td>Value: 'Duncan Brown <a href="mailto:duncan@gravity.phys.uwm.edu">duncan@gravity.phys.uwm.edu</a>'</td>
</tr>
<tr>
<td><strong>date</strong></td>
<td>Value: '$Date: 2003/10/01 09:05:08 $'</td>
</tr>
<tr>
<td><strong>version</strong></td>
<td>Value: '1.14'</td>
</tr>
</tbody>
</table>

3.3.2 Class \texttt{DataFindJob}

\texttt{DataFindJob}

A LAL\texttt{dataFind} job used by the inspiral pipeline. The static options are read from the section \texttt{[datafind]} in the ini file. The stdout from LAL\texttt{dataFind} contains the paths to the frame files and is directed to a file in the cache directory named by site and GPS start and end times. The stderr is directed to the logs directory. The job always runs in the scheduler universe. The path to the executable is determined from the ini file.

Methods

\texttt{__init__}(self, cp)

\texttt{cp} = ConfigParser object from which options are read.

Overrides: pipeline.CondorDAGJob.__init__

Inherited from \texttt{AnalysisJob}: \texttt{calibration, channel, get\_config}

Inherited from \texttt{CondorDAGJob}: \texttt{add\_var\_arg, add\_var\_opt}

Inherited from \texttt{CondorJob}: \texttt{add\_arg, add\_condor\_cmd, add\_ini\_opts, add\_opt, get\_stderr\_file, get\_stdout\_file, get\_sub\_file, set\_log\_file, set\_notification, set\_stderr\_file, set\_stdout\_file, set\_sub\_file, write\_sub\_file}

3.3.3 Class \texttt{DataFindNode}

\texttt{DataFindNode}

A \texttt{DataFindNode} runs an instance of datatfind in a Condor DAG.
3.3.3 Python Module *inspiral*

Methods

**init**(self, job)

job = A CondorDAGJob that can run an instance of LALdataFind.

Overrides: pipeline.AnalysisNode._init_

get_output(self)

Return the output file, i.e. the file containing the frame cache data.

Overrides: pipeline.AnalysisNode.get_output

set_end(self, time)

Set the end time of the datafind query. time = GPS end time of query.

Overrides: pipeline.AnalysisNode.set_end

set_ifo(self, ifo)

Set the IFO to retrieve data for. Since the data from both Hanford interferometers is stored in the same frame file, this takes the first letter of the IFO (e.g. L or H) and passes it to the –instrument option of LALdataFind. ifo = IFO to obtain data for.

Overrides: pipeline.AnalysisNode.set_ifo

set_start(self, time)

Set the start time of the datafind query. time = GPS start time of query.

Overrides: pipeline.AnalysisNode.set_start

Inherited from AnalysisNode: get_end, get_ifo, get_input, get_start, set_cache, set_input, set_output

Inherited from CondorDAGNode: __repr__, add_parent, add_var_arg, add_var_opt, job, set_log_file, set_name, set_retry, write_job, write_parents, write_vars

3.3.4 Class IncaJob

A lalapps_inca job used by the inspiral pipeline. The static options are read from the section [inca] in the ini file. The stdout and stderr from the job are directed to the logs directory. The job always runs in the scheduler universe. The path to the executable is determined from the ini file.

Methods

**init**(self, cp)

cp = ConfigParser object from which options are read.

Overrides: pipeline.CondorDAGJob._init_

Inherited from AnalysisJob: calibration, channel, get_config

Inherited from CondorDAGJob: add_var_arg, add_var_opt

3.3.5 Class IncaNode

pipeline.CondorDAGNode
    pipeline.AnalysisNode
        pipeline.CondorDAGNode
            IncaNode

An IncaNode runs an instance of the inspiral coincidence code in a Condor DAG.

Methods

__init__(self, job)
job = A CondorDAGJob that can run an instance of lalapps_inca.
Overrides: pipeline.AnalysisNode.__init__

get_ifo_a(self)
Returns the IFO code of the primary interferometer.

get_ifo_b(self)
Returns the IFO code of the primary interferometer.

get_output(self)
Returns the file name of output from the inca code. This must be kept synchronized with the name of the output file in inca.c.
Overrides: pipeline.AnalysisNode.get_output

set_ifo_a(self, ifo)
Set the interferometer code to use as IFO A. ifo = IFO code (e.g. L1, H1 or H2).

set_ifo_b(self, ifo)
Set the interferometer code to use as IFO B. ifo = IFO code (e.g. L1, H1 or H2).

Inherited from AnalysisNode: get_end, get_ifo, get_input, get_start, set_cache, set_end, set_ifo, set_input, get_output, set_start
Inherited from CondorDAGNode: __repr__, add_parent, add_var_arg, add_var_opt, job, set_log_file, set_name, set_retry, write_job, write_parents, write_vars

3.3.6 Class InspiralError

exceptions.Exception
    InspiralError
3.3. Methods

```python
_init_(self, args=None)
```
Overrides: exceptions.Exception._init_

Inherited from Exception: __getitem__, __str__

### 3.3.7 Class InspiralJob

```python
pipeline.AnalysisJob
```
```python
def init(self, cp):
    cp = ConfigParser object from which options are read.
    Overrides: pipeline.CondorDAGJob._init_
```

Inherited from AnalysisJob: calibration, channel, get_config

Inherited from CondorDAGJob: add_var_arg, add_var_opt

Inherited from CondorJob: add_arg, add_condor_cmd, add_ini_options, add_opt, get_stderr_file, get_stdout_file, get_sub_file, set_log_file, set_notification, set_stderr_file, set_stdout_file, set_sub_file, write_sub_file

### 3.3.8 Class InspiralNode

```python
pipeline.CondorDAGNode
```
```python
def init(self, job):
    job = A CondorDAGJob that can run an instance of lalapps_inspiral.
    Overrides: pipeline.AnalysisNode._init_
```

An InspiralNode runs an instance of the inspiral code in a Condor DAG.
3.3. Python Module *inspiral*

```python
def get_output(self):
    """Returns the file name of output from the inspiral code. This must be kept synchronized with the name of the output file in inspiral.c.
    """
    Overrides: pipeline.AnalysisNode.get_output

def set_bank(self, bank):
    Inherited from AnalysisNode: get_end, get_ifo, get_input, get_start, set_cache, set_end, set_ifo, set_input, set_output, set_start
    Inherited from CondorDAGNode: __repr__, add_parent, add_var_arg, add_var_opt, job, set_log_file, set_name, set_retry, write_job, write_parents, write_vars
```

### 3.3.9 Class TmpltBankJob

![Class Diagram]

A lalapps_tmpltbank job used by the inspiral pipeline. The static options are read from the sections [data] and [tmpltbank] in the ini file. The stdout and stderr from the job are directed to the logs directory. The job runs in the universe specified in the ini file. The path to the executable is determined from the ini file.

**Methods**

```python
@override(pipeline.CondorDAGJob.__init__)
def __init__(self, cp):
    cp = ConfigParser object from which options are read.
    Overrides: pipeline.CondorDAGJob.__init__
```

Inherited from AnalysisJob: calibration, channel, get_config
Inherited from CondorDAGJob: add_var_arg, add_var_opt

### 3.3.10 Class TmpltBankNode

![Class Diagram]

A TmpltBankNode runs an instance of the template bank generation job in a Condor DAG.
3.3. Python Module *inspiral*

Methods

```python
_init_(self, job)

job = A CondorDAGJob that can run an instance of lalapps_tmplbank.
Overrides: pipeline.AnalysisNode.__init__
```

```python
class TrigToTmpltJob

pipeline.AnalysisJob
pipeline.CondorJob
pipeline.CondorDAGJob

TrigToTmpltJob

A lalapps_trigtotmplt job used by the inspiral pipeline. The static options are read from the section [trigtotmplt] in the ini file. The stdout and stderr from the job are directed to the logs directory. The job always runs in the scheduler universe. The path to the executable is determined from the ini file.

Methods

```python
_init_(self, cp)

cp = ConfigParser object from which options are read.
Overrides: pipeline.CondorDAGJob.__init__
```

```python
Inherited from AnalysisJob: calibration, channel, get_config
Inherited from CondorDAGJob: add_var_arg, add_var_opt
```

3.3.11 Class TrigToTmpltNode

pipeline.CondorDAGNode

pipeline.AnalysisNode
pipeline.CondorDAGNode

TrigToTmpltNode

A TrigToTmpltNode runs an instance of the triggered bank generator in a Condor DAG.
3.3. Python Module **inspiral**

Methods

```python
__init__(self, job)
```

job = A CondorDAGJob that can run an instance of lalapps_trigtotmplt.

 Overrides: pipeline.AnalysisNode.__init__

**Inherited from AnalysisNode:** get_end, get_ifo, get_input, get_output, get_start, set_cache, set_end, set_ifo, set_input, set_output, set_start

**Inherited from CondorDAGNode:** __repr__, add_parent, add_var_arg, add_var_opt, job, set_log_file, set_name, set_retry, write_job, write_parents, write_vars
3.4 Inspiral Search Programs

This section of LALAPPS contains programs that can be used to search interferometer data for inspiral signals using templated matched filtering and associated veto strategies.
3.4.1 Program lalapps_inspiral_pipe

Name

lalapps_inspiral_pipe — python script to generate Condor DAGs to run the inspiral pipeline.

Synopsis

- `h`, `--help`       display this message
- `v`, `--version`    print version information and exit
- `u`, `--user-tag` TAG tag the job with TAG (overrides value in ini file)
- `d`, `--datafind`   run LALdataFind to create frame cache files
- `t`, `--template-bank` run lalapps_tmpltbank to generate a template bank
- `i`, `--inspiral`   run lalapps_inspiral on the first IFO
- `T`, `--triggered-bank` run lalapps_trigtotmplt to generate a triggered bank
- `I`, `--triggered-inspiral` run lalapps_inspiral on the second IFO
- `C`, `--coincidence` run lalapps_inca on the triggers from both IFOs
- `j`, `--injections` add simulated inspirals from injection file
- `p`, `--playground-only` only create chunks that overlap with playground
- `P`, `--priority` PRIO run jobs with condor priority PRIO
- `f`, `--config-file` FILE use configuration file FILE
- `l`, `--log-path` PATH directory to write condor log file

Description

lalapps_inspiral_pipe generates a Condor DAG to run the inspiral analysis pipeline. The configuration file should specify the parameters needed to run the jobs and must be specified with the `--config-file` option. A file containing science segments to be analyzed should be specified in the [input] section of the configuration file with a line such as

```
segments = S2H1L1v03_selectedsegs.txt
```

This should contain four whitespace separated columns:

```
segment_id   gps_start_time   gps_end_time   duration
```

that define the science segments to be used. Lines starting with an octothorpe are ignored.

The analysis chunk size is determined from the number of data segments and their length and overlap specified in config file. A chunk length is typically this is 1024 seconds for S2. The chunks start and stop times are computed from the science segment times and used to build the DAG.

The once the DAG file has been created it should be submitted to the Condor pool with the `condor_submit_dag` command.

Options

`--help`

Display a brief usage summary.
Example

```bash
lalapps_inspiral_pipe --log-path /people/duncan/dag_logs \ 
--datafind --template-bank --inspiral --priority 10 \ 
--playground-only --config-file l1_s2.ini

condor_submit_dag l1_s2.dag
```

Author

Duncan Brown
3.4.2 Program **lalapps_tmpltbank**

**Name**

*lalapps_tmpltbank* — program to generate inspiral template banks.

**Synopsis**

- **--help** display this message
- **--verbose** print progress information
- **--debug-level LEVEL** set the LAL debug level to LEVEL
- **--user-tag STRING** set the process_params usertag to STRING
- **--comment STRING** set the process table comment to STRING
- **--gps-start-time SEC** GPS second of data start time
- **--gps-end-time SEC** GPS second of data end time
- **--pad-data T** pad the data start and end time by T seconds
- **--frame-cache** obtain frame data from LAL frame cache FILE
- **--calibration-cache FILE** obtain calibration from LAL frame cache FILE
- **--channel-name CHAN** read data from interferometer channel CHAN
- **--sample-rate F** filter data at F Hz, downsampling if necessary
- **--resample-filter TYPE** set resample filter to TYPE [ldas|butterworth]
- **--disable-high-pass** turn off the IIR highpass filter
- **--enable-high-pass F** high pass data above F Hz using an IIR filter
- **--spectrum-type TYPE** use PSD estimator TYPE [mean|median]
- **--segment-length N** set data segment length to N points
- **--number-of-segments N** set number of data segments to N
- **--low-frequency-cutoff F** do not filter below F Hz
- **--high-frequency-cutoff F** upper frequency cutoff in Hz
- **--minimum-mass MASS** set minimum component mass of bank to MASS
- **--maximum-mass MASS** set maximum component mass of bank to MASS
- **--minimal-match M** generate bank with minimal match M
- **--order ORDER** set post-Newtonian order of the waveform to ORDER
  (newtonian|oneHalfPN|onePN|onePointFivePN|twoPN|twoPointFive|threePN|threePointFivePN)
- **--approximant APPROX** set approximant of the waveform to APPROX
  (TaylorT1|TaylorT2|TaylorT3|TaylorF1|TaylorF2|PadeT1|PadeT2|EOB|BCV|SpinTaylorT3)
- **--space SPACE** grid up template bank with mass parameters SPACE
  (Tau0Tau2|Tau0Tau3)
- **--write-raw-data** write raw data to a frame file
- **--write-response** write the computed response function to a frame
- **--write-spectrum** write the uncalibrated psd to a frame
- **--write-strain-spectrum** write the calibrated strain psd to a text file
Description

`lalapps_tmpltbank` is a stand alone code for generating inspiral template banks for LIGO data with the LAL bank package. The code generates a calibrated power spectrum at the specified time for the requested channel and uses this to compute the template bank. See the LAL bank package documentation for detailed information on the algorithms used to generate the banks.

Options

`--help`

Display a brief usage summary.

Example

```bash
lalapps_tmpltbank \n--gps-start-time 734357353 --gps-end-time 734358377 \n--frame-cache cache/L-734357345-734361107.cache \n--segment-length 1048576 --number-of-segments 7 \n--pad-data 7 --sample-rate 4096 --resample-filter ldas \n--enable-high-pass 5.000000e+01 --spectrum-type median \n--low-frequency-cutoff 7.000000e+01 --high-frequency-cutoff 2.048000e+03 \n--minimum-mass 1.000000e+00 --maximum-mass 3.000000e+00 \n--minimal-match 9.700000e-01 --calibration-cache \n/ldas_outgoing/calibration/cache_files/L1-CAL-V03-729273600-734367600.cache \n--space Tau0Tau3 --approximant TaylorT1 --order twoPN \n--channel-name L1:LSC-AS_Q --debug-level 33
```

Author

Duncan Brown
3.4.3  Program lalapps_inspiral

Name
lalapps_inspiral — stand alone inspiral search code

Synopsis

--help display this message
--verbose print progress information
--debug-level LEVEL set the LAL debug level to LEVEL
--user-tag STRING set the process_params usertag to STRING
--comment STRING set the process table comment to STRING

--gps-start-time SEC GPS second of data start time
--gps-start-time-ns NS GPS nanosecond of data start time
--gps-end-time SEC GPS second of data end time
--gps-end-time-ns NS GPS nanosecond of data end time
--pad-data T pad the data start and end time by T seconds

--frame-cache obtain frame data from LAL frame cache FILE
--calibration-cache FILE obtain calibration from LAL frame cache FILE
--channel-name CHAN read data from interferometer channel CHAN

--injection-file FILE inject simulated inspiral signals from FILE

--bank-file FILE read template bank parameters from FILE
--minimal-match M override bank minimal match with M (sets delta)
--start-template N start filtering at template number N in bank
--stop-template N stop filtering at template number N in bank

--sample-rate F filter data at F Hz, downsampling if necessary
--resample-filter TYPE set resample filter to TYPE (ldas|butterworth)

--disable-high-pass turn off the IIR highpass filter
--enable-high-pass F high pass data above F Hz using an IIR filter
--spectrum-type TYPE use PSD estimator TYPE (mean|median)

--segment-length N set data segment length to N points
--number-of-segments N set number of data segments to N
--segment-overlap N overlap data segments by N points

--low-frequency-cutoff F do not filter below F Hz
--inverse-spec-length T set length of inverse spectrum to T seconds
--dynamic-range-exponent X set dynamic range scaling to 2^X

--chisq-bins P set number of chisq veto bins to P
--snr-threshold RHO set signal-to-noise threshold to RHO
--chisq-threshold X threshold on chi^2 < X * ( p + rho^2 * delta^2 )
--enable-event-cluster turn on maximization over chirp length
--disable-event-cluster turn off maximization over chirp length
--enable-output write the results to a LIGO LW XML file
--disable-output do not write LIGO LW XML output file

--write-raw-data write raw data to a frame file
--write-filter-data write data that is passed to filter to a frame
--write-response write the computed response function to a frame
--write-spectrum write the uncalibrated psd to a frame
--write-snr-sq write the snr time series for each data segment
--write-chisq write the r^2 time series for each data segment

Description
lalapps_inspiral is a stand alone code for performing matched filtering of LIGO data for gravitational wave signals and Monte Carlo analysis.

Options

--help
Display a brief usage summary.

Example
lalapps_inspiral
--enable-output --inverse-spec-length 16 --segment-length 1048576
--low-frequency-cutoff 7.000000e+01 --pad-data 8
--bank-file L1-TMPLTBANK-734357353-1024.xml
--sample-rate 4096 --chisq-threshold 20.0 --resample-filter ldas
--channel-name L1:LSC-AS_Q --calibration-cache
/ldas_outgoing/calibration/cache_files/L1-CAL-V03-729273600-734367600.cache
--segment-overlap 524288 --snr-threshold 8.0
--frame-cache cache/L-734357345-734361107.cache
--number-of-segments 7 --dynamic-range-exponent 6.900000e+01
--enable-high-pass 5.000000e+01 --debug-level 33
--gps-start-time 734357353 --gps-end-time 734358377
--chisq-bins 8 --spectrum-type median --enable-event-cluster
--minimal-match 9.700000e-01

Author
Duncan Brown
3.4.4 Program **lalapps_inca**

**Name**

*lalapps_inca* — program does inspiral coincidence analysis.

**Synopsis**

```
lalapps_inca [--help] [--verbose] [--comment COMMENT] [--debug-level LEVEL]
[--no-playground] [--playground-only] --ifo-a IFOA --ifo-b IFOB
[--drhoplus δρ⁺] [--drhominus δρ⁻] [--dm δm] [--dt δt]
--gps-start-time SECONDS --gps-end-time SECONDS [--write-uniq-triggers]
```

(LIGO LIGHTWEIGHT XML FILES)

**Description**

*lalapps_inca* performs coincidence on triggers from the inspiral search code. At present it works for only two interferometers. The names of the two interferometers must be given. Output is written to a LIGO lightweight XML files. Two XML output files are written. The output files contain `process`, `process_params` and `search_summary` tables that describe the search. The primary ifo output file contains the triggers from IFOA that are found to be in coincidence with triggers in IFOB. The secondary output file contains the triggers from IFOB that are found to be in coincidence with the triggers from IFOA. Each trigger in the IFOA file corresponds to the coincident trigger in the IFOB file, so there may be duplicate IFOA triggers. To prevent this, specify the `--write-uniq-triggers` option.

The output files are named in the standard way for inspiral pipeline output. The primary triggers are in a file named

`IFOA-INCA_USERTAG-GPSSTARTTIME-DURATION.xml`

and the secondary triggers are in a file named

`IFOB-INCA_USERTAG-GPSSTARTTIME-DURATION.xml`

If a `--user-tag` is not specified on the command line, the `USERTAG` part of the filename will be omitted.

The default behavior outputs triggers during playground times only. To obtain those triggers that are not in the playground, use the `--no-playground` flag.

**Options**

- **--no-playground**
  Optional. Record all triggers that are not in playground data. The default behaviour returns only those triggers which lie in the playground data set.

- **--playground-only**
  Optional. Record only triggers that occur in the playground times. This is the default behaviour.

- **--ifo-a IFOA**
  Required. This is the name of the interferometer to use as the interferometer A in the coincidence algorithm. It must be a two letter IFO code e.g. L1, H1, etc.
--ifo-b IFOB
Required. This is the name of the interferometer to use as the interferometer B in the coincidence algorithm. It must be a two letter IFO code e.g. L1, H1, etc.

--drhoplus $\delta \rho_+$
Optional. Accept triggers with $\rho_B < (\sigma_B/\sigma_A)\rho_A + \delta \rho_+$ as possible coincidences. If not supplied, then $\delta \rho_+ = 0$.

--dhrominus $\delta \rho_-$
Optional. Accept triggers with $\rho_B > (\sigma_B/\sigma_A)\rho_A - \delta \rho_-$ as possible coincidences. If not supplied, then $\delta \rho_- = 0$.

--dm $\delta m$
Optional. Accept triggers as coincident if both mass parameters agree within $\delta m$. If not supplied, then $\delta m = 0$.

--dt $\delta t$
Optional. Accept triggers as coincident if their end times agree within $\delta t$ milliseconds. If not supplied, then $\delta t = 0$.

--gps-start-time GPS SECONDS
Required. Look for coincident triggers with end times after GPS SECONDS.

--gps-end-time GPS SECONDS
Required. Look for coincident triggers with end times before GPS SECONDS.

--write-uniq-triggers
Optional. The default behaviour is to only write all triggers from IFO A. However, a trigger from IFO A may match two or more triggers from IFO B, so it may be duplicated in the output. Specifying this option causes only unique IFO A triggers to be written.

--comment STRING
Optional. Add STRING to the comment field in the process table. If not specified, no comment is added.

--user-tag STRING
Optional. Set the user tag for this job to be STRING. May also be specified on the command line as -userTag for LIGO database compatibility.

--help
Optional. Print a help message.

--debug-level LEVEL
Optional. Set the LAL debug level to LEVEL. If not specified the default is 1.

Arguments

[LIGO Lightweight XML files]
The arguments to the program should be a list of LIGO Lightweight XML files containing the triggers from the two interferometers. The input files can be in any order and do not need to be time ordered as inca will sort all the triggers once they are read in. If the program encounters a LIGO Lightweight XML containing triggers from an unknown interferometer (i.e. not IFO A or IFO B) it will exit with an error.
Example

lalapps_inca \n--playground-only --gps-start-time 734357353 --drhominus 5.0 \n--dm 0.03 --gps-end-time 734358377 --ifo-b H1 --dt 20.0 \n--ifo-a L1 --drhoplus 5.0 --debug-level 33

Algorithm

The code maintains two poniters to triggers from each ifo, currentTrigger[0] and currentTrigger[1], corresponding to the current trigger from IFO A and B respectively.

1. An empty linked list of triggers from each interferometer is created. Each input file is read in and the code determines which IFO the triggers in the file correspond to. The triggers are appended to the linked list for the corresponding interferometer.
2. If there are no triggers read in from either of the interferometers, the code exits cleanly.
3. The triggers for each interferometer is sorted by the end.time of the trigger.
4. currentTrigger[0] is set to point to the first trigger from IFO A that is after the specified GPS start time for coincidence. If no trigger is found after the start time, the code exits cleanly.
5. Loop over each trigger from IFO A that occurs before the specified GPS end time for coincidence:
   (a) currentTrigger[1] is set to point to the first trigger from IFO B that is within the time coincidence window, δt, of currentTrigger[0]. If no IFO B trigger exists within this window, currentTrigger[0] is incremented to the next trigger from IFO A and the loop over IFO A triggers restarts.
   (b) If the trigger currentTrigger[0] is not in the playground data, start looping over triggers from IFO B.
      i. For each trigger from IFO B that is within δt of currentTrigger[0]
      ii. Call LALCompareSnglInspiral() to check if the triggers match as determied by the options on the command line. If the trigger match, record them for later output as coincident triggers.
   (c) Increment currentTrigger[0] and continue loop over triggers from IFO A.

Author

Patrick Brady, Duncan Brown
3.4.5 Program **lalapps_inspinj**

**Name**

lalapps_inspinj — produces inspiral injection data files.

**Synopsis**

```
```

**Description**

lalapps_inspinj generates a number of inspiral parameters suitable for using in a Monte Carlo injection to test the efficiency of an inspiral search. The various parameters (detailed below) are randomly chosen and are appropriate for a particular population of binary neutron stars whose spatial distribution includes the Milky Way and a number of extragalactic objects that are input in a datafile. The possible mass pairs for the binary neutron star companions are also specified in a (different) datafile.

The output of this program is a list of the injected events, starting at the specified start time, ending at the specified end time, and containing one set of random inspiral parameters every specified time step. The output is written to a file name in the standard inspiral pipeline format:

```
HL-INJECTIONS_USERTAG_SEED-GPSSTART-DURATION.xml
```

where USERTAG is TAG as specified on the command line, SEED is the value of the random number seed chosen and GPSSTART and DURATION describes the GPS time interval that the file covers. The file is in the standard LIGO lightweight XML format containing a *sim_inspiral* table that describes the injections. In addition, an ascii log file called *injlog.txt* is also written. If a --user-tag is not specified on the command line, the USERTAG part of the filename will be omitted.

**Options**

--help
Print a help message.

--source-file SFILE
Optional. Data file containing spatial distribution of extragalactic objects. Default is the file *inspsrcs.dat* provided by LALApps.

--mass-file MFILE
Optional. Data file containing mass pairs for the binary neutron star companions. Default is the file *BNSMasses.dat* provided by LALApps.

--gps-start-time TSTART
Optional. Start time of the injection data to be created. Defaults to the start of S2, Feb 14 2003 16:00:00 UTC (GPS time 729273613)

--gps-end-time TEND
Optional. End time of the injection data to be created. Defaults to the end of S2, Apr 14 2003 15:00:00 UTC (GPS time 734367613).

--time-step TSTEP
Optional. Sets the time step interval between injections. The injections will occur at TSTEP/π second intervals. Defaults to 2630/π.
--seed SEED
Optional. Seed the random number generator with the integer SEED. Defaults to 1.

--waveform WAVE
Optional. The string WAVE will be written into the waveform column of the sim_inspiral table output. This is used by the inspiral code to determine which type of waveforms it should inject into the data. Defaults is GeneratePPNtwoPN.

--user-tag STRING
Optional. Set the user tag for this job to be STRING. May also be specified on the command line as -userTag for LIGO database compatibility.

--ilwd
Optional. If this option is given, lalapps_inspinj also produces two ILWD-format files, injepochs.ilwd and injparams.ilwd, that contain, respectively, the GPS times suitable for inspiral injections, and the intrinsic inspiral signal parameters to be used for those injections.

The file injepochs.ilwd contains a sequence of integer pairs representing the injection GPS time in seconds and residual nano-seconds. The file injparams.ilwd contains the intrinsic binary parameters for each injection, which is a sequence of eight real numbers representing (in order) (1) the total mass of the binary system (in solar masses), (2) the dimensionless reduced mass — reduced mass per unit total mass — in the range from 0 (extreme mass ratio) to 0.25 (equal masses), (3) the distance to the system in meters, (4) the inclination of the binary system orbit to the plane of the sky in radians, (5) the coalescence phase in radians, (6) the longitude to the direction of the source in radians, (7) the latitude to the direction of the source in radians, (8) and the polar- ization angle of the source in radians.

Example
lalapps_inspinj --seed 45\n--source-file inspsrcs.dat --mass-file BNSMasses.dat

Environment
LALAPPS_DATA_PATH
Directory to look for the default mass file BNSMasses.dat and the default source file inspsrcs.dat.

Author
Jolien Creighton, Patrick Brady, Duncan Brown
### 3.4.6 Program lalapps_snglInspiralReader

**Name**

lalapps_snglInspiralReader — manipulates LIGO lightweight XML files of inspiral triggers allowing cuts and clustering.

**Synopsis**

```
```

**Description**

lalapps_snglInspiralReader processes triggers from the inspiral search code. The INFILE should contain a list of the XML files containing the triggers; the format is one filename per line. The default behavior outputs triggers during playground times to the file OUTFILE; to obtain all triggers, use the --noplayground flag. To apply a cut on SNR, use the flag --snrstar SNRSTAR: only triggers with \( \text{SNR} > \text{SNRSTAR} \) will be recorded. Events can also be clustered within MSEC msec, in which case the --sort flag is recommended unless you are certain that the triggers are time-ordered. There is a choice of several clustering algorithms, which can be selected using --clusteralgorithm.

**Options**

**--input** INFILE

Required. A file containing a list of LIGO lightweight XML files with triggers to be processed. The format of INFILE is one file name per line.

**--table** TABLENAME

Required. The name of the XML table containing the inspiral events, this will usually be sngl_inspiral.

**--outfile** OUTFILE

Required. Name of the file to be used for output. The output format is LIGO lightweight XML with sngl_inspiral.process and process.params tables.

**--snrstar** SNRSTAR

Optional. A threshold cut on signal-to-noise. Only triggers with \( \text{SNR} > \text{SNRSTAR} \) are recorded in the output file.

**--noplayground**

Optional. Record all triggers. The default behaviour returns only those triggers which lie in the playground data set.

**--sort**

Optional. Sort the triggers in time (before clustering).

**--cluster** MSEC

Optional. Cluster triggers within MSEC msec window. The clustering algorithm identifies the first trigger in a cluster, then displaces it if another trigger within the clustering window satisfies the appropriate condition (described below).

**--clusteralgorithm** CHOICENUMBER

Optional. This determines which condition will be used in clustering of the triggers. The current choices are snr_and_chisq — displace event if its SNR is exceeded by an event with a smaller CHISQ; snrsq_over_chisq — displace event if the quantity \((\text{SNR})^2/\text{CHISQ}\) is exceeded by a subsequent event’s. The default is snr_and_chisq.
--help
Optional. Print a help message.

Example
lalapps_snglInspiralReader --input xmlfilelist \
--table sngl_inspiral --outfile my.xml --snrstar 8.0 \
--sort --cluster 20 --clusteralgorithm snrsq_over_chisq

Author
Patrick Brady
3.4.7 Program `lalapps_inspinj_find`

Name

`lalapps_inspinj_find` — compares LIGO lightweight XML files containing inspiral triggers with an XML file containing injected signals and tests for time coincidence.

Synopsis

```
lalapps_inspinj_find --input INFILE [--inject INJECTFILE] --outfile OUTFILE
[--snrstar SNRSTAR][--sort][--noplayground][--deltat DT]
[--cluster CLUST][--clusteralgorithm CLUSTERCHOICE][--missedinjections MISSEDFILE]
[--help]
```

Description

`lalapps_inspinj_find` compares triggers from the inspiral search code with injections. The `INFILE` should contain a list of the XML files containing the triggers; the format is one filename per line. The triggers can be sorted, using the `--sort` flag. To apply a cut on SNR, use the flag `--snrstar SNRSTAR`: only triggers with \( \text{SNR} > \text{SNRSTAR} \) will be recorded. If the file `INJECTFILE` containing injections is provided then the program will compare the triggers with the injections, in which case the `--sort` flag is recommended unless you are certain that the triggers are time-ordered. Any trigger occurring within \( DT \) msec of an injection is retained. Additionally, any injection which is coincident with one or more triggers is also retained. The tables of triggers and injections are output to the file `OUTFILE`. Events can also be clustered within `CLUST` msec, after coincidence has been checked. If `CLUST` is twice `DT` then only one trigger per inspiral will survive. There is a choice of several clustering algorithms, which can be selected using `--clusteralgorithm`. Finally, specifying `--missedinjections`, creates a file `MISSEDFILE` containing a table of those injections which occurred during the times of the input files, and in the playground, which were not coincident with any triggers.

Options

**--input INFILE**

Required. A file containing a list of LIGO lightweight XML files with triggers to be processed. The format of `INFILE` is one file name per line.

**--inject INJECTFILE**

Optional. A file containing a list of inspiral events which were injected into the data. The `INJECTFILE` format is LIGO lightweight XML with a sim_inspiral table. If this file is not specified, the program runs in the same way as `lalapps_snglInspiralReader`.

**--outfile OUTFILE**

Required. Name of the file to be used for output. The output format is LIGO lightweight XML with sngl_inspiral, sim_inspiral, process and process_params tables.

**--snrstar SNRSTAR**

Optional. A threshold cut on signal-to-noise. Only triggers with \( \text{SNR} > \text{SNRSTAR} \) are checked for coincidence with the injections.

**--sort**

Optional. Sort the triggers in time (before checking coincidence).

**--noplayground**

Optional. Record all triggers. The default behaviour returns only those triggers which lie in the playground data set.
--deltat DT
Optional. This gives the maximum time difference DT allowed between the injection and trigger. If not specified, the default is 20msec.

--cluster CLUST
Optional. Cluster triggers within CLUST msec window. The clustering algorithm identifies the first trigger in a cluster, then displaces it if another trigger within the clustering window satisfies the appropriate condition (described below).

--clusteralgorithm CHOICENUMBER
Optional. This determines which condition will be used in clustering of the triggers. The current choices are snr_and_chisq — displace event if its SNR is exceeded by an event with a smaller CHISQ; snrsq_over_chisq — displace event if the quantity (SNR)^2/CHISQ is exceeded by a subsequent event’s. The default is snr_and_chisq.

--missedinjections MISSEDFILE
Optional. Output a sim_inspiral table in MISSEDFILE containing all injections which were not coincident with a trigger. Only injections occuring during during the times of the input files and within the playground (unless --noplayground is specified) are given.

--help
Optional. Print a help message.

Example
lalapps_inspinj_find --input xmlfilelist \ 
--inject injections.xml --outfile my.xml --snrstar 8.0 \ 
--coincidence 20 --sort --cluster 20 --clusteralgorithm snrsq_over_chisq \ 
--missedinjections missedinj.xml

Author
Steve Fairhurst
3.5 Power Tools

This section of LALAPPS contains programs that can be used to perform burst searches using the excess power algorithm.

Put a summary of the excess power algorithm here .........
3.5. Power Tools

3.5.1 Program lalapps_power

Name

lalapps_power — runs excess power code on chunks of (simulated) data.

Synopsis

lalapps_power --npts NPTS --nseg NSEG --olap OLAP --olapfctr OLAPFCTR \  
--minfbin MINFBIN --mintbin MINTBIN --flow FLOW --delf DELF --lnqth LNQTH \  
--nsigma NSIGMA --alphdef ALPHDEF --segdcle SEGDCLE --threshold THRESHOLD \  
--etomstr ETOMSTR --channel CHANNEL --simtype SIMTYPE --spectype SPECTYPE \  
--window WINDOW --start_time SEC --start_time_ns NSEC \  
--numpts NUMPTS [--printSpectrum] --srate SRATE \  
[--cluster][--noise VAR][--seed SEED] \  
[--comment COMMENT]

Description

lal_power runs the excess power code from LAL on a chunk of real or simulated data. Consider searching for signals with the following properties:

- Maximum signal time duration $T = 2^a$ seconds where $a$ is a positive or negative integer; the sampling rate of the data stream is taken assumed $\text{srate} = 2^b$ Hz.
- The frequency band of the signal is between $f_{\text{low}}$ Hz and $f_{\text{high}}$ Hz. Current versions of the code expect $f_{\text{high}} - f_{\text{low}} = 2^d$ Hz where $d$ is an integer.
- Minimum time duration,
- Minimum frequency bandwidth.

Options

--npts NPTS
Number of data points in a segment is determined by

$$NPTS = (T \times \text{srate}).$$

--nseg NSEG
Number of overlapping segments into which data should be divided for filtering; must be an integer.

--olap OLAP
Number of points overlap between segments. This is an argument for completeness, but in general it should be NPTS/2.

--olapfctr OLAPFCTR
Amount of overlap between neighboring TF tiles; must be an integer. A reasonable value for this parameter is 3. See LAL burstsearch package for details.

--minfbin MINFBIN
Smallest extent in frequency of TF tiles to search; must be an integer. A reasonable value for this parameter is 2. The product $\text{MINFBIN} \times \text{MINTBIN}$ is the minimum time-frequency volume to be searched. See LAL burstsearch package for details.
--mintbin MINTBIN
Smallest extent in time of TF tiles to search; must be an integer. A reasonable value for this parameter is 2. The product MINFBIN \times MINTBIN is the minimum time-frequency volume to be searched. See LAL burstsearch package for details.

--flow FLOW
Lowest frequency in Hz to be searched; a real number. This is obviously $f_{\text{low}}$ Hz from our description of the desired signal parameters above.

--delf DELF
This input should be set to $1/T$ Hz but it is ignored by the current version of the code; a real number.

--lngth LNGTH
may be determined by the following formula

$$\text{LNGTH} = T \times (f_{\text{high}} - f_{\text{low}}).$$

This is an integer which determines the maximum frequency bandwidth over which a signal is expected.

--nsigma NSIGMA
threshold number of sigma; a real number. Currently see LAL burstsearch package for details.

--alphdef –ALPHDEF
default alpha value for tiles with sigma $\leq$ numSigmaMin; a real number. Currently see LAL burstsearch package for details.

--segdcle SEGDCLE
Number of segments analyzed at a time; must be an integer. The current code uses SEGDCLE overlapping segments to compute the average (or median) power spectral estimate for use inside the code.

--threshold THRESHOLD
Identify events with alpha less than this; a real number. Currently see LAL burstsearch package for details.

--etomstr ETOMSTR
Number of events to be accepted from a search over NPTS of data; must be an integer.

--channel CHANNEL
The name used to identify the data to be analyzed; a character string matching the channel name in the frame files, e.g. H2:LSC-AS_Q.

--start_time SEC
The GPS time corresponding to the start of the time series read from frames. Note: OLAP points are discarded at the beginning and end of the data to avoid data corrupted by the low-pass filtering.

--start_time_ns NSEC
The number of nanoseconds after SEC for the time series read from frames.

--framecache FRCACHE
A LAL format frame cache file. The FRCACHE can be a filename in the local directory, or a filename including absolute path. These cache files are explained in the framedata package in LAL and can be constructed by making calls to LALdataFind on some systems.
---SIMTYPE
Type of simulation. Set it to 0, although it is ignored in the current version of the code.

---SPECTYPE
Spectrum estimator for whitening data; a character string [useMean, useMedian].

---WINDOW
Type of window to use on the data; must be an integer. [Possible values are: 0=Rectangular, 1=Hann, 2=Welch, 3=Bartlett, 4=Parzen, 5=Papoulis, 6=Hamming.]

---NUMPTS
The number of points of data to be extracted from the frame files may be determined by the following formula

\[
\text{NUMPTS} = \text{NSEG} \times (\text{NPTS} - \text{OLAP}) + 3 \times \text{OLAP}.
\]

Notice that this appears to be \(2 \times \text{OLAP}\) more points than you might expect. Since the data stream is high-pass filtered internally, the code ignores the first \(\text{OLAP}\) points and requires that there be an extra \(\text{OLAP}\) points at the end to avoid data corruption.

---CLUSTER
Apply a clustering algorithm to tiles identified by the excess power code. The result is reduction of overlapping triggers to a single trigger which covers a square time-frequency volume which encompasses all overlapping trigger regions. The signal-to-noise and the confidence associated with a clustered trigger belong to the most significant excess-power trigger in the cluster. [This is a prototype option. Its behavior is not robustly tested. Treat with care and look at the code to insure understanding.]

---COMMENT
A user defined comment string. It should be less than 256 characters and should not contain spaces (replace spaces by underscores). This string will appear in the name of the file to which output information is written.

---PRINTSPECTRUM
Print out the power spectrum to a file. Note: this needs to be enhanced. AT present it give some help with debugging and understanding the data.

---PRINTDATA
Print out the time series that is read in by the code.

---VERBOSE
Print out informational messages as the code runs.

---DBGLEVEL
Set the lalDebugLevel. The default is LALMSG_LVL2. A useful setting is 65 which turns off memory padding, but keeps memory tracking and error messages.

Example
To run the program, type:

```
lalapps_power --npts 2048 --nseg 719 --olap 1024 --olapfctr 3 \n   --minfbin 2 --mintbin 2 --flow 100.0 --delf 1.0 --length 512 --nsigma 2.0 \n   --alphdef 0.5 --segdcle 32 --threshold 1.0e-13 --etomstr 10 \n   --channel S1:LSC-AS_Q --simtype 0 --spectype useMedian --window 2 \n   --epoch 693768279 0 --numpts 1048576 --printSpectrum --noise 1 11 \n   --comment simulation
```

Author
Patrick Brady
3.5.2 Program **lalapps_snglBurstHistogram**

Name

**lalapps_snglBurstHistogram** — runs over LIGO lightweight files and histograms the triggers by frequency.

Synopsis

```
lalapps_snglBurstHistogram --input INFILE [--threshold THRESHOLD] \ 
    --freq FSTART FSTOP DF [--tfhist OUTFILE] [--help]
```

Description

**lal_snglBurstHistogram** reads in LIGO lightweight files and constructs a histogram of the triggers over frequency. This histogram data is then printed in the file `freq-hist.txt`. It also produces a list of triggers for each playground segment separately and that is printed in the `OUTFILE`, if provided. The code should be extensible to do a number of similar things like this.

Options

- **--input** `INFILE`
  The name of a file containing a list of XML files to parse; one XML file per line of `INFILE`.

- **--table** `TABLENAME`
  The name of the table to be parsed from the XML file. This will be needed when the process table is written into the XML files by the power code.

- **--threshold** `THRESHOLD`
  Identify events with alpha less than this; a real number. The meaning of the threshold is the same as `lalapps_power` itself. (Optional)

- **--freq** `FSTART FSTOP DF`
  Parameters which define a frequency histogram. `FSTART` is the lowest frequency; `FSTOP` is the highest frequency; `DF` is the width of abin.

- **--tfhist** `OUTFILE`
  The name of a file which will contain the list of triggers per playground segment for each frequency bin.

- **--help**
  Print usage instructions.

Example

To run the program, type:

```
lalapps_snglBurstHistogram --input files.txt --freq 100.0 1000.0 25.0 --tfhist tf.txt
```

This will read in the xml files listed in files (see below) and construct a frequency histogram with lowest frequency 100 Hz, highest frequency 1000 Hz and bin width 25 Hz. This output will be in `freq-hist.txt`. It will also produce the triggers for each playground segment and those will be in `tf.txt`. The file `files.txt` must contain a list of XML files. Here are the first few lines from such a file:

```
simtest-693768279-11.xml
simtest-693768311-21.xml
simtest-693768343-31.xml
simtest-693768375-41.xml
```
Author

Patrick Brady
3.5.3 Program lalapps_burca

Name
lalapps_burca — program does burst coincidence analysis.

Synopsis
lalapps_burca --ifo-a TRIGFILE.A --ifo-b TRIGFILE.B [--start-time STARTCOINCIDENCE] \ 
[--stop-time ENDCOINCIDENCE] [--drhoplus DRHOPLUS] [--drhominus DRHOMINUS] \ 
[--dt DELTAT] --outfile OUTFILE [--noplayground] [--help]

Description
lalapps_burca performs coincidence on triggers from the burst search code. (At present it works for only two interferometers.) It must be called with at least one input file from each instrument. The default behavior outputs triggers during playground times to the file OUTFILE; to obtain all triggers, use the --noplayground flag.

Options

--ifo-a TRIGFILE.A
Required. LIGO lightweight XML file with triggers from interferometer A. This argument can be called multiple times. Triggers are sorted after all files have been read in.

--ifo-b TRIGFILE.B
Required. LIGO lightweight XML file with triggers from interferometer B. This argument can be called multiple times. Triggers are sorted after all files have been read in.

--start-time STARTCOINCIDENCE
Optional. Look for coincident triggers with start times after STARTCOINCIDENCE. If not supplied, the STARTCOINCIDENCE = 0.

--stop-time ENDCOINCIDENCE
Optional. Look for coincident triggers with start times before ENDCOINCIDENCE. If not supplied, then ENDCOINCIDENCE = 977788813, i.e. 00:00 Dec 31, 2010 UTC.

--drhoplus DRHOPLUS
Optional. Not yet implemented.

--drhominus DRHOMINUS
Optional. Not yet implemented.

--dt DELTAT
Optional. Accept triggers as coincident if their start times agree within DELTAT in msec. If not supplied, then DELTAT = 0.

--outfile OUTFILE
Required. Name of the file to be used for output. The output format is LIGO lightweight XML with only a sngl_burst table.

--noplayground
Optional. Record all triggers. The default behaviour returns only those triggers which lie in the playground data set.

--cluster MSEC
--help
Optional. Print a help message.

Example
lalapps_burca --ifo-a L-POWER-734357353-1024.xml \
--ifo-b H-POWER-734357353-1024.xml --dt 10 --outfile my.xml \
--start-time 734357353 --stop-time 734358353 --noplayground

Author
Patrick Brady
3.6 Programs Related to Stochastic Background Searches

3.6.1 Program lalapps_olapredfcn

Name
lal_olapredfcn — computes overlap reduction function given a pair of known detectors.

Synopsis
lal_olapredfcn [-h] [-q] [-v] [-d debugLevel ] \ 
   -s siteID1 [-a azimuth1] -t siteID2 [-b azimuth2] \ 
   [-f fLow] -e deltaF -n numPoints -o outfile

Description
lal_olapredfcn computes the overlap reduction function \( \gamma(f) \) for a pair of known gravitational wave detectors. It uses the LAL function LALOverlapReductionFunction(), which is documented in the LAL Software Documentation under the stochastic package.

Options

- **-h**
  Print a help message.

- **-q**
  Run silently (redirect standard input and error to /dev/null).

- **-v**
  Run in verbose mode.

- **-d debugLevel**
  Set the LAL debug level to debugLevel.

- **-s siteID1 -t siteID2**
  Use detector sites identified by siteID1 and siteID2; ID numbers between LALNumCachedDetectors (defined in the tools package of LAL) refer to detectors cached in the constant array lalCachedDetectors[]. (At this point, these are all interferometers.) Additionally, the five resonant bar detectors of the IGEC collaboration can be specified. The bar geometry data (summarized in table 3.2) is used by the function LALCreateDetector() from the tools package of LAL to generate the Cartesian position vector and response tensor which are used to calculate the overlap reduction function. The ID numbers for the bars depend on the value of LALNumCachedDetectors; the correct ID numbers can be obtained by with the command

  ./lalapps_olapredfcn -h

- **-a azimuth1 -b azimuth2**
  If siteID1 (siteID2) is a bar detector, assume it has an azimuth of azimuth1 (azimuth2) degrees East of North rather than the default IGEC orientation given in table 3.2. Note that this convention, measuring azimuth in degrees clockwise from North is not the same as that used in LAL (which comes from the frame spec). Note also that any specified azimuth angle is ignored if the corresponding detector is an interferometer.

- **-f fLow**
  Begin the frequency series at a frequency of fLow Hz; if this is omitted, the default value of 0 Hz is used.
Table 3.2: Location and orientation data for the five IGEC resonant bar detectors, stored in the \texttt{lalCachedBars[]} array. The data are taken from \url{http://igec.lnl.infn.it/cgi-bin/browser.pl?Level=0,3,1} except for the latitude and longitude of ALLEGRO, which were taken from Finn & Lazzarini, gr-qc/0104040. Note that the elevation above the WGS-84 reference ellipsoid and altitude angle for each bar is not given, and therefore set to zero.

<table>
<thead>
<tr>
<th>Name</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>AURIGA</td>
<td>11°56′54″E</td>
<td>45°21′12″N</td>
<td>N44°E</td>
</tr>
<tr>
<td>NAUTILUS</td>
<td>12°40′21″E</td>
<td>41°49′26″N</td>
<td>N44°E</td>
</tr>
<tr>
<td>EXPLORER</td>
<td>6°12′E</td>
<td>46°27′N</td>
<td>N39°E</td>
</tr>
<tr>
<td>ALLEGRO</td>
<td>91°10′43″W</td>
<td>30°24′11″N</td>
<td>N40°W</td>
</tr>
<tr>
<td>NIOBE</td>
<td>115°49′E</td>
<td>31°56′S</td>
<td>N0°E</td>
</tr>
</tbody>
</table>

\textbf{Example usage}

To compute the overlap reduction function for LIGO Hanford and LIGO Livingston, with a resolution of 1 Hz from 0 Hz to 1024 Hz:

\begin{verbatim}
lalapps_olapredfcn -s 0 -t 1 -e 1 -n 1025 -o LHOLLO.dat
\end{verbatim}

To compute the overlap reduction function for ALLEGRO in its optimal orientation of 72°08 West of South (see Finn & Lazzarini, gr-qc/0104040) and LIGO Livingston, with a resolution of 0.5 Hz from 782.5 Hz to 1032 Hz (assuming \texttt{lalNumCachedBars} is 6):

\begin{verbatim}
lalapps_olapredfcn -s 9 -a 252.08 -t 1 -f 782.5 -e 0.5 -n 500 -o ALLEGROLHO.dat
\end{verbatim}

\textbf{Author}

John T. Whelan
3.7 Program **lalapps_ring**

**Name**

*lalapps_ring* — filters data through a bank of ringdown filters.

**Synopsis**

```
```

**Description**

*lalapps_ring* uses matched filtering to search for ringdown waveforms in gravitational wave data.

**Options**

- `-h`
  Print a help message.

- `-V`
  Print the version information.

- `-v`
  Verbose output.

- `-d dbglvl`
  Set LAL debug level to `dbglvl`.

- `-i infile`
  Read filter parameters from input file `infile` [stdin].

- `-o outfile`
  Write the output to file `outfile` [stdout].

- `-k`
  Keep filtering results (for use with option `-s`).

- `-s`
  Save intermediate filtering results as .dat and snr- files.

- `-f framefile`
  Read channel data from `framefile` [.gwf].

- `-r respfile`
  Read response function data from `respfile` [response.asc].

- `-c channel`
  Use channel `channel` data [H1:LSC-AS_Q].

- `-n numpoints`
  Use `numpoints` points of data [65536].

- `-t starttime`
  Use data starting at GPS time `starttime` [start of frame data].
3.7. Program *lalapps_ring*

- **-b b0,b1**
  Filter only template numbers \(b0\) to \(b1\) in bank [0, end of bank].

- **-- filterparams**
  Specify filter parameters as command line arguments `filterparams` (see below for filter parameters).

**Filter parameters**

The filter parameters can be specified either on the command line as arguments following the **--** option or in a resource file that is input using the **-i** option (or from stdin). As a resource file, each option-value pair should have their own line.

- **-segsz npts**
  Set the size of segments analyzed to \(npts\) points.

- **-speclen len**
  Set the size of inverse spectrum truncation to \(len\) points [0].

- **-flow flow**
  Set the low frequency cutoff to \(flow\) Hz.

- **-fmin fmin**
  Set the minimum frequency for the bank to \(fmin\) Hz.

- **-fmax fmax**
  Set the maximum frequency for the bank to \(fmax\) Hz.

- **-qmin qmin**
  Set the minimum quality for the bank to \(qmin\).

- **-qmax qmax**
  Set the maximum quality for the bank to \(qmax\).

- **-maxmm maxmm**
  Set the maximum allowed mismatch for the bank to \(maxmm\).

- **-thresh thresh**
  Set the ringdown event signal-to-noise ratio threshold to \(thresh\).

- **-scale scale**
  Scale the response function by a dynamic range factor of \(scale\) [1].

**Debug levels**

The LAL debug level can be specified as an integer or as a string of flags:

- **NDEBUG**
  No debugging information is printed and memory debugging code is disabled.

- **ERROR**
  Error messages are printed.

- **WARNING**
  Warning messages are printed.

- **INFO**
  Information messages are printed.
3.7. Program `lalapps_ring`

TRACE
Function call tracing messages are printed.

MEMINFO
Memory allocation information messages are printed.

MEMDBG
Debugging of memory allocation routines is enabled but no messages are printed.

The following composite levels are available:

MSGLVL1
   Equivalent to ERROR

MSGLVL2
   Equivalent to ERROR | WARNING

MSGLVL3
   Equivalent to ERROR | WARNING | INFO

ALLDBG
   All debugging messages are printed.

For example, the command

```
lalapps_ring -d "ERROR | INFO" ...
```

will set the debug level so that error and information messages are printed.

Environment

`LAL_DEBUG_LEVEL`
   Default LAL debug level to use.

Author
   Jolien Creighton
3.8 Program lalapps_trump

Name
lalapps_trump — postprocess data generated by the inspiral search code to determine an upper limit or perform detection.

Synopsis
lalapps_trump --veto filename --trigger filename --times filename ovlap [--detection] [--help]

Description
lalapps_trump manipulates the results of the inspiral search code and veto data stored in XML format to produce lists of candidate events for individual interferometers. It can also be used to perform a coincidence analysis using the output written for each interferometer.

Options

--help
Print a help message.

--veto filename
This is required. Name of the file containing metadata about the vetos to be applied to inspiral triggers. This file can contain multiple lines. Each line is a semi-colon separated list of the form:

name;filename;column;threshold;minusdtime;plusdtime;

Here name is a character string; filename is a character string naming the xml file with the veto triggers; column is the database column name to use for veto construction; threshold is a number (float), vetos have the value in column bigger than this; minusdtime and plusdtime give the interval of time (in seconds) which should be ignored before and after the veto trigger.

--trigger filename
This is required. Name of the file containing metadata about the inspiral triggers and simulated injections to determine the pipeline efficiency. This file contains a single, semi-colon separated line:

name;trigfile;injfile;snr*;chisq*;dt ime;injlog;

Here name is a character string; trigfile is a character string naming the xml file with the inspiral triggers; injfile is a character string naming the xml file with the inspiral triggers when software injections are made; snr* is a number (float), triggers have SNR greater than this; chisq* is a number (float), triggers have CHISQ less than this; dtime is a number (float) giving the interval of time (in seconds) between threshold crossings for clustering; injlog is a character string naming the ascii file with the information about software injections.

--detection
Use this option if you want to run in detection mode. The code will terminate after generating a list of triggers.

--times filename ovlap
Name of the ascii file with the list of data chunks analyzed. The expected format is three columns: (i) flag to indicate if it was analyzed or not, (ii) GPS start time, and (iii) GPS stop time. The floating point number ovlap indicates how much data in seconds is ignored in each chunk. The code assumes that ovlap/2 is ignored at the beginning and end of each chunk.
3.8. Program *lalapps_trump*

**Example**

To run the program, type:

```
lalapps_trump --veto l1vetoes --trigger l1cand \ 
   --times segment_S1_play_03.out 32.0 --detection
```

This command will look for information about vetoes in the file `l1vetoes`, information about triggers in the file `l1cand`, and information about the times analyzed in `segment_S1_play_03.out` with an overlap of 32 seconds. Since detection is turned on, a list of candidates is generated in a file called `triggers.dat` in the direction from which you execute the command.

**Uses**

This code uses LAL and the dataflow library. The code in `event_utils.c` includes some code written by Peter Shawhan to access the xml files.

**Author**

Patrick Brady
3.9 Program **lalapps_findchirp_post**

**Name**

lalapps_findchirp_post — post process event files from findchirp

**Synopsis**


**Description**

lalapps_inspinj post process event files from findchirp.

**Options**

- **-h**
  
  Print a help message.

- **-v**
  
  Print the version information.

- **-v**
  
  Verbose output.

- **-d dbglvl**
  
  Set LAL debug level to dbglvl.

- **-m**
  
  Maximize events over injections. This options caused only the loudest event (in SNR) in each window of length $100/\pi = 31.8309886183791$ to be processed. The window starts at the time of the first event.

- **-s minsnr maxsnr**
  
  Set minimum and maximum of the range of signal to noise ratio for creation of the histogram bins. (Default is 7.014.0.)

- **-c minchisq maxchisq**
  
  Set minimum and maximum of the range of chi squared veto statistic for creation of the histogram bins. (Default is 0.050.0.)

- **-b bins**
  
  Set the number of bins in the two dimensional histogram. (Default is 10.)

- **-e eventfile**
  
  Set the path to the file containing the list of inspiral events. (Default is eventfile.dat.) The event file must be of the format END_TIME END_TIME_NS EFF_DISTANCE MASS1 MASS2 MCHIRP ETA SNR CHISQ SIGMASQ. Each event should be separated by a new line. Lines beginning with an octothorpe are ignored.

**Debug levels**

The LAL debug level can be specified as an integer or as a string of flags:

- **NDEBUG**
  
  No debugging information is printed and memory debugging code is disabled.

- **ERROR**
  
  Error messages are printed.
WARNING
Warning messages are printed.

INFO
Information messages are printed.

TRACE
Function call tracing messages are printed.

MEMINFO
Memory allocation information messages are printed.

MEMDBG
Debugging of memory allocation routines is enabled but no messages are printed.

The following composite levels are available:

MSGLVL1
Equivalent to ERROR

MSGLVL2
Equivalent to ERROR | WARNING

MSGLVL3
Equivalent to ERROR | WARNING | INFO

ALLDBG
All debugging messages are printed.

For example, the command

    lalapps_inspinj -d "ERROR | INFO"

will set the debug level so that error and information messages are printed.

Environment

LAL_DEBUG_LEVEL
Default LAL debug level to use.

Author
Duncan Brown
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  KEY: Einstein:1905

[2] LIGO Scientific Collaboration *LAL Software Documentation*
  
  KEY: LAL
  
  Annotation: Manual for the LSC Algorithm Library (LAL)
  URL: [http://www.lsc-group.phys.uwm.edu/lal](http://www.lsc-group.phys.uwm.edu/lal)

  
  KEY: Press:1992
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lalapps_olapredfcn.62
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