Command Line Interface For Time Correlation Analysis

Motivation

Development of this application was stimulated by the discussion with Marcin Sikorski (meeting on 2012-08-30), doing xcs experiments.
Users need in real-time algorithm for calculation of image vs time auto-correlation function

```
g2(tau) = <I(t)*I(t+tau)> / (<I(t)> * <I(t+tau)>),
```

where `I(t)` is an image intensity at time `t`, and `tau` is a delay between two measurements.
Typical experimental condition can be described as follows:

- Run duration is about one hour at frequency up to 120 Hz that gives up to 10^5-10^6 images.
- Currently typical imaging devise is a Princeton camera with 1300x1340 pixels.
- Need to calculate `g2(tau)` for each pixel, averaged over all possible image times `t` with time difference `tau` between images.
- A set of `tau` should have about 30-100 points in log scale uniformly covering the run duration.
- Use for example xcsi0112-r0015: 500 images with 8 sec delay between images.
  Desired time for evaluation of the auto-correlation function should be comparable with run duration <1 hour. Currently this algorithm takes a few hours that can not be used for fast feedback in real time experiment.

Algorithm

Basic idea is (1) to split image vs time for small parts in image, (2) to process each part on separate computer node, (3) to merge results at the end of processing. It is clear that significant speedup (about T/N_nodes_) is achieved at the 2nd stage. These three stages are performed in separate C++ applications. Wrapping python script allows to submit job by a single command. It takes care about file and sub-process management in this job, as described below.

Code location

All modules for this application resides in the package ImgAlgos:

Module	Functionality
ImgVsTimeSplitInFiles	splitter
CorAna	base class with common methods
CorAnaData	data processing for split files
CorAnaInputParameters	provides storage for input parameters
CorAnaMergeFiles	merging algorithm
CorAnaProcResults	Example showing how to access results using C++ and produce a table for presentation
CorAnaPars.py	singleton class for parameter storage in the wrapping file manager
CorAnaSubmit.py	global methods for the file manager
app/corana_submit	pythonic script which defines the sequence of procedures
app/corana.cpp	main module for the part of image vs time correlation processing
app/corana_merge.cpp	main module for merging
app/corana_procres.cpp	main module for processing of results from correlator array

data/psana-corana.cfg	psana configuration file for ImgVsTimeSplitInFiles
data/PlotCorAnaResults.py	example of the python script which plots the resulting graphics

Image splitting

Image splitting is implemented as a regular psana module ImgAlgos::ImgVsTimeSplitInFiles.

Command to run interactively on `psana####` or submit in batch from `pslogin##` node:

```
psana -c <config-file> <xtc-file-list>
bsub -q psfehq -o log-file 'psana -c <config-file> <xtc-file-list>'
```

For example:

```
psana -c ImgAlgos/data/psana-corana.cfg  /reg/d/psdm/XCS/xcsi0112/xtc/e167-r0015-*
```

where `ImgAlgos/data/psana-corana.cfg` is an example of the configuration script for `psana` and `/reg/d/psdm/XCS/xcsi0112/xtc/e167-r0015-*` are the input xtc files for particular run.

A couple of limitations due to LCLS policy:
Interactive job can be run on `psana####` computer, but the batch queues are not seen from `psana####` nodes...
Batch job can be submitted from `pslogin##` computer, but data are not seen directly from `pslogin##` nodes...

Produces the files:

```
cor-ana-r0015-b0000.bin - file with a part of image vs time
cor-ana-r0015-b0001.bin
cor-ana-r0015-b0002.bin
cor-ana-r0015-b0003.bin
cor-ana-r0015-b0004.bin
cor-ana-r0015-b0005.bin
cor-ana-r0015-b0006.bin
cor-ana-r0015-b0007.bin
cor-ana-r0015-time.txt - list of time-records for all events in processed run.
cor-ana-r0015-time-ind.txt - list of time-records for all events in processed run with time index.
cor-ana-r0015-med.txt - file with metadata. In particular it has the original image size, number of image parts
for splitting, number of images in run, etc.
```

Algorithms:

- The <int16_t> image data array is split for ordered number of equal parts (by the parameters `nfiles_out` in psana-corana.cfg file) and each part is saved in the output `cor-ana-r0015-b####.bin` file sequentially for all selected events.
- The appropriate time record for selected event is saved in the file `cor-ana-r0015-time.txt`.
- At the end of the splitting procedure:
  - the average time difference and its rms between sequential events is evaluated for all recorded time records.
  - The file `cor-ana-r0015-time.txt` is re-processed and for each record the time index is evaluated as unsigned value of

    ```
    <time-index> = (<event-time> + 0.5 <average-time-between-events>) /  <average-time-between-events>
    ```

  - Event record with time index is saved in the file `cor-ana-r0015-time-ind.txt`
- All metadata parameters which are required for further processing, such as input parameters, image size, <`average-time-between-events`, maximal value of the time index etc., are saved in file `cor-ana-r0015-med.txt`.

This approach allows to apply the modest event selection algorithms in `psana` pre-processing stage.
But, it still based on uniform time indexing...
Q: Is it really good assumption for this kind of experiments?

Time correlation processing

`ImgAlgos/app/corana` application

Command to run interactively on `psana####` or submit in batch from `pslogin##` node:

```
corana -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]
bsub -q psfehq -o log-file 'corana -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]'
```

For example the interactive and batch mode commands:

```
corana -f cor-ana-r0015-b0001.bin -t my-tau.txt
bsub -q psfehq -o log-file 'corana -f cor-ana-r0015-b0000.bin'
```

Produce files:

```
cor-ana-r0015-tau.txt          - string of {{tau}} values for which the auto-correlation function is evaluated
cor-ana-r0015-b0000-result.bin - auto-correlators for the part of the image for all {{tau}} values
cor-ana-r0015-b0001-result.bin
cor-ana-r0015-b0002-result.bin
cor-ana-r0015-b0003-result.bin
cor-ana-r0015-b0004-result.bin
cor-ana-r0015-b0005-result.bin
cor-ana-r0015-b0006-result.bin
cor-ana-r0015-b0007-result.bin
```

Merging results

`ImgAlgos/app/corana_merge` application

Command to run interactively on `psana####` or submit in batch from `pslogin##` node:

```
corana_merge -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]
bsub -q psfehq -o log-file 'corana_merge -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]'
```

For example:

```
corana_merge -f cor-ana-r0015-b0001-result.bin -t my-tau.txt
```

This procedure produces file:

```
cor-ana-r0015-image-result.bin
```

Example of how to get and process results

`ImgAlgos/app/corana_procres`

Command to run interactively on `psana####` or submit in batch from `pslogin##` node:

```
corana_procres -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]
bsub -q psfehq -o log-file 'corana_procres -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]'
```

Basically it reads files with results and produces the histogram-like table `*-hist.txt`.

Automatic processing

`ImgAlgos/app/corana_submit` - is a wrapping script which allows to run all of above procedures by a single command from `pslogin##` node and it keeps eye on processing of jobs in batch and doing the file management. Command to start:

```
corana_submit [-c <config-file>] [-t <fname-tau>] [-x] <xtc-file-list>
```

For example:

```
corana_submit -c ImgAlgos/data/psana-corana.cfg -t my-tau.txt /reg/d/psdm/XCS/xcsi0112/xtc/e167-r0015-s00-c00.
xtc
```

This script sequentially performs operations for single run as follows:

1. Initialize all parameters
2. Run psana to split image for files
3. Check that all split files are produced
4. Submit job for time-correlation processing
5. Check that all processed files are produced
6. Submit job for merging
7. Check that merged file is produced
8. Submit job for test processing of the file with results
9. List all created files
10. Clean-up files in the work directory
11. List of preserved files

    The next to last procedure deletes all intermediate split- and log- files.
    In debugging mode this procedure may be turned off.

Manual sequential processing

In case of manual processing of all scripts, commands need to be issued in a right order. Commands `corana`, `corana_merge`, and `corana_procres` should have the same list of parameters. This is important, because all file names for these procedures are generated by the same base class `ImgAlgos/src/CorAna.cpp`

Right sequence of commands to run interactively on `psana####`

```
psana -c <config-file> <xtc-file-list>
corana         -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]
corana_merge   -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]
corana_procres -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]
```

or submit in batch from `pslogin##` node:

```
bsub -q psfehq -o log-file 'psana -c <config-file> <xtc-file-list>'
bsub -q psfehq -o log-file 'corana         -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]'
bsub -q psfehq -o log-file 'corana_merge   -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]'
bsub -q psfehq -o log-file 'corana_procres -f <fname-data> [-t <fname-tau>] [-l <logfile>] [-h]'
```

The `corana` batch jobs can be submitted and run on separate butch nodes in parallel. All other procedures can be submitted when previous is successfully finished and all necessary files are produced.
The `corana_procres` command is optional and is currently used for test purpose only. But, it may be replaced by real analysis code.

File formats

- File with split-image data for selected events `cor-ana-r0015-b000N.bin`:
  Currently this file contains <`uint16_t`> amplitude for each pixel in binary format for:

  ```
  <data-for-img-partN-of-img1> <data-for-img-partN-of-img2> ... <data-for-img-partN-of-imgLast>
  ```

- File with metadata parameters `cor-ana-r0015-med.txt`:

```
IMAGE_ROWS      1300
IMAGE_COLS      1340
IMAGE_SIZE      1742000
NUMBER_OF_FILES 8
BLOCK_SIZE      217750
REST_SIZE       0
NUMBER_OF_IMGS  500
FILE_TYPE       bin
DATA_TYPE       uint16_t
TIME_SEC_AVE    8.088413
TIME_SEC_RMS    0.063639
TIME_INDEX_MAX       499
```

- File with image time records `cor-ana-r0015-time.txt`:

```
     1        0.000000  0.000000  20120616-080236.671607864    5366      0
     2        8.026429  8.026429  20120616-080244.698036743    8255      1
     3       16.144788  8.118359  20120616-080252.816395836   11177      2
     4       24.154835  8.010048  20120616-080300.826443448   14060      3
    ...
```

where each record has:

```
<image-in-file#> <t(sec)-from-the-1st-event> <dt(sec)> <time-stamp> <fiducials> <event#-since-configure>
```

- File with image time records and evaluated time index `cor-ana-r0015-time-ind.txt`:

```
     1        0.000000  0.000000  20120616-080236.671607864    5366      0        0
     2        8.026429  8.026429  20120616-080244.698036743    8255      1        1
     3       16.144788  8.118359  20120616-080252.816395836   11177      2        2
     4       24.154835  8.010048  20120616-080300.826443448   14060      3        3
     5       32.281937  8.127102  20120616-080308.953545010   16985      4        4
    ...
```

where each record has:

```
<image-in-file#>  <t(sec)-from-the-1st-event> <dt(sec)> <time-stamp> <fiducials> <event#-since-
configure> <time-index-starting-from-0>
```

- File with split-image correlators for each value of `tau` `cor-ana-r0015-b000N-result.bin`:
Currently it saves `<float>` correlator for each pixel in binary format for:

```
<corr-for-img-partN-of-tau1> <corr-for-img-partN-of-tau2> ... <corr-for-img-partN-of-tauLast>
```

- `my-tau.txt`:

```
 1 3 5 7 9 10 12 14 16 18 20 24 28 30 32 36 40 ... 160 180 200 240 280 300 320 360 400
```

contains the `tau` values presented in terms of number of ordered images in the file.

Quick start guide

We assume that everything is set up to work on LCLS analysis farm, otherwise see Computing (including Analysis) and Account Setup.

How to run this procedure

If the version of the package ImgAlgos is available as a current software release, then you may run the script command(s) directly, for example:

```
cd <your-favorite-directory>
mkdir work_corana
sit_setup
corana_submit [-c <config-file>] [-t <fname-tau>] [-x] <xtc-file-list>
```

If the code in the package ImgAlgos has been recently changed and the updated release is not yet available, then one need to create the local release directory, get the latest/HEAD version of the package, and compile the code as shown below:

```
cd <your-favorite-directory>
newrel ana-current myReleaseDirectory
cd myReleaseDirectory
sit_setup
addpkg ImgAlgos HEAD
scons
```

Where to find results

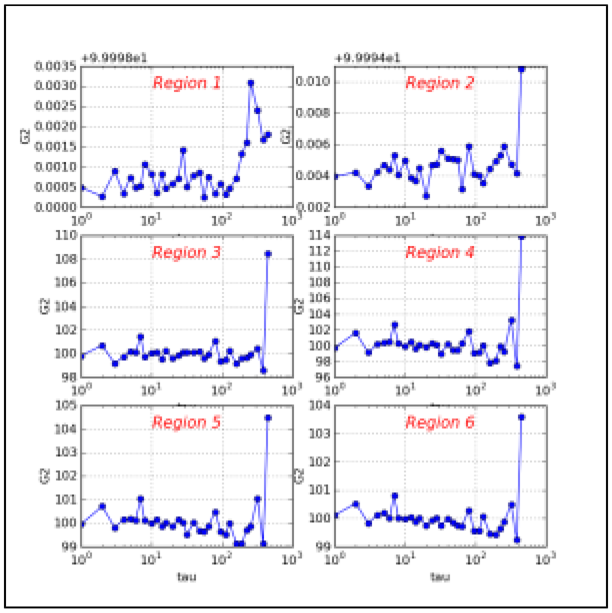
The procedure will produce a bunch of files in the `work_corana` directory. If everything is OK, then all spit - and log- files will be removed at the end of automatic `corana_submit` procedure. The most important files are preserved for further analysis:

File name tail	Format	Content
*-image-result.bin	binary for <float>	correlators for all image pixels for all tau values
*-time-ind.txt	text	time records for all selected events/images
*-tau.txt	text	the list of tau intervals
*-med.txt	text	meta data parameters
*-hist.txt	text	Histogram array with correlators averaged for ring regions of the image for all `tau` values, shown in the first column

How to look at results

It is assumed that all files listed in previous section may be used for further analysis, depending on particular goals. The optional script `corana_procres` is designed as an example of how to access data from C++ code. Class `CorAnaProcResults` produces the file `*-hist.txt`
A simple python script shows how to plot this file:

```
./ImgAlgos/data/PlotCorAnaResults.py work_corana/cor-ana-r0015-hist.txt
```



Another option is to use python script for direct processing of the resulting files.
This is not elaborated yet.
Q: What kind of further processing is desired and what tools are going to be used?