Algorithms for Time Correlation Experiments

This is a reference manual for algorithms implemented for the Integrated Data Processing Environment for Time Correlation Experiments. All work-flow can be split for main procedures:

- Pre-processing,
- Data processing, and
- Presentation of results,

covered by this note with extensive references to the specific code.

Content

Pre-processing

Pre-processing algorithms consist of four procedures

- Dark run scan,
- Pedestals averaging,
- Data scan, and
- Data averaging,

described in this section.

Dark run scan

Defines for the dark run

- the number of events
- time records and average time interval

Submit command

```
psana -c /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0020-peds-scan.cfg /reg/d/ana12/xcs/xcsi0112
/xtc/e167-r0020-*.xtc
```

PSANA configuration script `*peds-scan.cfg`

```
[psana]
#files = /reg/d/ana12/xcs/xcsi0112/xtc/e167-r0020-*.xtc
#skip-events = IS_NOT_USED
#events = FOR_ALL_EVENTS
modules = ImgAlgos.ImgTimeStampList

[ImgAlgos.ImgTimeStampList]
print_bits = 13
out_file = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0020-peds-scan-tstamp-list.txt
#======EOF======
```

PSANA module `ImgAlgos.ImgTimeStampList`

- ImgAlgos.ImgTimeStampList.cpp
- ImgAlgos.ImgTimeStampList.h

Pedestals averaging

Defines for dark run

- pedestals
- RMS
- hot pixel mask

Submit command

```
psana -c /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0020-peds.cfg /reg/d/ana12/xcs/xcsi0112/xtc
/e167-r0020-*.xtc
```

PSANA configuration script `*peds.cfg`

```
[psana]
#files = /reg/d/ana12/xcs/xcsi0112/xtc/e167-r0020-*.xtc
skip-events = 0
events = 75
modules = ImgAlgos.Tahometer ImgAlgos.PrincetonImageProducer ImgAlgos.ImgAverage

[ImgAlgos.Tahometer]
print_bits = 7

[ ImgAlgos.PrincetonImageProducer ]
source = DetInfo(:Princeton)
key_in =
key_out = img
print_bits = 1

[ImgAlgos.ImgAverage]
source = DetInfo(:Princeton)
key = img
avefile = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0020-peds-ave.txt
rmsfile = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0020-peds-rms.txt
hotpix_mask = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0020-hotpix-mask-thr-10.0ADU.txt
hotpix_thr_adu = 10.0
print_bits = 21
```

PSANA module `ImgAlgos.PrincetonImageProducer`

- ImgAlgos.PrincetonImageProducer.cpp
- ImgAlgos.PrincetonImageProducer.h

PSANA module `ImgAlgos.ImgAverage`

- ImgAlgos.ImgAverage.cpp
- ImgAlgos.ImgAverage.h

Data types:

- Input image may be : double, float, int, uint16_t, uint8_t
- Calculation: intensity in double, statistics in unsigned
- Save arrays in txt for

```
save2DArrayInFile<double> ( m_aveFile, m_ave, m_rows, m_cols, m_print_bits & 16 );
save2DArrayInFile<double> ( m_rmsFile, m_rms, m_rows, m_cols, m_print_bits & 16 );
if (m_do_mask) save2DArrayInFile<int> ( m_hotFile, m_hot, m_rows, m_cols, m_print_bits & 16 );
```

PSANA module `ImgAlgos.Tahometer`

- ImgAlgos.Tahometer.cpp
- ImgAlgos.Tahometer.h

Data scan

Defines for data run

- the number of events in the run
- saves time records and average time interval
- saves intensity monitor data

Submit command

```
psana -c /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-scan.cfg /reg/d/ana12/xcs/xcsi0112
/xtc/e167-r0015-*.xtc
```

PSANA configuration script `*data-scan.cfg`

```
[psana]
#psana -m psana_examples.DumpPrinceton /reg/d/psdm/XCS/xcsi0112/xtc/e167-r0015-s00-c00.xtc
#files = /reg/d/ana12/xcs/xcsi0112/xtc/e167-r0015-*.xtc
modules = ImgAlgos.Tahometer ImgAlgos.ImgTimeStampList ImgAlgos.IntensityMonitorsData
#skip-events = IS_NOT_USED
#events = FOR_ALL_EVENTS

[ImgAlgos.Tahometer]
print_bits = 11

[ImgAlgos.ImgTimeStampList]
print_bits = 13
out_file = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-scan-tstamp-list.txt

[ImgAlgos.IntensityMonitorsData]
print_bits = 45
#file_type = bin
#file_data = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-scan-mons-data.txt
file_data = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-scan-mons-data.txt
file_header = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-scan-mons-comments.txt
#======EOF======
```

PSANA module `ImgAlgos.ImgTimeStampList`

- ImgAlgos.ImgTimeStampList.cpp
- ImgAlgos.ImgTimeStampList.h
  Produces file with time records `*data-scan-tstamp-list.txt` :

```
     0        0.000000  0.000000  20120616-080236.671607864    5366      0        0
     1        8.026429  8.026429  20120616-080244.698036743    8255      1        1
     2       16.144788  8.118359  20120616-080252.816395836   11177      2        2
     3       24.154835  8.010048  20120616-080300.826443448   14060      3        3
     4       32.281937  8.127102  20120616-080308.953545010   16985      4        4
     5       40.400633  8.118696  20120616-080317.072241060   19907      5        5
...
```

PSANA module `ImgAlgos.IntensityMonitorsData`

- ImgAlgos.IntensityMonitorsData.cpp
- ImgAlgos.IntensityMonitorsData.h

IntensityMonitorsData produces files:

- with headers for intensity monitor data `data-scan-mons-comments.txt`:

```
Heder for the data file: /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-scan-mons-
data.txt
Number of sources: 5
Four values per source:
BldInfo(FEEGasDetEnergy) BldInfo(XCS-IPM-02) BldInfo(XCS-IPM-mono) DetInfo(XcsBeamline.1:Ipimb.4) DetInfo
(XcsBeamline.1:Ipimb.5)
Number of records in file: 500
```

- with intensity monitor data `data-scan-mons-data.txt`:

```
      0  2.19399 2.20273 0.05872 0.06004  0.62876 1.50444 0.60655 1.54488  0.00793 0.01758 0.00502
0.01968  0.00000 -0.00025 -0.00020 0.00000  0.00000 0.00000 0.00000 0.00000
      1  2.10433 2.10410 0.06630 0.06703  0.66294 1.56792 0.62547 1.61347  0.00572 0.01147 0.00227
0.01366  0.00000 -0.00025 -0.00020 0.00000  0.00145 0.00610 0.00069 0.00153
      2  2.40593 2.37730 0.06799 0.07501  0.69857 1.71524 0.70642 1.74614  0.00626 0.01590 0.00456
0.01946  0.00015 -0.00025 -0.00020 0.00000  0.00000 0.00000 0.00000 0.00000
      3  2.44108 2.46661 0.07772 0.10092  0.69842 1.72280 0.71169 1.76384  0.00000 0.00064 -0.00040
0.00008  0.00000 -0.00025 -0.00020 0.00008  0.00000 0.00000 0.00000 0.00000
      4  2.45779 2.45074 0.09505 0.08122  0.72374 1.71555 0.68254 1.74523  0.01320 0.03017 0.00952
0.03456  0.00000 -0.00025 -0.00020 0.00015  0.00000 0.00000 0.00000 0.00000
      5  2.12671 2.13944 0.08422 0.07668  0.66477 1.61919 0.65263 1.63864  0.06844 0.15933 0.04858
0.17990  0.00000 -0.00025 -0.00020 0.00008  0.00000 0.00000 0.00114 0.00000
...
```

Data averaging

Defines for data run

- average image for selected range of events
- evaluate saturated pixel mask

Submit command

```
psana -c /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-aver.cfg /reg/d/ana12/xcs/xcsi0112
/xtc/e167-r0015-*.xtc
```

PSANA configuration script `*data-aver.cfg`

```
[psana]
#files = /reg/d/ana12/xcs/xcsi0112/xtc/e167-r0015-*.xtc
skip-events = 0
events = 500
modules = ImgAlgos.Tahometer ImgAlgos.PrincetonImageProducer ImgAlgos.ImgAverage ImgAlgos.ImgMaskEvaluation

[ImgAlgos.Tahometer]
print_bits = 7

[ ImgAlgos.PrincetonImageProducer ]
source = DetInfo(:Princeton)
key_in =
key_out = img
print_bits = 1

[ImgAlgos.ImgAverage]
source = DetInfo(:Princeton)
key = img
avefile = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-ave.txt
rmsfile = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-rms.txt
print_bits = 25
#evts_stage1 = 100
#evts_stage2 = 100
#gate_width1 = 200
#gate_width2 = 50

[ImgAlgos.ImgMaskEvaluation]
source = DetInfo(:Princeton)
key = img
file_mask_satu = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-satpix-mask-level-65000ADU.txt
file_mask_nois =
file_mask_comb =
file_frac_satu = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-satpix-frac-level-65000ADU.txt
file_frac_nois =
thre_satu = 65000
frac_satu = 0
dr_SoN_ave = 1
thre_SoN = 5
frac_nois = 0.05
print_bits = 29
#======EOF======
```

PSANA module `ImgAlgos.ImgMaskEvaluation`

- ImgAlgos.ImgMaskEvaluation.cpp
- ImgAlgos.ImgMaskEvaluation.h

The `ImgAlgos.ImgMaskEvaluation` produces the saturated pixel mask; the image size txt file `*-satpix-mask-level-65000ADU.txt`, consistiong 0(zero) or 1(one) for each bin.

Data processing

Data processing stage consists of three procedures:

- Spliting,
- Processing, and
- Merging,
  described in this section.

Spliting

Submit command

```
psana -c /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-cora-xcsi0112-r0015-split.cfg /reg/d/ana12/xcs/xcsi0112
/xtc/e167-r0015-*.xtc
```

PSANA configuration script `*split.cfg`

```
[psana]
# Command to run this script from release directory:
# psana -c ImgAlgos/data/psana-split.cfg <path-to-xtc-file-name-pattern-for-one-run>

#files = /reg/d/ana12/xcs/xcsi0112/xtc/e167-r0015-*.xtc
skip-events = 0
events = 500

modules = ImgAlgos.Tahometer ImgAlgos.PrincetonImageProducer ImgAlgos.ImgCalib ImgAlgos.ImgIntMonCorr ImgAlgos.
ImgIntForBins ImgAlgos.ImgVsTimeSplitInFiles ImgAlgos.ImgAverage

[ImgAlgos.Tahometer]
print_bits = 7

[ ImgAlgos.PrincetonImageProducer ]
source = DetInfo(:Princeton)
key_in =
key_out = img
print_bits = 1

[ImgAlgos.ImgCalib]
source = DetInfo(:Princeton)
key_in = img
key_out = calibrated
fname_peds = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0020-peds-ave.txt
fname_bkgd =
fname_gain =
fname_mask =
fname_rms =
threshold_nrms = 0
do_threshold = true
threshold = 20.0
below_thre_value = 0
print_bits = 5

[ImgAlgos.ImgIntMonCorr]
source = DetInfo(:Princeton)
key_in = calibrated
key_out = imon_corrected
fname_imon_cfg = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-cora-xcsi0112-r0015-imon-cfg.txt
print_bits = 1

[ImgAlgos.ImgIntForBins]
source = DetInfo(:Princeton)
key_in = imon_corrected
fname_map_bins = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-cora-r0015-map-static-q.txt
fname_int_bins = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-cora-r0015-int-static-q.txt
number_of_bins = 1
print_bits = 33


[ImgAlgos.ImgVsTimeSplitInFiles]
source = DetInfo(:Princeton)
key = imon_corrected
fname_prefix = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-cora
file_type = bin
add_tstamp = false
ampl_thr = 20.0
ampl_min = 1
nfiles_out = 8
print_bits = 29


[ImgAlgos.ImgAverage]
source = DetInfo(:Princeton)
key = calibrated
avefile = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-ave.txt
rmsfile = /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-xcsi0112-r0015-data-rms.txt
#======EOF======
```

PSANA module `ImgAlgos.ImgCalib`

- ImgAlgos.ImgCalib.cpp
- ImgAlgos.ImgCalib.h
  This module is responsible for basic image intensity transformation. For correlation analysis it applys a couple of corrections:
- subtract pedestals and
- apply LLD threshold.

PSANA module `ImgAlgos.ImgIntMonCorr`

- ImgAlgos.ImgIntMonCorr.cpp
- ImgAlgos.ImgIntMonCorr.h
  Gets intensity monitor configuration file `imon-cfg.txt` produced in GUI:

```
BldInfo(FEEGasDetEnergy)         FEEGasDetEnergy  1 1 1 1   0 0     -1.0000   -1.0000    1.0000
BldInfo(XCS-IPM-02)              XCS-IPM-02       1 1 1 1   0 0     -1.0000   -1.0000    1.0000
BldInfo(XCS-IPM-mono)            XCS-IPM-mono     1 1 1 1   0 0     -1.0000   -1.0000   -1.0000
DetInfo(XcsBeamline.1:Ipimb.4)   Ipimb.4          1 1 1 1   0 0     -1.0000   -1.0000    1.0000
DetInfo(XcsBeamline.1:Ipimb.5)   Ipimb.5          1 1 1 1   0 0     -1.0000   -1.0000    1.0000
```

PSANA module `ImgAlgos.ImgIntForBins`

- ImgAlgos.ImgIntForBins.cpp
- ImgAlgos.ImgIntForBins.h

Gets the file `*-map-static-q.txt` with a map of static q bin numbers

Produces the file `*-int-static-q.txt` with intensities averaged over statis q bins:

```
      0  44.460
      1  27.982
      2  62.282
      3  0.875
      4  73.732
      5  698.901
      6  4.923
      7  227.669
      8  28.298
...
```

PSANA module `ImgAlgos.ImgVsTimeSplitInFiles`

- ImgAlgos.ImgVsTimeSplitInFiles.cpp
- ImgAlgos.ImgVsTimeSplitInFiles.h

Gets/produces the file `*-tau.txt` with a list of tau intervals in terms of time(event) indexes, for example:

```
1 2 3 4 5 6 7 8 9 10 12 14 16 20
```

Produces the file `*-med.txt` with metadata parameters from splitting algorithm:

```
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       f
TIME_SEC_AVE    8.088413
TIME_SEC_RMS    0.063639
TIME_INDEX_MAX       499
```

Processing

Submit command

```
corana -f /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-cora-r0015-b0000.bin -t ./tau-list.txt
```

Module `ImgAlgos.corana`

- ImgAlgos.corana.cpp

Module `ImgAlgos.CorAnaData`

- ImgAlgos.CorAnaData.cpp
- ImgAlgos.CorAnaData.h

Evaluation of correlators:

```
ImgAlgos/include/CorAna.h:  typedef float cor_t;

void CorAnaData::evaluateCorTau(unsigned tau) // tau in number of frames between images
{
  m_log << "\nCorAnaData::evaluateCorTau(tau): tau=" << tau;
  std::fill_n(m_sum_gi, m_blk_size, double(0));
  std::fill_n(m_sum_gf, m_blk_size, double(0));
  std::fill_n(m_sum_g2, m_blk_size, double(0));
  std::fill_n(m_sum_st, m_blk_size, unsigned(0));
  std::fill_n(m_cor_gi, m_blk_size, cor_t(0));
  std::fill_n(m_cor_gf, m_blk_size, cor_t(0));
  std::fill_n(m_cor_g2, m_blk_size, cor_t(0));

  for (unsigned ti=0; ti<m_tind_size-tau; ti++) {
       unsigned tf=ti+tau;

       if ( ! (tf<m_tind_size) ) break;

       // get the event index in array for time index
       int evi = m_tind_to_evind[ti];
       int evf = m_tind_to_evind[tf];

       // If the event does not exist for specified time index -> skip it in sum
       if(evi<0) continue;
       if(evf<0) continue;

       sumCorTau((unsigned)evi,(unsigned)evf);
  }
}

//----------------
void CorAnaData::sumCorTau(unsigned i, unsigned f) // i and f are the event indexes
{
   data_t* p_i = &m_data[i*m_blk_size];
   data_t* p_f = &m_data[f*m_blk_size];
   double Ii, If;

   for(unsigned pix=0; pix<m_blk_size; pix++) {
     Ii = p_i[pix];
     If = p_f[pix];
     m_sum_gi[pix] += Ii;
     m_sum_gf[pix] += If;
     m_sum_g2[pix] += Ii*If;
     m_sum_st[pix] ++;
   }
}
```

Averaging:

```
   for(unsigned pix=0; pix<m_blk_size; pix++) {
       if(m_sum_st[pix]<1) continue;
       m_cor_gi[pix] = cor_t( m_sum_gi[pix] / m_sum_st[pix] );
       m_cor_gf[pix] = cor_t( m_sum_gf[pix] / m_sum_st[pix] );
       m_cor_g2[pix] = cor_t( m_sum_g2[pix] / m_sum_st[pix] );
   }
```

Module `ImgAlgos.CorAna`

- ImgAlgos.CorAna.cpp
- ImgAlgos.CorAna.h

Module `ImgAlgos.CorAnaInputParameters`

- ImgAlgos.CorAnaInputParameters.cpp

- ImgAlgos.CorAnaInputParameters.h

Merging

Submit command

```
corana_merge -f /reg/neh/home1/dubrovin/LCLS/PSANA-V01/work/t1-cora-r0015-b0000-result.bin -t /reg/neh/home1
/dubrovin/LCLS/PSANA-V01/work/t1-cora-r0015-tau.txt
```

Module `ImgAlgos.corana_merge`

- ImgAlgos.corana_merge.cpp

Module `ImgAlgos.CorAnaMergeFiles`

- ImgAlgos.CorAnaMergeFiles.cpp
- ImgAlgos.CorAnaMergeFiles.h

Presentation of results

Presentation of results is implemented in the `GUIViewResults.py`, which basically is a panel of buttons for different plots.

Summary

In this note we presented a functional description of implemented procedures for time correlation analysis. All modules have convenient reference to the latest version of the code.

References

- Module `ImgAlgos.GlobalMethods`
- ImgAlgos.GlobalMethods.cpp
- ImgAlgos.GlobalMethods.h

- Modules of `ImgAlgos`
- ImgAlgos.*.cpp
- ImgAlgos.*.h