Plans of the Detector Characterization Working Group

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LIGO Scientific Collaboration Meeting

University of Florida

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Overview

Goal - Characterize the Interferometers

- Active diagnostics – Mainly LIGO responsibility
  (but on-site LSC members welcome to contribute!)
- Passive offline monitoring – Good for off-site LSC members
  $\Longrightarrow$ Primary focus of working group (for now)

Two broad monitoring tasks:

- Performance characterization (stationary noise)
- Transient analysis – Dedicated subgroup (chair: F. Raab)

Two additional subgroups dedicated to tools:

- Data set reduction (chair: J. Brau)
- Data set simulation (chair: S. Finn)

LSC Detector Characterization Working Group

This is the home page of the Detector Characterization Working Group of the LIGO Scientific Collaboration (LSC)

Working Group Bulletin Board

Goals of the Working Group

Working Group Members

Performance Characterization

Subgroups:

- Transient Analysis
- Reduced Data Sets
- Data Set Simulation

Meetings

What is this Working Group's role in LIGO?

Mock Data Challenge

Other LSC Data Analysis Working Groups:

- Astrophysical Source Indentification and Signatures (ASIS)
- Detection Confidence and Statistical Analysis

Other Relevant Links:

- LIGO Laboratory
- LIGO Scientific Collaboration
- LIGO Hanford Observatory (Washington)
- LIGO Livingston Observatory (Louisiana)

LSC Detector Characterization Working Group

Members and Observers

Working Group Chair: Keith Riles LIGO Laboratory Liaison: Daniel Sigg

Subgroup leaders:

Transient Analysis - Fred Raab
Reduced Data Sets - Jim Brau
Data Set Simulation - Sam Finn

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Performance Characterization

Goal - Quantify "steady-state" behavior of IFO's

- Monitor instrumental and environmental noise
- Measure channel-to-channel correlations
- Quantify instrument's sensitivity to GW sources
- Characterization can include description and correction

Examples of noise sources to be quantified:

- Electrical line contamination (60 Hz & harmonics)
- Seismic noise
- Stack vibration
- Violin modes
- Internal mirror resonances
- Total non-Gaussian noise level

Performance Characterization

Examples of instrumental behavior description:

- Operational state (*e.g.*, good lock, marginal lock, unlocked)
- Cross-coupling coefficients / transfer functions between dark port and other channels
- Calibration curve for dark port response
- Optical, RF, and geometrical parameters (should be stable)

Examples of astrophysical sensitivity description:

- Strain sensitivity at 150 Hz, 300 Hz, ...
- Maximum viewing distance for inspiral standard candle
- Frequency of single-IFO transients matching astrophysical templates

Performance Characterization

Examples of analysis tools:

- Statistical description (trends of mean, rms, min/max; total & band-limited rms; histograms)
- Power spectra and spectrograms
- Time-frequency plots (waterfall, carpet, wavelet transforms)
- Correlations, auto-correlations
- Matched filters
- Principal value decomposition

General Plan

- Set priorities & find volunteers
- Define structures of meta-database entries
- Implement & test simple algorithms to gain experience
- Improve & extend to more sophisticated algorithms

Transient Analysis

Goal: Identify transients due to instrument or environment

- Avoid confusion with astrophysical sources
- Identify / correct contamination in data stream
- Diagnose (and perhaps fix) recurring disturbances

Examples of transient types to be identified:

- Impulses (*e.g.*, dropped hammer, wire relaxation, BNC connector slippage)
- Flickering optical modes
- Ringdown of violin modes
- Servo instability
- Excitation of out-of-band resonance
- Onset of analog or digital saturation
- ADC / DAQ malfunction (*e.g.*, lost data, sticky bit)
- Earthquake / lightning / wind gust / cosmic shower
- Dust particle falling through the beam

Transient Analysis

Examples of transient signatures & detection methods:

- Discontinuities, missing data
- Stuck bits, duplicated data
- Sudden increase in total or band-limited rms (IFO or environmental channel)
- Large amplitude excursion
- Nonstationary time-frequency behavior (waterfall/carpet plots, wavelet analysis)
- Matched filters for automated transient classification

Identified transient should provoke a "trigger"

- Record written into meta-database
- And/or alarm broadcast to control room

Transient Analysis

General Plan

- Set priorities & find volunteers
- Define & implement simple triggers & alarms, including meta-database entries
- Extend to more sophisticated transient analysis

Data Set Reduction

Goals:

- Provide "standard" reduced data set (for everyone) (Definition subject to formal LSC approval)
- Provide "designer" reduced data sets (for individuals)

Mechanics:

- Use lightweight data format
- Make "designer" definitions dynamic & flexible (*e.g.*, time duration, channels of interest, decimation rates, perhaps filters, state of IFO)
- Reduced data can contain raw/filtered data, statistical measures, flags, histograms

Data Set Reduction

General Plan

- Define infrastructure (*e.g.*, specific parameters)
- Find volunteers to write code
- Implement & test

Data Set Simulation

Goals:

- Create simulation software infrastructure (short-term)
- Apply phenomenological models to create simulated data sets (medium-term)
- Work with LIGO to enhance End-To-End IFO simulation (long-term)

Infrastructure:

- Generic utility routines for creating time series data from power spectra
- Routines for superposing sources (noise, disturbances, astrophysics)
- Modelling of analog whitening / dewhitening filters, digitization discreteness, digital filters
- Provide templates for algorithm development

Data Set Simulation

Phenomenological modelling:

- Violin modes
- 60 Hz line noise & harmonics
- Servo gain peaking
- Impulses
- ADC / DAQ malfunctions
- Cross-coupling in longitudinal / orientation servo controls

Data Set Simulation

End-To-End Model:

Large LIGO effort already underway
to simulate IFO's from first principles

Some issues to investigate:

- Size & effects of residual higher-order transverse modes
- Size & effects of residual contrast defect between two arms
- Cross-coupling btw orientation & longitudinal servos
- Sensitivity of various optical pickoff signals
- Ground & stack motion
- Thermal lensing
- Light scattering & diffraction
- Internal electronic saturation

Data Set Simulation

General Plan

- Set priorities & find volunteers
- Create simulation infrastructure
- Implement phenomenological models
- Contribute to End-To-End effort

Agenda of Friday Parallel Sessions

Morning Sessions

9:00-10:30 - Session 1

10'	K. Riles / D. Sigg	Introduction
20'	B. Allen	Existing data monitoring tools (GRASP)
10'	W. Hua	Violin Modes of the 40 Meter
10'	All	Discussion
30'	D. Sigg	LIGO Global Diagnostics System
10'	All	Discussion

10:30-10:45 - Coffee Break

10:45-12:00 - Session 2

15'	M. Coles	Environmental monitoring at Livingston
15'	W. Johnson	Electromagnetic field monitoring
5'	All	Discussion
15'	W. Majid	LIGO algorithm library
15'	J. Zweizig	LIGO Data Monitor Tool
10'	All	Discussion

12:00-1:00 - Lunch

Agenda of Friday Parallel Sessions

Afternoon Sessions

1:00-2:30 - Session 3

20' S. Finn	Existing data monitoring tools (MATLAB)
15' F. Raab	Transient analysis subgroup plans
15' J. Brau	Data set reduction subgroup plans
15' S. Finn	Data set simulation subgroup plans
15' K. Riles / D. Sigg	Performance characterization plans
10' All	Discussion

2:30-2:45 - Coffee Break

2:45-3:45 - Session 4

15' H. Yamamoto	Overview of End-to-End Model
15' B. Bhawal	End-to-End optics implementation
15' S. Klimenko	End-to-End input optics modelling
15' All	Discussion

Further subgroup meetings to be arranged, as needed

Priorities & Timescales

Priorities:

- Detector characterization timescale different from those of other analysis working groups
- Completion of tasks by January 2002 much too late
- Nearly every task listed above is **essential**
  (along with others we haven't yet thought of...)
  $\Longrightarrow$ Almost arbitrary what we start on first,
  as long as everything gets done soon

Timescales:

- Short term: (next few months)
  - Establish infrastructure and templates (LIGO & LSC)
- Medium and long term: (Summer 1999 & later)
  - Fill in templates with real algorithms
  - Test algorithms on real data from Hanford / Livingston
  - Improve & iterate

LIGO Mock Data Challenge

As a test of analysis and detector characterization software, it is planned to create and analyze data from two or more interferometers, with inclusion of secret astrophysics sources.

This "Mock Data Challenge" should help stimulate analysis work and serve as a useful diagnostic on that work, helping real LIGO analysis in the future.

Initially, 40-Meter data from November 1994 will be used (two different time sequences combined as if in coincidence).

Later, as simulation improves in sophistication (*c.f.*, End-To-End Model), realistic Monte Carlo simulation, including signals is envisioned.

Although the LIGO lab has initiated this effort, each of the LSC analysis groups has been encouraged to join.

The entire detector characterization working group, not merely the simulation subgroup, will participate.