Real Time Improvement of Orbits of Space Debris by Fusing SLR and Astrometric Data Acquired by a Night–Tracking Camera

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Motivation

- Improvement of SLR observations
  - Satellite acquisition time
  - Number of observation per NPT
  - Pass Observation rate
  - Successful satellite acquisition (by visual inspection)

- Improved orbit determination through fusion of range and angular data (especially for short observation arc)
- Attitude studies based on light curve and laser light curve and range variation analysis
- Retrieving angular measurements for fast moving objects with small field of view (no reference stars for astrometry)
- Synchronous acquisition of measurements for attitude and orbit determination
The Night-Tracking Camera

- **ZIMLAT Telescope**
  - 1-m Aperture Ritchey–Crétien
  - Coudé focus for Laser
  - Nasmyth Focus for tracking and CCD cameras

- **Neo 5.5 sCMOS Camera**
  - 5.5 megapixel sensor, 6.5 μm pixels
  - 22 mm diagonal field of view
  - Rolling and Global Shutter
  - Rapid frame rates
    - 30 fps over extended kinetic series
    - Burst to memory at 100 fps full frame

- Integration of the new camera into the SLR system
- Development of observation and tracking software
- Development of a quasi–real time analysis pipe

Credits: Oxford Instruments 2018
The NightCam at Work

NightCam Capabilities

- Set up camera parameters

- Target Acquisition
  - Target Position w.r.t. Laser Position
  - Azimuth/Elevation ephemeris correction handling
  - Storing of Images with telescope data (pointing directions and measurement epoch)

- Synchronous observations acquisition
  - Azimuth/Elevation
  - Range
  - Light curve

Target: TOPEX  Date: 2018/10/19
Initial Ephemeris offset: ~68 arcsec
NightCam Output

Date: 2018/09/25
From: 22:03 UTC
To: 22:13 UTC
Target: TOPEX
Exp. Time: 0.1 s

*OBS–COM Difference from expected (given by ephemeris) and measured time of flight of the laser pulse.
NightCam Output

*OBS-COM Difference from expected (given by ephemeris) and measured time of flight of the laser pulse.

Date: 2018/10/19
From: 18:54 UTC
To: 19:03 UTC
Target: ENVISAT
Exp. Time: 0.1s
What can we do with these data?

- Light curve analysis → Attitude determination
  - Spin axis direction
  - Rotation period

- Ranges
  - Orbit Determination/Improvement (especially for short observation arc)
  - Attitude Determination

- Azimuth, Elevation → Orbit Determination/Improvement
  - Need to be validated
  - Error Estimation
  ⇒ Ephemeris Comparison

⇒ YES, we can improve it!!!
Orbit Determination Result: JASON 3

Orbit determination performed with only angular, only ranges, and merged measurements.

Comparison w.r.t. CPF Ephemeris.

Date: 2018/09/25
From: 21:47 UTC
To: 21:57 UTC
Target: JASON 3
Exp. Time: 0.1s
Orbit Determination Result: JASON 3

Orbit determination performed with only angular, only ranges, and merged measurements.

Comparison w.r.t. 2nd and 3rd Satellite pass.
Orbit Determination Result: TOPEX

Orbit determination performed with only angular, only ranges, and merged measurements.

Comparison w.r.t. 2nd Satellite pass.

Date: 2018/10/19
1st Pass From: 17:35 UTC To: 17:40 UTC
2nd Pass From: 19:31 UTC To: 19:35 UTC
Target: TOPEX
Exp. Time: 0.1s
E. Cordelli, Real Time Improvement of Orbits of Space Debris by Fusing SLR and Astrometric Data Acquired by a Night Tracking Camera, 21st ILRS Workshop, Canberra, Australia, 5-9 November 2018.

Orbit Determination Result: GLONASS

Orbit determination performed with only angular, only ranges, and merged measurements.

Comparison w.r.t. 2nd obs. series. of Satellite

Date: 2018/10/19
1st Obs. Series From: 21:47 UTC To: 21:59 UTC

Target: GLONASS 91025B

Exp. Time: 0.7s
Conclusions

Summary

- Integration of the new camera into the SLR system
- Development of observation and tracking software
- Real time orbit improvement via ephemeris correction
- Quasi real time orbit improvement using short arc data fusion
- Simultaneous observation for orbit and attitude determination of space debris
- Validation of estimated orbit via real measurements

Interesting outcomes

- LEO Orbit determination without astrometric data reduction
- Possibility of SLR tracking of LEO and MEO defunct satellites
- Generation of ephemeris which allow target reobservation in the next pass
Outlook

Next Steps

- Improvements of Azimuth, Elevation accuracy
  - Laser Pointing Model

- Correction improvements from Azimuth, Elevation to Along-, Cross-Track

- Automatization
  - Object recognition
  - Ephemeris Correction
  - Analysis pipeline
    - Orbit determination/improvement
    - Ephemeris Generation

- Active Real time tracking of object with poorly known or unknown orbit (Stare and Chase)

- Day time application?!
Thank you for your attention!
Back Up Slide
Derivation of Pointing Model

To apply corrections to satellite ephemeris, we needed to determine:

- The Azimuth Elevation direction in the camera system
  - Number of reflections
  - Camera orientation
  - Derotator position
- The pointing of the laser on the camera
  - Telescope pointing direction
  - Derotator position

Star fields for camera orientation
Derived from images when laser hits the target
Improvement of the Pointing Model

- Temporary Solution → Average Laser coordinates on chip
- Optimal Solution → Modelling of the wobble due to telescope pointing direction → To be implemented
91025B–X6: 2019/10/19 1st part of Obs.

Date: 2018/10/19
1st Obs. Series
From: 21:47 UTC To: 21:59 UTC
2nd Obs. Series
From: 22:18 UTC To: 22:25 UTC
Target: GLONASS 91025B (X6 Internal)
Exp. Time: 0.7s