Surveyor's Applications for Least Squares Adjustment

An Open Source Geodetic Least Squares Adjustment Software Suite

Stephen Johnson[1], J. Clark Hughes[1], **Corwin Olson**[1], Jae-Ho Song[1], Brian Tolman[1], Don Tucker[1], Bradley Beal[2]
[1]Applied Research Laboratories, The University of Texas at Austin, [2]National Geospatial-Intelligence Agency

(G33B-0682)

Download: https://www.arlut.utexas.edu/salsa

Motivation / Objective

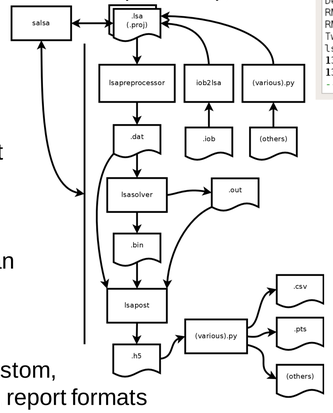
- Motivation: user-friendly, high performance **3D** (versus 2D+1) weighted least squares (WLS) adjustment program for survey applications that is also rigorous and transparent (open source)
- Objective: optimally combine dissimilar spatial measurements to minimize survey network measurement residuals, yield optimal estimates of surveyed point positions to desired precision with desired confidence and redundancy (and no blunders)

Software

- Free and open source: GNU General Public License (GPLv3)
- C++ (user interface and processing engine)
- Open source libraries employed: ARL:UT GPS Toolkit, Eigen, Marble, Qt, others
- Supports Microsoft Windows and Linux

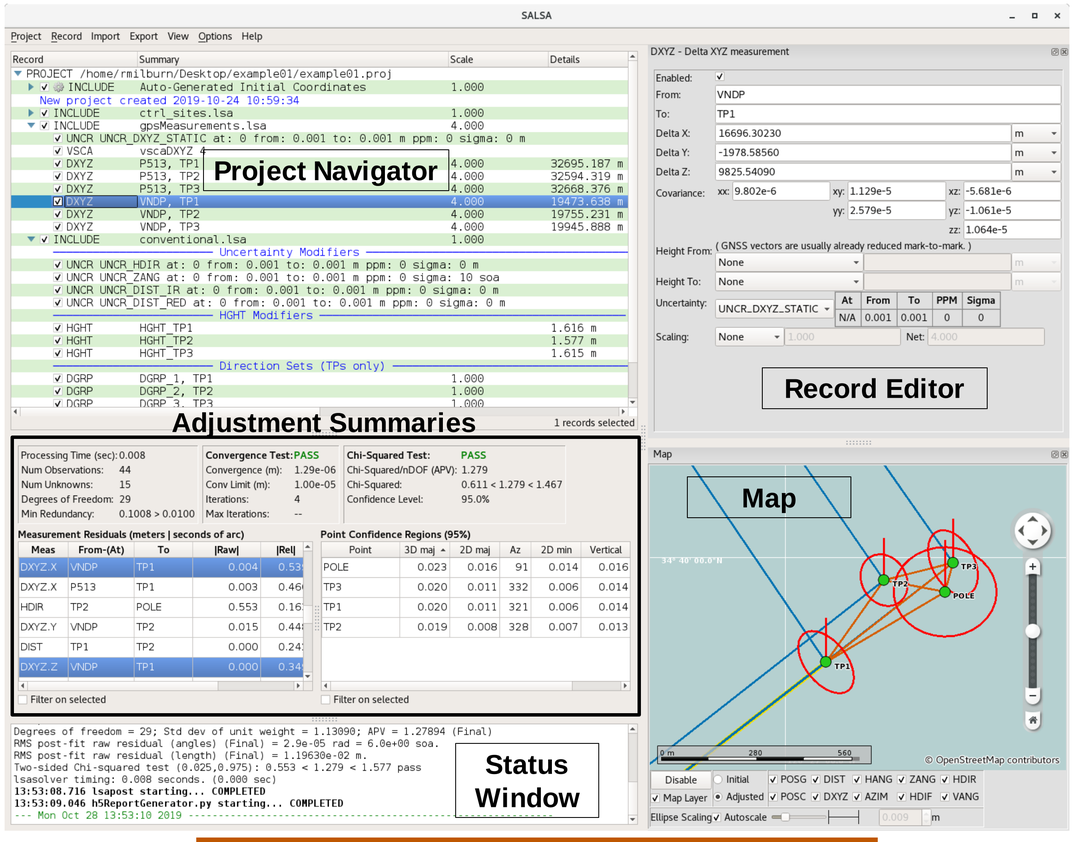
Processing Engine

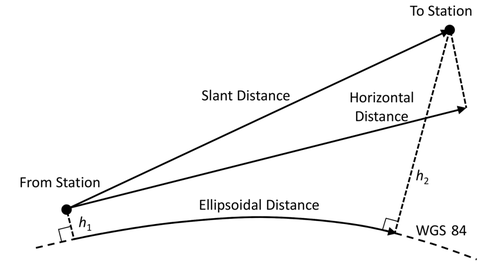
- Three Command Line Interface Programs: prep, solver, post
- Two methods for 3D iterative linearized WLS Adjustment:
  1) Square Root Information Filter
  2) Conjugate Gradient Method (Eigen)
- Frame: WGS 84 geodetic frame (Cartesian ECEF)
- Gravity models included: EGM08, EGM96
- Geoid undulations: global or user-specified geoid models
- Accepts all common geodetic survey measurement types: Distances; Direction Sets; Horizontal and Vertical Angles; Height Differences; GNSS-Derived: 3D Vectors (Diff Proc), Absolute Positions (PPP)
- A priori computations (as needed): 1) Delta Addition 2) Azimuth Vector Addition 3) Horizontal Angle Vector Addition 4) Triangulation 5) Two Azimuth Lines 6) Resection (3-point Resection Problem) 7) Ranging 8) Leveling Loop Formation 9) Side shot handling 10) Center of Mass
- Derived Points: 1) 3D Offset 2) Mean (all cross covariance info mapped)
- Constraints: constrain positions in East, North, and/or Up directions
- Import / Export Scripts: including custom, converters for input measurements, report formats
- Reduced Dimension: 1D (Leveling) and 2D adjustments

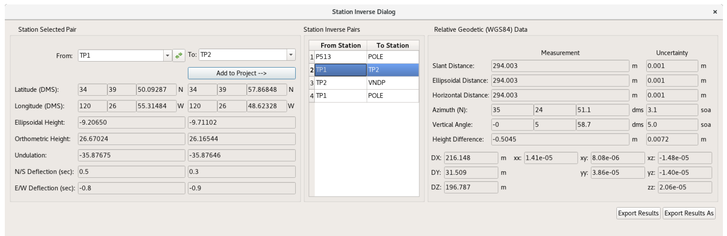


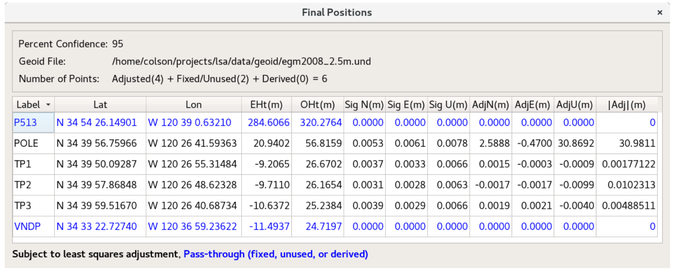
User Interface

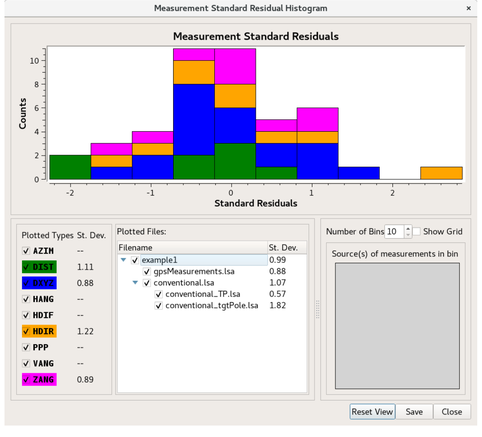
Main UI: **Resizeable** & **Dockable** Widgets











Definitions

- Convergence Metric: RMS of adjustment (state update) vector
- Raw Residuals: Postfit Measurement Residuals, R_{raw}
- Relative Residuals: $R_{rel} = \sqrt[C]{MCov}^{-1} R_{raw}$ $(\sqrt[C]{MCov}\ \sqrt[C]{MCov}^{T} = MCov)$
- Chi-Squared Metric: $\chi^2 = \left(RMS(R_{rel})\right)^2 N_{obs}$
- Redundancy: $Q_{RR} = MCov - H\ Cov\ H^T$ $Rd = [Q_{RR,11} MCov^{-1}{}_{11} \quad Q_{RR,22} MCov^{-1}{}_{22} \quad \cdots]^T$
- Degrees of Freedom (Observables Redundancy): $N_{DOF} = N_{obs} - N_{Unknowns}$
- A posteriori variance (APV): $APV = \chi^2 / N_{DOF}$ (Scale Covariance by APV)
- Standard Residuals: $R_{rel} = \left[R_{rel,1}/\sqrt{APV \cdot Rd_1} \quad R_{rel,2}/\sqrt{APV \cdot Rd_2} \quad \cdots\right]^T$

Acknowledgements

Funding and support provided by the National Geospatial-Intelligence Agency
Approved for Public Release #20-165