Open Challenges For Mobile Mapping Systems

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Presentation Outline

- NCALM
- Technical Challenges
  - GNSS Outages
  - Measurement Correlation
  - Lower Cost Sensors
- Challenges from An Industry Perspective
  - TRB Survey
  - Data Storage, Visualization
  - Fusion
- Summary and Conclusions

The National Center for Airborne Laser Mapping

UNIVERSITY of HOUSTON • UNIVERSITY of CALIFORNIA, Berkeley

Director: Ramesh L Shrestha • ***Co-Director:*** Bill Dietrich (Berkeley)
Co-PIs: Bill Carter and Craig Glennie

Funded by:

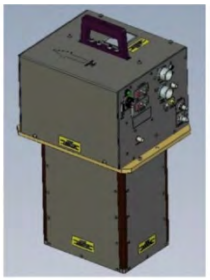
Division of Earth Sciences, Instrumentation and Facilities, NSF

• Separate Operational Budgets for UH and UC Berkley

• Additional funds to UH from NSF peer reviewed PI projects

(Over 100 national and international projects completed)

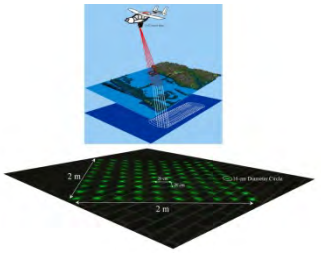

Cessna 337


Gemini


Aquarius


DiMAC


CASI 1500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Research Grade Remote Sensing Data For the Scientific Community

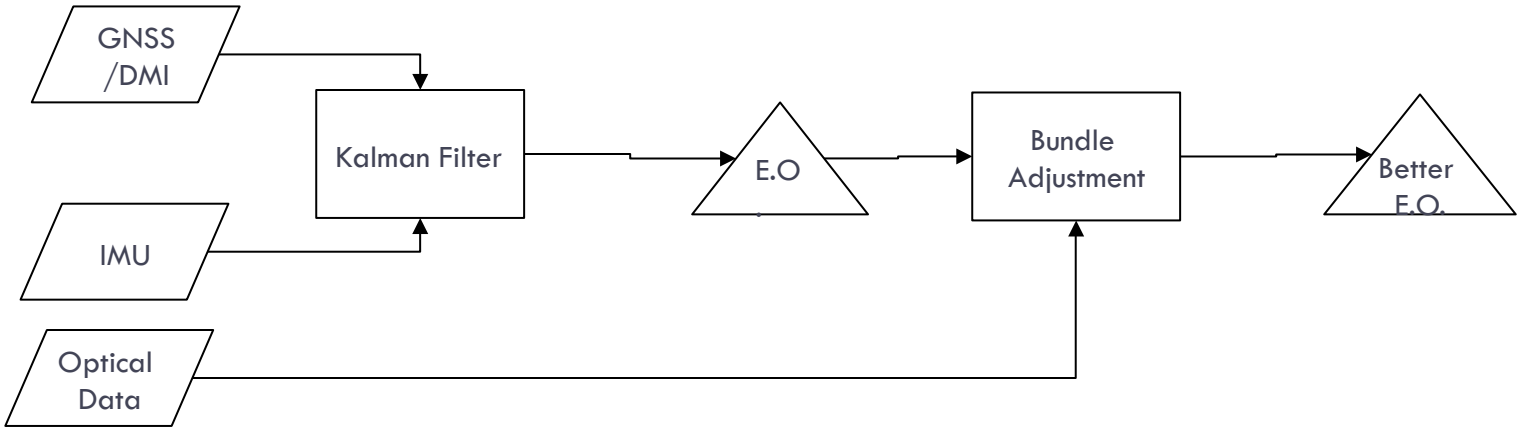
Technical Challenges in MMS

Challenge #1 – GNSS Outages

- GNSS Only Works With Line of Sight
- Obstructed Environments Require Additional Observations
  - DMI Constraints Not Sufficient for Highest Accuracy
- Desirable to Use Optical Sensors Onboard (Digital Image, LiDAR) for Updates.

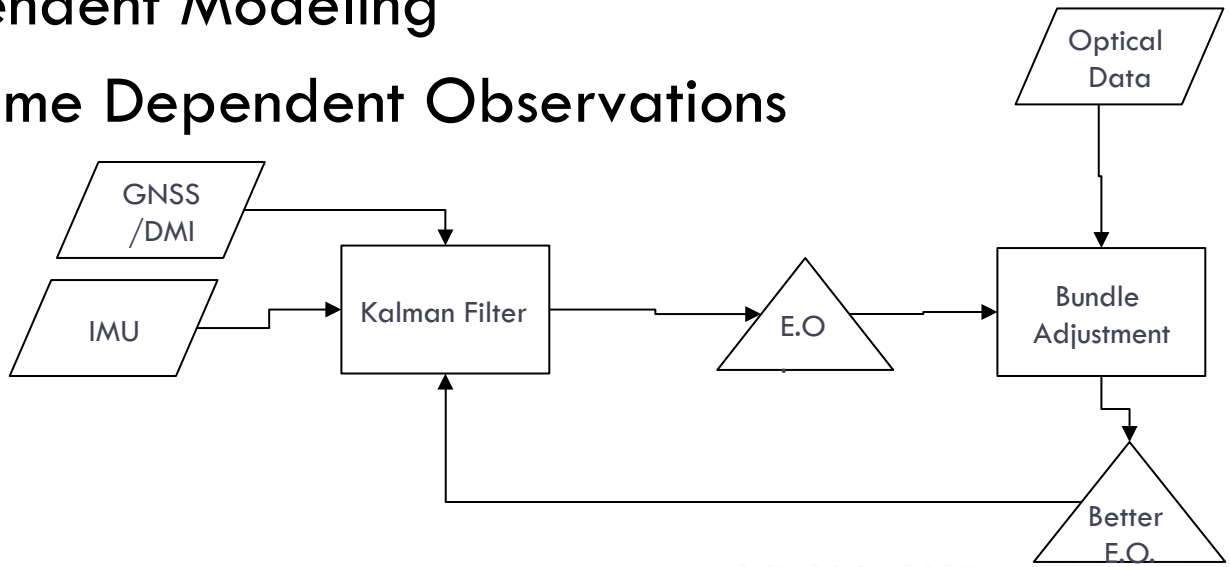
Optical Approach #1

- Photogrammetric Solution
  - Use Tie-Features to Correct Trajectory at Exposure Times
  - No Corrections in between Exposures
  - No Feedback to Kalman Filter



Optical Approach #2

- SLAM(Simultaneous Location and Mapping) Solution
  - Optical Measurements Fed Back Into Filter As Updates to States
  - Allows Model of Inertial System Behaviour
  - Solution Resembles an Open Traverse With Time Dependent Modeling
  - No Time Dependent Observations



Additional Information?

Rigorous Solution

- Addition of Time Correlated Measurements
- Methodology to Handle Both Space and Time Dependency
- Dynamic Network Adjustments To Combine Navigation and Optical Data at Measurement Level
- Initial Implementations
  - 2005 – Colomina, Blazquez, Térmens – Gravity Disturbances
  - 2011 – Rouzaud, Skaloud – Mobile Mapping Platforms (Simulations)

Obstacles to Implementation

- Correlation Process Should Be Automated
- Implementation is Challenging
  - Large System of Normal Equations
  - Successful Inversion Requires Mathematical "Tricks"
- Increased Complexity Might Not Be Warranted In All Cases

Challenge #2 – Measurement Correlation

- For All Mapping Calibration (LiDAR and Photogrammetric) Errors Are Assumed to Be Time Independent Random Variables
  - Inertial Errors Modeled As Gauss Markov Processes With hour(s) time constants. They are Cumulative, even in presence of GNSS and filtering
  - GPS Errors Also Correlated In Time (atmospheric, orbital, reference multipath)
- Assumption Normally Circumvented By Increasing Sigma Values for Observed Position/Orientation

Correlated Observations – What to Do?

- Are Correlations Significant?
  - Especially When High Accuracy Required
- Change Mathematical Model
  - Blázquez and Colomina (2012). "Relative INS/GNSS Aerial Control in Integrated Sensor Orientation: Models and Performance" ISPRS Journal, 67, 120-133.
- Include Correlations In Weighting Matrix

Lower Cost Sensors

- Current MMS Platforms Can be > 500K EUR
- Desirable to Reduce Cost but Maintain Accuracy With Lower Cost Sensors:
  - Tactical Grade IMU
  - Alternative Laser Scanners (Velodyne, Ibeo Lux)
- To Be Successful, Both Challenges Need to Be Overcome

Calibration Procedures

- LiDAR – Traditionally Only Calibrate for boresight angles, and perhaps scale
  - Lower Cost Sensors Have Increased Temporal Instability
  - May Need Additional Calibration Parameters
    - Glennie, C., (2012), "Calibration and Kinematic Analysis of the Velodyne HDL-64E S2 LiDAR Sensor," PE&RS, 78(4).
    - Glennie, C., D. Lichti, (2011), "Temporal Stability of the Velodyne HDL-64E S2 Scanner for High Accuracy Scanning Applications," Remote Sensing, (3), 539-553.

Example Velodyne Calibration

- Static Calibration Using Planar Surfaces
  - RMSE of Residuals from 3.6 cm to 1.3 cm
- Temporally Stable Calibration
  - RMSE of Residuals from 3-4 cm to ~2 cm
- Kinematic Calibration
  - RMSE from 3.7 cm to 2.3 cm (ranges < 25 m)

Velodyne Versus Riegl

- Kinematic Results Using Three Different Scanners
  - Different Collection Dates, but Similar Observational Conditions

TABLE 6. SPECIFICATIONS FOR RIEGL LMS-Q120I, VZ-400 (www.riegl.com) AND VELODYNE HDL-64E S2

	LMS-Q120i	VZ-400	Velodyne
Range Accuracy (mm)	15	5	20
Beam Divergence (mRad)	2.7	0.3	2.0
Angular Resolution (°)	0.01	0.0005	0.09
Measurement Rate (Hz)	10,000	125,000	1,333,333

TABLE 7. PLANAR RMSE RESIDUALS FOR DIFFERENT MOBILE LASER SCANNERS

	Velodyne Kinematic Calibration	Velodyne Kinematic Calibration H From Static Calibration	LMS-Q120i	VZ-400
RMSE (meters)	0.025	0.023	0.020	0.013

Industry Perspective on Challenges

TRB Mobile Laser Scanning Guidelines

- 60% of Mobile Data in N. America for Departments of Transportation

- Problems with Adoption:
  - Most DOTs are still designing in 2D, 2.5D
  - No Appropriate Software for Design and Analysis
  - Lack of Technical Expertise Within DOT
  - No Methodology to QA/QC of Products

Challenges From A Commercial Perspective (1/2)

- "Massaging" of Trajectory Takes Significant Amount of Time.
  - Methods are Mostly Manual
  - Empirical Data Driven Adjustments
  - Focused on Vertical Adjustments Only

Challenges From A Commercial Perspective (2/2)

- Lack of Specialized Software for:
  - Data Analysis
  - Data Fusion
  - Automated Feature and Object Extraction
  - Delivery Formats to Client (75% of DOTs get ASCII)

- Privacy Concerns
  - e.g. December 15, 2010 Belgium Privacy Commission Recommendation on Mobile Mapping

Challenges From a User Perspective

- Validation of Delivered Product
  - Airborne has focused on vertical only. Mobile mapping clearly needs horizontal validation
  - COTS software packages for data fusion (e.g. imagery and LiDAR) are lacking
  - Information Extraction Is Mostly Manual
  - Data Does Not Yet Fit Into Design and Engineering Processes

Summary

- Technical Challenges Include Better Trajectory Estimation, More Rigorous Calibration and Integration of Lower Cost Sensors

- From a Commercial Adoption Perspective, Software to Analysis/Process/Extract from data is clearly lagging far behind the Hardware to collect it.

Klaus-Peter Schwarz (1938-2012)

- IAG President, 1995-1999
- Founding Faculty, Geomatics Engineering, University of Calgary (1980-2001), Chair (1990-1995)
- Inertial Geodesy and Gravimetry

Questions?

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