GIS Data Development: Comparing Code vs. RTK GPS

Including Discussions on the Importance of Professional GIS Certification and/or Survey Licensing

By: Howard S. Hodder, Jr., GISP

TUGIS
March 19, 2007
Agenda

• Welcome and Introduction
• Project Background
  – Why did I choose to research this topic?
• Project Goals and Objectives
• Project Methodology (4 Steps)
• Results
  – Project Description / Development
  – RMSE Calculations
  – Developed Network Comparisons
  – Lessons Learned / Project Pitfalls
• Certification / Licensure Importance?
• Questions / Answers / Comments
Who am I?

- **Howard S. Hodder, GISP**, earned his bachelor’s degree in geography from Bloomsburg University in 1998 and will be completing his Masters in GIS from Penn State University in March 2007. He is the Regional Manager of Geographic Information System services in the Lancaster office of HRG and is a certified GIS professional (GISP). As such, he develops and maintains diverse GIS applications for municipalities, authorities, public agencies, and the private sector. He has extensive knowledge of both GPS surveying and GIS technology in addition to his computer programming and Microsoft Access database development skills. His responsibilities include field data collection, internal data processing and editing, project development, map and exhibit creation, and client support. Mr. Hodder also administers web-based GIS applications for our clients. Over the years, he has created dozens of GIS applications covering such uses as utility management (for water, sewer, and stormwater systems), property management, zoning and tax parcel administration, landscape mapping, watershed mapping, and recreational facilities mapping.
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- Surveying
- Transportation
- Water & Wastewater Systems
- Land Development
- Electrical Engineering
- Financial
- Water Resources/Environmental Studies and Design
Many clients do not understand the values of GPS data collection or what is involved with the different GPS data collection techniques. Many factors need to be addressed and a proper technique chosen before a project begins.

- Data usage – project specific and future use
  - utility network mapping, independent feature locations, etc.
- Data precision – How accurate does the data need to be?
- Collection Techniques – Code vs RTK
- Long Term versus Short Term Benefits / Project Costs
Project Goals and Objectives

• Define GPS collection techniques
  – What is Code GPS?
  – What is RTK GPS?
• Present the comparison of Code vs RTK to better define the difference
• Better present the proper GPS data collection technique choice according to specific project types
• Better define the “Who?” of data collection and data development. (Surveyor, GIS Professional, Intern, etc.)
Note: Trimble ProXH and Trimble GPS Total Station 4800 were used for this project.
GPS Data Collection – Differential Surveying (Code)

- Mapping Accuracy:
  - Horizontal = +/- 1 meter. (ProXH = +/- 1 ft)
  - Vertical = ~3x’s Horizontal

- 1 – 2 minute occupation times.

- Uses the code portion of the GPS signal.

- Requires post-processing for most accurate results.

- Real-time corrections are available.
  (e.g. WAAS)
GPS Data Collection – RTK Surveying

- Survey Accuracy:
  - Horizontal = $\pm 1\text{cm} + 1\text{ppm}$
  - Vertical = $\pm 2\text{cm} + 1\text{ppm}$

- 5 second occupation times.

- Relative Positioning uses carrier phase portion of the GPS signal.

- No post-processing required.
GPS Data Collection – RTK Surveying

- RTK requires a minimum of two GPS receivers (base station and rover).
- Base broadcasts data to the rover via radio or cellular modem.

“As a rule of thumb, every 10 m of [absolute] error in the base station coordinates can introduce approximately 1 mm/km uncertainty in GPS baseline vectors.” (Featherstone and Stewart, p. 44, 2001).
Project Methodology
(Based on Public Sanitary Sewer Network Example)

• **Step One – Data Collection**
  – Survey ~12 Known/Predetermined Benchmarks using both RTK and Code GPS
  – Survey Two Separate Project Areas (~25 features per area) using both RTK and Code GPS in each area and at the same time to control satellite constellation, time of day and weather factors
  – Record time/effort spent for collection and post processing of data and any project pitfalls
Step Two – Utility Network Development

- Create utility network systems by connecting the collected features in the predetermined areas
  - Calculate the network length for each project area
  - Calculate the difference between the Code and RTK based network lengths
  - Spatially portray feature locations over predefined base map to show discrepancies
Step Three – Error Calculations

- Determine final data error calculations for each GPS collection method
  - Calculate Root Mean Square Errors (RMSE) for each GPS collection method by comparing the collected benchmark coordinates to the known/predetermined benchmark coordinates
  - Calculate location discrepancies between the Code and RTK collected features in each area
  - Spatially portray feature locations by overlaying their determined coordinated on a predefined projected base map

[RMS Error = \( \sqrt{\frac{\sum d^2}{n}} \)]

[http://www.geo.ed.ac.uk/agidexe/term?982]
• **Step Four – Results / Conclusions**
  
  – Present Findings of Real-World Utility Network in a Side-by-Side comparison

• Include
  
  – Calculated Errors
  – System Length Calculation Discrepancies
  – Spatial Error using Base Map
Results

Sanitary Manhole Comparison

Benchmark Comparison

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Results

- **RMS Error** –
  
  - Root mean square error is a measure of the dispersion of points around a centre. It is mathematically the spatial equivalent to the standard deviation.
  
  - Often used as a measure of the accuracy of points indicating the discrepancy between known point locations and their calculated locations. i.e The lower the RMS error, the more accurate the point.

\[ \text{RMS Error} = \sqrt{\frac{\sum d^2}{n}} \]
# Results

## Code vs RTK

### VS Benchmarks

**(X - Easting) Horizontal Comparison**

<table>
<thead>
<tr>
<th>ID</th>
<th>Code</th>
<th>RTK</th>
<th>Keyed</th>
<th>E(Code)</th>
<th>E(RTK)</th>
<th>E(Code)^2</th>
<th>E(RTK)^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4676a</td>
<td>2395345.776</td>
<td>2395347.371</td>
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<td>-1.595</td>
<td>0.000</td>
<td>2.544</td>
<td>0.000</td>
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<td>4677a</td>
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<td>2393193.441</td>
<td>2393193.465</td>
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<td>2389785.769</td>
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<td>0.002</td>
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<td>PS10a</td>
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<td>0.013</td>
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<tr>
<td>PS11a</td>
<td>2396144.868</td>
<td>2396144.751</td>
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<td>0.004</td>
<td>0.003</td>
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<td>PS13a</td>
<td>2388927.378</td>
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<td>PS16a</td>
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<td>2388378.278</td>
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<td>-0.002</td>
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<tr>
<td>PS17a</td>
<td>2388533.099</td>
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<td>PS1a</td>
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<td>2401663.368</td>
<td>2401663.412</td>
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<td>PS20a</td>
<td>2396464.733</td>
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<td>PS2a</td>
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<td>2405278.178</td>
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<td>-3.073</td>
<td>-0.020</td>
<td>9.443</td>
<td>0.000</td>
</tr>
</tbody>
</table>

|       | Average   | 1.641 | 0.002 |

**RMSE** 1.281 0.040
## Results

**Code, RTK vs Benchmarks**

### (Y - Northing) Horizontal Comparison

<table>
<thead>
<tr>
<th>ID</th>
<th>Code</th>
<th>RTK</th>
<th>Keyed</th>
<th>E(Code)</th>
<th>E(RTK)</th>
<th>E(Code)^2</th>
<th>E(RTK)^2</th>
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</thead>
<tbody>
<tr>
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<td>259095.141</td>
<td>259092.180</td>
<td>259092.110</td>
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<td>9.187</td>
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<td>256063.526</td>
<td>256063.395</td>
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<td>0.131</td>
<td>28.026</td>
<td>0.017</td>
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<tr>
<td>PS11a</td>
<td>256631.099</td>
<td>256626.449</td>
<td>256626.265</td>
<td>4.834</td>
<td>0.184</td>
<td>23.368</td>
<td>0.034</td>
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<tr>
<td>PS13a</td>
<td>256300.044</td>
<td>256297.267</td>
<td>256297.181</td>
<td>2.863</td>
<td>0.086</td>
<td>8.197</td>
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<tr>
<td>PS16a</td>
<td>271223.023</td>
<td>271219.701</td>
<td>271219.697</td>
<td>3.326</td>
<td>0.004</td>
<td>11.062</td>
<td>0.000</td>
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<tr>
<td>PS17a</td>
<td>267371.263</td>
<td>267369.061</td>
<td>267369.049</td>
<td>2.214</td>
<td>0.012</td>
<td>4.902</td>
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<td>PS1a</td>
<td>260985.334</td>
<td>260981.624</td>
<td>260981.588</td>
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<td>0.036</td>
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<td>PS20a</td>
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<td>261449.813</td>
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<td>4.186</td>
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<td>17.523</td>
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</table>

Average: 11.972  0.007

**RMSE** 3.460  0.082
## Results

### Code, RTK vs Benchmarks

#### (Z - Elevation) Vertical Comparison

<table>
<thead>
<tr>
<th>ID</th>
<th>Code</th>
<th>RTK</th>
<th>Keyed</th>
<th>E(Code)</th>
<th>E(RTK)</th>
<th>E(Code)^2</th>
<th>E(RTK)^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4676a</td>
<td>348.832</td>
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<td>4677a</td>
<td>365.560</td>
<td>369.364</td>
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<td>4678a</td>
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<td>354.320</td>
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<td>0.005</td>
</tr>
<tr>
<td>4680a</td>
<td>370.222</td>
<td>373.363</td>
<td>373.290</td>
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<tr>
<td>PS10a</td>
<td>362.642</td>
<td>364.956</td>
<td>364.963</td>
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<td>0.000</td>
</tr>
<tr>
<td>PS11a</td>
<td>333.759</td>
<td>337.909</td>
<td>337.952</td>
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<tr>
<td>PS13a</td>
<td>366.969</td>
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<td>370.613</td>
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<td>13.279</td>
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<tr>
<td>PS16a</td>
<td>337.379</td>
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<td>340.669</td>
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<td>10.824</td>
<td>0.006</td>
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<tr>
<td>PS17a</td>
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<td>305.557</td>
<td>-2.981</td>
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<td>353.113</td>
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<td>-4.055</td>
<td>0.096</td>
<td>16.443</td>
<td>0.009</td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>E(Code)</th>
<th>E(RTK)</th>
<th>E(Code)^2</th>
<th>E(RTK)^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.062</td>
<td>0.007</td>
<td>29.020</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**RMSE**

| 3.750   | 0.082  |
## Results

**Code vs RTK Manholes**

<table>
<thead>
<tr>
<th></th>
<th>AREA 1</th>
<th>AREA 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RMSE (X)</strong></td>
<td><strong>RMSE(Y)</strong></td>
<td><strong>RMSE(Z)</strong></td>
</tr>
<tr>
<td><strong>Code (Uncorrected) - Area 1</strong></td>
<td>2.532</td>
<td>3.572</td>
</tr>
<tr>
<td><strong>Code (Corrected) - Area 1</strong></td>
<td>0.288</td>
<td>2.783</td>
</tr>
<tr>
<td><strong>Code (Uncorrected) - Area 2</strong></td>
<td>2.712</td>
<td>3.316</td>
</tr>
<tr>
<td><strong>Code (Corrected) - Area 2</strong></td>
<td>0.509</td>
<td>2.611</td>
</tr>
</tbody>
</table>

*As compared to the RTK feature location information.*
<table>
<thead>
<tr>
<th>GPS Technique</th>
<th>Calculated Segment Length (ft) (59 Segments)</th>
<th>Difference (ft) (Compared to RTK Survey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code (No Correction)</td>
<td>14,737.131</td>
<td>8.125</td>
</tr>
<tr>
<td>Code (Corrected)</td>
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<td>0.548</td>
</tr>
<tr>
<td>RTK</td>
<td>14,729.006</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Results - Review

- **GPS Calculations**
  - Moderate inequalities between utility networks developed by each GPS collection style (linear)
  - High inequalities between Code and RTK field located features (specifically elevations)
    - RTK – Quicker Collection / No Post -Processing
    - Code – Further Range (this is changing)

- **Project “Pitfalls”**
  - Weather, Equipment, Scheduling
  - Data Collection and Processing Issues / Errors
Results – Review
GPS Data Collection -
Factors / Techniques

Some Questions to Consider:
(Define proper GPS data collection techniques according to specific projects.)

Budget / Schedule?
(New RTK Technology – Better Accuracy, Further Distance, Quicker / Cheaper)

Is Elevation Important? How accurate must the data be?
What will be the future use / analysis of the data?
Who will conduct field data collection / process the data?

– RTK GPS
• Utility Systems (Networks)
  » Potable Water
  » Sanitary Sewer
  » Storm Water

– Code GPS
• Reference locations
  » Signs
  » Crime Locations
  » Water samples
  » Wetland Delineation
Defining the “Who?”
GPS Data Collection &
GIS Data Development

– When is a licensed surveyor “needed” for data collection?
(Licensed Surveyor, or supervised by licensed surveyor)

– Who should put the data together in the office?
(GISP – GIS Certification Institute, or supervised by GISP)
Defining the “Who?”
Importance of GIS Certified and Survey Licensed Individuals working on a project

• GPS data collection should be performed by licensed surveyor(?)
  – **SURVEYING** - the practice of measuring angles and distances on the ground so that they can be accurately plotted on a map
    [http://wordnet.princeton.edu/perl/webwn?s=surveying]
  – Importance of data quality and insurance (Surveyor’s Seal)
    • Precise Locations important, Elevations important
  – “True Understanding” of data collection
    • Projection, Datum, Error Calculations
    • Not just know how to use hardware
  – Required by Local / State / Federal Mandates
GIS Certification

– Still very controversial – Mixed Opinions

Is there a GIS “profession”?- Multiple uses for GIS


[A Critical Perspective on GIS Professional Certification, GeoSpatial Matters, Cordova, Henry. www.geoplace.com/hottopics/giscertification/AntiCertification.asp]

GIS Art or Science? – Is it certifiable?

[Stay on Your Own Side, Where is the line between surveying and mapping?. Al Butler, AICP, 2000]

– Usefulness of Certification

• Professionalism / Experience
• QA / QC
• Standards / Values
• Code of Ethics
GIS Certification / Survey License Importance

- I believe many are unaware of importance of the need for a licensed individual to complete or QA/QC field GPS feature collection and final GIS data development and analysis.
- Mixed results and opinions for both GIS Certification and GPS Survey by Licensed Surveyor.
- **DM:** Two states (*North Carolina* and *Oregon*) have endorsed GISP certification. **SG:** The North Carolina and Oregon endorsements were unsolicited but not surprising. There are a number of states that have seen tremendous value in the program. Florida, California, Colorado, Michigan, Ohio, Texas, Virginia, Washington, Wisconsin, etc. all have gravitated toward the credential. North Carolina and Oregon have progressive geographic information councils who wanted to back their GIS professionals by removing any doubt or obstacles those professionals had regarding the GISP.

Defining the “Who?”
Importance of GIS Certified and Survey Licensed Individuals working on a project

Final Thought: “It Depends…”
The client must be the final judge as to what type of data collection best suites their circumstances and who will perform the collection, but, in my opinion, it is the consultants’ duty to educate the client / prospective client on the different options available so they are able to make that informed decision.
Questions / Answers / Comments

• References:
  • GIS Certification Institute, www.GISCI.org
  • GPSworld, www.GPSworld.com
  • GeoWorld, www.geoplacel.com
  • Trimble, www.trimble.com
  • Jackson, GIS, Janet and Rambeau, PLS, Randy. Intersect: How do you make a GIS person understand the importance of data accuracy?, Professional Surveyor, October 2005, Volume 25, Number 10.
Questions / Answers / Comments

• Special Thanks:
  • Scott Faulkner – GPS Field Collection Assistant – Surveyor In Training
  • Chris French – GPS Field Collection Assistant
  • Eric Orndorff – GPS/Survey Manager – MS, PLS
  • Al Kling – Survey Manager – PLS
  • Robert Haag – Survey Manager – PLS
  • Steve Gochenaur – GIS Professional
  • Al Butler – AICP, Certified Mapping Scientist – GIS/LIS
  • Herbert, Rowland & Grubic, Inc. – www.HRG-Inc.com
  • Penn State University – Master of Geographic Information Systems
    http://www.worldcampus.psu.edu/MasterinGIS.shtml