Exploring Optimal GPS Signals for Autonomous Vehicles

Christopher Miller
Overview

I. Background
   I. Motivation
   II. Autonomous Vehicle (AV) Requirements

II. Methodology
   I. Area of Concentration
   II. Data Inputs
   III. Workflow

III. Tentative Results
Background: **Motivation**

1.3 billion currently to 2 billion in 2030
Background: *Motivation*
**Background: AV Requirements**

**Automated Driving System:**

“hardware and software that are collectively [...] used specifically to describe a level 3, 4, or 5 driving automotive system” - SAE International, 2018a
Background: AV Requirements
Background: AV Requirements

“Provide high resolution and accurate 3D maps around the vehicle that allow obstacle detection and support safe navigation” - Filgueira, 2017
Background: **AV Requirements**

“reduced contrast of the lanes (e.g. reflections, low light) or other disruptive factors such as snow or old lane markings” (Adali, 2018).
Background: AV Requirements
Background: AV Requirements
Methodology: Area of Concentration

Washington, D.C.

Access to data – opendata.dc.gov

Infrastructure – future integration potential

Interest within the City –
Need to improve
Member of an initiative group
Methodology: **Data Inputs**

Viewshed Tool in ArcMap

Surface elevation raster – digital surface model (DSM)

Point data, including height (OFFSET)

Longitude, Latitude and Altitude
Methodology: **Data Inputs**

Point data, including height (OFFSETA) – satellite locations

**Almanac** – easy to use .txt files, but less accuracy and additional calculations

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**El-naggar’s paper:**

New method of GPS orbit determination from GCPS network for the purpose of DOP calculations

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**YUCA FORMAT**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Health:</td>
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<tr>
<td>Eccentricity:</td>
<td>0.1958465576E-001</td>
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<td>Time of Applicability(s):</td>
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<td>Orbital Inclination(rad):</td>
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<td>Argument of Perigee(rad):</td>
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<td>Af0(s):</td>
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<td>Af1(s/s):</td>
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</table>
Methodology: **Data Inputs**

Point data, including height (OFFSETA) – satellite locations

**Broadcast Ephemerides** – more accurate but harder to use

El-naggar’s paper:
New method of GPS orbit determination from GCPS network for the purpose of DOP calculations
Methodology: *Data Inputs*

Point data, including height (OFFSETA) – satellite locations

**Precise Ephemerides** – most accurate

![Image](path/to/image.png)

- .sp3.z format – UNIX compressed ASCII
- Elmaghar’s paper: *New method of GPS orbit determination from GCPS network for the purpose of DOP calculations*
Methodology: *Data Inputs*

Point data, including height (OFFSETA) – satellite locations

- **Almanac** – easy to use .txt files, but less accuracy and additional calculations
- **Broadcast Ephemerides** – more accurate but harder to use
- **Precise Ephemerides** – most accurate
Methodology: Workflow

Precise Ephemerides –

XYZ geocentric coordinates of satellites
Methodology: Workflow

Precise Ephemerides –
XYZ geocentric coordinates of satellites

Conversion into geodetic –
Latitude and Longitude: NGS’s NCAT

Altitude:

\[ h = \text{scos}\mu+(pz+e^2N\sin\mu)\sin\mu-N \]

where the radius of curvature in the vertical prime (\(\bar{N}\)) is given by
\[ N = R_G(1-e^2)(\sin\mu)^2 \]
Methodology: **Workflow**

- Data Retrieval
- Display
- Analysis
Methodology: **Workflow**

1. **Data Retrieval**
   - `.sp3.z` orbital properties
   - Street Polylines
   - Lidar .las files

2. **Conversion**

3. **Query**

4. **Calculation**

5. **Output**

6. **Display**
   - DSM

7. **Analysis**

*Using Python or Model Builder*
Methodology: **Workflow**

- **Data Retrieval**
  - .sp3.z orbital properties
  - Street Polylines
  - Lidar .las files

- **Conversion**
  - Conversion
  - Query
  - Calculation

- **Query**
  - Repeat*

- **Calculation**
  - Repeat*

- **Output**

- **Display**
  - Data Source Inputs
  - Viewshed Output
  - Intersection of Polylines

- **Analysis**

*Using Python or Model Builder*
Methodology: Workflow

Data Retrieval
- .sp3.z orbital properties
- Lidar .las files

Conversion
- Street Polylines
- DSM

Query
- Calculation
- Output

Calculation
- Repeat*

Display
- Data Source Inputs
- Viewshed Output

Analysis
- Repeat*

Intersection of Polylines
- Optimal Routes, Improvements

*Using Python or Model Builder
Tentative Results

Obstacle when obtaining .sp3.z files

Hypothesis:
  Conversion still possible

  Line of sight will be present for the majority of the city

  Building height and street width increase visibility

  Forest canopies in northwest may be only areas of limitation
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<thead>
<tr>
<th>ID</th>
<th>DESCRIPTION</th>
<th>ESTIMATED COMPLETION</th>
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<tbody>
<tr>
<td>1</td>
<td>Download lidar point cloud files from opendata.gov</td>
<td>Dec-19</td>
</tr>
<tr>
<td>2</td>
<td>Import to LP360</td>
<td>Jan-20</td>
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<tr>
<td>3</td>
<td>Create a DSM from point cloud</td>
<td>Jan-20</td>
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<tr>
<td>4</td>
<td>Import raster DSM to ArcMap</td>
<td>Jan-20</td>
</tr>
<tr>
<td>5</td>
<td>Determine calculation necessary for satellite locations</td>
<td>Jan-20</td>
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<tr>
<td>6</td>
<td>Submit Abstract</td>
<td>Feb-20</td>
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<tr>
<td>7</td>
<td>Assess ephemerides and Almanac data source parameters</td>
<td>Mar-20</td>
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<tr>
<td>8</td>
<td>Calculate satellite locations coordinates</td>
<td>Apr-20</td>
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<tr>
<td>9</td>
<td>Convert XYZ coordinates to geodetic latitude, longitude and altitude</td>
<td>May-20</td>
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<tr>
<td>10</td>
<td>Use Viewshed to determine visible areas across DC area</td>
<td>May-20</td>
</tr>
<tr>
<td>11</td>
<td>Replicate using for multiple satellites, dates and times – potential to use model builder or Python</td>
<td>Jun-20</td>
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<tr>
<td>12</td>
<td>Use polyline road features from open data DC or lidar classified road points as intersection against viewshed</td>
<td>Jun-20</td>
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<tr>
<td>13</td>
<td>Display areas of visibility from least to the greatest obstruction</td>
<td>Jun-20</td>
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<tr>
<td>14</td>
<td>Analyze areas including city street routes of optimal visibility</td>
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<td>Draft Report</td>
<td>Sep-20</td>
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<td>Present Findings</td>
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<tr>
<td>18</td>
<td>Finalize Report</td>
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