Evaluation of Multi-path and Accuracy Improvement method in a stand-alone Positioning

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Outline of our study

- Understanding of multi-path
- Data analysis
- Accuracy improvement
- Result and conclusion
Object of our study

Use “code - carrier” measurement technique

- Detect SVs contaminated with multi-path
- Remove SVs from positioning

*Improve accuracy in positioning*
Picture 1  Direct and multi-path GPS signal

- **Multi-path GPS Signal**
- **Direct GPS Signal**
- **GPS Satellite**
- **Concrete Building**

**Multi-path error**
- carrier phase $\leq$ a few cm
- code phase $\leq$ 50 m
Reduction in pseudorange error by DGPS technique

- Satellite clock stability
- Satellite perturbations
- Ephemeris prediction error
- Ionospheric delay
- Tropospheric delay

Most of error sources in GPS positioning

Multi-path and Receiver noise are not reduced.
Data collection

- **Period**: 2000/12/2 ~ 12/3 (48 hours)
- **Place**: On the roof of laboratory
  //there is a wall and high steel tower
- **Antenna**: Aero Antenna Technology AT2775
- **Receiver**: NovAtel RT-2
  //Mask  5 degrees
  //Csmooth 20 seconds (L1,L2)
Investigation of multi-path

Investigation consists of 2 points

1. Relationships between code multi-path and accuracy
2. Accuracy improvement by removing SV (Satellite Vehicle) contaminated with multi-path
Caribration of code multi-path

Standard “code-carrier” technique

\[
\text{Code multi-path + bias} = L1\_code - 4.0915 \times L1\_carrier \\
+ 3.0915 \times L2\_carrier
\]

Errors concerned with carrier phase are negligible. Ionospheric term can be removed

Code multi-path error traces tend not to be zero-mean. In this study, we consider them zero-mean. Because we don’t use absolute multi-path error but we use only variation of multi-path error.
Fig. 1 Code multi-path error for 30 min.

Day-to-day repeatability of multipath

GPS Time (s)

Multipath error (m)

2000/12/2

2000/12/3

+5m offset
Fig. 2  Relationships between code multi-path error and elevation
Fig. 3 12 hours Stand-alone positioning error

Positioning error (m) vs GPS Time (s)

- X(-30m)
- Y(+50m)
- Z(0m)

Period for analysis: 545000 - 595000 GPS Time (s)
Fig. 4 Code multi-path and rate of carrier phase SV49

Under 10 degrees
Fig. 5 Temporal variation of multipath error and the rate of carrier phase (SV17)

Under 10 degrees
Fig. 6 Temporal variation of multipath error and the rate of carrier phase (SV25)

- Under 10 degrees
Fig. 7 Transition of elevation

![Graph of elevation transition for SV49, SV17, SV25](image)
Fig. 8  Stand-alone positioning with and without SV49

upper: without SV49  
lower: all visible SVs

Fig. 8 Stand-alone positioning error with and without SV49
**Fig. 9** Stand-alone positioning with and without SV17

- **X-axis error (m)**
  - Upper: without SV17
  - Lower: all visible SVs

- **Y-axis error (m)**
  - Without SV17

- **Z-axis error (m)**
  - Without SV17

**Legend:**
- Upper: without SV17
- Lower: all visible SVs
**Fig. 10** Stand-alone positioning with and without SV25

Upper: without SV25  
Lower: all visible SVs
Fig. 11 Algorithm to remove SV contaminated with multi-path

Sliding window

Multipath error (m)

exceeds threshold or not?

GPS Time (s)

Fig. 11 Algorithm to remove SV contaminated with multi-path
Fig. 12 The interval removing SV contaminated with multi-path

Fig. 12 SV removed from positioning

![Graph showing GPS time and PRN numbers with intervals for SVs 25, 17, and 49]
Fig. 13  Stand-alone Positioning without SV contaminated with multi-path

upper: without SV contaminated with multi-path
lower: all visible SVs
**Standard deviation in positioning**

<table>
<thead>
<tr>
<th>Threshold(m)</th>
<th>average</th>
<th>X_std(m)</th>
<th>Y_std(m)</th>
<th>Z_std(m)</th>
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<td>6</td>
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<tr>
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<td>0.85</td>
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</tbody>
</table>

Table1  Relationships between Std, average SVs and threshold by proposed algorithm

<table>
<thead>
<tr>
<th>average</th>
<th>X_std(m)</th>
<th>Y_std(m)</th>
<th>Z_std(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.8</td>
<td>2.01</td>
<td>3.29</td>
<td>4.17</td>
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</table>

Table2  Output of RT-2 receiver
Summary

Significant accuracy improvement in a stand-alone positioning by proposed algorithm

In urban environment, more over the number of SVs decrease due to surrounding obstacles (causing multi-path)

We need SVs as many as we can in positioning (at least 4SVs).

We would like to develop the positioning algorithm, which use different weight coefficients for SVs contaminated with multi-path not remove SVs.