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ORIGINAL ARTICLE

The ratio test for future GNSS ambiguity resolution

Sandra Verhagen · Peter J. G. Teunissen

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Abstract The performance of the popular ambiguity ratio test is analyzed. Based on experimental and simulated data, it is demonstrated that the current usage of the ratio test with fixed critical value is not sustainable in light of the enhanced variability that future global navigation satellite system (GNSS) ambiguity resolution will bring. As its replacement, the model-driven ratio test with fixed failure rate is proposed. The characteristics of this fixed-failure rate ratio test are described, and a performance analysis is given. The relation between its critical value and various GNSS model parameters is also studied. Finally, a procedure is presented for the creation of fixed failure rate look-up tables for the critical values of the ratio test.

Keywords Integer ambiguity resolution · Ratio test · Fixed failure rate · Integer aperture estimation · GNSS

Introduction

Any carrier phase-based GNSS model with integer ambiguities can be formulated in linear(ized) form as

$$E(\boldsymbol{y}) = \boldsymbol{A}\boldsymbol{a} + \boldsymbol{B}\boldsymbol{b}; \quad D(\boldsymbol{y}) = \boldsymbol{Q}_{yy} \tag{1}$$

with $E(.)$ and $D(.)$ the expectation and dispersion operators, respectively, and where $\boldsymbol{y}$ is the carrier phase and code observations, $\boldsymbol{a}$ denotes the integer carrier phase ambiguities, $\boldsymbol{b}$ represents real-valued parameters such as baseline/range and/or atmosphere, $\boldsymbol{A}$ and $\boldsymbol{B}$ are design matrices that link observations to the unknown parameters, and $\boldsymbol{Q}_{yy}$ is the variance–covariance matrix of phase and code observations.

The procedure for obtaining the least-squares (LS) solution of model (1) can be divided into three steps. In the first step, one discards the integer nature of the ambiguities and performs a standard least-squares adjustment. As a result, one obtains the so-called float solution of all the parameters, that is, ambiguities, baseline components and possibly additional parameters such as atmospheric delays, together with their variance–covariance matrix

$$\begin{bmatrix} \hat{\boldsymbol{a}} \\ \hat{\boldsymbol{b}} \end{bmatrix}, \begin{bmatrix} \boldsymbol{Q}_{\hat{a}\hat{a}} & \boldsymbol{Q}_{\hat{a}\hat{b}} \\ \boldsymbol{Q}_{\hat{b}\hat{a}} & \boldsymbol{Q}_{\hat{b}\hat{b}} \end{bmatrix}.$$

In the second step, the real-valued float solution of the ambiguities is further adjusted, so as to take the integer constraints into account. As a result, one obtains an integer solution for the ambiguities $\breve{\boldsymbol{a}} = I(\hat{\boldsymbol{a}}) \quad \text{with} \quad I : \mathbb{R}^n \to \mathbb{Z}^n$.

Integer rounding, integer bootstrapping and integer least-squares are different methods for obtaining the integer solution. Integer least-square (ILS) is optimal, as it can be shown to maximize the probability of correct integer estimation (Teunissen 1999). In contrast to rounding and bootstrapping, an integer search is needed to compute the ILS solution. This can be efficiently done with the LAMBDA method (Teunissen 1995). We restrict attention to the ILS principle.

The third step consists of correcting the float solution of all other parameters by virtue of their correlation with the ambiguities. As a result, one obtains the so-called fixed solution $\breve{\boldsymbol{b}} = \hat{\boldsymbol{b}} - \boldsymbol{Q}_{\hat{b}\hat{a}}\boldsymbol{Q}_{\hat{a}\hat{a}}^{-1}(\hat{\boldsymbol{a}} - \breve{\boldsymbol{a}})$. The fixed solution will have an accuracy that is in accordance with the high precision of the phase data, provided ambiguity resolution has been successful.

S. Verhagen (✉) · P. J. G. Teunissen
Delft University of Technology, Delft, The Netherlands
e-mail: A.A.Verhagen@TUDelft.nl

P. J. G. Teunissen
Curtin University, Perth, Australia
e-mail: p.teunissen@curtin.edu.au