Chapter 13
Discussions

The previous chapters of this book covered the most important material regarding static, kinematic, and dynamic GPS, including theory, algorithms, and applications. At the end of the book, the authors will emphasize, discuss, and comment on some important topics and remaining problems with GPS.

13.1 Independent Parameterisation and A Priori Information

A Priori Information

As discussed earlier with regard to the parameterisation of the GPS observation model (Sects. 9.1 and 9.2), clock errors and instrumental biases, as well as ambiguities, are partially over-parameterised or linearly correlated (related to and between themselves). Generally speaking, cancelling the over-parameterised unknowns out of the equation or modelling them first and then keeping them fixed using the a priori method (Sect. 7.8) will be equivalent. As long as one knows which parameters should be kept fixed, the a priori information used is true, and is just used as a tool for fixing the parameters to zero. If the model is not parameterised regularly, and one does not know exactly which parameters are over-parameterised, then the normal equation will be singular and cannot be solved. Again, using a priori information may make the equation solvable. However, in this case, the a priori information has the meaning of direct “measures” on the related parameters. Therefore, the a priori information used must be true and reasonable; otherwise, the given a priori information will affect the solution in unreasonable ways. If different a priori information is given, different results will be obtained. Therefore, the a priori information used should be based on true information.

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Independent Parameterisation of the Observation Model

A priori information can be obtained from external surveys or from the experience of long-term data processing that does not use a priori information. A regular (independent) parameterisation of the GPS observation model is a precondition for a stable solution of a normal equation without using a priori information. As mentioned above, parameterising the model independently and fixing the over-parameterised unknowns are equivalent. However, in order to keep some parameters fixed, one must know which parameters are over-parameterised and need to be fixed. Therefore, in any case, one must understand how to parameterise the GPS observation model in a regular manner. Fixing the over-parameterised unknowns after a general parameterisation is equivalent to a direct independent parameterisation. Therefore, regular parameterisation of the GPS observation model is important.

Inseparability of Some of the Bias Effects

Independent parameterisation is necessary because of the linear correlation of some parameters. The linear correlation party merges the different effects so that they cannot be exactly separated from each other. The constant parts of the different effects are nearly impossible to separate without precise physical models, whereas many model parameters are presented in the GPS observation equation and have to be codetermined. The inseparability of the bias effects comes partly from the physics of the surveys and is dependent on the survey strategy. Understanding the inseparability of the bias effects is important in designing surveys. The physical models must be determined more precisely in order to separate the constant parts of the effects.

Change in the Physical Meaning of the Parameters

Because of the linear correlation and inseparability of some parameters, the parameters that are to be adjusted may change their physical meaning. For example, the instrumental biases of the reference frequency and channel are linearly correlated with the clock errors. This indicates that these biases cannot be modelled separately so that the clock error parameters represent the summation of the clock errors and the related instrumental biases. They may be separated only through extra surveys or alternative models. If the clock errors of the reference satellite and receiver are not adjusted, then the other clock errors represent the relative errors between the other clocks and the reference clocks. If the other instrumental biases are not modelled, they will be partially absorbed into the ambiguities. In this case, the ambiguities represent not only the ambiguities, but also part of the instrumental biases, such that the ambiguities are no longer integers. The double difference may eliminate the instrumental biases so that the double-differenced ambiguities are free from the effects of instrumental biases, whereas the undifferenced ambiguities include those biases. If the instrumental errors are not modelled, the undifferenced ambiguities are no longer integers, whereas the double-differenced ambiguities are integers (no data combinations are considered here).

Zero Setting and Fixing of the Parameters

Setting a parameter to zero or fixing the parameter to a definite value must be done carefully. Any incorrect setting or fixing is similar to a linear transformation (translation) of the linearly correlated parameters. For example, the clock errors and instrumental biases of the reference station and satellite are generally not zero. Keeping the clock errors and instrumental biases of the reference as zero is similar to carrying out a time system translation with an unknown amount, and such a translation is inhomogeneous, because the orbit data are given in the GPS time system. External surveys may help for a correct zero setting.

Independent Parameterisation of Physical Models

Independent parameterisation of the bias parameters of the GPS observation model indicates the need for further study of the parameterisation problem. As long as the parameters of the physical models must be codetermined by the GPS observation equations, parameterisation of the physical models should be investigated with great care.

13.2 Equivalence of the GPS Data Processing Algorithms

Equivalence Principle

For definitive measurement and parameterisation of the observation model, the uncombined and combining algorithms, undifferenced and differencing algorithms, and their mixtures are equivalent. The results must be identical and the precision equivalent. The practical results should obey this principle.

The equivalence comes from the definite information contents of the surveys and the definitive parameterisation of the observation model. For better results or better precision of the results, better measurements are necessary.

Traditional Combinations

Under traditional parameterisation, the combinations are equivalent. Under independent parameterisation, the combinations are also equivalent. However, the combinations under the traditional parameterisation and independent parameterisation are not equivalent. Because of the inexactness of traditional parameterisation, traditional combinations will lead to inexact results.

Traditional Differencing Algorithms

Traditional differencing algorithms usually take into account only the differencing equations and leave the undifferenced part aside. In this way, the differencing part of equations includes fewer parameters and the systematic effects are reduced. Meanwhile, however, the information content of the observables is also reduced proportionally. The results of the parameters of interest remain the same.

Equivalent Algorithms

Equivalent algorithms are general forms of undifferenced and differencing algorithms. The observation equation can be separated into two diagonal parts. Each part uses the original observation vector (therefore the original weight matrix); however, the equation possesses only a part of the unknown parameters. The normal equation of the original observation equation can also be separated into two parts. This indicates that any solvable adjustment problem can be separated into two sub-problems.

13.3 Other Comments

Data Communication in Real-Time GNSS Positioning

Real-time GNSS positioning technology has become a fast, efficient navigation tool that can yield survey-grade coordinates for use in a variety of applications. One of the most important rules for real-time positioning is that a robust communication link is needed for acquiring the data from the rover station or corrections to the observables at the base station (as in relative positioning methodology). When considering data communication, there are several methods to choose from. The use of radios is one option, which is robust, but its range of communication can be limited, especially in urban areas where interference and frequency usage are high. On the other hand, wireless data modems are typically CDMA (Code Division Multiple Access), GSM (Global System for Mobile communications), and GPRS (General Packet Radio Service) communication formats using TCP/IP (Transmission Control Protocol/Internet Protocol) over cellular provider networks. This will allow longer ranges in the case of good cell coverage areas. Maintaining a strong, continuous communication link for data communication in real-time GNSS positioning can still be a challenge.

Indoor Positioning

Indoor positioning has become a focus of research and development over the past decade, and has been widely applied in many areas, such as indoor location-based service (LBS). It is apparent that the widely used GNSS performs poorly within indoor environments due to signal outages. Technologies using FM radios, radars, cellular networks, DETC phones, WLAN, ZigBee, RFID, ultra-wideband, high-sensitivity GNSS, and pseudolite systems have been developed. The integration of different techniques in a multi-sensor positioning system is another solution in indoor positioning. However, the indoor environment lacks a system that can provide excellent performance with high accuracy, short latency, high availability, high integrity, and low user costs like GNSS in outdoor environments. Current capable indoor positioning systems have different levels of accuracy, and the provision of global indoor positioning at a low cost and with accuracy of 1 m is far from a reality. Many indoor positioning applications are still waiting for a satisfactory solution.