Chapter 10
Research on Inverse RTD Positioning Algorithm and System Implementation

Mengqi Wu, Jiming Guo, Lili Shen and Xu Ding

Abstract Due to high cost and difficult to achieve real-time monitoring of receivers with the existing RTD technology, this paper proposes the inverse real-time pseudo-range differential technology (IRTD) based on CORS, which adds data center server between receiver and CORS system, transferring differential calculating from receiver to data center server. Data center server receives raw pseudo-range sent back by the receiver and RTCM data broadcast by CORS system, gets positioning result through parallel algorithms and returns location information to the receiver for displaying. Experiments show that without increasing data traffic, IRTD can solve the work area control problem, maintain secrecy of local coordinate parameters, realize real-time monitoring of multi-terminal, which can hardly be solved by the traditional RTD technology. And with a better accuracy, IRTD has a wide application prospect in rapidly obtaining and updating urban spatial information.

Keywords IRTD · CORS · Data center server

10.1 Introduction

Real-time differential technology (RTD) can provide positioning result with sub-meter accuracy and is widely used in urban land inspections, traffic supervision, underwater topographic survey and other industries [3]. But this technology cannot send back location information to the data center server, monitor the working condition of the rover station, and is difficult to realize data sharing. With the increasing maturity of China's urban construction, quick access of geographic

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information, real-time monitoring and information sharing is becoming more and more important. The inverse RTD technology proposed in this paper transferred the differential calculating from receiver to data center server, which can monitor the location of the rover station, realize data collection and data processing simultaneously and improve the production efficiency.

10.2 Introduction to Inverse RTD Technology

For the traditional RTD technology, differential calculation is directly on the rover station. So each rover station work independently and positioning result is displayed only in the rover station. The core idea of inverse RTD technology is to add data center server between receiver and CORS system, transferring differential calculating from receiver to data center server. With powerful computing capability, data center can obtain more accurate and reliable positioning results. Since all the rover stations' positioning results are processed in the data center, the rover station's operation area can be easily controlled. With parallel algorithms, data center can simultaneously handle a couple of rover stations. And if local coordinate parameters are saved on the data center, rover station can obtain local coordinate directly. Since IRTD can solve many difficulties which stumped traditional RTD technology, the technology has a practical application in urban mapping, traffic management, planning, supervision and etc. Meanwhile, IRTD is easy to implement, does not need to upgrade the hardware of data collection terminal and can be applied both to single base station RTD and the network RTD.

10.3 Data Processing Flow

After connecting to the data center, rover station sends NMEA data (which includes coordinates information) and raw pseudo-range to data center, data center forward NMEA data to CORS center and then receives RTCM data (which includes atmospheric delay, satellite clock error and etc.) fed back by CORS. After correcting pseudo-range with the corresponding RTCM data and combining the ultra rapid ephemeris downloaded from the internet, we can easily get the coordinates of rover stations. Figure 10.1 exhibits the flow of data processing in the data center.

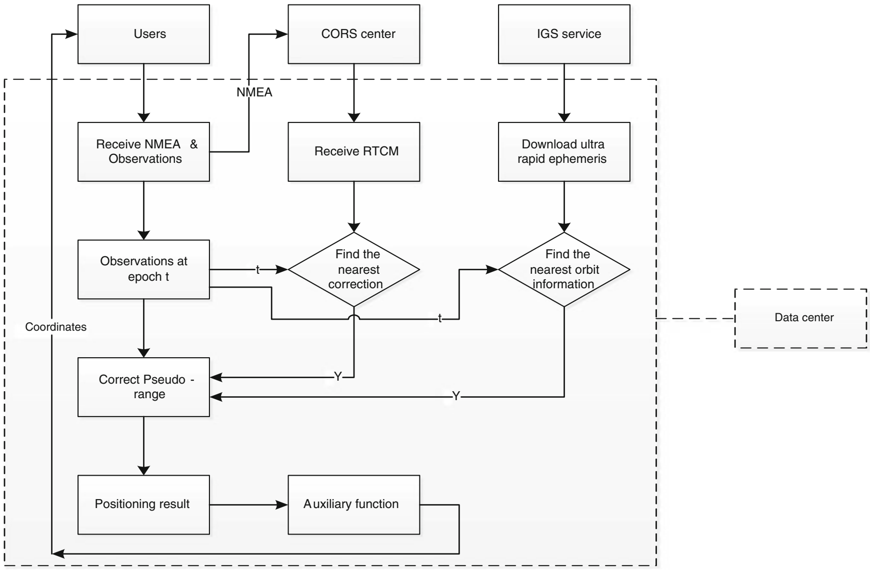

Fig. 10.1 Data flow in the data center

10.4 Key Technologies in the Algorithm

10.4.1 Decode RTCM2.3

The protocol of RTCM SC-104 is a kind of DGPS message developed by the special committees of Section 104 (SC-104) of the Maritime Radio Technical Commission (RTCM), which Include differential correction information. With the method of Byte scan, Byte scroll, Byte get complement, Message synchronization and Parity implementation [1], this paper decode type 1 message of RTCM2.3 and extract pseudo-range corrections and range rate corrections for all the available satellites.

10.4.2 Algorithm Design

The algorithm of the IRTD is similar with the traditional RTD. After single point positioning calculation with the corrected pseudo-range observations, we can get rover stations' location information. The specific process is as follows:

1. The interval of Z count in RTCM message is 0.6 s, generally not the same with GPS time of the receiver. After finding the nearest pseudo-range corrections

and range rate corrections, combining with the extrapolation method, we can get the pseudo-range correction for the current epoch. The formula is as follows:

$$PRC(t) = PRC(t_0) + RRC \cdot [t - t_0] \tag{10.1}$$

where PRC(t_0) is the pseudo-range correction, RRC is the range rate correction, and t_0 is the modified Z-count [2]. These parameters are all associated with the satellite.

2. The pseudo-range measured by the user, PRM(t), is then corrected as follows:

$$PR(t) = PRM(t) + PRC(t) \tag{10.2}$$

3. The corrected pseudo-range simplifies the observation equation significantly. Combined with ultra rapid ephemeris, we can get the rover station's coordinates.

The original observation equation is:

$$\begin{aligned} \mathrm{R}_{\mathrm{A}}^{\mathrm{j}} = \rho_{\mathrm{A}}^{\mathrm{j}} + \mathrm{c}\delta_{\mathrm{t}}^{\mathrm{j}} - c\delta_{t_A} + \delta\rho_{\mathrm{A,ion}}^{j} \\ + \delta\rho_{\mathrm{A,trop}}^{\mathrm{j}} + \delta\rho_{other} \end{aligned} \tag{10.3}$$

Since the pseudo-range correction contains ionospheric delay, tropospheric delay, satellite clock error, the corrected observation equation is:

$$\mathrm{R}_{\mathrm{A}}^{\mathrm{j}} + \mathrm{PRC(t)} = \rho_{\mathrm{A}}^{\mathrm{j}} - c\delta_{t_A} \tag{10.4}$$

10.5 Analysis of Experimental Data

Connecting data center with three rover stations for experiment. With parallel algorithms, data center can handle these rover stations and obtain positions simultaneously. Then rover stations can be monitored easily. And if local coordinate parameters are saved on the data center, rover station can obtain local coordinate directly. Then local coordinate parameters can achieve confidentiality. And since data center records the rover stations' coordinates, the operating area of different authorized users can be effectively controlled. Once exceed the operating area, data center immediately stop its provision of services for the illegal user.

Theoretically, when 12 satellites are visible each epoch, with traditional RTD technology, rover station receives 110 bytes RTCM data per second at least, while with IRTD technology, rover station sends 118 bytes pseudo-range observations per second to the data center. Experiment shows that after an hour, RTD consume

566 KB data traffic while IRTD consume 484 KB data traffic, which fully illustrates that IRTD doesnot increase data traffic.

Settle the rover station in a good environment to collect data with the interval of 1 s. The rover station sends NMEA data and raw pseudo-range to the data center in real time and records raw observations and the positioning results returned by the data center simultaneously. Afterward, combine the raw pseudo-range of the rover station and CORS reference station to solve baseline to get the high precision coordinates of the rover. Project the coordinates to Gaussian plane and make analysis of residuals, we can obtain Figs. 10.2, 10.3, 10.4, 10.5. And the accuracy comparison of RTD and IRTD is exhibited in Table 10.1.

Compared with traditional RTD technology, IRTD technology applies precise ephemeris and transfers differential calculating from receiver to data center, while core algorithms and calculation process is basically the same. As can be seen from the data in Table 10.1, the plan coordinates accuracy of IRTD is slightly better than the traditional RTD technology, both can achieve sub-meter.

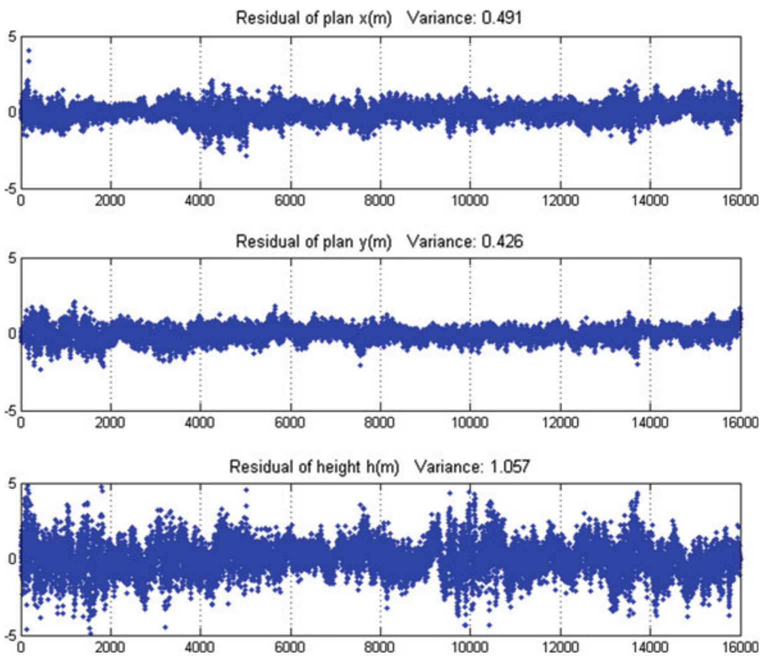

Fig. 10.2 Residuals charts of RTD (the first experiment)

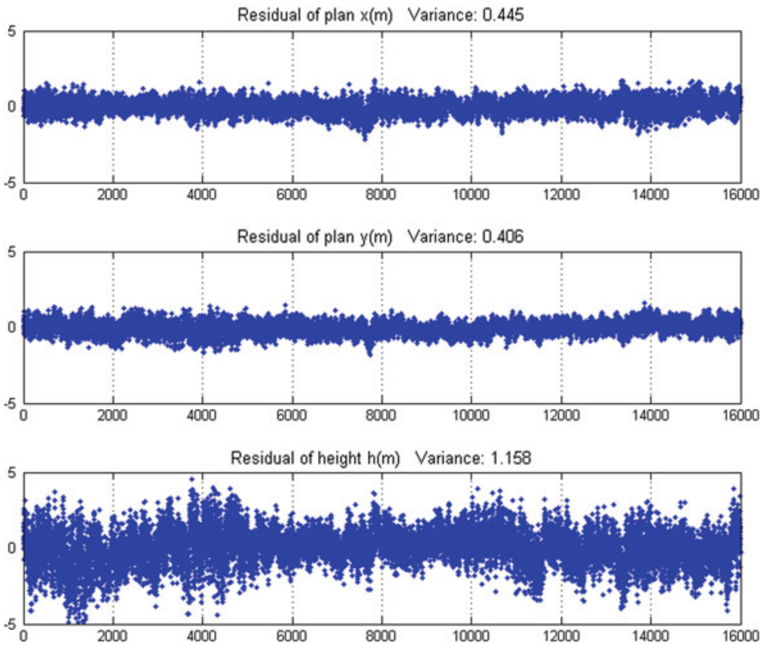

Fig. 10.3 Residuals charts of IRTD (the first experiment)

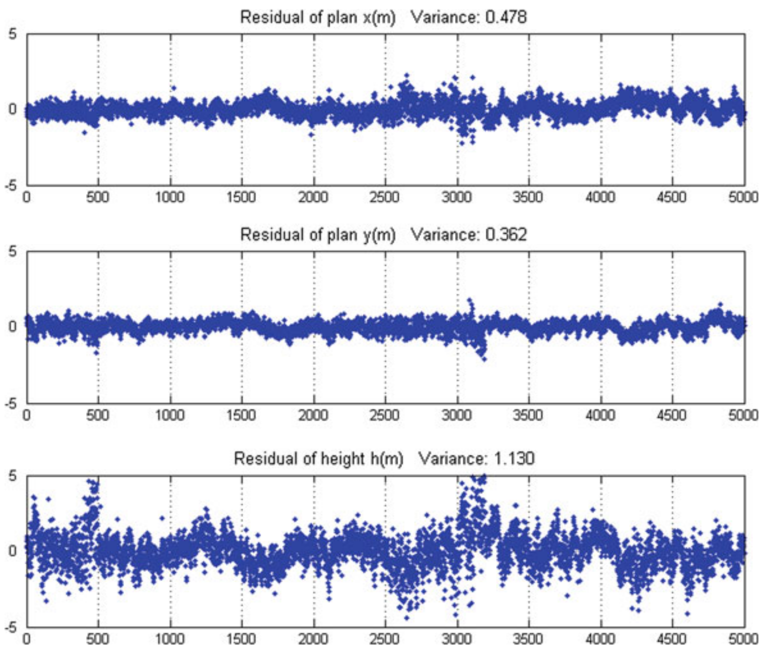

Fig. 10.4 Residuals charts of RTD (the second experiment)

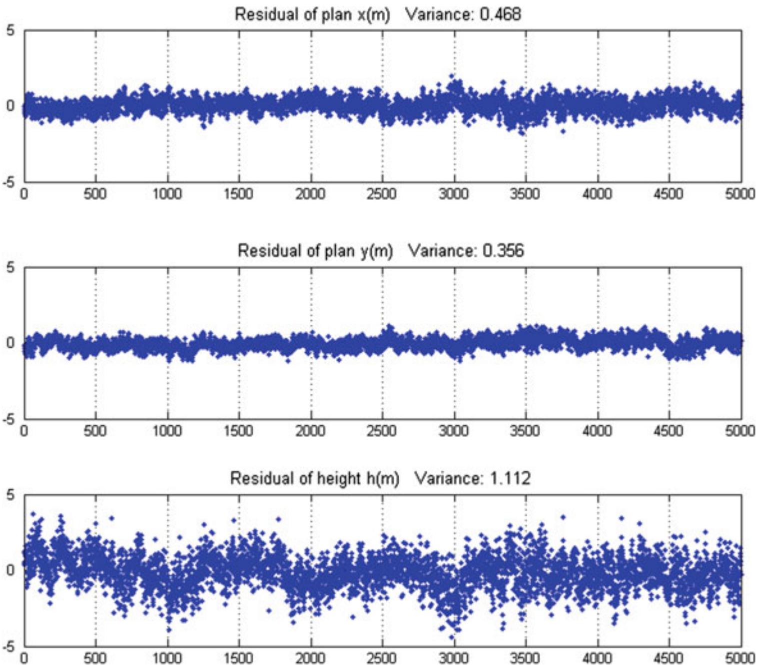

Fig. 10.5 Residuals charts of IRTD (the second experiment)

Table 10.1 Residuals tables

Experiment	RTD			IRTD		
	Var(x)	Var(y)	Var(h)	Var(x)	Var(y)	Var(h)
1	0.491	0.426	1.057	0.445	0.406	1.158
2	0.478	0.362	1.130	0.468	0.356	1.112

10.6 Conclusion

Inverse RTD technology transfer differential calculation from rover station to data center, which make it possible to monitor the working condition of rover station and realize data collection and data processing simultaneously. Experimental data show that positioning accuracy of IRTD can achieve sub-meter, which is slightly better than traditional RTD and has a broad application prospects in urban mapping, traffic management.

References

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