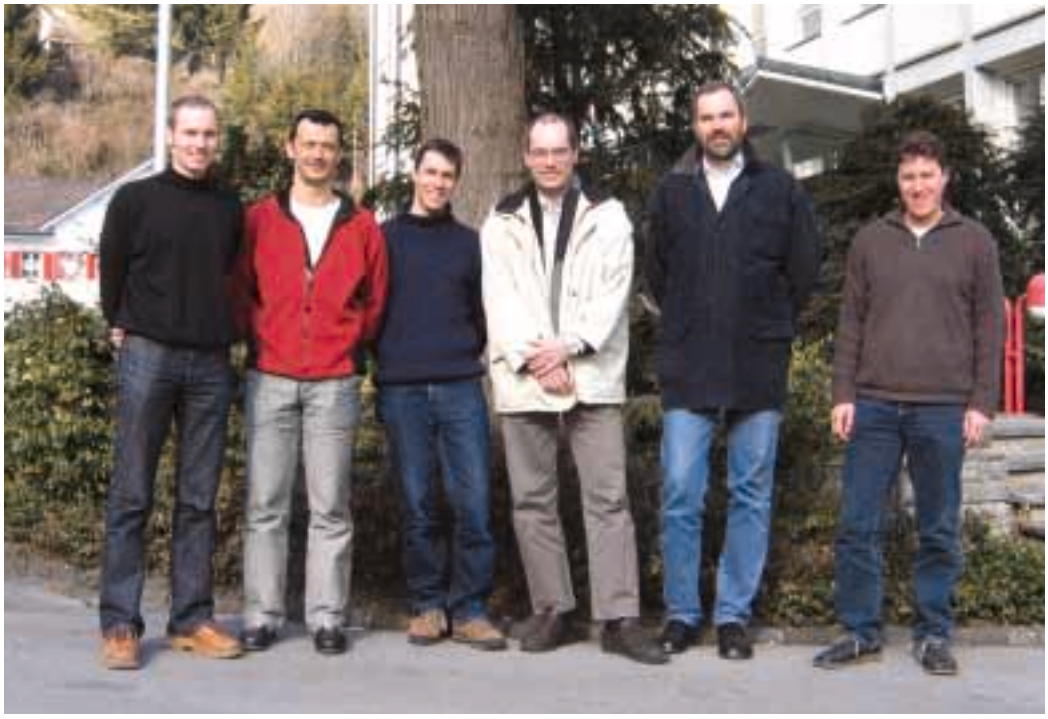
Emerging permanent reference station networks



(right): members of the CTC Positioning and Navigation Group (from left): Stephan Seeger, Dejan Seatovic, Frank Takac, Benedikt Zebhauser, Hans-Juergen Euler and Oliver Zelzer

Over the last few years, permanent reference station installations have emerged in several countries. These installations allow for roving GPS users in the field to achieve instant centimetre accuracies without the need of setting up a GPS reference station on a known station. This is quite appealing, since in areas with considerable GPS surveying activity, a number of users might share the infrastructure and the associated costs. Some of the installations are operated by companies and provide a service to the surveying community.

Background

Installations can be just single reference stations, a number of single reference stations, or networking reference stations. A single reference station set-up within up to 20-30 km is required if a user is operating in baseline mode. Otherwise the performance, accuracy, and with some systems the reliability of user's RTK is degraded. The integration of several reference stations into a combined network is providing benefits for the user by increasing distances to reference stations and overall user system performance. These permanent reference station networks are requiring real-time communication to a networking computation center and real-time estimation of biases between reference stations. Leica Geosystems is actively participating worldwide in setting up and maintaining all kinds of installations.

Group leader Hans-Jürgen Euler: "Researchers in CTC are observing the upcoming opportunities and are investigating the modern approaches for our products for the future."

A key factor of success is the distribution of the information generated within the networking computation center to the roving user in the field. Some of the installations are relying on proprietary formats and restricting themselves with the field equipment. However, in general it is in the interest of service providers to supply the service for more than a single type of RTK field equipment. Therefore, the detailed understanding of the supplied information such as applied corrections or the way of processing is absolutely mandatory.

Two approaches

Today, installations are supplying the information basically in two ways: the so-called FKP-approach (FKP stands for the German word of spatial correction parameter) and the VRS approach (Virtual Reference Station). Both approaches deliver observations that are supposed to be operational with modern RTK equipment. However, as noted above, the way the computational algorithms running at the networking computation center are proprietary. The optimal interoperability is not guaranteed, since the definition and an interface mechanism is missing. While the roving user equipment might work optimally with one vendor's networking SW providing a service, it might have degraded performance with another vendor's software.

Independent RTCM format

Traditionally, the communication interface between different manufacturer's equipment is the manufacturer independent RTCM format, which is jointly defined in a committee and all manufacturers have the possibility to participate in the definition discussions. Networking services based on either FKP or VRS approaches are providing the observations via the RTCM standard, but are basically operating in a mode not defined in the

standard document. Figure 1 shows the schematic sequence of operations and calculations required until a rover's position has been calculated. Several steps are distinguishable and are realized in one way or another in all environments where several permanent reference stations are providing their observation for a combined rover solution. In principle, the best approach would be to run the full calculations for the rover's position in one place, either the networking SW or the rover's firmware, since than the whole process can be optimized for performance and reliability. Only when all computations are completed in one location do the programmers have the full knowledge of applied models and bias estimations within the software. However, the current networking approaches are distributing the principle calculations over the software of the network and the rover. The arrows, 1 through 5, indicate possible interfaces that could be utilized for the information transmission from the reference station network to the roving user system. It should be mentioned that as long as calculation steps are performed within the same software, these steps can be combined into one step. This is actually done in some approaches.

Interfaces for information transmission

Some of the interfaces are easily described while others are quite sophisticated and need a detailed description of the manipulations completed, since all these manipulations are affecting the remainder of the processing chain. The first two interfaces, 1 and 2, marked in green are quite easily described. Through the first, the raw observations of all reference stations are transferred. Within the second schematic box the main calculations for fixing and removing are the so-called integer ambiguities are summarized. Through the interface afterwards basically the raw observations leveled to a common integer ambiguity level transferred to the next calculation step.

The next three interfaces are carrying information modified by algorithms of the previous boxes and need detailed descriptions. In order to keep the computational burden low on the roving user system the most logical is interface 2, since the network has already resolved the integer ambiguities between reference stations. The remainder of the calculations can be optimized within one software, the roving user's firmware.

The future: a standardised way of interfacing

In the RTCM committee, a Network RTK working group is working on the future standardized way of interfacing between networking reference stations and roving field users. Leica is actively participating in the definition of the standard messages. Interface 2 as described above has been identified and proposed by Leica as the most common ground between all vendors. After the initial proposal in 2001, the Network RTK messages of RTCM are being jointly discussed with other vendors and reached in the meantime conclusion. After some testing the RTCM standard for Network RTK should be released soon.

Continuing research

Several publications were prepared and published by researchers of Leica's Corporate Technology Center (CTC) in Heerbrugg, Switzerland for detailing the basis of the Network RTK. These publications define and describe the advantages in comparison to the currently used approaches. The focus is on the interface itself. More recent publications by the same authors are focusing on methods used at the roving equipment.

During the ION GPS/GNSS 2003 symposium in Oregon held in September 2003, Hans-Juergen Euler, Oliver Zelzer, Frank Takac, and Benedikt Zebhauser published their research results of approaches for RTK field equipment utilizing Network RTK information. The significance of the publication was recognized by the selection for a Best Presentation Award in its session. The paper investigates two different approaches for required calculations within a roving platform for optimal performance of the system. It proves the functionality of the interface definition for interoperability and provides a first stepping-stone for further investigations in that area. Detailed statistics show the improvement of observation quality for the final steps of positioning calculations. By using these methods, remaining geometry and ionospheric biases have been greatly reduced.

Another session's Best Presentation Award was given to Leica Geosystems' second publication during ION GPS/GNSS 2003. The team consisting of Holger Kotthoff, Christian Hilker and Christian Ziegler was awarded for their paper "Strategy of Reliable Ambiguity Resolution for Static and Kinematic Applications".

Within this decade the European Community is establishing the new satellite positioning system Galileo. The system will be interoperable with the American GPS. In the future both systems will help to provide better performance for Leica Geosystems' rover equipment. Researchers in CTC are observing the upcoming opportunities and are investigating the modern approaches for our products for the future.

Hans-Jürgen Euler

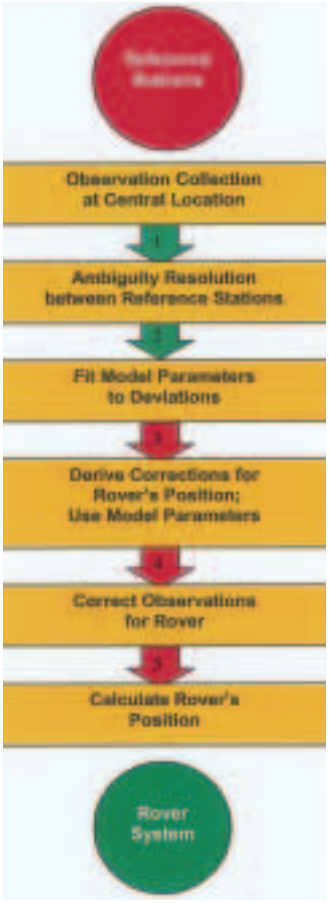


Figure 1, Schematic Sequence of Processing