HEPOS: Modern network-based GPS surveying

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The Hellenic positioning system (HEPOS) – Greece's RTK network.

THE HELLENIC POSITIONING SYSTEM (HEPOS) is a modern RTK network with nationwide coverage over Greece.

The network was established by Ktimatologio SA, a state-owned private sector company that is in charge of establishing the Hellenic cadastre. Although the main purpose of HEPOS is to facilitate the establishment of the cadastre, the network can also be used for a wide variety of applications, mainly in the fields of surveying and geodesy. This article deals with some technical issues that are of interest to the users of GPS networks.

Network description

HEPOS consists of 98 permanent reference stations (RS) distributed all over Greece (figure 1). The reference stations transmit their measurements to a control centre, which is situated at the headquarters of Ktimatologio SA in Athens. The user connects to the control centre to get the required data for real-time (RT) or post-processing applications. The reference stations are equipped with Trimble NetRS receivers with Zephyr Geodetic antennae. In the control centre, the running networking software is the Trimble GPSNet. A detailed description of the system can be found in Gianniou (2008).

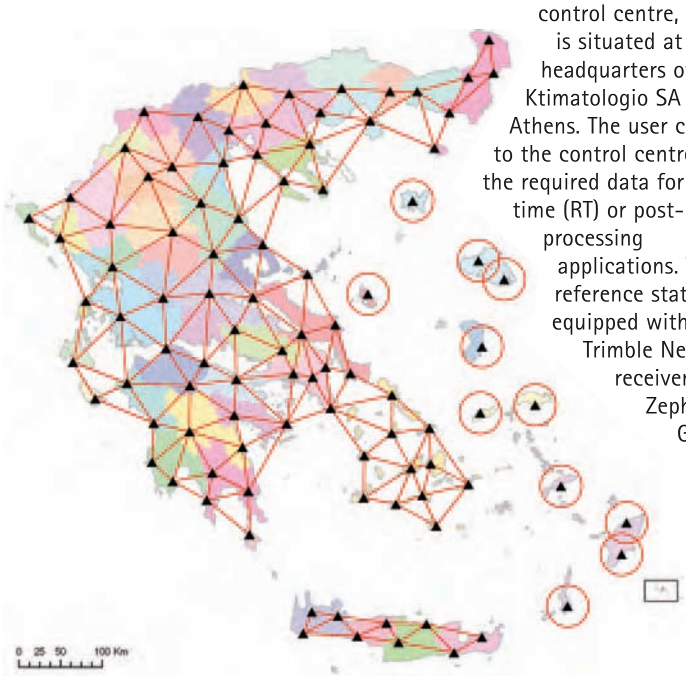

Figure 1: The 98 reference stations of HEPOS.

Network-based techniques

Relative geodetic positioning means that the rover data (collected at an unknown point) are processed together with the base data, i.e. data collected at a reference point with known coordinates. In conventional GPS-surveying, the reference data are from a receiver operating on a known point.

Nowadays, network-based techniques are becoming daily praxis and methods like network-RTK are widely used. 'Network-based techniques' means that reference data are not from just one receiver on a known point, but actually are computed from several reference stations that belong to a network. HEPOS offers three techniques that are widely used and are supported by the majority of GNSS manufacturers:

1. Virtual reference station (VRS)

In this case, the reference data are not from a (real) reference station. Instead, they are computed and refer to a point within the network area, from which it would be convenient for the user to obtain data. Ideally, this virtual point is selected to be at the centre of the surveying area.

According to the VRS concept, the calculated reference data will coincide with the data of a (real) reference station that would have been measuring at the virtual point. The VRS concept can be used both in real-time and post-processing applications.

2. Area correction parameters (FKP)

The acronym FKP stands for a German word, which means area correction parameters. Unlike the VRS concept, the FKP approach does not create reference data

MODE	TECHNIQUE	FORMAT
DGPS	Single-Base	RTCM 2.3
	Network	RTCM 2.3
RTK	Single-Base	RTCM 2.3
	Network (VRS)	CMR+
	Network (FKP)	RTCM SAPOS
	Network (VRS)	RTCM 2.3
	Network (VRS)	RTCM 3.0
	Network (MAC)	RTCM 3.1

Table 1: Real-time services offered by HEPOS.

for a point in the surveying area. Here, the parameters of a correction surface are supplied to the user, so that they can interpolate and compute corrections at their position. The FKP method can be used only in real-time applications.

3. Master-auxiliary concept (MAC)

In the case of the master-auxiliary concept, the user receives in compact form a big amount of information, i.e. data from a master RS plus additional data from auxiliary RSs. In this way, the user can benefit from detailed information from the network.

The amount of data that will actually be used depends on the equipment of the user and the algorithms that are implemented by it. The MAC approach can be used only in real-time applications.

Post-processing services

For post-processing applications, the user measures in the field using a geodetic receiver (single or dual-frequency) and downloads the necessary reference data from the webserver of HEPOS. This reference data could be from one of the 98 reference stations of the system or from a virtual RS. The sampling interval of the observations can be selected from a list of eight predefined intervals, like 1 second for kinematic applications (e.g aerial surveys), 15 seconds for rapid-static applications or 60 seconds for high precision geodetic static surveys. The user can also choose to obtain the data in RINEX or CRINEX (compact RINEX) format. The last format saves storage space and is preferable, provided that the office software to be used supports this format. In any case, there are free converters from CRINEX to RINEX available on the internet.

(Left) Figure 2: Bluetooth-connection between a cellular phone with GSM/GPRS modem and an RTK-controller. (Right) Figure 3: A GSM/GPRS CF card installed on an RTK-controller.

Real-time services

HEPOS supports all real-time GPS techniques as well as all standard data formats. Depending on accuracy requirements, the user can select DGPS or RTK, achieving sub-metre or centimetre-level accuracy respectively.

Furthermore, depending on the capabilities of the equipment, the user can choose between network-solution or conventional single-base GPS-surveying. Table 1 summarises the supplied RT-services of HEPOS.

Equipment for RT connections

For real-time applications, the user can use either GPRS or GSM to communicate with the control centre and receive the data. For this connection a GSM/GPRS modem is required. If the user does not have a modern RTK-system with an integrated GSM/GPRS modem, there are two main alternatives; i) use of a cellular phone (figure 2) or ii) use of a GSM/GPRS compact flash card (figure 3).

NETWORK FORMAT	DATA RATE
VRS RTCM 2.3	6845 bps
VRS RTCM 3.0	2742 bps
SAPOS FKP	6850 bps
MAC RTCM 3.1	Depends on: • Number of auxiliary stations • Update rate

Table 2: Rate of data transmitted for different Network-RTK formats (Trimble Navigation Ltd, 2005).

RT connections: GPRS v GSM

Worldwide, the current trend is the usage of GPRS and some recently established networks do not support GSM-connections at all. There are many reasons for this. The use of GPRS is more convenient for the user and it is also more inexpensive, as will be explained in the next paragraph. Furthermore, the support of GSM-users requires expensive equipment at the control centre of the network and also complicates the system set-up and the administration of the network. However, there are some areas without GPRS-coverage.

In addition, older receivers cannot be used for GPRS-connections as they do not support the required protocol for RT-surveying via the internet, namely the NTRIP (networked transport of RTCM via internet) protocol. For these reasons, during the design phase of HEPOS, it was decided that the system should also support GSM-users.

Benefits of GPRS-connections

The main benefit of GPRS-connections is that the user is charged by the telecom company based on the amount of transferred data and not on the connection time, like in the case of a GSM-modem. Depending on the country and the contract with the telecom

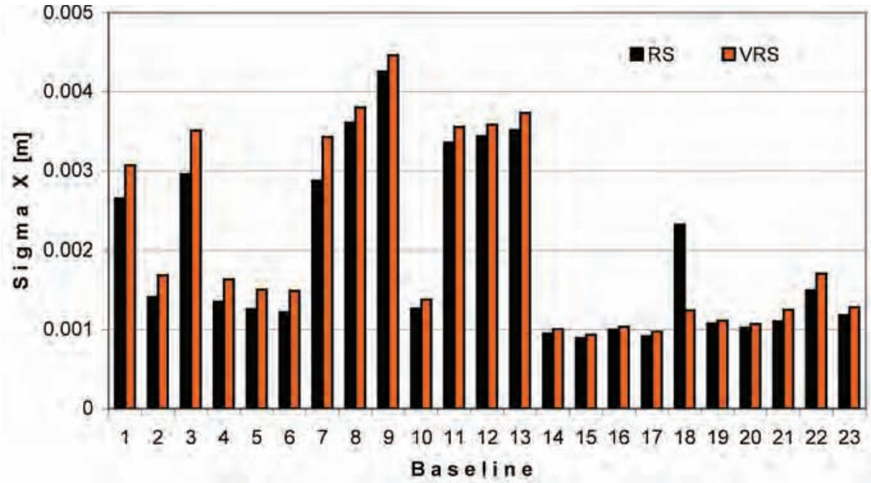

Figure 4: Baseline estimation – Comparison between RS and VRS.

company, the cost of a GPRS-connection can be as low as 10% of the cost of a GSM-connection. Obviously, the data rate associated with each data format plays an important role in the costs of GPRS-connections. Table 2 gives (in bits per second) the amount of data that have to be transmitted in dependence of the used data format. It can be seen that the difference in the required data rate can be significant. In order to further reduce the telecommunication costs, other methods like Trimble's RTK On Demand have been developed. Here, the user remains connected to the network but can pause the data reception when moving from point to point or generally when they are temporally not measuring.

Besides the reduced telecommunication costs, the use of GPRS has further advantages. When connecting to a network via GPRS, the user only needs to know the IP address and the port of the network's NTRIP caster. After connecting to this address, the source table appears showing all the services the user has subscribed to. The user then selects each time the service they want to use. On the contrary, a GSM-user has to dial different telephone numbers in order to use different services.

Post-processing: VRS v RS

In the case of post-processing applications, the user faces the dilemma of using either VRS data or data from a (real) RS. Theoretically, the VRS data result from computations and can hardly be as good as data from a real RS. On the other hand, isn't it better to use data from a VRS station in the centre of the working area, than from the closest RS of the network if this station is 20 or more kilometres away?

In order to answer this question, an assessment of the quality of the VRS data is needed. To gain an estimation of the quality of the VRS data of HEPOS, the following procedure was followed. VRS data were computed at points next to an RS of the network. The baselines between these stations and all neighbouring RSs were solved. These steps were repeated four times for an equal number of areas in the network leading to 23 pairs of baselines (RS-RS and RS-VRS). The baseline length varied between 25-70km. The purpose was to compare the sigmas of the baseline components (east, north, up).

However, the software used (Trimble Geomatics Office) gives these numbers with three decimal digits. At this level, the results were practically identical. The full variance-covariance matrix is supplied for the ΔX, ΔY, ΔZ baseline components (ECEF coordinates). For revealing small differences, these values were used. Figure 4 gives the sigmas of ΔX for the 23 pairs of baselines. It can be seen that the sigmas of the baselines to the VRSs are slightly higher than the

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sigmas of the baselines to the (real) RSs. However, the degradation is in the order of 10-4. Thus, the results can be considered practically equivalent. Similar behaviour was also found to be true for the ΔY and ΔZ components.

The above test gives just an indication of the quality of the VRS data. A detailed comparison of RS and VRS data requires extended data processing and analysis and is far beyond the scope of this article. The reader should keep in mind that the above test simply compares RS and VRS data under the same conditions, i.e. the RS and the VRS are almost at the same point.

For the user, the situation is actually different: They have to choose between a (real) RS that could be some tens of kilometres away and a VRS inside their survey area. As is known from GPS-surveying theory, the longer the baseline length, the worse the baseline precision. Given that the quality of the VRS data is comparable to that of the RS data, it becomes obvious that if the nearest RS is not close to the survey area, the user should prefer the use of VRS data.

Another advantage of the VRS data is that they are free of cycle slips and direct multipath factors that affect the data of (real) RSs. As a result, sometimes the VRS data are processed with fewer difficulties. An example can be seen in figure 4. For baseline 18, the sigma for the RS station is much higher that the sigma of the VRS. This is because the default processing settings led to a float solution for the RS, while in the case of VRS the same settings led to a fixed solution.

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