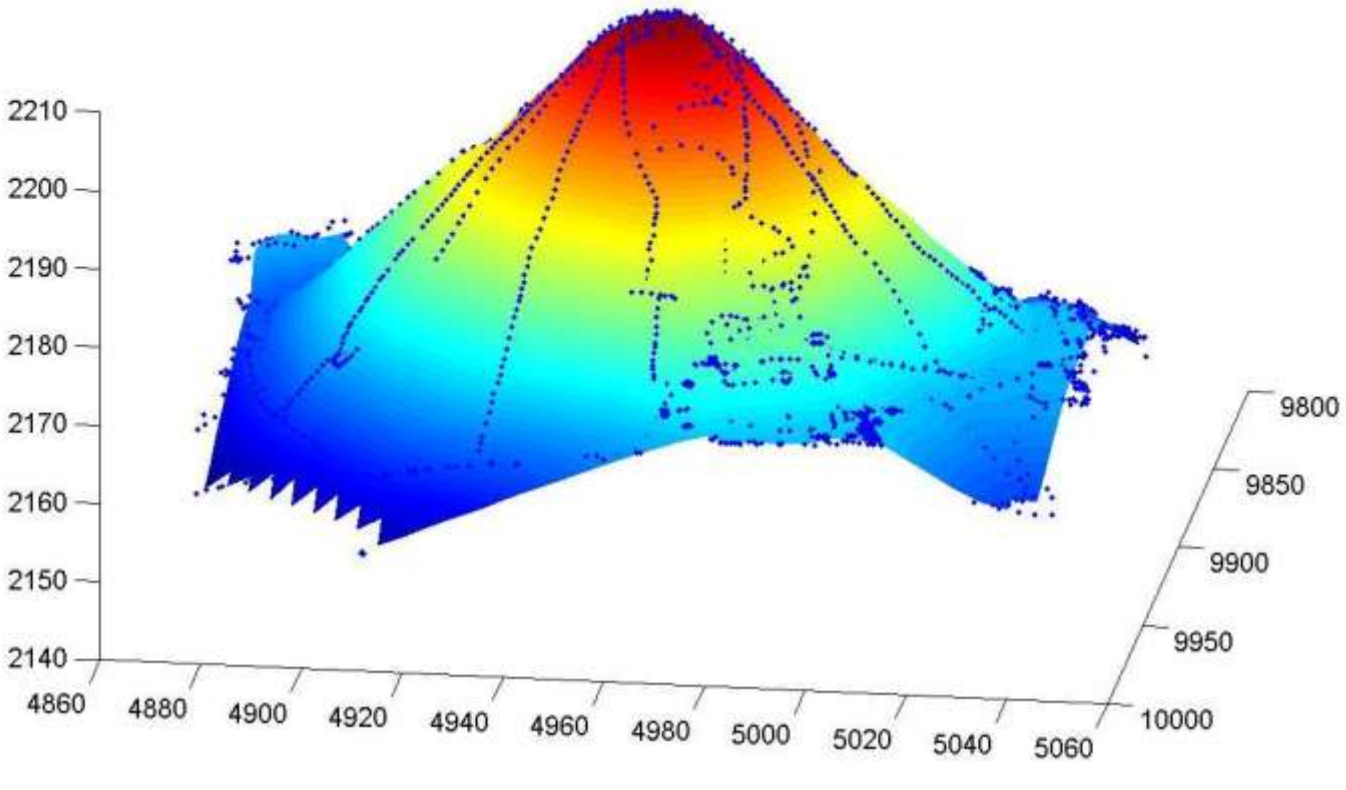
GPS-survey as base of the

Site Information System (SIS)

of the

Nemrud



Report October 2001

Departement of Geodesy
Delft University of Technology

Hans Garlich and Rien Kremers

1. Introduction

In preparation of the restoration of the Nemrud and possible later excavations the International Nemrud Foundation (INF) started to make a Site Information System (SIS). In this digital system all the relevant information about the Nemrud will be stored.

On the 28th of February 2001 the president of the INF and the section Mathematical Geodesy and Positioning (MGP) of the Delft University of Technology discuss the possibility for surveying and digital mapping of the Nemrud and direct surroundings. This and following consultation results in a written agreement in which the Nemrud project and further conditions are defined.

For this unique project two co-workers of the section MGP are given the opportunity to enlarge their experience in the field of the Global Positioning System (GPS). Besides two weeks of adventures, especially the non-Dutch circumstances under which the surveying is conducted are a challenge. Hans Garlich and Rien Kremers are carrying out the GPS measurements from the 6th until the 16th of August, with the assistance of Thorstin Crijns.

2. Measuring network

In this chapter in brief the measuring techniques GPS-RTK, the definition of a local co-ordinate system and some explanations regarding the measuring network, are described.

2.1 Measuring techniques GPS-RTK

GPS is a modern worldwide positioning system based on the use of satellites. The American Ministry of Defense has developed the system. The fully satellite configuration consists of 24 satellites in 6 orbital planes. The time of revolution of a satellite in its orbit is 12 hours. Nowadays there are at least 30 satellites available, because the health of a satellite is longer than planned. In any moment there are more than 5 satellites above the horizon (see figure 1).

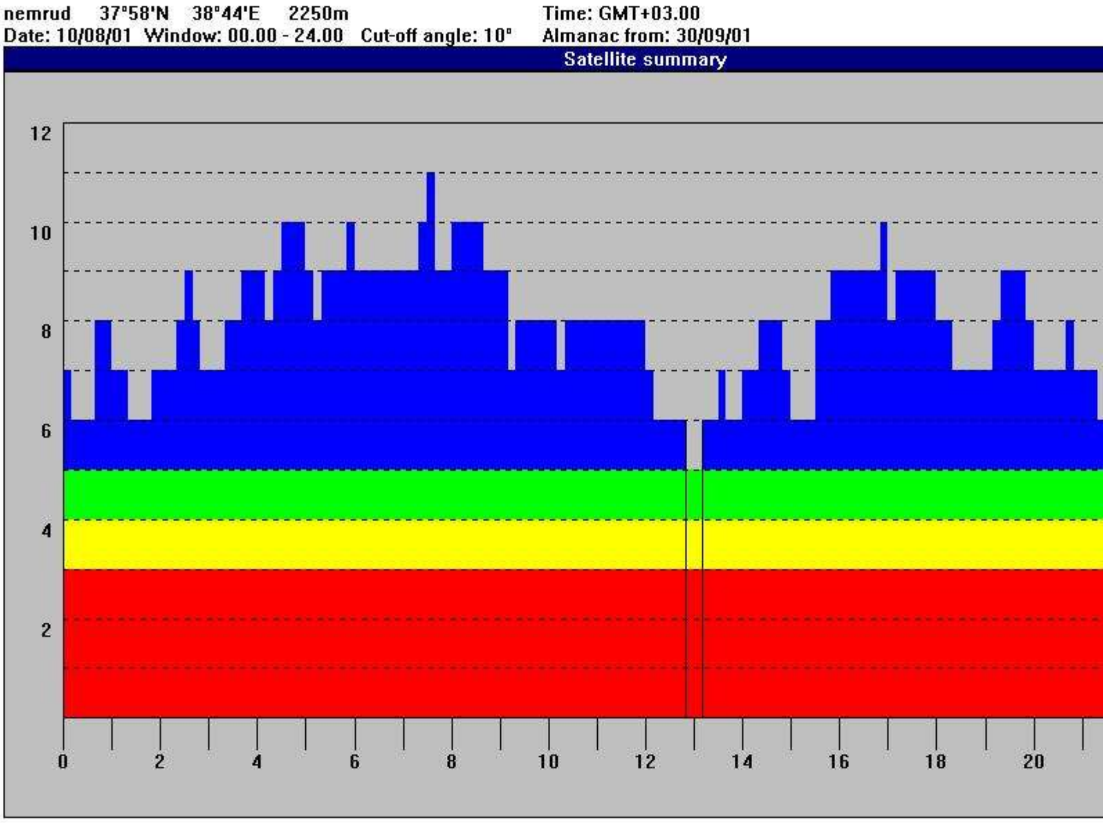


Figure 1: Satellite summary

The principle of positioning with GPS is based on distance measurements to minimal 4 satellites with known positions. The accuracy is approximate 10 metres. With special measuring- and calculating techniques several effects of error sources can be reduced. In this way accuracy is possible of one centimeter on a distance of hundreds of kilometers. This can be used i.e. for measuring earth shifts.

The method used for this project is called GPS-RTK (Real Time Kinematic). A reference station with a radio transmitter sends reference data to the moving station, the so-called rover. The rover combines its own measuring data with the reference data to calculate the direct position. The position is relatively to the co-ordinates of the reference station. The accuracy is a few centimeters.

2.2 Local co-ordinate system

For this project the co-ordinates of the fixed point (number 1) on the east terrace are taken from the analog map of Springer measured in 1989. The height of this point has been corrected later on. The top of the tumulus increases to 2206 m above sea level (see paragraph 4.2). The local network of the measurements is fixed to the GPS north (geographical north of the world geodetic system 1984 (WGS 84) and the scale factor is 1.
In this system 4 fixed points are measured with GPS-RTK. These points are later on used for positioning the reference station or controlling the rover. The rovers are daily checked on one of the control points. The accuracy is 2 centimetres or less.

2.3 Number of measuring teams

By way of precaution 4 GPS receivers are used. With those instruments two measuring teams can operate independent of each other, having their own reference station. Or three measuring teams can work at the same time with one shared reference station. However, in that case a disadvantage is that there must be a good tuning between the three teams because one reference station can not cover the whole measuring area. The first two measuring days we formed three measuring teams. This means that Thorstin Crijns had to learn quickly how to handle the GPS equipment. This went fast without any problems.
During the third day one receiver broke down so there were two receivers left. An advantage was that there could be formed teams with two persons. And that was very handy for making drawings and notes. It is also more secure when doing difficult “measuring expeditions” down into the valley.

2.4 Optimum measuring period

For easy measuring with GPS-RTK at least 5 satellites must be received. If there are horizon obstructions (for instance a mountain, a statue or a rock-face), there must be at least 7 satellites above the horizon will the measurements be rather successful. Figure 1 shows the satellite configuration for the Nemrud. In the morning and afternoon the configuration is excellent, but not from 12 until 15 p.m.
That is why we sometimes worked out the measurement data directly after lunchtime.

3. Measuring circumstances

The measuring location lies on a distance of about 10 kilometres of the hotel Kervansaray where the Nemrud team was hosted. The way up to the measuring area is bumpy and steep (rising percentage about 10 %). The ride in a minibus takes about half an hour. Afterwards we walked up the mountain with the necessary equipment (food, water, batteries etc.). The height difference is about 120 metres. The receivers could fortunately be stored on the mountain during the night in the cabin of the monument guards on the mountain, because otherwise there was a lot of measuring equipment to be carried up and down the mountain. After installing the reference station and controlling the rovers the measurements started at about 9.30 a.m. Till 12 p.m. the satellite configuration was very favourable (see figure 1) and the measurements were conducted without any problem. After lunch we preferred measuring in an area with a minimum of horizon obstacles.
After downloading the data and storing the receivers the team returned to the hotel at about 3.00 p.m. So there were only 4 to 5 hours available on a working day for GPS measurements.
During the measurement campaign the temperature in this area was about 40 degrees Celsius. On top of the mountain it was a bit less warm and due to the strong wind the temperature even felt very nice. Once the wind was so strong that the reference station was blown away! By coincidence we were changing the batteries so we could save the reference station just in time.
Because of the need of measurements of the entrance roads, ice caves, steles and other important archaeologic objects several times surveys were done down into the valley. An exhausting climbing back to the top of the mountain followed after these measurements. In the valley it was extreme hot because there was very little wind. Measuring was sweating then!
With the survey results of the valley it was possible to produce a global contour map of the surroundings of the mountain. For making a contour map of the mountain, the tumulus had to be climbed several times.

4. <u>Results of the measurements</u>

4.1 Local network

In paragraph 2.2 the local network is described. The height of the points in the AutoCAD-file is adjusted so that the top of the mountain becomes 2.206 m. The co-ordinates of the fixed point on the east terrace (point number 100) becomes in metres: x =10.000,00; y =5.000,00 and z =2.168,17
On the map of Springer from 1989 are several fixed points. The co-ordinates of these points are not known but can be measured from the map with an accuracy of several decimetres. Because of this little accuracy they are not fit for the network. Four of these points (number 1, 3, 4 and 12) have also been measured with GPS. These points are clearly marked in the field so they can be used as network points for future measurements. These points have the following numbers in the AutoCAD file: 100, 104, 10999 and 33037.

When the map of Springer (as well as the map of Brokamp) is compared to that of our GPS, it shows that there is a rotation between the two co-ordinate frames. The orientation of our GPS based map (geographical north) is 4.6 degrees **west** compared to the north of the map of Springer and Brokamp. According to Mr. Springer he used a compass to determine the magnetic north. The compass orientation on the Nemrud according to appendix 5 has a declination of about 4 degrees in the year 1989. The compass orientation, the magnetic north, lies about 4 degrees **east** of the geographic north.

4.2 Calculating the altitude of Nemrud

On former archaeologic maps and recent tourist information folders the height of the Nemrud is 2.150 metres above sea level. From the GPS-measurements it appears that this is not correct. That is why we tried to find a local benchmark. This was not easy because the mountain lies in military area and the height of the mountain is 'secret’. Thanks to the INF we could see a Turkish topographic map of the area on which a height of 2.206 m was recorded, so 56 metre higher than on the map of Springer. In the AutoCAD file this height is applied.

The height of the mountain is also calculated with the data from two permanent GPS-reference stations (Ankara and Delft) with an accuracy of several decimeters. In order to transform the calculated GPS-height to a height above sea level the earth geoid model EGM96 is used. The calculated height is **2.206,7** metres above sea level. This corresponds very well with the Turkish topographic map.

4.3 Contour map

Due to several measurement campaigns to the valley it is possible to make a global contour map of the surroundings of the Nemrud. This contour map has to be interpreted carefully because only the height information of the measured points is correct; the rest of the height information is based on interpolation between the measured points. If one needs height information in areas where there are only few points measured, one must use extra information from e.g. air photo’s, satellite images or other maps.

4.4 Topographic

The local network points described in paragraph 2.2 and 4.1 were used as reference points for the topographic measurements. The following objects were measured: the statues on the east- and west-terrace, large pieces of stone of the statues which were fallen down, steles, fire altar, processional roads, rock stairs, etc. Not all the points on the west terrace could be measured directly with GPS. Some points of the statues have been constructed by using information from the map of Theresa Goell (see appendices 1 and 2).
On the north terrace the remains of the steles were measured and the still visible remains of the former gravel depots. Also measured were : the tumulus and the surroundings of the tumulus (see appendix 3), a part of the entrance road on the north-east side, the processional road on the south side and the entrance building, the plains in front of the ice-caves at the south-east side of the mountain and some points at the former quarry east of the Nemrud.

5. Mapping

The map is made with the software package LisCAD. Each day the measurements were used to update the map. This was done in our hotel on a laptop. At the Delft University the map was finished. The final result can be seen in appendix 3 (plus network points) and appendix 4 (plus contour map).
The LisCAD-file is converted to an AutoCAD-file. This file becomes the base for the SIS. There are also made some plots on A0 and A1size. For this purpose the LisCAD-file is converted to Microstation.

6. Final remarks

By means of this project useful experience was gained with the use of GPS in mountain areas as well as the use of mapping software.
Before the project started we did not expect that is was possible to obtain so many measurements and to process all these data as well, in less than two weeks.
The project resulted in a database suited for research and education in the field of digital terrain modeling and for promotional activities.

Thanks to the efforts of INF all our questions and problems were solved quickly. We are much obliged for that. Finally we want to thank all the people involved in the project for the good and pleasant co-operation.

Delft, 22th of October 2001

Hans Garlich and Rien Kremers