STUK-YTO-TR 88

GPS positioning and desktop mapping

Applications to environmental monitoring

Report on task JNT B898 on the Finnish support programme to IAEA safeguards

A. Kansanaho, T. Ilander, H. Toivonen

OCTOBER 1995

STUK

SÄTEILYTURVAKESKUS
Strålsäkerhetscentralen
Finnish Centre for Radiation and Nuclear Safety

STUK-YTO-TR 88
OCTOBER 1995

GPS positioning and desktop mapping
Applications to environmental monitoring

Report on task JNT B898 on the Finnish support programme to IAEA safeguards

A. Kansanaho, T. Ilander, H. Toivonen
Research Department
Aerosol Laboratory

The study was supervised by
M. Tarvainen

FINNISH CENTRE FOR RADIATION AND NUCLEAR SAFETY
P.O.BOX 14, FIN-00881 HELSINKI, FINLAND
Tel. +358-0-759881
Fax +358-0-75988382

ISBN 951-712-066-4
ISSN 0785-9325

Painatuskeskus Oy
Helsinki 1995

KANSANAHO, Ahti, ILANDER, Tarja, TOIVONEN, Harri (Aerosol Laboratory). GPS positioning and desktop mapping. Applications to environmental monitoring. Report on task JNT B898 on the Finnish support programme to IAEA safeguards. STUK-YTO-TR 88. Helsinki 1995. 16 pp. + Appendices 11 pp.

ISBN 951-712-066-4
ISSN 0785-9325

Keywords: GPS, digital maps, dose rate, environmental monitoring, safeguards

ABSTRACT

Satellite navigation has been used for in-field applications by the Finnish Centre for Radiation and Nuclear Safety since 1993. Because of this experience, training in the use of GPS positioning and desktop mapping was chosen as a task under the Finnish Support programme to IAEA safeguards. A lecture and a field experiment was held in the training course on environmental monitoring at the IAEA headquarters in June 1995. Real-time mapping of the co-ordinates and storing information on sampling sites and procedures can make safeguards implementation more efficient and effective. Further software development are needed for these purposes.

CONTENTS

FOREWORD

Pilot training course on environmental monitoring

Overview:

This session deals with the use of Global-Positioning Satellite receiver technology to provide accurate position (latitude and longitude) information which can be used to locate environmental sampling points in the field. The topics which will be covered include:

1. Description of the GPS system and receiver technology.
2. Discussion of the types of maps and geographical data available and how desktop mapping can be used to manipulate such data.
3. Use of GPS/PC techniques to navigate to the next sampling point and logging of sampling data.

Objectives:

After the session, the participant will be able to:

- Describe the principles of GPS positioning and desktop mapping.
- Describe the use of a GPS system for locating and logging sampling points in an environmental monitoring campaign.
- Describe the sources of maps and geographical data for use with desktop mapping software.

1 INTRODUCTION

Satellite navigation is a simple method to determine current position anywhere in the world. When the satellite navigator data is displayed using a computerised mapping system, anyone can easily spot the location exactly. Portable computers and tiny satellite navigators enable use of satellite navigation system in the field.

A suitable map of the area of interest is the key of successful navigation. During the last couple of years, the production of digital maps has increased and now it is possible to purchase digital maps for many applications. An advanced user of a mapping software can also handle the production of digital maps, starting from high-quality printed maps.

A satellite navigation system, known as SAHTI, was produced in STUK for real-time navigation and environmental measurements. It includes a GPS -receiver and a LapTop computer, equipped with tailored software above a commercial mapping package.

2 GPS - SATELLITE NAVIGATION

The Global Positioning System (GPS) is a satellite navigation system designed, built and controlled by the US Department of Defence. The GPS system is based on 24 satellites which circle the earth at an altitude of 20,000 km. These satellites are controlled by the Ground Control Segment of the system. It's main tasks are to calculate new parameters of the satellite orbits and to correct the satellite clocks. The exact time is essential for the whole system, since the positioning is based on measurement of time delays in signals from satellites down to earth. A successful navigation requires that the receiver can "see" at least 3 satellites. However, a position, which is calculated from signals from 4 or more satellites gives higher accuracy.

To utilize the GPS system, the user needs a GPS receiver, which picks up the satellite signals and calculates current position. The accuracy of 100 metres (95 % probability) is available for all users (C/A code, civil code), whereas the US military can reach an accuracy of 10 metres (P code, military code). Accuracy of C/A code is usually enough for navigation and environmental monitoring. For special purposes higher accuracy can be achieved locally by utilizing differential correction techniques. In some countries, e.g. in Finland and Sweden, a radio-transmitted signal is available, and thus an accuracy of 2 m is possible even in real-time applications.

GPS receivers are of different sizes, from a PCMCIA card up to briefcase-size models. The smaller instruments are less precise, but still useable for navigation and for visualisation of environmental monitoring data. GPS receivers return the current position in longitude-latitude coordinates based on WGS-84 datum (World Geodetic System). In most GPS -receivers position data can be passed into a computer using a serial interface. Figure 1 shows the GPS system.

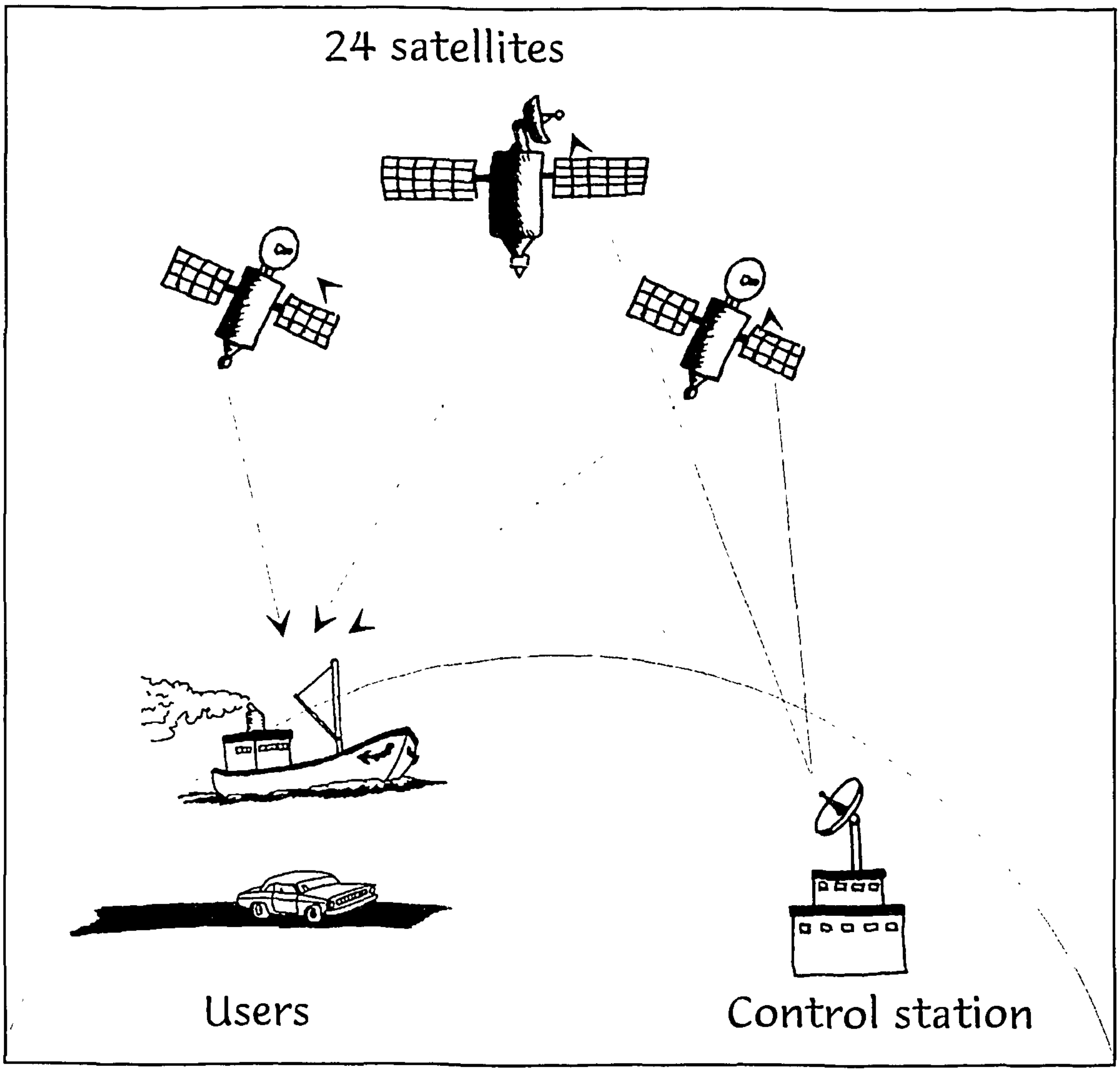


Figure 1. GPS system.

3 DESKTOP MAPPING

3.1 MapInfo for Windows

Desktop mapping software is a powerful tool for presenting data which has geographical significance. Data points are displayed on a digital map with exact location. In addition to normal data analysis, Desktop Mapping offers geographical analysis (measuring distances, areas etc.). It is possible for the user to spot and display the location on earth correctly from the position data of the satellite navigator. This, however, requires that a high quality digital map is used as a base map.

A desktop mapping software, known as MapInfo for Windows, was selected for the SAHTI system. MapInfo is not capable of navigation by itself. However, MapInfo is fully programmable through the MapBasic-language. This enables the user to produce customised applications utilizing all MapInfo's functions.

3.2 Base maps and coordinate systems

MapInfo for Windows can handle both major types of digital maps, vector maps and raster images. Vector maps consist of individual objects, like lines, regions etc. Vector maps are stored on disk in special MapInfo format. Raster Images are standard picture files (TIFF, BMP, GIF etc.). Both types of maps are commercially available. The best way to find them is to ask the local National Survey Board for advice. The commercial suppliers for digital maps can also help to find MapInfo compatible maps.

Once a plane map is created, a mathematical model, known as projection (Transverse Mercator, Lambert etc.), is used to transform the locations of features on the earth's surface to locations on a two-dimensional map surface. A coordinate system is created by specifying the parameters for the projection used. One of the parameters is known as datum (WGS-84, ED-50, ED-79). It defines which ellipsoid is used as well as the location of the origin. An ellipsoid estimates the shape of the globe. When a digital map is being selected for a base map, it would be desirable to find out the coordinate system of the original map.

Coordinates returned from GPS will not show the correct position on the map if the coordinate system of the map is not based on WGS-84 (the difference may be hundreds of metres). There are mathematical conversion formulas defined to transform coordinates from one system into another. The accuracy is a few mm. However, these formulas include usually very complicated mathematical functions. Since the accuracy of GPS is only 100 m, a more simple method for coordinate correction should be used. SAHTI system can only perform mathematical corrections between Finnish co-ordinate systems. Therefore, in global use the correction must be performed in another way. See section 4.3.

3.2.1 Vector map as a base map

Vector maps are usually produced from printed paper maps using a special digitizing table. MapInfo handles vector maps as database tables where one column in a data record refers to a geographical object (poly line, region, symbol etc.), that corresponds to a real feature on the earth's surface. A data record can therefore contain information about the object (inhabitants of the town, number of houses etc.). Vector maps are especially useful when large areas are viewed. They can also be re-sized on the screen without any limits. However, inaccuracies and "shortcuts" in digitizing become disturbing when the map is zoomed down to the finest details.

A wide range of vector maps is commercially available. The accuracy of these maps depends on the material they have been produced from and on the person who has performed the digitizing. The price of these maps is also relative to the accuracy of a map. MapInfo allows the user to change the coordinate system of a vector map. Disk space and memory of the PC determine the level of details on a map, since every detail is a single drawn object. MapInfo can show several vector map layers simultaneously and also include or exclude layers when a map screen is re-sized.

The user can also define his own coordinate systems for MapInfo. This, however, requires a good knowledge of MapInfo and coordinate systems. If vector maps are used for GPS -navigation, suppliers should be asked to provide their maps with WGS-84 system. See Figure 2a) for an example of a vector map.

3.2.2 Raster image as a base map

Raster images are mainly scanned images of printed maps. They are ideal base maps if the area of interest is fairly small in diameter (< 10 km). All the details in a printed map are included in the raster image. If a colour scanner is used, true colours of the printed map can be applied, too. Raster images are used only as backdrops onto which transparent vector layers are superimposed. Raster image is registered by defining three or more control points with known location.

Because the raster image consists of small dots, re-sizing is limited by the resolution of the image. The coordinate system, in which the original material is created, cannot be changed either. If a raster image is based on a system other than WGS-84, a coordinate correction may have to be performed to display the coordinates from GPS at the right position in the map window. A simple correction is presented in section 4.3.

Two other types of raster images, which are potentially useful for safeguards purposes, are a SPOT satellite image and an aerial photograph. SPOT satellite images are supplied with the requested coordinate system and they are already in digital form. Aerial photographs do not have any built-in coordinate system. Using these as base maps requires either GPS -measurements on the spot or some reference map where the coordinates of the corresponding objects are found. Figure 2b) is an example of a raster image.

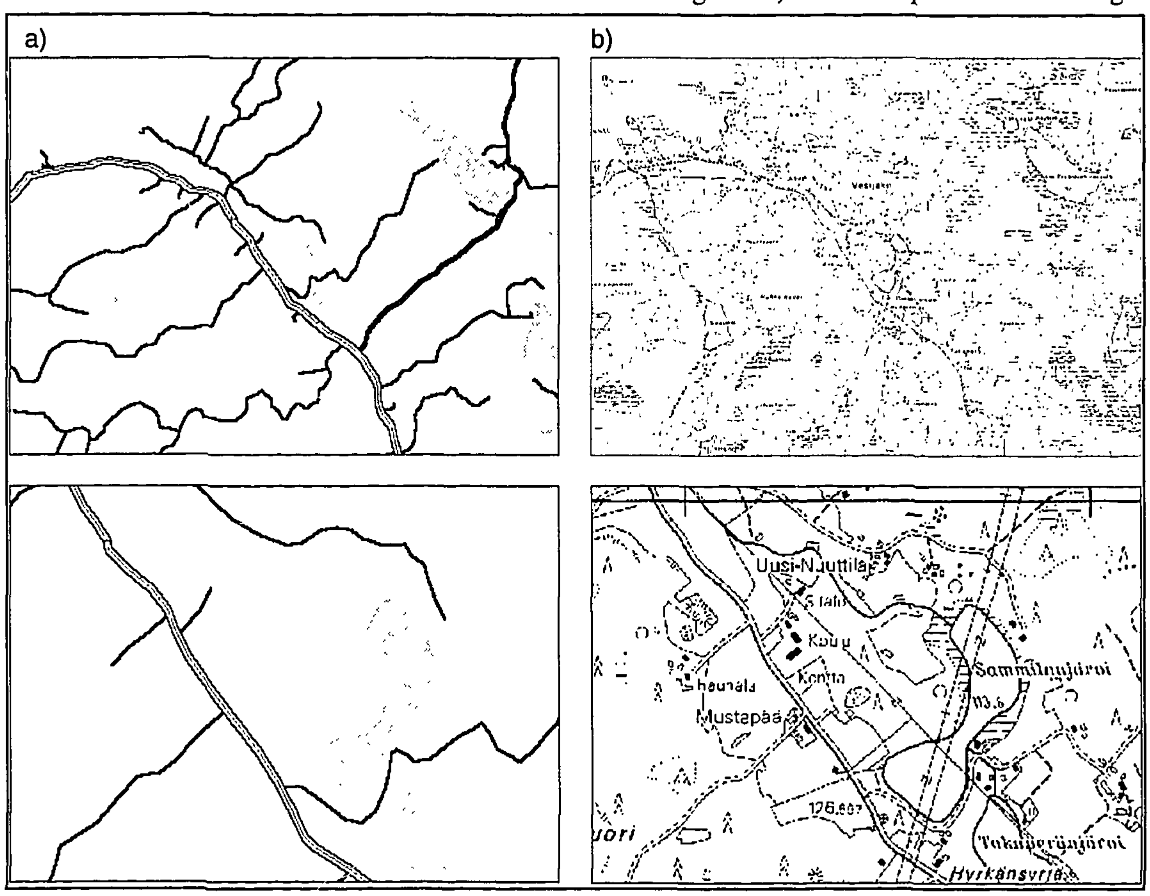


Figure 2. *An example of a) a vector map and b) of a raster image. The top view has a scale which is 3.7 times larger than the bottom one.*

4 SAHTI SATELLITE NAVIGATION SYSTEM

SAHTI system was built at STUK, Finland, by the aerosol laboratory. Radiation measurement results and GPS co-ordinates have been combined in the laboratory since 1993. These applications were based on retrospective desktop mapping. Following the same ideas, a real-time navigation system, SAHTI, was developed for in-field measurements and, later, for safeguards purposes under the Finnish support programme to IAEA. The system consists of a GPS -receiver (Trimble, Mobile GPS or SV-6) and a LapTop computer. The software is produced using Visual Basic and MapBasic programming languages.

4.1 Overview of SAHTI software

The main body of the system, the SAHTI control panel, performs coordinate acquisition, stores time and coordinates into a file and passes the information to the mapping application. This program is known as SAHTI.exe. A MapBasic program, known as SAHTI.mbx, runs within MapInfo and displays the position on a selected base map. Some display settings can also be performed in SAHTI.mbx program. A third part of the system is known as IMPORT.exe, which handles the viewing of previous measurements. Figure 3 shows a layout of the whole system.

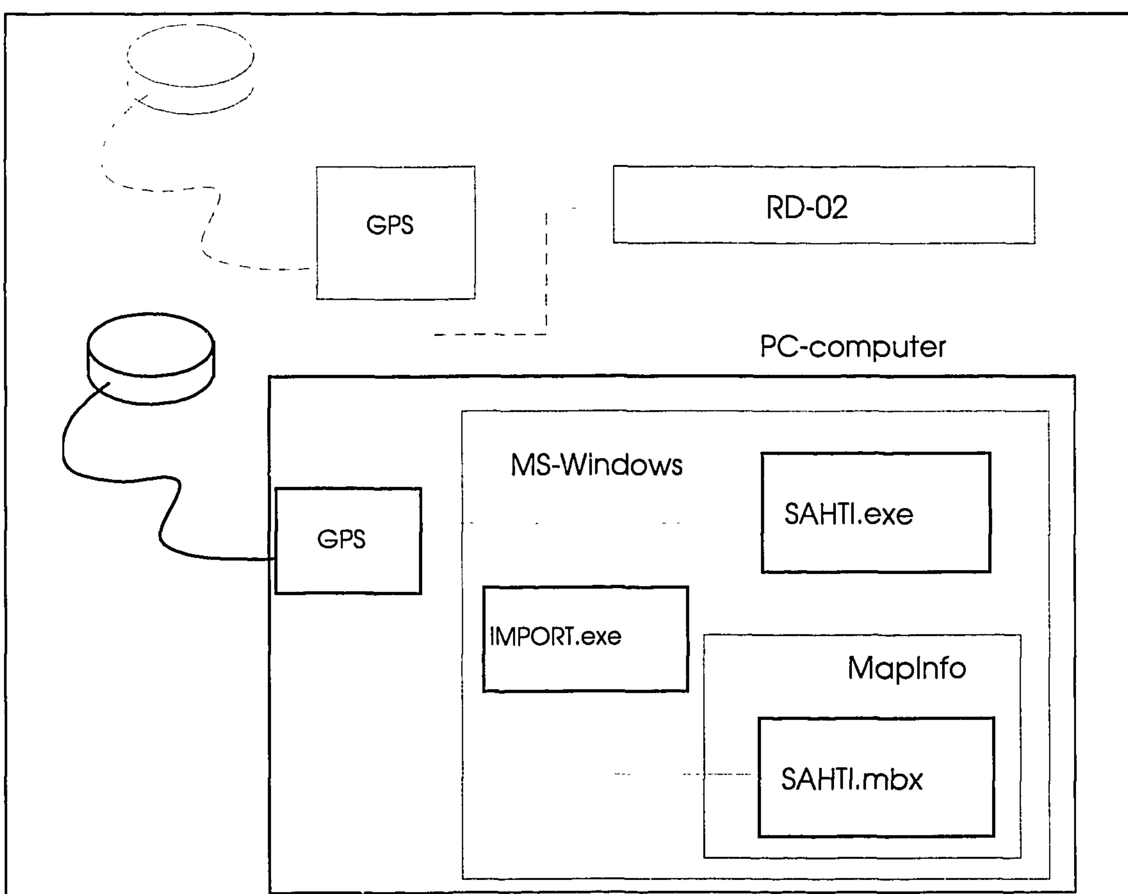


Figure 3. *SAHTI system.*

4.1.1 SAHTI control panel, SAHTI.exe

This program communicates with a GPS -receiver and displays position, time and status of the receiver. There are settings for SAHTI system configuration (Basic SetUp in Options menu), for save path (Save Path), file name and for map selection list (Edit map list). Use of MapInfo and Dose-rate meter (optional, Rados RD-02) can also be confirmed through the "Options" -menu. Figure 4 shows the layout of SAHTI.exe.

4.1.2 GPS application for MapInfo, SAHTI.mbx

When SAHTI.mbx is executing, a drop-down menu, "GPS", appears in MapInfo's menu bar. The main task of this part of the system is to display the position in the MapInfo's map window. When the "GPS" menu is selected, a list of items appears. The symbol, that shows the position, can be changed by selecting item "Edit symbol". Co-ordinate correction can be per-

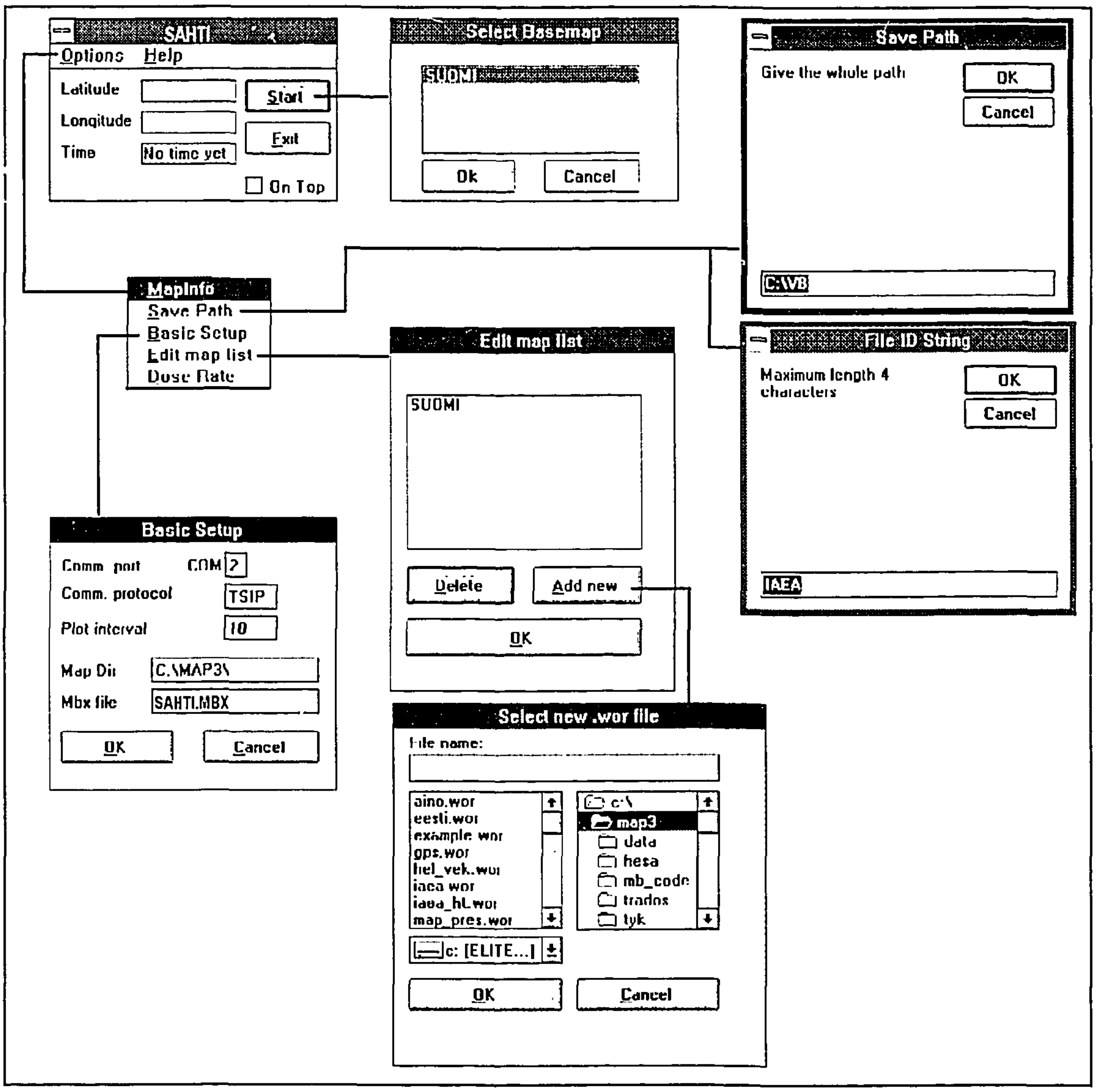


Figure 4. SAHTI.exe. Selecting an item in the "Options" menu brings out new windows in which the system can be modified (Save Path, Basic Setup, Edit map list). Selecting the item "MapInfo" confirms the use of MapInfo in the system and it starts automatically when positioning is started by clicking the "Start" -button. Every time the co-ordinates are updated, information is passed to SAHTI.mbx, using Windows DDE -link.

formed by selecting item "Corrections" and selecting a suitable correction in the corrections window. Through the "Draw mode" item, the display can be set in cumulative mode. The user can mark positions that have special interest by selecting item "Mark positions". Description for a marked location can be typed into a text box, which appears on the screen (max. 50 characters). When all desired locations are marked, a MapInfo table or an ASCII file can be saved with a name defined by the user. If the draw mode is changed into cumulative mode while positions are being marked, already marked positions must be saved first. Old position data can be imported for viewing purposes by selecting item "Show Previous". Figure 5 shows the layout of SAHTI.mbx.

4.1.3 Previous data viewer, IMPORT.exe

This program executes automatically when "Show previous" is selected in MapInfo's "GPS" menu.

An ASCII file is opened for reading through a standard Windows File Open dialog. The co-ordinate correction which is used for a certain map is applied when old data is imported. The data is automaticly updated in MapInfo's map window. Figure 6 is the layout of IMPORT.exe.

4.2 Starting positioning

Before starting the system, the user should ensure that there are digital maps available of the area

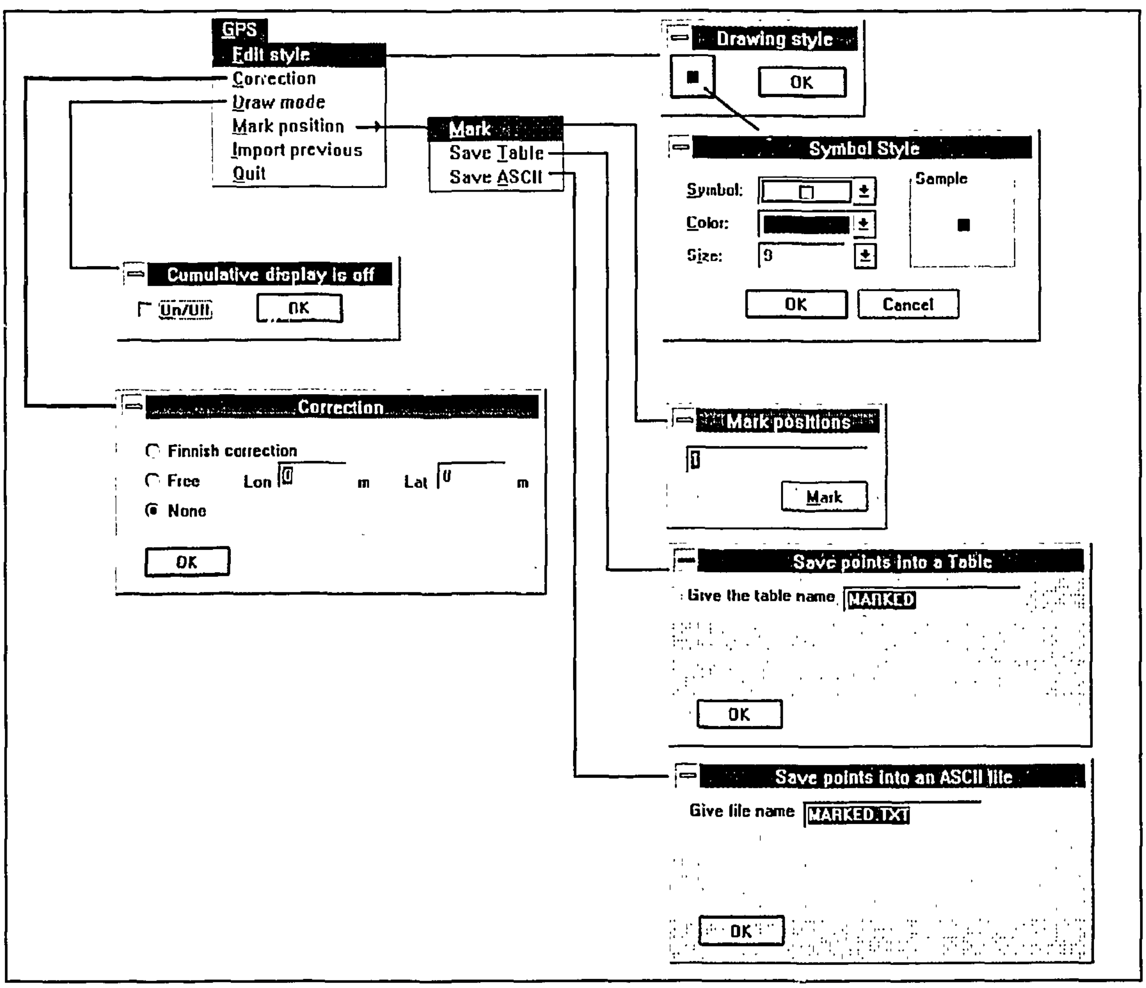


Figure 5. A layout of SAHTI.mbx. A drop-down menu appears in MapInfo when SAHTI.mbx is executing. Several functions are performed by selecting an item in the drop-down menu. Follow the lines to determine the function when a item is selected.

of interest. Digital maps can also be produced from paper maps by using a digital scanner and MapInfo.

Once the maps have been purchased or produced, a MapInfo workspace for navigation must be prepared. A workspace is a set of map layers, which are displayed in the way the user wants. For creating a MapInfo workspace, see Appendix 1.

Before starting the navigation, it should be checked that the antenna can see enough open sky (not too many buildings or trees around). Because of signal attenuation, the accuracy of positioning might be lower or the receiver might not get signals from the satellites at all. Step-by-step instructions for using the system are given in Appendix 2.

After the program has been started, it may take some 3 to 8 minutes before the coordinates appear on the screen. This delay goes to when the navigator finds three useable satellites and calculates the first position. The co-ordinates are updated in the SAHTI window with the interval selected by the user. The title of the window shows the status of the navigator. There is a label with caption "HEALTH", appearing and disappearing on the bottom of the SAHTI window, showing that the communication is working. When a sufficient number of satellites is noticed by the GPS -receiver, the label on the bottom of the window reads "OK" and the status of the navigator changes to "Doing Position Fixes". If MapInfo is used, a symbol appears in the map window, showing the current position every time the coordinates are updated. All the coordinates are stored in a file, which is defined by the user. The file name consists of four characters given by the user, the date with four characters and an extension (e.g. IAEA1906.WGS). When the position symbol moves away from the area shown in current map window, the view is automatically updated so that the last position symbol is shown in the middle of the map window. Navigation is finished by quitting "GPS" -menu in MapInfo and selecting "exit" in SAHTI program.

4.3 Confirming the position on the map

If the base map is used for the first time, the user should confirm that the position obtained from the GPS -receiver corresponds to the location found on the base map. This is especially important if the coordinate system is not based on WGS-84, or has not been completely defined. Confirmation is performed by letting SAHTI system to run on one spot for a long time with the plot interval of 10 seconds. The "Draw mode" must be set in cumulative mode (setting in MapInfo, GPS menu). After about an hour, the centroid of all measured positions is estimated and the distance between the measured centroid and the location on the map is measured using MapInfo's ruler tool. The centroid corresponds to the real location in the nature with an accuracy of 30 metres or better.

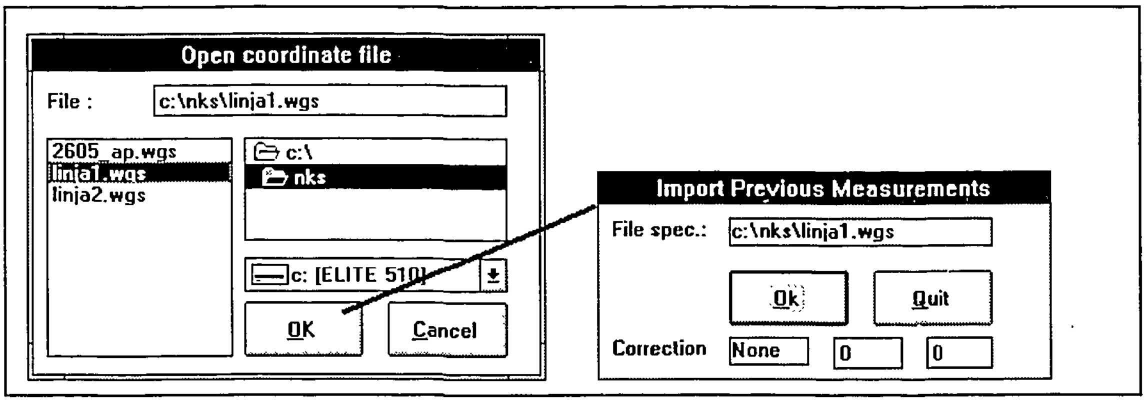


Figure 6. Layout of IMPORT.exe. Data is read from an ASCII file with standard format. Symbols of the old measurements are automatically added in the current Map window.

If the centroid of all measurements is less than 50 m away from the corresponding position on the map (measured with MapInfo's ruler tool), the map fits in its correct position well enough and no correction is needed. If the centroid is clearly further away from corresponding position on the base map, a correction must be performed.

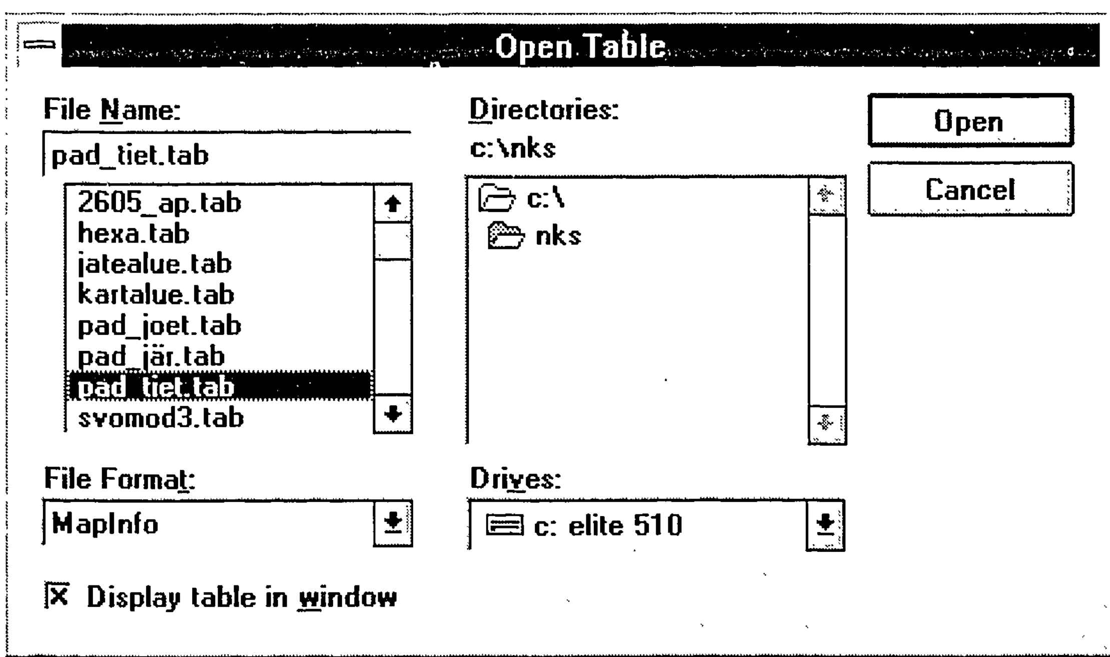
There are some simple methods to perform the correction. The easiest method is a linear correction, where the symbol is forced by a certain number of metres in the right direction. In MapInfo's GPS menu there is a submenu for corrections. Linear correction of given number of metres is performed by selecting "Free correction" and typing the distances into the text boxes beside. The same correction parameters are applicable over 100 km away from the spot on which the correction was defined. The same linear correction parameters should be used every time when the map is used. Therefore the correction should be carefully recorded. "Finnish correction", in corrections window, is a local correction applied only in Finland with the Finnish base maps.

Especially for raster images, there is another method. Once one spot has been determined with GPS reliably (long time acquisition), the distance between position according to GPS and correct position on the map is measured with MapInfo (with the ruler tool). Raster Image Registration in MapInfo is changed to bring the map object at the same position with the measured one. This is performed by adding (or subtracting) the differences into X and Y coordinates of Raster Image control points, respectively. The advantage in moving the whole map is that it only has to be performed once. There is no need to remember any correction parameters either.

MapInfo's workspace is a selection of maps in one or more map windows. Names of tables and display settings (colour, region fill style, etc.) are stored into a file with an extension ".WOR". You can include in your workspace several map layers (vector and raster). It is recommended that the bottom layer in map window is a large vector map, e.g. map of World or Europe. Preparation includes following steps:

1. Make sure that all the maps you want to include are stored on the hard disk of your computer.
2. Start MapInfo.
3. Select Open a Table in File menu. Through the dialog which appears, open a map which you want to include in your workspace (largest map first, e.g. map of world). Repeat until all desired maps are opened.

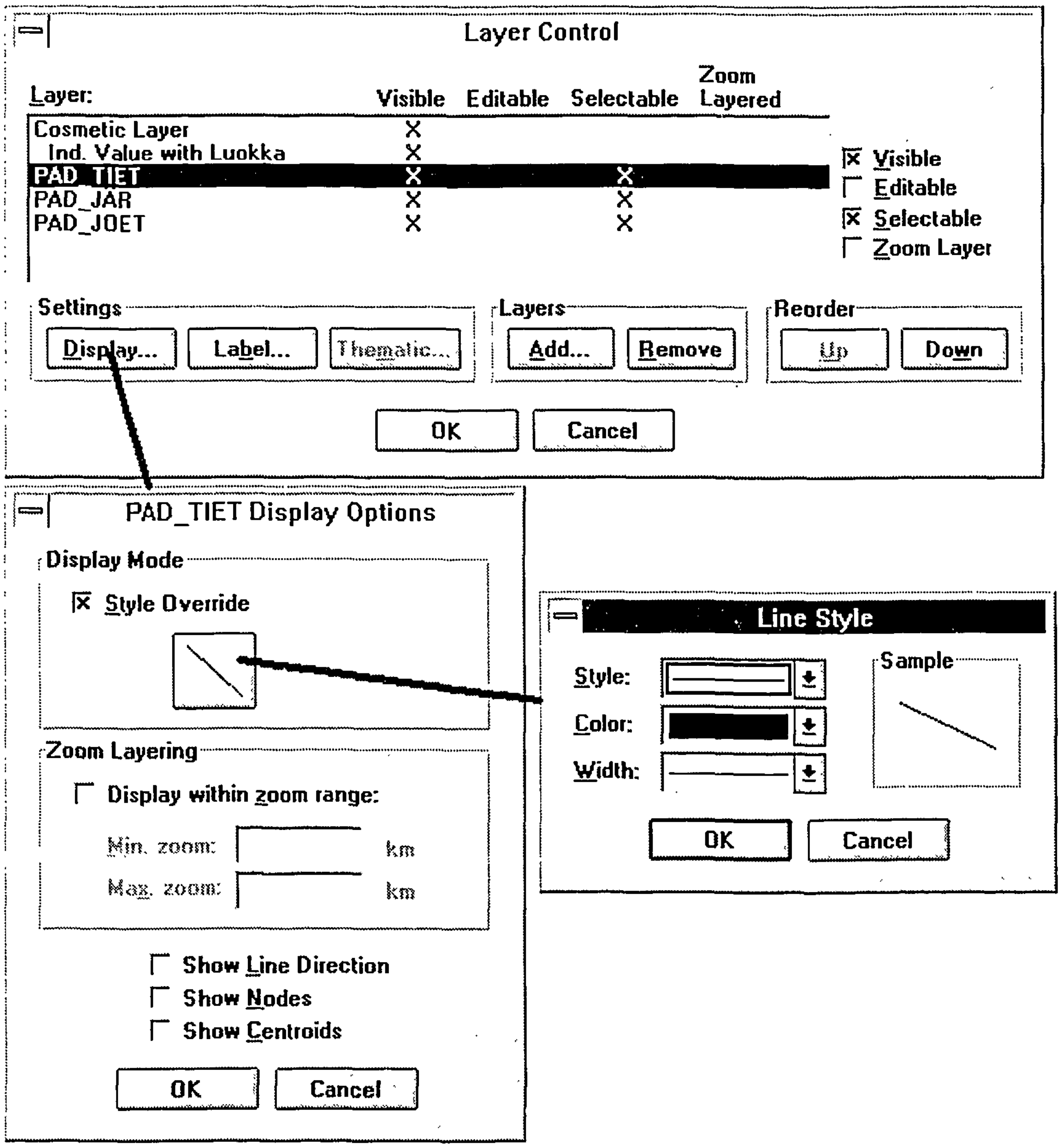
File > Open Table



APPENDIX 1

4. If any vector layers are included, you can change the display style.

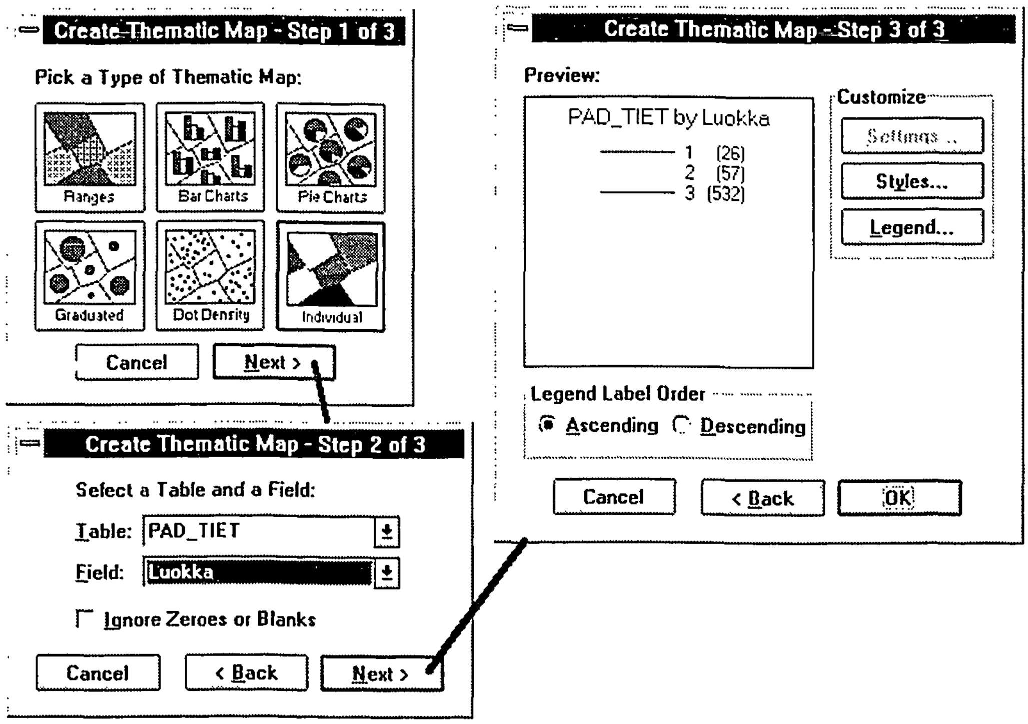
Map > Layer control > display > display mode



APPENDIX 1

Here you can change the style of the objects in the layer (style override)

Map > Create Thematic map

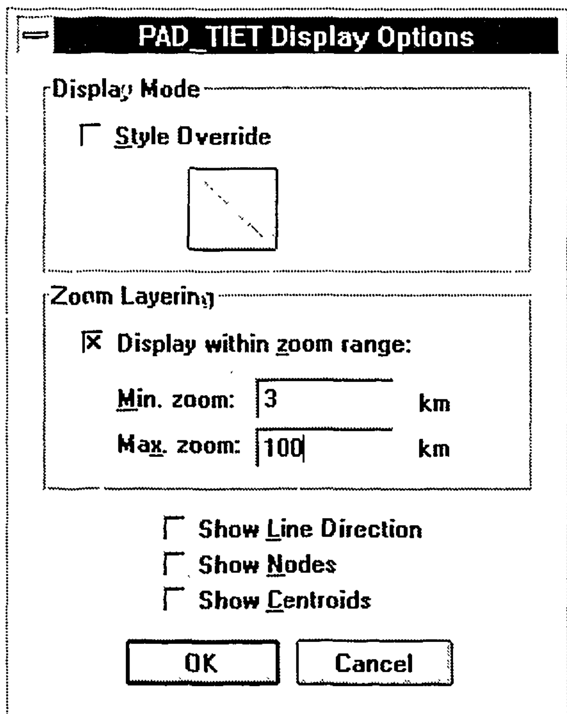


Here objects are coloured or styled according to a value of selected variable (e.g. colour of the road corresponds the road classification)

APPENDIX 1

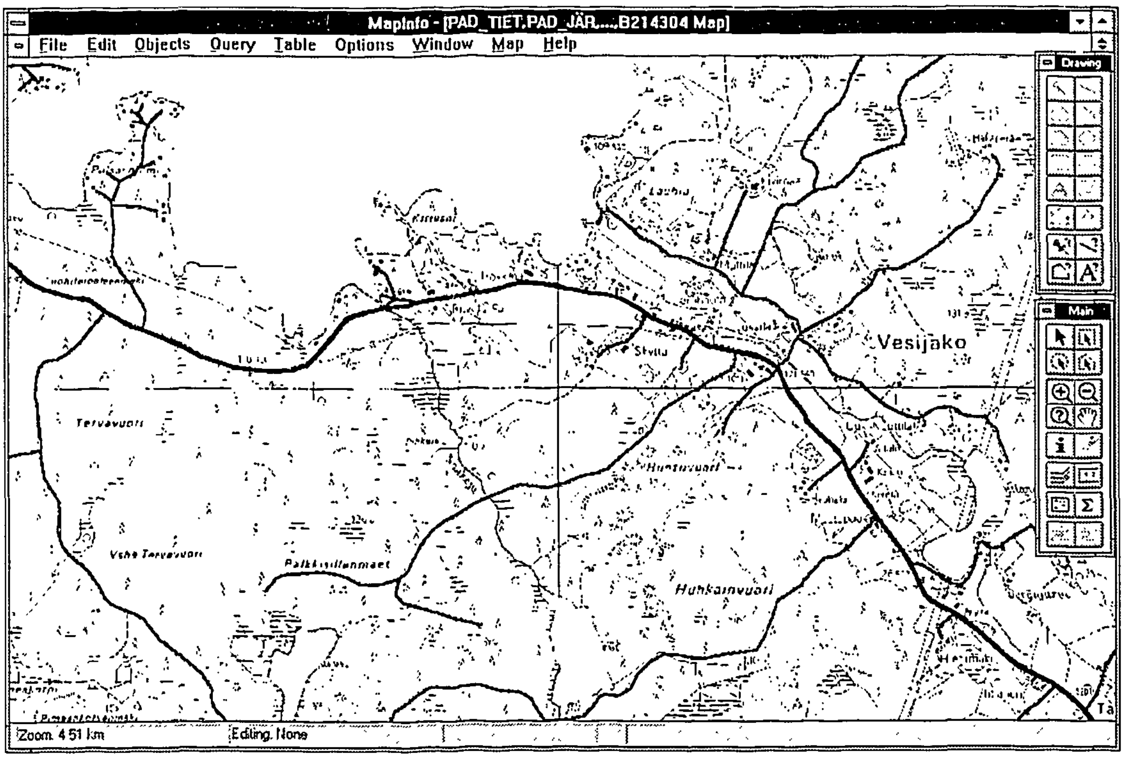
5. Set the display limits for each layer. This means to set the smallest and the largest zoom where the particular map is visible. Vector layers with large number of details and raster layers must become visible only when the scale (the zoom) of a map window is so that all details are visible.

Map > Layer control > display > zoom layering



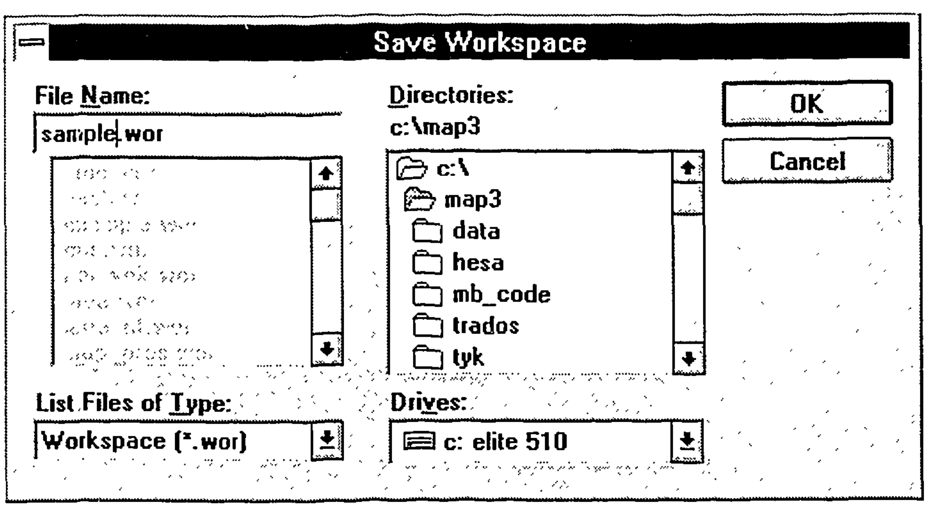
APPENDIX 1

6. Zoom and move the map so that the area of interest is in the middle of the map window.



7. When all modifications are performed, save the workspace

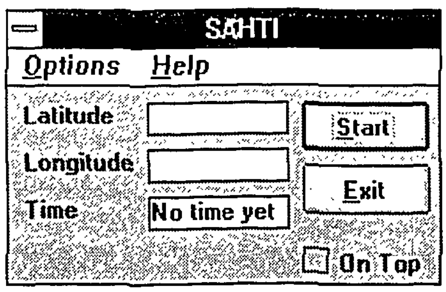
File > Save workspace...



APPENDIX 2 Step-by-step instruction of using SAHTI system with PCMCIA GPS

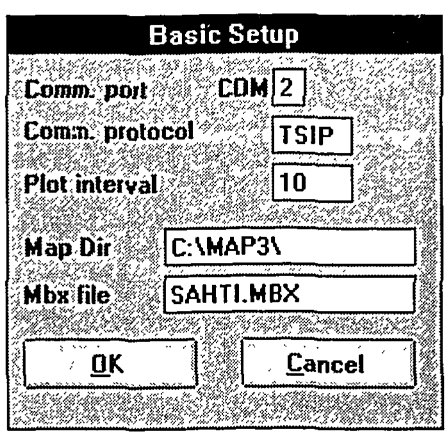
The following example assumes that a suitable MapInfo workspace is prepared earlier. Starting the system is performed according to the following steps:

1. Check that the PCMCIA card is in the slot and attach the antenna cable to the connector in the card.
2. Check that MapInfo's security key, if it is needed to run your software, is attached to the parallel port of the computer.
3. Turn on the computer and make sure that the PCMCIA card is set up properly by automatic PCMCIA card drivers (a sound signal).
4. Place the antenna on an unobscured surface. Check that there is not many high buildings or trees covering open sky.
5. Start Windows and program "SAHTI" in program group GPS.
6. A window as follows appears.



7. Check the "Basic Setup" for following parameters. Alternative values may be changed by typing new values in the text boxes.

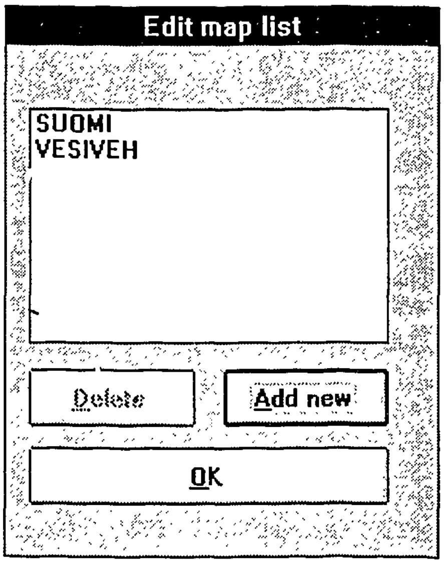
Options > Basic Setup



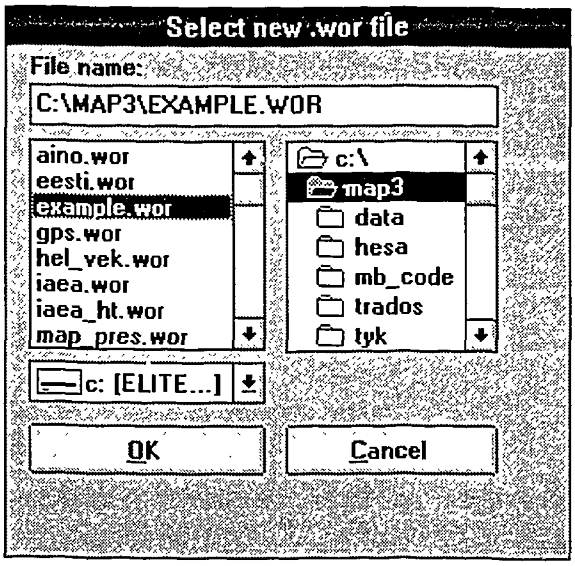
The port must be "COM2" and protocol must be "TSIP" (Trimble Standard Interface Protocol). Map directory is the directory, where MapInfo and the required MapBasic programs are stored. Suitable plot interval is 10 (the interval of passing data to MapInfo, approximately in seconds).

8. If the system is used for the first time, you must add a new MapInfo workspace in the system.

Options > Edit Map list



Selecting "Add new", brings out a standard Windows file open dialog, through which a prepared MapInfo workspace (Extension ".WOR") is added in the system.



APPENDIX 2 STEP-BY-STEP INSTRUCTION OF USING SAHTI SYSTEM WITH PCMCIA GPS

9. Click the check box "On Top" to set the SAHTI window to stay always on top.
10. Confirm that you are using MapInfo to display the position on a digital map.

Options > MapInfo

11. Start navigation by clicking the start button.

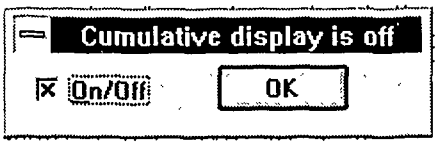
12. Select a suitable base map from the list. MapInfo starts then automatically with selected workspace.

Co-ordinates should be updated first time at the latest after 5 minutes. If there is no update, check that GPS is receiving signals from satellites (status on the top of the SAHTI window) and make sure that antenna is placed properly.

Once the navigation is working properly, the co-ordinate correction must be set as defined for the base map. If the correction is not defined yet, it should be performed to obtain higher accuracy navigation. Section 4.3. explains the principles of co-ordinate correction. Defining of the correction is performed as follows:

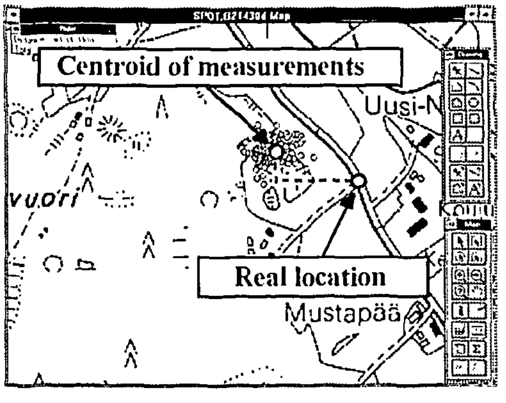
1. Set the draw mode to cumulative through GPS menu in MapInfo

GPS > Draw mode



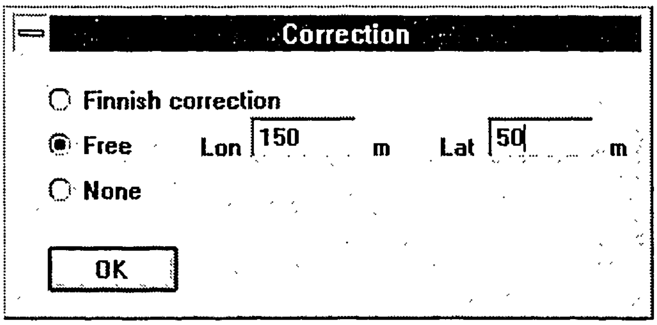
Click on the check box to change the mode to cumulative.

2. After about an hour, re-scale the map window so that all measured positions are seen (zoom tools in main tool box). The centroid of all measurements is estimated and the distance between the measured centroid and real location on the map is measured using MapInfo's ruler tool (in the main tool box). In this example we assume that the distance is 150 m west and 50 m north.



3. Linear correction: Select "Corrections" in GPS menu.

GPS > Corrections

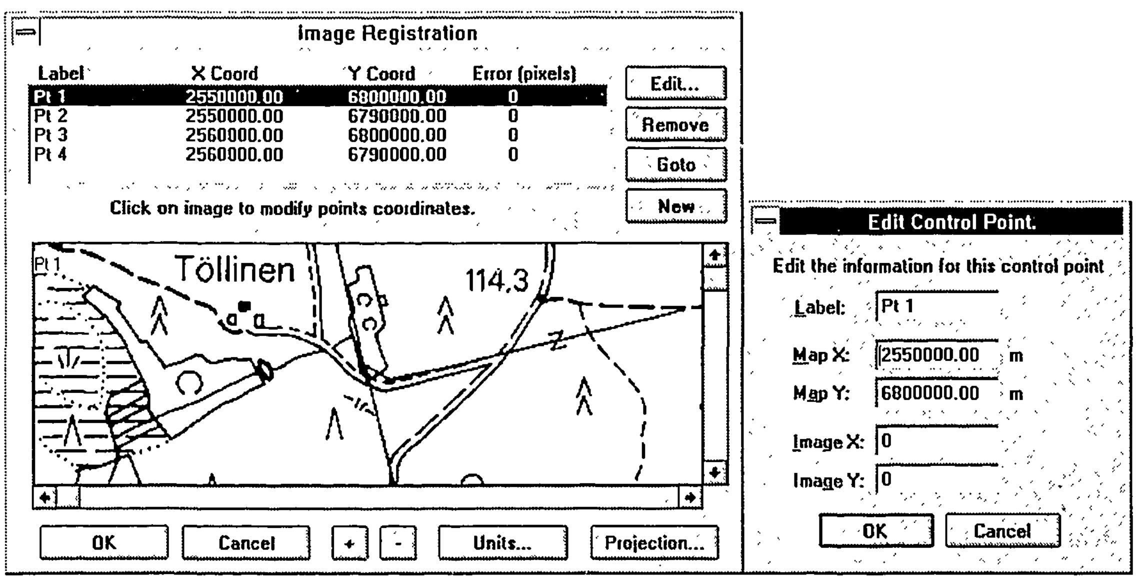


Choose "Free correction". Type 150 in the text box with label Lon and -30 in the text box with the label Lat. Click OK button.

4. Method for raster a image as a base map

Raster image can be moved into right position by changing the values for Raster Image Registration in MapInfo. This is possible if the coordinates of control points are expressed in meters, feet etc. In this case you must subtract 150 m from X co-ordinate and add 30 m to Y co-ordinate.

Table > Raster > Modify Image Registration

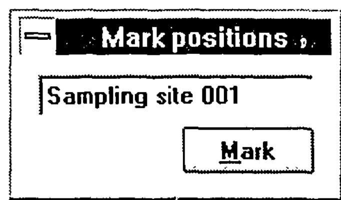


APPENDIX 2 STEP-BY-STEP INSTRUCTION OF USING SAHTI SYSTEM WITH PCMCIA GPS

Locations with special interest (e.g. sampling point) can be marked and co-ordinate information saved in ASCII file and MapInfo table. At first the draw mode must be non-cumulative. Marking and saving goes the following way:

1. Wait that the co-ordinates update while you stay on the interesting spot. Select "Mark" in GPS menu.

GPS > Mark positions > Mark

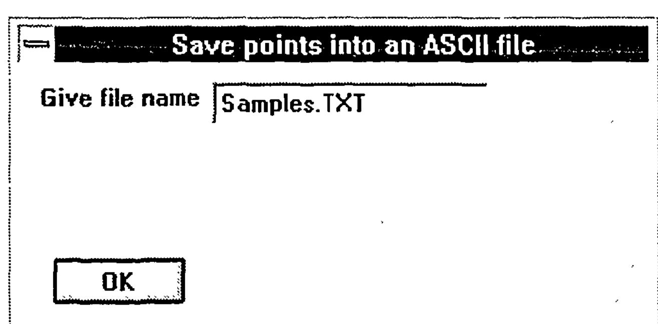


A dialog where you can type 50 characters long description appears. Click OK and a red spherical symbol, which corresponds the marked location, appears in the map window.

2. Repeat the procedure above as many times as needed.

3. Save an ASCII file selecting "Save an ASCII file" in GPS menu.

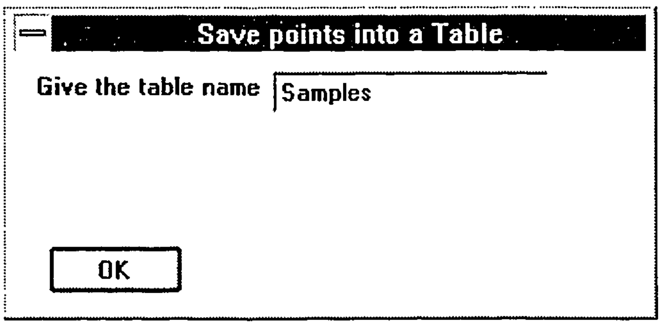
GPS > Mark positions > Save an ASCII File



You can type the name (max. 8 characters and the extension) in the text box. The file is saved in the "USER" directory in your MapInfo directory.

4. Save a MapInfo table selecting "Save a Table" in GPS menu.

GPS > Mark positions > Save a Table



As above, you can type the name (max. 8 characters, NO extension) in the text box. The table is saved in the "USER" directory in your MapInfo directory.

Finishing the navigation is performed in the following way:

1. In MapInfo select "Quit" in GPS menu

2. Click buttons "Stop" and then "Exit" in SAHTI window.

STUK-YTO-TR 88 GPS positioning and desktop mapping

ISBN 951-712-066-4
ISSN 0785-9325
Painatuskeskus Oy
Helsinki 1995