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MASTER'S THESIS

PeeGee - a PDA-GPS based navigation tool for scanned maps

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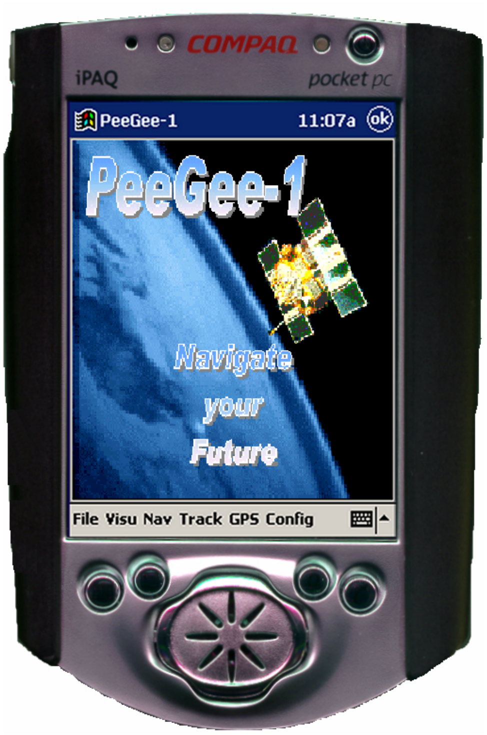
PeeGee

a PDA-GPS based navigation tool

for scanned maps



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Abstract

The development of small and powerful PDAs (Personal Digital Assistant) has made it possible to make programs that can be used on the move. Satellite navigation GPS receivers have also developed in the last years and are now very small and accurate.

PDA and GPS is a good combination for navigation and position based services. GPS is more accurate than for example GSM positioning and can be used for precision navigation.

The aim of this master thesis is to develop a PDA software program for visualization of a position on a digital map by using a GPS receiver connected to the PDA. Development of software is made in Microsoft developing environments for Windows CE platforms, namely the Embedded Visual Tools version 3.0. The software program so called PeeGee is the result. The PeeGee application is a prototype navigation tool for use with scanned or digital maps and GPS position information. The conclusion is that it is possible to develop a good navigation program that is fully functional but a lot of features can be added and it is also found that it would be smother to have the GPS integrated in the PDA or as a GPS card inserted in the PDA.

To enable better scanning and calibration of maps the aim is also to find algorithms and methods to scan and calibrate an paper map into an electronic version for the PDA. The result is a description and a detailed table of how the user should do with resolution, file format, map scale etc. This is included in the software manual.

The aim is also to make a small error estimation to examine the GPS accuracy and the accuracy of the software system as a whole. The conclusion is that accuracy depends on many things such as GPS receiver, GPS receiving conditions, map scale, map scanning, map calibration etc. It is therefore difficult to get an overall error estimation. Map scanning and calibration was found to be a big error source. At the scenario where a map in the scale 1:100 000 has been scanned and calibrated by hand the accuracy is around 60 meters. If the map is digital and calibrated, an accuracy of around 10 meters can be achieved.

The results of the error estimation should be interpreted with precaution since the statistic material is very small and made during a short period of time, parameters have been roughly estimated, no consideration has been made to map projection errors etc.

The possibilities for this kind of program are immense. It can be used for various implementations. The main purpose is for navigational aid but also for location based services with GSM/GPRS/WLAN or Bluetooth application implemented. The map can be downloaded wireless when entering a new area or wanting specific information of the neighborhood.

Sammanfattning

Utvecklingen av små och kraftfulla handdatorer har gjort det möjligt att göra program som kan användas ute i fält. Satellitnavigeringsmottagare, GPS, har också utvecklats de senaste åren och är nu mycket små och noggranna.

Handdatorer och GPS kan med fördel kombineras för navigerings och positionsbaserade tjänster. GPS kan användas för precisions navigering och har bättre noggrannhet än t.ex. GSM positionering.

Målet med detta examensarbete är att utveckla en PDA-mjukvara för visualisering av en position på en digital karta genom att använda en GPS-mottagare kopplad till PDA'n. Utvecklingen av mjukvaran har skett i Microsoft utvecklingsmiljö för Windows CE, Embedded Visual Tools version 3.0. Resultatet är ett program kallat PeeGee. PeeGee är en prototyp av ett navigationsverktyg för användning med skannade eller digitala kartor och GPS positionering. Slutsatsen är att det är möjligt att utveckla ett bra navigeringsprogram som är fullt funktionellt men fler funktioner bör läggas till. Det hade också varit smidigare att ha en GPS-mottagare integrerad med PDA'n eller ett GPS-kort som kan sättas in i PDA'n.

För att underlätta skanning och kalibrering av kartor är målet också att finna algoritmer och metoder att skanna in och kalibrera en papperskarta till en elektronisk version för PDA'n Resultatet är en beskrivning och en detaljerad tabell över hur användaren ska göra med upplösning, filformat, kartskala, etc. Detta är inkluderat i användarhandboken.

Arbetet har också som mål att göra en feluppskattning för att undersöka GPSens och hela systemets noggrannhet. Slutsatsen är att noggrannheten beror på många saker såsom GPS-mottagare, GPS mottagningsförhållanden, kartans skala, kartans skanning, kartans kalibrering etc. Det är därför svårt att ge en heltäckande felupskattning. Kartskanning och kalibrering upptäcktes vara en stor felkälla. När en karta i skala 1:100 000 har skannats och kalibrerats för hand är noggrannheten ca: 60 meter. Om kartan är digital och kalibrerad kan en noggrannhet runt 10 meter uppnås.

Felundersökningens resultat bör tolkas med försiktighet eftersom det statistiska materialet är väldigt litet och gjord under en kort tidsperiod, vissa värden har uppskattats grovt, ingen hänsyn har tagits till fel beroende på kartprojektion etc.

Möjligheterna för dessa typer av program är stora. De kan användas till flera tillämpningar, i huvudsyfte som navigationshjälp men också för positionsbaserade tjänster med GSM/GPRS/WLAN eller Bluetooth-tjänster. Kartan kan då nedladdas trådlöst när man kommer till ett nytt område eller vill ha annan information om grannskapet.

Preface

This work is a Master Thesis in Environmental Engineering at Luleå University of Technology. It has been made as the final part of a Master of Science degree at the division of Geographic Information Technology. The work was performed during spring and summer of 2001 at Ericsson Erisoft AB in their premises in Luleå. The main goal with this thesis was to produce software that allows a user to use scanned maps and a GPS receiver as a navigational basis on a PDA (Personal Digital Assistant).

Acknowledgements

Many people have been involved in this master thesis and I would like to thank them all. Special thanks to my supervisors Christophe Pichon and Per Danielsson at Ericsson Erisoft, which have supported and helped me at all times. I will also like to thanks all other employees at the Network Centric Systems department for a welcoming and helping hand.

Thanks also to the University, my examinator Anders Östman, classmates (especially Karin Augustsson) and family.

Luleå 2001-08-22

Mats Olofsson

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1 Introduction

1.1 Goals

The aim of this master thesis is to develop a user-friendly PDA (Personal Digital Assistant)[1] software program for visualization of a position on a digital map by using a GPS receiver. The PDA uses Windows CE 3.0 as operating system. The PDAs screen shall show a map overlaid by position symbols to aid positioning and navigation.

The program shall allow a user to use scanned maps as a navigational basis. The positions will be given by a GPS receiver that provides the software application different kinds of information such as position, speed and heading. This information is then used on the PDA to perform precision navigation.

A second goal is to find algorithms and methods to scan and calibrate an paper map into an electronic version to be downloaded to the PDA.

The goal is also to get some formal support to estimate errors due to factors such as, GPS measurement, grid conversion, map projection, scan resolution, map scale and zoom factor.

1.2 Scope

The aim is to implement a PDA software to display a position on a scanned map. It is however an impossible task to make a fully featured program in such a short time. This master thesis creates a framework for the system and the program consists of the basic functions for navigation and map handling. It is also possible to save sentences in order to "replay" them again later to show the movement.

No investigation on other position techniques or wireless loading of maps with GSM, GPRS, UMTS, Wireless LAN or Bluetooth has been done, nor has differential GPS been tested or used.

A more thorough and mathematical statistical investigation of the error estimation would have been desirable but time shortage made it impossible.

[1] Abbreviations and acronyms can be found in chapter 1.5

1.3 Disposition

This chapter gives an introduction to the master thesis and explains the goals, scope and abbreviations and definitions used. Chapter 2 gives an overview and description of how the satellite navigation works with position accuracy and contributing error sources. Chapter 3 informs of what kind of coordinate system is used in Sweden and how coordinate transformation is done. Chapter 4 illustrates the Development environment and describes the Windows CE Operating system. Existing programs that are similar to PeeGee are described and commented in chapter 5. Further on in chapter 6 an error estimation is done of the error sources from satellite to position mark in the program. Conclusion in chapter 7 describes what has been done and chapter 8, Future work tells what can be done to improve the program. Three important Appendixes are included for more information of the PeeGee program; PeeGee specification and Peegee user manual (B and C) and appendix A that describes the coordinate transformation.

1.4 About Ericsson Erisoft AB

Ericsson Erisoft AB was founded in 1982 and is a development and product company in the Ericsson group. It has around 750 employees, is the largest Software company in Northern Sweden and had a turnover in year 2000 of 1 123 MSEK (Ericsson Erisoft presentation 2001-02-23). The company develops software products and systems, the business concept being:

- to contribute to Ericsson's product development within well-defined areas, taking responsibility for the development and administration of systems or parts of systems.
- to develop, sell and deliver products and services that add value to the Ericsson product portfolio.

The Company's mission is to assist Ericsson in maintaining and consolidating its position as a market leader in the field of telecommunications and other domains (Ericsson Erisoft AB Annual Report 1999).

Product areas are; Network Centric Systems, PDC, Network Optimization and Management, GSM, Wideband Radio Networks, and Research and Experiment.

1.5 Abbreviations and acronyms

API Application Program Interface, A set of routines used by an application program to direct the performance of procedures by the computer’s operating system.

ETRS 89 European Terrestrial Reference System 1989 (Ellipsoid GRS 1980) System is connected to the global system ITRS at epoch 1989.0 (1st of January 1989).

EUREF European Reference frame, sub commission in IAG (International Association for Geodesy).

GPS The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS receivers receive signals from different satellites and can calculate a position. It was developed and launched by the US Department of Defense for military reasons but is available for everyone free of charge.

ITRF 89 International Terrestrial Reference Frame. An international three-dimensional reference system with ellipsoid GRS 1980(Jivall Lotta, 2001).

OS Operating System. Is the central nervous system of the whole computer, which allows some kind of interface and runs, interprets and manages all tasks (programs etc) that a computer does from power on to power off.

PDA Personal Digital Assistant, name of electronic device that combines the use of calendar, address book, e-mail, word processing and other services. Examples are Palm Pilot and Compaq Ipaq. They run under different OS platforms depending on device and manufacturer. Many believe that PDAs and Mobile phones will be one unit in the near future.

PeeGee Name of the software program developed in this master thesis.

RH 70 Rikets höjdsystem 1970. Heigth system, zero level defined by Normaal Amsterdams Peil (NAP).

RN 92 Is the old geoid model used for converting ellipsoid heights in RR 92 and RH70.

RR 92 Rikets Referenssystem, RR92 is Swedens three dimensional reference system used until 26th of may 2001 consisting of RT90 plane coordinates, altitude system RH70 and geoid altitude system RN92. It is no longer used.

RT 90 Rikets Koordinatsystem 1990, Sweden’s reference system used today in plane, a Swedish local geodetic datum, for parameters see text. The coordinates emanate from the third triangulation of Sweden (1967-82)(Lantmäteriverket 2001).

SWEN 01L Geoid model (a height correction model) used to convert heights over ellipsoid in SWEREF 99 to height over ocean in RH 70. The rising of the land from 1970 to 1999 is accounted for.

SWEREF 93 Swedish three-dimensional reference system (ellipsoid GRS 1980). Realisation of ETRS 89.

SWEREF 99 Swedish three-dimensional reference system (ellipsoid GRS 1980). Latest realisation of ETRS 89.

WGS 84 World Geodetic System 1984. Global three-dimensional reference system used by GPS. Ellipsoid GRS80.

1.6 Definitions

Flattening A parameter for the ellipsoid. Defined as

$$f = \frac{a - b}{a}$$

where
a= the semi-minor axis (half polar axis)
b=the semi-major axis (equator radius)

Geodetic datum Definition of the reference earth model that is being used. Contains data about:

- the ellipsoid position in reference to earth mass center.
- the ellipsoid position in reference to form and position of the geoid.
- the ellipsoid used - semi-major axis and the flattening.

2 Satellite navigation overview

2.1 GPS

Navigation Satellite Timing And Ranging Global Positioning System (Navstar GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. Civil GPS receivers for navigation are widely available from many manufactures and in a wide price range. They receive signals from different satellites and can calculate the position of the receiver. Navstar GPS was developed and launched by the US Department of Defense for military reasons but is available for everyone free of charge. It has been available since 1993 for civil purposes. Until 1 May 2001 US signal interference called Selected Availability made position accuracy as best just under 100m. Accuracy is now at best around 6-15 meter. The Selected Availability can be turned on again at any time by the US Department of Defense.

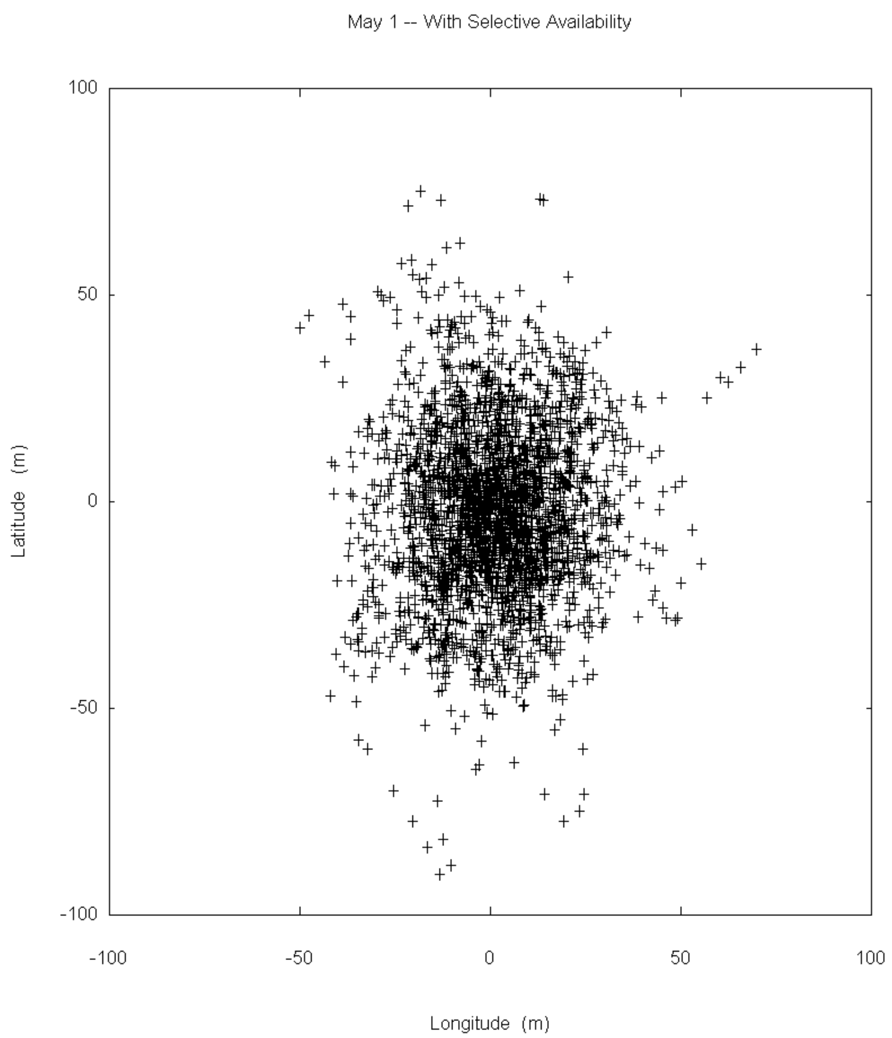

Figure 2.1. *24-hour scatter from GPS with Selected Availability turned on (National Geodetic Survey, NOAA, 2001).*

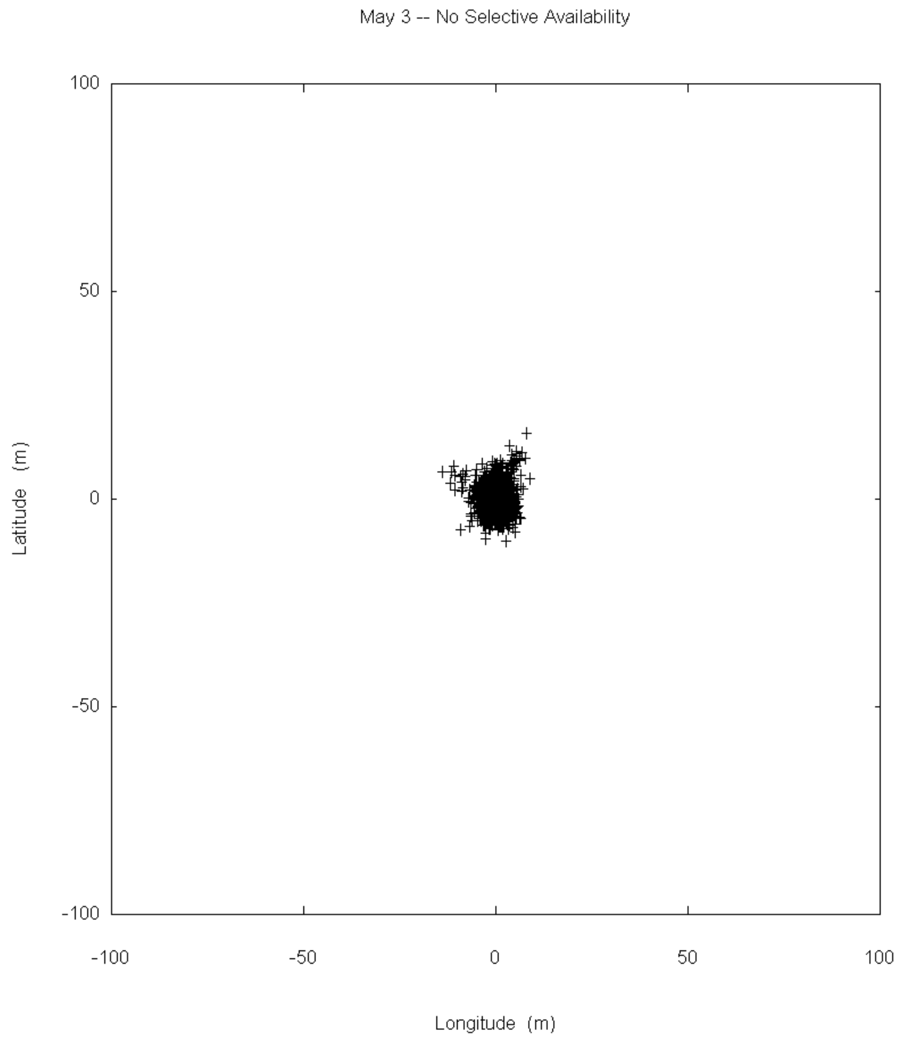

Figure 2.2. *24-hour scatter from GPS with Selected Availability turned off.*

Figure 2.1 and 2.2 shows the accuracy of GPS with and without selective availability (SA). The position plot is during 24 hours. The plots show that SA causes 95% of the points to fall within a radius of 45 meters and without SA 95% falls within 6.3 meters (NOAA, 2001).

2.2 GLONASS

Soviet union launched GLONASS as their positional system in the 80s. GLONASS (GLObal NAvigation Satellite System) is built like Navstar GPS with a satellite based radio navigation system which enables unlimited number of users to make all-weather 3D positioning, velocity measuring and timing anywhere in the world. Russian federation ministry of defense now controls it. It has two types of navigation signals; standard precision navigation signal (SP) and high precision navigation signal (HP). Standard precision navigation is available to civil users with an accuracy of 57-70m (European Parlament, 2001).

Since 1997 there are receivers on the civil market that can receive both GPS and GLONASS signals (Onsala rymdobservatorium Chalmers, 1998).

2.3 Galileo

Since Navstar GPS is controlled by the USA and no guarantee for free access has been given after 2007 a European Navigation system called Galileo has been under investigation during several years. Galileo system will have operator responsibility, high reliability and high precision. No decision has been taken to this date how the system will be built and financed. System is to be compatible with GPS and GLONASS. Total cost for the project is 3250 million euro. Hopefully the system can be operational 2008 (Schenker-BTL AB, 2000).

2.4 Satellite measurement

The Navstar GPS consists of 24 satellites, five ground stations and all receivers. Satellites run in orbit 20 200 km above earth surface, rotation period are 12 hours. This makes it possible to receive signals from four satellites almost everywhere and at anytime. Ground stations monitor the GPS satellites, checking operational health and exact position in space. The master ground station transmits corrections for the satellite's orbit and clock offsets back to the satellites. Position is calculated by measuring distance as a function of the time it takes for a signal to travel from satellite to receiver. Radio waves travel with the speed of light at 300 000 000 m/s (e.g. 299 792 458 m/s) (Physlink, 2001).

GPS satellites send out signals on two frequencies, L1 and L2. Most civilian receivers use only L1 frequency signals.

To get a three-dimensional fix at least three satellites must be in view. However the clock in a GPS receiver is not as exact as the four atomic clocks in each satellite (which is also corrected four times a day from the ground stations). Therefore four satellites must be in view to correct the clock in the receiver.

Two distance calculation methods are possible, carrier-phase and code-phase measurements. Carrier-phase measurement is made by measuring the phase difference between satellites Doppler shifting frequency and the constant frequency the receiver generates. Most civil receivers however use the less accurate code-phase measurement. It gives an error of around 10 m. A specific code for each satellite is sent on the same frequency. By measuring the difference in the code that is generated by receiver and satellite the time travelled by the satellite code can be calculated, see figure 2.3. The code is called “Pseudo Random Code” (PRC) and is a fundamental part of GPS. It has a sequence of “off” and “on” pulses and looks almost like random electrical noise (Trimble, 2001).

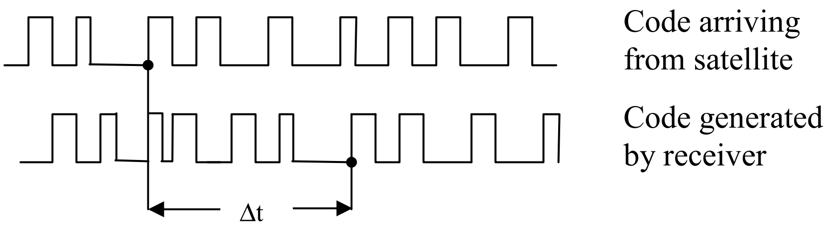

Figure 2.3. *Code-phase, Δt is the time difference.*

This makes the GPS small and cheap since this signal can easily be amplified so that no big satellite dish has to be used to receive data.

A position can be establish using the following equations:

$$
\begin{aligned}
(X - X_1)^2 + (Y - Y_1)^2 + (Z - Z_1)^2 &= c^2(\Delta t_1 - b)^2 \\
(X - X_2)^2 + (Y - Y_2)^2 + (Z - Z_2)^2 &= c^2(\Delta t_2 - b)^2 \\
(X - X_3)^2 + (Y - Y_3)^2 + (Z - Z_3)^2 &= c^2(\Delta t_3 - b)^2 \\
(X - X_4)^2 + (Y - Y_4)^2 + (Z - Z_4)^2 &= c^2(\Delta t_4 - b)^2
\end{aligned}
\qquad (2.4.1)
$$

where X_i, Y_i and Z_i is *i*:th satellites position, c the speed of light, Δt is time difference and b is clock synchronization error (Geodetisk Mätningsteknik, 1996)

GPS satellites send their own position in a global reference system called WGS84 (World Geodetic System). It's a three-dimensional geocentric system coordinate system with origin in earth's centre of gravity. Position is therefore calculated in WGS84 reference system and if any other coordinate system is to be used it has to be transformed.

2.4.1 Possible GPS Errors

There are mainly five things that contribute to position error:

Satellite orbit	Can vary and produce errors.
Atmospheric influence on signals	Signals travels 20 200 km and is affected by the atmosphere.
Multipath error	The signal may bounce on trees, buildings etc.
Clock errors	Although atom clock is very accurate errors can arise.
Satellite configuration	Geometric Dilution of Precision, if receiver picks satellites that are close together it makes the intersecting

circles that define a position cross at very shallow angles. This increases the error margin around a position (Trimble, 2001).

Differential GPS (DGPS) can be used to enhance position accuracy by receiving additional position information from a point that has known coordinates. This information is sent over the FM band in Sweden.

2.4.2 NMEA

National Marine Electronics Association created the NMEA 0183 Interface Standard that is used to exchange data between marine electronic products, first released in March of 1983. It can be used on almost every GPS receiver to send and receive GPS coordinates etc. Data is sent using ASCII code. Current standard is Version 3.0 released in July 2000, it is implemented in GPS receivers that is sold today. The standard is further developed within a committee in NMEA (NMEA, 2001)

NMEA protocol sentences look like the following:

```
$GPRMC,145418,A,6536.9034,N,02208.8863,E,7.5,205.5,050401,6.9,E,A*1C
$GPRMB,A,,,,,,,,,,,,A,A*0B
$GPGGA,145418,6536.9034,N,02208.8863,E,1,04,2.9,-4.6,M,24.1,M,,*6D
$GPGSA,A,3,,03,,11,,,21,,,,31,,3.4,2.9,1.0*3D
$GPGSV,3,1,11,02,20,334,00,03,29,175,00,09,14,049,00,11,33,268,45*78
```

Where values between commas are data and name of sentence describes what it contains. The sentences needed for PEEGEE is GPRMC, GPGGA, GPGSA and PGRME where position, speed, course, altitude, fix and Estimated Position Error (EPE) can be identified. PGRME with EPE is a Garmin proprietary NMEA sentence.

Example: The GPRMC sentence is built like this:
$GPRMC,145420,A,6536.8997,N,02208.8820,E,7.5,205.5,050401,6.9,E,A*11

The data fields are: Time of fix in Universal Time Coordinated (hhmmss), Status (A=OK,V=Warning), Latitude, N/S, Longitude, E/W, Speed over ground (knots), Track course (degrees, true north), Date (ddmmyy), Magnetic Variation (degrees, E/W) and Checksum.

2.4.3 Garmin protocol

Garmin is one of the market leaders of GPS Receivers. They have developed a protocol to communicate with computer software in order to upload or download waypoints, tracks etc. In difference from the NMEA protocol the Garmin protocol is binary. There are programs that convert Garmin protocol to standard ASCII text files and also conversions to MapInfo or ArcView formats.

3 Coordinate transformation

The shape of the earth is not completely spherical but more like an ellipsoid. Therefore all more accurate system is built on an ellipsoidal earth model with an equatorial radius and a polar radius. The GPS-system uses a reference system called WGS 84 (World Geodetic System 1984) with a ellipsoid called GRS 80 that has a polar radius of 6356752.314140 meters and a Equatorial radius of 6 378 137 meters.

The most commonly used coordinate system to describe the earth shape is the latitude, longitude and height system. A prime Meridian and the Equator are the reference planes to define latitude and longitude.

- The geodetic latitude is the angle from the equatorial plane to the vertical direction of a line normal to the reference ellipsoid.
- The geodetic longitude is the angle between a reference plane and a plane passing through the point, both planes being perpendicular to the equatorial plane.
- The geodetic height is the distance from the reference ellipsoid to the point in a direction normal to the ellipsoid.

Geodetic datum is used to define which reference system is used.

To get plane coordinates a projection of the reference ellipsoid is made. The general Swedish maps are made in Gauss conformal projection and the coordinate system is called RT 90. The Gauss projection, also called Transversal Mercator projection, has true angles and true lengths along the central meridian. Most Swedish maps are using a central meridian at 2,5 Gon (1 Gon = 0,9 °) west of Stockholm’s old observatory which is identical to 15°48'29".8 East of Greenwich. A false Easting of 1500 000 m is used to avoid negative Y-coordinates (1500 000 is simply added to the y-value). Which false Easting that is used can be read on the map where for example RT 90 2.5 Gon V 0:-15 stand for central meridian 2.5 Gon west of Stockholm’s old observatory and an false Easting of 1500 000 m.

Parameters for general Swedish maps in RT 90 2.5 Gon V 0:-15, see table 3.1.

Table 3.1. *Parameters for general Swedish maps.*

Reference Ellipsoid	Bessel 1841
Semi Major Axis – Equatorial radius (a)	6377397.155
Semi Minor Axis – Polar Radius (b)	6356078.962818
Inverse flattening (1/f)	299.1528128
Projection	Gauss-Krüger (Transverse Mercator)
Central meridian	15°48'29".8 East of Greenwich
Latitude of origin	0°
Scale along central meridian	1.0
x_0 False Northing	0 m
y_0 False Easting	1500 000 m

Since development of software is done in Sweden and Swedish maps are used, coordinates are transformed from WGS84 to Swedish coordinate system RT 90. Sweden uses SWEREF 93 as a three-dimensional system, which is on decimeter level equal to WGS84. It is a realisation of the European ETRS 89 system. However Sweden has changed system from 26th of May 2001 to SWEREF99. This system differs from SWEREF93 with only a few cm and is due to different guidelines parameters from EUREF. Since the world’s tectonic plates moves constantly (called continental drift) and earth elevation changes, the earth coordinates changes constantly. Euroasian plate moves 2 cm a year. EUREF 89 states the situation 26th of January 1989. The earth was also compressed by the ice during the last ice age and is therefore rising with various speed in Sweden; in Luleå for example the speed is 9 mm each year (Jivall et al, 2001).

Since Swedish maps have a plane coordinate system called RT90 a transformation has to be done from WGS84 coordinates. This is called a 3-dimensional 7-parameter Helmert transformation. A rotation to RR92 is made followed by a Transverse Mercator projection to RT 90 plane coordinates. RR92 is a three dimensional system consisting of RT90 plane coordinates, altitude system RH70 and geoid altitude system RN92. See Appendix A for the 7-parameter SWEREF 93 transformation and the new SWEREF 99 transformation parameters. Instead of using the formal RR 92 system and RN92, the new transformation uses a ”temporary” Cartesian system for RT 90 and heights over Bessel ellipsoid that is “artificial” (Lantmäteriverket, e-mail, 2001), Hence RR 92 and RN92 are no longer used. For new heights transformation geoids model SWEN 01L and RH 70 must be used.

4 Development environment

A very important factor to succeed in making good programs is the development environment. This includes operating system, debuggers, editors, sample code, emulators and help documentation.

4.1 Windows CE

The operating system (OS) in the PDA being used is Windows CE 3.0 which sometimes is referred to as Pocket PC but Pocket PC is rather the standard configuration of Windows CE 3.0. Windows CE is a modular operating system, therefore engineers and developers can select which part of the operating system they want and customize it for their purpose. The OS can be embedded in for example a gas pump, ATM or a mobile phone. There are other standard configurations: for example a handheld PC that has a bigger screen then the Pocket PC and support for keyboard is called Windows CE 2.11. The 3.0 version is designed to provide real time operating system characteristics and better support for multimedia and communication (Grattan Nick, Marshall Brain, 2001).
Programming is simplified for those who have programmed for Windows since Windows CE is built on the Win32 API. Windows CE is built from scratch but has many similarities with Windows 95/98/NT though several features are unique to Windows CE (Burdick Robert, 1999).

4.2 Microsoft eMbedded Visual Tools 3.0

There are two Microsoft developing environments for Windows CE platforms, namely the Embedded Visual Tools version 3.0 with Visual Basic and Visual C++. Both tools are versions of Visual Basic and Visual C++ but have been adapted to the limited functions that are available in Windows CE. Until recently this programming environment where embedded in the Visual Basic and Visual C++ programs. The Embedded Tools programs are freeware from Microsoft and are downloadable from Microsoft's homepage. It is a very nice environment if one is used to the Visual Basic and Visual C++ programs, which almost every windows programmer have used. Before starting to develop, the Windows SDK, Software Development Kit for Pocket PC must also be installed. It is a set of tools that contains the emulator for the Pocket PC.

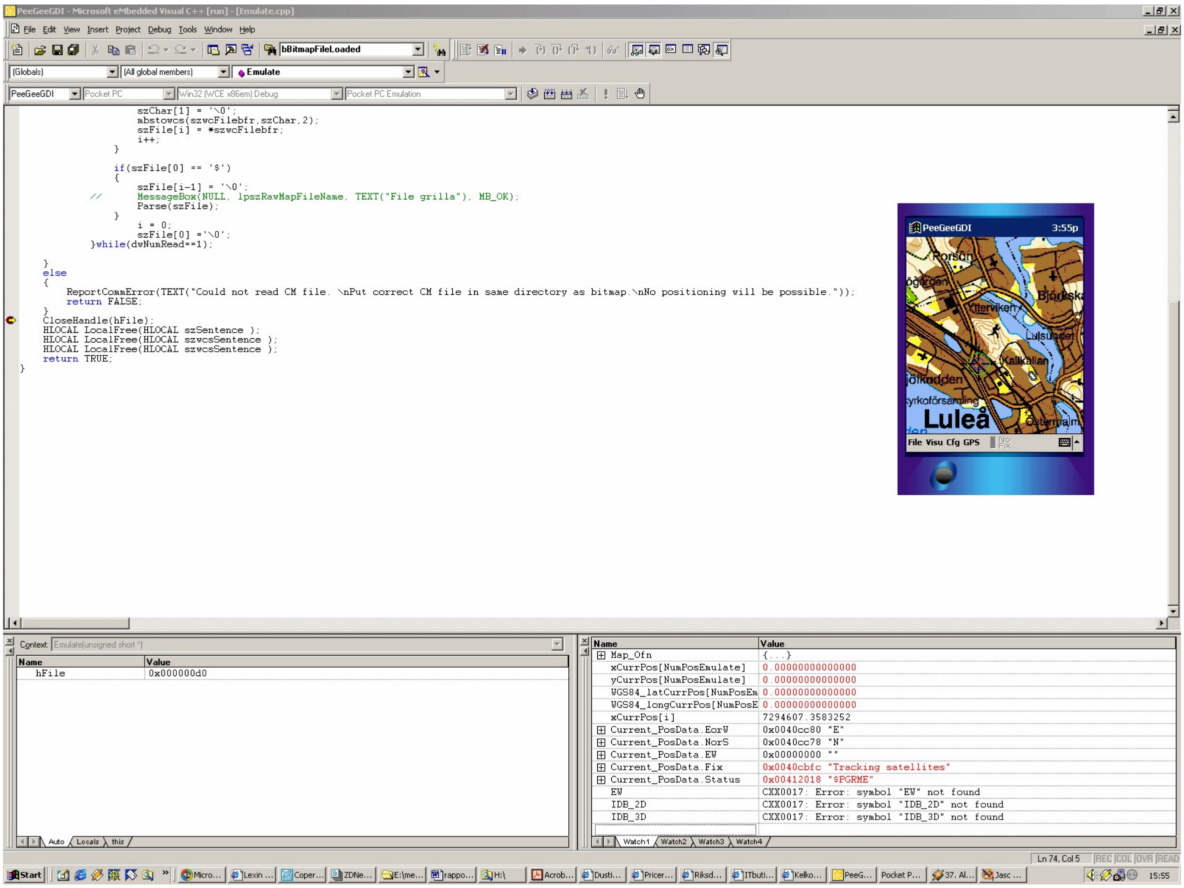

Figure 4.1. *Develop environment for eVC++ under debug mode with the emulator running.*

The PDA is connected to the PC via cradle and a USB cable (or infrared) and it is possible to download the program to the PDA simply by pressing, “Run” in the development environment. The programmer chooses which processors to target (Compaq Ipaq has ARM processor but for example HP Jornada has MIPS processor) and the target device (the real one or an emulator). A small program called “Active Sync” in the host PC handle the link to the PDA. This program handles all communication, updating of address book and mail and of course also the movement of files between the PC and PDA. The Windows CE has a somewhat different way of storing files so every file has to be converted and compressed to that format before copying; Active Sync does this automatically.

Microsoft is known for good debuggers and it is very convenient to run the program under debugging mode to find out what is wrong when the program doesn’t work, see figure 4.1. With the program comes an emulator that runs on the PC so one doesn’t have to run the program on the PDA every time something has to be tested. This is much slower since program and commands have to be downloaded to the PDA using USB cable.

The emulator is however not perfect and software that runs smoothly under emulation can crash on the real device. The emulator also misses emulation features for some of the main functions in the program such as serial port communications. This means that testing the serial communication for receiving GPS sentences and the function for buffering them has to be developed without emulator and debugger, which of course complicate programming. Debugging the serial port cannot be done on the device since one cannot send sentences or connect the GPS receiver since debugger is using the serial port.

For help Microsoft has the online MSDN library, which is available on the Internet for free. Documentation on the Windows CE 3.0 OS has however proved to be poor and actually wrong on some occasions. This makes programming harder.

4.3 PDA programming

Programming for Pocket PC or other PDA differs from desktop programming in the sense that many things have to be hard coded and many add-ins are missing. Another thing one has to be very thoughtful about is Graphical User Interface (GUI). With the small screen it is important to hide as many functions and values as possible without making it impossible to use the program. One command bar with a limited number of menus has to contain everything in the program. When the user needs additional info on program settings or GPS position info, an overlapping dialog box can be used.

5 Existing Programs

To investigate what kind of similar navigation programs that where available on the marked a few programs where tested. This was done to get a view of how the implementation where made, what functionalities that where available and of course how the GUI was implemented. The programs tested are GPSBoy, Garmap Win, Garmap CE, NMEA Monitor and ESRI ARCPad.

5.1 GPSBoy

GPS boy is described in Microsoft MSDN Magazine by Joshua Trupin. It is a program originally written for a desktop PC (Microsoft magazine, 2001). The article describes how to port it to The Pocket PC platform. It is coded in Visual basic. The Pocket PC version receives GPS sentences from the GPS receiver through the serial port. This program only shows the information that are in the sentences. This program has no map function. The program is very simple to understand and the programming behind is fairly simple. It’s a good program for showing satellite reception strength, speed, course etc.

5.2 Garmap

Garmap Win is a freeware desktop PC program to receive Garmin tracklogs, Waypoints, Routes and coordinates. It can draw tracks etc on a calibrated map that is generated by a separate program. The program cuts up the original map into segments that is loaded when needed in order to save program memory and performance. This is a very good program and it is nice to be able to load down tracks after being out in the woods. It’s not the only program to support Garmap protocol and maps but it is one of few that has been ported to Pocket PC platform and it is freeware.

Garmap CE is the Pocket PC version of Garmap Win, see picture 5.1. It has almost the same features and can receive positions tracks etc as well. Maps that are used in these programs have to be northward centred and since Swedish maps have a TM projection they have to be rotated in most part of the country with the correct meridian convergence. Convergence is not constant throughout the map why position marking on the map will not be fully correct. It is however a very nice program and is very useful if one wants to be able to use Garmin protocol to upload wayoints etc. Both NMEA and Garmin protocol navigation are supported. It is a bit difficult to handle and there is no User manual.

***Figure 5.1.** Garmap CE*

5.3 NMEA Monitor CE

This is a program that is very similar to GPSboy and shows the satellite reception strength, position, speed etc. It has the same manufacture as Garmap Win and Garmap CE and it is freeware but no source code is available. It's possible to save NMEA sentences. The program is a "sub program" to Garmap CE.

5.4 ESRI ArcPad CE

ESRI is a well known producer of GIS software such as ArcInfo, Arcview and ArcIMS. ArcPad is a program for PDA's that is filled with features and has a range of functions for handling GIS data, see figure 5.2. However this program is very complex with several ways of loading and saving layers etc. The 20 minutes trial version that was available didn't have enough time to figure out how things worked before closing down. GUI is not fully developed for the small PDA screen and it feels like menus and command bars cover half of the screen. GPS implementation where not tested and can't be evaluated. The program might be good if one has time to learn the usage and is used to other ESRI programs.

Figure 5.2. *ESRI ArcPad CE.*

6 Error Estimation

To get an idea of how accurate the GPS position on the map is, a small error analysis was made. A full error analysis has not been done since time was limited but evaluations of the major factors have been made to offer a brief error estimation.

6.1 GPS Error

To be able to estimate the error of GPS measurements, a known reference point was used. This was only done to achieve a rough estimate and it does not follow scientific recommendations for this kind of studies.

There are two different ways of measuring, a relative and absolute method. In relative measurement, two or more receivers are used where one is a reference station and the position is calculated and corrected against the reference station. In absolute measurement only one receiver is used where position is calculated directly.

There are also two ways of using the time. A static measurement is made by measuring over a time period which will increase accuracy and a kinematic measurement is done while moving or stopping briefly. To be able to get good measurement, the time measuring should be at least 15 minutes (Caliterra, 2001).

The measurements in this study was made by an absolute and both static and kinematical measurement. The kinematical measurement was only preformed under 6 min 12 sec due to problems in saving the data.

Measurement took place on reference point 241880 on Hertsö berget, which has been measured by Lantmäteriverket. The reference point has the RT90 coordinates measured to x=7293544.076 y=1794055.456. WGS84 values where calculated through Lantmäteriverkets homepage both as SWEREF99 and SWEREF93. Values that were measured and calculated can be viewed in table 6.1.

Table 6.1. *Values over reference point from measurement.*

Reference Point	**No:241880**
True RT 90 from Lantmäteriverket	1794055.456 y , 7293544.076 x
Calculated WGS84 from 7-parameter formula on LM homepage	65°36'32.00350"N 22°11'32.49322"E
Absolute kinematic WGS84 measured	65°36'31.98000"N 22°11'32.54401"E
Absolute kinematic RT90 calculated from LM hp (SWEREF99)	1794056.179 y , 7293543.418 x
Absolute kinematic RT90 calculated from LM hp (SWEREF93)	1794056.061 y , 7293543.519 x
Aboslute kinematic RT90 calculated in program (SWEREF93)	1794056.062 y , 7293543.516 x
Absolute static WGS84 mean measured 6min 12sec, 182 st	65°36'31.98226"N 22°11' 32.53257"E
Absolute static RT90 mean calculated from LM hp (SWEREF99)	1794056.026 y , 7293543.473 x
Absolute static RT90 mean calculated from LM hp (SWEREF93)	1794055.907 y , 7293543.574 x
Absolute static RT90 mean calculated in program (SWEREF93)	1794055,908 y , 7293543,571 x
Error kinematic RT90 measurement calculated (SWEREF99)	0,723 in y -0.658 m in x
Error kinematic RT90 measurement calculated (SWEREF93)	0.605 in y -0.557 m in x
Error kinematic RT90 calculated in program (SWEREF93)	**0.606 in y -0.560 m in x**
Error static RT90 measurement calculated (SWEREF99)	0.570 in y -0.603 m in x
Error static RT90 measurement calculated (SWEREF93)	0.451 in y -0.502 m in x
Error static RT90 calculated in program (SWEREF93)	**0.452 in y -0.505 m in x**

The accuracy both on kinematical and relative measurements are very good. Error sources apart from receiver, receiving conditions and satellite errors are position of antenna and the time of the relative measurement. GPS signals can under these conditions (time, weather, clear view of sky, etc) give an accuracy of under 1 meter, which is very impressive. According to measurement done with better receivers and during 24-hour 95% of the positions is within 6,3 meter divergence (NOAA, 2001).

But in the total error estimation below, values have been taken from an official GPS performance page for measurement made during 24 hours August 28th of 2001 with a global standard deviation of 3,02 meters (United States Space Command, 2001).

Note - After this test measurement was done the program transformation from WGS 84 to RT 90 was modified to adapt to the new SWEREF 99 transformation and so the values that is calculated by the program is no longer the same as above. They are close to the calculated SWEREF 99 values. For instance the absolute kinematic calculated SWEREF 99 value is now in the program: 1794056.181 y, 7293543.418 x, which is 0,725 m divergence in y and negative 0,658 divergence in x.

6.2 Scanning errors

The scanner used during development (HP ScanJet 5p) had a linearity problem. Since the scanner does not scan a paper exactly linear, a few pixels differ from top to bottom. Why this is the case has not been investigated but it might have something to do with copyrights and legal matter. With a simple test that consisted of scanning an A4 paper, the result pointed to several pixels in difference in various places on the resulting "A4" image. To minimize errors due to inequalities in the paper it was turned the other way around and scanned again.

A total of seven distance measurements were made. The standard deviation for the seven values where calculated. Standard deviation is calculated with the following formula:

$$s = \sqrt{\frac{1}{n-1}\left(\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2\right)} \qquad (6.2.1)$$

where *s* is standard deviation, *n* number of values, *i* the ith number, x_i the ith value (Vännman Kerstin, 1990).

It can be shown that:

$$s_d^{\ 2} = 2s_x^{\ 2} = s_r^{\ 2} \qquad (6.2.2)$$

where s_d^2= standard deviation for distance error, s_x^2= standard deviation for x error and s_r^2= standard deviation for radial error.

Applying the formula (6.2.1) and (6.2.2) gives a standard deviation, s_d for the scanner of 2,43 pixels per 1000 pixels.

If one assumes that the error is equivalent regardless of which resolution scanning is done in we can get an estimation for different scales. For various scales this corresponds to different distances in the terrain. A4 paper is by definition 21 cm x 29,7 cm. This means that on a 21 cm distance on a paper map the standard deviation is 0,51 mm. This corresponds to 51 meters in terrain on a 1:100 000 map, see table 6.2.

Table 6.2. *Scanning errors in meter for various scales.*

Scale	1:100 000	1:50 000	1:12 500
Standard deviation	51 meter	25,4 meter	6,37 meter

Since no measurements were made of the vertical error, presumption is that this is the total overall spherical error.

Scanning errors seems to be big compared to other error sources and because a map often is bigger than the scanner, a scanned map might consist of several parts stitched together that might make the errors even bigger.

Scanning errors are of random nature since every scanner behaves differently. Usage of scanning, placing of maps (if it is straight etc), stitching big maps together and the condition of the map (if it is folded etc) also contribute to big position errors, such errors are not taken into account for this estimation.

6.3 Calibration errors

Before the map is loaded into the PDA, a calibration file has to be made. Calibration is made by stating the coordinates of the top left and bottom right corner. A mistake of a few pixels comparing to the "true" value can make errors even bigger than scanning errors. Also this error is random but to be able to give a total error estimation the error is estimated as below:

For all maps the standard deviation is estimated to 3 pixels when calibration points are easy to distinguish. The error is estimated at a resolution of 210 pixels per inch, which is 82,677 pixels/cm, see table 6.3.

Table 6.3. *Calibration errors in meter for various scales.*

Scale	1:100 000	1:50 000	1:12 500
Standard deviation	36 meter	18,1 meter	4,54 meter

6.4 PDA Screen errors

Compaq Ipaq screen consists of 240x320 pixels with a pixel pitch of 0.24 mm (Compaq, 2001). When a position is to be marked, the program must calculate which pixel corresponds to the right position. This is done by converting screen coordinates to ground coordinates. When the bitmap is loaded a text file is also loaded containing the RT 90 coordinates of the maps top left and bottom right position. The number of pixels of the bitmap file is known and therefore each pixel can get it's corresponding RT90 coordinate size, that is each pixel corresponds to for example the distance 2 meters in RT 90 coordinates. This way, it is easy to calculate what coordinate corresponds to which pixel. The screen can only show 240x320 pixels. This means that on different scales of map and different resolution one pixel corresponds to different distances.

Pixels can be seen as having a rectangular (or uniform) distribution. This means that each pixel has rounding off errors. The standard deviation of each pixels length value can be calculated with the formula:

$$\sigma = \frac{b-a}{\sqrt{12}} \qquad (6.4.1)$$

where *b* is beginning of pixel and *a* is the end of the pixel (Råde,Westergren,1995).

This means that the deviation for the pixel can be calculated for the length and height and then the total deviation can be calculated according to (6.6.2). Table 6.4 shows pixel correspondence to distance in terrain.

Table 6.4. *Pixel correspondence to distance in terrain.*

Scale	resolution (dpi)	Terrain distance/pixel	Standard deviation
1:100 000	315	8,1m	3,31m
1:100 000	210	12,1m	4,94m
1:100 000	105	24,2m	9,88m
1:50 000	315	4m	1,63m
1:50 000	210	6m	2,45m
1:50 000	105	12,1m	4,94m
1:12 500	315	1m	0,40m
1:12 500	210	1.5m	0,61m
1:12 500	105	3m	1,22m

6.5 Zoom errors

With various zooming levels the pixel-coordinate condition changes and the further down in a map you zoom the “better” condition one gets. But the map picture still consists of the same number of pixels so a much zoomed map does not look good and does not help navigation much.

A very zoomed out map gives the opposite pixel-coordinate condition and the further out one zoom the poorer visually accuracy gets.

6.6 Total error estimation

It has under development proved difficult to identify the range of errors concerning scanning and calibration; therefore it is difficult to give a total error estimation.

For results that would be more interesting one has to do a lot more thorough investigation of all error sources.

If one assumes the errors above to be average values independent of each other and that all errors have the standard deviation stated and could be presumed to have normal distribution a simple summarizing estimation can be done.

Pixel errors have a rectangular (or uniform) distribution but can with the central limit theorem be seen as a normal distribution and therefore can be added in the same way as the other errors.

Summarizing stochastic variables which the different values can be seen as in an normal distribution can be made by the following formula:

$$\xi_1 + \xi_2 + \xi_3 + \ldots \in N\left(\mu_1 + \mu_2 + \mu_3 + \ldots, \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^3 + \ldots}\right) \qquad (6.6.1)$$

where ξ is the stochastic variable, μ is the expectation, σ is the standard deviation (Vännman Kerstin, 1990).

Consequently the total standard deviation can be calculated by:

$$\sigma = \sqrt{\sigma_n^2 + \sigma_n^2 \ldots} \qquad (6.6.2)$$

where σ is standard deviation and n number of standard deviations (Vännman Kerstin, 1990).

To estimate the standard errors for digital maps (210 dpi) that have a digital calibration table 6.5 was made.

Table 6.5. *Total error and standard deviation for a digital map with calibrated corners.*

Type of error	Scale 1:100 000	Scale 1:50 000	Scale 1:12 500
GPS	3,02 m	3,02 m	3,02 m
PDA screen pixel	4,94 m	2,45 m	0,61 m
Standard deviation	**5,79 m**	**3,89 m**	**3,08 m**

The error is not very big but it is under good receiving condition. No consideration has been taken to map projection errors. The screen resolution here plays a major role since GPS position error is smaller than the pixel size.

To estimate the standard errors for digital maps (210 dpi) that do not have “digital” calibration table 6.6 was made.

Table 6.6. *Total error and standard deviation for digital map with manual calibration.*

Type of error	Scale 1:100 000	Scale 1:50 000	Scale 1:12 500
Calibration	35 m	17,8 m	4,43 m
GPS	3,02 m	3,02 m	3,02 m
PDA screen pixel	4,94 m	2,45 m	0,61 m
Standard deviation	**35,5 m**	**18,2 m**	**5,40 m**

For the total error estimation from scanning to position on screen se table 6.7 below.

Table 6.7. *Total error and standard deviation for the whole chain of possible errors.*

Type of error	Scale 1:100 000	Scale 1:50 000	Scale 1:12 500
Scanning	51 m	25,4 m	6,37 m
Calibration	36 m	18,1 m	4,54 m
GPS	3,02 m	3,02 m	3,02 m
PDA screen pixel	4,94 m	2,45 m	0,61 m
Standard deviation	**62,7 m**	**31.4 m**	**8.4 m**

Table 6.7 shows how much error there are in calibration and scanning. They contribute with the most error. But these errors are also very insecure and should be interpreted with cautiousness.

Standard deviation values mean that 68 % of the position values are within that error.

7 Conclusions

7.1 Conclusions related to the aims of this thesis

This thesis has resulted in the software program PeeGee which is a fully functional program. The Program is installed on a PDA and connected to a GPS receiver via cable. The PeeGee application is a prototype navigation tool for use with scanned or digital maps and GPS position information. The conclusion is that it is possible to develop a good navigation program that is fully functional but a lot of features can be added and it is also found that it would be smother to have the GPS integrated in the PDA or as a GPS card inserted in the PDA.

Finding algorithms and methods to scan and calibrate an paper map into an electronic version has resulted in a description and a detailed table of how the user should do with resolution, file format, map scale etc. This is included in the software manual.

The conclusion is that accuracy depends on many things such as GPS receiver, GPS receiving conditions, map scale, map scanning, map calibration etc. It is therefore difficult to get an overall error estimation. Map scanning and calibration was found to be a big error source. At the scenario where a map has been scanned and calibrated by hand the accuracy is around 60 meters for a map in the scale 1:100 000. If the map is digital and calibrated an accuracy of around 10 meters can be achieved. The option of using a more accurate scanner has not been investigated.

7.2 Comments

It's interesting to see that the GPS accuracy isn't the main source of position error. With digital maps extracted with true calibration the accuracy is very impressive and the program can be used for precision navigation. When using scanned maps with manual calibration the error is quite big but that is also understandable with all the uncertainty in the scanning and calibration process.

The results of the error estimation should be interpreted with precaution since the statistic material is very small and made during a short period of time. Values have been estimated, statistic material is set to be normal distributed in order to be able to summarize errors on a simple way and no consideration has been made to map projection errors etc.

Programming started with building a small application in Visual Basic that was most familiar, however after a while it came forward that Visual Basic is interpreted on Windows CE, (code is not translated to machine code but runs on an "interpreter" which slows down performance). Changing to Visual C++ made it more difficult to program since little experience of developing in Visual C++ existed. After working with Win CE API for several months the knowledge of C++ programming in the Win CE environment has increased tremendously.

PeeGee is developed for the NMEA version 3.0 and may not function properly with another version since sentence definition can vary. In the sense that PeeGee program should be available for all GPS receivers it does not yet support other protocols such as the Garmin protocol. The NMEA protocol is however almost always available in GPS receivers.

Running the receiving of NMEA sentences from the GPS in the background is possible trough a separate thread. A thread is created when port is opened and runs in the background in order to enable the program to be responsive to the user.

The PeeGee program uses a linear rotation matrix that produce a few millimeter difference in the transformation compared to the complete rotation matrix in the 7-parameter Helmert transformation. These system inequalities are discarded since position accuracy in PeeGee program is more than 2 cm. PeeGee has been adapted to SWEREF 99 parameters late during development.

The application is further described in two documents as appendix B and C with software specification/description and user manual.

8 Future work

There are many things that have not been implemented in this first increment.

The way GPS sentences are received is not user friendly since two separate devices and a cable between them have to be carried. There are GPS cards that can be used in the PDA instead. Furthermore the way maps are downloaded today the PDA must be synchronized and connected to a computer. With other techniques such as GSM, GPRS, WLAN and Bluetooth, maps could be sent wireless to the PDA.

With more maps or a range of layers that cover the same area these could be visible or not visible depending on zooming level. For instance it would be possible to have a rough map over Sweden and have your position plotted, after that you have zoomed a more accurate map appears and you can se smaller streets and houses. A variety of layers with additional information such as gasoline stations, restaurants etc could be placed over the map with possibilities to turn them on and off.

Another thing that can be done to improve performance of program and allow bigger maps that exceeds 10 Mb is to cut the map into pieces and then load them into the program when it is necessary.

It is possible to improve map calibration with possibilities to calibrate more than two points and calibrate the map while running the program out in the field. This is done by the least square method.

Many more features can be added; such as support for more earth datum's and projections, other map file types, the Garmin binary protocol, waypoints, routes, and a more sophisticated tracking system.

The GUI is not fully developed either and a different menu system called rebar would add a nicer looking menu and save space for the map since it is put over the "taskbar".

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APPENDICES

Appendix A Coordinate transformation - RT 90

Appendix B PeeGee Software specification

Appendix C PeeGee User manual

PeeGee

Increment 1

PDA-GPS TRACKER

Coordinate transformation – RT 90

Document Title	**: PeeGee Increment 1 Coordinate transformation**
Document Num	**: PeeGee-DEV-Coordinate transformation**
Prepared by	**: Mats Olofsson**
Approved by	**: Christopher Pichon**
Company	**: Ericsson Erisoft AB**
Created	**: 2001-04-09 08:53**
Modified	**: 2002-01-01**
Version	**: V1**

Table of Contents

1 Coordinate transformation – RT90

Coordinate transformation below is mainly an extraction from Lantmäteriverket homepage, Lantmäteriverkets report series; ”Transformationssamband mellan SWEREF 99 och RT 90 / RH 70” and Geodetisk Mätningsteknik, Kungliga tekniska högkolan, Institutionen för Geodesi och Fotogrammetri, October 1996, ISBN 91-7774-061-0.

1.1 Transformation parameters

1.1.1 SWEREF 93 -> RR 92

$\Delta X = -419.375$ m — $\omega_x = +0.850458$ arcseconds
$\Delta Y = -99.352$ m — $\omega_y = +1.817245$ arcseconds
$\Delta Z = -591.349$ m — $\omega_z = -7.862245$ arcseconds
$\delta = +0.99496$ ppm

1.1.2 SWEREF 99 -> RT 90

Coordinates measured by GPS in SWEREF 99 or WGS 84 can be transformed to RT 90 using the 7 parameters below:

$\Delta X = -414.0978567149$ m — $\omega_x = -0.8550434314$ arc seconds
$\Delta Y = -41.3381489658$ m — $\omega_y = +2.1413465185$ arc seconds
$\Delta Z = -603.0627177516$ m — $\omega_z = -7.0227209516$ arc seconds
$\delta = 0.0$ ppm (scale = 1.0)

Transformation accuracy

$$\sqrt{\sigma^2{}_{Easting} + \sigma^2{}_{Northing}} = 0.07 \text{ (r.m.s)} \qquad (1.1.2.1)$$

(Root Mean Square)

1.2 Transformation model (Bursa Wolf) SWEREF 93/99

The formula to be used in conjunction with the presented parameters is:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{To} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + (1+\delta)R \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{From} \qquad (1.2.1)$$

where
X,Y,Z = geocentric coordinates in SWEREF 93/99 respective RR 92/RT 90
ΔX ΔY ΔZ= translation between the systems
δ = scale factor
and R is the rotation matrix defined by:

$$R = R_z R_y R_x = \begin{bmatrix} \cos\omega_z & \sin\omega_z & 0 \\ -\sin\omega_z & \cos\omega_z & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\omega_y & 0 & -\sin\omega_y \\ 0 & 1 & 0 \\ \sin\omega_y & 0 & \cos\omega_y \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega_x & \sin\omega_x \\ 0 & \cos\omega_x & \cos\omega_x \end{bmatrix} (1.2.2)$$

The transformation model is the same for SWREF 93 and SWEREF 99.

A linearized matrix can be used instead to simplify calculation. This gives a difference of 3-4 mm compared to the complete rotation matrix. The linear matrix is shown below (HMK page 124):

$$R = \begin{bmatrix} 1 & \omega_z & -\omega_y \\ -\omega_z & 1 & \omega_x \\ \omega_y & -\omega_x & 1 \end{bmatrix} \qquad (1.2.3)$$

For inverse transformation see Lantmäteriverket home page for further information.

1.3 Complete transformation diagram

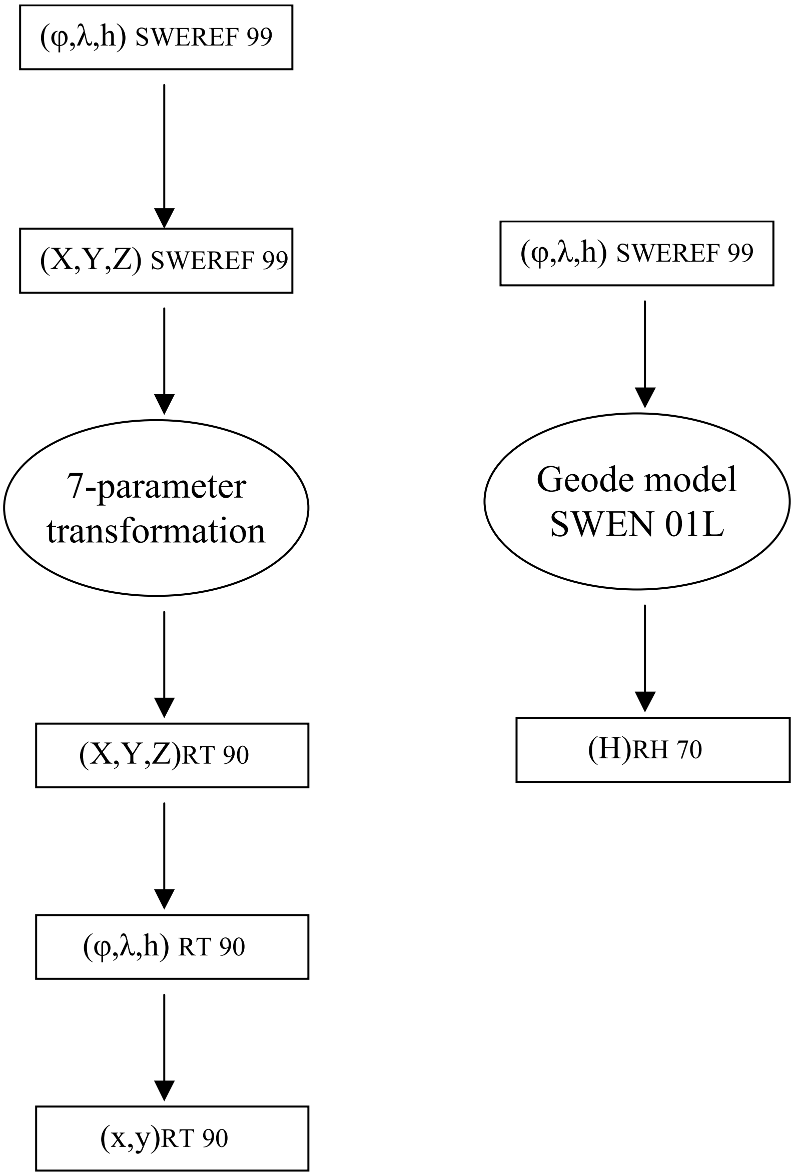

Figure 1. *Transformations from SWEREF 99 to RT 90 and SWEREF 99 to RH 70. The (X,Y,Z)RT 90 and the h value of (φ,λ,h) RT 90 does not have a real meaning. Heights are calculated trough SWEN 01L and RH 70 (to the right).*

1.4 Example of transformation

1.4.1 SWEREF 93

SWEREF 93	Latitude	58° 0' 0.000000''
	Longitude	17° 0' 0.000000''
	Elevation	30.000
SWEREF 93	X	3240036.3696
	Y	990578.5272
	Z	5385763.1648
RR 92	X	3239535.0069
	Y	990625.8659
	Z	5385201.6355
RR 92	Latitude	58° 0' 1.210419''
	Longitude	17° 0' 11.681623''
	Elevation	-0.8713
RT 90 2.5 gon V 0:-15	x	6431274.5414
	y	1570650.2131

For transformation (lat, long, elev) ⇔ (X,Y,Z), the following values are used:

System	**ellipsoid**	**a=**	**1/f=**
SWEREF 93	GRS 1980	6378137 m	298.257222101
RT 90	Bessel 1841	6377397.155 m	299.1528128

1.4.2 SWEREF 99

SWEREF 99	Latitude	58° 0’ 0.000000’’
	Longitude	17° 0’ 0.000000’’
	Elevation	30.000
SWEREF 99	X	3240036.3696
	Y	990578.5272
	Z	5385763.1648
RT 90	X	3239532.6315
	Y	990625.1745
	Z	5385197.8446
RT 90	Latitude	58° 0’ 1.213296’’
	Longitude	17° 0’ 11.683659’’
	Elevation	-5.3970
RT 90 2.5 gon V 0:-15	x	6431274.6309
	y	1570650.2449

The corresponding values calculated in the PEEGEE program is:

RT 90 2.5 gon V 0:-15	x	6431274.6303
	y	1570650.2470

For transformation (lat, long, elev) ⇔ (X,Y,Z), the following values are used:

System	**ellipsoid**	**a=**	**1/f=**
SWEREF 99	GRS 1980	6378137 m	298.257222101
RT 90	Bessel 1841	6377397.155 m	299.1528128

PeeGee

Increment 1

PDA-GPS TRACKER

Description of Product / Software specification

Document Title : **PeeGeeE Software specification Increment 1**
Document Num : **PeeGeeE-DEV-SPEC-1**
Prepared by : **Mats Olofsson**
Approved by : **Christopher Pichon**
Company : **Ericsson Erisoft AB**
Created : **2001-04-09 08:53**
Modified : **2002-01-01**
Version : **V4**

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Godkänd - *Approved*				Tillhör/referens - F*ile/reference*
QPL/ Christophe Pichon				C

Table of Contents

1 Introduction

The aim of this document is to describe the functionalities of the software as well as the entities involved. The software package consists of two software units, one PC-based program to scan, calibrate and prepare maps for the other program that will run on a Windows CE PDA.

The first increment however, which this document describes, focuses on a limited Windows CE version hence no PC-based preparation-tool will be made in this first increment.

The PDA GPS Tracking software (hereafter called 'PeeGee' in this document) is a software application that runs on a Pocket PC device. This document does not describe using Windows CE PDAs nor Windows 2000 (that shall be used during development). The Windows CE based Pocket-PC to be used in this project will be a Compaq® Ipaq H3630 and the GPS-receiver will be a Garmin® eTrex Summit.

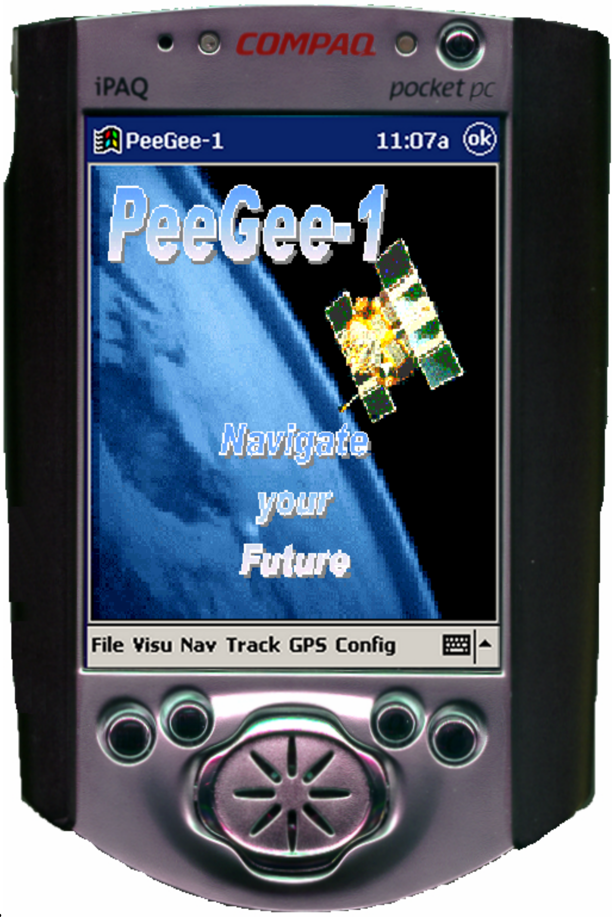


Figure 1. *PeeGee Splash screen*

2 Application Basic Description

The basic idea of the system is to interface a PDA (Personal Digital Assistant) with a GPS (Global Positioning System) device.

The purpose of the system to which this document applies is to provide an easy to use software allowing to visually establish a position on a map by using positional information given by a GPS receiver. The visualization shall be done on a Windows CE based PDA screen. The PDA´s screen shall show a map overlapped with appropriate symbols to aid positioning and navigation.

This interfacing will enable a user to visualize his position on a map, and permit him to navigate and track his movements.

The basic functions can be summarized as follows:

- Visualization functions.
- Navigation functions.
- GPS related functions.
- User Interface configuration.

2.1 Menu

The menu function is described below, first an introduction and further down a description of every menu and submenu.

2.1.1 Introduction

The main menu shall be the drivers of the development and in later increments in conjunction with Popup Menus and Icon Trays. The menu of the user interface shall contain the following elements:

`[FILE]`
Here the user shall be able to load and close maps and calibrated maps from file. This menu is also where the exit function lays.

`[VISU]`
This functionality encompasses the visual handling of a map, that is to say, zooming in and out, panning, centering the map on the GPS position and lock on it, and returning to a full extent scale.

`[GPS]`

Here, the user shall be able to choose the communication interface, and to configure this interface, in the appropriate manner. He shall also through this menu be able to visualize all the specific GPS information such as:

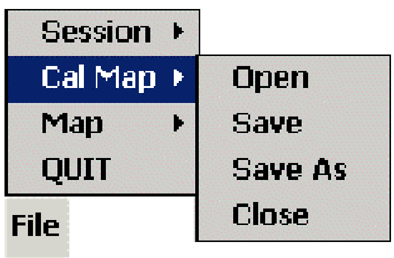
- Communication Protocol.
  - NMEA 0183 Version 3.0 and 2.0 only.
- Log, enable the tracking mechanism to record positions sent by the GPS.
- Serial Port Configuration.
  - Configure (The configuration of the COM port shall not open it).
  - Open. The opening of the serial port, launches the GPS status screen showing navigation status.
  - Close.

2.1.2 Menu-Explanations

The main menu and the splash screen shall look like the following:

Figure 2. *Menus in PeeGee.*

2.1.2.1 File Menu



The file menu shall be used to handle elements that are to be loaded or stored in files and that can be reused later on with the exception of the log file of GPS-position that are output by the device to file.

File/ Cal-Map menu
The "Cal-Map" menu stands for "Calibrated Map" menu.
This menu will be used to handle calibrated maps. A calibrated map is a bitmap map of which at least two clearly distinct points have been identified,

and the co-ordinates have been given. These two points have to be clearly separated both vertically and horizontally in order to have a good quality calibration. The optimal solution and the only one supported in Increment 1 is to have top left corner and bottom right corner points.

File/Cal-Map/ Open menu
The “Open” menu shall be used to load a calibrated map into memory. The following identifies a calibrated map − It shall:

- have the ".CM" extension.
- be stored in the same folder as the raw bitmap.
- be a standard ASCII text file.
- contain the name of the raw bitmap file.
- contain the co-ordinates in RT 90 format of the top left and bottom right corner of the bitmap. (The limitation to RT90 is a restriction applying to Increment 1.)
- have the top left and bottom right corner on two different lines.

File/Cal-Map/ Recalibrate menu
The “Recalibrate” menu shall enable to launch the calibration process of the existing map and to save the new parameters instead of the existing old ones.

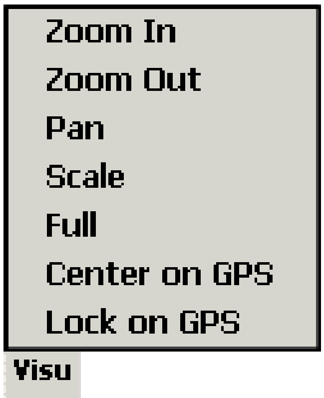
File/Cal-Map/ Save menu
The "Save" menu shall enable to save all the above parameters in the file that conforms with the above description.

File/Cal-Map/ Save as menu
The "Save as" menu has the same functionality as the save menu except that the destination file shall have a different file name.

File/Cal-Map/ Close menu
The “Close” menu shall enable to terminate the usage of the open calibrated map file.

File/ Quit menu
This menu will terminate the program prompting to save or quit without saving if any changes has been made in the open session/calibrated map/map/route/track.

2.1.2.2 Visu Menu



The “Visu” menu stands for visualization and shall be used to handle the map functionalities. This includes zooming in and out, pan, scale, zoom to full extent, center on GPS, Lock on GPS and show/hide toolbar for easier map handling.

Visu/ Zoom In menu
The “Zoom In” menu shall be used for zooming the map in to a smaller extent.

Visu/ Zoom Out menu
The “Zoom Out” menu shall be used for zooming the map out to a bigger extent.

Visu/ Pan menu
“Pan” menu means that it is possible for the user to pan the map at the presented extent.

Visu/ Scale menu
Scale mode shall be used to make it possible for the user to choose a custom scale.

Visu/ Full menu
Choosing the ”Full” menu will show the complete map on the screen regardless of current scale.

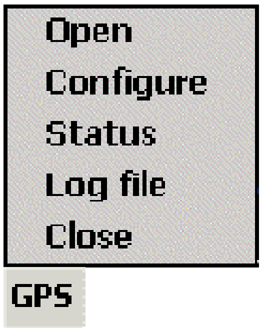
Visu/ Center on GPS menu
This menu will place the GPS-position at the center of the screen and center the map on that position.

Visu/ Lock on GPS menu
The “Lock on GPS” menu will center the map under the present extent on the current GPS-position keeping the current position centred when the user

moves. That is having the map moving and the GPS position locked at the center of the screen.

Visu/ Show map toolbar menu
This menu will open the map toolbar where it will be possible to push buttons to handle the map functionalities. This way managing the map will be faster and easier. When the user wants to close the toolbar he goes back to this menu to “Hide map toolbar”.

2.1.2.3 GPS Menu



GPS menu is used to manage communication settings and display GPS-status. Communication settings include configuring/opening/closing the serial port.

GPS/ Open menu
Opens the serial port for input of GPS data. It also launches the GPS status screen.

GPS/ Configure menu
The “Configure” menu shall be used to make the proper configurations for the serial port. This includes; which port, baud rate, data bits, parity, stop bits, flow control and GPS communication protocol.

GPS/ Status menu
Will show current position fix indicated by "Acquiring", "2-D Nav", or "3-D Nav" in the status field. Estimated Position Error (EPE) is shown as the current horizontal accuracy in meters.

GPS/ Log file menu
”Log file” menu shall manage the log file that shall be produced when GPS-signals are received. It’s possible to choose how the log file is stored, file name and maximum file size until the oldest record is deleted and how often track will be recorded, time or distance based.

GPS/ Close menu
This menu closes the serial port for further communication and closes the GPS logfile.

2.2 Entities

This section describes all the entities (objects) that are going to be manipulated by the software.

2.2.1 Calibrated Maps

Name: Calibrated map

Purpose: Calibrated maps are used for enabling the program to calculate a position in the bitmap map.

Description: Calibrated map is a map that has been calibrated with geo-coordinates in order to make it possible to calculate a position on the bitmap map. Any map that has the same scale-factor over the whole map and two corners coordinates can be calibrated. Calibrated maps shall in later increments be made from the PeeGee Prep Tool.

A calibrated map shall:

- have the ".CM" extension.
- be stored in the same folder as the raw bitmap file preferably under the"\CAL_MAP" directory under the application standard directory.
- be a standard ASCII text file.
- contain the name of the raw bitmap file.
- have the same name as the raw bitmap file .
- contain the co-ordinates in RT 90 format of the top left and bottom right corner of the bitmap.
- have the top left and bottom right corner on two different lines.
- have the top left and bottom right clearly identified by keywords.
- have the top left and bottom right written in ASCII equivalent of the numeric value.
- contain map scale.
- contain map resolution.
- separate values with “tab” or “end of row” sign.

Example: The Swedish “Gröna kartan 24L NO” made by Lantmäteriverket covering the area of Luleå has a scale of 1:50 000. The top left corner of the map

is in RT90 coordinates; X: 7300000,Y: 1775000 and bottom right corner X: 7275000, Y: 1800000. Top coordinates will be placed first with the x value first.
The bitmap file that has been produced from scanning of the map has the name "lulea.bmp". The calibrated map file with name "lulea.cm" will therefore look like the following:

```
PeeGee
RT90_2.5_gon_V_ 0:-15     Grid
lulea.bmp        RawBitmapFile
7300000          XPosTopLeft
1775000          YPosTopLeft
7275000          XPosBottomRight
1800000          YposBottomRight
1:100000         MapScale
315              Resolutiondpi
```

2.2.2 Log

Name: log

Purpose: The log file enables the user to investigate and analyze his session.

Description: A log is a file output with GPS-position. It automatically records the GPS-position to a file.

From the GPS/Log menu in the application it shall be possible to:

- Decide where output file will be generated.
- Choose if the track should be time or position based.
- Choose at what distance the user must move before track will be recorded (if position based).
- Choose at what rate the track will be recorded (if time based).

Example: When the user starts the program he decides that output will be recorded in the folder "log" and in the case position-based with 100m interval. When user puts on GPS, the first position is recorded to file but no more position is recorded until the user starts to move and when user has moved more than 100 meters the second position is recorded to file.
Time based means that a position will be recorded at the given rate (for example every 60 seconds) to the file regardless if the user has moved or not.

Output file will for example look like the following with 100 m intervals in RT90 coordinates:

7251155	1751123
7251255	1751123
7251255	1751223

Here the user has moved 100 meters in x-direction and thereafter 100 meters in y-direction.

2.2.3 Coordinates

Name: Coordinates

Purpose: Coordinates are in this case used to describe a position on the map that corresponds to the same position in reality.

Description: Coordinate systems are in extensive use in several areas all over the world and one could say that even the Postal Codes is a coordinate system.

Plane coordinate system describes the earth as a two-dimension system in a plane with x and y coordinates.

Three-dimension system is defined with respect to two orthogonal planes. Orthogonal coordinates, which can be two or three dimension, are often called Cartesian systems.

The earth is not round but more like an ellipse, therefore all more accurate system is built on an ellipsoidal earth model. An ellipsoid with an equatorial radius and a polar radius is defined. The GPS-system uses a reference system called WGS 84 (World Geodetic System 1984) with a ellipsoid called GRS 80 that has a Polar radius of 6356752.314140 meters and a Equatorial radius of 6378137.000 meters.

The most commonly used coordinate system to describe the earth shape is the latitude, longitude and height system. A prime Meridian and the Equator are the reference planes to define latitude and longitude:

- The geodetic latitude is the angle from the equatorial plane to the vertical direction of a line normal to the reference ellipsoid.
- The geodetic longitude is the angle between a reference plane and a plane passing through the point, both planes being perpendicular to the equatorial plane.
- The geodetic height is the distance from the reference ellipsoid to the point in a direction normal to the ellipsoid.

Geodetic datum is used to define which reference system is used.

To get plane coordinates a projection of the reference ellipsoid is made. The general Swedish maps are made in Gauss conformal projection and called RT 90. Gauss projection also called Transversal Mercator projection has true angles and a true length meridian. Most Swedish maps are using a length meridian at 2,5 Gon (1 Gon = 0,9 °) west of Stockholms old observatory which is identical to 15°48'29".8 East of Greenwich. A false Easting of 1500 000 m is used to avoid negative Y-coordinates (1500 000 is simply added to the y-value). Which false Easting that is used can be read on the map where for example RT 90 2.5 Gon V 0:-15 stands for central meridian 2.5 Gon west of Stockholm's old observatory and an false Easting of 1500 000 m. Parameters for general Swedish maps in RT 90 2.5 gon V 0:-15 is shown in Table 1.

***Table 1**. Parameters for general Swedish maps in RT 90 2.5 gon V 0:-15.*

Reference Ellipsoid	Bessel 1841
Semi Major Axis – Equatorial radius **(a)**	6377397.155
Semi Minor Axis – Polar Radius **(b)**	6356078.962818
Inverse flattening **(1/f)**	299.1528128
Projection	Gauss-Krüger (Transverse Mercator)
Central meridian	15°48'29".8 East of Greenwich
Latitude of origin	0°
Scale on central meridian	1.0
x_0 False Northing	0 m
y_0 False Easting	1500 000 m

In the applications first increment only RT 90 coordinates will be used in calibrated maps. Every calibrated map shall have a ASCII-text file with the same name as the map and the extension .CM with the bottom left and top right coordinates.

Example: The center of the city park "stadsparken" in Luleå has the position:

x-coordinate: 7290450
y-coordinate: 1792212

in the reference system RT90 2.5 gon V 0:-15 and the position:

latitude: 65° 34' 58.73'' N
longitude: 22° 08' 45.12'' E

in reference system WGS84.

1.4.3 Position

Name: Position

Purpose: Position is described by the coordinates and is used in the software to calculate correct scale and displaying of the map and the GPS-position.

Description: Position is based on the RT 90 coordinate system in the first increment. A position is marked by an x-coordinate and a y-coordinate. Calibrated maps have a text file with map coordinates marked in bottom right and top left corner to enable the program to calculate a position on the map. The map must be placed with the grid and y-coordinate as north heading (not regarding the meridian convergence).

In the application the GPS-position marker show position on map.

Position Error Estimation: GPS receiver will calculate a Position Error Estimate (EPE) that will be displayed on GPS-status screen. EPE will give an estimation of the GPS position error, but when using another grid than WGS-84, a coordinate transformation error has to be added. In first increment RT90 will be used and this transformation gives rise to an error not larger than one meter. True error however is also of course depending on the map calibration and the map scale. Small scale and bad calibration means big position error and large scale and good calibration means small position error. With a scanned map at a scale of 1:100 000 the total error is estimated to be around 60 meters.

Meridian convergence: Since Swedish maps use Gauss conformal projection true north deviation from “map north” varies from map to map (see Figure 3). This should be taken into consideration when using the map as a navigation tool. In the Luleå-area “Gröna kartan 24L NO”, scale 1:50 000 (50*50 km), the positive deviation is from 5,4° to 5,9°.

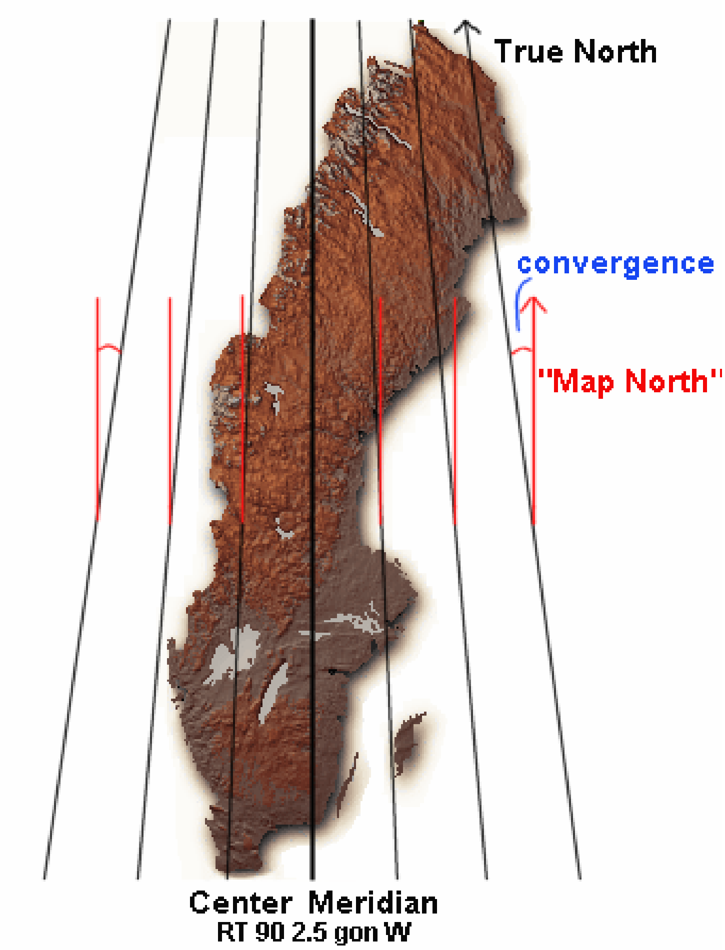


***Figure 3.** Meridian convergence.*

Magnetic false: The magnetic false can be up to 6,5°. This phenomenon occurs since the magnetic north pole isn't the same as the true North Pole. This should also be taken under consideration when navigating.

Example: For position example see above in 2.2.3 Coordinates.

2.2.4 GPS status

Name: GPS status

Purpose: For the user to see if the GPS receives enough satellite data for a position fix and how accurate the fix is.

Description: GPS status describes the current fix-type and estimated position error, EPE.

Position error is indicated with the current overall spherical equivalent position error (estimated position error, in m).

The receiver status will be shown as one of the following conditions:

- Searching − the GPS is looking for any available satellites in view.
- Auto locate − the GPS is initializing and collecting new almanac data. This process can take five minutes, depending on the satellites currently in view.
- Acquiring − the receiver is collecting data from available satellites, it has not collected enough data to calculate the 2D-Fix.
- 2D-Nav − at least three satellites with good geometry have been locked onto and a two-dimensional position fix (latitude and longitude) is being calculated. "2D-Nav" shall appear when this state has been reached.
- 3D-Nav − at least four satellites with good geometry have been locked onto, and position is now being calculated in latitude, longitude and altitude.
- Poor GPS coverage − the receiver isn't tracking enough satellites for a 2D or 3D fix due to satellite geometry, weather or reduced view of sky.

The GPS uses the standard NMEA protocol version 2.0 or version 3.0. This protocol enables the application to get information regarding position, EPE, speed, course, number of satellites etc.

NMEA protocol sentences look like the following:

```
$GPRMC,145418,A,6536.9034,N,02208.8863,E,7.5,205.5,050401,6.9,E,A*1C
$GPRMB,A,,,,,,,,,,,,A,A*0B
$GPGGA,145418,6536.9034,N,02208.8863,E,1,04,2.9,-4.6,M,24.1,M,,*6D
$GPGSA,A,3,,03,,11,,,21,,,,31,,3.4,2.9,1.0*3D
$GPGSV,3,1,11,02,20,334,00,03,29,175,00,09,14,049,00,11,33,268,45*78
$GPGSV,3,2,11,14,27,138,00,18,32,065,00,21,66,110,00,23,26,061,00*78
$GPGSV,3,3,11,26,00,010,00,29,23,146,00,31,54,217,39*48
$GPGLL,6536.9034,N,02208.8863,E,145418,A,A*4F
$GPBOD,,T,,M,,*47
$PGRME,12.8,M,17.0,M,21.8,M*18
$PGRMZ,139,f*0F
$HCHDG,322.8,,,6.9,E*2D
$GPRTE,1,1,c,*37
$GPRMC,145420,A,6536.8997,N,02208.8820,E,7.5,205.5,050401,6.9,E,A*11
```

The sentences needed for first increment is GPRMC, GPGGA, GPGSA and PGRME where position, speed, course, altitude, fix and EPE can be identified.

Example: The GRMC sentence is built like this:

$GPRMC,145420,A,6536.8997,N,02208.8820,E,7.5,205.5,050401,6.9,E,A*11

The data fields are: Time of fix in Universal Time Coordinated (hhmmss), Status (A=OK,V=Warning), Latitude, N/S, Longitude, E/W, Speed over ground (knots), Track made good (degrees true), Date (ddmmyy), Magnetic Variation (degrees, E/W), Checksum.

2.2.5 Display

Name: Display

Purpose: Display entity is needed to know the composition of the screen.

Description: Display describes how map and menu bars etc will be displayed.

Different screens are shown in account of which function that is activated.

Display map function needs to calculate the relationship between number of pixels in width and height at different times that corresponds to the correct length and height on the current scale of the map. When the map is in full extent the number of pixels width and height correspond to the entire length and width of the map. When zooming, the software must calculate the correct length and width corresponding to at which map extent the user is in.

In the software it shall be possible to:

- Zoom in.
- Zoom out.
- Pan.
- Scale.
- Zoom to full extent.
- Center on GPS.
- Lock on GPS.

In this increment it shall be possible to hide the navigation bar and command bar in order to get a full screen view over the map.

Regarding colors, the best performance will be under 8 bit (256 colors) since 24 bit colour takes a lot more space and CPU resources.

2.2.6 Serial Port

Name: Serial port

Purpose: The serial port communicates with the GPS to collect position data.

Description: Serial Port is the port that enables communication with other devices. It is necessary to describe what settings the communication port shall use to open a connection.

Settings that is necessary:

Port, which port to use (usually port number one on PDA's)
Speed, at what maximum rate in bits per second data will be sent through the port (this is usually set regarding to at what rate data will be sent from GPS-receiver, new GPS often has 4800bps).
Data, the number of data bits that each character is sent with (usually 8 data bits).
Parity, enables error checking (is set to none).
Stop bits, changes the time between each character being transmitted (usually set to one).
Flow control, changes how the dataflow is controlled using software or hardware handshaking (set to none).

In the application it shall be possible to set:

- Port.
- Speed, bits per seconds.
- Data.

Other parameters have default settings in software.

Example: When communicating between a Garmin® eTrex Summit to a Compaq® Ipaq the settings will be:

Port: COM1
Speed: 4800 bps
Data: 8 bits
Parity: None
Stop bits: 1
Flow Control: None

3 References

- Handbok till mätningskunggörelsen – Geodesi -GPS, Lantmäteriverket, 1996, ISBN 91-7774-061-0
- Standard for Interfacing Marine Electronic Devices, National Marine Electronics Association, NMEA 0183,Version 3.00, July 1 2000
- Webpage, http://www.lantmateriet.se/, Lantmäteriet 2001-05-18

PeeGee

Increment 1

PDA-GPS TRACKER

Software User Manual

Document Title	**: PeeGee Increment 1 User Manual**
Document Num	**: PeeGee-1-DEV-USERMANUAL-1**
Prepared by	**: Mats Olofsson**
Approved by	**: Christophe Pichon**
Company	**: Ericsson Erisoft**
Created	**: 2001-05-08 09:43**
Modified	**: 2002-01-01**
Version	**: V1**

Table of Contents

1 Introduction

1.1 Purpose

This User Manual is intended to describe usage of the PeeGee1 first increment software from an users point of view.

1.2 Scope

This instruction covers the PeeGee1 first increment User Interface.

1.2.1 Identification

This document complies with:

Software name	PeeGee-1
Version	1.0
Software programmer	Mats Olofsson

The Software is part of a Master thesis preformed during spring and summer 2001.
Instructor is Christopher Pichon and Per Danielsson.

1.2.2 System overview

The idea of the system is to interface a PDA (Personal Digital Assistant) with a GPS (Global Positioning System) device.

The purpose of the system to which this document applies is to provide easy to use software allowing to visually establish a position on a map by using positional information given by a GPS receiver. The visualization is done on a Windows CE based PDA screen. The PDA´s screen shows a map overlapped with symbols to aid positioning and navigation. PDA used during development was a Compaq iPAQ 3630.

Document related to this is:

PeeGee-1 Increment 1 – Software specification

PeeGee-1 Increment 1 – Coordinate transformation – RT 90

1.2.3 Document overview

This document shall describe the usage of the PeeGee software. This program is shareware but is copyright protected to Ericsson Erisoft AB.

1.3 References

See PeeGee software specification, Appendix B in PeeGee master thesis.

1.4 Definitions

Course The course is the direction of travel against true north.

Flattening A Parameter for the ellipsoid. Defined as

$$f = \frac{a-b}{a}$$

where
a = the semi-minor axis (half polar axis)
b = the semi-major axis (equator radius)

Geodetic datum Definition of the reference earth model that is being used. Contains data about:

the ellipsoid used - semi-major axis and the flattening.
the ellipsoid position in reference to earth mass center.
the ellipsoid position in reference to form and position of the geode.

GPS The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS receivers receive signals from different satellites and can calculate a position. It was developed and launched by the US Department of Defense for military reasons but is available for everyone free of charge.

2 Software Summary

2.1 Software application

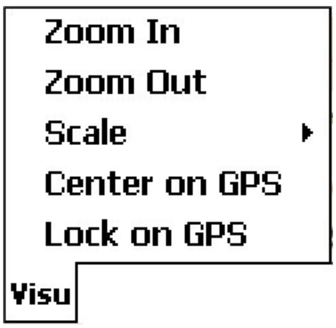
This software is to be used on a Pocket PC with a GPS receiver. It receives signals from GPS via the serialport and enables the user to plot his position on a digital map. The map is scanned and calibrated before loaded into the Pocket PC device and opened in the PeeGee-1 program. PeeGee-1 First Increment only manages the basic functions that are needed for navigation thus a more advanced program with full navigation and visualization possibilities will hopefully be available later.

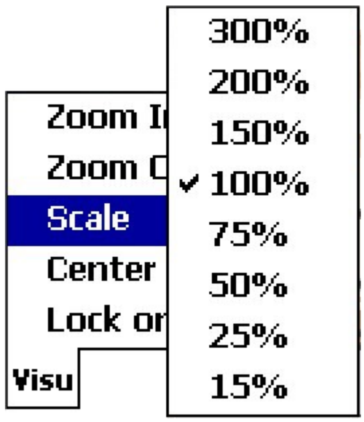
Figure 1. *PeeGee program with a loaded map and a 3D position fix.*

2.2 Menus and symbols

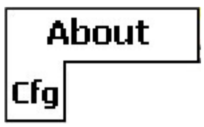
All menus and symbols:

File menu. Opens calibrated and uncalibrated maps and closes the program.

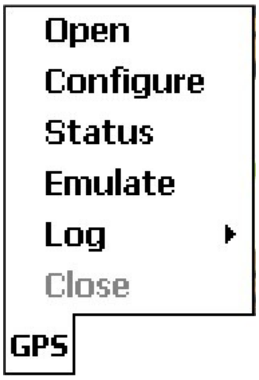


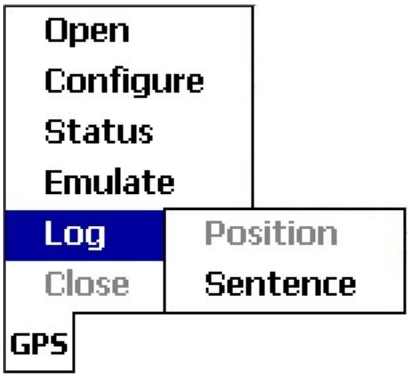


Visu menu. Handles map functions such as zooming in and out or to a preset scale and also center or lock on GPS position.



Cfg menu. Handles About dialog which shows version number, author etc.





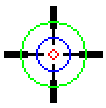
GPS menu. Handles GPS functions such as open and close port for communication, GPS status showing GPS-position speed fix etc and log function to save sentences and later emulate them.

Receiving status symbol — States that no Fix is available.

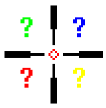
Receiving status symbol — States that a two-dimensional fix is available.

Receiving status symbol — States that a three-dimensional fix is available.

Map symbols:



Position marker — Marks position of GPS when a Fix is available.



Position marker — Marks the last known position where GPS signals where lost.

3 Installing and Configuration

Before installing the user needs a working Active Sync connection with the PDA.

It is only one file that is necessary to download and install.

For installing the ARM version (for example Compaq Ipaq) simply click PEEGEE_ARM.exe and the setup program will start and guide you through the installation. When installation is complete the program can easily be removed and added again from Active Sync.

For MIPS and SH3 CPU download and install PEEGEE_MIPS.exe or FHFG_SH3.exe.

3.1 Supported maps

There are many maps that can be used in the PeeGee program. Any map that has the same scale factor over the whole map and two corners coordinates can be calibrated. That means that virtually every map can be scanned and used in the PeeGee program. First increment will only support map with coordinates in RT90 2.5 gon V 0:-15 grid. Beware though; position error will of course be big if a map covers a large area. Swedish maps are mostly made in Gauss conformal projection with true angles and true length meridian. This means that the further away from the central meridian a map covers the bigger the error will be on the out bounds of the map.

In the first increment the maps top left and bottom right corner coordinates have to be known.

Main purpose with the program is to be able to scan any map that the user wishes to use. Digital maps can of course also be used and often offers easier image handling and better calibration. Swedish Lantmäteriverket sells paper maps as well as digital maps over Sweden in different scales.

Digital maps can be viewed in Lantmäteriverkets program “Kartex” where areas can be selected and exported to file with different file formats such as rik, bmp or tiff. When these areas are selected it is possible to view what coordinates the corners have or even get them in a separate file when saving the image file. Only bitmap (bmp) images are supported by PeeGee but a tiff image can of course be converted to a bmp image in an image program. This simplifies the map handling and a better-looking map is produced. It gives correct calibration values that can be hard to produce when scanning a map.

Note that most maps are copyright protected - follow the law!

3.1.1 Map Scanning

To start navigating with a map the only thing needed is a digital map. If no true digital map is available scanning will easy produce a digital map. Place appropriate map in scanner and scan. See scanning recommendations for details of resolution etc. Limited CPU-power and disk space is always an issue on PDAs; hence try to keep the picture file-size as small as possible. There must be more space available in memory then the size of the map file since the whole map is read into the PDAs memory. Map files over 10 Mb are not recommended.

3.1.1.1 Scanning recommendations

Scanning is a complex subject and this section will only take up a few hints to enable better scanning for maps. First of all try to have the map straight when scanning it, rotating it in scanner/photo program can be tricky. To enable calibration the map must be a square or a rectangle.

For different reasons it may be necessary to scan one part of the map at the time in order to cover the whole map. Different types of scanners used under development have proved to be non-linear. This means that trying to stitch different parts of one map together will end up in problems. A few pixels differ from the size of the scanned map at the top and at the bottom. A way of diminishing this problem is to scan small parts of the map. But still no perfect result will arise. Try to keep these stitching errors as small as possible to get a good calibration. No matter if the map is stitched together or if it is scanned in one part this error will result in the map being not true in scale and affect the position error.

Scanning is best done in 24 bits true colour. When scanning has been done sharpening and gamma correction might be a good idea to enhance the map quality. Convert colour resolution to 8 bits (256 colour) before saving the map to disk. This is done to save space and there are few maps that use more than 256 colours.

Appendix i shows an overview of which maps that could be used for different purposes. These are covering nearby orientation, trekking, bike riding and tourism purposes. It also gives the most appropriate picture resolution and out coming file size for the area coverage indicated by the type of use. Recommendations can be used as a “Rule of thumb” when scanning. File sizes are approximate.

Appendix ii shows a more detailed table with scanning resolution, file size, examples of maps and recommendations covering some of the most commonly used maps in Sweden. This can be used as a guide when trying to get the perfect map for your use. File sizes are approximate.

3.1.2 Map calibrating

Maps can be calibrated to be used for navigation. To calibrate a map the user must know the correct coordinates for the top left and bottom right corner of the scanned (or digital) map. Coordinates at top left and bottom right corner of the map must be as exact as possible to enable a good calibration. The user must then create a file which is called “map file name”.cm, where the “map file name” is replaced by the map file name of the users map.
Please note again that calibration coordinate values must be correct otherwise no correct position can be plotted. Calibration file will in later increments of PeeGee be made in the PeeGee Prep Tool where preparation of maps will be possible. For now the user has to make a .cm file by hand in Notepad or a similar program where it’s possible to save an ANSI text file. In first increment the only thing read from the .cm file are the coordinates. It is however important that the file follows the structure below to ensure that it is read correctly by the program. No words should be separated by space. If coordinates include decimal values they should be separated by a dot (“.”) and not a comma (“,”).

To create a .cm file the user must do the following:

1. Open Notepad (or similar program).

2. Type in the word “PeeGee” on the first row, press Return.

3. Write the name of the grid, press “TAB” key and type “Grid”, press Return (since only RT 90 2.5 Gon V the name of grid would be: RT90_2.5_gon_V_ 0:-15).

4. Type the name of the bitmap file, press “TAB” key and type “RawBitmapFile”, press Return.

5. Now type in the important position, start with x-coordinate of the top left position, press “TAB” and type XposTopLeft, press Return. Repeat this step for all four coordinates; see example below.

6. Type map scale followed by “TAB” and the word “MapScale” and Return.

7. Type resolution of map file followed by “TAB” and the word ”Resolutiondpi” and Return.

8. Save file as a ANSI file, with Bitmap file name and the extension .cm.

9. Put .cm file in the same directory on the PDA as the map bitmap file.

Example: The Swedish “Gröna kartan 24L NO” made by Lantmäteriverket covering the area of Luleå has a scale of 1:50 000. The top left corner of the map is in RT90 coordinates; X: 7300000,Y: 1775000 and bottom right corner X: 7275000, Y: 1800000.

Top coordinates will be placed first with the x value first.
The bitmap file that has been produced from scanning of the map has the name "lulea.bmp". The calibrated map file with name "lulea.cm" will therefore look like the following:

```
PeeGee
RT90_2.5_gon_V_ 0:-15      Grid
lulea.bmp           RawBitmapFile
7300000             XPosTopLeft
1775000             YPosTopLeft
7275000             XPosBottomRight
1800000             YposBottomRight
1:100000            MapScale
315                 Resolutiondpi
```

4 Program usage

When application has been successfully installed on the PDA the program can be started from the “Start-menu”. The PeeGee splash screen will show and program will open.

4.1 Load map

4.1.1 Load map

It is possible to load a non-calibrated map and explore it (zoom, pan etc). No navigation or positioning will be possible on the map though.

1. Press File menu on the command bar.
2. Select Map. A submenu opens.
3. Select Open on the submenu.
4. Choose the appropriate directory and choose map.

Map will open and display on the screen when it has been read into memory.

4.1.2 Load calibrated map

When a calibrated map has been made (see Calibrated maps in section 3) it is possible to open the map for navigation.

1. Press File menu on the command bar.
2. Select CMap. A submenu opens.
3. Select Open on the submenu.
4. Choose the appropriate directory and choose map.

Map will open and display on the screen when it has been read into memory.
When starting to receive GPS sentences the position will automatically be plotted on the Map.

4.2 Establish first connection to GPS

Connect cables between the serial port of the PDA and the GPS-receiver, see GPS receiver User Manual for details on cables etc.

For connection between Compaq Ipaq 3630 and Garmin eTrex Summit use a serial 9-pin connector male PC Interface Cable from Garmin, a USB to serial 9-pin male connector from Compaq and between them a two way female serial 9-pin connector with switched Transmit and Receive data pins.

Set GPS receiver on output for NMEA sentences. On Garmin e-trex this is made through the setup menu on the main menu page and interface menu on the setup page, choose NMEA OUT from I/O Format menu. Baud rate is set to 4800. Be sure to check baud rate on device to ensure that a correct connection is established.

1. Press the GPS menu in the PEGEEE program and select Configure.

   The first time this is done a message box appears telling the user that old values could not be loaded from the registry.

2. Press OK.

   A dialog box appears and user can choose:

which com port to use —	in almost every case COM 1.
how many databits —	default value is 8.
what baud rate to use for communication —	here it is very important that the same value is used as the baud rate the GPS receiver sends with (on Garmin eTrex 4800, see above).

3. Press OK.

Values is stored in the Registry and the next time the configuration dialog box is opened these values will be default.

Configuration only has to be done once (as long as program is not reinstalled or hardware is changed).

4.3 Open port

Open port when cables has been connected

1. Press GPS menu.
2. Select Open.
3. Put on the GPS receiver.

GPS status screen open automatically and shows the status of the GPS. If everything works the position values will be shown after the GPS has located satellites. If no position can be seen the status screen value “Fix” should read “Tracking satellites” if the connections work but no position can be established. Move to an area with clear view of the sky.

To exit from GPS status screen press OK.

If a Calibrated Map has been loaded the position will be plotted on the map.

4.4 Zoom

When a map is loaded it is possible to zoom in and out in the map. There are two ways of doing this, Zoom in/out and the Scale function.

4.4.1 Zoom in/out

1. Press Visu menu on command bar.
2. Select Zoom In or Zoom Out.

Program will now enhance or decrease the map size. Repeat for further zooming.
When maximum zooming has occurred menu option Zoom In or Zoom Out is grayed.

4.4.2 Scale

1. Press Visu menu on command bar.
2. Select Scale. A submenu with zooming level in percent appears. Current scale is marked.
3. Press wanted zoom level.

4.5 Pan

When a map is loaded it is possible to move the view of the display. Simply put stylus on screen and move towards the direction wanted.

4.6 Full screen

To get optimal screen size of map it is possible to obtain full screen. Double tap on the map and the command bar and status bar will disappear. To get back to normal view double tap once more.

4.7 Center on GPS

To move and center the map on the current GPS position:

1. Press Visu menu.
2. Select Center on GPS.

Map moves and centers on the current GPS position.

4.8 Lock on GPS

To lock the position in the center and have the map to move when position has changed.

1. Press Visu menu.
2. Select Lock on GPS.

Map will now move and center on the current position keeping the position centered when position has changed. To unlock, the user has to go back to Visu menu and deselect Lock on menu.
Note that no paning will be possible when Lock on GPS function is active since program keeps map automatically locked constantly.

4.9 GPS status

GPS status screen shows different useful navigation values.

1. Press GPS menu.
2. Select Status.

Status screen opens and shows the following information:

- Last known X and Y coordinates.
- Estimated Position Error from GPS – EPE.
- Fix that is currently available –Tracking satellites, 2D-Nav, 3D-Nav or differential GPS.
- Current speed.
- Current course.
- Current Altitude.

4.10 Emulate

If GPS sentences have been saved during a session with the GPS and PDA it is possible to run an emulation of that session. Emulation will discard speed etc and simply run the positions from start to end and repeat until Emulate is deselected.

1. Press GPS menu.
2. Select Emulate.
3. Select the ASCII text (.txt) file that has the GPS sentences.
4. After reading the sentences into memory the program will run the position mark over the session until Emulate is deselected.

Note - Port has to be closed under Emulation. End emulation before opening port and receiving GPS-sentences.

4.11 Log file

This function is for logging GPS sentences that comes in through the port. This text file can later be used to emulate a GPS session. Remember that a long logging time will generate big files. Program will only handle a certain amount of positions.

1. Press GPS menu.
2. Select Log.
3. State the name of file and where it will be stored.
4. Press OK.
5. To stop logging select Log from GPS menu once again.

4.12 Close Map

To discard a map and erase it from memory:

1. Press File menu.
2. Select Map or CMap.
3. A submenu with Open and Close appears.
4. Select Close.

If the purpose of closing a map is to open another one this closing is also done automatically when opening a new map.

4.13 Close Port

To close port:

1. Press GPS menu.
2. Select Close.

A Message Box reading “Port Closed” appears if everything is normal.

4.14 Exit

To end PeeGee:

1. Press File menu.
2. Select Exit.

If the serial port is still open it will close before ending.

5 Troubleshooting

Possible errors and possible reasons why they arise.

Error	**Answer**
No GPS position is shown.	Check reception of satellites on the GPS. Check that cables are connected correctly. Configure the serial port according to this manual. Be sure to have a Calibrated Map as underlay.
Position symbol shown with question marks.	Last known position is shown with that symbol, check connection to GPS and check that GPS is running and have a satellite lock.
Not possible to open the serial port.	The port is already open or an error in the program has occurred, reset the PDA and try again.
Bitmap not opened.	Something wrong in the bitmap or the bitmap is to big. Look if it is enough memory on the device to load the bitmap. Free Memory, make a new smaller bitmap or try to reload the bitmap from PC.
Could not open cm file.	A Calibrated Map must have a cm file with the same name as the map in order to make it possible to plot position. Check that a cm file exists and is in the same directory. Investigate if the content of the cm file is correct; see this manual.
Accuracy of the map position	Position accuracy depends on many things. GPS signals can be as accurate as up to 5 meters but can also be 100 meters depending on satellite reception and if the Selected Availability is activated by the US Department of Defense. The map position also depends on map, map scale and calibration.
Navigation without a map	It is possible to navigate without a map as an underlay. Open the serial port and start the GPS,

GPS status view will now show and the user can se position coordinates, speed, course etc.

Appendix i: Map scan resolution, Rule of thumb

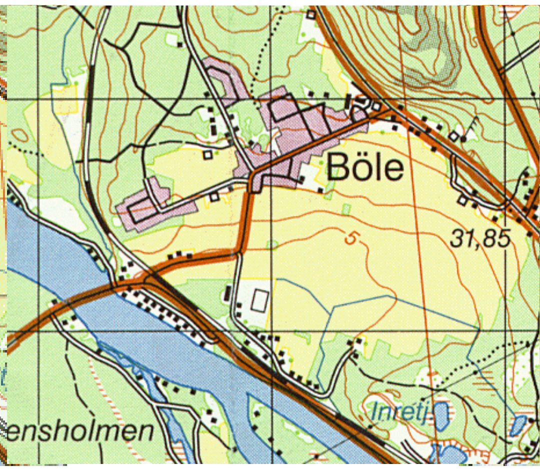
Type of use	Area coverage	Recommended map scale	picture resolution	Picture size
Nearby orientation, city walking / cycling	10*10= 100 km2	1:12 500 (Fastighetskartan)	105 dpi	13000 KB
		1:50 000 (Gröna kartan)	315 dpi	3000 KB
Trekking - foot activities	25*25 = 625 km2	1:50 000 (Gröna kartan)	210 dpi	8000 KB
		1:100 000 (Fjällkartan, Blå kartan)	315 dpi	9000 KB
Cycling / Snowmobile / Sailing	70*70 = 4 900 km2	1:100 000 (Fjällkartan, Blå kartan)	105 dpi	8000 KB
		1:250 000 (Röda kartan)	160 dpi	8000 KB
		1:500 000 (Översikts Sjökort)	256 dpi	10000 KB
Tourism - land-wheeled activities	200*200 = 40 000 km2	1:1 000 000 (Road /Country maps)	105 dpi	13000 KB
		1:1 000 000 (Road /Country maps)	144 dpi	13000 KB

Appendix ii: Map scan resolution, Detailed

Map name	Map scale	dpi	Color depth	File-format	Size of map	File-size	File-size A4	Recommendations
					Area:6776 km^2		Area:616 km^2	
Fjällkartan	1:100 000	105	8 bits (256colors)	bmp	ca: 88*77=6776 cm^2	10000 KB	1000 KB	For whole map 6776 km^2
Fjällkartan	1:100 000	210	8 bits (256colors)	bmp	ca: 88*77=6776 cm^2	44000 KB	4000 KB	For A4 / 616 km^2, saving space
Fjällkartan	1:100 000	315	8 bits (256colors)	bmp	ca: 88*77=6776 cm^2	99000 KB	9000 KB	For A4 / 616 km^2
					Area:625 km^2		Area:154 km^2	
Gröna kartan	1:50 000	204	4 bits (16 colors)	bmp	50*50=2500 cm^2	8000 KB	2000 KB	
Gröna kartan	1:50 000	144	8 bits (256colors)	bmp	50*50=2500 cm2	6000 KB	2000 KB	For whole map 625 km^2, saving space
Gröna kartan	1:50 000	160	8 bits (256colors)	bmp	50*50=2500 cm2	10000 KB	2500 KB	For whole map 625 km^2
Gröna kartan	1:50 000	204	8 bits (256colors)	bmp	50*50=2500 cm2	16000 KB	4000 KB	
Gröna kartan	1:50 000	256	8 bits (256colors)	bmp	50*50=2500 cm2	25000 KB	6000 KB	For A4 / 154 km^2, saving space
Gröna kartan	1:50 000	300	8 bits (256colors)	bmp	50*50=2500 cm2	34000 KB	9000 KB	For A4 / 154 km^2
					Area:25 km^2			
Fastighetskartan	1:12 500	160	8 bits (256colors)	bmp	40*40=1600 cm^2	6000 KB		For whole map 25 km^2, saving space
Fastighetskartan	1:12 500	210	8 bits (256colors)	bmp	40*40=1600 cm^2	11000 KB		For whole map 25 km^2
Fastighetskartan	1:12 500	300	8 bits (256colors)	bmp	40*40=1600 cm^2	22000 KB		

Gröna kartan 144 dpi

Gröna kartan 256 dpi



Fastighetskartan 160 dpi

Fjällkartan 105dpi