

# Using Linux on a Handheld Device: an Obstacle Course?

Merciadri Luca

Luca.Merciadri@student.ulg.ac.be

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**Abstract.** As more and more (principally free) Linux PC-distributions (commonly called “distro’s”) are appearing on the Internet, a lack is observed for handhelds’ Linux distributions, especially for Pocket PC’s ©. This article summarizes the most important (and recent) points about this fact, and tries to cover the whole subject with not-too-technical details, giving a basical overview about the different O.S. which are available for handhelds devices.

**Keywords:** Linux, Pocket PC, Palm, handheld devices.

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## 1 Introduction

### 1.1 The Context

More and more (principally free) PC-distributions (commonly called “distro’s”) are appearing on the Internet. For example, just throw a glance to <http://www.distrowatch.com/>. These distributions are often Linux-based ones, and are much appreciated by the *public*, essentially because of the prohibitive prices of other commercial O.S. Thenceforth, free distro’s are now widely spread, and it is not going to stop now.

The same phenomenon is noticed when looking at the softwares, as more and more free softwares are used.

However, the handheld devices’ community<sup>1</sup> is a little bit disappointed, because of the lack of Linux-based O.S. for these special computers.

The most of the current handheld devices (Personal Digital Assistants (PDA), smartphones, ...) are, when bought, pre-installed. By “pre-installing,” we want to say that the manufacturer’s O.S. is already installed when purchasing the product. It is a scheme which is comparable to the one in laptops’

and netbooks’ market. Like in PC’s domain, this is a facility for some (essentially *amateur*) users, and an inconvenience for others.

Anyway, it is clear that handheld devices are commonly used for various purposes, mainly by users who *need* such devices for their everyday work. They are often businessmen, persons working in marketing, physicians, physicists, researchers, ..., and they absolutely *need* their handheld device for evident working reasons. These persons do *count* on their handheld devices, and thus want powerful and reliable operating systems and softwares, to make the most of their device, thus making the most of their job, if possible.

Unfortunately, the operations which can be carried on these handheld devices with pre-installed O.S. are often limited because of operating systems’ and softwares-inherent limitations. It is more noticeable on Pocket PC ©’s than on smartphones, because there are lots of O.S. for smartphones (by decreasingly-order importance): Symbian OS ©(with 67% of marked parts), Windows Mobile ©(13%), BlackBerry ©(10%), iPhone OS ©(7%), Palm OS ©, Linux (5%: LiMo, Android, OpenMoko)

<sup>1</sup> We will precise in the next paragraphs what it consists of.

[3]). That is why we will focus on Pocket PC and non-smartphone devices in this paper.

In addition to this limit, O.S. problems is frequent when using handheld devices, and this should not be the case.

Absurd situations do also occur: for example, if you buy a given powerful model one year, and that, following(s) year(s), a new O.S. is developed, there will be two disappointing kinds of situations you will have to cope with:

1. If you are lucky, the new O.S. has also been ported to your device (in the worst cases of this point, it is “only supported”) and you can *buy* a copy of this O.S. for your device. If you are really lucky, it will be in your desired language, but, habitually, it is only ported in English. Anyway, it is clear that your device’s warranty will be lost;
2. Otherwise, you have –according to the manufacturer– to keep your old O.S., and you are thus blocked if you want to enjoy new capabilities your device supports, but the old O.S. it is powered by are not right with.

Furthermore, pre-installed O.S. are sometimes somewhat confusing, because of the lack of conscientiousness teams conceived the O.S. with.

For these reasons, users do often feel satisfied neither by the O.S. which was already pre-installed on the device they acquired, nor by the after-sales service. Anyway, they have bought the company’s product, and the company has nothing to do with them yet.

## 1.2 The Reaction

There are many remedies to such software incomprehensions. Looking for better solutions, consumers often become frustrated, realizing the lack of handheld-available O.S. (except for smartphones). For essentially *amateur* users, they are then tempted to buy other kinds of devices, hoping being better satisfied. For “others,” it is generally not the case, as, in reaction to the insatisfaction coming from the available and user-accessible O.S., or available softwares, more and more users turn towards free Unix-based distributions, whatever the platform. This is marked with PC’s: there is an upsurge in terms of Linux users. On Pocket PC’s ©, we can cite the Mozilla Minomo © project ([10]) (see

<http://www-archive.mozilla.org/projects/minimo/>), which is an alternative to the Pocket PC’s pre-installed Microsoft Internet Explorer © navigator. On other PC’s, Mozilla Firefox © (see <http://www.mozilla-europe.org/en/firefox/>) is also widely used amongst computers’ users, concurrencing Microsoft Internet Explorer ©. It is the same with The Gimp © (see <http://www.gimp.org>), which is free: the old Microsoft Paint © has nothing to do with it. Other Pocket PC’s (sometimes free) softwares are often better than the pre-installed programs, and it is also inadmissible, because, when purchasing your product, you need to have *useful* pre-installed softwares, albeit marketing publicity.

Unfortunately, in 2004, only 0.9 % of the PDA were Linux-powered ([29]).

We here center this document on the case of the Pocket PC’s © PDA platform. Thus, we shall speak mainly about Pocket PC’s © devices, and Windows © CE-powered handheld devices. A brief incursion is done in the next section about Palm © handheld devices, to give a complete overview of the field.

## 2 Palm © Devices

For the case of *Palm* © handheld devices, many attempts to run Linux on various models were achieved with success (consider, for example, [14]).

Furthermore, the Palm © enterprise seems to be inclined to work with Linux-based O.S., as they are building a new smartphone, using an OpenEmbedded-Linux, called WebOS (see [9,12]).

There are other projects. For example, consider [8], on <http://palmtelinux.sourceforge.net/>, even if last modifications date of 2006/07/29.

Opie has also been ported to Palm ©: consider [7], for example. For screenshots, see Figure 1.

## 3 Current Available Distro’s for Pocket PC’s

When we were looking on the Internet, we encountered many handheld’s users’ posts, containing questions about the way Linux could be installed on their device. When correct<sup>2</sup> answers are given to these somewhat desparate messages, a traditionally-given link is <http://www.handhelds.org>. This link is often given because this website is plentiful (compared to others, at it is not so comprehensive *per se*)

<sup>2</sup> We here consider the answers advocating the uselessness of Linux-powered devices as incorrect, and uncalled-for.

of pieces of information about the most prominent handhelds' O.S. We shall now discover step-by-step every currently-known distro.

As the project of adapting Linux distributions to handheld devices such as the one we spoke about seems very exciting, most projects have often tumbled.

For example, I decided to subscribe to a good-looking newsletter –whose name won't be revealed–, which aim was to warn me about news on Linux developments for my handheld device. Thus, I decided to subscribe using my “good-mails” adress, where others aim to filter spam. Some days after my inscription, I was receiving, every day, lots of spams, about things which had completely no links with the computer universe. Once again, it corroborates the fact that these projects are often –unfairly– abandoned.

### 3.1 Familiar

The *Familiar*<sup>3</sup> distro was last updated 2007/03/08. It is under GNU GPL license, and has two user environments (interfaces), called GPE and Opie, described as “containing full PIM suite and other applications.” Their full package management is said to be based on `ipkg` (which is like the `dpkg` utility on Debian, and `yum` on CentOS and Red Hat-like PC's distro's). According to [26], `ipkg` files are collected into *feeds*<sup>4</sup> or *releases*. A Dropbear SSH server is also said to be included by default.

However, the last stable release was v0.8.4 ([21]), and dates back to 2007/03/08.

**GPE** We here give the definition of GPE written in [19], adapted to this article. “The *GPE* Palmtop Environment provides a user interface environment for Palmtop/handheld computers running the GNU/Linux or any other UNIX-like operating system. GPE is not a single piece of software, but an entire environment of components which aim to make it possible to use a GNU/Linux handheld for standard tasks such as Personal Information Management (PIM), network access and multimedia and various other purposes. Apart from its main focus to

provide a GUI environment for Palmtop/handheld computers it is useful on all sorts of mobile devices with only limited resources.”

“In addition, GPE provides an infrastructure for both easy and powerful application development and good compatibility to existing desktop solutions. GPE uses the X Window System, and the GTK+ widget toolkit. Besides providing core software such as shared libraries, and perhaps more importantly, the GPE environment defines standards for program design and interaction. It is based on the C programming language and other common standards such as SQL, XML, DBUS” ([19]).

After some research on the Internet, we discovered the GPE's new website: <http://gpe.linuxtogo.org/>. There, they say that “GPE provides an infrastructure for easy and powerful application development by building on available technology including GTK+, SQLite, DBUS and GStreamer and several more common standards” ([5]).

It seems very interesting. On <http://gpe.handhelds.org/> no modifications were made since 2006/05/03. *Per contra*, on <http://gpe.linuxtogo.org/> the last modification dates of 2008/10/23. For screenshots, see Figures 2 and 3. To make an analogy, GPE is equivalent to the well-known GNOME desktop environment, for PC's.

**Opie** We here give the definition of Opie typeset in [24], adapted to this article. “The Open Palmtop Integrated Environment (Opie) is a completely Open-Source based graphical user environment and suite of applications for PDA's and other devices running Linux. It is included in various embedded Linux distributions such as Ångström, Familiar, OpenSIMpad, and OpenZaurus<sup>5</sup>” ([24]).

Once again, it seems interesting. Here, last modifications date back to 2008/09/30.

The key highlights of Opie are given in [22], and are principally, in a category-classified way:

**Opie Desktop** – Sophisticated PIM framework (including an easy to use access API) with

<sup>3</sup> See <http://handhelds.org/familiar/> for news, screenshots, and more pieces of information.

<sup>4</sup> According to [26], a *feed* is just a collection of “ipkgs” that is accessible via HTTP, FTP, or the local filesystem along with a “packages” file that contains the description of the latest version of each “ipkg” in the feed.

<sup>5</sup> Note that Familiar, OpenSIMpad and OpenZaurus are in the *OpenEmbedded* project, whose website is <http://wiki.openembedded.net/>. This project allows developers to create a complete Linux Distribution for embedded systems ([9]).

- address book, to-do list, today, mail, draw-pad, datebook, texteditor and search-all-facility;
- Full network setup support through plugins (WLAN, Ethernet, PPP, IrDA);
- Network based installation and setup management;
- Linux shell/terminal providing access to the operating system (for those<sup>6</sup> who care);
- Adaptive backlight settings and calibration (for devices with light sensors);
- Multiple input plugins to ease data input;
- Network time support and time correction capabilities;
- Advanced security supporting Linux security services;
- Backup and Restore capabilities to CF/SD cards;
- Data exchange with Palm’s, Pocket PC’s, mobile phones and other Bluetooth/IrDa capable devices;
- Fully localized;
- Themes and styles to adapt look and feel to your personal flavor.

- Opie Applications** – Today application featuring plugins for dates, to-do’s, mails, birthday’s, weather and stock values;
- Multimedia capabilities provided by `xine`, based upon `opieplayer2` (featuring audio and video streaming) and image viewer;
  - Palm doc compatible opie-reader for eBooks’ reading;
  - PDF reader based on `xpdf`;
  - IRC client, Konqueror web browser and mails’ reader;
  - Synchronization with KDE PIM/Kolab, Microsoft Outlook © and Qtopia Desktop;
  - Voice memos;
  - ...

Opie is also said to run on various devices. The more common ones are ([23]):

- Hewlett-Packard iPAQ’s ©: h36××, h37××, h38××, h39××, h54××, h55××, h22××, h191×, h194×, h4×××;
- Siemens Simpad ©: CL4, SL4, SLC, T-Sinus;
- Sharp Zaurus ©: SL 5x00, SL 6000, C7x0, C8x0, C1000, C3x00;

- Palm Tungsten ©(T/T2/T3/T5/C/E/E2), LifeDrive, TX, Zire 71/72, Treo 600/650/680/700w/700p/750/755p, Foleo;
- HTC Universal ©;
- Motorola EZX © A780, E680;
- GMate YopY ©;
- M&N Ramses ©;
- Many ×86 PC’s and notebooks.

Opie’s minimal hardware requirements are given as follows ([23]):

- x86 or ARM processor;
- touchscreen with a minimal resolution of 320 × 240;
- 10 MB of flash memory.

Opie seems also to run on some smartphones (consider [18]), even if there were no updates there since 2003. For general screenshots, see Figures 4 and 5. To make an analogy, Opie is equivalent to the well-known KDE desktop environment, for PC’s.

### 3.2 Intimate

The *Intimate* distro is said to be “a fully Debian-based Linux distribution for the Compaq iPAQ ©” ([17]).

“It takes the work being done by the Familiar Project, and combines it with Debian package management, and access to the thousands of existing Debian ARM packages. The goal is simple: associating the best of both worlds. The minimum requirements are currently around 140 MB of storage for the base image” ([17]).

Despite these seductives sentences, when looking at <http://intimate.handhelds.org/news.html>, the project’s page, one notices that no more news have been written since 2005/05/20. For screenshots, see Figure 6.

### 3.3 Ångström

The *Ångström distribution* was started by a small group of people who worked on the OpenEmbedded, OpenZaurus and OpenSimpad projects to unify their effort to make a stable and userfriendly distribution for embedded devices like handhelds, set top boxes and network-attached storage devices and

<sup>6</sup> It means that you are not obliged to use the terminal for everyday tasks.

more ([13]). Ångström is actually based on OpenEmbedded.

It is now able to work with Opie and GPE user environments ([2,13]). For a screenshot, see Figure 7.

### 3.4 OpenZaurus

The *OpenZaurus* project is an alternative O.S. for the Sharp Zaurus © handheld device. It is based on the Debian distro, and the two available graphical environments are (again) GPE and Opie. The Sharp Zaurus was the first PDA working under Linux and having a big success ([30]). Unfortunately, their website became unavailable (<http://www.openzaurus.org/>) many times. It is now working, but the project is dead, by lack of developers, as said in [11]. OpenZaurus was under GNU GPL license.

### 3.5 Debian-Based Projects

Some *aficionados* have also tried to port “as much as possible” Debian to handheld devices, such as Pocket PC’s ©. It is done from scratch, using *debootstrap*. Anyway, no remarkable results have still emerged.

## 4 Where We Are

Clearly, two distributions are promising: Familiar and Ångström, either using GPE or Opie front-ends.

Interesting documents are [26,28], where (practical and) technical pieces of information are given about how to get started with Linux on an Hewlett-Packard iPAQ ©. The Familiar and Ångström distributions are the central point of view of this document. We shall now give the most general and prominent news, presented in these two documents, which are only related to Familiar.

### 4.1 Ways of Installing Linux on an iPAQ – Familiar

**Native Install** It is known that the Windows CE is installed in the ROM of the iPAQ Pocket PC ©. Anyway, it can be replaced, furnishing a *native install*. For<sup>7</sup> this, you typically need

1. The Compaq © *bootldr*, which is a firmware<sup>8</sup> that can boot Pocket PC © or Linux from flash ROM;
2. Then to install Linux on the iPAQ ©, by
  - (a) Using Microsoft ActiveSync © to copy *bootldr*, and *BootBlaster* to the iPAQ ©;
  - (b) Using *BootBlaster* to install *bootldr*;
  - (c) Installing *task-bootstrap* via the serial port or from a CF card;
  - (d) Trying to install the network to install the rest of packages.

**External Install** It seems less dangerous to use an *external install*, such as a CF install. It is also basically done using Compaq © *bootldr*. Here is the procedure to follow to boot Linux from CF card:

1. Using Microsoft ActiveSync © or the network to copy *bootldrlinux.zip* to the iPAQ’s © CF card;
2. Unzipping *linux.zip*;
3. Running *BootBlaster* from CF card to install *bootldr*;
4. Pushing the reset button of the iPAQ ©;
5. Pushing the “Q<sup>9</sup>” button to boot Linux from *vfat*.

**Dual-Booting** According to [26], “The safer way to install Linux on your iPAQ © device would be to use a dual-booting, but it seems to be still a bit troublesome, as Pocket PC’s keep most user files in DRAM. When Linux is booted, it uses all of DRAM, overwriting any user data that Pocket PC’s had there. We have a scheme in mind where DRAM could automatically be copied to disk before booting Linux and restored from disk before rebooting Pocket PC’s, but it is currently unimplemented. It might also be possible to partition DRAM so that Linux did not touch Pocket PC’s user data, but we do not know enough about how Pocket PC’s use DRAM to know whether or not this is feasible.”

There is also the CyaCE utility, but no pieces of information are available on the Internet, except the name of this subject, and the URI <http://www.handhelds.org/download/projects/cyace/>. This project seems also to be abandoned.

<sup>7</sup> For complete instructions, including how to install the *BootBlaster* via Microsoft ActiveSync ©, please read [26].

<sup>8</sup> And is very useful, according to [28], to backup everything on the Pocket PC iPAQ ©.

<sup>9</sup> “Q” is the second button from right on the most of iPAQ ©.

## 4.2 Warnings – Familiar

**Installing Without Danger** According to [26], it must be noted that

1. Installing the `bootldr` or Linux on the iPAQ © will cause loss of user data and applications from the Pocket PC ©;
2. Linux on the iPAQ © is not currently supported by the Compaq © support organization;
3. Installing Linux or reinstalling PocketPC can sometimes render the iPAQ © unbootable (it is then called “a brick”).

## 4.3 Warnings – Ångström

As presented in [15], backing up the data on the Pocket PC © is essential. Linux, once booted, uses the entire device RAM for its operation. That means that when booting, all of the previous contents of the RAM is lost. As pre-WinCE5 devices used RAM as kind of RAMdisk to store important settings and user data, they will be lost after booting Linux. Or in other words, booting Linux is the equivalent of hard resetting the device (and often to boot, it is needed to perform a hard reset first, as boot procedure requires some deal of free memory, which not every user has all the time). With post-WinCE5 devices, the situation is less clear: they store most of the data in flash; and still, they are known to keep at least some settings in RAM ([15]).

If backups are done, as described above, there is virtually zero chance of data loss. Still, there always may be obscure bugs and circumstances leading to unpredictable results. So, as usual, “PERFORMING LINUX INSTALLATION AT OUR OWN RISK” is the usual sentence ([15]).

Anyway, Ångström gives the opportunity of using something like a LiveCD ([15]): a file is downloaded, put where you want it to be (e.g. on a memory card, or even on the flash disk). Finally, users without a flashdisk and lacking a card can try to copy it to RAM with ActiveSync and start from there. Caveat: a LiveRamdisk is big, and requires as much big memory to startup. So, even devices with more than 64

megabytes of memory may have troubles running in such way.

For example, to install Ångström for everyday use, flashing it to the internal FlashROM is needed. Another solution would be to create a dedicated partition on a memory card. Both options are complicated, and flash install is supported only for small subset of older devices. So, to the rescue comes installing using a loopback image. “Installing” is a strong way to say it, as the whole loopback image is prepared for you already. You download it, and uncompress on your card (to the root directory). You also download an Ångström bootmanager, packaged as an `.exe`, and you put it somewhere you can run it from (the easiest place to put it is the root of the card, too).

Then, you start the bootmanager, and in few seconds it shows you the menu of the boot locations available. You would only have a single, loopback source (ignore NFS and any other options you might have). Once you made your selection (cursor keys, then action button to confirm), Ångström will start to boot.

## 4.4 Others Special Things

By installing Linux, whatever the platform, you are assumed to have some prerequisites and a kind of “general knowledge” about computers and Linux systems. Evidently, it also applies on handheld devices.

For example (e.g. with Familiar), to transfer files to the Linux-powered iPAQ ©, using `zmodem` (resp. accessible for reception and sending *via* the `rz` and `sz` commands) has to be common: Microsoft ActiveSync © is a proprietary technology, and, as said in [28], it has to be disabled to use a Linux-powered handheld device with a PC running Linux, for compatibility reasons.

Thus, communications are most often established using PPP (Point to Point Protocol), which provides a way to use TCP/IP over a serial line ([28]). Anyway, cardbus cards are no longer supported ([26]).

## References

1. *Angstrom Distro - Desktop*. <http://www.flickr.com/photos/28573526@N00/577070961/>.
2. *AngstromFaq - GoWiki*. <http://linuxtogo.org/gowiki/AngstromFaq/>.
3. *Canalys: 115 millions de smartphones écoulés en 2007*. <http://www.generation-nt.com/canalys-perspectives-smartphones-2007-actualite-67815.html/>.

4. *GPE Screenshots*. <http://gpe.linuxtogo.org/gallery/gallery/albums.php/>.
5. *GPE: The GPE Palmtop Environment*. <http://gpe.linuxtogo.org/>.
6. *Intimate Screenshots*. <http://intimate.handhelds.org/images/screens.html/>.
7. *Linux corriendo en una Palm TX La PDA de tungsteno*. <http://www.pdatungsteno.com/2007/11/12/linux-corriendo-en-una-palm-tx/>.
8. *Linux on Palm Tungsten E*. <http://palmtelinux.sourceforge.net/>.
9. *Main Page - Openembedded*. <http://wiki.openembedded.net/>.
10. *Minimo project page*. <http://www-archive.mozilla.org/projects/minimo/>.
11. *OpenZaurus*. <http://www.openzaurus.org/wordpress/>.
12. *Palm présente un téléphone tactile sous Linux - Actualité sur Journal du Net Solutions*. <http://www.journaldunet.com/solutions/systemes-reseaux/actualite/palm-presente-un-telephone-tactile-sous-linux.shtml>.
13. *The Angstrm Distribution — Embedded power*. <http://www.angstrom-distribution.org/>.
14. *TheGlu's Blog: "Que faire avec un Palm? [1/2: installer linux]"*. <http://blog.theglu.org/index.php/2008/07/07/que-faire-avec-un-palm-12-installer-linux/>.
15. *WinCeQuickInstall - GoWiki*. <http://www.linuxtogo.org/gowiki/WinCeQuickInstall>.
16. *iPAQ Linux Overview*, 2001. Compaq.
17. *The Intimate Project*, 2001. <http://intimate.handhelds.org/>.
18. *QUASAR Communication Technology Holdings Limited*, 2003. [http://www.quasarcomm.com/en/p\\_qsp02.htm/](http://www.quasarcomm.com/en/p_qsp02.htm/).
19. *GPE: The GPE Palmtop Environment*, 2006. <http://gpe.handhelds.org/>.
20. *Opie 1.2*, 2007. <http://opie.handhelds.org/gallery/main.php/v/opie12/>.
21. *the Familiar Project*, 2007. <http://handhelds.org/familiar/>.
22. *Features - Opie*, 2008. <http://opie.handhelds.org/cgi-bin/moin.cgi/Features/>.
23. *Hardware - Opie*, 2008. <http://opie.handhelds.org/cgi-bin/moin.cgi/Hardware/>.
24. *News - Opie*, 2008. <http://opie.handhelds.org/cgi-bin/moin.cgi/>.
25. *Ben's Linux CE work*, 2009. <http://skyscraper.fortunecity.com/arpanet/47/lince.html/>.
26. HICKS, JAMEY, *How to Run Linux on iPAQ Handhelds*. (<http://www.handhelds.org/handhelds-faq/handhelds-faq.pdf/>).
27. LITTLER, JOHN, *Linux on Pocket PCs*, 2003. [http://www.linuxdevcenter.com/pub/a/linux/2003/11/13/linux\\_pocket\\_pc.html/](http://www.linuxdevcenter.com/pub/a/linux/2003/11/13/linux_pocket_pc.html/).
28. STEMPIN, MICHEL, *The Linux iPAQ HOWTO, Instructions for Familiar v0.5.3*. 2002.
29. WIKIPEDIA, *Assistant personnel - Wikipédia*. [http://fr.wikipedia.org/wiki/Assistant\\_personnel/](http://fr.wikipedia.org/wiki/Assistant_personnel/).
30. —, *Zaurs - Wikipédia*. [http://fr.wikipedia.org/wiki/Zaurus\\_Linux/](http://fr.wikipedia.org/wiki/Zaurus_Linux/).

The articles coming from Wikipedia have naturally been rechecked. The URI related to these documents have voluntarily been given, but keep in mind that these pages are often subject to numerous modifications. Links with no given author (which constitute the most of the given links) are classed by date of browsing.

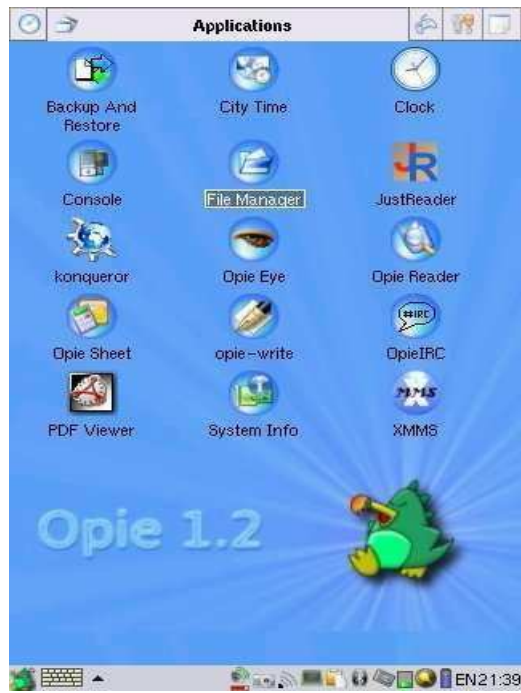
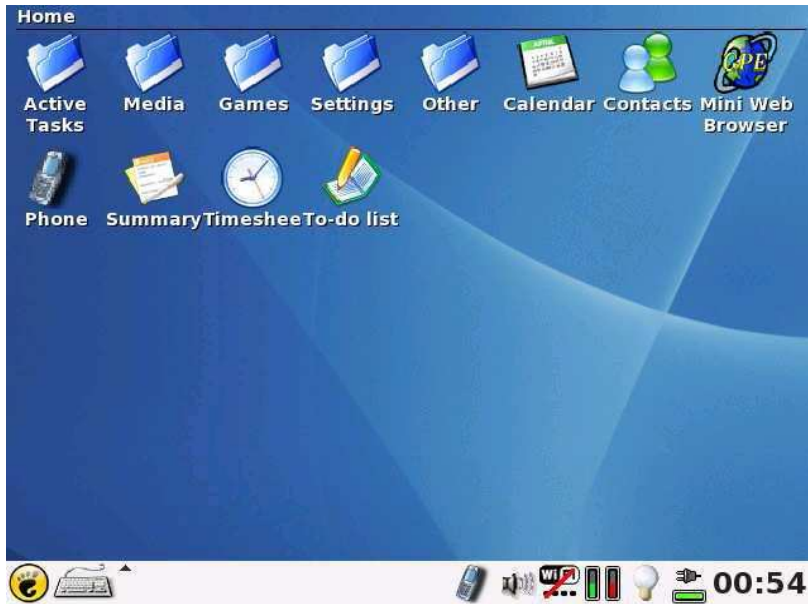


Fig. 1. Screenshots of Opie (on Palm ©) ([20]).





Fig. 2. Screenshots of GPE (on Pocket PC ©) ([4]) (1).



**Fig. 3.** Screenshot of GPE (on Pocket PC ©) ([4]) (2).

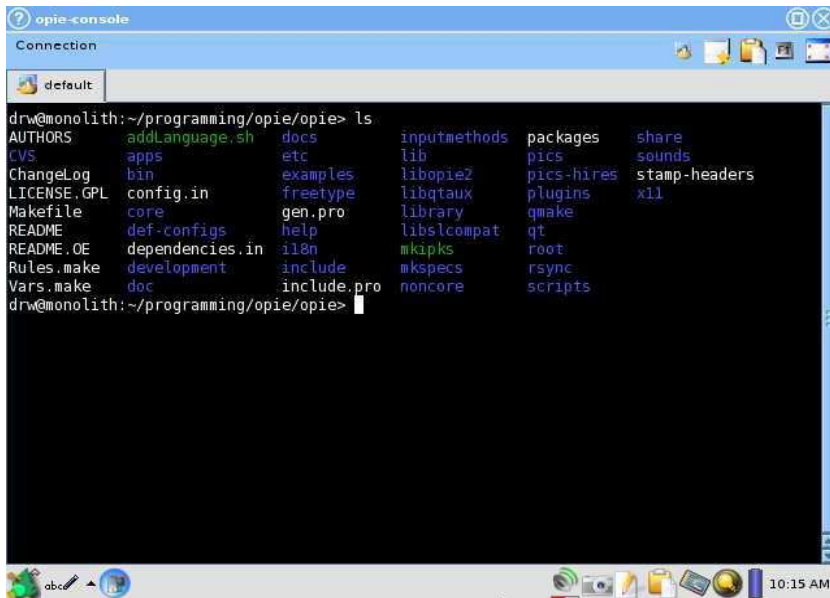


Fig. 4. Screenshots of Opie (on Pocket PC ©) ([20]) (1).



Fig. 5. Screenshots of Opie (on Pocket PC ©) ([20]) (2).

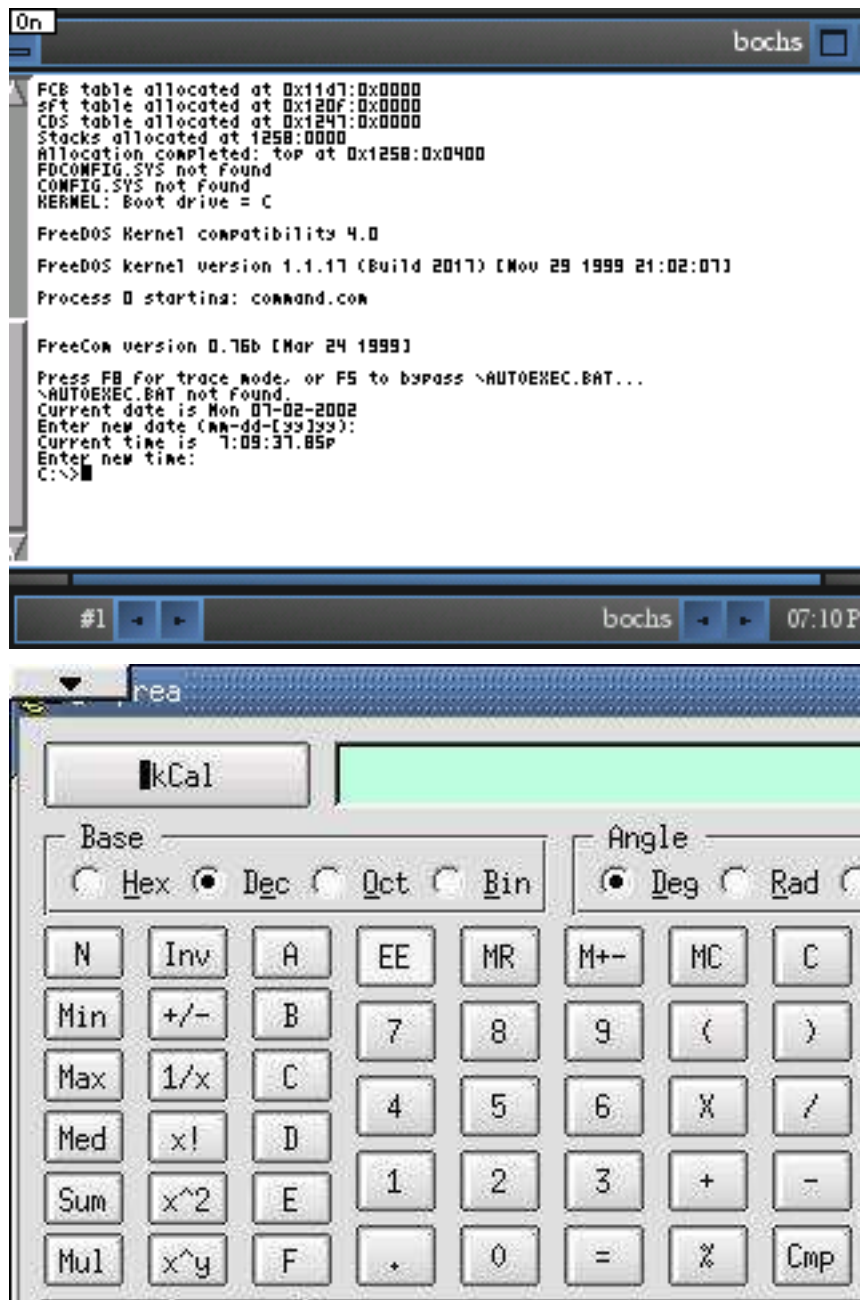


Fig. 6. Screenshots of Intimate (on Pocket PC ©) ([6]).





Fig. 7. Screenshot of Ångström (on Pocket PC ©) ([1]).