Mobile Devices and Portative Classroom Based on Raspberry Pi Computers

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***Abstract*—In this paper the possibility of using Raspberry Pi microcomputers for effective training in practical skills of operating systems and computer networks administration and configuration is described. The algorithm for assembling a mobile device based on it and installing the software is given. The necessary resources and stages of the developing of individual training kits are provided. To complete the training kits a required number of devices and MicroSD with necessary operating systems and working environments, extra peripheral items, and study materials were evaluated.**

Keywords—Raspberry Pi, computer networks, operating systems, training, hardware-software device, portative classroom

I. INTRODUCTION

Nowadays, Raspberry Pi is a subject of large number of publications, the topics are making of flexible programmable equipment for numerous projects, information security, robotics, learning, Internet of Things. Thus, in [1], using of clusters built from these microcomputers to realize the data analyzing algorithms is proposed, and this technique were efficiently enough. The client-server technology example based on Raspberry Pi which is used to conduct surveys of students by mobile devices is described in [2]. Some other projects were emplemented in papers (for example, [3]-[7]) and books in different approaches: making some specific technical devices ([8]-[10]); using certain programming language ([11]-[14]); using hardware peripherals ([15[-[17]).

It can be named significant such aspect of professional education in “Operating Systems” as well as “Computer Networks” as the difficulty of practical classes performing because of hardware resources are needed in enough amount for their effective organizing. This condition provides achieving the stable high-demanded practically oriented vocational skills on the educational courses.

In the publications devoted to this direction, a couple of main points can be separated. One group of the works is covered to researching the possibility of applying different software in carrying practical classes in these subjects. The another side of investigations in this field appeals to the possibility of using auxiliary and alternative devices for organizing practical courses in resource intensive disciplines. In [18], a review of works on this topic is made. As for the equipment discussed in second group of works, it should be note an important role of single-board microcomputers such as Raspberry Pi, as well as software and hardware systems such as Arduino. Raspberry Pi is a microcomputer based on the ARM processor that has long gained prevalence. The most recent models are 3B+ and 4B (4-core, RAM up to 4 GB, network card, 1000 Mbps Ethernet, etc.). A more detailed characteristics and some possible configurations of devices are given, for example, in [19]-[21].

Because the Raspberry Pi's storage media is a MicroSD card, it's easy to switch the operating system on the computers; it's also a cost-effective way to supply each student with multiple computers that run different operating systems. In contrast to machines and networks, the solution allows analyzing and comparing, fine-tuning system settings (installing and uninstalling of the system, registry related activity, manipulations with disks and disks partitions, boot record, low-level operations with disk); in the event of failure of operating system or its individual components and modes malfunction, recovery is easy enough. “Computer Networks” is a field that is gaining in importance as the globe becomes more interconnected and, as a result, cyberattacks become more sophisticated. Network schemes, network administration and configuration, working with network peripheral devices, monitoring and testing of network security, access control in corporative networks, and firewalls handling are all skills and knowledge that today specialists in the information technologies field, particularly information security, need.

II. DESCRIPTION OF SOME DEVELOPMENT STAGES

The purpose of the investigation is the development, production, implementation and analysis of aspects of using in the educational process the sets of software and hardware instruments and related description for studying "Operating Systems", "Computer Networks" subjects, as well as development of a methodology guidelines for teaching the disciplines with these kits. The practicability of projecting and production this solution is supported to the merits of the

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minicomputer. In addition, these advantages and certain business research performed in some our works maintain the forecasting of profitability and effectiveness.

A. On the assembling software-hardware device

Here steps for developing a devices based on the Raspberry Pi 3 Model B or 4 Model B are shortly presented. Note that the resources [22], [23] here were very useful.

• Write operating system images to a microSD card. In our model case, the Kali Linux image was used.

a) Unpacking the image

```
unxz /media/root/Setup/kali-linux-2021.1-rpi.img.xz
```

b) Writing the image to a microSD.

c) The partition can be expanded to the card full size using the `gparted` or `fdisk` utilities. Then expand the file system according to the size of the partition by running the command:

```
resize2fs /dev/mmcblk0p2
```

d) After activating the wireless network interface, insert the memory card into the appropriate slot on the computer board.

• Connecting the display (a display with a GPIO connector is considered)

There are several ways to access the system to install the display driver:

a) connect an HDMI display;

b) connect the Raspberry Pi via an Ethernet cable directly to the router to get a dynamic IP address and connect to the device via SSH protocol;

c) some developers offer private solutions using special equipment.

We focus on the method b).

- The assignment of a static IP can be found in the" Setting a Static IP " section of the resource [22]; note, however, that a static IP increases the system boot time.

- The section "By The Way: Modifying Headless Raspberry Pi Boot Sequence" of the resource [22] is very useful for solving problems with ssh startup;

We created a script to solve this problem (put it in the `/etc/init.d` directory and make it executable, create a symbolic link to this script in the `/etc/rc2.d` directory) ([19]).

- Activation of the wireless network interface. Since such a network is usually protected, the device itself cannot activate the wireless network interface in Headless mode without initial configuration. You can find out how to configure it by following the link [24]. However, when there is no console access to the machine, this method does not work, but having access to the partition with the installed system, you can solve the problem by modifying the files `/etc/wpa_supplicant/wpa_supplicant.conf` and `/etc/network/interfaces` ([21]). After the reboot, the wireless network should work.

• Preparing the system for operation and installing the driver for display operation (loading and configuring).

- Changing the standard password for the root user

-SSH key recovery

- Changing the time zone

- Update the repository list and update the system

- Installing and configuring the alternative `Slim` login manager

- Changing the computer name

- Downloading and installing the core with support for the TFT display. Here we follow the instructions [23] (commands for updating the utility, configuring the display, selecting a driver for an existing display, and displaying a list of supported devices).

- In order to increase the system performance, change the `GNOME` environment to `Xfce`. Also, an alternative solution is to use only window managers, such as `i3`, which significantly reduces the consumption of RAM.

• Some solutions to possible problems

- You may need to install net-tools

- Sometimes it happens that due to file system errors on the Flash card, the root partition / is mounted in read mode and, accordingly, many things do not work as they should. In this case, you need to fix the file system errors: fix the SD card on another Linux-machine or edit the file `/boot/cmdline.txt` ([25]).

-Problem with DNS name resolution ([26]).

Fig. 1 shows a device running on the mains, Fig. 2 shows a mobile device running on a lithium battery (GPIO connector).

Fig. 1. Raspberry Pi with different displays

Fig. 2. Battery-powered Raspberry Pi (wired keyboard and USB mouse connected)

B. *Teaching the disciplines of "Computer networks" and "Operating systems" by using software and hardware.*

The analysis of the courses specific tasks, as well as the development of an illustrative scenario for teaching classes, allows us to develop basic distributing individual sets comprising software and hardware for doing different practical tasks to each of the courses. The hardware and software for providing individual sets for the "Computer Networks" and "Operating Systems" disciplines are following:

- microcomputers Raspberry Pi 3B+,
- power adapter,
- MicroSD card with installed applications and made settings (OS, network and other required software - Communication equipment.

Also there can be some additional components such as input devices, extra equipment such as transceivers, repeaters, hubs, bridges. Equipment for organizing additional training classes in the “Computer Networks” discipline should also include network devices (modem, router, network switch).

To teaching these subjects applying the constructed sets there is required a conventional classroom (not a computer laboratory) with power outlets.

C. *Boot file and working environment*

The microSD card “with a pre-installed working environment” discussed in the paper above is a boot media with a specific operating systems with settings and appropriate software, pre-recorded instructions and books, specified working directory. The possibility of downloading this environment as archive is implemented, and after unpacking, a functional microSD is received immediately. Users can avoid looking for required systems images, using and even making some scripts, searching for and installing applications for producing boot medias, and repairing faults by utilizing this archive (boot image).

So, the composition of individual handout kits for studying the discipline "Operating Systems" can include three microSD cards with Windows 10 (IoT), Ubuntu, FreeBS. There are Fedora, Kali Linux, Ubuntu Server boot files too. Some services, file and process managing utilities are already included in Windows images.

We created a script which does the following:

• starting the command line interpreter with appropriate parameters and options (as well as correct font settings for Russian and Kazakh languages with Unicode encoding support) or, in the case of Unix/Linux, the terminal;

• necessary useful system commands (ipconfig/ifconfig, etc.) with generated output file;

• switching to the current directory;

• starting the file manager (Far/mc), as well as a few utilities.

Handout kits are also provided with microSD with required configured operating systems, some applications (such as PuTTY, WinSCP, Wireshark, Nmap) and instructions to learn the topic "Computer Networks". Apart from these functionalities the created script executes the following::

• launching some network application commands;

• checking the network firewall settings.

D. *Instructions and guidelines*

A memo was created that includes a table of contents, draft instructions for assembling sets and supporting the Raspberry Pi and other equipment, as well as guidelines and recommendations for teaching the relevant subject by the kits and tasks samples.

The manual contains information about the purpose of the sets' equipment, as well as the conditions of effective and safe operation them, component specifications, and safe connections types and methods.

The methodology guidelines explain how to compile and start possible hardware configurations depending on the disciplines being studied (which can be done in the first practical/laboratory lesson). There is also a rough list of practical activities and suggestions for completing them. We take note of the potential for altering and creating new tasks. Software instruments and their capabilities for setting up networks and shared folders, as well as a firewall, are detailed for the “Computer Networks” subject. The topic of testing network security via Kali Linux utilities is discussed.

Cases containing sets are expected to be numbered, come with a letter to fill out depending on the discipline, and be delivered in the classroom based on this information and numbers (additional conditions of usage are described in the attached guidelines).

III. ON PRACTICAL DEPLOYMENT OF THE RESULTS

Works [27], [28] describe the use of the Raspberry Pi in the conducting of specific disciplines; for instance, [28] discusses teaching experience in the information security area. As a result, the authors of this paper successfully employed a Raspberry Pi-based device in cryptography and cryptanalysis classes, which require pre-installed special software (algorithm implementations, compilers, libraries, and computer algebra tools) ([29]).

Higher education institutions, secondary and secondary special educational institutions, research organizations, testing organizations, commercial educational organizations, and training centers are all prospective users of the Raspberry Pi-based multidiscipline computer class. Actual quantity of

consumers estimates are obtained during the study and segmentation of consumer market based on the studied statistical data, with consideration the influence of numerous factors.

Below is a unit from the "Multidisciplinary Mobile Computer Classroom Based on the Raspberry Pi" personal handout kit:

- A case with a label with the relevant information and number on the outside surface;
- Content in accordance with one of the B choices.
- A content memo;
- A user's handbook;
- Instructions for delivering courses in one of the disciplines using this kit, as well as tasks samples

IV. CONCLUSION

Developed kits and corresponding working environment described in the paper allows organizing precisely individual performance of all practical tasks in studying of operating systems and computer networks. It should be stressed that by using presented kits demonstrativeness and accessibility are provided. Here real equipment is used in compare to some simulating platforms.

In addition, a technological plan of the production project, the market analysis, a forecast of efficiency, a risk assessment, with respect to the mainly to Kazakhstan, were done.

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