INTEGRATION SOFTWARE FOR A DISTRIBUTED GROUP OF MOBILE SERVICE ROBOTS

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Abstract

This article describes the study of the problems of testing and integration of the group of mobile service robots (Amur-307 type) hardware and software complex using the virtualization support library. The architecture of the software solution and its features, that simplify integration testing and speed up debugging of compilation and reliability errors are described. An approach to emulation of hardware, sensors and electric driver of robots with manipulators specific to this software and hardware complex is also outlined, which allows creating a complete virtual analogue of it and speeding up software development (especially in terms of routing a robotic complex) using unit tests.

Keywords: integration software; service mobile robots; emulation and testing of hardware and software; based on microprocessors and on-board computers.

1. Introduction

Currently, one of the most successful approaches to software development is continuous integration. The software must be ready at any time for launch and execution, so that execution errors do not occur at any arbitrary time [15]. This approach also justifies itself in the development of client software for the Amur-307 robotic complex [1, 2]. In particular, the developed software can be used for the entire spectrum of robotic systems, including underwater ones [17-22], providing better results compared, for example, with work [23].

When developing software in a team, it is necessary to conduct testing at various levels of abstraction: unit testing, integration testing and user interface testing. However, when the program code interacts with various robot equipment, there are moments, that add the need to conduct additional testing using physical equipment [16]. Hardware virtualization is often used to speed up full-featured testing and its automation, which allows not using physical hardware [6]. It is this method, that we have relied on in this work.

2. Applied software for development and integration

When developing client software for the Amur-307 robot, the following structure of applied technologies was formed (Fig.1.):

Fig. 1. The structure of applied technologies in the life cycle of client software.

The proposed architecture for testing and debugging client software allows, after making edits to the source codes, to automatically assemble and test software for the Raspberry Pi platform without resorting to manual testing on a real microcomputer. Also, due to the need for fast and convenient work with the program code, technologies of continuous integration and continuous testing in the repository were used.

For the functioning of the client software, the need for the use of specialized libraries was identified, which would allow to root the development, simplify the testing of system modules, as well as reduce the load on the processor and network [5]. After comparative tests, the following were selected:

1. Network framework gRPC + Protobuf serialize library. This framework was needed for convenient and fast serialization of data into binary format, to reduce the transmitted data and increase the speed of exchange in comparison with the REST API. Also, this framework made it possible to maintain backward compatibility with older versions of microservices, which in turn made it possible to simply change the structures of the transmitted data.
2. piGPIO library. This library provides software for working with peripheral equipment of the Raspberry Pi microcomputer. For this microcomputer, there are several programs for working with GPIO ports, the most popular are WiringPi and piGPIO. WiringPi - at the moment the library is not supported and does not have the necessary DMA modulation to increase the number of PWM signals. At the moment, piGPIO is most often used, due to its functionality and speed of operation. For these reasons, this particular library was chosen.
3. Library libconfig. This library is used to work with configuration files. Its main advantage is cross-platform and entry into the POSIX standard. The configuration file format is readable, and the markup language itself has good functionality.

3. Applied technologies of continuous integration and deployment of the project.

For representativeness, versioning and unification of commits, a separate *commitizen* program is used. This program significantly saves time when accepting a request to add code to the repository, when viewing the commit history, and also allows you to do some work with the project in semi-automatic mode, such as assigning the current software version and generating a change file. Also, the *cloc* software package is used to estimate the amount of code, comments and obtain some statistics on the amount of program code. The Git system has a built-in git hooks mechanism, that allows you to perform an action on a specific event. This mechanism is used for additional verification of the commit before it is accepted and access is restricted.

Continuous Integration and Continuous Deployment technologies based on the *Github Actions* service are used to accelerate development and testing. These technologies allow you to find out the test result, generate documentation and assemble the application package on a third-party server, which in turn greatly reduced the time spent to obtain results. When a new commit is received, two YAML scripts are run on the server, one of which describes the assembly of documentation, and the second describes the assembly and testing of the project itself. The documentation is assembled by *Doxygen* [13]. Documentation and diagrams are generated based on the client software program code. After the documentation is assembled, build status alerts are sent to the Telegram work chat and if the build was successful, the documentation is updated on the project website.

To compile a project consisting of a large number of code files, it is necessary to use an assembly system that, according to a certain algorithm, will assemble all the files in the correct sequence, and also allow you to run additional precompilation steps. There are several build systems for the C++ language: *qmake*, *make*, *cmake*, *autotools*. Since there is no pre-installed *Qt library* in the Raspberry Pi distribution, the *qmake* build system is not suitable due to the large size of the library, the *make* system is not cross-platform like *autotools*. Therefore, the *CMake* build system is used to build the program, which provides a more user-friendly interface than the *Makefile* and is cross-platform. Since the final program must be run on an ARM processor, cross-compilation is used, which allows you to compile the project on the server and not load a low-power Raspberry Pi processor. After that, unit testing is required to evaluate the performance of individual modules using the *GTest library*. After successfully passing the unit tests, it is necessary to run interface testing to make sure that the system as a whole is working properly. For this, a QEMU virtual machine with emulation of Raspberry Pi hardware, including its I/O ports, is used. With the help of a set of programs, an image is created with the recorded Amur-307 [17].

4. Implementation of a virtual environment for integration testing.

For virtualization, the following technologies are used to provide interfaces for interaction with virtual hardware: *tun/tap*, *iproute2*, *iptables*, *qemu*, *socat*. An example of hardware virtualization can be found in the article [7]. Virtualization in this case uses the full implementation of the TCP/IP stack (this is necessary, among other things, for debugging the server part of the software, which remains outside the scope of this article). When creating a test virtual machine, the topology of the test network is described, since virtualization does not provide automatic access to the local computer network, so it became necessary to add support for the network stack by automatically assigning virtual network interfaces. For this purpose, the TUN/TAP virtual network interface mechanism was chosen [8] since it is already implemented in the Linux OC kernel. To solve the problem of creating, deleting and assigning an ip address, routing, and managing network bridges (the implementation of a virtual network router, also implemented in the OS kernel), the *iproute2* package is used [12]. In this case, this interface was chosen for the speed of development and maximum portability of the code, due to the fact, that *ifconfig* and *route* tools similar in purpose are no longer supported in new versions of Linux-based distributions, which in turn will complicate project support.

To connect a virtual machine to a local computer network, the NAT (network address translation) mechanism is used using the *iptables* package [14]. In this case, the choice of the package is unambiguous: *ipfwadm* and *ipchains* are outdated and no longer supported, while the choice of *iptables* is due to the need to isolate the subnet of the test virtual machine for security and the implementation of an arbitrary network topology.

With the help of a *qemu-based* virtual machine, it is also launched via the *socat* interface [9, 10] (which emulates the serial port) we get the result of integration testing, which shows the absence or presence of execution errors when running the Amur-307 software on a virtual machine [3, 4]. The result of this launch falls into the pipeline of the sequential integration environment, in our case it is *Github Actions*.

5. Mechanism for checking the correctness of source codes and generating executable code.

Next, debugging of execution errors and new functionality is performed using the integration software described above, if any. The *qemu* virtual machine allows the use of *gpio* virtual sensors, which allows us to debug the functionality of the components of the Amur-307 client software on a virtual machine, for example, basic tests of the functionality of various sensors. In addition, it is possible to emulate the work of the robotic complex as a whole, namely, movement along the route, interaction with manipulators and much more, which significantly reduces the debugging time directly on the robot's equipment and allows you to identify machine-independent errors.

After successful testing, the installation *apk* package for *Raspbian OS* is automatically assembled, which is published in the repository releases and also published on the project website.

6. Conclusion

As a result of the conducted research, an environment for continuous development with the possibility of testing software on virtual hardware was identified, created and configured. This system allows you to save time developing software for the AMUR-307 robot by eliminating constant testing on real robot hardware, as well as counting the automatic launch of tests with each new commit. As a result of the work of this software package, after the assembly and publication of the release, the package is installed by the user on the robot or updated from the project repository. Thus, the mechanism of continuous development, continuous integration and continuous deployment was implemented.

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