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Evaluation and technological solutions for a dynamic, unified cloud programming development environment

Ease of use and applicable system for uniformized practices and assessments

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***Abstract*—The dynamic development and change of the world also result in the modernization of teacher-student relationships. In the training, educational processes must be planned with innovative strategies that meet the increasingly changing needs of students, which today go beyond the traditional classroom and methodological frameworks. In this article, we present a technological solution to support the renewal efforts in the education world that, on the one hand, takes advantage of the benefits of cloud-based services, and on the other hand, ensures that students can acquire the material of a given course in a unified, stable environment. The isolated environment offered by the virtual space guarantees private work sessions, and multi-project activities can also be handled more easily and uniformly. The analysis of the teaching program presented below provides insight into the practical and appropriate solutions offered by the containerization process. In addition to these, the topic will also cover the widely used and popular Docker application that supports the implementation of the process, as well as the NodeJS environment closely related to the project.**

Keywords—teach program, virtual environment, containerization, Docker, NodeJS, cloud-based services

Introduction

In recent years, there has been steady growth in the development of cloud-based Integrated Development Environments (IDEs) to provide fast and reliable development services to software developers. The trend has been accelerated by the emergence of Docker Container-based online IDE solutions, which allow developers to access their development environments from anywhere with just an internet connection. This paper examines the effect of Docker Container-based online IDE [2] solutions on software developers from an economical and practical perspective. Furthermore, this paper will explore how Docker Container-based online IDE solutions can revolutionize software development.

The development of modern computing systems and their applications have brought about various programming environments, each with advantages and disadvantages. For example, specific programming languages are more suited for web development, while other programming languages provide better support for machine learning algorithms. Additionally, specialized programming environments exist to solve distinct programming tasks, such as scripting and software automation, but they come with decreased readability compared to more general-purpose programming languages. Furthermore, programming environments can also be divided into language-specific and platform-specific ones. Unfortunately, platform-specific programming environments often require significant effort in their setup, which is often incompatible across different computers. Additionally, relying on platform-specific libraries and frameworks can introduce version compatibility and maintenance issues. These problems can be daunting to newcomers and experienced programmers and should be considered when selecting a programming environment.

Uniformized programming environments offer significant advantages to students. These environments provide a pre-configured and consistent work environment easily shared between users and machines. This uniformity provides a common platform for course material, enabling efficient collaboration and providing a consistent experience across classrooms and institutions. Furthermore, these environments allow efficient tracking of once identified issues and bugs and enable efficient sharing of software libraries and code among users. Finally, these environments can also offer connectivity to external tools, such as cloud resources, allowing students to access additional software, data, and resources [14]. Overall, uniformized programming environments provide students with consistent, accessible, and robust platforms to facilitate their learning of programming.

In our work, we create a unique, virtual-server-based system for programming students. This solution is helpful for both practice and examination purposes.

Alternativ Solutions

There are many paid or free tools on the Internet. Unfortunately, most of them are too expensive for education purposes.

1. Cloud9: Cloud9 is a development platform that lets anyone write, run, and debug code in various

languages, in any browser, or on any platform. It comes pre-installed with popular development tools and integrated libraries for many languages.

2. AWS Cloud9 IDE: Amazon Web Services Cloud9 IDE offers an integrated development environment based on the Eclipse platform. The IDE contains unique features that allow developers to create, debug, and deploy applications on AWS's servers.
3. Codeanywhere: Codeanywhere is a collaborative cloud-based IDE that allows teams of developers to work side-by-side on projects. It includes support for a variety of programming languages, as well as integration with popular version control systems.
4. Code Envy: Code Envy is a cloud-based development environment that supports popular programming languages, such as Java and JavaScript. It allows developers to edit, debug, and deploy their code in the cloud without any external installation.
5. Koding: Koding is a cloud-based IDE that provides a graphical interface for quickly creating and testing web applications. It supports various programming languages, including Python, Ruby, HTML, CSS, and more.

These are good solutions for companies or individuals, but some abilities are missing for education purposes.

Missing important features: full access to the virtualized operating system, teachers can create templates, and preinstalled software.

TECHNOLOGY FOUNDATIONS

VPS

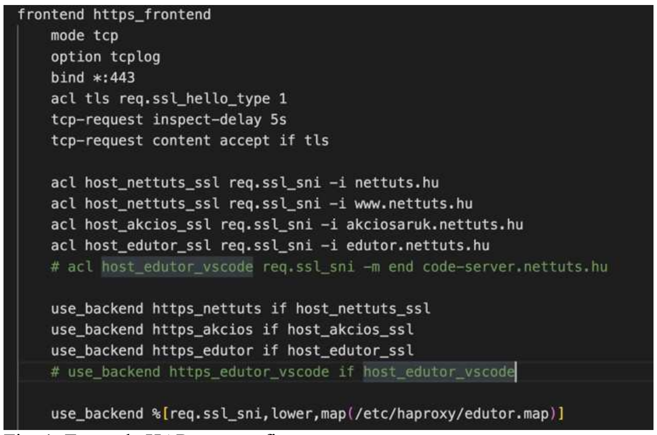
A Virtual Private Server (VPS) is a virtualized server, a software simulation of physical server hardware. It is a secure and cost-effective solution to host websites and applications, enabling multiple users to run multiple operating systems and software on a single server. A VPS typically also provides data storage and remote access via the Internet, creating a mix of physical and virtual infrastructure. VPS architecture allows us to create cost-effective applications.

We use an Ubuntu VPS. This OS is the host of Docker containers. The VPS runs a special software for proxying HTTP requests named HAProxy.

HAProxy is a high-performance load balancer and a reverse proxy that enables an optimized delivery of applications. It helps improve an application's availability and performance by distributing the workload across multiple servers. It can also be used for other types of network traffic, such as HTTP, MSBB, DNS, TCP, and UDP. [9] In addition, HAProxy can detect server failures in real-time and can be used as a proxy for HTTP, HTTPS, SMTP, POP3, and IMAP servers. It also supports WebSockets, content switching, and SSL/TLS offloading, among other features.

Furthermore, HAProxy can route requests to multiple web servers while ensuring that the traffic is distributed optimally. It also helps to ensure that IP whitelisting and rate-limiting rules are applied. HAProxy provides SSL certificate management, automatic SPOF prevention, and health checks to ensure that only healthy servers receive traffic.

HAProxy has config files that contain domain mappings. The host machine runs Docker containers on specified ports and HAProxy redirects requests to these.



```
frontend https_frontend
    mode tcp
    option tcplog
    bind *:443
    acl tls req.ssl_hello_type 1
    tcp-request inspect-delay 5s
    tcp-request content accept if tls

    acl host_nettuts_ssl req.ssl_sni -i nettuts.hu
    acl host_nettuts_ssl req.ssl_sni -i www.nettuts.hu
    acl host_akcios_ssl req.ssl_sni -i akciosaruk.nettuts.hu
    acl host_edutor_ssl req.ssl_sni -i edutor.nettuts.hu
    # acl host_edutor_vscode req.ssl_sni -m end code-server.nettuts.hu

    use_backend https_nettuts if host_nettuts_ssl
    use_backend https_akcios if host_akcios_ssl
    use_backend https_edutor if host_edutor_ssl
    # use_backend https_edutor_vscode if host_edutor_vscode

    use_backend %[req.ssl_sni,lower,map(/etc/haproxy/edutor.map)]
```

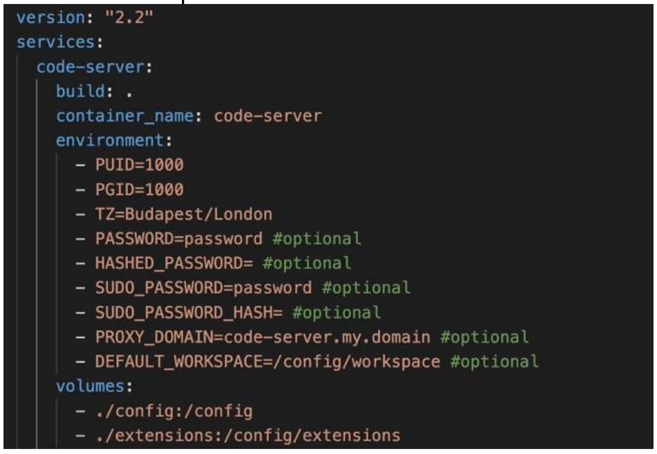
Fig. 1. Example HAProxy config

Docker

Docker [1] is an open-source software platform that enables developers to easily package, deploy, and manage applications in a virtual environment known as a container. Docker Compose is an open-source tool for defining, running and managing multi-container applications. It provides a way to define and configure all the services (containers) that make up an application in a YAML file. It also allows users to manage and scale their applications effectively.

To manage containers, we use dockerfile and docker-compose files. The dockerfile contains the configuration of the container instance, such as VSCode server installation steps, exposed ports, and secured directories.

The docker-compose file contains environment variables and a list of real ports.



```
version: "2.2"
services:
  code-server:
    build: .
    container_name: code-server
    environment:
      - PUID=1000
      - PGID=1000
      - TZ=Budapest/London
      - PASSWORD=password #optional
      - HASHED_PASSWORD= #optional
      - SUDO_PASSWORD=password #optional
      - SUDO_PASSWORD_HASH= #optional
      - PROXY_DOMAIN=code-server.my.domain #optional
      - DEFAULT_WORKSPACE=/config/workspace #optional
    volumes:
      - ./config:/config
      - ./extensions:/config/extensions
```

Fig. 2. Example docker-compose.yml

Web Server

NodeJS is a JavaScript-based run-time environment for building web applications. NodeJS allows us to write server-side JavaScript code for our web applications and run it directly in the server environment. [8] In addition, NodeJS is an open-source software, so anyone can use it to create great web applications quickly and easily.

We needed a secure and easy-to-use interface to manage containers. We chose NodeJS and a web interface. Each student can login to their virtual environment through a webpage.

THE FUNCTIONALITY

- Firstly, the teacher creates a new virtual environment in the MongoDB database server. This environment has a unique key, which is the MongoDB ID field. The teacher has to share it with the student. This id will be the first part of the public URL of the environment.
- After that, the student opens the welcome page, types the id into an input field, and clicks the OK button. Next, the NodeJS routine checks the running containers by URL. If the requested Docker container runs, the webpage redirects students into the environment. If a container with the requested ID does not exist, NodeJS runs a terminal command and initializes a new container.
- Finally, the VSCode server appears in the browser and asks for the password. Students can work in the virtual environment when they provide a correct password. There are two secure lines, the first is the container ID, and the second is the environment password.

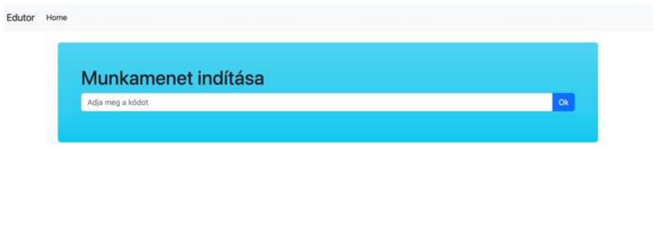


Fig. 3. The login page

DIFFICULTIES

So, therefore this project was pretty complex, and there were many difficulties.

When students start in a new environment, the system often duplicates them. So we created a routine that checks the environment names and opens the existing ones if available.

The second was with the resources. [4] We ran Angular applications in the Docker container. Angular needs a lot of memory and CPU time for building applications because it is built with TypeScript. Browsers do not know TypeScript code; therefore, before running an application in the browser, it is necessary to create JAVASCRIPT codes from it. Converting TypeScript to JAVASCRIPT is the building task.

When the container ran with 1GB of memory, the VSCode server hung an out-of-memory error. So we had to find the proper memory amount for this task. It will be 1.3GB of memory. After all, we created a new and more memory-efficient builder for Angular written by GoLang instead of the original NodeJS implementation.

We found that each setup requires thorough pre-testing for good functionality. It requires testing memory, CPU, and file system.

SUMMARY

Cloud-based development environments provide quick, easily accessible opportunities for development, including collaboration [5] [14]. They also support education well by significantly reducing the time required to prepare and manage the technical implementation of educational processes. In the current educational system, the role of teachers must also constantly evolve and adapt to the direction of digitalization [6] [11] [15]. With central regulation, it is possible to quickly and efficiently provide the necessary technological background for teaching, and a failure of a particular machine does not affect the entire system [10] [12]. There are many cloud servers that offer their services to the market, but we must consider that their use can be financially burdensome for education and teachers may have limited options. Taking into account modern technological opportunities, this article presents a solution for creating a unique, virtual server-based system designed for the unified and efficient teaching of programming to university students. Using VPS Docker, we provide a container-based environment for students to work on a unified interface, yet independently and without interference. The containers run simultaneously on the server, and Docker provides a platform for managing the containers that allow for the setting of different environmental variables, installation, development, and testing of applications in an isolated environment [7] [13]. We provide an Ubuntu LTS server system for VPS. This Debian-based Linux operating system provides a high level of security and scalability for such systems, and it is completely free. The biggest challenge in our work was the proper use of resources, but an effective solution to this could be the further development or migration of the application to Kubernetes. The current development environment is only suitable for serving small groups, but with Kubernetes, it can easily be integrated into the system of large providers, and the management of resources is also optimized.

The benefits of using virtual environments are undeniable, and the educational programs running in them also bring the same advantageous characteristics, such as mobility, flexibility, and consideration of personal attitudes, as their counterparts used on other platforms. With the system we introduced, we wanted to present an alternative option for using technology for educational purposes, which we plan to develop further in order to publish many additional possibilities in the future.

ADDITIONAL OPPORTUNITIES

We need to create an admin panel to change the program's settings. The required subpage is environment manager, user manager, and resource manager.

We plan to use Kubernetes for effective container management. [3]

Finally, there is a requirement for a template system for docker-compose files. In this place, teachers can create and reuse their templates.

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