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Assignment of bachelor's thesis

Title:	DevOps concepts - CI/CD, implementation of authorization & authentication, presented on a BI-DBS portal frontend
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Instructions

The BI-DBS portal undergoes an evolutionary transfer to a microservice architecture with a Vue.js frontend. Therefore, the frontend needs new automated deployment, testing, and a clear permissions structure.

Fulfill the requirements:
- Describe the current and planned state of the BI-DBS portal.
- Analyze and describe DevOps principles, focus on CI/CD.
- Configure and describe an automated deployment for the BI-DBS portal.
- Analyze roles and permissions of the BI-DBS portal.
- Implement and describe the authorization and authentication services and provide suitable regression tests for a CI pipeline.

Electronically approved by Ing. Jaroslav Kuchař, Ph.D. on 26 January 2023 in Prague.

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DevOps concepts - CI/CD, implementation of authorization & authentication, presented on a BI-DBS portal frontend

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Supervisor: Ing. Oldřich Malec

April 17, 2023

Acknowledgements

I would like to thank ...

Declaration

I hereby declare that the presented thesis is my own work and that I have cited all sources of information in accordance with the Guideline for adhering to ethical principles when elaborating an academic final thesis.

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In Prague on April 17, 2023   . . . .

Citation of this thesis

Abstrakt

V několika větách shrňte obsah a přínos této práce v českém jazyce.

Klíčová slova   Replace with comma-separated list of keywords in Czech.

Abstract

Summarize the contents and contribution of your work in a few sentences in English language.

Keywords   Web application, DevOps, CI, CD, OAuth, frontend, authentication, authorizarion

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Introduction

TODO: zminit navazani na bakalarky a diplomky pouzite pro psani teto prace

Analysis of the application state

In this chapter, I will introduce the educational web application helping to teach database systems subject at the university. Furthermore, I will describe the current and planned state of the application from the perspective of software architectural patterns and the used set of core technologies with a focus on the frontend. The goal is to identify the existing problems of the current application, outline how they will be solved in a new portal, as well as to indicate what difficulties we can face developing the new application using a new stack of technologies and new architecture.

1.1 The BI-DBS portal

The BI-DBS portal is a web application used for teaching database systems subject in a bachelor's study program at the Czech Technical University at the Faculty of Information Technology. The portal is complex and has many useful functionalities. It allows managing and tracking all the student's studying progress during the semester, including semester tests, complex semester work, and exams. Besides, teachers have an overview of all their student's work in one application.

The current application was developed, as well as a new one being developed by students and teachers in subjects BI-SP1, BI-SP2 subjects, bachelor and master theses. That is a unique fact about this project. Every year, new students begin working on application development. They are open to sharing their ideas for improving the application. Thus, we are designing and implementing a better and better product each year.

1.2 Current state of the application

The current BI-DBS portal was deployed for the first time in 2016[1]. Over time it gained new features and grew large. Currently, it has a total of around

120000-140000 lines of code[2]. Used technologies became less relevant and it became difficult to maintain it.

1.2.1 Architecture

The current application was built in a traditional way, using a monolithic architecture approach and following the Model-View-Presenter architectural pattern[3][4]. Figure 1.1 shows the visualization of the architecture. The application is presented as one monolithic unit, and it is composed of three components.

- *The model:* Communicates with the database and handles domain and business logic.

- *The view:* Provides visualization and directs user commands to the presenter, does not contain logic.

- *The presenter:* Manages interactions between the database and the view. Receives data from the model and formats it to display in the view.
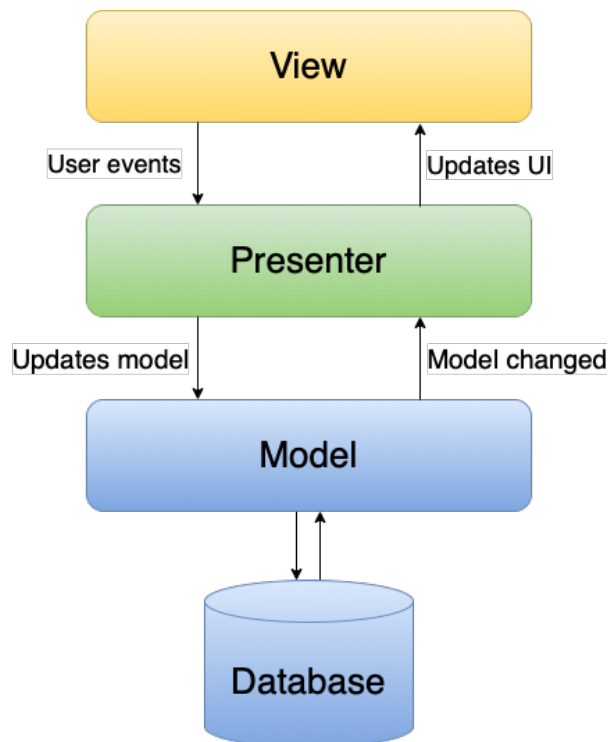
Figure 1.1: Monolithic architecture, MVP pattern

This architecture's main concept is having one code base that benefits in simplifying development, testing, debugging, and deployment.
However, we can have those benefits only until the application grows large. Then all those processes get slower, more complex, and become problematic. In addition, with a lack of flexibility and scalability, it becomes challenging to maintain the application and keep it secure.

The BI-DBS portal is being developed by students. Students generally do not have much experience developing large applications and dealing with complex dependencies. Besides, they have limited time to progress in learning and then designing and developing the portal. Therefore it takes a lot of time for students to learn before contributing to the project. Thus it is more problematic for students to benefit from learning and for maintainers to keep it functioning correctly.

1.2.2   Technologies

PHP.   PHP is a general-purpose, open-source scripting language that can be integrated into HTML.[5][6] It differs from client-side scripting languages in that its HTML is generated on a server and then sent to a client. That feature allows rapidly building a web application with a thick server and thin client. This is one of the approaches to using PHP to build an application, and it is used in the current project.
Using his approach leads to creating dependencies between the user interface and the application logic, which makes any changes more effortful since a developer needs to adjust it on both sides.

Doctrine.   "Doctrine ORM is an object-relational mapper for PHP 7.1+ that provides transparent persistence for PHP objects. It sits on top of a powerful database abstraction layer. One of its key features is the option to write database queries in a proprietary object-oriented SQL dialect called Doctrine Query Language."[7]
This framework did not cause problems during the development process and has no significant disadvantages for the correct operation of the BI-DBS.

Nette.   Nette is an open-source framework for creating web applications in PHP. It helps with developing both the client and server sides of the application and also reduces security vulnerabilities. Moreover, it manages application states using sessions and routing.[8]
Frontend and backend dependencies are strengthened, indicating that they are a single unit. The fact that they are so strongly dependent is a drawback. Because of this, it is difficult to make changes to one side without having an impact on the other.

Latte. Nette framework uses a template system called Latte. It compiles templates down to the optimal PHP code.[9]

AdminLTE. AdminLTE is a fully responsive administration template. Based on Bootstrap 4.6 framework and also the JS/jQuery plugin.[10]

Vue 2. Vue.js is a javascript framework for building user interfaces and single-page applications.
Most of the frontend is implemented using Latte templates and AdminLTE bootstrap. However, in order to reduce dependencies between the frontend and the backend and also modernize it, a few components were refactored to the Vue.js version 2. The logic is defined using the Options API. It is a traditional object-oriented way, and up until Vue 2 it was the only way to create components in Vue.[11, 12]

Javascript. JavaScript is a high-level programming language used for defining the behavior of webpages. It is a dynamically-typed scripting language that lets you control multimedia, animate graphics, and generate dynamically changing content.[13]
In the current BI-DBS portal it is used for defining logic on the frontend. Dynamically-typed languages are easy for development, but this feature reduces the code's readability, requires more testing and are prone to run-time errors. Large applications like BI-DBS are likely to experience problems as a result of its drawbacks because it is better suited for smaller applications with simple logic.

Webpack. Primarily, Webpack is a static module bundler for modern JavaScript programs. When Webpack processes your application, it internally creates a dependency tree from one or more entry points and then merges every module your project requires into one or more bundles.[14]
Webpack is used in a current application for bundling a few modernized frontend components implemented in Vue.js and javascript.

1.3 Planned state of the application

The main reason for creating a new application instead of refactoring the current one is a change in the application's architecture. A new modernized architectural design of the BI-DBS portal was composed by Ing. Andrii Plyskach in his master thesis[2]. We are aiming to correct all the mistakes made in the current application. It is essential to ascertain that we have chosen the right stack of technologies according to the newly chosen architecture.

1.3.1 Architecture

Microservices architectural pattern[4] is based on the concept of a series of loosely-coupled services. They can be developed using different technologies and deployed independently. It is more complex architecture than a standard monolithic one. You can see the diagram illustrating microservices architecture in Figure 1.2.
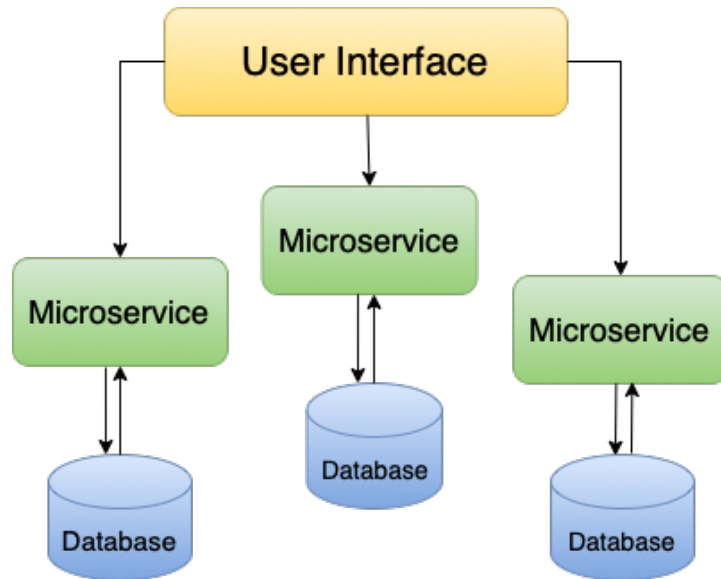
Figure 1.2: Microservice architecture

Advantages:

- *Code readability:* When services are not strongly dependent the code appears to be better structured and easier to understand, which is a significant benefit for the BI-DBS portal.

- *Independency in choosing a stack of technologies:* Microservices can be developed using different technologies which can be chosen according to each microservice functionality without affecting other microservices.

- *Faster deployments:* Since all microservices can be deployed independently, the deploying part is much smaller and the time for deploying one service is rather shorter.

- *Fault tolerance:* Because of loose-coupling, failing one of the microservices will not bring down the entire application.

Disadvantages:

- *Difficult debugging and testing:* Each service needs to be first tested separately and only then as one unit. Besides, it is more difficult to track down errors.

- *DevOps required:* To benefit from the fast deployment it should be configured and maintained. It requires knowledge of development operations.

- *Longer development time and limited reuse of code:* Microservices need to be managed separately, therefore it requires more time.

1.3.2 Technologies

PHP. Since version 5.0, PHP supports object-oriented functionality[15]. PHP is easy to learn, flexible, and supports all required functionalities for our application. It is used in a new project for a domain and business logic on the backend for API implementation.

Symfony. Symfony is a powerful backend framework for creating complex applications which consists of reusable components.[16] Thanks to Doctrine Symfony provides all of the tools required to use databases in the application. It is constantly growing and improving, besides it has a strong community. It is easy to learn and has well-written documentation.

Vue 3. When the decision to create a new BI-DBS portal had not yet been made, its frontend was getting modernized by rewriting components to Vue.js version 2. In the new project, it was chosen to carry on using the Vue.js framework but use a new version 3. This version comes with certain advantages for the application.[17]

New features:

- *Composition API:* Composition API is a set of APIs that allow us to create Vue components by importing functions rather than defining options. It mainly benefits our project in better code organization, thus making the project better structured and the code easier to read. Moreover, Composition API enables efficient logic reuse.[18]

- *Vite:* Vite is a frontend build tool from the creator of Vue.js - Evan You. It is a module bundler that is built on top of Webpack, it will bundle the entire project on startup, hot reloads, and compilation. The primary purpose for the change is for speed. The server starts instantly since it uses native browser support for JavaScript modules.[19]

- *Increased rendering performance.*

- *Smaller Vue core.*

Typescript   Typescript is based on JavaScript, which is dynamically typed. TypeScript has an additional syntax that makes it statically typed. That has advantages in catching errors during development. It also gives a code more structure and makes it predictable. Typescript is more suitable for big applications than JavaScript. For our project, writing code that will be easy to read is crucial.[20]

Quasar   Quasar is a web framework based on Vue.js. It provides us with ready-to-use components which are customizable and easy-extendable. Moreover, it makes the application less vulnerable to XSS attacks due to its escaping feature. When using Quasar, developers do not need deep knowledge of CSS and scripting languages to build a good-looking and responsive application. Besides, it is suitable for developing single-page applications(SPA).[21]

Pinia   Pinia is a Vue.js storage library and state management framework. It is mainly designed for the development of front-end web applications, and it uses declarative syntax as well as its own state management API. It allows sharing a state across components and pages securely. Moreover, it has server-side rendering support. With Pinia plugins we can also persist the state across page reloading using local or session storage.[22]

1.4   Summary and implications

The BI-DBS development team aims to dispose of problems and modernize the current project in every single aspect of development. Starting from choosing the right stack of technologies and designing a suitable architecture to implementing more complex and valuable features. However, even correctly chosen technologies and architecture for reducing the problems of the current project do not save us from the potential new challenges brought by the changes.

1.4.1   Summary

In order to summarize all changes and provide a better visualization of them, I arranged them all in Table 1.1.
Evidently, the Nette framework is the core of the current project, which is responsible for managing the application in many ways. Although it can function well, it creates dependencies between the functionalities and makes the project less flexible, which is a significant disadvantage for large applications like the BI-DBS portal.

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The planned state does not have dominating technologies that would cause this problem. Most of them are replaceable and flexible.

	Current state	Planned state
Architecture	Monolitic	Microservices
Backend language	PHP 7.2	PHP 8.0
Backend framework	Nette	Symfony
Frontend framework	Nette, Vue.js 2	Vue.js 3
Frontend templates and styling	Latte, AdminLTE	Quasar
Scripting language	Javascript	Typescript
Frontend templates and styling	Latte, AdminLTE	Quasar
Module bundler	Webpack	Vite
State management	Nette Sessions	Pinia
Routing	Nette Router	Vue.js Router

Table 1.1: Visualisation of changes.

1.4.2 Implications

From the analyses in sections 1.2 and 1.3, we can see that existing problems in the current project are eliminated by chosen architecture and technologies for the planned state. Let's examine the main possible negative effects of the changes and how to deal with them.

- Microservices architecture provides such advantages as agility and fast deployment. This architecture is more complex in comparison with a monolithic one. Therefore it comes along with establishing some of the DevOps principles for the project. Mainly configuring continuous integration and automated deployment. DevOps concepts and automation including CI and CD are described in the second chapter.

- In the current application, Nette is a core full-stack framework that is also responsible for managing the application's security. Besides, the monolithic architecture allows you to store all the data on the server side. The communication between the client side and server side is secure.
  In microservices applications, there is constant communication between the frontend and the backend and exchanging sensitive data. Therefore it is crucial to control every step of that communication with control of permissions and inputs validation on both the client and server sides. Thus the application should have a clearly defined access management system which I will introduce in the third chapter.

- Since all the services are developed, deployed and tested separately, there is a higher chance of failure in communication between them. Obviously,

It is not enough to test only the functionalities of singles services but to test their integration. Therefore it is essential to design a new integration testing system for the application. It is necessary to eliminate the possibility of the cascade failure of services.

Analysis of the DevOps model

The DevOps and microservices are two important trends in application development. Considering that both of them are mainly focused on providing better agility, flexibility, and operational efficiency, we can assume that they would work better together.[23]

In this chapter, I will describe the main DevOps concepts and practices, analyze their possible advantages for the BI-DBS application and decide whether adopting the DevOps model would be beneficial.

2.1 What is DevOps?

The term **DevOps** is derived from the combination of software **dev**elopment and IT **op**eration**s**.

DevOps is a relatively new term. Around 2007 and 2008 concerns about the separate work of software creators and software operators were raised. The concept started to grow on online forums and meet-ups. The first conference named "DevOps" was held in 2009.[24]

DevOps is a software development methodology composed of a set of cultural philosophies, practices, and tools that improve an organization's ability to deliver applications, services, and improve products faster than traditional software development and infrastructure management processes. It represents a cultural shift that significantly affects a team that adopted that methodology and the software they make.[25]

2.2 DevOps concepts

DevOps concepts are a common set of rules which are the core of this methodology. It is not just a set of tools, but a cultural philosophy, a way of project lifecycle organization. Those rules are not strictly defined, they come from a DevOps culture and can be interpreted differently describing the same model.

In this section, I will analyze and combine the culture philosophy and most frequently mentioned rules[26, 27] in 5 concepts that represent the DevOps methodology.

2.2.1 Automation

DevOps approach is meant to benefit in fast development and improvement. Needless to mention that automation is one of the golden rules for increasing the speed of the application lifecycle. Everyone in a team should aim to automate as many phases of the process as it is possible. As a result, team members are satisfied with a decreased need for doing repetitive tasks. Thus they can focus on significant tasks and work on new features. Overall it helps minimize human errors and boosts team output.

Usage in the BI-DBS project   This concept was the main reason for me to consider adopting DevOps model in the BI-DBS project. Due to microservices architecture the project needs to have new automated deployment and testing processes. These and other automation practices we might want to adopt are described in subsection 2.3.

2.2.2 Data-Based Decision Making

With the DevOps approach, decisions from choosing a technology stack for the application to adding features should be made based on collected data. The first part of making a decision should always be collecting as much relevant data as it is possible. Then, based on the collected data analysis of the team, a decision should be made. It helps to create software that solves real problems effectively. Decisions made without considering client feedback data, colleagues' opinions, and proper analysis would lead to creating badly-functional software full of useless features which does not fulfill the client's needs.

Usage in the BI-DBS project   This concept is very suitable for our new growing project since in the current phase we create are creating a core which should be done properly based on analyses of collected data to avoid having useless features, too complex design and irrelevant technologies.

2.2.3 Responsibility Throughout the Lifecycle

DevOps methodology comes with a requirement for team members to fully understand the process of software development from the feature idea to implementation and deployment and take responsibility for it. End-to-end responsibility helps to reduce failures and resolve bugs quickly.

Usage in the BI-DBS project   From my experience, students usually want to finish their part of the job as fast as it is possible. Therefore they sometimes tend to skip spending time to understand the idea of the task properly. Thus they get to implement it without thinking of the consequences their changes might cause. Moreover, they do not always get to test it properly. It is essential to integrate this concept more into development student teams to increase the quality of produced code.

2.2.4   Constant Improvement

Constant improvement is a special concept and practice of DevOps methodology. The main idea is a focus on improvements, updates, and experimenting. It tells each team member not to be afraid of failures but take them as an opportunity to learn. Whatever the outcome of an experiment, a person will have a deeper understanding of what works and what does not. Besides, this rule gives more responsibility to a person and allows them to consistently push code changes to minimize waste, do speed optimization and improve development efficiency.

Usage in the BI-DBS project   This concept is friendly for students in a way that they can try new things without fear of failure if things do not work out. Adopting this concept will benefit the project in case it is used with the two previous concepts, otherwise, students might take the development less seriously and do experiments only for the purpose of faster finishing the task, but not improving.

2.2.5   Collaboration

This concept is a collaboration of different IT departments on the project. That means that the team's roles are not as strict and independent as in a traditional work and team organization. Developer and operation roles are getting closer to full-stack roles, leading to a better understanding of the software development lifecycle by the whole team.

Usage in the BI-DBS project   This illustrating DevOps methodology concept is beneficial in two ways for the BI-DBS portal. Firstly, students will learn essential operation processes and understand the basics of automation. Secondly, the portal always needs at least one person to be available to manage application operations. Using this concept will increase the number of people who understand the processes and thus are able to manage operations in case of a need.

2.3   DevOps cycle and practices

DevOps concepts reflect in a set of practices during the DevOps delivery cycle. The cycle is visualized in Figure 2.1. These practices mainly represent the automation concept but also come together with other concepts.[28]
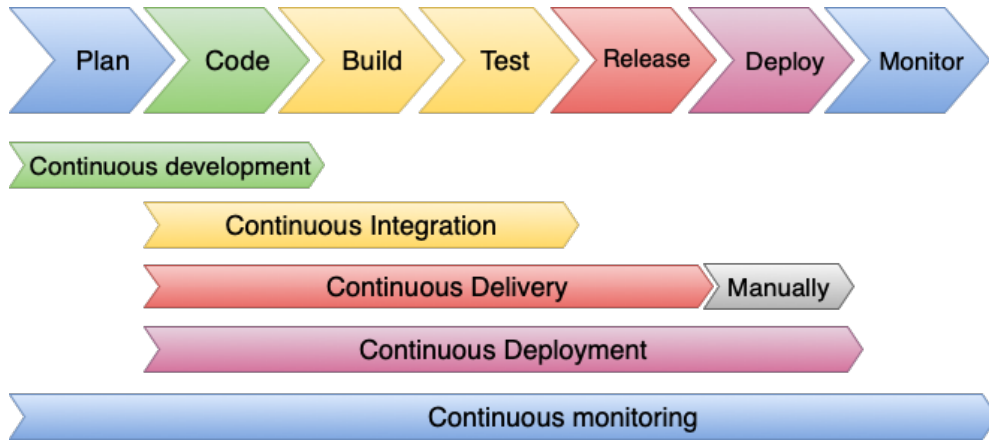

Figure 2.1: Devops cycle and practices

2.3.1   Continuous development

Continuous development is a practice composed of agile planning and coding. The goal of agile planning is to divide big problems into smaller logical problems, estimate the complexity of created tasks and plan the amount of tasks for some short time period(sprint), usually it is from one to four weeks period. This method allows getting some large significant tasks done in a shorter time, because after its division developers can work on the subtasks simultaneously and it is more effortless for testing.

2.3.2   Continuous integration (CI)

In order to avoid a problem with the integration of large parts of code, DevOps CI offers continuous pushing the code changes to the remote shared repository on the server. Every change pushed to the repository triggers a build and tests configured in a CI pipeline to make sure new changes do not affect already functioning features and also does not contain new errors.

2.3.3   Continuous delivery (CD)

Continuous delivery is an extension of continuous integration. After building and testing the code from the repository it automatically deploys releases to the testing environment and also prepares it to be deployed to the production.

It requires human intervention to deploy a release to production. This is a safer version of fast and frequent deployment, in a case when the pipeline does not contain strong testing tools and the application needs to be tested manually.

2.3.4 Continuous deployment (CDE)

Coupled with continuous delivery, the continuous deployment also deploys the release to the production. Using this practice no human intervention is required. Every change pushed to the main shared remote repository will be automatically deployed to production. The only obstacle to the deployment would be a failed build or test.

2.3.5 Continuous monitoring (CM)

Continuous monitoring is an automated method that allows to observe and discover compliance concerns and security vulnerabilities throughout the DevOps lifecycle. It also finalizes the cycle by providing feedback on monitoring and informing about existing or possible failures. It helps to resolve issues in real-time.

2.3.6 Infrastructure as Code (IaC)

Infrastructure as a code is a practice of managing infrastructure that enables automation in the DevOps lifecycle. It offers using scripts for configuring deployment environment and other infrastructure, including establishing a version control system.

2.3.7 Containerization

Containerization is the practice of packaging an application in one container. It provides better flexibility for deployment and needs fewer resources to run. Currently, Docker provides the most frequently used container toolset.

2.4 DevOps adoption

The idea of adopting the DevOps model came to me with a need to configure the new deployment of the new BI-DBS portal due to the transfer to microservices architecture. Before analyzing the DevOps concepts, I assumed that the DevOps model is just an automation idea. In fact, I was wrong and did not know it is a solid methodology bringing huge advantages to the project. From my own observations, it is a pretty common misunderstanding of the DevOps model, which leads to missing out important concepts.

"Even while automation helps speed up manual operations, cooperation and communication are the key objectives of DevOps. Automating your operations won't bring about the desired business benefits unless everyone involved in the software development, delivery, testing, and operating processes adopts excellent communication and collaborative practices."[29]

The analysis makes it clear that the DevOps model is suitable and valuable for the BI-DBS portal project management and development.

Adoption steps:

1. *Devops philosophy.* This thesis can be used to introduce the DevOps methodology to students. Before getting to development as well as learning the processes of development students should learn team organization management including DevOps concepts.

2. *DevOps Practices.* Analyze which practice we would like to adopt and how it will be beneficial and then complete the three next steps:

   a) Choosing relevant tools for a practice we would like to adopt

   b) Application of the practice using chosen tools

   c) Document the configuration of the practice for a team

   I will adopt the most important DevOps practices for the BI-DBS portal in the automation chapter using these steps.

Design

3.1 Access management

8 role — 3 role aktory, diagramy pristupu do modulu a component (zhruba) konkretni implementace je na tom kdo dela navrh modulu

Implementation and automation

CHAPTER **5**

Testing

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Acronyms

BI-DBS - Database systems

BI-SP1 - Team software project 1

BI-SP2 - Team software project 2

MVP Model View Presenter

PHP Hypertext Preprocessor

HTML HyperText Markup Language

ORM Object Relational Mapping

SQL Structured Query Language

JS JavaScript

SPA Single-page application

DevOps Development and Operations

OAuth Open authorization

IT Informational technology

Contents of enclosed CD