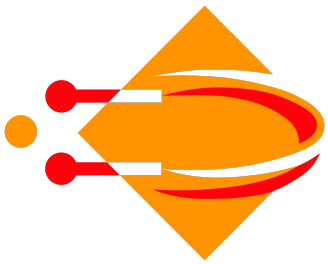
IT University Copenhagen



DevOps Exam Project

Computer Science

DevOps
MiniTwit - A Go‘ Application

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Organization:
DevelOpsITU

Repositories:
MiniTwit
ServerDeployment
DataScraper

Contents

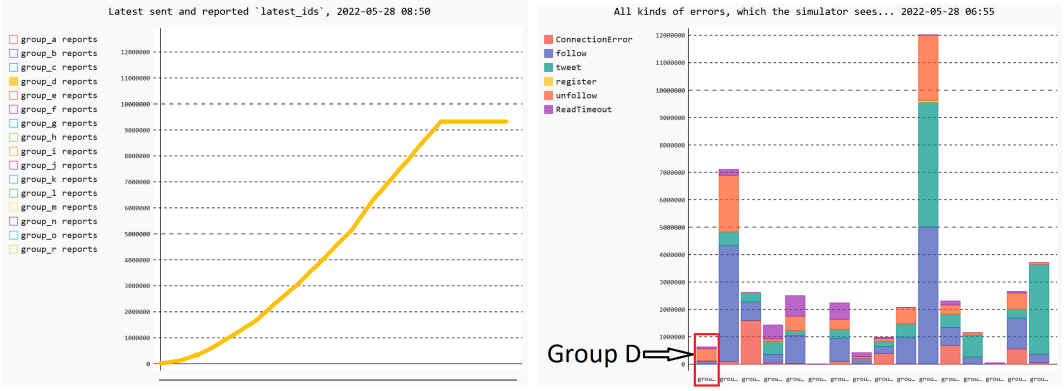
1 Introduction

This report is based on a project made during the 2022 spring course of DevOps, Software Evolution and Software Maintenance, MSc. Course material.

The project's focus was on making software that can evolve, scale and be easily maintained. An old application copying the social media platform Twitter, that had not been touched for years was provided to us. From this we were to create our scalable, maintainable, and automatable version, which we baptized MiniTwit, see Figure 1.

Figure 1: Front page of MiniTwit as a public user (Source: Own image)

To generate traffic to the site, the professors have created a simulator see Figure 2



(a) The flow of requests from the simulator. (b) Errors seen from the simulator

Figure 2: Feedback loop from the simulator to the groups (Source: Simulator)

2 System's Perspective

The system is sectioned into different services. The services are "Application", "Database", "Monitoring/Logging" and "Loadbalancer". The split is done to make each of the services scaleable and maintainable independently of each other [3].

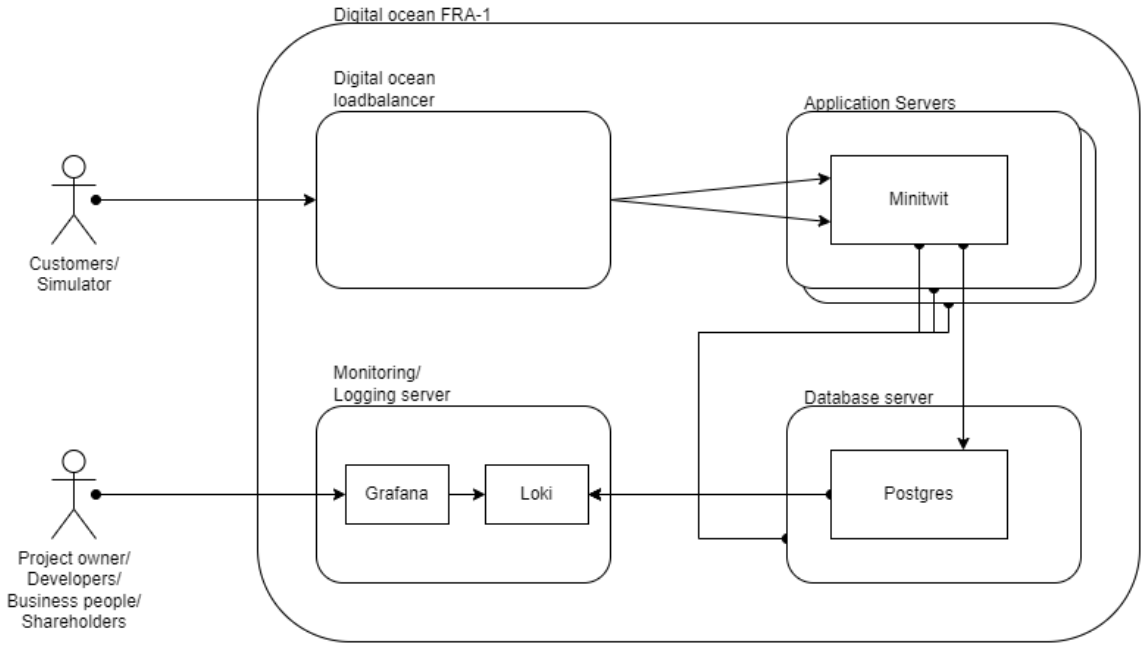


Figure 3: Image of server deployment

To access each of the services and enable the option to use Transport Layer Security (TLS), there have been configured Domain Name System (DNS) records to each of the services, with sub domains to the domain "thomsen-it.dk". The configuration can be seen in Table 1

Domain	Server(s)
thomsen-it.dk www.thomsen-it.dk	Managed Loadbalancer
database.thomsen-it.dk	Database Server
grafana.thomsen-it.dk prometheus.thomsen-it.dk monitoring.thomsen-it.dk	Monitoring Server

Table 1: DNS record overview

All the servers have been configured to redirect traffic from port 80 to port 443 and the Nginx reverse proxy on the servers terminates TLS traffic [15].

2.1 Design and architecture of of the ITU-MiniTwit system

The code follows the onion architecture pattern seen in Figure 4. This pattern have been chosen to easily separate segments of the code.

The presentation layer for accepting the incoming REST web requests and translate them to method invocations to the application layer. The application layer calls the domain layer and makes sure that the business logic and rules are kept / maintained for each call to

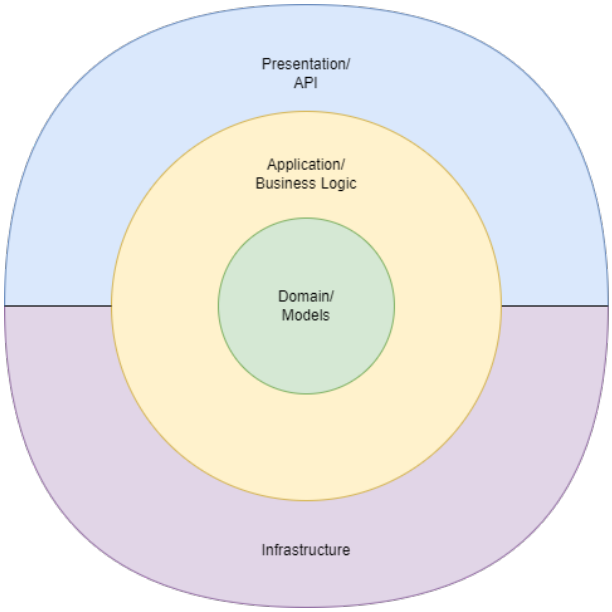


Figure 4: Onion architecture

the database layer and returned to the presentation layer. The communication between the different layers are depicted in Figure 5.

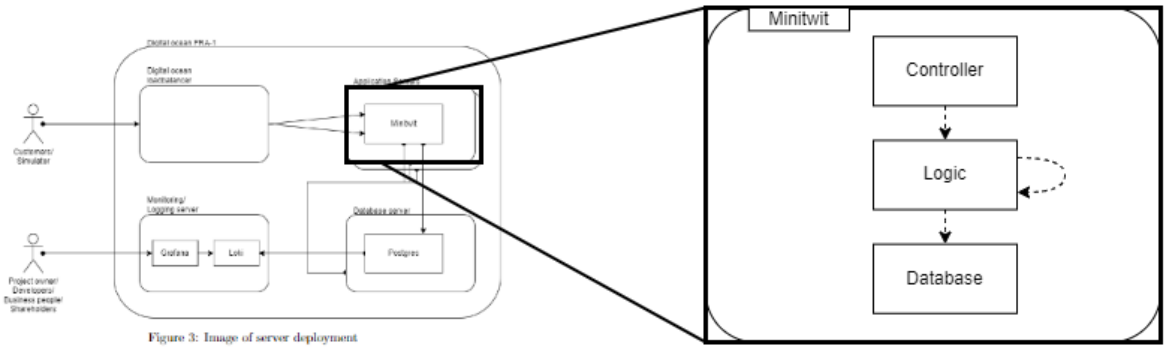


Figure 5: System design of Minitwit Application

2.2 Dependencies of the ITU-MiniTwit system

One of the first important choices were choosing a programming language and suitable web framework as can be seen documented in #33. Here the language Golang and web framework Gin were selected. For package management in Golang, the "go.mod" file contains all the packages that the project needs, indirect packages. These are maintained by Go's own package manager.

For docker images, the team has based the Go application on an official docker image build called "golang:bullseye", which is maintained by the "Docker community"[16]. The rest of the docker image dependencies are maintained by the respective project maintainers and are: "postgres:13.5, prom/prometheus:v2.33.5, grafana/grafana:8.4.3, fluent/fluent-bit:1.9.0-debug, nginx:1.15-alpine, grafana/loki:2.4.2", which can be seen the "docker-compose.yaml"[6] file.

For hosting, provisioning and management of VM's, the group choose to use Vagrant and the hosting provider DigitalOcean (DO), which both offers services like docker registry,

-databases, -Kubernetes and managed apps like Grafana for monitoring. None of these services were used however, since the group saw it against the idea of avoiding "Vendor-locking" and makes "Infrastructure-As-Code" harder to make vendor independent. However the team did give in, when the task of scaling came and setting up a managed load balancer just seemed easier to do#174.

Lastly the group depend on Github both for version control and Github Action for Continuous Integration and pushing to Dockerhub.

2.3 Important interactions of subsystems

Figure 6 shows the interactions between different services, the developer and the user. Code is developed on individual developer's computers and is pushed and pulled from and to the different GitHub repositories. From a configured CI pipeline code is pulled from the Minitwit repository, tested and build into docker images, uploaded to Docker Hub. The developer manually runs scripts from the ServerDeployment repository to update the droplets in Digital Ocean.
The user accesses the application through a reverse proxy, which sends it to the managed load balancer, that sends the user to either running application droplet.
The monitoring server interacts with the other droplets, by pulling information from them. Only the two application droplets interact with the database.

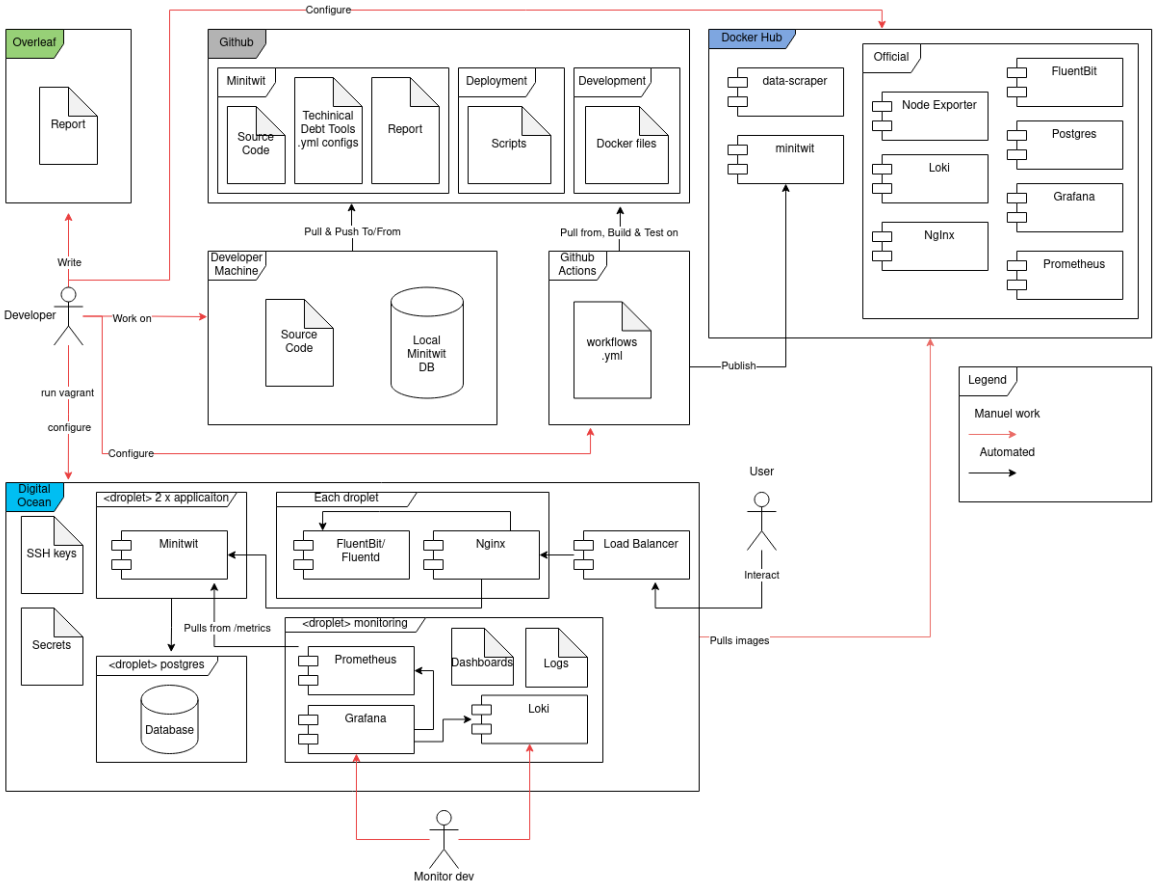


Figure 6: Interactions between services

2.4 Current state of the ITU-MiniTwit system

The current state of the system shown by the static analysis and quality assessment tools can be seen in Figure 7

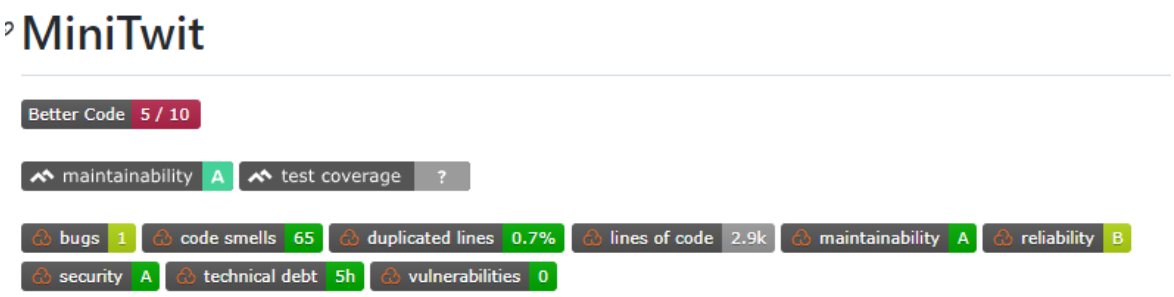


Figure 7: Code Quality of Minitiwit Application (Source: own image)

From these quality metrics, it can be seen that the results of Sonarcloud returns mostly positive quality, with a bunch of code smells. However, from these code smells only 24 are critical, yet these are not of great importance.
Compared to Sonarcloud, Better Code results in a much lower score due to a several reasons including too many lines in single functions, code duplication and low test coverage.

2.5 Chosen project license

In order to decide on a project licence, we had to audit whether it would be compatible with the licenses in our direct dependencies. In our case, these dependencies were Go binaries and it was difficult to find a general-purpose licence scanner for our project (for example, the tool "scan-code", which was proposed by our guest lecturer, did not work in our case). However, after doing some research, we decided that "Lichen" would be the best option (we also tried out "GoLicence", but we couldn't make it work). As can be seen in issue #113, we used "Lichen" to count the number of different direct licences our Go project contained. In total, our project contained 31 MIT, 6 Apache -2.0, 5 BSD-3-Clause and finally one BSD-2-Clause licence. Consequently, we choose an Apache-2.0 licence, since this is compatible with MIT, BSD-2 and 3-Clause. This decision stem from the fact that our project include Apache-2.0 licences and since Apache-2.0 is less permissive than MIT, BSD-2 and 3-Clause, we need to match the Apache-2.0 licence, which is more restrictive than the three aforementioned licences. As a final note, we also tried other scanning tools for licence detection, but these lie outside the scope of this chapter.

3 Process' perspective

3.1 Interaction as developers

Communication and interaction between team members have been moderately split between informal, formal, synchronous and asynchronous communication throughout the entire course. Initially Microsoft Teams and Github issues were used. As we later experience Microsoft Teams to not be sufficient and fitting for the team, we moved to using Discord instead of Microsoft Teams.

3.2 Team organisation

The team is organised with all members having equal authority. Project scope and project requirements are set by Helge and Mircea, as well as extra needs requested by the group.

3.3 Description of CI/CD chains

Github Actions is used for CI. TravisCI was initially used, since this was well-documented and also separated the deployment from the codebase by not having everything at Github (see issue see issue #58). However, as the free plan on TravisCI expired, CI chain was moved to Github actions, as developers were familiar with this, as well as Github actions providing a faster pipeline (mainly spinning up VM's) (see issue see issue #117).

3.3.1 CI Chain

CI chain is setup according to the operation on branches (see issues see issue #69 and see issue #117), such as seen in Figure 8:

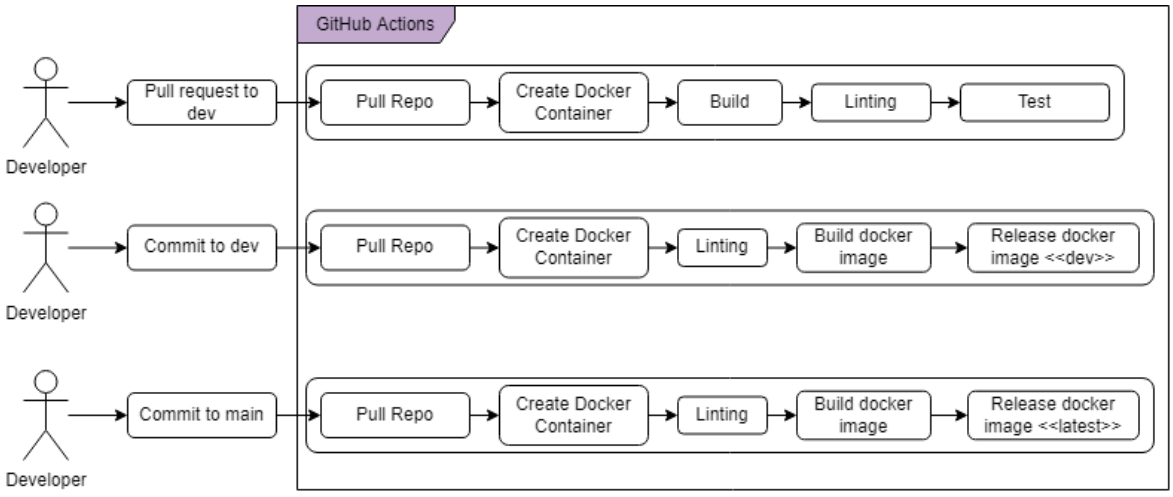


Figure 8: Different GitHub actions

An example of the "pull request to dev" CI run can be seen at GitHub [1]. The Linting tools used are Go lint[8], for linting the application code, Shellcheck [25], for linting all scripts. After Linting and testing, scancode [23], scans for licenses, however, the result is not actually used, since it has been commented out in the yml file[22]. For the other chains if everything passes, a docker image is build, linted using hadolint[12] and released.

Besides these GitHub actions SonarCloud is setup to run static analysis of the changes, and describe if code has become worse with the pull-request. Git Guardian, also checks for vulnerabilities, leaked passwords etc.

3.4 Organisation of repositories

The project is split up into three repositories.[2]

- minitwit (main application)
- minitwitdevelopment (docker containers for use in development environment)
- serverdeployment (files for setup and maintenance of server applications)

3.5 Applied branching strategy

main	used as base branch, from which releases are created. this must always be buildable and runnable.
dev	used for development. this must always be buildable and runnable. every branch (except main) is derived from this branch.
*	branches derived from dev have the following templates, depending on the issue's topic: - features/#(issueid)-(issue_title / relevant_title) - bugs/#(issueid)-(issue_title / relevant_title)

Table 2: branching strategy [2]

An example of the branching strategy applied, can be seen on Figure 9, where the green, purple and yellow all are feature branches. They are all branched out from the dev branch, and any merge conflicts should be handled in the feature branch, before doing a pull request back to dev.

Figure 9: Github network flow graph

3.6 Applied development process

For issues, Github's own issue management is used. Most issues are created and managed in *MiniTwit* repository for simplified structure and readability. Issues are then assigned to individual members, whom are responsible for the issue (with assistance from other team members).
Commits are expected to happen regularly and to be descriptive. The commits' subject is limited to 50 chars, with few exceptions. Large commits are to be described in bulletpoints. Pull-requests are to not be reviewed by the author himself, but by one more team members. [2]

3.7 Monitoring of MiniTwit

To monitor MiniTwit is the visualisation tool Grafana used. Grafana can pull data from various sources and display it on dashboards, which can have different focuses. The reasons to choose Grafana can be found in issue #100 and are summarized here below:

- Free
- Previous experience
- Extensive documentation
- Integrates well with many different data sources
- Works well with Loki[1]

To gather data from different services have Prometheus been deployed, its a tool that pulls data from services that offers a /metrics endpoint. The reason for why Prometheus have been chosen can be found in #99 and is summarised here below:

- Free
- Previous experience
- Extensive documentation
- Many library Application Programming Interface (API) interactions
- Integrates well with Grafana

The process and flow of data can be seen in Figure 10. The users query Grafana which then queries both, or Prometheus and PostgreSQL. Prometheus continuously pulls data from the different servers and applications, which provides a metric endpoint.

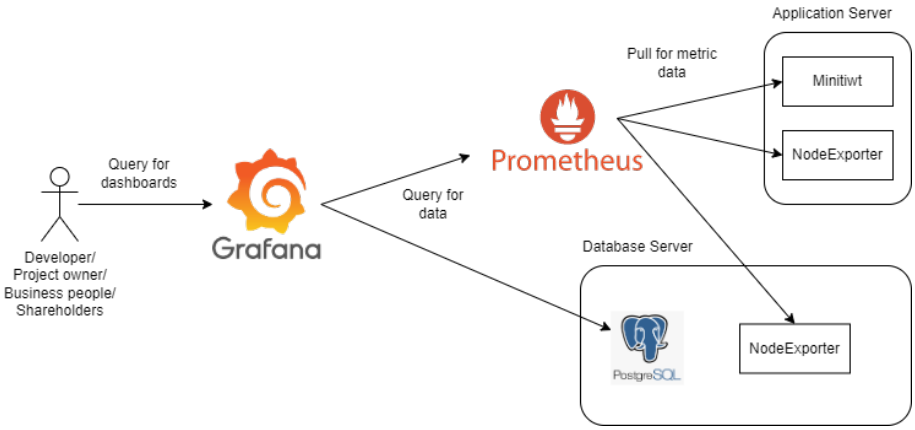


Figure 10: Grafana and Prometheus data sourcing process. (Source: own image)

Monitoring is used to provide information about: Business Intelligence, Endpoints, Server instances and the Simulator. (See Appendix A for visual of graphs and described in issues: #103, #121, #124, #126 and #151)

All monitoring information can be viewed at three endpoints: *grafana.thomsen-it.dk*, *prometheus.thomsen-it.dk* and *monitoring.thomsen-it.dk* (See issue #105).

heatmaps (issue 135)

Maybe find newer photos of updated dash-boards

[1] will be described later

As a combination with the monitoring system, alerts are set up via discord to notify of severe changes in data. Currently only Disk space, Ram usage, Response time and significant increase in Errors are setup with alerts (see issue see issue #150).

3.8 Logging of MiniTwit

Logging of the application follows the structure:
{"$level$" : "$info$","$time$" : "$2022-03-04T16:48:07Z$",
"$message$" : "$Starting\ MiniTwit\ application\ startup\ checks$"} (See appendix B and issue #90).

For logging we use Loki, which is a log aggregation system, that is inspired by Prometheus[10][11]. Since it is inspired by Prometheus and also started at Grafana Labs, it integrated well with Grafana, aswell as developers already having experience with Prometheus from previous and current project.

3.9 Security assessment

In lecture 9, the group were tasked with doing a security assessment with pentesting tools, which resulted in the work described in Appendix C and in the Minitwit Github repo's wiki.[14] The result indicates that the group still has some work to do on the security of the application, postgres server setup and a possible change of the development workflow.

3.10 Applied strategy for scaling and load balancing

The application server is scaled by having two application servers hosted. To manage these two, a load balancer is setup up to direct traffic between them (see issue #175.
The use of load balancer and two application servers also supplies the purpose of blue green deployment, such that one server at a time can be taken down, updated and put back online. This guarantees that at least one server will be active at all times. [26].

4 Lessons learned perspective

Throughout the project, the group was faced with many difficulties requiring careful considerations, due to our simulated users, needing uninterrupted access to the application.

4.1 Migration of our database

Our largest DevOps challenge throughout the project, was the necessary migration of our database from SQLite to PostGRE. Our docker container repeatedly crashed due to a memory leak from SQLite, sometimes causing everything to disappear, including the current SQLite database file.

We'd talked from the beginning of the project about separating the database and introducing a database abstraction layer (see issue #37). However, had not done so, before the simulator had started. Very concerning was the discovery, that all passwords could not be brought over due to them being binary data (BLOB), which has no direct translation into PostGRE's types, also discussed in the issue regarding the migration (see issue #92).

We found no way to translate the BLOB data, and decided to replace all passwords with the same working hash, so we could move all our data. In a real life scenario we decided we would ask all users to change their password, which would result in all newly updated passwords to be created and stored with compatibility of the new database.

revisit this sentence

4.1.1 Learnings

From our unfortunate migration problems, we learned to never put any database into production before having setup an ORM framework to help make sure a transition between database systems is easy. In a casual project we would have deleted everything and started over in a fresh new database system with fresh empty tables. However, due to the DevOps part of the course, it became important to us, to successfully move all the data, and try to have as little downtime as possible.

For our migration we used something called PGLoader[20], although in future attempts we may try something different, e.g. many database systems can save and load database tables as .csv files. This was an idea given to us by other groups later in the progress.

4.2 Request latency

Towards the end of the project, we noticed an unusual long request latency for the front page of the application. We concluded the bottleneck was the database (see issue #182). Either an odd query or the lack of an index could cause a slow lookup, causing the request latency. For future projects, especially ones with a lot of data. More effort will be put into queries and tables in the database, to make sure it scales.

4.3 Memory devouring monitoring server

At the end of the project another maintenance issue was noticed. A constant crashing monitoring server. The monitoring server crashes constantly presumably due to missing memory in the container. In future projects, we would ensure monitoring/logging services are provided more memory, due to a lot of data being held in memory when querying for these services. Additionally, we did not have much filtering of logging and no set schedule and plan of storing the logging information, which led to the memory continuously increasing.

References

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Appendices

A Grafana Dashboards

Figure 11: Business Intelligence - Grafana (Source: Own image)

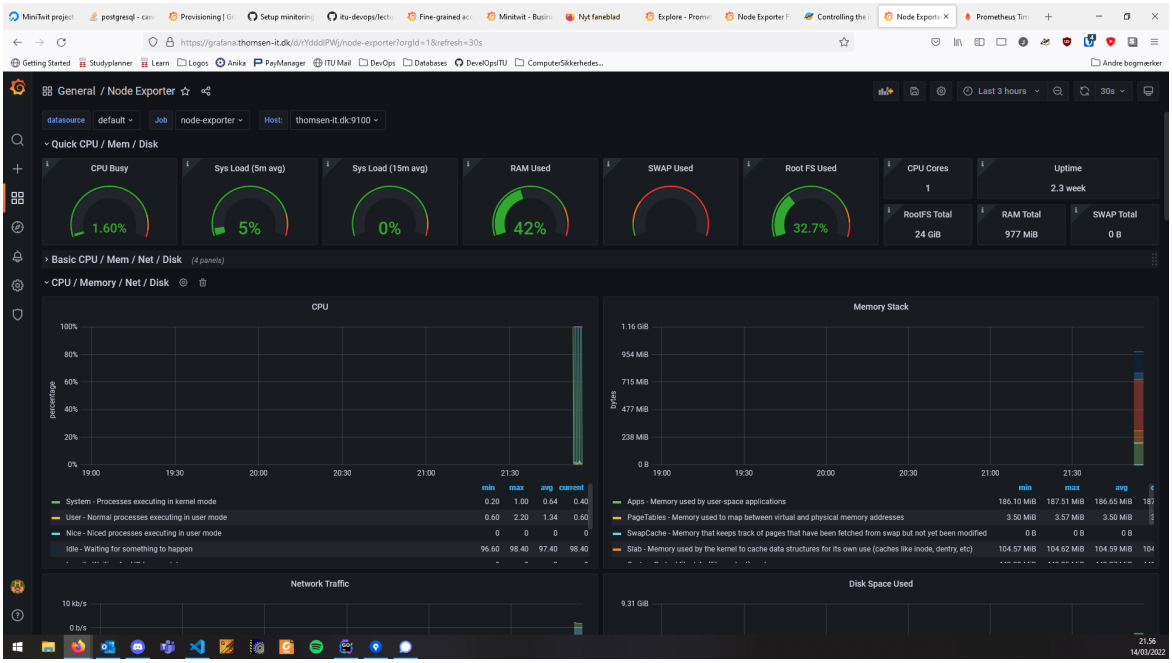

Figure 12: Node Exporter - Grafana (Source: Own image)

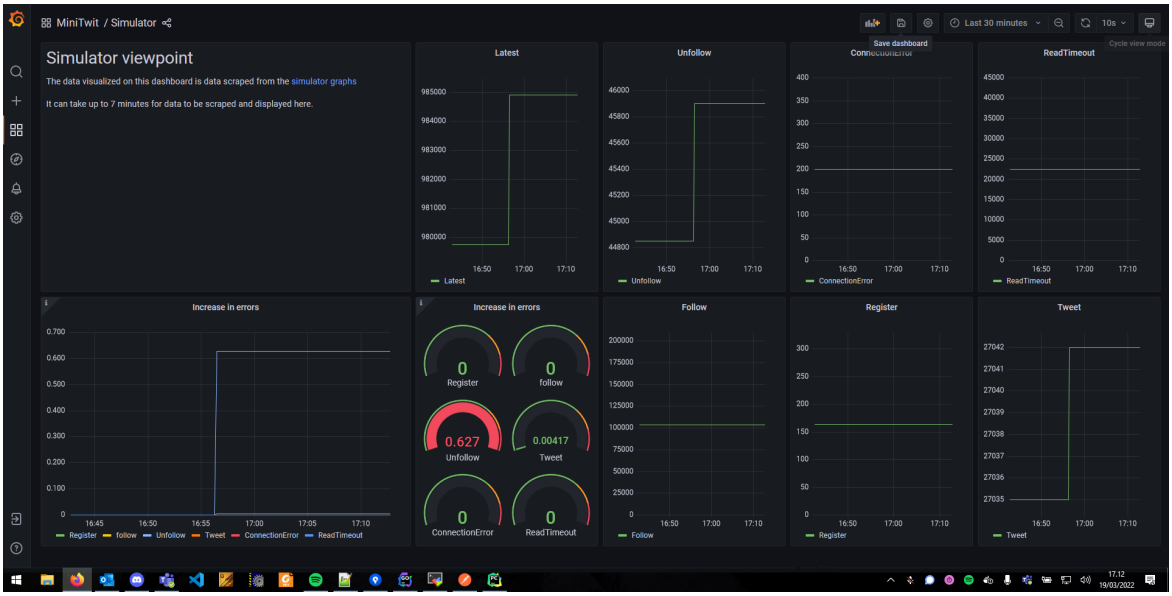

Figure 13: Simulator - Grafana (Source: Own image)

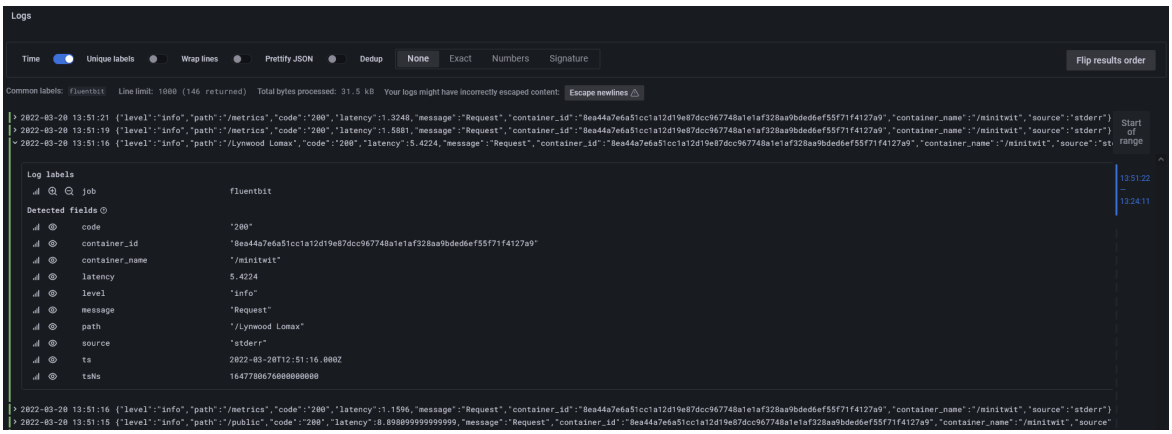

Figure 14: Logging - Grafana (Source: Own image)

Figure 15: Alerts - Grafana (Source: Own image)

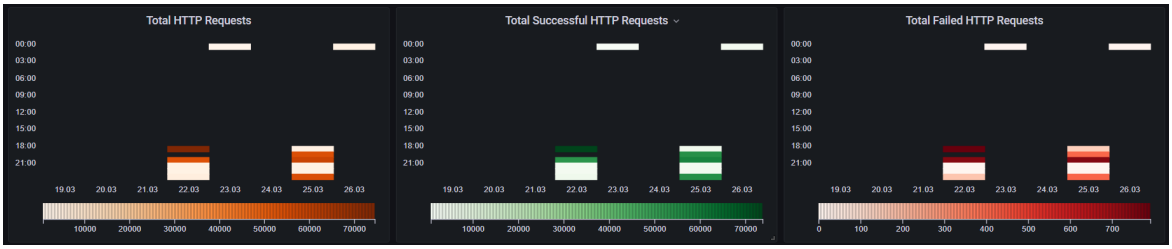

Figure 16: Heatmaps - Grafana (Source: Own image)

B Logging Structure


```
{"level":"info","time":"2022-03-04T16:48:07Z","message":"Starting MiniTwit application startup checks"}
{"level":"info","time":"2022-03-04T16:48:07Z","message":"Starting MiniTwit application startup checks - complete"}
{"level":"info","path":"/","code":"302","latency":0.3588,"time":"2022-03-04T16:48:20Z","message":"Request"}
{"level":"info","path":"/public","code":"200","latency":0.5233,"time":"2022-03-04T16:48:20Z","message":"Request"}
```


Figure 17: Logging Structure Examples (Source: Own image)

C Security assessment

C.1 Risk Identification

Firstly all of Develops "assets" are identified, to define the scope of the assessment.

C.1.1 Identifiy assets

1. Minitwit Web Application Server
2. Postgres Database Server
3. Logging and Monitoring Server
4. DigitalOcean as Cloud Provider
5. Dockerhub as Docker Registry Provider
6. Github as Code Version Control, SCM, project documentation and CI/CD provider.
7. Discord Channel as secret sharing and communication.

The first 3 are servers monitoring, running and serving the Minitwit Web Application to customers. They are all small VMs hosted at Digital-Ocean, with 1 GB of RAM, 25 GB disk and a single CPU core (as can be seen on Figure 18). The 4., 5. and 6. are crucial 3rd party service providers, that are used in the minitwit project. The 7. is the team's communication and secret sharing channel, which both contains passwords and keys, but also monitor alert notifications from the "Logging and Monitoring Server".

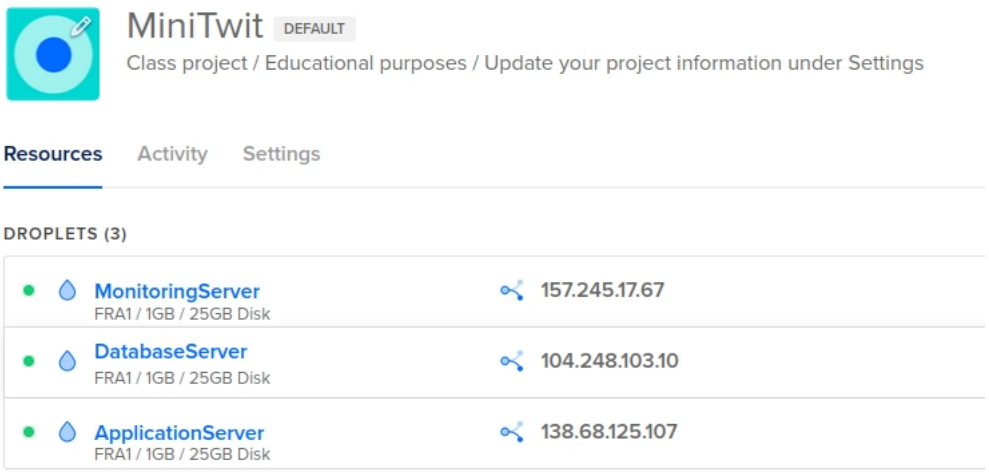

Figure 18: Caption

C.1.2 Identify threat sources

Minitwit Web Application Server - A vulnerability assessment with tools was done, with several tools. The full report[13] showed that we had several high risk threats. These threats include:

1. Path Traversal
2. SQL Injection

3. Absence of Anti-CSRF Tokens
4. CSP Header Not Set
5. Missing Anti-clickjacking Header

A path traversal attack aims to gain access to directories and files, which are not stored in the web root folder[17]. When running the automated vulnerability assessment, patch traversal was highlighted as a high risk threat. However, this does not seem to be relevant for our web-application, since it is impossible to access sensitive directories and files with "dot-dot-slash" sequences.

SQL injection attacks consists of injecting SQL queries through input fields in a web-application[18]. This attack can be used to maliciously modify database columns or even execute administrator operations on the database itself. However, this is not an issue for our application, since we're using an object-relational-mapping (ORM) to handle all database operations. Thus, we're not using dynamic queries to execute operations on the database, but delegate this to the ORM. This means that the efficacy of any SQL injection attack depends on the integrity of the ORM that we're using for our MiniTwit application. In this case, we're using GORM.[9]

Adding Anti-CSRF Tokens is also suggested by the vulnerability scanner. This makes sense, since this does not seem to be handled by default by Gin. In this case, it is worth to think about the impact an CSRF-attack would have on our MiniTwit application. A successful CSRF-attack is only limited to the privileges of the user and in this case, these include tweeting, following and unfollowing users.

Lastly it is important to note, that the application does not have any rate limiting. So it would be possible to deploy a Denial-of-Service (DoS) brute-force attack on the /login page, to obtain valid username and password combinations.

Postgres Database Server The database server has several services running, with WAN exposed ports like the Postgres server through NGINX and the node exporter service, with only the postgres server really being of interest. This can be seen on Figure 19

Threats to the postgres server could be if it was used to do privilege escalation on the machine that it is running on, which seems pretty unlikely. In a real business scenario data exfiltration could also be a threat, if any customer GDPR or business crucial data was present in the database.

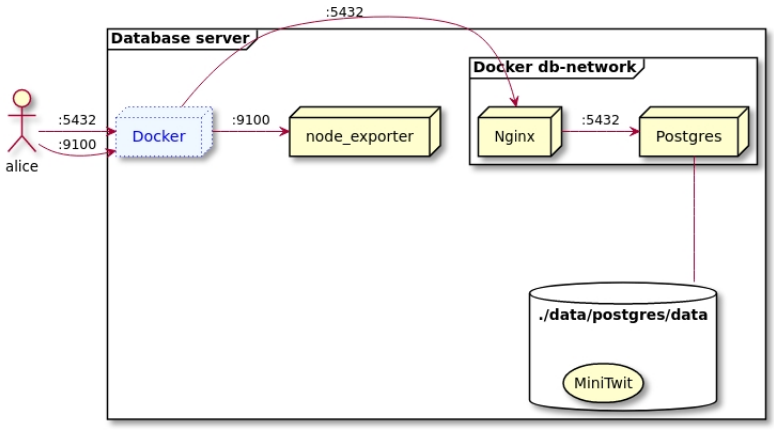

Figure 19: Database server diagram

Logging and Monitoring Server

The Logging and Monitoring server also has several services running, with WAN exposed ports through NGINX to: Loki, Grafana and Prometheus. Prometheus also talk to a node exporter and the groups own datascraper service. This can be seen on Figure 20. Loki is used to gather logging information from the application and Prometheus is gathering infrastructure metrics for monitoring.

Threats to these services:

1. Access to the Grafana dashboard might reveal business or deployment sensitive information.

2. Privilege escalation vulnerabilities to the machine in any of the service.

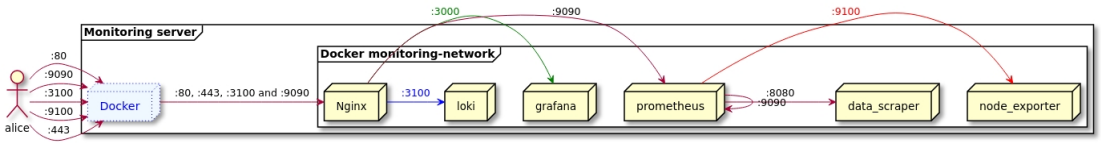

Figure 20: Monitoring and Logging server diagram

DigitalOcean as Cloud Provider DigitalOcean is used by the group as the Cloud provider, which offers a website for teams to configure their cloud infrastructure. The configuration can also be accessed through a REST API with an API key, which can be used to provision and configure current or new VMs. The website also provides a "web console", which gives the authorised user a web terminal, with access to the root user of the VMs.

Github as Code Version Control, SCM, project documentation and CI/CD provider The group uses Github for both its version control and doing Continues Integration with Github Actions. Since all the code is in public repositories, the group has to be extra cautious whenever pushing and dealing with secrets in the codebase. Another point, which was mentioned by Helge was that it can be a bit of a risk to depend on a single service provider like Microsoft's Github for multiple functions/roles.

Discord Channel as secret sharing and communication - Is the group's chosen method of communication and sharing secrets like Digital Ocean API keys, database passwords and etc. in cleartext. Discord is a communication platform, which is mostly used by the gaming community and thus not directly targeted to enterprise use. The platform has access control and with the use of a private server, should make it so it is for invited members only. However, scams[5] that lead to account takeovers or misconfigured server permissions, can lead to outsiders accessing "private" channels without being authorized and viewing secrets.

C.1.3 Risk scenarios, their impact and likelihood

Minitwit Web Application Server An adversary could in case of a SQL injection vulnerability get access to mess with the database server.(1) Not very likely, but could have high impact.

Another scenario would be that the response time of service would be degraded due to a password brute-force or a dedicated DoS attack.(2) Highly likely with medium impact, depending on the degree of degradation.

Postgres Database Server The current configuration of the server leaves the database open to anyone trying to brute-force access to the postgres database, which is only protected by a password.(3) Highly likely with high impact.

Logging and Monitoring Server A successful bruteforce attack of the grafana login page could lead to people getting access to business data and possibly get information about the database server setup.(4) Not very likely with low impact.

DigitalOcean as Cloud Provider The API key is leaked by a member through the Discord channel or in a commit to the public Github repository. The API key could then be used to destroy/remove the group's infrastructure. A worse scenario would be, that the intruder spins up powerful VM's (driving up our bill) and use them for cryptocurrency mining, connect them to a botnet or use them for criminal activity.(5) Not very likely with High impact.

Another scenario would be that one of the team members does not follow common password-policy practices, and therefore has the same passwords for several accounts with the same email address. Then in an event that there is a database/password-leak on any service that the member uses, an intruder could get access to all additional services like the member's DO account. By having access to the account the intruder could upload their own keys to the servers or simply use the web-based terminal to gain root access to the servers. (6) Not very likely with High impact.

Github as Code Version Control, SCM, project documentation and CI/CD provider The group uses Github for both its version control and doing Continues Integration with Github Actions. Since all the code is in public repositories, the group has to be extra cautious whenever pushing and dealing with secrets in the codebase. (7) Highly likely, since the group has already tried it with medium-high impact.

Another point, which was mentioned by Helge was that it can be a bit of a risk to depend on a single service provider like Microsoft's Github for multiple functions/roles.

Discord Channel as secret sharing and communication Someone gets access to one of the developers account, who accidentally also uses their Discord account in their spare time.(8) Or access could be given through an invitation link, by adding a malicious Discord

Bot or by using other social-engineering tricks. Not very likely with High impact.

C.2 Risk Analysis

From the previous section, the following risk matrix can be created.

Likelihood/Impact	Low	Medium	High
Likely		2,7	3
Possible			1
Unlikely	4		5,6,8

From this, we can sort the scenarios in a prioritised order: "3,2,7,1", where likelihood is more important than impact. The following mitigation plan based on discussion and research was decided on.

Postgres Database Server password bruteforce (3) Instead of having the postgres server open up for password-authentication, the team could setup an alternative authentication method like Kerberos, described in the postgres documentation[21]. Alternatively setting up SSH connection or simply setup a VPN between the application server and the database server.

Minitwit Web Application Server DoS or bruteforce (2) Setup rate limiting in the post message and login endpoints, will result in it becoming harder to do those attacks. Anti DDos solutions like proxying traffic through Cloudflare or use a CDN for static content, are also popular mitigation strategies.[**owasp˙dos˙mitigation**]

Github as Code Version Control, SCM, project documentation and CI/CD provider (7) There are several mechanisms that tries to automate secret detection like gitguardian[24], which uses git-hooks that can catch any secret leaking before committing or pushing leaking code. Running these scans and check, could be enforced by a company policy and don't have to run on each developer's machine. Other companies and the project's hosting provider DigitalOcean also scan open repositories, and tries to warn the owners, that a potential API key has been leaked.[4] The group even managed to receive an email from DigitalOcean, about leaking of the groups API key, at some point.

Minitwit Web Application Server DoS or bruteforce (1) As described in the subsubsection C.1.2, SQL injections happens often when the programmer is creating dynamic queries, typically using simple string concatenation. These are mostly seen in very naive implementations, where an ORM nor any input validation are present. Lastly using an ORM correctly, using prepared statements or stored procedures are usually recommended to avoid creating an SQL injection vulnerability.