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Concepts for the IT infrastructure at a University of Applied Sciences Using the Example of Data Management in the EU project DIVAGRI

Interdisciplinary tasks of business informatics in the areas data management, data quality management and service-oriented IT

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Content

Abstract **4**

Keywords **4**

1. Introduction **5**

2. IT Infrastructure for Virtualization in Teaching and Research **7**

2.1 Redundancy for Resiliency and Agility 7
2.2 Service-oriented Provision of Virtual Systems 7
2.3 Modernization of the Virtualization Infrastructure 8

3. Concepts for Data Management in the EU Project DIVAGRI **9**

3.1 Data Management Plan 10
3.2 Server Architecture and Data Communication 10

4 CMS-Backend and Farmer-App **11**

4.1 Requirements Analysis and Product Selection 12
4.2 Strategies for Development, Delivery and Agile Development 13

5. Productive Use **14**

5.1 Continuous Delivery Process 14
5.1 Ensuring Data Quality 15
5.2 Monitoring and Reporting 16

6. Summary and Future Plans **16**

6.1 Infrastructure Concept and Further Development 16
6.2 CMS User Administration 17
6.3 Open Data Access 17

Funding **18**

Acknowledgements **18**

Bibliography **19**

Abstract

Virtualization is indispensable for a service-oriented IT infrastructure, and hybrid models are also obvious in research and teaching in order to use cloud environments and on-premises solutions equally. In addition to multi-cloud solutions, internal integration concepts are also important if an organization advantageously operates multiple server infrastructures. The strategies for this are summarized in this article. The internationally oriented EU project DIVAGRI at Wismar University of Applied Sciences serves as a case study, in which innovative bio-based solutions for agricultural production in sub-Saharan Africa are implemented and tested. The IT management and business information systems of the Business Faculty are involved in the area of data management. In particular, the processes and experiences in the gradual provision and agile development of a headless CMS and a farmer app are described and discussed, and perspectives for ensuring data quality, monitoring and reporting are shown.

Keywords

agricultural, DevOp, diversification, headless CMS, virtualization

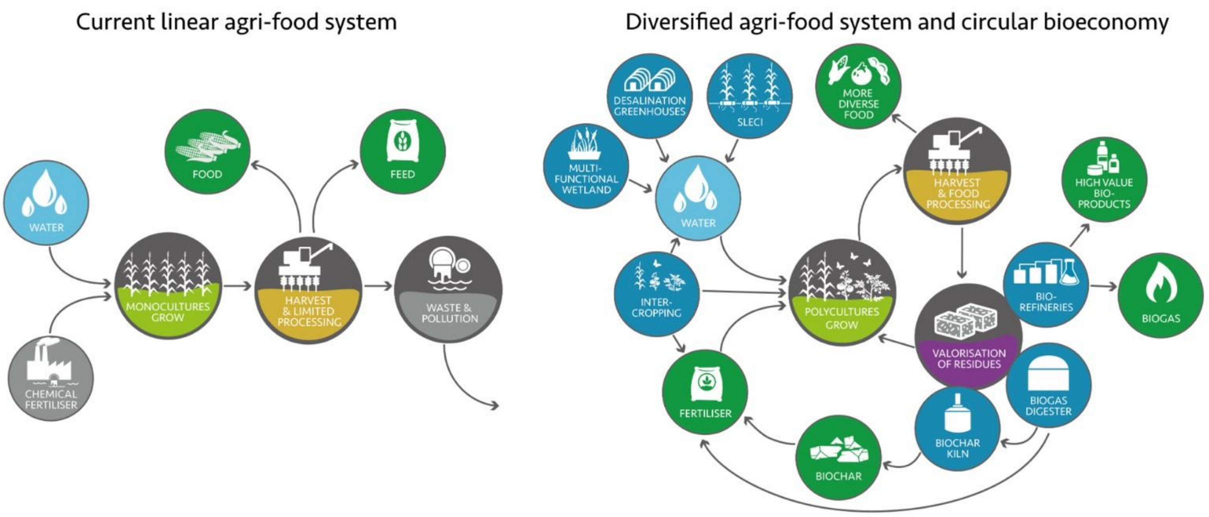
1. Introduction

The Business Faculty at Hochschule Wismar, University of Applied Sciences: Business, Technology and Design provides a large part of its IT services for teaching and applied research via terminal server and application services. These are supplemented by a so-called VM store, which offers virtual desktop and server systems with subject-related or project-related applications as a subscription via a web-based self-service portal. The underlying hardware is a network of servers that form an ESX cluster [VM05,VM23]. The basic concept for this was implemented in 2011/12 as part of a large device application with blade center systems [SH12] and is currently being modernized for greater flexibility and performance. The faculty's virtualization system is linked to the central virtualization system of the ITSMZ (IT Service and Media Center), which means that a partially redundant concept was deliberately created. This has proven useful in many ways and is highlighted in the case study described in this article.

The EU project DIVAGRI (Revenue DIVersification pathways in Africa through bio-based and circular AGRIcultural innovations) is part of the European Union's Horizon 2020 research and innovation program. It aims to improve the productivity, income and economic opportunities of subsistence and small-scale farmers in arid and semi-arid regions of sub-Saharan Africa by implementing cutting-edge, innovative bio-based solutions. These are intended to improve agricultural production, enable crop diversification, increase value creation, create ecological, social and economic sustainability and open up new local economic opportunities. The overall goal is to provide African subsistence and small-scale farmers with tools to sustainably improve agricultural productivity, profitability and resilience through improved management of agricultural resources, production diversification and creation of high-quality circular organic products. Developments and experiments of the project are illustrated in Fig. 1.

The coordinator and project manager of DIVAGRI and the work of its 21 consortium partners is the Wismar University of Applied Sciences with the independent Institute for Polymer Technology, which also developed and tested one of the DIVAGRI solutions. The senior scientific manager and technology developer comes from alchemia-nova GmbH, Austria [DIV23]. Suitable technologies were selected and developed in collaboration with project partners. For this purpose, guidelines for implementing the technologies were created, which will be tested at pilot locations in the first stage. In a second stage, the promising technologies will be implemented on selected farms (demo sites) with local small farmers. Within the project structure, these implementations are assigned to numbered work packages (WP#). Deliverables are results and reports that must be created at certain points in time during the project.

Fig. 1: Diversified agricultural and food system and circular bioeconomy - developments and experiments for the EU project DIVAGRI. Source: [DIV23]



The IT requirements initially relate to the storage of files in various formats (e.g. spreadsheets, images, films). A data management plan is provided to specify the formats and scope. Structured storage of data is not yet possible, especially in the pilot phase, because parameter lists will only be created during the course of experiments. The peculiarity of collecting data in the second stage on farms is that it is unclear which devices will be available and whether internet access will be available. Furthermore, free access to scientific publications and other project materials on the Internet must be ensured in the long term (Open Access Data Center, OADC).

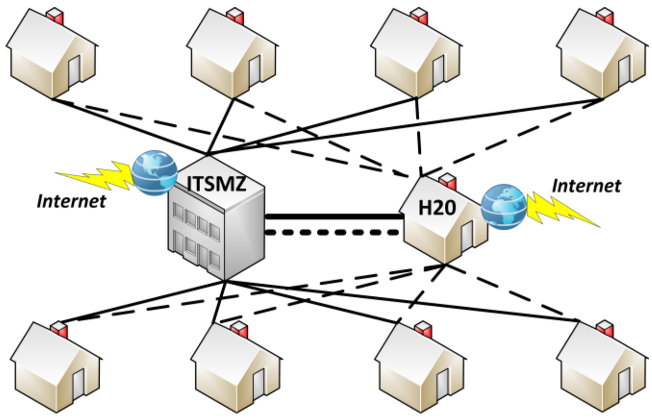
The infrastructure of the Wismar University of Applied Sciences must be used to provide IT systems. It turned out that the faculty’s virtualization concept was ideally suitable for the IT requirements of the DIVAGRI project. This concept is described in the following chapter and how the IT systems for DIVAGRI could be embedded without any extraordinary steps. The concept and servers for the data management are presented in the third and fourth sections. Findings from productive use are described in section five. Next steps and future plans are outlined and discussed in the final section.

2. IT Infrastructure for Virtualization in Teaching and Research

2.1 Redundancy for Resiliency and Agility

The topology of the campus network at Wismar University of Applied Sciences follows a high availability design, which is shown in a very simplified manner in Fig. 2. A detailed description can be found in [SH12a]. The houses symbolize faculty and administrative buildings with users. All buildings are connected via a so-called backbone network with fiber optic cables, which are shown as lines in Fig. 2. Internet access exists in the ITSMZ and also in the faculty building H20, which is located at the opposite end of the campus area for reliability. Connections for this fail-safe Internet access are shown as dashed lines.

Fig. 2: Campus network HS Wismar [SH11]



The bandwidth of 10 Gbit/s in principle also enables the networking of storage systems (Network Attached Storage, NAS or Storage Area Network, SAN). Local storage systems can be connected with cost-effective Internet-based technologies with up to 100 Gbit/s [Lub18].

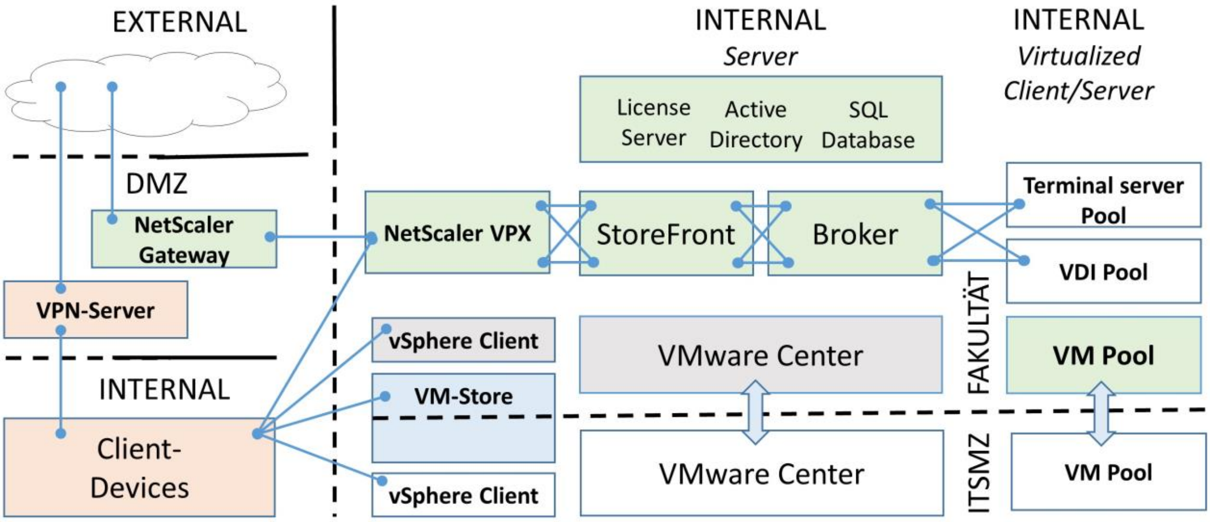
The following section summarizes the overall concept for the IT infrastructure of the Business Faculty, which was designed in particular for the interaction of teaching and research in direct and distance learning study courses. Interoperability with the central virtualization system of the central data center ITSMZ is also of particular importance, which has proven itself in an agile concept in the EU project DIVAGRI.

2.2 Service-oriented Provision of Virtual Systems

The components of the IT infrastructure for virtualization are shown in Fig. 3. The core is the virtualization system VMware, which provides virtual machines (VM) [VM05,VM23]. The vertical and horizontal lines symbolize the firewall. Access to individual systems is explicitly enabled by firewall rules (dashed lines) where access to the internal network (i.e. the intranet) is also restricted. Systems in the so-called demilitarized zone (DMZ) can be accessed from the public Internet (EXTERNAL).

All server components marked green are also implemented with VMs. NetScaler, Store-Front and Broker are part of a Citrix system with which applications and complete desktops (VDI, terminal server) can be provided [Cit20]. These components are mirrored for resiliency and load balancing. A NetScaler Gateway service is located in the DMZ area of the network and can therefore be accessed externally as mentioned before. Likewise, a physical VPN server (Virtual Private Network), through which an external client is virtually located in the internal network. They therefore have access to the services just like the internal client devices.

Fig. 3: IT infrastructure for virtualization with Citrix and VMware as hypervisor.



Virtual computers can be requested via a service-oriented marketplace web application (VM store) realizing PaaS, SaaS, and DBaaS. The marketplace environment is currently being updated or revised in terms of system technology [Voi21] but alternative concepts using Citrix are also being investigated. In the context of this project, the marketplace could be used to provide multiple test environments for further developments also in study projects. The arrows are not physical connections but symbolize the exchange of virtual machines for this purpose.

2.3 Modernization of the Virtualization Infrastructure

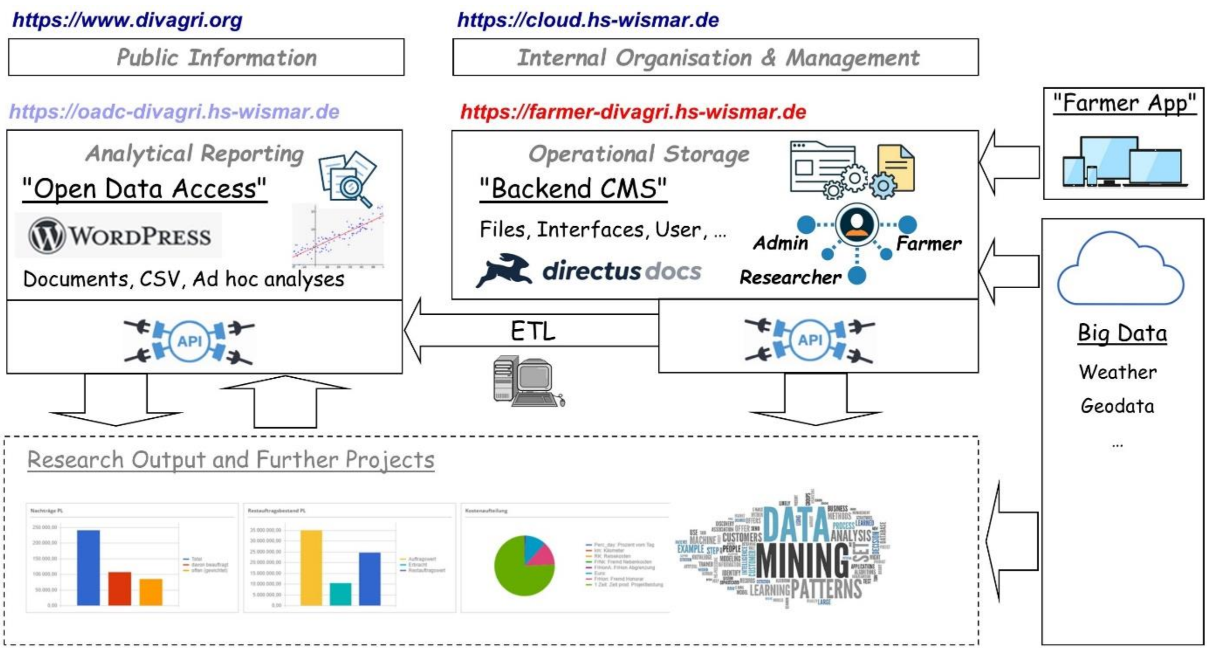
The faculty's VMware system was designed and implemented in 2011/12 [SH12a] and is currently being renewed with more flexible rack servers instead of blade center systems [Des05, Hal22]. These concepts are based on sophisticated experiences in research and teaching including distance learning study programs. For example, current study projects require powerful servers with graphics cards, for which rack servers can be used as an alternative. Other important criteria for the faculty are:

- Easier scalability
- Standardization and synergies
- Household economic aspects and sustainability
- Cybersecurity

3. Concepts for Data Management in the EU Project DIVAGRI

The overall concept for data management is shown in Fig. 4 with regard to the IT infrastructure or server architecture, whereby data actually means information, so that, strictly speaking, we should speak of information management. First, a distinction is made between public information (project website) and internal administrative data (project management). A PowerFolder system[1], known as the university's campus cloud, is used for the latter. When it comes to the data collected (surveys or measurement data), a distinction is made between operational storage and public provision for research purposes including visualization (Analytical Reporting).

Fig. 4: Basic IT concept in the EU project DIVAGRI (Source: Deliverable 7.4 [Stef22])



[1] https://www.powerfolder.com/

In the project, the work package WP7 has the title “Project and data management & coordination” and is assigned to the Wismar University of Applied Sciences. Deliverable 7.3 includes the so-called data management plan [Mat21] and Deliverable 7.4 refers to the mentioned IT infrastructure for operational data (“Data management and software operational”) [Stef22].

3.1 Data Management Plan

The Deliverable 7.3 outlines the data management lifecycle for all datasets collected, processed or generated in the EU DIVAGRI project and describes how this data will be handled during the project. In particular, the types and extent of data that should be stored during the implementation of the project are determined or estimated. This also includes the procedures that must be followed to ensure “fair” (discoverable, accessible, interoperable, reusable) access to data and the possible technical and legal or ethical issues. In addition, Deliverable 7.3 describes the open access approach to be followed for the publication of scientific results.

3.2 Server Architecture and Data Communication

Based on the data management plan, the server concept shown in Fig. 4 with the two components “Operational Storage” and “Analytical Reporting” was developed. Productive operation is to be implemented by virtual machines (VM) of the ITSMZ infrastructure, for which web addresses (see Fig. 3) and corresponding SSL certificates [Dig19] are provided for secure communication. Data should be transferred automatically using ETL (Extraction-Transformation-Load) processes, as is known from traditional data warehouse concepts [Inmon96]. As an alternative for the “Analytical Reporting” component, free and open online storage services should initially be used, such as Zenodo[2]. The development at this point therefore concentrates on the operational component with the following minimal requirements [Mat21, Stef22]:

(1) The application should be able to store and manage files persistently.

(2) The application should be available for both PCs (Windows or browser version) and mobile devices (Android/iOS), especially for use on farms (demo sites).

(3) The data/files should initially be stored locally and then synchronized with the server as soon as an Internet connection is possible.

[2] https://zenodo.org/

(4) There should be three types of users: farmers (access only to their own documents), researchers (access to all documents) and administrators (access to all documents and user management).

(5) Each user should have an identification number and access should be password protected. Two-factor authentication should be supported.

Point 1 of the list of requirements shows that a central location must be found for storing the files, which at the same time offers management options and enables an individual rights system (points 4 and 5). In an initial concept, the aim was to develop a database with integrated web applications for backend and app, for which templates (VM store in Fig. 3) have already been developed for teaching (PaaS, DBaaS) [3]. However, since data collection primarily creates files in terms of a data basis [SV22], a (free) content management system (CMS) should be used, which, in terms of interfaces, has data management properties that are comparable to an approved relational database system.

4 CMS-Backend and Farmer-App

The choice of content management system (CMS) cannot be made without further restrictions, as there is a very large selection of products and options that equally fulfill points 1, 4 and 5 above. With today's CMS, a distinction can be made between three types:

- **Traditional CMS** - The CMS provides both the backend and frontend. The frontend is the type of website that is offered to the user.
- **Headless CMS** - The CMS completely foregoes providing a front end, but instead offers interfaces (API) for retrieving the data. This approach is therefore also called “API-only”. The frontend can be provided independently of the CMS and its internal structures.
- **Decoupled CMS** - Is a mix of a traditional and a headless CMS. A frontend is available like a traditional CMS, but is optional and does not have to be used. However, interfaces for retrieving the data are available as with headless CMS (“API-first”).

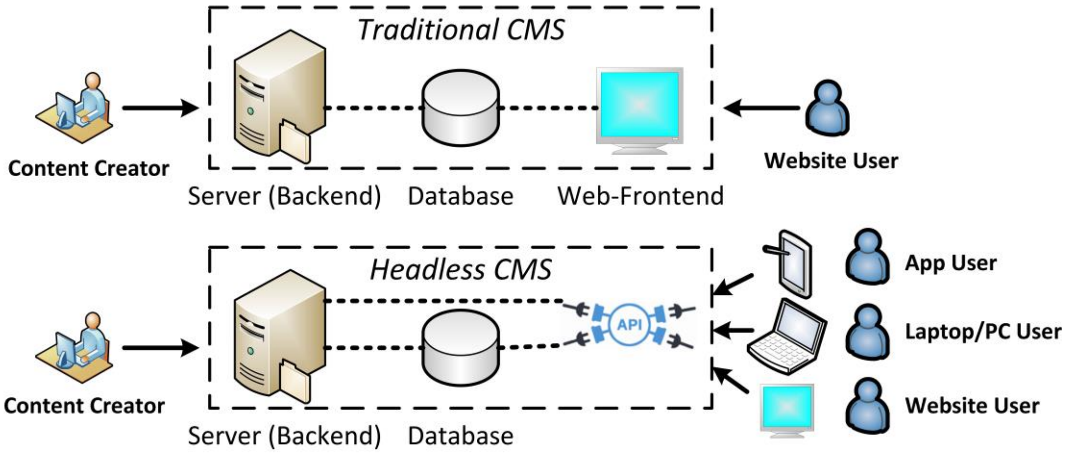
The basic difference between a traditional and a headless CMS is shown in simplified form in Fig. 5. Both types require an internal database system for persistent storage. The APIs in the headless CMS also allow direct access to the database system. Frontends can be developed user-specifically. In both cases there is

[3] https://apex.oracle.com/en/

separate access for the content creator, which is usually also a web-based application.

Furthermore, headless CMSs are more scalable than traditional CMSs. As the demand for omnichannel content and flexibility continues to grow, headless CMSs will certainly become the de facto standard for content management[4].

Fig. 5: Headless CMS compared to a traditional CMS[4].



4.1 Requirements Analysis and Product Selection

Points (3) and (4) of section 3.2 are the decisive selection criteria. The combination of offline use (3) and the diversity of end devices (4) results in the following options for developing an app with a connection to the CMS:

- **Native apps for Android, iOS and Windows** – applications that are designed to be used on a specific platform or device.
- **Progressive Web Apps (PWA)** – web applications that provide extended functionality regardless of the device by using modern web APIs. The traditional CMS mentioned above could be configured as a PWA.

Both variants offer almost the same functionalities such as offline use or installability. However, in the case of a PWA, it must be taken into account that in order to install the application, the user must first find and access the website of the web application using a browser in order to be able to install it in the second step. In the case of native apps, installation takes place via the respective stores for Android, iOS and Windows. In order to make the distribution of the application as easy as possible, it was decided to develop a native app. This means that the circle of potential CMS can be limited to headless CMS, since the frontend part is not

[4] https://www.aceinfoway.com/blog/headless-vs-traditional-cms

required. When comparing free open source variants, the candidate Directus CMS[5] stands out in particular due to the data management functionalities mentioned above. Directus was selected based on the positive experience in previous projects[6].

Directus is a content management system that allows the definition of structured data independently and flexibly and make it available automatically via an API. This makes it possible to configure the structures for capturing files via the admin interface, instead of providing "custom code" on the CMS side. It also meets points 1, 4 and 5 of the list of requirements mentioned above. If self-hosted, it is also free and an open source product. In order to keep the development costs for the native application as low as possible, a cross-platform framework was chosen. This means that it is no longer necessary to develop a separate application for each platform. There are two frameworks to choose from:

- **Flutter** – is an open-source UI framework developed by Google in 2017 and aims to develop cross-platform apps that run on mobile, Windows, macOS and Linux, as well as the web.
- **React Native** – is an open-source UI software framework developed by Meta Platforms, Inc. It is used to develop applications for Android, Android TV, iOS, macOS, tvOS, web, Windows and UWP.

In contrast to React Native, Flutter comes with a large number of ready-made components and scores highly in terms of documentation and community, which makes developing the application much easier. Since the React Native architecture uses so-called JavaScript bridging, the applications usually react more slowly than applications written in Flutter.

4.2 Strategies for Development, Delivery and Agile Development

The prototype configuration of the CMS was initially carried out in a Docker container[7] that runs on a virtual cloud server from AWS[8] with Ubuntu Linux. This is therefore a double, nested virtualization. The Docker container was ported to a VM in the faculty infrastructure and adapted and tested with regard to IP addresses and certificates. Finally, it was migrated to the central infrastructure of the ITSMZ for productive use (see Fig. 3). In the first version, the functionality of the app is

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[5] https://www.directus.io/

[6] https://www.click-solutions.de/

[7] https://www.docker.com

[8] https://aws.amazon.com

limited to offline marking of files, which are then automatically uploaded to the CMS as soon as an Internet connection is available. Here, after porting and migration, only the server name had to be adjusted.

The aim is the continuous development of the backend CMS and the app. As described in the introduction, the EU project DIVAGRI has two stages, pilot sites and farms (demo sites), so that requirements change by definition and must be responded to flexibly. The concept described allows agile development processes that are first comparable to Rapid Application Development (RAD), which is a prototypical process model [Mar91]. However, the iterative steps are planned and test cases are clearly defined, especially in the pilot phase of the project, which on the other hand corresponds to test-driven development (TDD). RAD is based on the spiral model, whereby in this case the migration process of prototypes described is cyclically repeated.

5. Productive Use

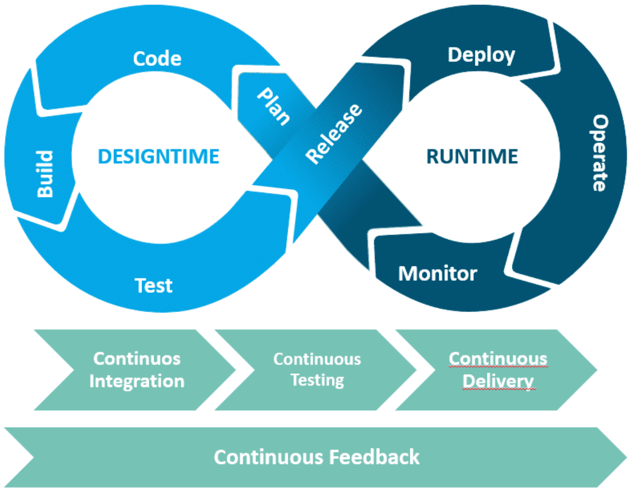
5.1 Continuous Delivery Process

The faculty's virtualization infrastructure has proven itself for years for use in teaching and research, and the experience gained is being used in the current modernization. The advantage of a redundant infrastructure was demonstrated using a specific case study, so that the parallel virtualization system (upper VMware Center in Fig. 3, used for further development) also represents a type of backup, provided that a copy of the production system is created regularly. However, other measures for maintenance and backups is not described in this article.

No special configurations were required for use in the DIVAGRI project and the planned further development could be started with the mirrored system as a proof of concept. The VM-Store of the faculty (marketplace) made it easy to integrate student assistants without the need for administration on the part of the central ITSMZ data center, which helps to relieve its workload. The security settings for faculty teaching could be adopted immediately.

When comparing the strategies of section 4.2 with an agile process model, it becomes clear that the interaction of use in the project (runtime) and further development (design time) of the CMS corresponds to the principle of DevOps[9]. In fact, the DevOp principle is not only used in the field of pure programming and software development but is also applied in data management in a data warehouse environment [Hue12].

Fig. 6: DevOps phases and continuity processes [FP20].



These findings make it clear that the concept of double virtualization with the described infrastructure can be directly transferred to other projects.

5.1 Ensuring Data Quality

Thorough monitoring and maintenance of data quality is of great importance to ensure the reliability and validity of the data. Most approaches and methods for assessing data quality are either tailored specifically to a use case or problem, or provide a general assessment without practical guidance or adaptation to a specific context. This can lead to organizations choosing an assessment method that does not meet their needs and current situation. In order to make a framework for assessing data quality applicable in a specific context, it is necessary to adapt the selection of dimensions and metrics as part of the assessment process. The following dimensions are given the highest priority: Accessibility, Accuracy, Completeness, Consistency, Integrity, Timeliness, Uniqueness, Validity. [Mat23]

To ensure data quality, the first step is to ensure uniform names for folders and files in the CMS. Parameter lists were created for the evaluation and assessment of the technologies in the DIVAGRI project, which are recorded in a monitoring program. The different data types are saved in a CMS via an app and are available as raw data for evaluations. The different data from various technologies and pilot sites are saved in a clear folder structure. The folders are named using listed abbreviations for work package, technologies and pilot sites. The name of the file

[9] https://devops.com/the-evolution-of-devops/

also reflects the folder structure. This redundancy ensures that the file names can be clearly assigned even outside the folder structure if they are incorrectly classified. File names are made up of the abbreviations for work package, technology, pilot site and content type of the data:

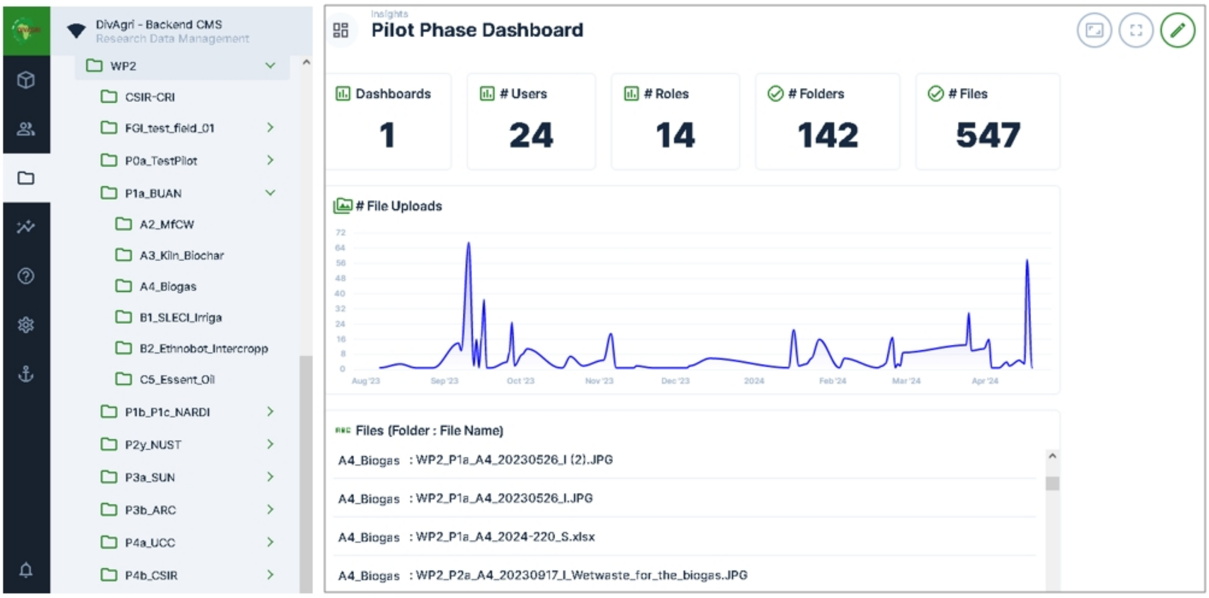
```
DIVAGRI/WP2/C3/P1a/WP2_C3_P1a_20230110_S.xlsx
```

For example, the measurement data for the "Insect Farming" technology (C3) are recorded using Excel (S=Spreadsheet), which were collected by the Experimental Farm BUAN (P1a) on January 10, 2023.

5.2 Monitoring and Reporting

The folder structure in the CMS for implementing the naming concept described can be seen on the left in Fig. 7. On the right side of the figure, an analysis of the content is shown, where the options of Directus CMS can be used to create dashboards. As an example of monitoring, the time course of file uploads is included.

Fig. 7: Folder structure and analysis of the pilot phase in the CMS.



6. Summary and Future Plans

6.1 Infrastructure Concept and Further Development

This article summarized an infrastructure for virtualization for research and teaching and showed that it could be used for the DIVAGRI project without further adaptations (Fig. 3 and 4). Double virtualization for the development and provision of a headless CMS (Directus) supports the further development of the system and is in principle comparable to the concept of DevOps (Fig. 6). This continuous delivery life cycle within a DevOp-like environment corresponds to the so-called Disciplined Agile Delivery (DAD) method where a team learn from experiences [Amb20].

Currently, the CMS is in the runtime section of Fig. 6 for the first time. The documentation of the further development will empirically prove the assumed DevOp concept.

6.2 CMS User Administration

The Directus CMS supports roles which are assigned to pilot leaders regulate the access rights to the individual pilot folders through so-called CRUD-permissions (*create, read, update, and delete*) which are in turn assigned to the roles. Despite these options for fine-grained permission control, a certain amount of self-discipline is still required when saving files. Although researchers can be expected to have this IT-oriented competence, additional functionality would be desirable e.g. to enforce compliance with file names. This is also the reason why a separate app was provided for uploading files from the second project phase with farms (demo sites). Overall, the effort for the programming actions required for this was underestimated in the budget and should be better taken into account when planning future projects. It is obvious to use the proven folder structure also for the demo phase.

When monitoring uploads as shown in Fig. 7, it would also be interesting to see which file types were uploaded. The interfaces of the headless CMS are currently being used to create a separate web application that offers more sophisticated reporting and visualization options.

6.3 Open Data Access

Open access means free and open access to scientific information online. Open access can include scientific publications and research data. In the European Union's Horizon 2020 research and innovation program, scientific publications from the projects must be made freely available under open access conditions.

As shown in Fig. 4, the IT concept includes a server for open data access in addition to the CMS. However, this was beyond the scope of this project, so a freely available system shall initially be used for this, such as Zenodo. But in addition to files and folders, the CMS used also enables the creation of database-like tables (so-called collections) or dashboards (see section 5.2) and the role concept described includes the possibility of setting up open access.

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