smart skills
smart sustainable agriculture

Course 1:

Digital Farming and Precision Agriculture

IoT – Database and IoT

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Learning Outcomes

The aim of using cloud computing in modern agriculture is to enable real-time access to data and ensure scalable, efficient management of information. Agricultural data—gathered from IoT sensors monitoring soil, climate, and livestock—is stored and processed via cloud platforms to support better decision-making. Despite its benefits, key challenges remain in ensuring data security, privacy, and system interoperability. Cloud-based decision support systems (DSS) help optimize operations such as irrigation, fertilization, and harvesting. Applying data management skills is essential for developing simple cloud-based solutions for monitoring and control.

Describe…

…how agricultural data is collected, stored, and managed using cloud-based platforms.

Identify…

…key challenges related to data security, privacy, and integration in smart farming systems

Explain…

…..the role of cloud computing in modern agriculture and its benefits for data accessibility and scalability.

contents

Click to type..

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01

Introduction

Infrastructure as a Service (IaaS)

Infrastructure as a service (IaaS) is a form of cloud computing that provides virtualized computing components (Virtual servers with CPU, memory, storage, network access, etc.) over the Internet. IaaS consumers do not manage or control the physical cloud infrastructure but has control over operating systems, storage, and deployed applications.

Companies that lack an owned data center can turn to IaaS for a quick, cheap infrastructure that can be expanded or terminated as their business requirements change. Traditional companies that need compute power to run variable workloads on tight budget are perfect uses cases of IaaS adoption as they will only pay for the services they use.

Platform as a Service (PaaS)

This computing delivers development/operating environments as a service. It includes set of tools and services designed to make coding and deploying the applications quickly and efficiently.

A PaaS provider hosts the hardware and software on its own infrastructure. As a result, PaaS frees users from having to install and manage in-house hardware and software to develop or run a new application.

Development companies and/or factories that want to implement agile methodologies are the most suited for PaaS. PaaS providers publish many services that can be consumed inside applications. Those services will be always available and up-to-date.

Software as a Service (SaaS)

Here is an expanded and simplified version of the provided text, rewritten for a **general (non-technical) audience**:

In the Software as a Service (SaaS) model, users can access and use software applications that are hosted on remote cloud servers, instead of installing them on their own computers. These applications are managed and maintained by the service provider, so users don’t need to worry about updates, security, or technical maintenance.

The main advantage of SaaS is **convenience**—you can use these applications from almost any device that has internet access. This includes desktop computers, laptops, tablets, and smartphones. Most of the time, you simply open a web browser (like Chrome or Safari) and log in to the application, just like you would with email services like Gmail or Outlook.com. Some SaaS platforms also allow connections through programming tools or dedicated mobile apps.

This model is widely used today in business, education, and daily life because it allows people to work, communicate, and share data easily—without needing complex setups or powerful hardware.

Cloud services

Key characteristics of cloud computing include global accessibility, allowing users to run services from anywhere with internet access. It uses a **pay-as-you-go** model, so you only pay for what you use. The cloud is highly **flexible**, adapting to your changing needs. With **on-demand self-service**, resources like storage or applications can be launched instantly. Finally, it ensures **security and reliability** through built-in protections, backups, and 24/7 availability.

Introduction to Leading IoT Cloud Platforms

Modern precision agriculture relies heavily on cloud-based platforms to collect, process, and analyze data from IoT devices. Several major technology providers offer robust IoT solutions that support smart farming, automation, and data-driven decision-making.

- Microsoft Azure IoT Suite
- AWS IoT Platform
- Google Cloud's IoT Platform
- Google Cloud's IoT Platform
- IBM Watson IoT Platform
- Oracle IoT Platform
- Cisco IoT Cloud Connect

Cloud IoT services

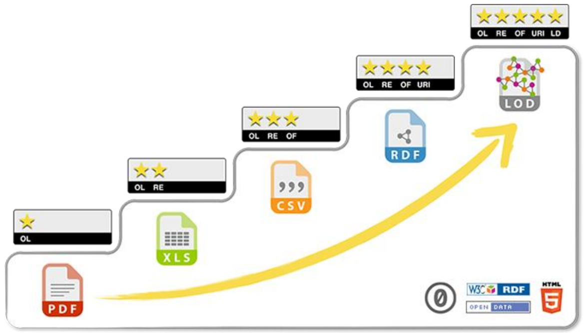
- Connectivity - ensure seamless data transfer using APIs or real-time streaming.
- Control services (Device management) - enable efficient device management and remote configuration.
- Data processing services - ransform raw inputs into usable insights.
- Data store services - provide scalable and secure storage for collected data.
- Analytics services - help detect patterns and trends, while **dashboards and visualization tools** present the results clearly to support decision-making.

Data, information, data set, open data

Data is a collection of discrete values that convey **information**

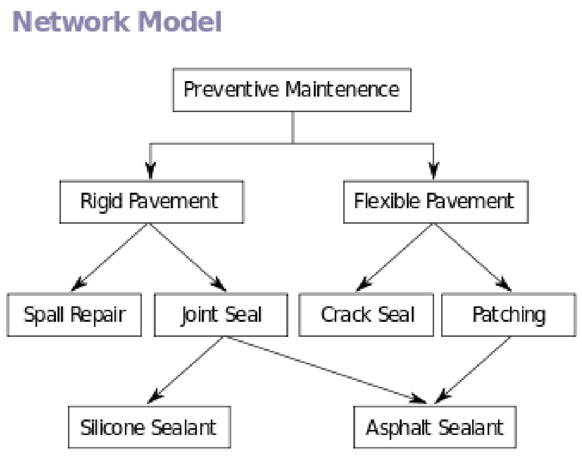
Data set is a collection of data (usually table)

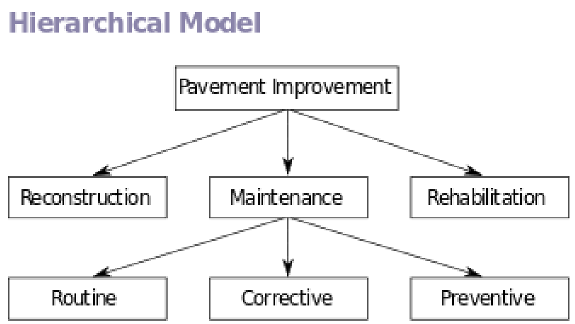
Open data is data that is openly accessible, exploitable, editable and shared by anyone for any purpose, even commercially

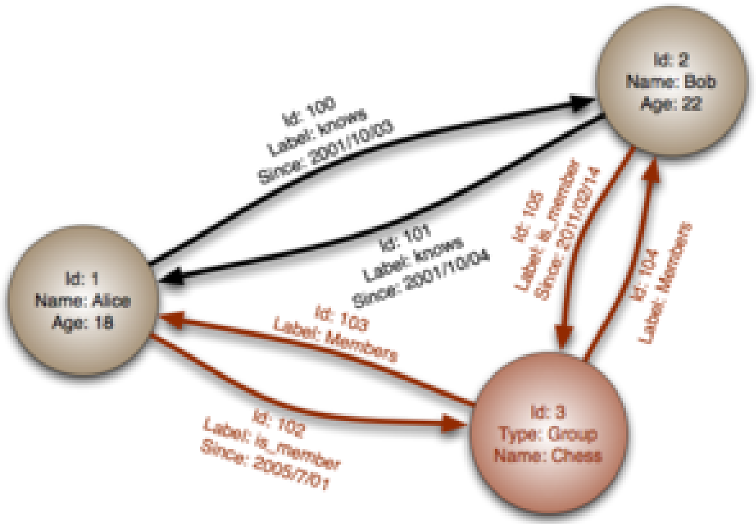


Database model

- Flat model (table)
- Hierarchical model
- Network model
  - Inverted file mode
  - (Document-oriented database)
- Relational model
  - Dimensional model (OLAP)
- Post-relational database models (NoSQL)
  - Graph model (Nodes, Edges, Properties)
  - Multivalue model
  - Object-oriented database models
- https://www.educba.com/types-of-database-models/







What is the CAP Theorem

- CAP theorem is also called brewer's theorem. It states that is impossible for a distributed data store to offer more than two out of three guarantees
- **Consistency:**
  - The data should remain consistent even after the execution of an operation. This means once data is written, any future read request should contain that data. For example, after updating the order status, all the clients should be able to see the same data.
- **Availability:**
  - The database should always be available and responsive. It should not have any downtime.
- **Partition Tolerance:**
  - Partition Tolerance means that the system should continue to function even if the communication among the servers is not stable. For example, the servers can be partitioned into multiple groups which may not communicate with each other. Here, if part of the database is unavailable, other parts are always unaffected.

02

IoT and Database

IoT and Database

InfluxDB

- Open-Source time series database
- Accepts data via HTTP, TCP, and UDP
- Provide data via REST API
- Used closely with grafana

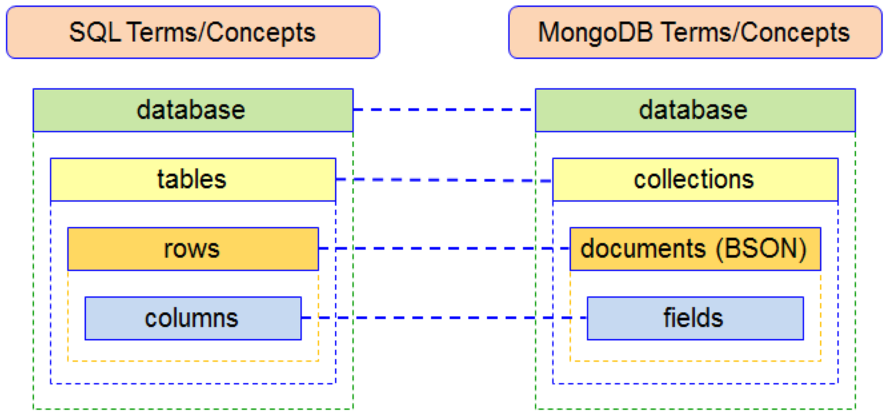
PostgreSQL

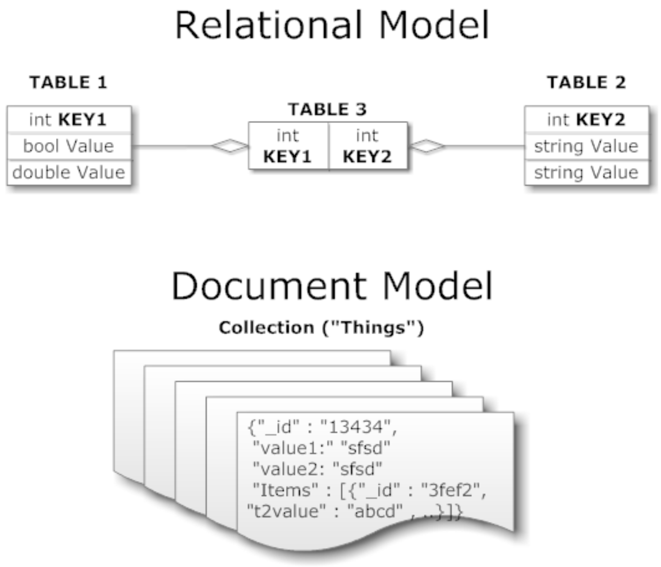
  - Relational
  - Open source
  - Big community
  - (ArcGIS)

IoT and Database

MongoDb

- source-available cross-platform document-oriented database





IoT and Database

Elasticsearch is a powerful search engine that helps users find and analyze information quickly from large amounts of data. It is especially good at **full-text search**, which means it can scan and match content from long texts, documents, or websites—similar to how a search engine like Google works, but used inside companies or apps.

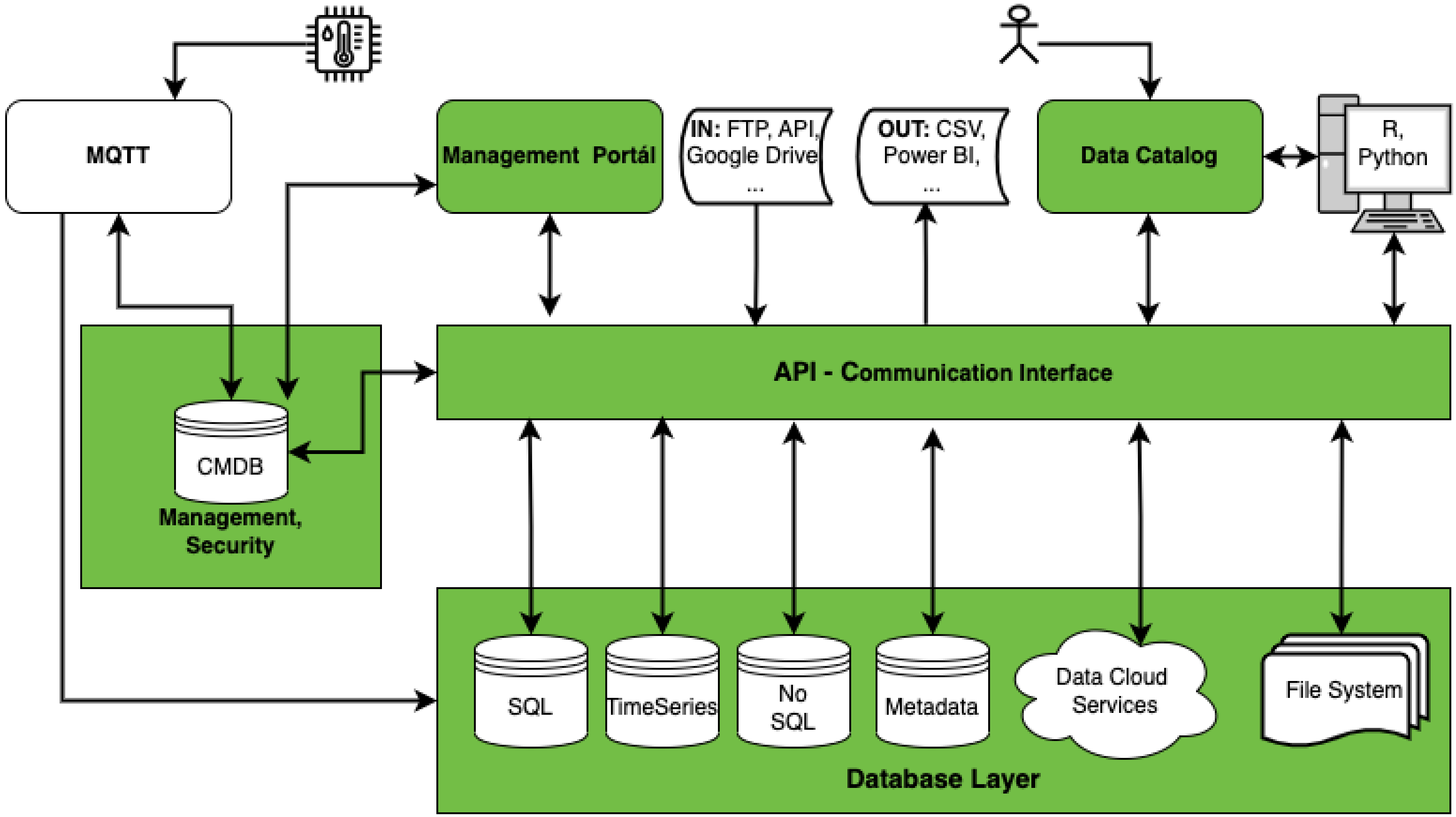
One of its strengths is that it can support **multiple users (tenants)** at once, each working with their own data. It communicates through a simple **web interface (HTTP)**, which makes it easy to connect with other software. Data is stored and searched in a flexible format called **JSON**, which doesn't require a fixed structure in advance—making it ideal for fast-changing or complex data.

In short, Elasticsearch allows developers and organizations to create **fast, flexible search and analytics tools** for websites, applications, or internal systems.

Data Management Platform CZU

03

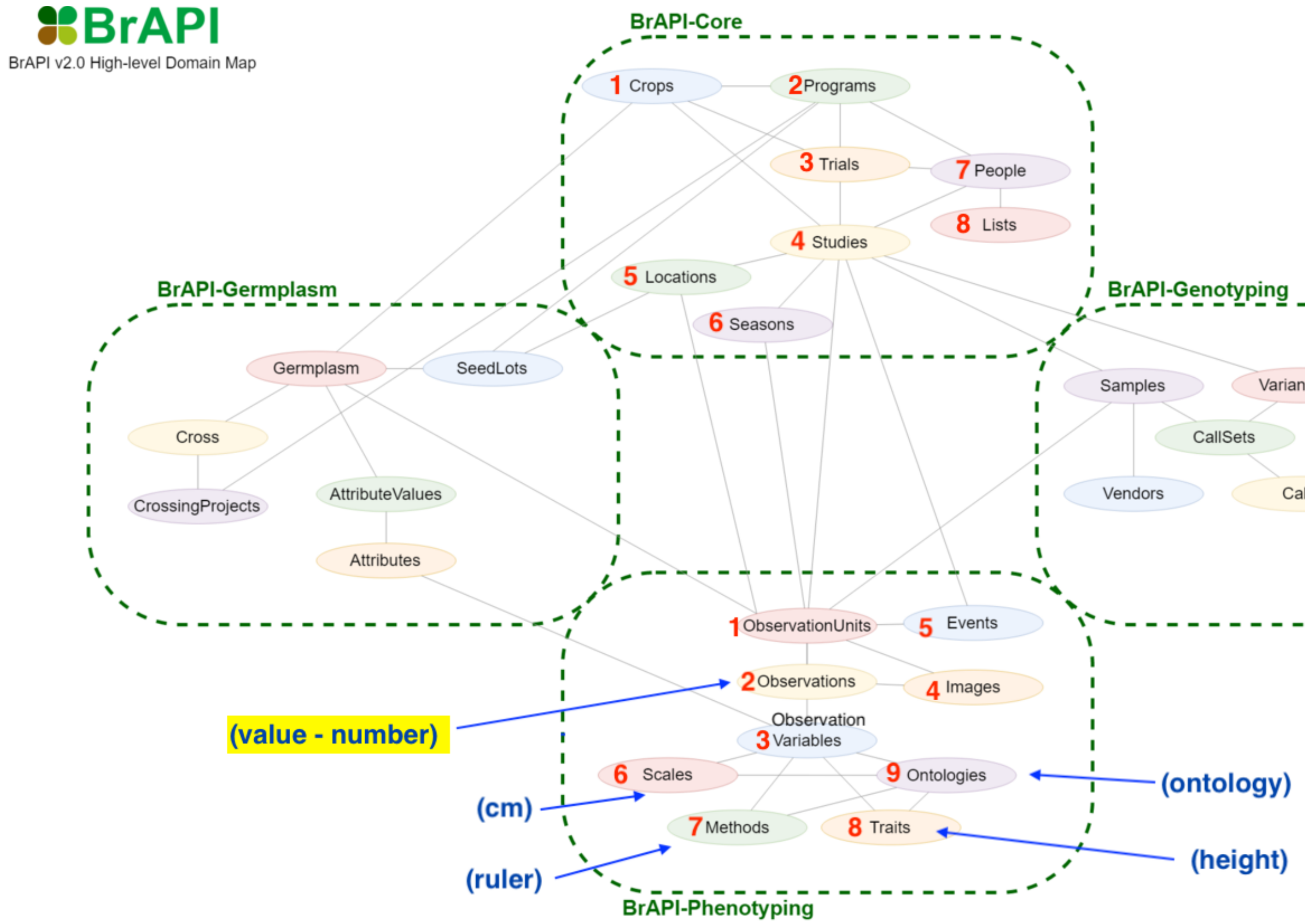
Data Management Platform CZU - DaMP



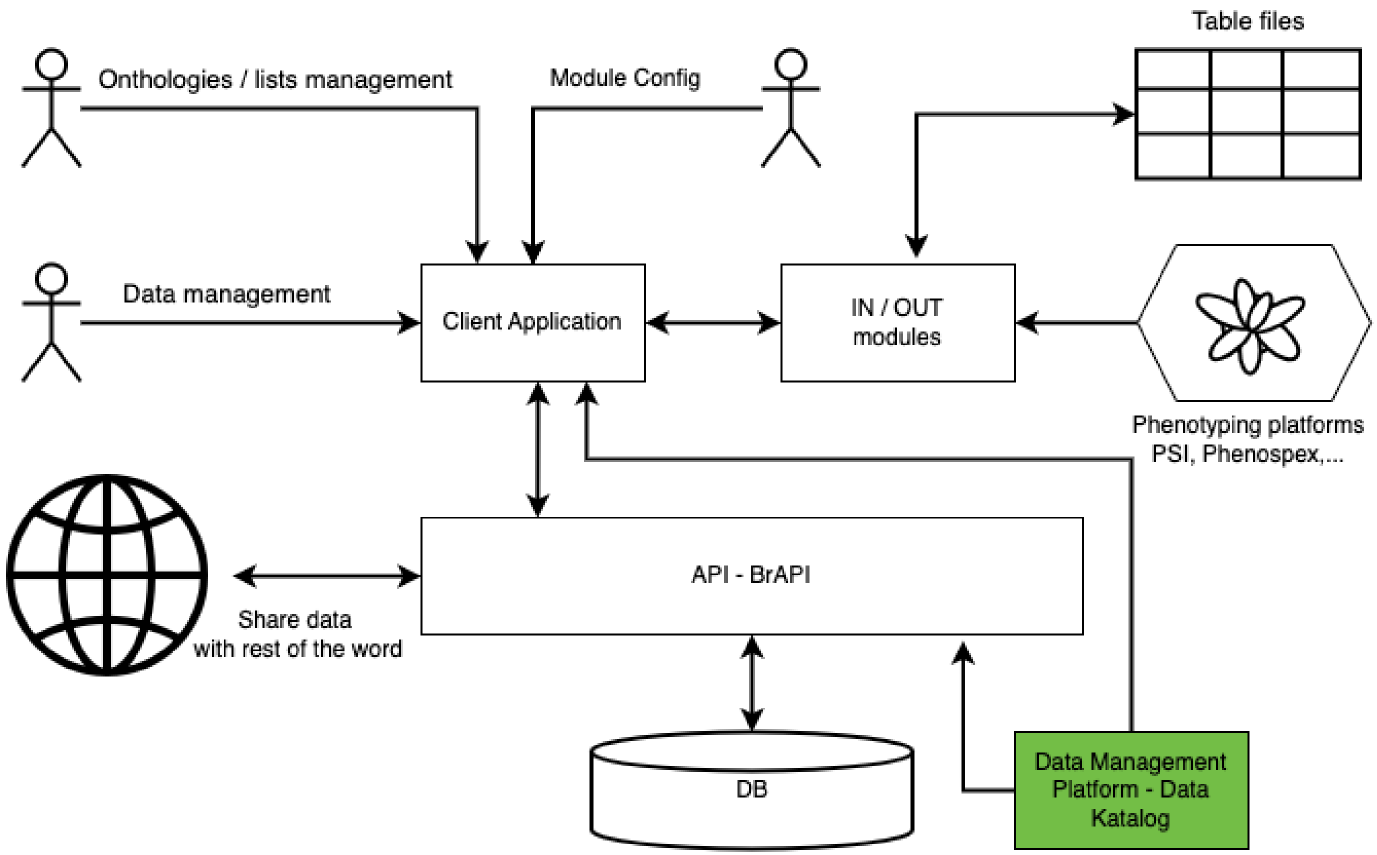
Subject/Domain-specific repositories/DB

- The trend of sharing results globally between disciplinary research teams
- The platform has implemented a pilot for the area of plant phenotyping, which uses the global industry standard for describing plant traits - BrAPI (communication) + MIAPPE (Ontology, dictionaries)
- Ready for further implementations e.g. hydrology

Subject/Domain-specific repositories/DB

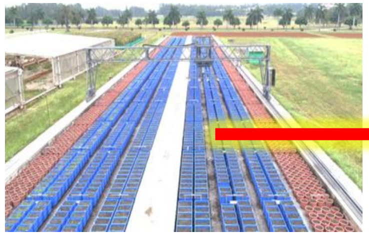


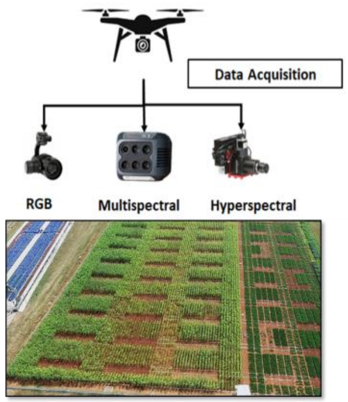
Subject/Domain-specific repositories/DB

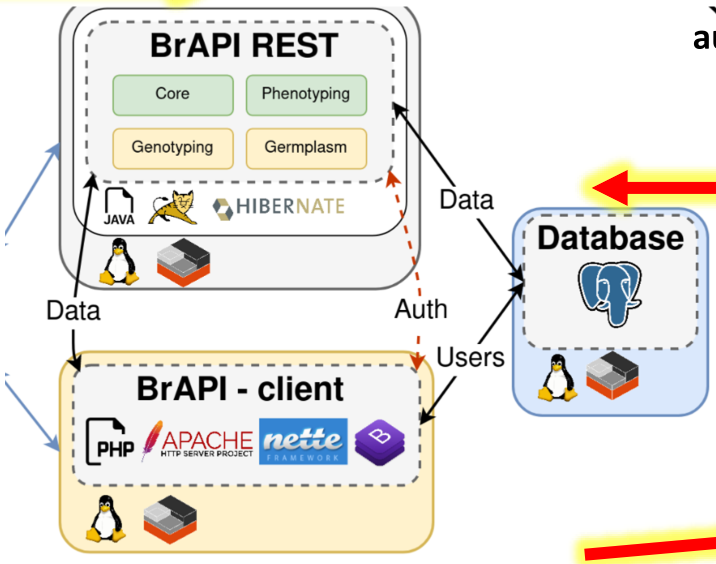


Pipeline in progress - example breeding

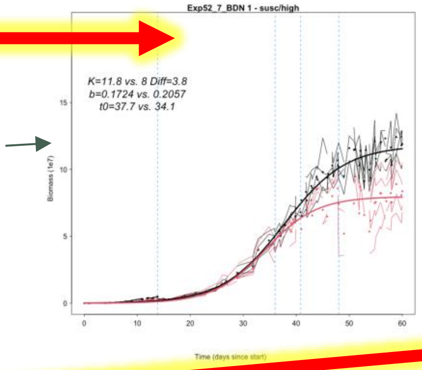
Phenomic systems



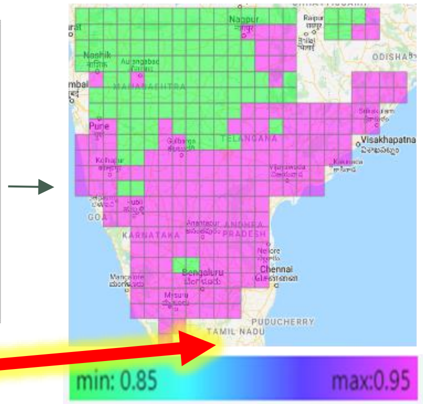




automated calculation of model coefficients



effect of phenotyped G & selection on a go



$$y(t) = \frac{K}{1 + exp(-b(t - t_0))}$$

Further Development of IoT in Agriculture

- Predictive maintenance
  - Sensors
  - Sound

- Digital twins

Criticism of IoT

- Buzzword
- Incompatibility
- A large amount of data
- People Tracking Tools - Big Brother
  - RZ, cameras, GDPR
- Unsecured devices
- Industry 4.0 – less work for people

IoT Trends

- Trends in IoT use of AI/ML
- Development of wireless technologies (5G, NB)
- Power supply development
  - battery
  - alternative
- Healthcare
- Agriculture, biology
- Safety
- Transport/Cities
- Energy saving

04

Case Study

Case Study: Data Management Platform at CZU – Plant Phenotyping

Problem:
Agricultural researchers face challenges in managing, sharing, and standardizing large datasets related to plant traits, especially across international projects.

Solution:
The Czech University of Life Sciences (CZU) developed a domain-specific data management platform using global standards like BrAPI and MIAPPE for plant phenotyping.

Implementation:
The platform allows researchers to store, annotate, and share data using structured ontologies and standardized formats. The pipeline also includes automated analysis of plant images and calculation of model coefficients for breeding programs.

Results:
Improved data interoperability and sharing across research teams, faster evaluation of genotypes, and readiness to expand the system to other domains like hydrology.

Case Study: Predictive Maintenance with IoT Sensors

Problem:
Agricultural machinery often fails unexpectedly, causing downtime during critical operations like planting or harvesting.

Solution:
IoT-based predictive maintenance uses sensors and AI to monitor machine condition and anticipate failures before they occur.

Implementation:
Sensors installed on equipment track sound, temperature, vibration, and usage patterns. The data is analyzed in real time to detect anomalies and predict failures.

Results:
Reduction in unplanned downtime, increased machinery lifespan, and improved planning of service intervals, leading to significant cost savings.

Case Study: InfluxDB and Grafana for Time Series Analysis in IoT Agriculture

Problem:
Managing and visualizing high-frequency sensor data (e.g., soil moisture, temperature) can be difficult with traditional databases.

Solution:
InfluxDB, a time-series database, combined with Grafana for visualization, allows efficient monitoring of real-time agricultural data streams.

Implementation:
Sensor data is transmitted via HTTP/UDP and stored in InfluxDB. Grafana dashboards provide dynamic visualizations, enabling farmers or researchers to track trends and anomalies in near real-time.

Results:
Improved visibility into field conditions, quicker reaction to environmental changes, and better understanding of long-term data patterns.

Case Study: MongoDB for Flexible Data Storage in Smart Farming

Problem:
Traditional relational databases are too rigid for handling the diverse and unstructured data types generated by modern agricultural technologies.

Solution:
MongoDB, a document-oriented NoSQL database, offers a flexible schema-free structure ideal for storing heterogeneous agricultural data.

Implementation:
Used to manage IoT device outputs (e.g., from cameras, weather stations), MongoDB stores JSON-like documents that can evolve over time without requiring schema redesign.

Results:
Faster development of applications, easier integration with mobile/web platforms, and better adaptability to changing data requirements in agricultural research and farm management.

Well done!

You finished the third module of **Course 1**!
Keep going on this learning journey.

In the **next module** you will learn about GIS Mapping and Field Optimization**.**

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