Development of a smart farming dashboard based of 5G mobile Data

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Abstract: This work in progress paper is written as a short description mainly of the backend of project 5G, which is in the field of smart farming. The project focuses on using different technologies and machines for weed management. This work in progress paper highlights the need for efficient weed management. It discusses the problems which are associated with weed management and it raises questions that need to be addressed in this domain. Moreover, the topic of using weed management 5G, UAV (unmanned aerial vehicle) and field robotics in agricultural and farming services is an important topic at present. Besides, the work in progress paper shows possible technical concepts and processes which can be implemented into smart farming to increase its efficiency. This paper discusses special methods, which can be used in weed management by using AI (artificial intelligence). In addition to the project description, the paper includes an evaluation of the current state of the research and an outlook of potential future research.

Keywords: Smart farming, Dashboard, Weed Management, 5G mobile data, AI, UAV, UGV

1 Introduction Smart Farming

The world population is growing exponentially. While there were only 1 billion people at the beginning of the 18th century, by 2021 there were already 7.9 billion [Sc21]. It is estimated that the world population will increase to 9.8 billion by 2050. Considering thus increasing demand, it is a great challenge to ensure individual food supply. The most important cause for the reduced increase in yields is climate change, with food production and distribution itself responsible for 30% of greenhouse gas emissions [EH15]. One potentially environmentally damaging aspect in agriculture is the overuse of certain pesticides [Eu22]. Therefore, an important objective within the framework of the Farm to

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Fork and Biodiversity Strategies of the European Commission is to significantly reduce the use, risk and dependency on pesticides [Eu23].

A possibility to reduce the amount of pesticides and herbicides is smart farming [Lo17]. smart farming is an approach through which efficiency, effectiveness and productivity in agriculture can be increased. Through various smart technologies it is possible not only to monitor, but also to control agricultural processes in detail [GH17]. Important components are in particular the networking of different systems known as Internet of Things (IoT) [Ja16] and the use of unmanned aerial vehicles (UAV). UAV enable the health status and the development of plants to be monitored. This relates, among other things, to the early identification of weeds and enables an optimized use of pesticides [PPP17]. A possible implementation of this use is presented in more detail in this work in progress paper.

1.1 5G-Smart-Country Project

In the BMVI-funded project "5G-Smart Country", the technological development and application for rural areas is investigated in the districts of Helmstedt and Wolfenbüttel in Lower Saxony during the project period from 12/2021 to 11/2024 [La21].

Various 5G applications are tested under real conditions to investigate the potential of 5G mobile communication. The aim of the project is therefore to describe the opportunities and possibilities of 5G and thus to be a decision-making aid for potential users before their possible purchases. This is intended to promote the implementation of 5G mobile technology also in the private sector [Bu20]. The project consists of two subprojects (“Smart Farming” and “Smart Forestry”), whereby subproject “Smart Farming” contains a work package (“Detection, location and regulation of weeds”) related to weed control.

In this work package, various imaging sensor systems on UAV and unmanned ground vehicle (UGV) are used for detection of weed patches. This enables a specific weed detection and mechanical weed removal. Further details will be described in this work in progress paper.

1.2 Weed Management

Weeds are unwanted plants, as they compete with crops for nutrients, space and sunlight [Es21; Mu23; Zh22]. This results in yield reduction and so to reduction in profit for farmers [Es21; Zh22]. Since the introduction of herbicides for the chemical weed control, they have been the second most sold pesticides [Es21]. However, the use of pesticides poses several problems. There is evolving herbicide resistance and a lack of new mode of action. This leads to fewer herbicides on the market. Furthermore, the reputation for pesticides has declined. This is also reflected in the stricter regulations in the EU [Lo21]. Therefore, a new more sustainable alternative is necessary.

One such possibility is site-specific weed control. Here, the entire field is not treated as before, but only the weeds that have emerged [Lo11]. In the case of herbicide application, this can result in up to an 89% reduction [Ge22]. In addition to herbicide application, mechanical weed control has gained importance again. Here, site-specific control can also be carried out using a combination of sensor technology and UGV.
This form of weed control involves several steps. These include data collection, decision-making, weed control and evaluation [Lo11; Zh22].
During the data collection, the sensor records the field. These sensors can be classified into ground-based and airborne remote sensors [St19; Zh22]. This work in progress paper focuses on data collection using UAVs, which are airborne remote sensors [Zh22].
Decision-making is also called management planning [Lo11]. It includes a distinction between weeds and crops [Mu23]. By evaluating the data, a weed map can then be created which is used to navigate the robot.
A robot widely used for weed control is defined as […] *an autonomous machine capable of sensing its environment, carrying out computations to make decisions, and performing actions in the real world*" [IE18]. Agricultural robots have mainly been developed for mechanical weed control. They can target individual weeds, for example, using hoeing blades. Necessary senor-robot communication is performed via external information processing and transmission using 5G technology [Ge22]. This form of communications is especially needed in the form of weed control presented here. This is because the AI for evaluating the images does not sit on the robot.
The final evaluation is necessary to determine how well the weed control was performed. This allows savings to be calculated, but also experience to be gained.

This study presents this process of weed control in more detail. A case study was used to illustrate the data collected by the UAV. This is followed by data processing on an external platform. Finally, the possible data transfer to the robot and its functions are explained (Fig. 1).

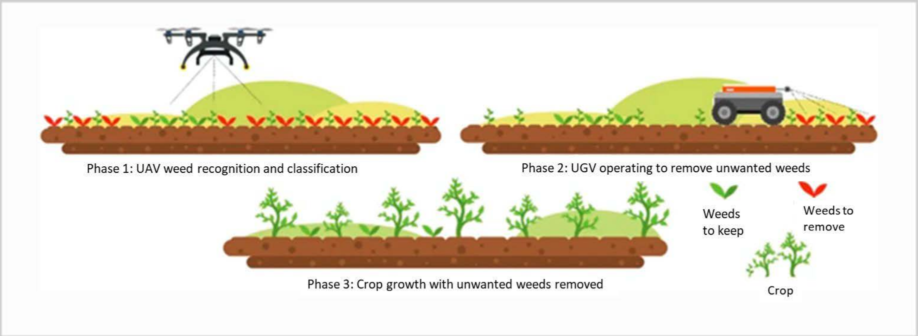

Figure 1 Weed detection by UAV and site-specific weed management by UGV[Es21]

2 Information Sources

Information procurement is of central importance for the entire process, which will be briefly described in the following chapter. Therefore, two main components are considered: UAV and UGV. An additional unit called Field-Edge for data-preprocessing is in preparation for the near field data collection, storage and transition to the cloud.

2.1 UAV for scouting tasks

A first building block in the networked system is the UAV, with a DJI M30T being used in the project. The focus of the UAV is on data acquisition and scouting. Data acquisition is primarily done via UAV, as this allows data to be obtained quickly from large areas, which is then available for the UGV's mission planning.
The DJI M30T has a thermal imaging camera and two RGB cameras (wide angle and zoom) and can therefore be used flexibly for different tasks and at different altitudes. The benefit of 5G connectivity with its minimal latency combined with high data throughput means that data acquisition is ready for distant real time processing. Within the scope of an in-house development, a connection of the overall system of cloud and Robot Operating System 2 (ROS2) network is now being worked out.

The software basis is the Payload Software Development Kit (SDK) from the manufacturer DJI, which provides basic functions for controlling the UAV in the programming language C and is available on GitHub [Dj23]. The programming is realized on a Linux-based embedded system (e.g. Raspberry Pi or Intel NUC) mounted on the UAV with USB and Transistor-Transistor-Logik (TTL) connection for communication. For the use case of weed detection, depending on the task and situation one of the RGB cameras is applied and the images are subsequently analysed in the cloud with the help of AI. But the first step of the data transmission is the preprocessing on the field edge.

2.2 Field Edge as preprocessing unit

The Field-Edge is a mobile processing unit with network access for a field near use, physically located at the edge of the field in a car. Figure Fig. 2 locates the Field-Edge between the on-field machinery and the Cloud-Services.
The concept of the Field-Edge is firstly a preprocessing and data transmission step for the previously mentioned UAV collected data to reduce the amount of data. This will be mainly used for image and video data provided for the AI-Processes and Live-Streams. Furthermore, the Field-Edge transmits the state information of the field machinery to the cloud-services via the Message Queuing Telemetry Transport (MQTT)-Standard.
Secondly, the edge will collect the processing results of the cloud-services, again via MQTT-Standard, and enqueue resulting tasks in a list of tasks. Every defined task in the process needs to be defined by at least a location e.g. weed management and a date/time of discovery to enable enhanced robot task scheduling. The base of the scheduling process

is a representation of the domain including the machinery as well as the mounted implement or sensors. All machines live-states need to be considered in the domain description to gain more information such as recharge necessity, occurring emergency state and task fulfillment status.

Due to the complexity of the domain the machinery scheduling depends on an advanced and adaptable task planning architecture. Currently, the first tests and adaptations are made on a combination of the existing PlanSys2 [Ma21] and the Unified Planning Framework [Un23] which is currently under development. Up to now, the architecture contains Mock-Ups for state prediction of the environment or machinery. To enable forecasting by task scheduling architecture substituting this Mock-Ups is mandatory.

2.3 UGV for agriculture processing

The Dino by Naïo Technologies is one of the most sold high-automated field robots without manufacturer-supplied capabilities of replanning the task while processing or site-specific field management abilities [We19a]. For detection and demonstration of 5G-communication potentials in agriculture, the hardware and software abilities of the Dino need to be extended. As carrier machine, the Dino is controlling the different implements such as a weeding tool or a seeding unit. An adaptation of the mentioned implements is required to ensure good process qualities in the site-specific field management. To allow field tests in agriculture surroundings with processes realistic influences on the machine a self-concepted seeding unit is under development.

Communication advices shall enable the Dino to access topics of a shared ROS2 network to send its state information like odometry data and receive scheduled tasks live on field. A promising potential of a 5G connection between the Dino and the infrastructure is the ability of live changes in machinery planning and monitoring focuses in a sufficient speed and information density in both directions of communication. Additionally, a safe state control should interrupt the machinery actions in emergency cases or noticeable data incidents detected by the distant cloud processing.

3 AI and Weed Management

The 5G Smart Country project intends to implement the development and testing of concrete 5G applications under real conditions. The software which consists of frontend and backend is designed in a way which can ease its use for customers and can make it compatible for future development for developers. In addition, the project presents the software as the main part which can be developed with time at the expense of the hardware, which makes the expenses of using both software and hardware for the farmers less. In the following section, we will delve deeper into the use of artificial intelligence (AI) in smart farming. There are many ways to use AI in smart farming [We19b; PSB22].

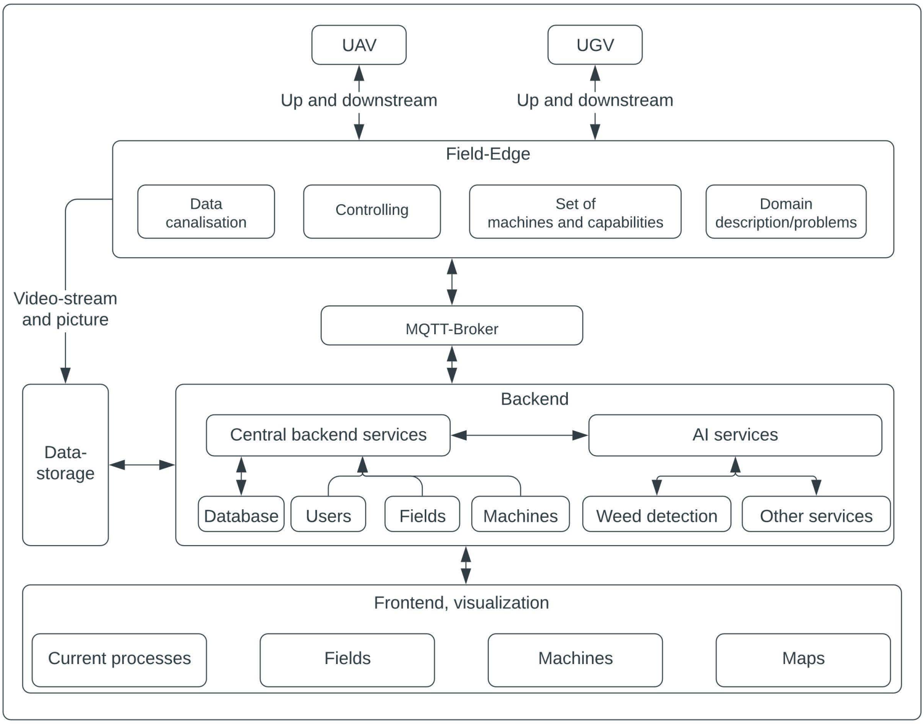

Figure 2 Overview of the technical concept and machines (own source)

Figure 2 illustrates a simplified representation of the backend system of weed detection. The backend is built based on Node and provides API interfaces to receive common requests, images and conducting simple mission. After authenticating the request, the image is forwarded to the AI-backend (in Fig. 2 ‘AI-Services’), which is located on the same network and can only be accessed through localhost. This prevents external requests and avoids additional authentication processes. The AI server, which is developed in Python programming language, is based on FastAPI [Ti23]. One of the services integrated into the backend is weed detection. The technologies used for weed detection include Tensorflow, Segmentation Models, Open-Source Computer Vision, an GPU RTX 3080, NVIDIA CUDA, and U-Net [RFB15; Un23].

3.1 Increasing the efficiency and the costs with 5G and M2M communication

The important role of the backend of the software stems from the better chance for sustainable use of the machines from one side in addition to facilitating the use of the technology for the farmers. Furthermore, the server send the orders to the UGV and UAV from the start of the process till the end. Moreover, the server is a central real-time server for all robots in the different locations in the project. This improvement will be reflected in the functions of robots without any need to change or to update them. Therefore the central server plays a crucial role in controlling machines and robots. By transferring intelligence to the server, the machines are primarily responsible for executing commands, resulting in reduced maintenance work. This approach brings forth several advantages:

Improved software updates: With the central server, it becomes possible to implement better software updates. The server can simultaneously serve multiple machines, enabling efficient utilization of computational power. Additionally, this setup allows for location-independent usage, benefiting various farmers.
Easy updates and upgrades: The concept of centralizing intelligence on the server facilitates straightforward updates and upgrades. This ease of maintenance and scalability make it conducive to continuous improvement and transferability.
Support for Real-Time Scenarios: Leveraging 5G technology enhances the feasibility of real-time scenarios. The high-speed and low-latency capabilities of 5G networks ensure responsive and time-critical operations, thereby facilitating the integration of time-sensitive applications.
Enhanced Sustainability: By reducing the computational resources embedded within individual machines, the centralized 5G server promotes sustainability. It optimizes resource allocation and minimizes the overall environmental impact, leading to a more sustainable approach.

By implementing a central 5G server for controlling machines and robots, the project unlocks several benefits such as improved software updates, efficient resource utilization, seamless updates and upgrades, support for real-time scenarios, and enhanced sustainability.

3.2 Smart Farming Dashboard

The frontend of the software application is the main gate for the customers/farmers to get all information which are need to know about their field and plantings in real-time. The frontend is made with Angular [Go23; Ak22a]. Therefore, the function of the frontend is to demonstrate all outcomes of the prepared data, sensors and cameras for the customers, like: weather focus, fertility of the soil and its quality, production standard, as well as detecting diseases and weeds in the field and in the plantings, which can cause a threat to their crops. The previous step is followed by a second one to find out how to deal with the problem.

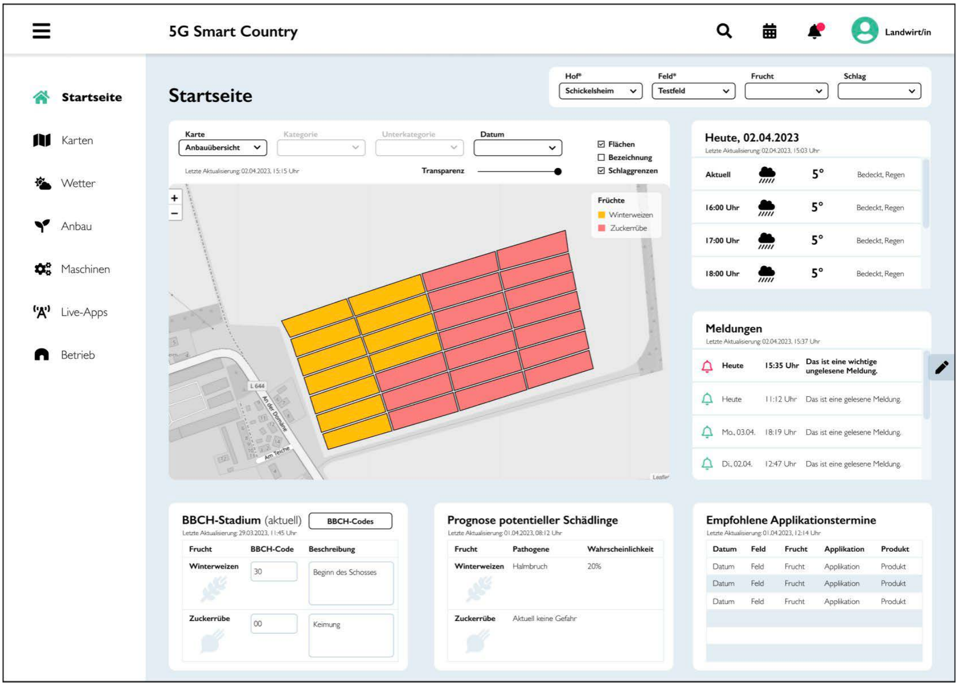

Figure 3 Developed concept for the dashboard, how the start page could look like [Ak23]

This work in progress paper focuses on the methods which are used to deal with weeds in the field in the 5G Smart Country project.

The process of the operation: The customer decides a timeline for the unmanned aerial vehicle to scan his field and for the robot to grab and remove the detected weeds. The movement of the unmanned aerial vehicle followed by the robot is programmed to do the mission automatically in a planned path or manually by the customer. The customer can choose a time and a certain path to check part of his field in case of a specific need. The mission of the unmanned aerial vehicle is to show live streaming to the customer and to simultaneously send photos in real-time to the AI-Server through the machine-to-machine communication protocol MQTT.

3.3 Implementation of the AI model

The use of AI is intended to make weed treatment more efficient. The AI models have been exclusively trained for weed detection, while cultivated plants were omitted. With reliable predictions, conclusions can be drawn between weeds and cultivated plants. All plants that are not identified as weeds could be treated as cultivated plants. Initially, segmentation models were trained on the dataset by the University of Bonn with different preprocessing methods, input sizes, and types of backbones. Segmentation models are open source, which is based on Keras and TensorFlow and can be used for image segmentation with AI [Ya19]. Afterward, all the tested models were compared. The comparison was based on the two previously developed metrics Intersection-Over-Union and F1-Score [Te22]. The resulting best model (ResNet18) was then further optimized, considering the hyperparameters ‘epoch’ and ‘loss’ [Ma23]. Finally, the results were also tested on a self-created dataset. The prediction of our self-created dataset (90 images made with an UAV) was a prediction accuracy of approximately 88% and from the dataset of the University of Bonna prediction accuracy of approximately 90%. The dataset of the University of Bonn has round about 5TB but there were only 3GB (2241 RGB and NIR images made with UGV) of the data used. However, it needs to be mentioned that the AI is not the focus of this work. The AI integration serves as an example to demonstrate the possibilities of the dashboard.

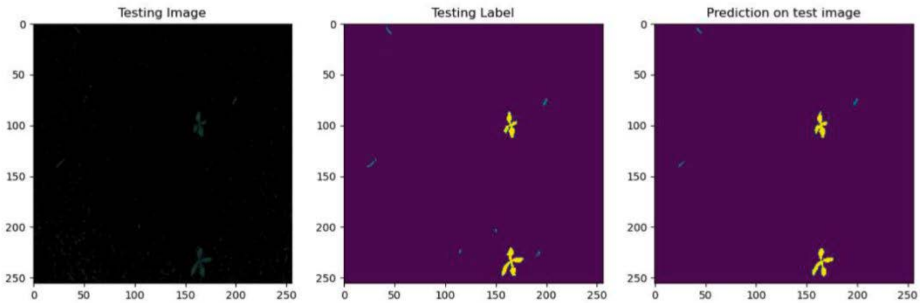

Figure 4 Visualization of the results of a model [Ak22b]

4 Evaluation and Outlook

This work in progress paper highlights the main methods that project 5G follows to reach its goals. It clarifies the important role of machines, who are connected to each other using 5G mobile data. This approach shows, how different machines can enhance the processes and visualization in smart farming. With a dashboard, the user can see in real-time all information he need. Besides, the farmer’s decisions can be supported (i.e. weed management) . This approach has a cheap and effective method, for example to deal with the problem of defining and of dealing with weeds. These new methods exist in the backend part of the project. The solutions which the project 5G Smart Country seeks for are based on the data which have been mainly collected from the photos which have been taken by the UAV and the UGV. The photos have been analyzed and defined by a python based backend FastAPI [Ti23]. It is an important issue in the project to connect different software between the frontend and the backend to serve the goal of the project. These software works differently in collecting the data, in analyzing it and in sending back the orders to the UAV and to the UGV.

5 Sources

[Ak22a] Akveo; Ngx-admin - most popular admin dashboard on Angular 9+ and Nebular, 27.04.2022, https://akveo.github.io/ngx-admin/. Last accessed: 22.05.2023.

[Ak22b] Akyol, A. University of Oldenburg. Bachelor thesis in 5G-Smart-Country Project. 2022 (not public)

[Ak23] Akyol, A. University of Oldenburg. Bachelor thesis in 5G-Smart-Country Project. 2023 (not public)

[Az09] Azubi, L. et.al.: Die Fußnote in LNI-Bänden. In (Glück, H. I., Hrsg.): Formatierung 2009. Format-Verlag, Bonn, pp. 135-162, 1999.

[Bu20] Bundesministerium für Verkehr und digitale Infrastruktur: Bekanntmachung der Förderrichtlinie "5G-Umsetzungsförderung im Rahmen des 5G-Innovationsprogramms.", https://www.bav.bund.de/SharedDocs/Downloads/DE/5G/Foerderrichtlinie.pdf?__blob=publicationFile&v=3. Last accessed: 15.05.2023.

[Dj23] dji-sdk/Payload-SDK, https://github.com/dji-sdk/Payload-SDK. Last accessed 11.05.2023.

[EH15] Ehrlich, P.; Harte, J.: Opinion: To feed the world in 2050 will require a global revolution. Proc Natl Acad Sci USA, 112(48), pp. 14743–14744, 2015.

[Es21] Esposito, M., M. Crimaldi, V. Cirillo, F. Sarghini, A. Maggio: Drone and sensor technology for sustainable weed management: a review. Chemical and Biological Technologies in Agriculture 8 (1), DOI: 10.1186/s40538-021-00217-8, 2021.

[Eu22] European Commission, Development of future scenarios for sustainable pesticide use and achievement of pesticide-use and risk-reduction targets announced in the Farm to Fork and Biodiversity Strategies by 2030, https://food.ec.europa.eu/system/files/2022-06/pesticides_sud_eval_2022_foresight_exec-sum.pdf. Last accessed 31.05.2023

[Eu23] European Commission, Sustainable use of pesticides, https://food.ec.europa.eu/plants/pesticides/sustainable-use-pesticides_en. Last accessed 31.05.2023

[Ez99] Ezgarani, O.: The Magic Format – Your Way to Pretty Books, Noah & Sons, 2012.

[Ge22] Gerhards, R., D. Andújar Sanchez, P. Hamouz, G.G. Peteinatos, S. Christensen, C. Fernandez-Quintanilla: Advances in site-specific weed management in agriculture—A review. Weed Research 62 (2), 123–133, DOI: 10.1111/wre.12526, 2022.

[GH17] O'Grady, M. J.; O'Hare, G. M. P.: Modelling the smart farm. Information Processing in Agriculture 4, pp. 179-187, 2017.

[Go23] Google. Angular - Introduction to the Angular docs, 2023, https://angular.io/docs. Last accessed 22.05.2023.

[IE18] IEEE, 2018: What Is a Robot?: Top roboticists explain their definition of robot, URL: https://robots.ieee.org/learn/what-is-a-robot/.

[Ja16] Jayaraman, P. P. et al.: Internet of Things Platform for Smart Farming: Experiences and Lessons Learnt. Sensors 2016, 16 (11), 1884, 2016.

[La21] Landkreis Wolfenbüttel: Bund fördert 5G-Pionierprojekt in den Landkreisen Wolfenbüttel und Helmstedt mit 3,9 Millionen Euro, https://www.lkwf.de/Aktuelles/Presse-und-Meldungen/Bund-f%C3%B6rdert-5G-Pionierprojekt-in-den-Landkreisen-Wolfenb%C3%BCttel-und-Helmstedt-mit-3-9-Millionen-Euro.php?ModID=255&FID=3282.23011.1. Last accessed: 15.05.2023.

[Lo11] López-Granados, F., 2011: Weed detection for site-specific weed management: mapping and real-time approaches. Weed Research 51 (1), 1–11, DOI: 10.1111/j.1365-3180.2010.00829.x.

[Lo17] Lottes, P. et al.: UAV-Based Crop and Weed Classification for Smart Farming. IEEE International Conference on Robotics and Automation (ICRA), 2017

[Lo21] Loddo, D., J.S. McElroy, V. Giannini, 2021: Problems and perspectives in weed management. Italian Journal of Agronomy 16 (4), DOI: 10.4081/ija.2021.1854.

[Ma21] F. Martín, J. G. Clavero, V. Matellán and F. J. Rodríguez, "PlanSys2: A Planning System Framework for ROS2," 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Prague, Czech Republic, 2021, pp. 9742-9749

[Ma23] MathWork (2023). ResNet-18 convolutional neural network. Last accessed 24.05.23 ResNet-18 convolutional neural network - MATLAB resnet18 (mathworks.com)

[Mu23] Murad, N.Y., T. Mahmood, A.R.M. Forkan, A. Morshed, P.P. Jayaraman, M.S. Siddiqui, 2023: Weed Detection Using Deep Learning: A Systematic Literature Review. Sensors (Basel, Switzerland) 23 (7), DOI: 10.3390/s23073670.

[Un23] University of Freiburg;U-Net: Convolutional Networks for Biomedical Image Segmentation, 22.05.2023, https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/. Last accessed 22.05.2023.

[PPP17] Petcovics, I.; Petcovic, D.; Petcovics, A.: IoT Decices vs. Drones for Data Collection in Agriculture. DAAAM International Scientific Book 2017, pp. 63-80, 2017.

[PSB22] Pamornnak, B., Scholz, C., Becker, S. & Ruckelshausen, A., (2022). A digital weed counting system for the weed control performance evaluation. In: Gandorfer, M., Hoffmann, C., El Benni, N.,

[RFB15] Ronneberger, O., Fischer, P., & Brox, T. (2015). U-Net: Convolutional Networks for Biomedical Image Segmentation. In arXiv. https://arxiv.org/pdf/1505.04597v1.pdf

[Sc21] Scholik, N.: Limit. Ein Essay zur Lage der Weltbevölkerung. Teil 1: Grenzen und Herausforderungen. Z. Außen Sicherheitspolit., 14, pp. 189–212, 2021.

[St19] Steward, B., J. Gai, L. Tang, 2019: The use of agricultural robots in weed management and control. In: Billingsley, J. (ed.). Robotics and automation for improving agriculture, Burleigh Dodds Science Publishing, 161–186, DOI: 10.19103/AS.2019.0056.13.

[Te22] TensorFlow Addons. (03.06.2022). Computes F-1 Score. F1-Score. Last accessed 24.05.2023 https://www.tensorflow.org/addons/api_docs/python/tfa/metrics/F1Score

[Ti23] Tiangolo; FastAPI, 22.05.2023, https://fastapi.tiangolo.com/#optional-dependencies. Last accessed am 22.05.2023.

[Un23] Unified Planning Framework Homepage, https://www.ai4europe.eu/research/ai-catalog/unified-planning-framework, last accessed 2023/05/07.

[We19a] Wegener J., Urso, L., Hörsten, D., H. Hegewald, T. Minßen, J. Schattenberg, C. Gaus, T. Witte, H. Nieberg, F. Isermeyer, L. Frerichs, G. Backhaus,: Spot farming – an alternative for future plant production, Journal für Kulturpflanzen: Neue Pflanzenbausysteme, pp. 70-89 (2019)

[We19b] Wegener, Jens Karl: Gezielter und flexibler – Trends in der Pflanzenschutztechnik. In: Frerichs, Ludger (Hrsg.): Jahrbuch Agrartechnik 2019. Braunschweig: Institut für mobile Maschinen und Nutzfahrzeuge, 2020. – S. 1-7

[Ya19] Yakubovskiy, P. Segmentation Models. GitHub Repository. https://github.com/qubvel/segmentation_models. Last access 2019

[Zh22] Zhang, W., Z. Miao, N. Li, C. He, T. Sun, 2022: Review of Current Robotic Approaches for Precision Weed Management. Current robotics reports 3 (3), 139–151, DOI: 10.1007/s43154-022-00086-5