A Connected farm Metamodeling Using Advanced Information Technologies for an Agriculture 4.0

Loubna Rabhi[1], Brahim Jabir[2], Noureddine Falih[2], Lekbir Afraites[1], Belaid Bouikhalene[2]

[1] Mathematics and Interactions Team, Faculty of Sciences and Technics, Sultan Moulay Slimane University, Beni Mellal. Morocco

[2] Laboratory of Innovation in Mathematics, Applications and Information Technologies, Polydisciplinary Faculty, Sultan Moulay Slimane University, Beni Mellal, Morocco

Abstract

The agriculture 4.0 revolution is an opportunity for farmers to meet the challenges in food production. It has become necessary to adopt a set of agricultural practices based on advanced technologies following the agriculture 4.0 revolution. This latter enables the creation of added value by combining innovative technologies: precision agriculture, information and communication technology, robotics, and Big Data. As an enterprise, a connected farm is also highly sensitive to strategic changes like organizational changes, changes in objectives, modified variety, new business objects, processes, etc. To strategically control its information system, we propose a metamodeling approach based on the ISO/IS 19440 enterprise meta-model, where we added some new constructs relating to new advanced digital technologies for Smart and Connected agriculture.

Keywords

Agriculture 4.0, metamodeling, advanced information technologies, digital agriculture, connected farm.

Rabhi, L., Jabir, B., Falih, N., Afraites, L. and Bouikhalene, B. (2023) "A Connected farm Metamodeling Using Advanced Information Technologies for an Agriculture 4.0", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 93-104. ISSN 1804-1930. DOI 10.7160/aol.2023.150208.

Introduction

The Digitalization of agriculture refers to the use of modern machinery, computerized tools, and information and communication technologies in the agricultural sector (Sung, 2018). These technologies make it possible on the one hand to access, store, transfer, and manipulate information, but also to analyze it and give it meaning, to transform agriculture into a more profitable, sustainable, and inclusive sector (Fielke et al., 2020).

Today agriculture is a highly variable area. It is subject to climate change and impacted by diverse and varied parameters that make the farmer ask several questions about which fertilizer to use? And with how much quantity? Is it profitable? Which phytosanitary treatment to use for a particular disease? What is the estimated harvest at the end of the season? What measures should be taken to limit the impacts of climate change? These are repeated questions for the farmer and the entire agricultural value chain. Of course, the farmer's experience and his ability to react to similar events and situations are important in this regard. What is even more important today is that we have data more digitalized and with large quantities coming from the farm. This data can be management data, climate data, data fed back by IoT sensors, or data that come from satellite imagery or drones... (Triantafyllou, Tsouros, et al., 2019). The Internet of Things has the potential to impact every part of modern life from healthcare to education, to manufacturing, and agriculture will be no exception. Connected sensors, cameras, and other devices will give farmers a better understanding of what is going on in their fields. These smart farming equipment, ranging from tractors to planters to sprayers, will be able to monitor problems and fix issues without the farmer's direct involvement (Marcu et al., 2019).

Some IoT devices are developed for specific tasks. For instance, instead of digging ditches by hand or with an excavator, farmers can use robot mowers to trim weeds and grass around ditches. Other devices may be more application-specific. For example, the agricultural drone which connects to a tablet or phone for controlling and viewing video from a drone can be used to count cows or scout for pests (Radhi, 2018). The cost of connected devices will decline as the number of manufacturers producing these products increases. It will make it easier for smaller farmers to afford internet-connected devices. As more farming equipment incorporates connected features, farmers will be able to manage their operations from home or on the go and forego having expensive IT infrastructure at their farms.

One of the goals of big data is to process massive data to get out knowledge. So typically, processing images from drones or satellite images help to estimate the harvest over large areas. Moreover, through this imagery, it is possible to detect deficiencies or diseases, or pests in plants in a very automatic way and with a high level of precision. Then, by capturing patterns and agricultural practices, for example, we can know the impact of using such fertilizer with such a quantity on a given crop and variety. Therefore, the combination of this data, which can be of different forms and different quantities with a high generation speed, allows having metrics in hand to make the right decisions at the right time. Big Data is a technological tool for the farmer that precisely makes him achieve a high level of productivity and profitability, monitor the quality of production, and respect the environment with precision (Li and Niu, 2020).

This article is structured as follows: in section 2, we first recall Related works of Smart agriculture based on digital advanced technologies. Section 3 deals with the ISO 19440 metamodel to understand the different views of the model. Then, a new connected farm metamodel is proposed as a research method. For each view of the model, we specify the IT entities and their contribution to the farm. In section 4, we describe the 4 views of the irrigation scheduling process case study. The conclusion of this work situates the action plan proposed in this article to underline its contribution as well as the future investigations to be developed.

Materials and methods

Smart agriculture based on digital advanced technologies: Related works

Agriculture 4.0 is the most recent technological development in agriculture based on Big Data Analytics, the Internet of Things, and Artificial Intelligence (Symeonaki et al., 2020). It is expected to enhance productivity, efficiency, and sustainability in agriculture. Agriculture 4.0 will be a game-changer that can lead to more productivity in agriculture and increase the incomes of farmers by using high-technology sensors, satellite imagery, and remote sensing applications. Together with the use of drones, artificial intelligence, and robotics, agricultural transformation towards agribusiness entrepreneurship can be achieved.

Smart agriculture is the application of modern information and communication technologies in the practice of agriculture. It implements a variety of techniques including sensors, robotics, drones, and data analytics technologies. Several processes in smart farming are candidates for digitalization such as irrigation, plowing, fertilizing, and breeding...

- *Breeding*

Animals and parcels are connected using IoT tools. This technology is used to manage herds of animals, and it's based on the physiological processes of animals. With this system, farmers can control the animals' heat by monitoring their temperatures and sending a mobile message to the owner if their temperature reaches the reproductive period. In this case, the example comes from connected collars for cattle and sheep farms. This very advanced technology allows breeders to know precisely the heat periods of cows but also, for dairy farms, the quantity of milk produced per day or their need for food supplements. This means that digital affects agriculture as a whole, upstream and downstream. Also, these sensors can be set to detect different behaviors of animals and automatically update data about their health. They are connected to networks and servers and send information over the internet. Modern farmers can now improve their genetics with the help of wireless sensor networks and save time, while also knowing where the animals are and what they're doing.

- *Weather forecasting*

Environmental factors like weather influence crop growth and agricultural production in general. This latter has spatial yield variability, partly because of spatial variability in soil properties and interactions with the weather, which is also spatially varied. Artificial intelligence techniques, like machine learning, could be used to predict the weather for farmers to assist them in their decision-making (Yang et al., 2018).

Authors (Verma et al., 2020) implement a real-time weather prediction system that can be used in agriculture. The system utilizes a temperature and humidity sensor. Then the sensed data are uploaded to a cloud server. A logistic regression model is used for setting up the machine learning environment. The result of this model is compared with other works available that used Decision Tree and Artificial Neural Network models. The proposed system is slightly better in terms of accuracy.

- Crop yield prediction and crop selection

Popular artificial intelligence techniques such as artificial neural networks and machine learning techniques have proven to be effective in crop selection and yield prediction. They are based on various factors such as weather, soils, natural calamities, famine, and other inputs. Using several soil characteristics such as soil depth, phosphorous, potassium, salt, organic matter, and magnesium saturation as input of artificial neural networks, (Coble et al., 2018) confirmed the prediction of corn and soybean yields.

- Irrigation

The irrigation system scheduling is one of the most critical processes in agriculture that could affect crop productivity and quality. A farmer must answer the questions "When do I water?" and "How long do I water?" during irrigation scheduling. Watering crops is an important part of crop management. To ensure adequate and timely water supply, it is essential to select the most effective irrigation system to meet the needs of crops. Both overwatering and underwatering can cause crop damage, reduced yields, and poor crop quality which hurt crop yield and profit margins. This latter can improve the water use efficiency by a better understanding of soil moisture, crop health, and weather forecasting and providing only as much water to the plants as needed. Wireless sensor networks are used to automate irrigation systems. They transmit water information from sensors to irrigation controllers, which decide when to measure soil moisture and adjust the irrigation system. The farmer doesn't have to be at the field all day or argue about when to water plants with someone else (Muangprathub et al., 2019).

- Nurturing and crop protection

The easiest way to meet the growing need for food is by applying Fertilizers. Measurement of soil Nitrogen (N), Phosphorus (P), Potassium (K), temperature, and humidity of the soil is necessary to determine the suitable fertilizer. Authors (Naresh et al., 2020) and (Bondre and Mahagaonkar, 2019) have researched the topic of Crop Yield Prediction and Fertilizer Recommendation. They tented to provide an accurate decision in predicting crop yield and deliver the end-user with proper recommendations about the required fertilizer based on atmospheric and soil parameters of the land (N, P, K, moisture, rainfall, etc.). They have used data mining techniques to organize the data set and gather the required data using machine learning and algorithms. These goals are achieved by applying data science models on agriculture data to recommend a suitable fertilizer for every particular crop.

Bindu et al. (2020) have realized a review on Smart Fertilizer Distribution System with Crop Yield Prediction. They conclude that with the help of technologies like IoT, Machine learning, Data mining, and big data, they can achieve yield prediction and proper fertilizer distribution. Fertilizer distribution is feasible based on Nitrogen (N), Phosphorous (P), and Potassium (K) NPK values of soil. Alex and Kanavalli (2019) design, prototype and implement intelligent computational techniques for the prediction of crop yield based on the big data from a large number of scattered agriculture fields. They built a big data analytics model for precision agriculture and fertilizer management to improve the agriculture field using a convolutional neural network (CNN). Dahikar et al. (2015) proposed an Artificial Neural Network Approach for Agricultural Crop Yield Prediction based on various parameters. They allowed suggesting fertilizer by using ANN. They confirmed that the result was satisfactory.

- Plowing

Tractors have been used in agriculture for a long time, but the advent of autonomous tractors underlines and allows you to use them effectively. These tractors can be equipped with machines that spray liquid fertilizers or plant protection products. With this equipment, farmers can improve their production by reducing labor costs. An autonomous tractor operates on a private road whose operation can be automated through route planning and automatic or manual deflection of the vehicle to avoid incidents. The invention also has techniques for detecting obstacles and automatic or manual deflection of the vehicle to avoid collisions with them. It can even stop and start automatically within the presence of a moving barrier. with GPS-guided features, it allows farmers to operate under better conditions and improve their crop production. However, obtaining an expensive transporter is not enough for many farmers; they need more assistance to develop this strategic business model.

- Agricultural policy and trade

Big Data Analytics can be beneficial when simulating agricultural policy impacts. Indeed, A larger quantity of data like crops' production, changes in costs' input, market demand, market supply, market price trends, cultivation costs, wages, transportation costs, and marketing costs could be learned by Advanced algorithms to predict support prices for farmers by governments in both developed and developing countries.

- Poultry farming

Poultry farming is the process of raising domesticated birds such as chickens, turkeys, ducks, and geese to farm meat or eggs for food. Weatherproof sensors can be attached to the bird or the building to track such parameters as the birds' location, temperature, and humidity and monitor their health and hygiene. The sensors can send alerts when a flock is on the farm where they should be and if there is an unauthorized movement. Also, sensors can be implanted under the skin of chickens to provide information on their sleep cycle which can then be used by software to predict egg production.

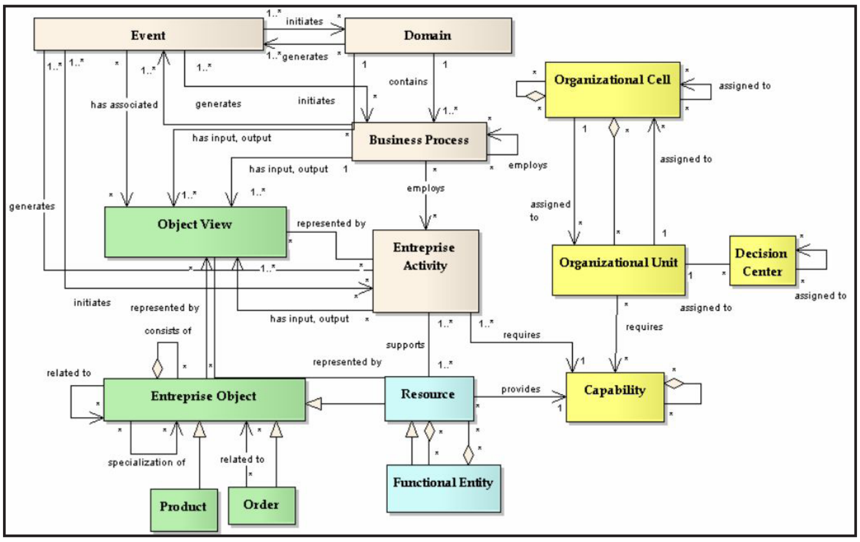
To sum up, agriculture is becoming impacted by various parameters, namely climate change, crop and soil conditions, etc. What is even more important today is having Big Data that is increasingly digital and with large amounts coming from the farm. Moreover, the mastery of data is a wealth for the actors of the agricultural world whose actors use it wisely. Big Data, for its part, makes it possible to analyze data and thus guide farmers in their choices and procedures.

ISO 19440/DIS 2007 Enterprise Metamodel

Researchers done in1990s, in terms of enterprise modeling, led to a standardized framework that meets the needs of a systemic approach to the enterprise. It's the ISO 19440 meta-model-oriented process model. The standard offers four views on these models: the organizational view, the informational view, the functional view, and the view of resources (Falih et al., 2019). The ISO/IS 19440 standard proposes a set of modeling elements for the representation of the enterprise. In this section, we present the meta-model proposed in the framework of ISO/DIS 19440. This model integrates the four views (Figure 1).

The functional view aims to model enterprise functionality and enterprise behavior. It describes the tasks or activities that must be done and in which order they must be accomplished. It contains Domain, event, Business process, and Enterprise Activity constructs. A domain represents the boundary and the content of an enterprise or a part of an enterprise. A business process represents a part of the enterprise's behavior. It is an aggregation of the business process and/or business activity and the information described by the business rules. The business activity is the realization of a transformation from inputs to outputs by specific resources. An event initiates the execution of a business process or an activity.

The informational view aims to model objects



Source: Boulmakoul, Falih, and Marghoubi, 2009)

Figure 1: Meta-model ISO 19 440.

of the enterprise, their states, and their flows (Vernadat, 2020). Enterprise Object and Object view constructs constitute the informational view. Enterprise Object represents the set of information that describes a generalized or a real or an abstract entity. Object View defines the object's nature (material or information) and represents the object state by a subset of the Enterprise Object attributes.

Resource view aims to model human, technical, or IT agents and components required to execute operations and which roles, capabilities, and skills are required. The resource represents the provided capabilities required to execute an Enterprise Activity. A functional Entity is a specialization of the Resource construct able to perform a functional operation(s) required by an Enterprise Activity. Capability Set represents the capability characteristics of either a Resource or an Enterprise Activity.

The organizational view aims to model organization units, decision centers, decision levels, and their relationships as well as associated responsibilities and authorities. Organization Unit represents an entity of the organizational structure of the enterprise. Below, we briefly recall the semantics of each construct (Kosanke et al., 2014).

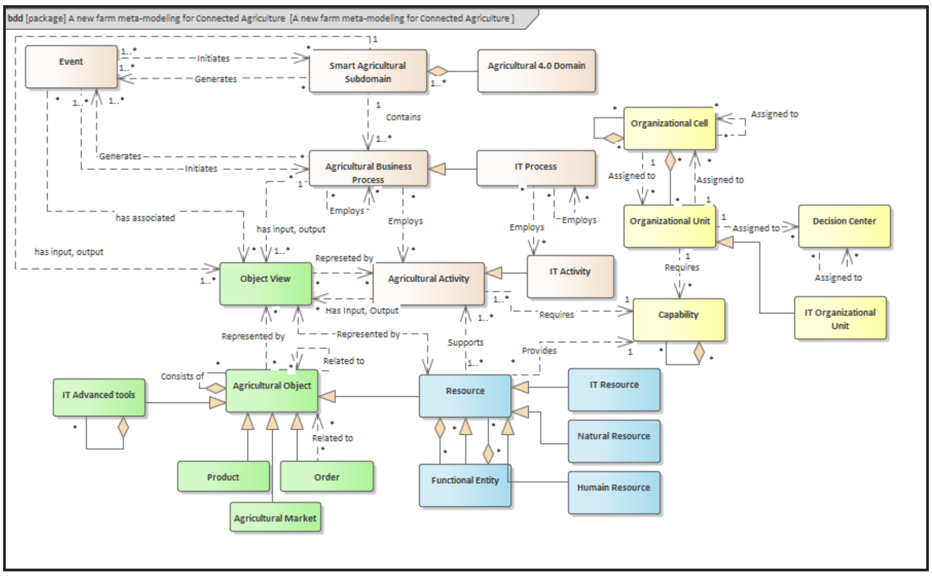
A new Connected Farm Metamodel

In this section, we propose a holistic meta-modeling based on a formal extension of the ISO/DSI 19440 meta-model. This meta-modeling highlights the alignment between functional, informational, organizational, and resource views and supports an arrangement of constructs allowing to deal with a connected farm to model an agriculture 4.0. Our proposed formal extension of the meta-model integrates aspects of Big Data Analytics into smart farms.

Modeling the farm as a complex socio-technical dynamic system is an indispensable means of organizational research to extract useful knowledge. The modeling of relationships between the different entities of the farm and the analysis of their impacts on the overall performance is called structural analysis (Jones et al., 2017). By highlighting associations between specific entities, the analysis can define different views of an enterprise and, therefore, gain in-depth insight into the performance from multiple points of view. Structural analysis can be used to produce a functional, organizational, informational, or resource viewpoint. Such analysis is helpful in a wide range of business scenarios, from business design to real-time performance monitoring.

The figure below (Figure 2) presents our holistic meta-modeling incorporating the Big Data Analytics approach and allowing us to look at the farm from an overhead perspective to establish the different views of the farm. The proposed meta-modeling provides a formal framework that gives global representativeness through a holistic view of the farm. In this paper, our study goes beyond the explicit definitions of functional, organizational, informational, and resource entities to also delve into the relationships and associations linking these entities.

The main contribution is a proposal for an extension of ISO 19440 enterprise



Source: author

Figure 2: A new Connected Farm Metamodel.

Metamodel to allow a semantic representation of a digital farm. Agriculture 4.0 is a concept that combines ideas of precision farming with sensors, cloud-based analytics, and artificial intelligence (AI) in the context of a new IoT farm model. The agriculture 4.0 model proposes a new set of stakeholders and entities, relationships between these entities, and models of how the actors interact with the various entities. It is enabled through a combination of new sensor technologies, cloud-based analytics, artificial intelligence (AI), mobile technology, robotics, and autonomous control systems. Smart farming modeling provides a holistic view using interlinked components that work together to provide innovative design solutions required to meet future agricultural needs in increasing productivity, improving sustainability, and supporting rural communities (Cho Yongbeen, 2019).

- Functional view of the extended Metamodel

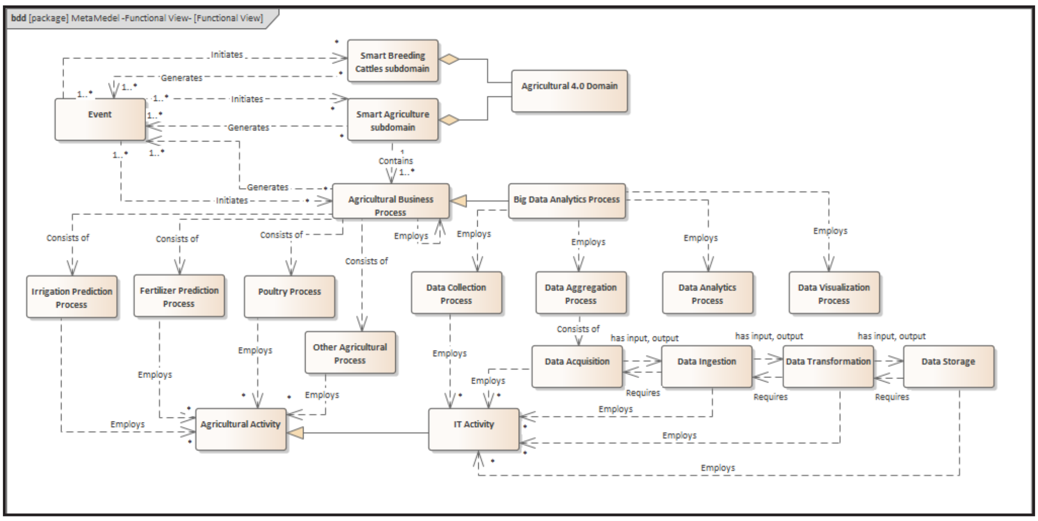
Agriculture 4.0 in general refers to two domains. The first one concerns land issues (smart agriculture) like plowing, Fertilizing, harvesting, afforestation, etc. The second one concerns breeding cattle issues. The functional view of smart agriculture aims to meet the different processes and activities involved in smart agriculture (Figure 3). To carry out these processes and activities in a smarter manner, it is important to exploit IT processes (Perakis et al., 2020). They can be done towards increasing the efficiency of irrigation, selecting the optimal stage of planting or harvest, identifying anomalies, and more services by the analysis of large data sets to find useful information that helps make decisions. Based on the data collected by sensors, farmers can also modify their processes to improve their land yields. For example, the amount of fertilizer that is required for optimal growth can be determined.

Furthermore, soil type and moisture levels can be identified which will allow farmers to make adjustments to their irrigation methods based on the needs of the crops. Indeed, based on the data that is being collected from agricultural sensors and gathered from weather satellites it is possible to maintain finer control over irrigation systems. This will allow for optimal water usage to save money and replenish groundwater stores for later use. Climate data from satellites and ground stations allows for early forecasting to minimize risks such as floods and droughts. This information collects data on soil moisture levels, surface temperatures, precipitation patterns, and more are fed into climate models that then simulate future conditions thus allowing farmers to plan accordingly. By utilizing this technology, it is possible to predict droughts before they happen to help prevent crop loss (Rabhi et al., 2021b).

IT Process refers to the Big Data Analytics process. We inspired it by the Functional big data analytics-based framework for connected agriculture (Rabhi et al., 2021a). It includes Data Collection, Data Aggregation, Data Analytics, and Data Visualization processes.

- Informational view of the extended Metamodel

The informational view regroups the used sources of agricultural data (Figure 4). Data is the core of the proposed extension of ISO 19440 metamodel. It is based on a comprehensive set of agricultural objects. It classifies agricultural objects according to the functionalities they support. Each process requires data information such as climate data, soil moisture content, real-time crop status, etc. (Ngo, 2020). Agricultural objects are now more and more



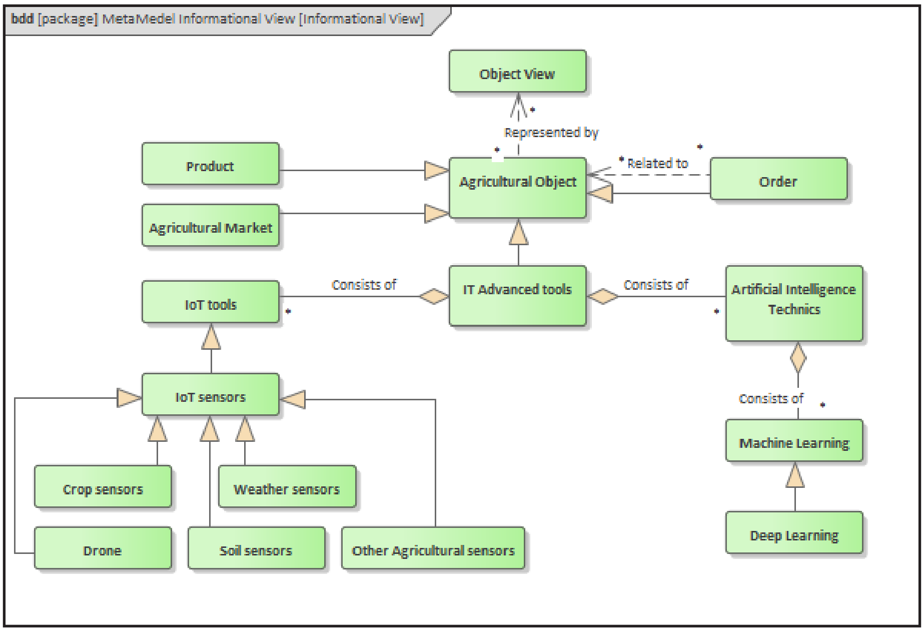
Source: author

Figure 3: Functional view of the extended Metamodel.

connected by using sensors and IA (Wang et al., 2021). They are part of the Internet of Things (IoT), which incorporates a variety of objects, systems, and services that communicate information using Internet connections. Agricultural objects include tractors, harvesters, GPS devices, robots, drones, etc. (Triantafyllou, Sarigiannidis, et al., 2019). The set of these agricultural objects is classified into functionalities entities that they support such as planting, spraying, harvesting, repairs, etc. Sensors are placed on the ground or on the plant to characterize its soil and its health (water, temperature), as well as drones that fly above the farm to measure certain parameters such as the presence of snow or insects. The proposed extension metamodel highlights machine learning (ML) and deep learning (DL) technologies that are necessary for handling massive amounts of big data produced by sensors (Jabir et al., 2021). Besides, IoT enables the collection of huge amounts of agricultural data using sensors. Machine learning can be used by exploiting this data with Big Data and cloud technologies to create a new level of intelligence in agriculture practices (Symeonaki et al., 2020; Rabhi et al., 2021a).

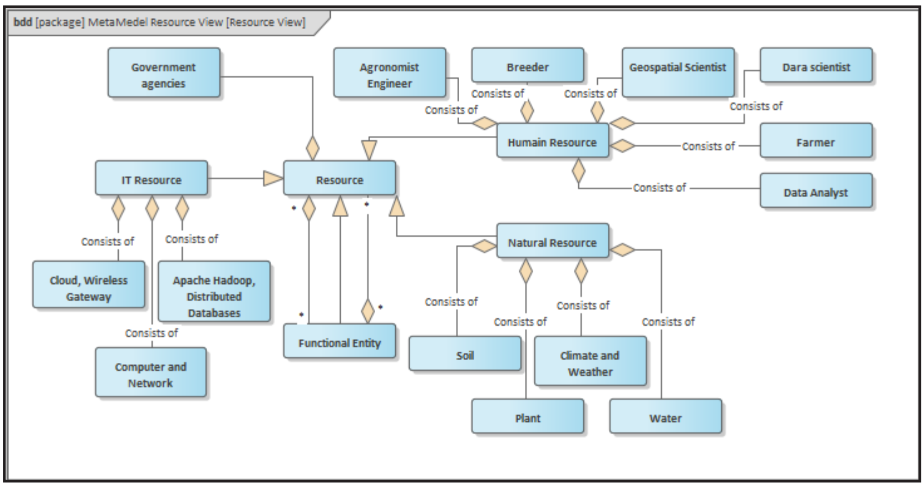
- *Resource view of the extended Metamodel*

The proposed metamodel is a classification of different types of agricultural resources (Figure 5). The resource is a superclass that defines



Source: author

Figure 4: Informational view of the extended Metamodel.



Source: author

Figure 5: Resource view of the extended Metamodel

all the natural, human and IT resources entities of the farm. The agricultural resource is presented as a hierarchy of different levels, each level representing an aggregation that contains other resources within it.

Smart agriculture is a collection of technologies that use computers, sensors, systems, and communication networks to track farm data in real-time and use it for decision-making. A diversity of IT tools are used (Rabhi et al., 2021a) like Hadoop, Hive, Pig, Spark, etc.

Among human resources in smart agriculture is a data scientist, he is a person who excels at the practical application of statistics and mathematics to solve practical problems. He is good at acquiring, cleaning, and processing large amounts of data and also analyzing this kind of data using sophisticated algorithms (for example machine learning algorithms) to extract meaningful information. He can be responsible for developing new analytical tools, for example, machine learning ones; for preparing and managing large amounts of data needed for their research; for preparing interactive visualizations that help with problem-solving in complex domains; or even for alerting people about possible problems in their environment.

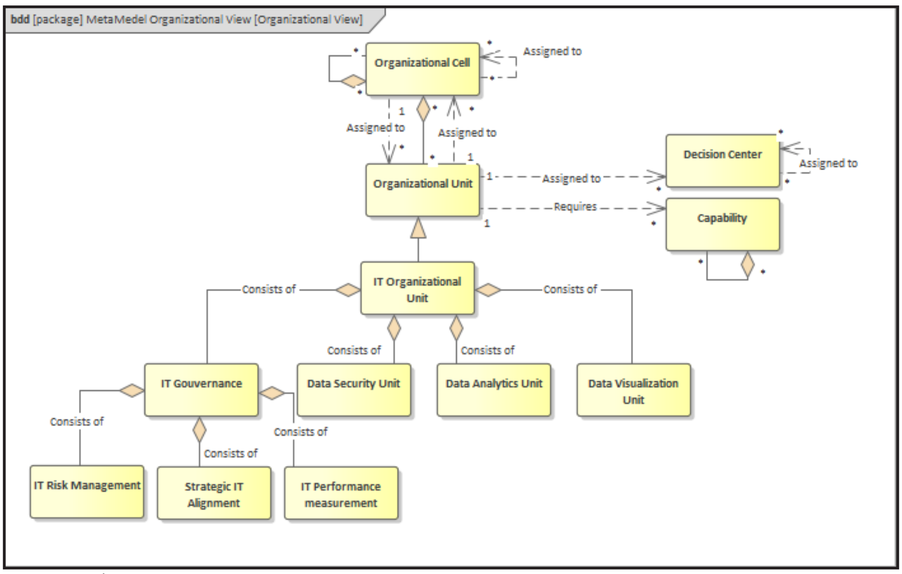
- *Organizational view of the extended Metamodel*

The Organizational view is a farm model view that enables the representation and modification of the organizational and decisional structure of the farm and the responsibilities and authorities of the persons and organization units within the farm. It describes the relations between the different organizational entities on the farm and identifies their responsibilities. These responsibilities can be on different levels of the organization and are usually carried out by members of the organization entity authorized for the decision-making.

The Organizational Unit is a construct that represents an entity of the organizational structure of the farm such as IT Governance, Data Security, Data Analytics, and Data Visualization Units. The organizational Unit's content shall be determined by naming the assigned entities for which it has authority or responsibility, or both. Indeed, Each Organizational Unit shall contain at least one relationship to an Organizational Role specifying the required or provided organizational skills and responsibilities.

IT governance is a construct that aims to improve the overall management of IT and derive improved value from investment in information and technology. It enables organizations to manage their IT risks effectively and ensure that the activities associated with information and technology are aligned with their overall business objectives.

Risk consideration in smart agriculture modeling is of increasing importance since the business environment is becoming more and more competitive and unpredictable. This need has given rise to the risk-aware agricultural business process management paradigm. It consists of the integration of risk aspects into business process management to increase the risk awareness of a farm's business processes (Lamine et al., 2020) (Figure 6).



Source: author

Figure 6: Organizational view of the extended Metamodel.

Results and discussion

As an application of the meta-model explained above, we will use the case study treated in one of our previous articles named "Digital agriculture based on big data analytics: a focus on predictive irrigation for smart farming in Morocco" (Rabhi et al., 2021b). This article deals with the issue of predictive irrigation using the Big Data Analytics approach. In this section, we will show the 4 views of the metamodel: Functional, Informational, Organizational, and Resource views.

- Functional view

The goal of the irrigation scheduling process is to control the timing and amount of water used on a given field or farm. Irrigation scheduling is used on crops to help manage growth, optimize yields, and improve fertilizer efficiency. It also helps reduce soil erosion and improve crop yields. When a crop is unnecessarily watered too much, either so it's overwatered or has irrigation water sitting in the soil without being taken up by the plant roots. This can cause plant damage and reduced yields. With so many ways to damage crops, it's important to implement a smart irrigation system. With the big data analytics process, we can catch how much water is being lost and track areas that need more water. This way can maximize crop yields while minimizing the financial and practical impact of damage on crops (Figure 7).

We have predicted whether the soil is dry or not based on its state of moisture and crop temperature. Thus, we used Big Data Analytics technics to predict the position of the pumping motor. If the soil is dry, the pump will be set to "ON" else to "OFF".

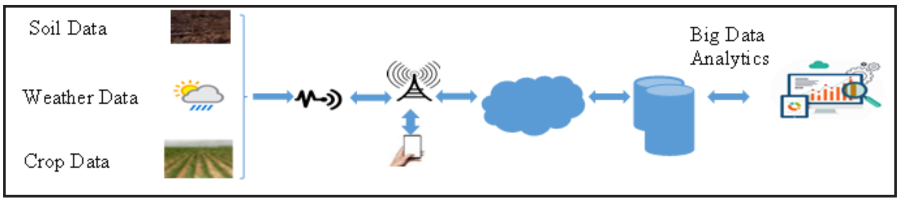
- Informational view

Through sensors placed directly on the plant and soil, connected devices allow measures that concern soil and crop conditions. Coupled with weather data, these Big data will be transmitted via a wireless sensor network and then stored and analyzed with advanced tools of big data analytics to extract useful insight (Figure 8). We worked with an existing dataset where information is collected from sensors (temperature and moisture). We used a dataset containing a large amount of data. If the pump state contains one, that means the pump is ON and the soil is dry. If it contains zero, that means it's OFF and the soil is watered. We've imported a CSV file with information on the moisture and temperature. The first columns have the parameters of moisture and temperature, while the last one represents a class (pump).

The Databricks platform is also used to create a combination of big data storage and analytics to quickly build, manage and share data pipelines. It is a big data processing platform founded by Apache Spark. The data is analyzed in the Databricks platform using machine learning technics: SVM and Artificial Neural Network models.

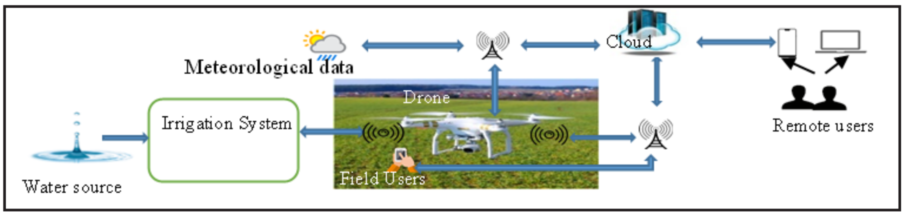
- Resource view

Smart irrigation scheduling is a collection of technologies that use computers, sensors, and communication networks to track irrigation data in real-time and use it for decision-making. A wide range of technologies is used in this study like Hadoop, Apache Spark, Databricks, etc. The main actor who can contribute to solving the Irrigation



Source: author

Figure 7: functional view of Irrigation 4.0.



Source: author

Figure 8: Logical view of Irrigation 4.0.

scheduling problem is a Data scientist. He is an analyst having statistics and mathematics skills. Its goal is to make sense of the data being manipulated and extract insight from it to help taking decisions. He can be responsible for collecting agricultural data (Data Ingestion), storing data (Data Storage), Transforming (Data Processing), Analyzing data, and restituting the final result (Data Visualization). All of these operations can be done using analytical tools (Databricks, HDFS, Apache Spark ML, Graphx…).

- *Organizational view*

The Organizational Unit is a main organizational structure of a farm that closely represents the entity of the farm. It can contain aspects such as Data Security and Data Analytics units, as well as Data Visualization units. The case study presents graphs and plots to visualize the result of the data analysis. Comparison criteria are used to assess the effectiveness and accuracy of the proposed models.

Conclusion

Agriculture 4.0 is the future of farming, integrating cutting-edge technologies like data management and analytics, communication infrastructures, sensor technologies, robots, artificial intelligence, and blockchain. Through the use of these technologies, farmers can automate their crop management, produce higher quality yields, save resources, and have access to data-driven insights to aid their decision-making process. By transitioning to smart agriculture, farmers can create a more efficient agricultural market and ensure a secure, sustainable food supply for generations to come. So, investing in advanced technologies for smart agriculture is a small step to ensuring a more hopeful and prosperous future.

The paper presents a novel conceptual Metamodel for a digital farm based on the concept of IoT technologies and Artificial intelligence. This new Metamodel aims to provide dairy farmers with all the tools they need to manage their farms in an intuitive and user-friendly way while benefiting from a powerful tool that helps make decisions. As a consequence, metamodeling is an important research topic for supporting the development of smart agriculture platforms. Researchers are invited to technically develop 4.0 platforms based on this proposed "Connected Metamodel". In our future work, we will present case studies detailing how each view of the proposed metamodel works in practice.

Corresponding authors:
Rabhi Loubna
Mathematics and Applications Laboratory, Faculty of Sciences and Technics
Sultan Moulay Slimane University. Av Med V, BP 591, Beni Mellal, Morocco
Phone: +212 610 081 260, Email: rabhi.lubna@gmail.com

References

[1] Alex, S. A. and Kanavalli, A. (2019) "Intelligent Computational Techniques for Crops Yield Prediction and Fertilizer Management over Big Data Environment", *International Journal of Innovative Technology and Exploring Engineering*, Vol. 8, No. 12, pp. 3521-3526. E-ISSN 2278-3075. DOI 10.35940/ijitee.L2622.1081219.

[2] Bindu, C. A., Ravi, P. and Kumar, N. (2020) "Smart Fertilizer Distribution System with Crop Yield Prediction: A Review", *International Advanced Research Journal in Science, Engineering and Technology*, Vol. 7, No. 6, pp. 197-204. E-ISSN 2393-8021, ISSN 2394-1588. DOI 10.17148/IARJSET.2020.7627.

[3] Bondre, D. A. and Mahagaonkar, S. (2019) "Prediction of Crop Yield and Fertilizer Recommendation Using Machine Learning Algorithms", *International Journal of Engineering Applied Sciences and Technology*, Vol. 4, No. 5, pp. 371-376. E-ISSN 2455-2143. DOI 10.33564/ijeast.2019.v04i05.055.

[4] Cho Yongbeen, H. L. (2019) "*The Bigdata Management and USe Case Study for Agriculture Based on Data (2019)",* FFTC Agriculure Policy Plaform. [Online]. Available: https://ap.fftc.org.tw/article/1630 [Accessed: Jan 15, 2023].

[5] Coble, K. H., Mishra, A. K., Ferrell, S. and Griffin, T. (2018) "Big data in agriculture: A challenge for the future", *Applied Economic Perspectives and Policy*, Vol. 40, No. 1, pp. 79-96. ISSN 1058-7195. DOI 10.1093/aepp/ppx056.

[6] Dahikar, S. S., Extc, P. G. S. and College, S. (2015) "An Artificial Neural Network Approach for Agricultural Crop Yield Prediction Based on Various Parameters", *International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)*, Vol. 4, No. 1, pp. 94-98. ISSN 2278-909X.

[7] Falih, N., Jabir, B. and Rahmani, K. (2019) "Systemic approach for optimizing information technology resource as a contribution of information system governance", *Indonesian Journal of Electrical Engineering and Computer Science*, Vol. 14, No. 1, p. 135. E-ISSN 2502-4760, ISSN 2502-4752. DOI 10.11591/ijeecs.v14.i1.pp135-142.

[8] Fielke, S., Taylor, B. and Jakku, E. (2020) "Digitalisation of agricultural knowledge and advice networks: A state-of-the-art review", *Agricultural Systems*, Vol. 180 , p. 102763. ISSN 0308-521X. DOI 10.1016/j.agsy.2019.102763.

[9] Jabir, B., Falih, N. Sarih, A. and Tannouche, A. (2021) “A Strategic Analytics Using Convolutional Neural Networks for Weed Identification in Sugar Beet Fields", *AGRIS on-line Papers in Economics and Informatics*, Vol. 13, No. 1, pp. 49-57. ISSN 1804-1930. DOI 10.7160/aol.2021.130104.

[10] Jones, J. W., Antle, J. M., Basso, B., Boote, K. J., Conant, R. T., Foster, I., Godfray, H. C. J., Herrero, M., Howitt, R. E., Janssen, S., Keating, B. A., Munoz-Carpena, R., Porter, C. H., Rosenzweig, C. and Wheeler, T. R. (2017) "Toward a new generation of agricultural system data, models, and knowledge products: State of agricultural systems science", *Agricultural Systems*, Vol. 155, pp. 269-288. ISSN 0308-521X. DOI 10.1016/j.agsy.2016.09.021.

[11] Kosanke, K., Vernadat, F. and Zelm, M. (2014) "Means to enable Enterprise Interoperation: CIMOSA Object Capability Profiles and CIMOSA Collaboration View", *IFAC Proceedings Volumes*, Vol. 47, No. 3, pp. 3292-3299. ISSN 1474-6670. DOI 10.3182/20140824-6-ZA-1003.01294.

[12] Lamine, E., Thabet, R., Sienou, A., Bork, D., Fontanili, F. and Pingaud, H. (2020) "BPRIM: An integrated framework for business process management and risk management", *Computers in Industry*, Vol. 117, p. 103199. ISSN 0166-3615. DOI 10.1016/j.compind.2020.103199.

[13] Li, C. and Niu, B. (2020) "Design of smart agriculture based on big data and Internet of things", *International Journal of Distributed Sensor Networks*, Vol. 16, No. 5. E-ISSN, ISSN 1550-1329. DOI 10.1177/1550147720917065.

[14] Marcu, I., Voicu, C., Drăgulinescu, A. M. C., Fratu, O., Suciu, G., Balaceanu, C. and Andronache, M. M. (2019) "Overview of IoT basic platforms for precision agriculture", In: Poulkov, V. (eds) *Future Access Enablers for Ubiquitous and Intelligent Infrastructures*, FABULOUS 2019, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Vol. 283. Springer, Cham. E-ISBN 978-3-030-23976-3, ISBN 978-3-030-23975-6. DOI 10.1007/978-3-030-23976-3_13.

[15] Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A. and Nillaor, P. (2019) "IoT and agriculture data analysis for smart farm". *Computers and Electronics in Agriculture*, Vol. 156, pp. 467-474. E-ISSN 1872-7107, ISSN 0168-1699. DOI 10.1016/j.compag.2018.12.011.

[16] Naresh, V., Vatsala, B. R. and Raj, C. V. (2020) "Crop Yield Prediction and Fertilizer Recommendation", *International Journal for Research in Engineering Application & Management*, Vol. 10, No. 6, pp. 135-138. E-ISSN 2454-9150. DOI 10.35291/2454-9150.2020.0452.

[17] Ngo, V. M. (2020) "Crop Knowledge Discovery Based on Agricultural Big Data Integration", *ICMLSC '20: Proceedings of the 4th International Conference on Machine Learning and Soft Computing, January 2020, Haiphong City Viet Nam.* pp. 46-50. ISBN 978-1-4503-7631-0. DOI 10.1145/3380688.3380705.

[18] Perakis, K., Lampathaki, F., Nikas, K., Georgiou, Y., Marko, O. and Maselyne, J. (2020) "CYBELE – Fostering precision agriculture & livestock farming through secure access to large-scale HPC enabled virtual industrial experimentation environments fostering scalable big data analytics", *Computer Networks*, Vol. 168, p. 107035. ISSN 138-1286. DOI 10.1016/j.comnet.2019.107035.

[19] Rabhi, L., Falih, N., Afraites, L. and Bouikhalene, B. (2021a) "A functional framework based on big data analytics for smart farming", *Indonesian Journal of Electrical Engineering and Computer Science*, Vol. 24, No. 3, pp. 1772-1779. E-ISSN 2502-4760, ISSN 2502-4752. DOI 10.11591/ijeecs.v24.i3.pp1772-1779.

[20] Rabhi, L., Falih, N., Afraites, L. and Bouikhalene, B. (2021b) "Digital agriculture based on big data analytics: a focus on predictive irrigation for smart farming in Morocco", *Indonesian Journal of Electrical Engineering and Computer Science,* Vol. 24, No. 1, pp. 581-589. E-ISSN 2502-4760, ISSN 2502-4752. DOI 10.11591/ijeecs.v24.i1.pp581-589.

[21] Radhi, A. (2018) "Design and Implementation of a Smart Farm System Smart Farming is a modular platform made up of sensors that can be integrated", *Association of Arab Universities Journal of Engineering Sciences,* Vol. 24, No. 3, pp. 227-241. E-ISSN 2616-9401, ISSN 1726-4081.

[22] Sung, J. (2018) "The Fourth Industrial Revolution and Precision Agriculture", In: Stephan, H. (ed) *Automation in Agriculture - Securing Food Supplies for Future Generations*. ISBN 978-953-51-3874-7. DOI 10.5772/intechopen.71582.

[23] Symeonaki, E., Arvanitis, K. and Piromalis, D. (2020) "A Context-Aware Middleware Cloud Approach for Integrating Precision Farming Facilities into the IoT toward Agriculture 4.0", *Applied Sciences*, Vol. 10, No. 3, pp. 1-35. ISSN 2076-3417. DOI 10.3390/app10030813.

[24] Triantafyllou, A., Sarigiannidis, P. and Bibi, S. (2019) "Precision agriculture: A remote sensing monitoring system architecture", *Information*, Vol. 10, No. 11, p. 348. ISSN 2078-2489. DOI 10.3390/info10110348.

[25] Triantafyllou, A., Tsouros, D. C., Sarigiannidis, P. and Bibi, S. (2019) "An architecture model for smart farming", *Proceedings - 15th Annual International Conference on Distributed Computing in Sensor Systems, DCOSS 2019*, pp. 85-392. DOI 10.1109/DCOSS.2019.00081.

[26] Verma, G., Mittal, P. and Farheen, S. (2020) "Real Time Weather Prediction System Using IOT and Machine Learning", *6th International Conference on Signal Processing and Communication, ICSC 2020*, pp. 322-324. DOI 10.1109/ICSC48311.2020.9182766.

[27] Vernadat, F. (2020) "Enterprise modelling: Research review and outlook", *Computers in Industry*, Vol. 122, No. 1-44. ISSN 0166-3615. DOI 10.1016/j.compind.2020.103265.

[28] Wang, B., Tao, F., Fang, X., Liu, C., Liu, Y. and Freiheit, T. (2021) "Smart Manufacturing and Intelligent Manufacturing: A Comparative Review", *Engineering*, Vol. 7, No. 6, pp. 738-757. ISSN 2095-8099. DOI 10.1016/j.eng.2020.07.017.

[29] Yang, F., Wang, K., Han, Y. and Qiao, Z. (2018) "A Cloud-Based Digital Farm Management System for Vegetable Production Process Management and Quality Traceability", *Sustainability*, Vol. 10, No. 11. ISSN 2071-1050. DOI 10.3390/su10114007.