Architecting IoT-based Farm Management Information Systems

16 September 2020
Virtual Meeting

Co-funded by the Erasmus+ Programme of the European Union

VIRAL

viralerasmus.org

Prof.dr. Bedir Tekinerdoğan

Wageningen University,
Chair Information Technology,
Wageningen, The Netherlands

bedir.tekinerdogan@wur.nl
https://linkedin.com/in/bedir

WAGENINGEN
UNIVERSITY & RESEARCH

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Agriculture teaching staff has a great need and is willing to learn novelties about application of ICT technologies in agriculture. This is also one of the most important goals of the Erasmus + VIRAL project.

Due to health security (COVID 19), the First Educational seminar on ICT in agriculture in a series of trainings within the VIRAL project will be organized online on September 16, 2020. The lecturers are professors and researchers from the Information Technology Group of the University of Wageningen.

Through the introductory workshop, 5 lectures will be presented with topics of importance for ICT in agriculture - from design to practical application (see table below). The workshop is intended primarily for teaching staff of higher education institutions in Bosnia and Herzegovina and Montenegro, but also for other interested individuals, primarily participants in the VIRAL project, as well as representatives of the business sector and students in master's and doctoral studies.

The activity is implemented within the work package 2 (WP 2.1) whose coordinators are the University of Wageningen and the University of Donja Gorica.

In order to access the platform on which the workshop will be organized, information will be provided to all interested parties in a timely manner. We invite you to take part in this event.

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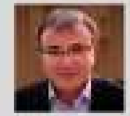
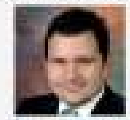
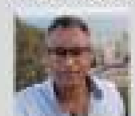
Agenda

Wageningen University – online introductory workshop		
September 16th, 2020		
TIME	TOPIC	LECTURER
15:30-16:00	*Architecting IoT Based Farm Management Information Systems*	BEDIR TEKINERDOGAN  https://www.wur.nl/en/Persons/Bedir-prof.dr.ir.-B-Bedir-Tekinerdogan.htm
16:00-16:30	*Machine Learning/Deep Learning in Agriculture*	CAGATAY CATAL  https://www.wur.nl/en/Persons/Cagatay-prof.-C-Cagatay-Catal.htm
16:30-17:00	*IoT in Agriculture*	QINGZHI LIU  https://www.wur.nl/en/Persons/Qingzhi-dr.-Q-Qingzhi-Liu.htm
17:00-17:15	**Break**	
17:15-17:45	*Business-IT Alignment in Agri-Food Supply Chains*	AYALEW KASSAHUN  https://www.wur.nl/en/Persons/Ayalew-dr.ir.-A-Ayalew-Kassahun.htm
17:45-18:15	*Drones in Agriculture*	JOÃO VALENTE  https://www.wur.nl/en/Persons/Joao-dr.-IR-Joao-Pereira-Valente.htm
18:15-18:45	**Summary/Questions**	

Background

Prof. Tekinerdogan received his MSc degree (1994) and a PhD degree (2000) in Computer Science, both from the University of Twente, The Netherlands. From 2003 until 2008, he was a faculty member at the University of Twente, after which he joined Bilkent University until 2015. At Bilkent, he has founded and led the Bilkent Software Engineering Group, which aimed to foster research and education on software engineering in Turkey. Currently, he is a full professor and chair of the Information Technology group at Wageningen University, The Netherlands.

He has more than 25 years of experience in information technology and software/systems engineering. He is the author of more than 300 peer-reviewed scientific papers. He has been active in dozens of national and international research and consultancy projects with various large software companies, whereby he has worked as a principal researcher and leading software/system architect. Hence, he has got broad experience in software and systems engineering in different domains such as consumer electronics, enterprise systems, automotive systems, critical infrastructures, cyber-physical systems, satellite systems, defense systems, production line systems, command and control systems, physical protection systems, radar systems, smart metering systems, energy systems, and precision farming. He has a broad and in-depth background and experience in software engineering. In parallel, has increasingly taken a holistic systemic approach to solve real industrial problems. With this, he has ample experience in software and systems architecting, software and systems product line engineering, model-driven software engineering, aspect-oriented software engineering, global software development, systems engineering, system of systems engineering, data science, and artificial intelligence. All of these topics, he is also actively teaching. He has developed and taught around 20 different academic courses and has provided software/systems engineering courses to more than 50 companies in The Netherlands, Germany, and Turkey.

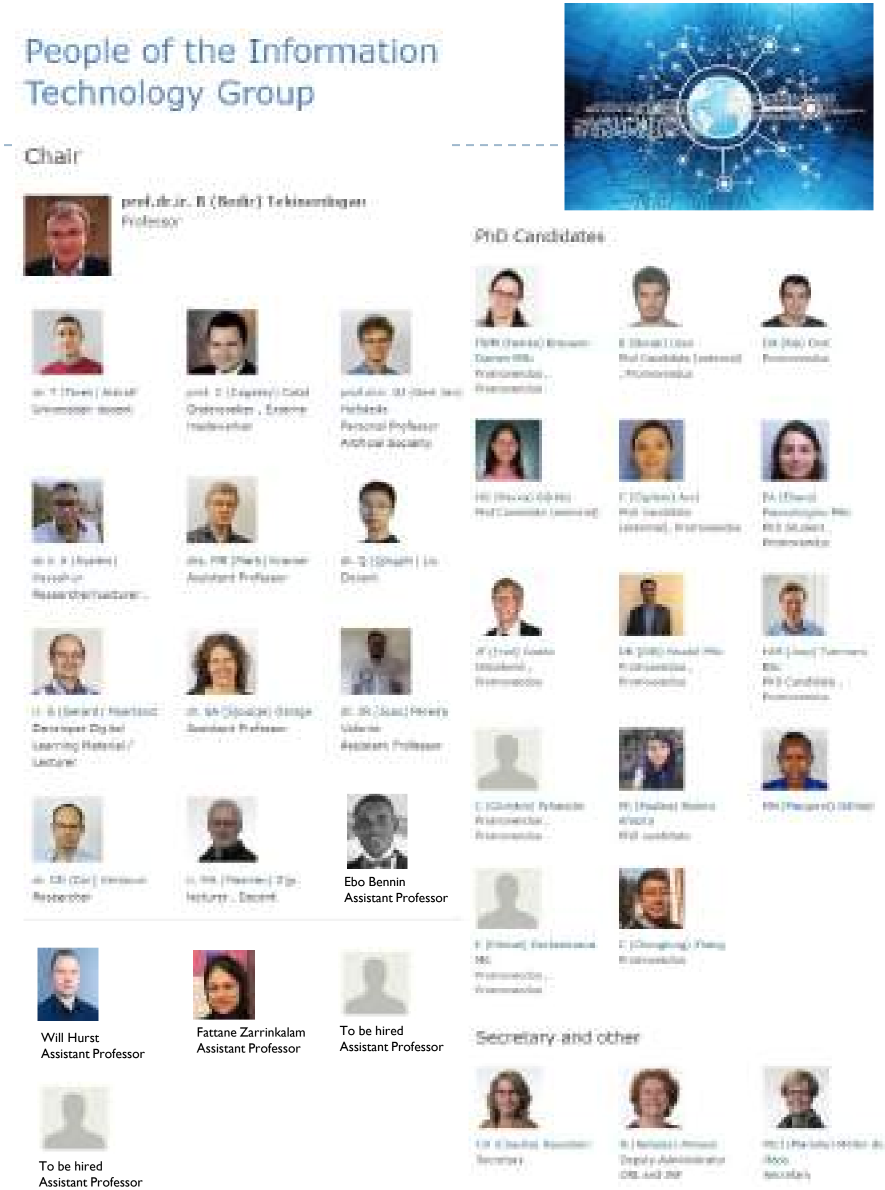
He has graduated more than 50 MSc students and supervised more than 20 PhD students. He has reviewed more than 100 national and international projects and is a regular reviewer for more than 20 international journals. He has also been very active in scientific conferences and organized more than 50 conferences/workshops on software engineering topics.

He can communicate in five languages (English, Dutch, Turkish, French, German).

https://www.linkedin.com/in/bedir/

Bedir Tekinerdogan

https://www.researchgate.net/profile/Bedir_Tekinerdogan

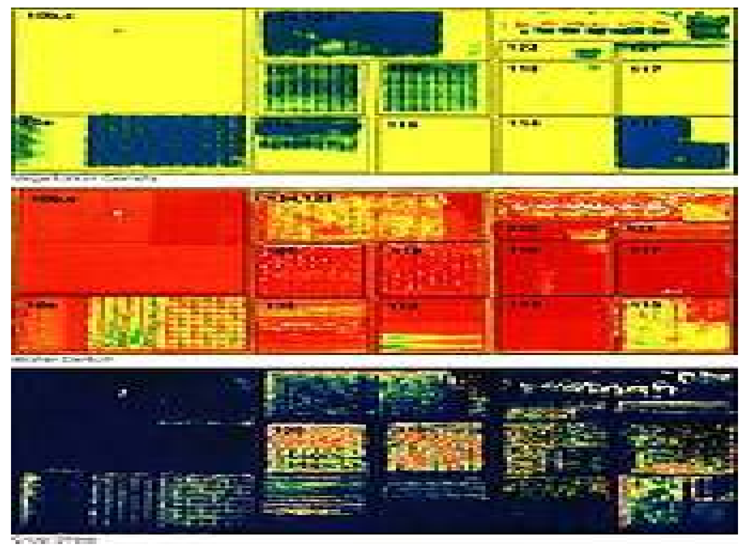


Wageningen University & Research

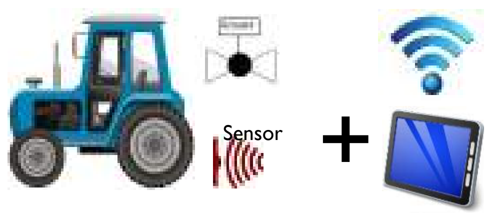
- Focus on *life sciences*, which comprises the branches of science that involve the scientific study of **living organisms**,
- like plants, animals, and human beings.

Precision Farming

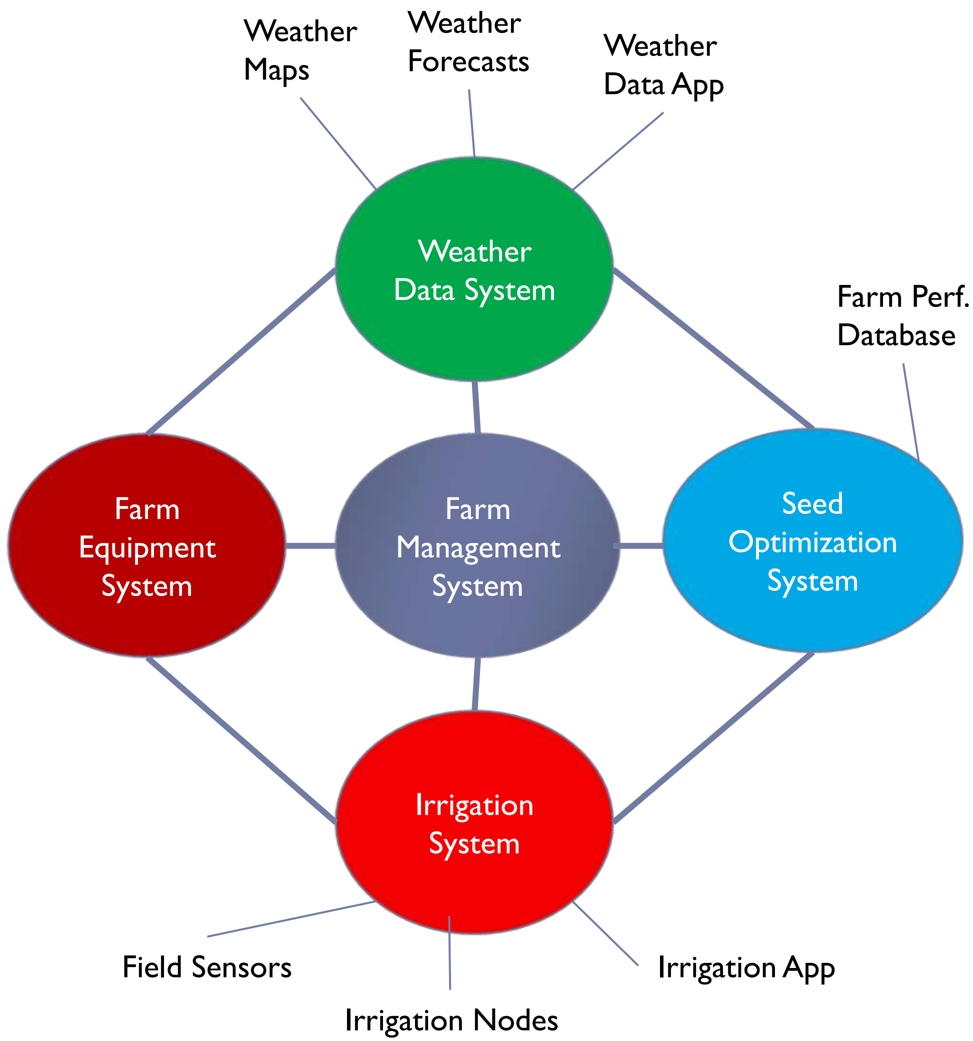
- Precision agriculture (PA) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops.
- define a decision support system for whole farm management with the goal of optimizing returns on inputs while preserving resources.
- an application of breakthrough digital farming technologies
  - Robotics
  - Drones and UAV
  - Internet of Things
  - Cloud Computing
  - Machine Learning/Deep Learning
  - Software Engineering



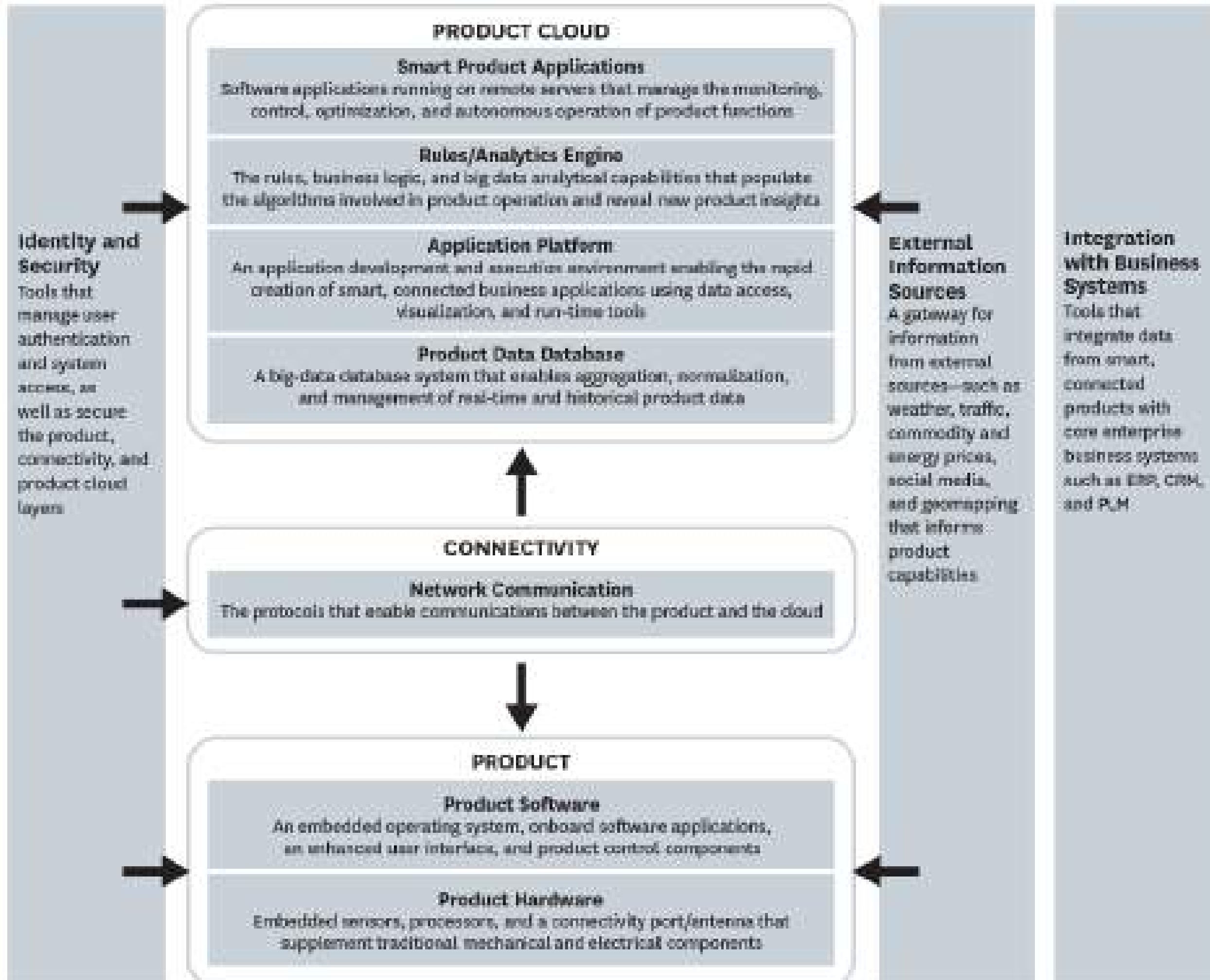
Farming System-of-Systems



Smart Connected Product



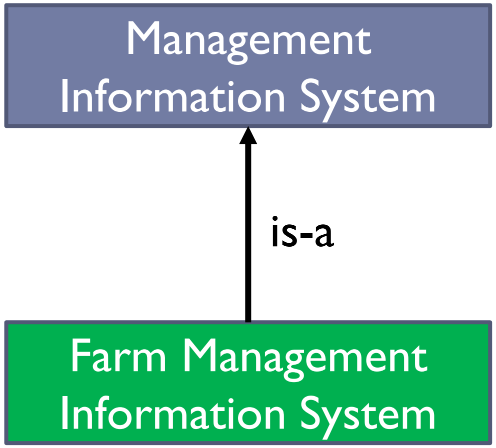
Connected Smart Systems



SOURCE "HOW SMART, CONNECTED PRODUCTS ARE TRANSFORMING COMPETITION," HBR, NOVEMBER 2014

Farm Management Information System

- **Management information system (MIS)** is an information system used for decision-making, and for the coordination, control, analysis, and visualization of information in an organization.
- Involves people, processes and technology in an organizational context.
- the ultimate goal of the use of a management information system is to **increase the value and profits of the business**
- Farm management information systems (FMIS) is an MIS that supports the automation of data acquisition and processing, monitoring, planning, decision making, documenting, and **managing the farm operations**.
- A key element of smart farming



INF Research – Farm Management Information Systems

Computers and Electronics in Agriculture
Volume 157, February 2019, Pages 189-204

Review

Obstacles and features of Farm Management Information Systems: A systematic literature review

J. Tummers, A. Kassahun, B. Tekinerdogan

Computers and Electronics in Agriculture
Volume 165, October 2019, 104939

Original papers

Architecture framework of IoT-based food and farm systems: A multiple case study

Cor Verdouw, Harald Sundmaeker, Bedir Tekinerdogan, Davide Conzon, Teodoro Montanaro

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Architecture design approach for IoT-based farm management information systems

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Precision Agriculture 20, 926–958(2019) | Cite this article

Springer Link

Open Access | Published: 01 June 2020

Reference architecture design for farm management information systems: a multi-case study approach

J. Tummers, A. Kassahun & B. Tekinerdogan

Precision Agriculture (2020) | Cite this article

Obstacles of FMIS

Computers and Electronics in Agriculture
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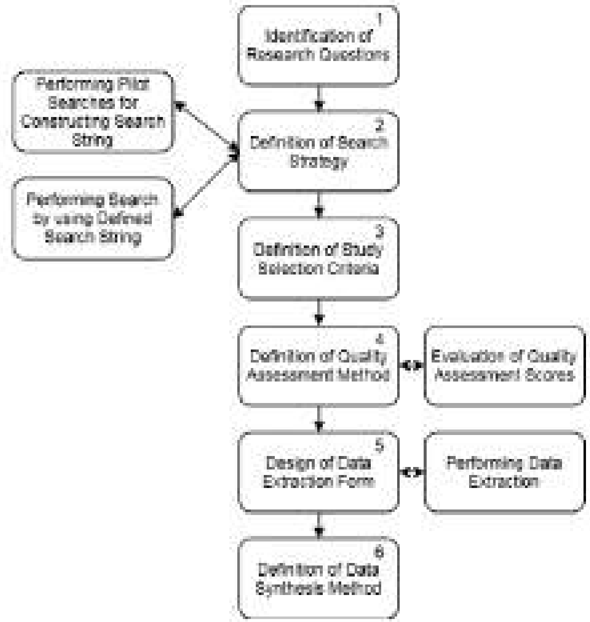
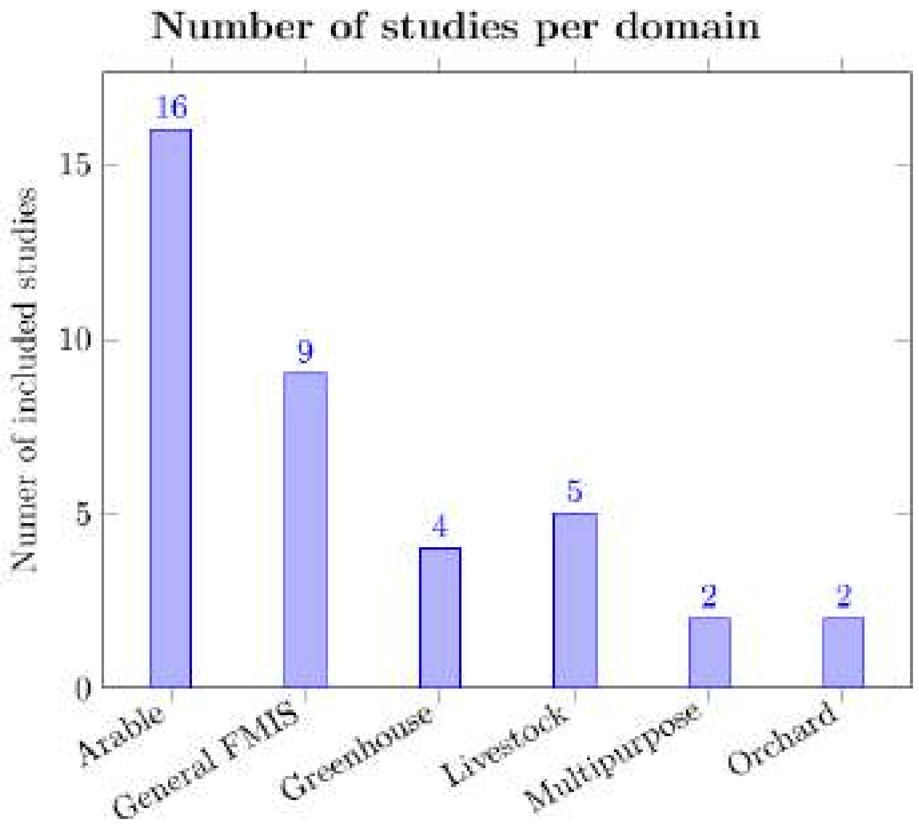


- RQ1: What are the current FMISs described in the literature?
  - RQ1.1: Which domains are supported?
  - RQ1.2: Which modeling approaches are applied?
  - RQ1.3: What are the delivery models?
  - RQ1.4: Who are the identified stakeholders?
- RQ2: What are the features of existing FMISs?
- RQ3: What are the obstacles to existing FMISs?

Overview of search results and study selection.

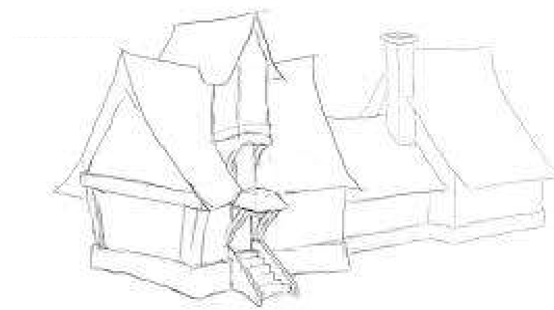
Source	*After automated and manual search*	*After applying selection criteria*	*After reading complete study and quality assessment*
IEEE Xplore	111	20	7
ACM Digital Library	102	10	5
Wiley Interscience	120	1	0
Science Direct	138	7	6
Springer	135	6	1
ISI Web of Knowledge	422	14	7
Manual search	20	20	12
Total	1048	78	38

FMIS Domains

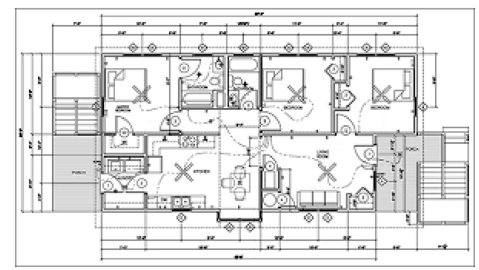


Maturity of Models…

- **Sketch** – simple drawing model; not precise or complete, nor is it intended to be. The purpose of the sketch is to try out an idea. The sketch is neither maintained nor delivered.

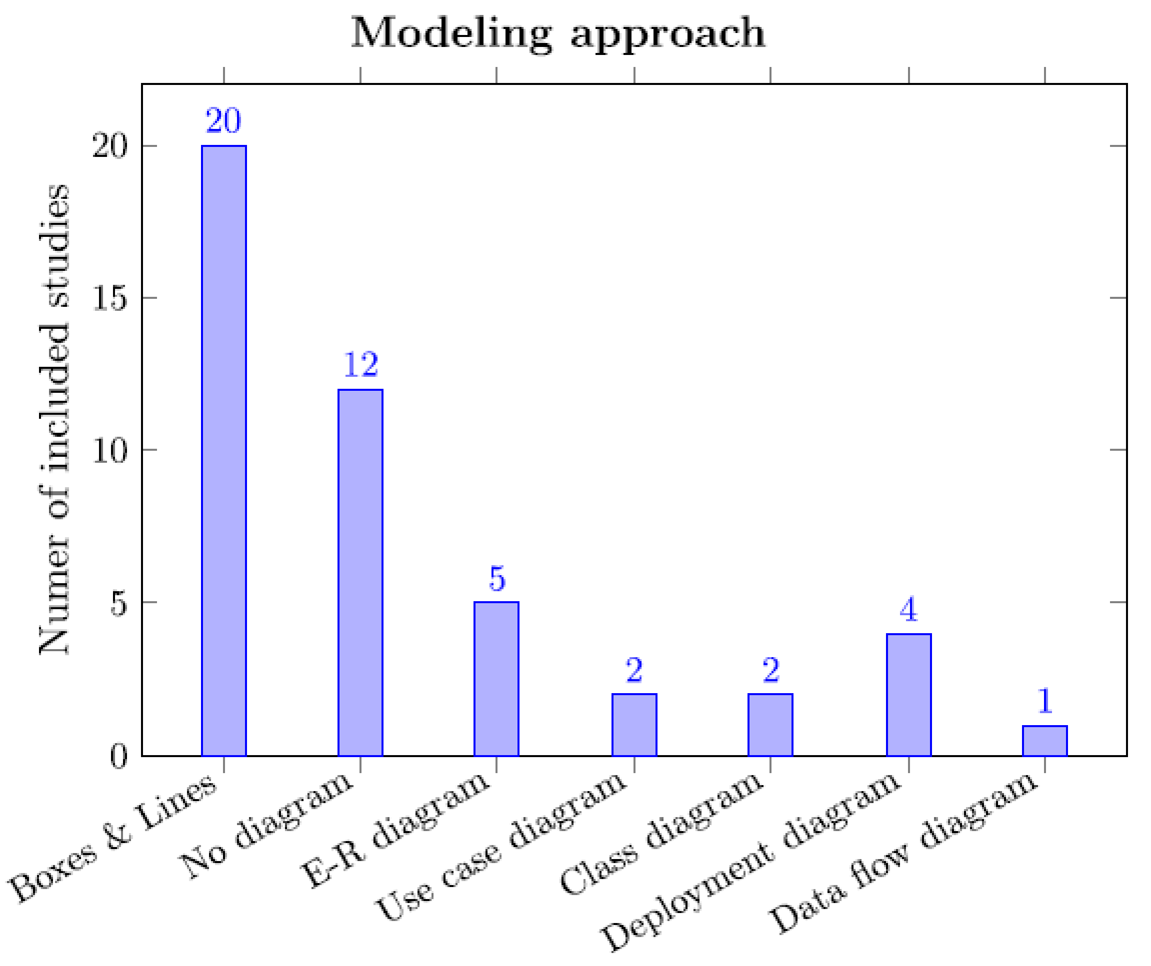


- **Blueprint** – document/design model describing properties needed to build the real thing. In other words, the blueprint is the embodiment of a plan for construction

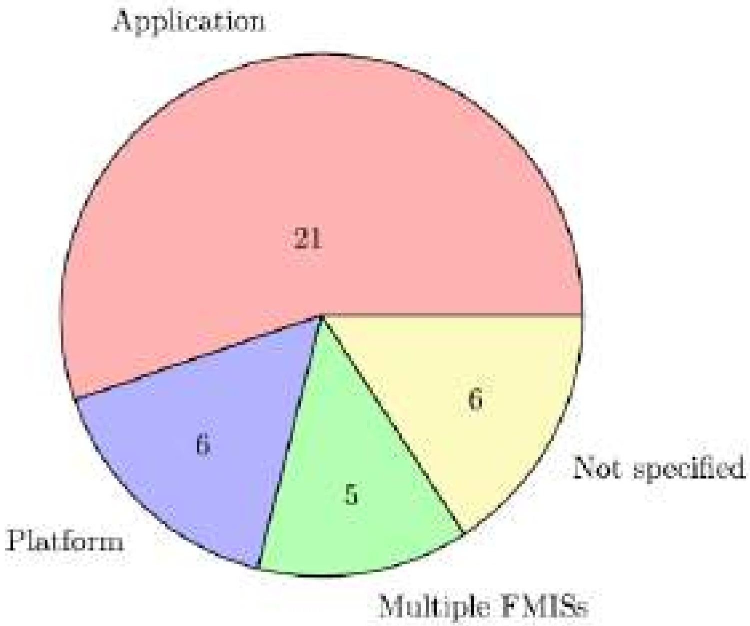


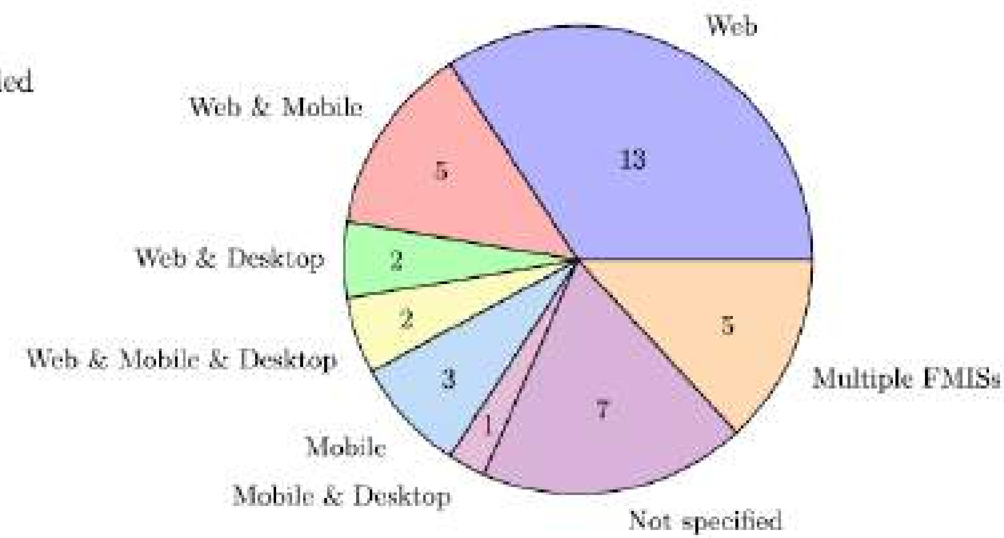
- **Executable** – software model that can be compiled and executed; can be automatically translated into other models or code

FMIS Modeling Approaches



FMIS Delivery Models





FMIS Stakeholders

The identified stakeholders and their relationship to FMISs.

Stakeholder name	Description	#
Farmer	Responsible person on the farm and end-user of the system.	38
Governmental	Umbrella term for multiple stakeholders that relate to the government. Has an interest in FMIS for registration purposes, and to obtain farm information	10
Agricultural expert	Has expert knowledge about the agricultural sector and can be used for requirements for FMISs.	7
Farm employee	Works on the farm and has to work with the FMIS.	6
Research Institute	Multiple kinds of researchers and institutes can be used as knowledge input for FMISs.	6
FMIS developer	Develops the FMIS and its underlying software.	5
Input supplier	Delivers inputs to the farm, these inputs can be registered in an FMIS	5
Agricultural advisor	Helps the farmer with making decisions based on their knowledge, an FMIS can assist them.	4
Agriculture service provider	Assists the farmer with the providence of services. Can use FMIS for registration purposes.	4
Contractor	Hired by the farmer to perform field tasks. FMISs can improve the communication with the farmer.	4
Equipment producer	Makes new machinery for the farmer, an FMIS can provide machinery management.	4
Customer	Companies and other entities greater than an individual consumer. FMIS can provide details about the purchased products.	3
Administrator	Can setup system, and manages the FMIS. Is not necessary the FMIS developer.	2
Farmers association	Organized group of farmers with common interests. Want FMIS for implementation of modern technology.	2
Neighbour	Is influenced by decisions of FMIS (Odor nuisance, noise disturbance, etcetera).	2
Non-governmental	Group of persons with their own (ecological) interest that can be intertwined with the FMIS.	2
Product processor	FMIS can provide information on products coming from the farm.	2
Veterinarian	Can use the FMIS for retrieving animal information and can register veterinarian actions.	2
Accountant	Can use the financial modules of FMISs to verify and assist the farmer with bookkeeping.	1
Equipment dealer	Can provide machinery support and services via the FMIS.	1
Media	Provides communication with the outside world and has an influence on the farm image.	1
Weather service provider	Provides weather information as input for the FMIS.	1

FMIS Features

Identified Features in descending order.

Financial management	17	Expert knowledge	5	Transport management	2
Reporting	14	Livestock management	5	Calibration management	2
Data aquisition	13	Sales	5	Experience management	2
Operation plan generation	10	Harvest management	4	Marketing and sales	2
Crop management	10	Machinery tracking	4	Reproductivity management	2
Resource management	9	Pesticide management	4	Weighing management	2
Equipment management	9	Scheduling	4	Best practice	1
Field monitoring	9	Work management	4	Collect produce information	1
Data processing	9	Knowledge management	4	Communication	1
Fertilization management	9	Legal management	4	Condition management	1
Human resource management	7	Activity monitoring	4	Delivery management	1
Weather service	7	Customer management	4	Feed management	1
Data management	7	Alerting	4	Grazing management	1
Field management	7	Production monitoring	3	Herd management	1
Accounting	7	Seed management	3	Printing	1
Inventory management	7	Yield monitoring	3	Real estate management	1
Decision support	6	Parameter monitoring	3	Remote controlling	1
Operation management	6	Data sharing	2	Risk analysis	1
Yield estimation	6	Driver assistance	2	Society management	1
Field mapping	6	Energy management	2	Supply management	1
GIS management	6	Health management	2	Task file management	1
Irrigation management	6	Information search	2	Task supervision	1
Sensor management	6	Model production parameters	2	Vision planning	1
Traceability	6	Performance management	2	B2B Collaboration	1
Data transfer	5	Scenario simulation	2	Company information	1
Data storage	5	Strategic planning	2	Environmental monitoring	1
Disease management	5	Technology management	2	Planting management	1

FMIS Features

- **Financial management**: Is defined out of the sub-features coming directly from the studies like making a billing plan, financial analysis, financial planning, calculate economic results, and budgeting.
- **Reporting**: Consists of sub-features coming from the data synthesis like documentation generation, report making, and automation of filling in documents. This feature occurs over multiple domains.
- **Data Acquisition:** Is described as the collecting of data coming from the farm. Also occurs over multiple domains.
- **Operation plan generation**: Making a plan about how the farm will be managed regarding its strategy and execution. Occurs over multiple domains and is a very general, broad term.
- **Crop management**: The selection of crops, getting information from the crops, checking the quality of the crops and more crop related sub-features.
- **Resource management**: The process of using the companies resources as efficient as possible. This feature is mainly present in studies that describe FMIS in general.
- **Equipment management**: Includes all sub-features that relate to the equipment on the farm like tractors, implements, and other machinery.
- **Field monitoring**: Mainly occurs in the domain of arable farming. Consists of sub-features that monitor the farmland status and their parameters.
- **Data processing**: Occurs over multiple domains. Makes sure raw data is converted into useful information for farmers.
- **Fertilization management**: Everything that has to do with the fertilization of the fields, like determining the fertilizing frame, making a fertilizing plan and the tracking of fertilizers. Occurs mainly in the arable farming domain.
- **Human resource management**: The management of labor, its main goal is to improve the performance of the employees.
- **Weather service**: Includes all sub-features related to the weather; weather forecasting, climate forecasting, and information about the previous weather.
- **Data management**: Includes all the sub-features that deal with data or are controlling data.
- **Field management**: The field operation management and field-specific management.
- **Accounting**: The recording of transactions and the keeping of financial records.
- **Inventory management**: The management of the inventory and stock.
- …..

Obstacles of FMIS

Identified Features in descending order.

Financial management	17	Expert knowledge	5	Transport management	2
Reporting	14	Livestock management	5	Calibration management	2
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Data transfer	5	Scenario simulation	2	Company information	1
Data storage	5	Strategic planning	2	Environmental monitoring	1
Disease management	5	Technology management	2	Planting management	1

Obstacles of FMIS

- **Standardized data formats:** Causes problems with the interoperability between different systems and components.
- **System integration**: FMISs and their components do not integrate with each other easily. Results to problems with interchangeability between applications and platforms.
- **Adoption rate of FMIS**: The adoption of new technologies in agriculture is rarely instantaneous and multiple factors influence the decision-making processes and can therefore be a result of multiple obstacles.
- **Cost of FMIS**: Farmers find FMISs too expensive, or they are not able to see the profitability potential of an FMIS.
- **Incomplete FMIS**: Multiple FMISs are specialized for one specific task on the farm. However, these systems are therefore missing features that will cause the farmer to use multiple FMISs, instead of one FMIS that can provide in all needs.
- **Understandability**: Current FMISs are not always easy to understand and use for farmers, due to difficult user interfaces or other factors that make them complex.
- **Data size**: The accumulation of data over the years is seen as a concern
- **Connection to internet**: Some FMISs are only accessible with an active internet connection; this connection is however not always reliable in more rural areas.
- **Insufficient farmer skills**: Farmers frequently have a low level of education, and therefore farmers are not always able to obtain the full potential of FMISs.
- **Language and regional**: Sometimes FMISs are only available in one language. Furthermore, there are big regional differences between countries concerning agricultural practices; FMISs can therefore not always foresee in all farmers needs due to these differences.
- **Security**: There are currently concerns about the security and privacy of the data that is used in the FMIS.

Architecture Design of FMIS

Computers and Electronics in Agriculture
Volume 165, October 2019, 104939

Original paper

Architecture framework of IoT-based food and farm systems: A multiple case study

Cor Verdouw, Harald Sundmaeker, Bedir Tekinerdogan, Davide Conzon, Teodoro Montanaro

Modeling

SpringerLink

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Ö. Köksal & B. Tekinerdogan

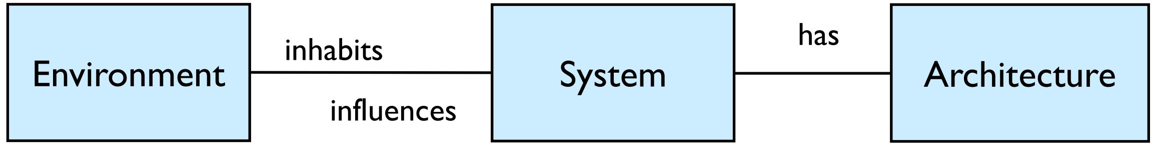
Precision Agriculture 20, 926–958(2019) | Cite this article

Design

Architecture

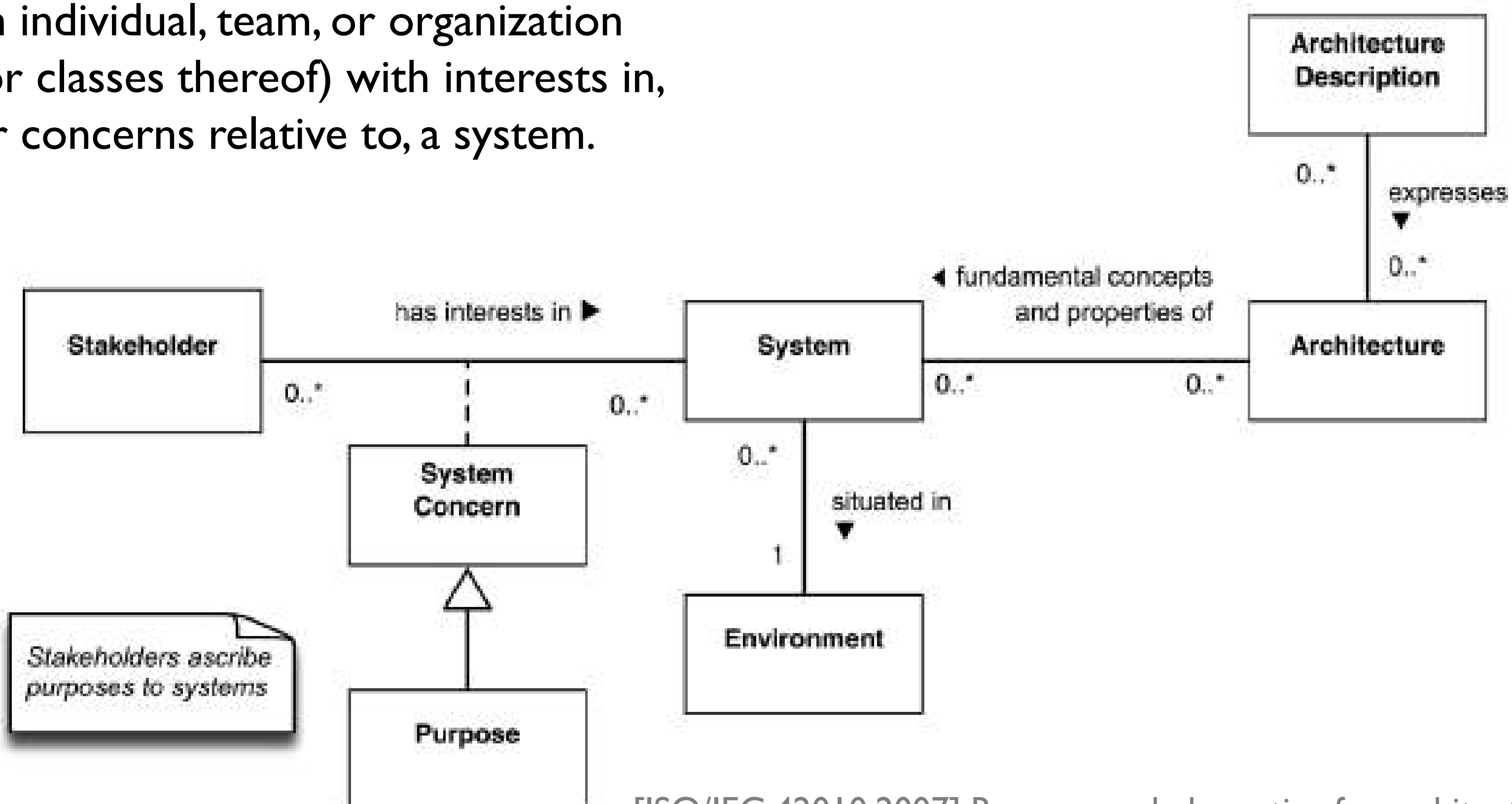
- "Software architecture is the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution"

IEEE. IEEE Product No. : SH94869-TBR: *Recommended Practice for Architectural Description of Software Intensive Systems*. IEEE Standard No. 1471-2000. Available at: http://shop.ieee.org/store/.



Architecture Stakeholders

- **system stakeholder:**
  an individual, team, or organization (or classes thereof) with interests in, or concerns relative to, a system.



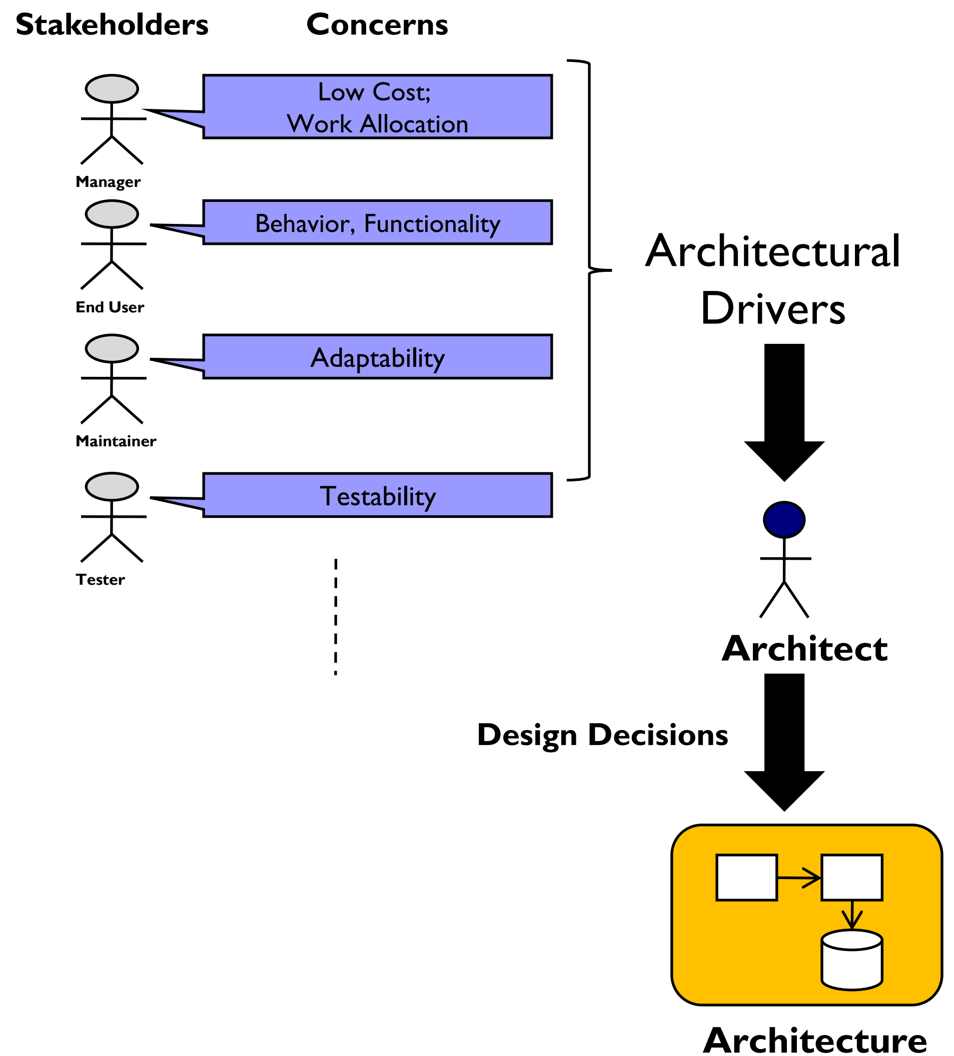
[ISO/IEC 42010:2007] Recommended practice for architectural description of software-intensive systems (ISO/IEC 42010) July 2007.

Architectural Drivers

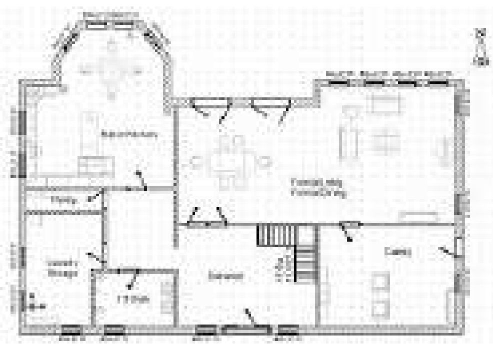
- **Stakeholder** is any person who has interest in the architecture

- Each stakeholder can have different **concerns**

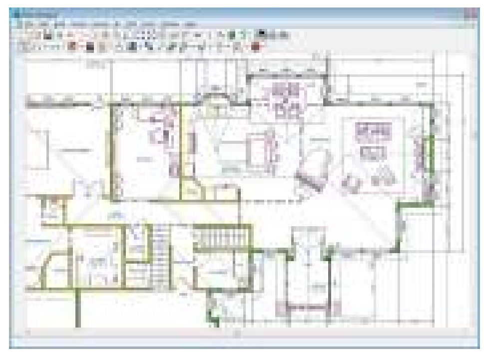
- Each concern puts forces on the architect and influences the early design decisions that the architect makes.



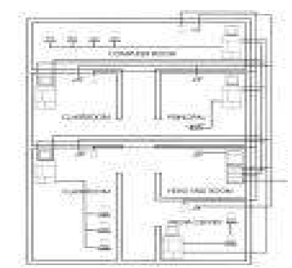
Multiple Views of the Architecture…



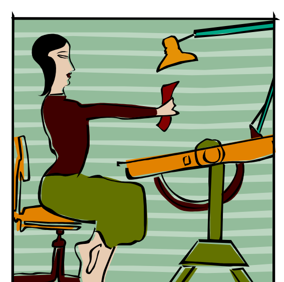
Floor plan



Interior Plan



Wiring Plan



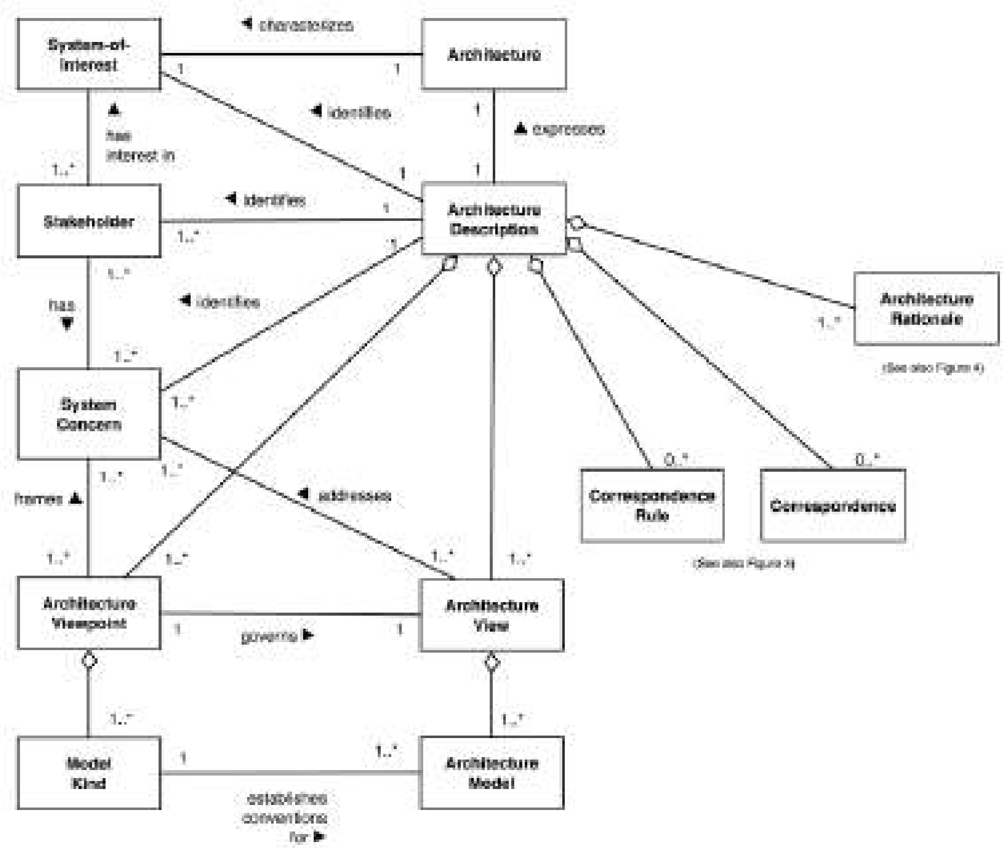
Architectural Viewpoints

View:

- a representation of a system from the perspective of one or more concerns which are held by one or more stakeholders.

Viewpoint:

- A pattern or template from which to construct individual views.

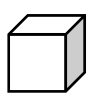


[ISO/IEC 42010:2007] Recommended practice for architectural description of software-intensive systems (ISO/IEC 42010) July 2007.

Example – UML Deployment Viewpoint

Viewpoint

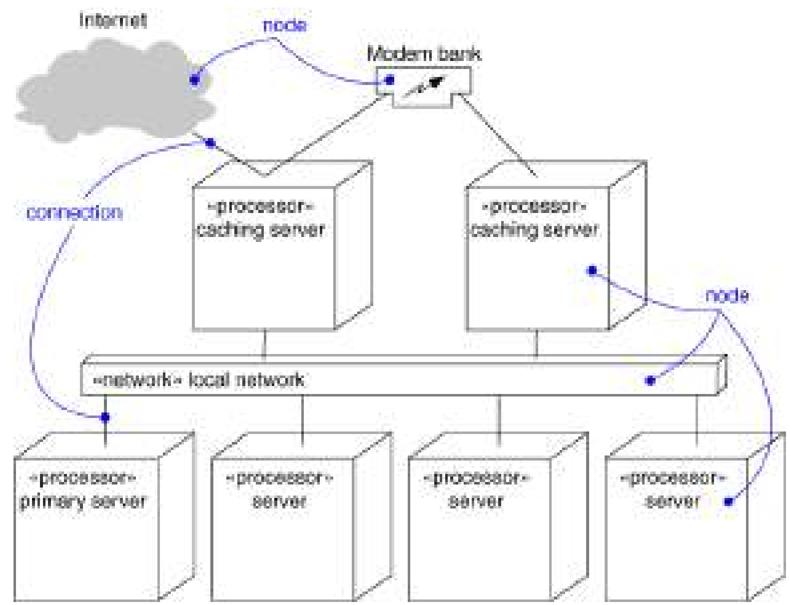
- Name: Deployment Viewpoint
- Stakeholders:
  - System Designer
- Concerns:
  - System Design
- Components:
  - Processing Nodes
- Notation



Node

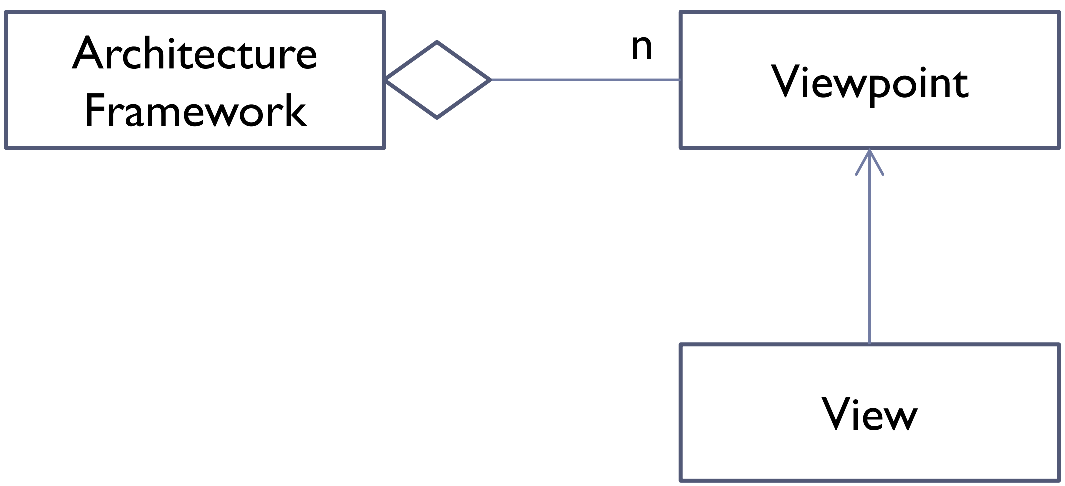
Connection

Deployment View - Example



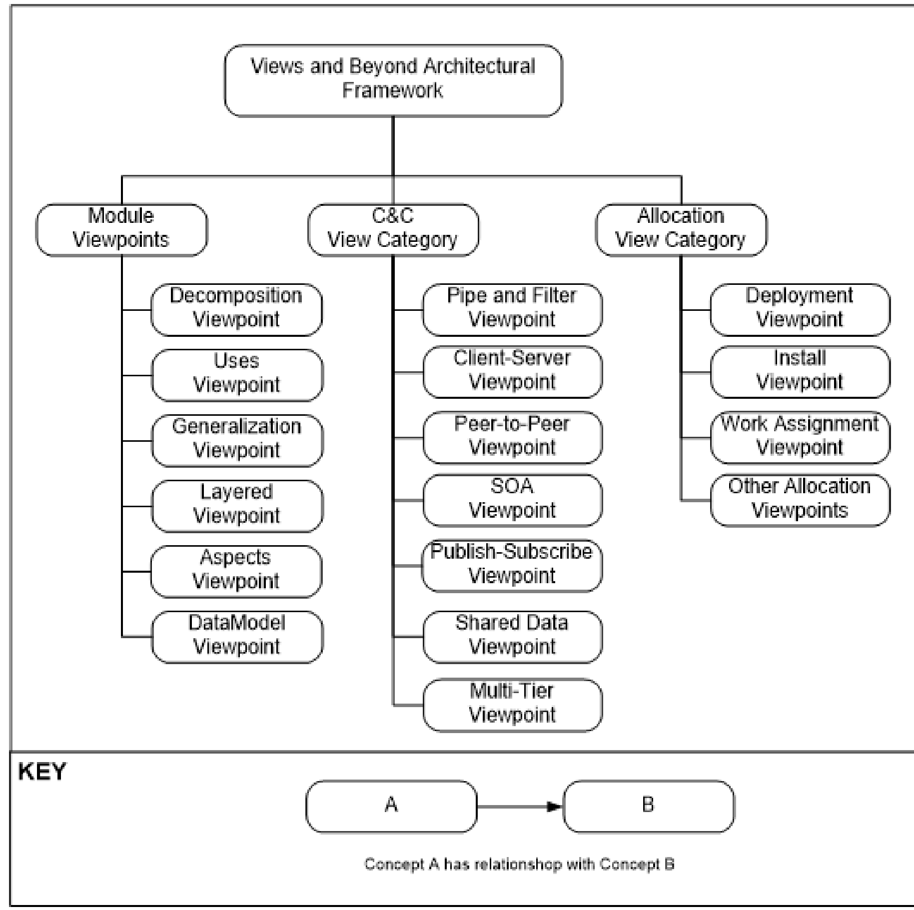
Architecture Framework

- Coherent set of viewpoints
- Each viewpoint addressing single concern
- Separation of Concerns



Example Architecture Framework

- **Module Styles**
  - How is the architecture structured as a set of implementation units?
- **Component-and-Connector Styles**
  - How is the architecture structured as a set of elements that have run-time behavior and interactions?
- **Allocation Styles**
  - How does the architecture relate to non-software structures in its environment?



P. Clements, F. Bachmann, L. Bass, D. Garlan, J. Ivers, R. Little, P. Merson, R. Nord, J. Stafford. Documenting Software Architectures: Views and Beyond. Second Edition. Addison-Wesley, 2010

Architecture Frameworks

http://www.iso-architecture.org/42010/afs/frameworks-table.html

Last Updated: 09/14/2016 21:00:21

Survey of Architecture Frameworks

The specification of *architecture frameworks* is one area of standardization in ISO/IEC/IEEE 42010:2011 (the international revision of IEEE 1471:2000).

WG42 is collecting examples of architecture frameworks, listed below.

ID	Name	Purpose	Scope	Classifiers	Notes
AF-EAF	Air Force Enterprise Architecture Framework	"The AF Enterprise Architecture Framework (AF-EAF) provides a logical structure for classifying, organizing and relating the breadth and depth of information that describes and documents the Air Force Enterprise Architecture (AF-EA)."	Air Force IT systems	Communication, Guidance, Enterprise Architecture Descriptions	"The AF-EAF does not define the AF-EA content, rather it consists of various approaches, models, and definitions for communicating and facilitating the presentation of key architecture components (i.e., architecture vision, g[illegible] principles, guidance, pr[illegible] required for the d[illegible] integration of AF archi[illegible] AF-EAF establis[illegible] foundation [illegible] comparing and m[illegible] architec[illegible] the overarching [illegible] generating [illegible] [All quotes f[illegible] June 2003]
AFIoT	IEEE P2413 – Architecture Framework for the Internet of Things	"This standard defines an architectural framework for the Internet of Things (IoT), including descriptions of various IoT domains, definitions of IoT domain [illegible]			"The architectural framework f[illegible] provides a reference model that defines relationships among various IoT verticals (e.g., transportation, healthcare, etc.) and common architecture elements. It also provides a blueprint for data abstraction and the quality 'quadruple' trust that includes protection, security, privacy, and [illegible]

FMIS Architeture Framework?

FMIS Architecture Framework

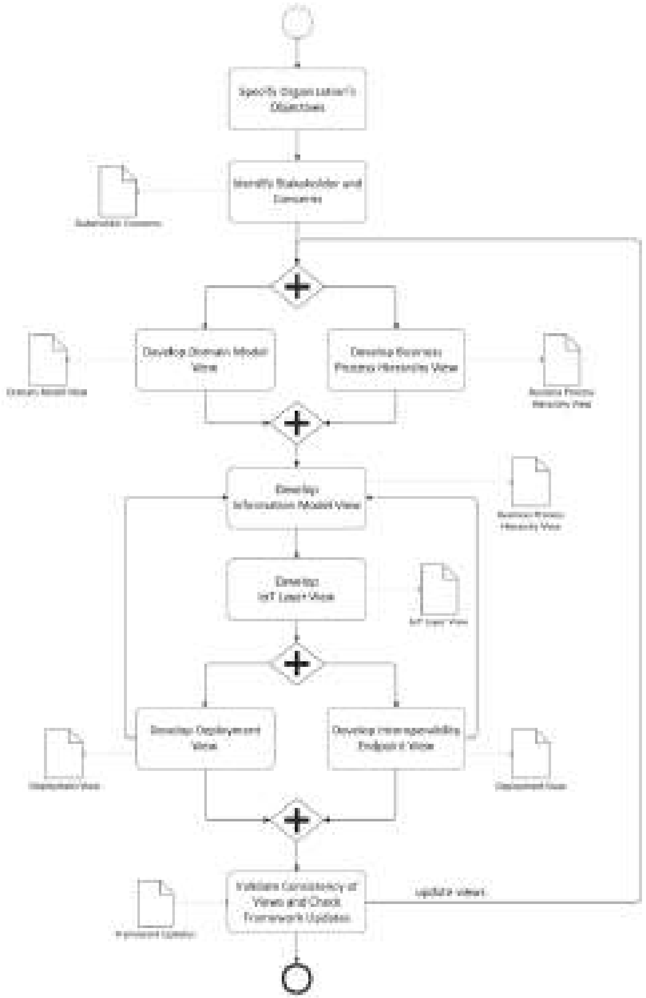
Computers and Electronics in Agriculture
Volume 165, October 2019, 104939

Original papers

Architecture framework of IoT-based food and farm systems: A multiple case study

Cor Verdouw, Harald Sundmaeker, Bedir Tekinerdogan, Davide Conzon, Teodoro Montanaro

- **Domain model viewpoint**: general view of key functional aspects of an IoT-based system
- **Business process hierarchy viewpoint**: overview of business processes and their interrelations
- **IoT layer viewpoint**: classifies IoT functionalities into different technical layers ranging from device layer until application layer
- **Deployment viewpoint**: visualizes the location of hardware and software components and how they are deployed
- **Information model viewpoint**: depicts the data entities of an IoT-based system, including data models of databases used, specifications of raw data collected by deployed IoT sensors, standard identification schemas, data entities in communication protocols, etc.
- **Interoperability endpoints viewpoint**: defines main interfaces for integration with external systems including standards and protocols to be used, derived from the information model viewpoint;



Adopted Case Studies

Trial/ sector	Case	Challenge	Focal Country	Chain Role	Adopter Type	Conven-tional / Organic
Arable	1.1 Within-field management zoning	Defining specific field management zones by developing and linking sensing- and actuating devices with external data	NL	Farming, Logistics	Early adopters and majority	Both
Arable	1.2 Precision Crop Management	Smart wheat crop management by sensors data embedded in a low-power, long-range network infrastructure	FR	Farming	Majority	Conven-tional
Arable	1.3 Soya Protein Management	Improving protein production by combining sensor data and translate them into effective machine task operations	AT, IT	Farming	Early Adopters	Both
Arable	1.4 Farm Machine Interoperability	Data exchange between field machinery and farm management information systems for supporting cross-over pilot machine communication	DK	Farming	Majority	Conven-tional
Dairy	2.1 Grazing Cow Monitor	Monitoring and managing the outdoor grazing of cows by GPS tracking within ultra-narrow band communication networks	BE	Farming	Both	Both
Dairy	2.2 Happy Cow	improving dairy farm productivity through 3D cow activity sensing and cloud machine learning technologies	NL	Farming	Early Adopters	Both
Dairy	2.3 Silent Herdsman	herd alert management by a high node count distributed sensor network and a cloud-based platform for decision-making	UK	Farming	Majority	Conven-tional

Trial / sector	Case	Challenge	Focal Country	Chain Role	Adopter Type	Conven-tional / Organic
Dairy	2.4 Remote Milk Quality	remote quality assurance of accurate instruments and analyses & pro-active control in the dairy chain.	NL	Processing, Consumption	Majority	Both
Fruit	3.1 Fresh table grapes chain	real-time monitoring and control of water supply and crop protection of table grapes and predicting shelf life	IT, GR	Farming, Logistics	Early Adopters	Both
Fruit	3.2 Big wine optimization	optimizing cultivation and processing of wine by sensor-actuator networks and big data analysis within a cloud framework	FR	Farming, Processing	Early Adopters	Both
Fruit	3.3 Automated olive chain	automated field control, product segmentation, processing and commercialization of olives and olive oil	SP, IT	Farming, Processing, Logistics	Majority	Conven-tional
Fruit	3.4 Intelligent fruit logistics	fresh fruit logistics through virtualization of fruit products by intelligent trays within a low-power long-range network infrastructure	GE	Logistics, Consumption	Majority	Both
Vegs	4.1 City farming	value chain innovation for leafy vegetables in convenience foods by integrated indoor climate control and logistics	NL	Farming, Logistics	Early Adopters	Conven-tional
Vegs	4.2 Chain-integrated greenhouse production	integrating the value chain and quality innovation by developing a full sensor-actuator-based system in tomato greenhouses	SP	Farming, Logistics, Consumption	Majority	Both
Vegs	4.3 Added value weeding data	boosting the value chain by harvesting weeding data of organic vegetables obtained by advanced visioning systems	NL, AT	Farming	Majority	Organic
Vegs	4.4 Enhanced quality certification system	enhanced trust and simplification of quality certification systems by use of sensors, RFID tags and intelligent chain analyses	IT	Farming, Logistics, Consumption	Majority	Both
Meat	5.1 Pig farm management	optimize pig production management by interoperable on-farm sensors and slaughter house data	BE, NL	Farming, Processing, Consumption	Both	Both
Meat	5.2 Poultry chain management	optimize production, transport and processing of poultry meat by automated ambient monitoring & control and data analyses	SP	Farming, Logistics, Processing	Majority	Conven-tional
Meat	5.3 Meat Transparency and Traceability	enhancing transparency and traceability of meat based on an monitored chain event data in an EPCIS-infrastructure	GE, NL	Farming, Logistics, Processing, Consumption	Majority	Both

Adopted Case Studies

Number of main elements addressed in each viewpoint

Use case	Domain concepts	Layer: IoT functions	Business Process Hierarchy: Objects/Processes	Deployment: nodes/components	Information: data elements	Interoperability Endpoints
1.1 Within field management zoning	15	14	9/16	7/16	N.A.	2
1.2 Precision Crop Management	16	19	5/12	10/38	25	13
1.3 Soya Protein Management	12	9	4/10	5/10	N.A.	3
1.4 Farm Machine Interoperability	19	23	5/15	5/16	19	4
2.1 Grazing Cow Monitor	13	8	6/11	3/6	8	2
2.2 Happy Cow	16	9	4/10	5/11	10	3
2.3 Silent Herdsman	8	8	5/15	5/9	8	4
2.4 Remote Milk Quality	17	13	7/16	6/15	14	5
3.1 Fresh table grapes chain	21	13	9/17	6/20	10	6
3.2 Big wine optimization	37	23	12/21	12/22	7	N.A.
3.3 Automated olive chain	10	12	7/10	5/11	8	5
3.4 Intelligent fruit logistics	19	10	11/18	8/16	10	5
4.1 City farming	16	10	N.A.	5/9	7	4
4.2 Chain-integrated greenhouse production	9	8	6/12	5/9	5	5
4.3 Added value weeding data	26	18	6/17	11/48	31	8
4.4 Enhanced quality certification system	20	23	9/16	9/22	19	11
5.1 Pig farm management	23	12	7/17	8/17	25	12
5.2 Poultry chain management	20	10	8/15	19/16	18	10
5.3 Meat Transparency and Traceability	10	10	0/8	5/9	11	3

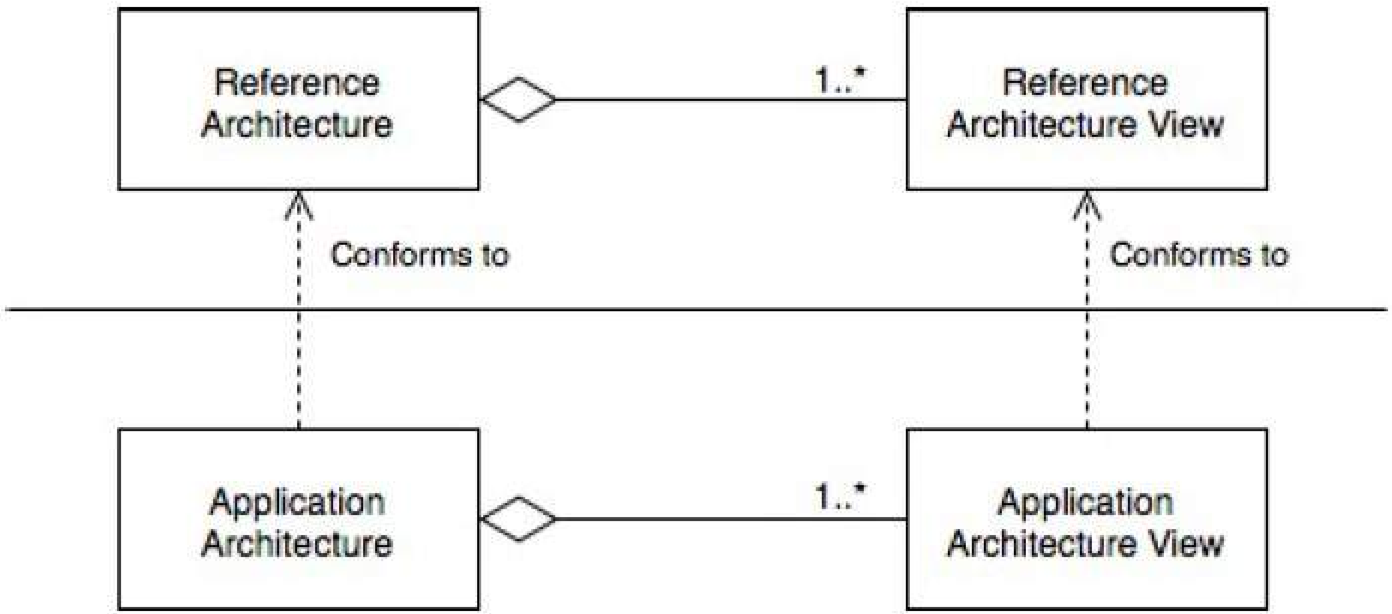
Obstacles of FMIS

- **Standardized data formats:** Causes problems with the interoperability between different systems and components.
- **System integration**: FMISs and their components do not integrate with each other [illegible] to [illegible] with interchangeability between applications and platforms.
- **Adoption rate of FMIS**: The adoption of new technologies in agriculture [illegible] factors influence the decision-making processes and can therefore be a result of [illegible]
- **Cost of FMIS**: Farmers find FMISs too expensive, or they are not able to [illegible]
- **Incomplete FMIS**: Multiple FMISs are specialized for one specific task on th[illegible] therefore missing features that will cause the farmer to use multiple FMISs, instead of one [illegible] needs.
- **Understandability**: Current FMISs are not always easy to understand and use for farmers, due to difficult user interfaces or other factors that make them complex.
- **Data size**: The accumulation of data over the years is seen as a concern
- **Connection to internet**: Some FMISs are only accessible with an active [illegible] is however not always reliable in more rural areas.
- **Insufficient farmer skills**: Farmers frequently have a low [illegible] to obtain the full potential of FMISs.
- **Language and regional**: Sometimes FMISs are only available [illegible] differences between countries concerning agricultural practices; FMISs can [illegible] to these differences.
- **Security**: There are currently concerns about the security and privacy of the data that is used in the FMIS.

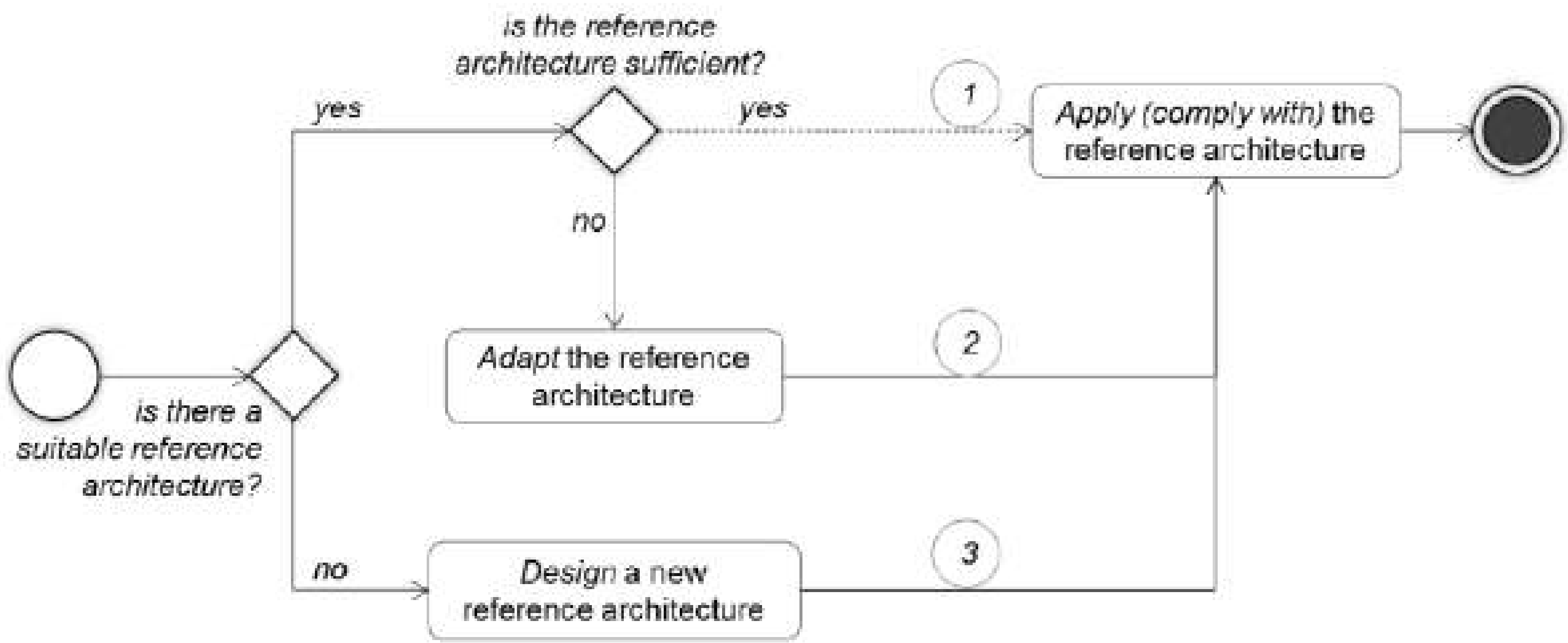
Variability

Multi-System Scope Reference Architecture Needed!

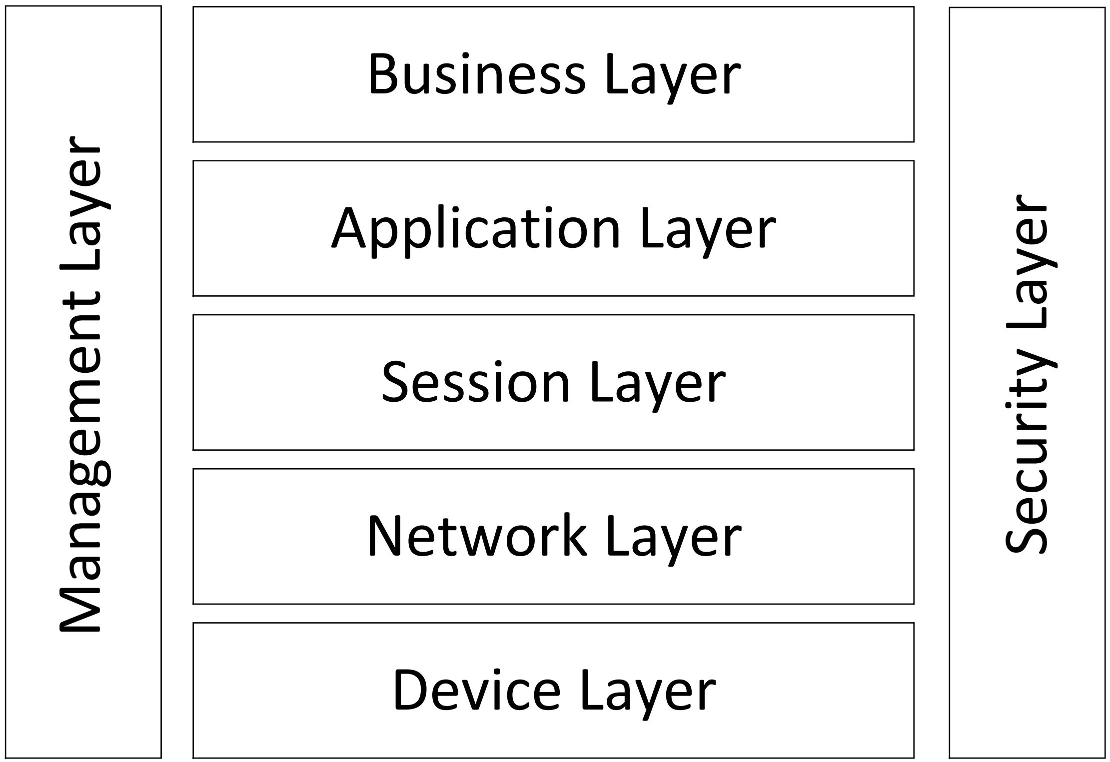
Reference Architecture vs. Application Architecture



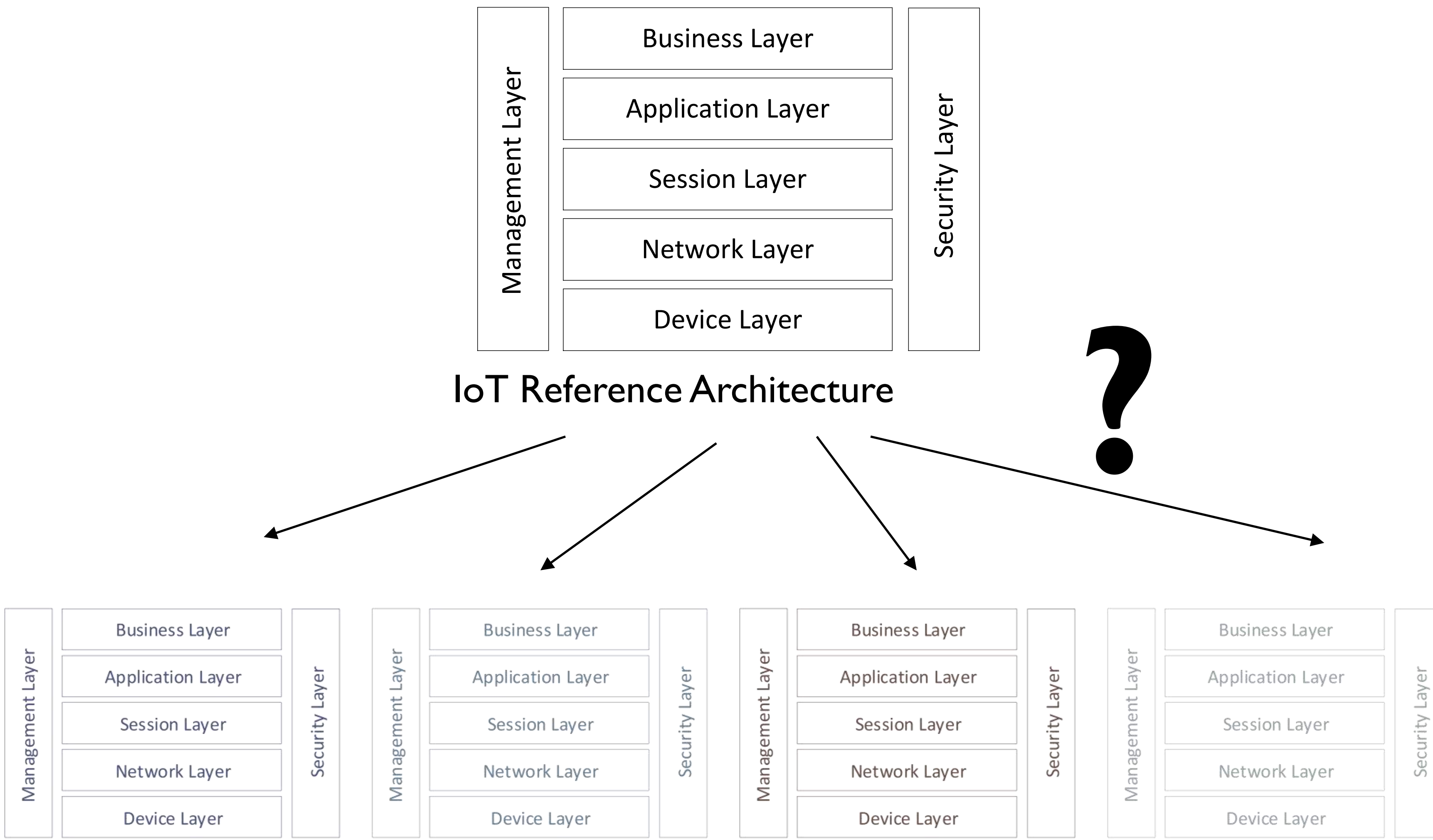
Reference Architecture Design



IoT Reference Architecture



Reference Architecture vs. Application Architecture



IoT-based FMIS Architecture Design Approach

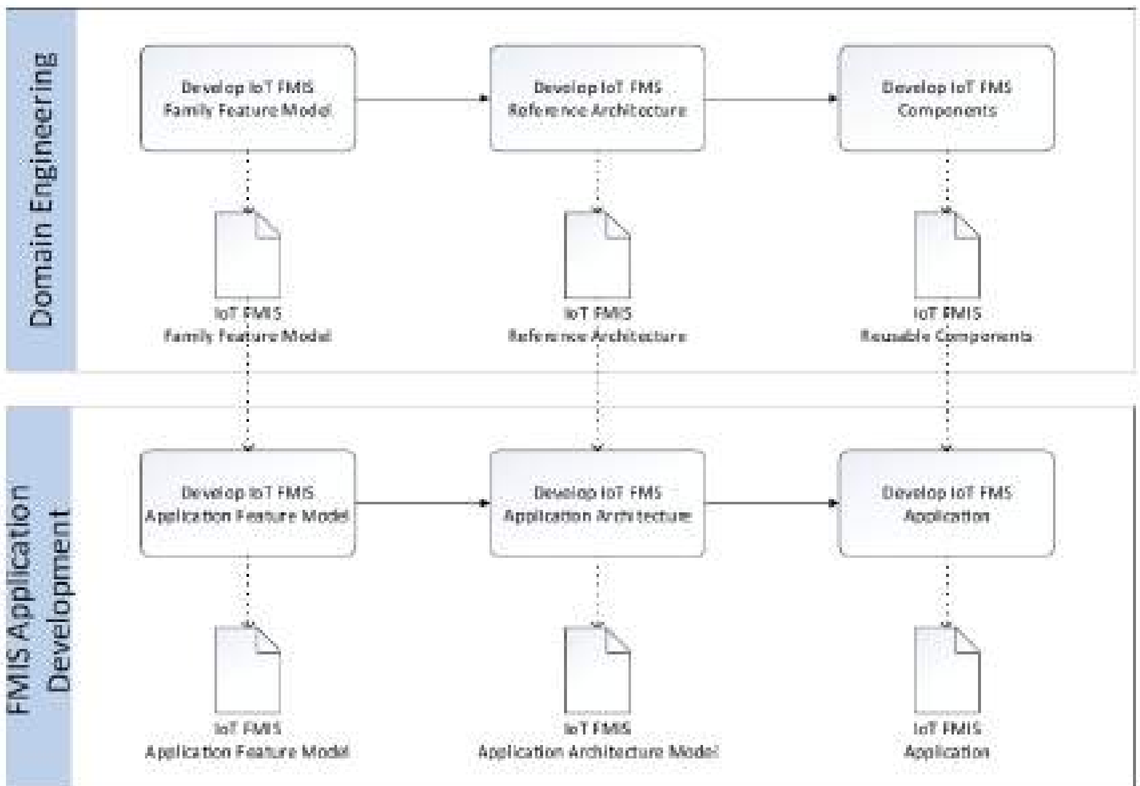
SpringerLink

Open Access | Published: 11 December 2018

Architecture design approach for IoT-based farm management information systems

Ö. Köksal & B. Tekinerdogan

Precision Agriculture 20, 926–958(2019) | Cite this article

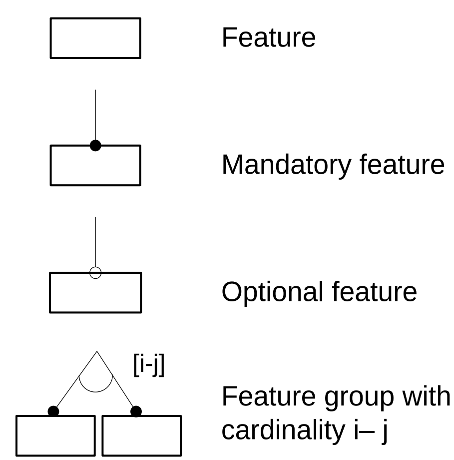


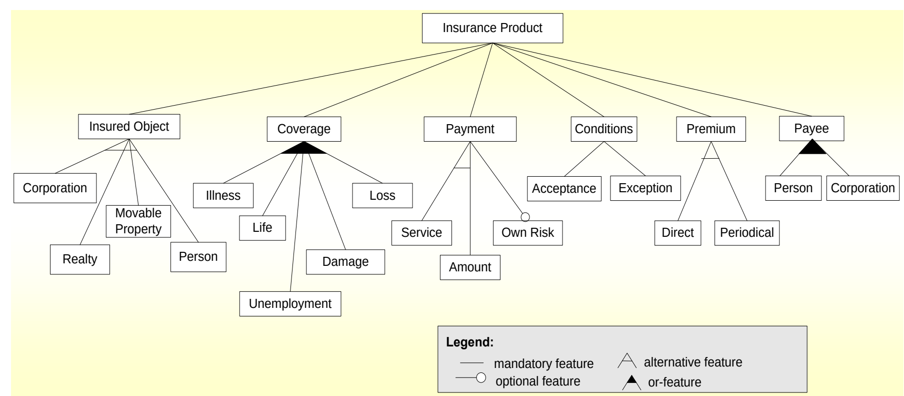
Feature-Oriented Domain Modeling

- A **feature model** represents the common and the variable features of products and the dependencies between the variable features.

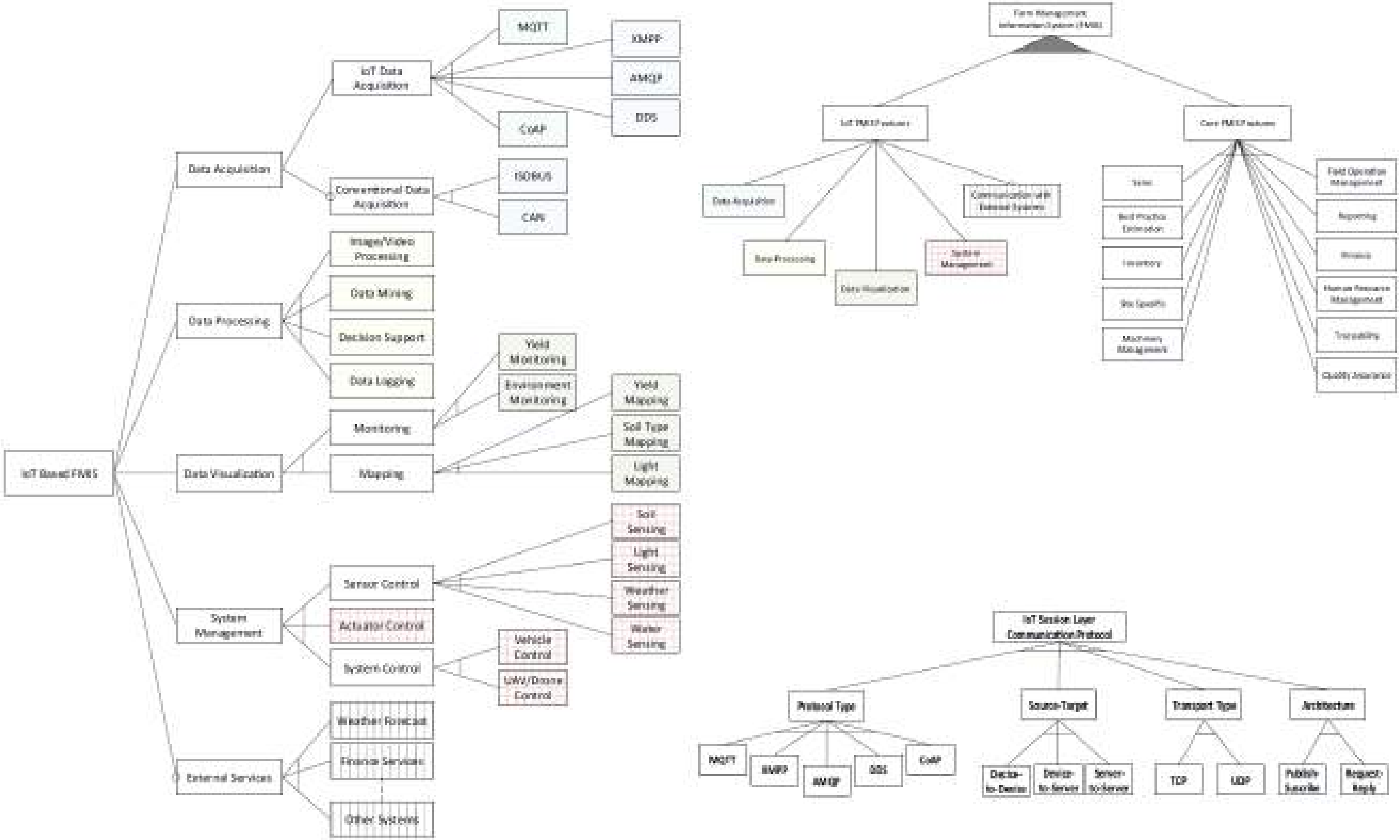
- **Feature**:
  - a distinctive property of a concept (domain model)
  - user visible characteristic of a system (requirements).

- **A feature diagram** consists of a set of nodes, a set of directed edges, and a set of edge decorations.

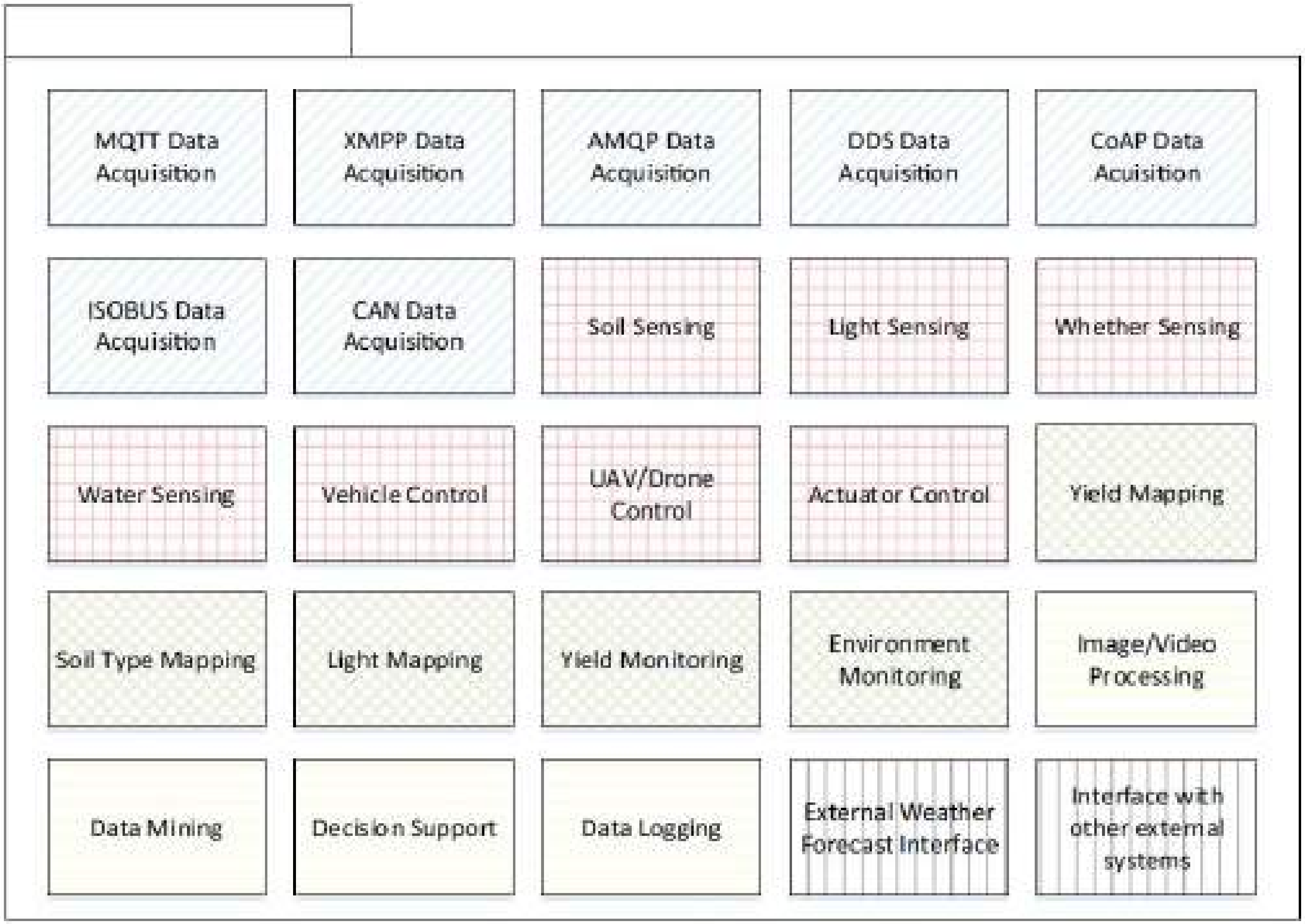




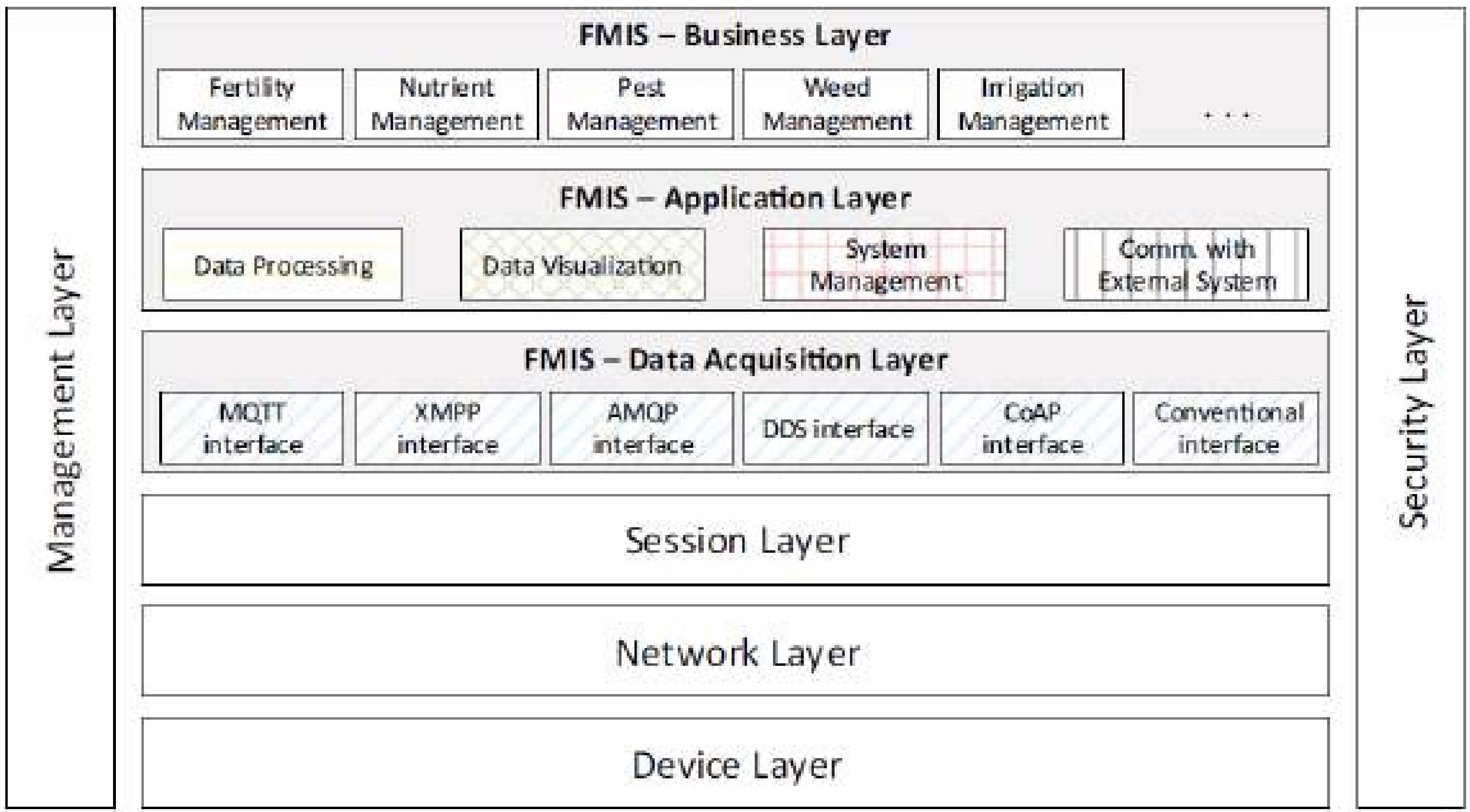
Feature Model for IoT



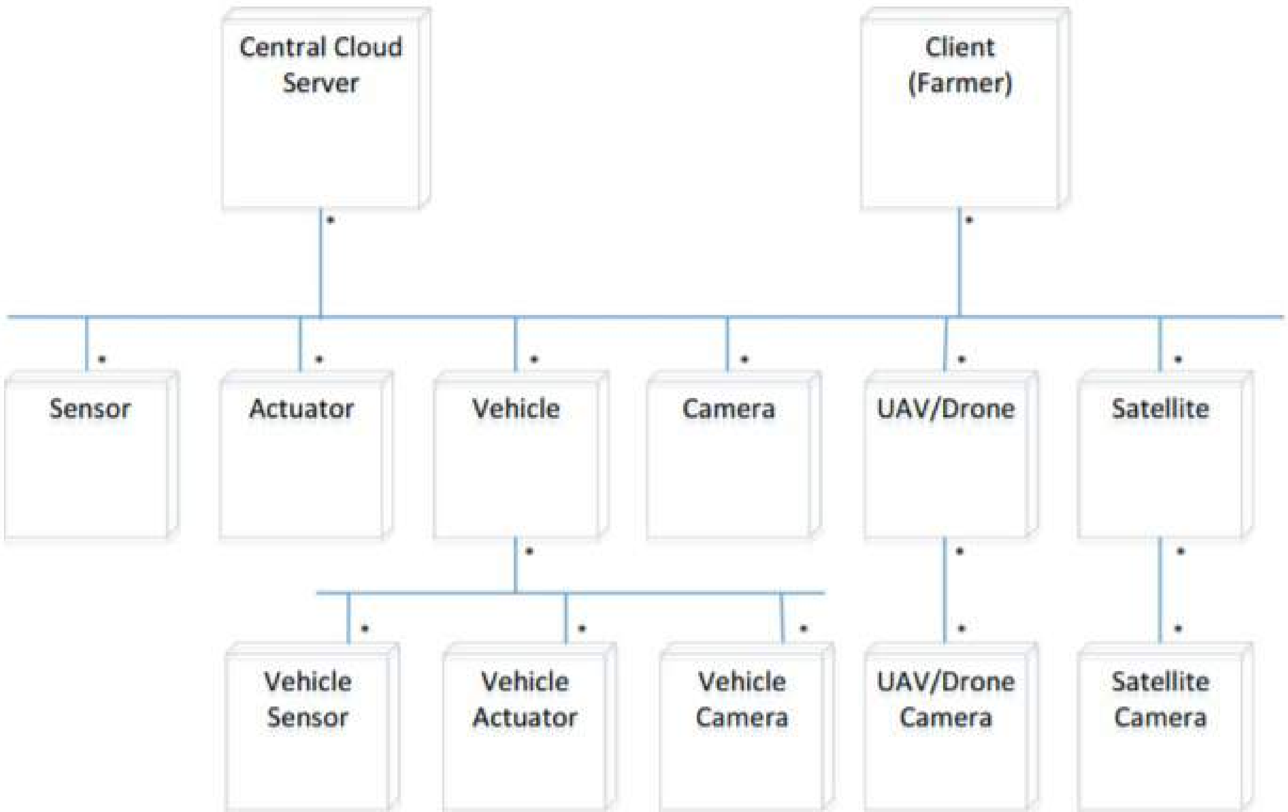
FMIS Decomposition View



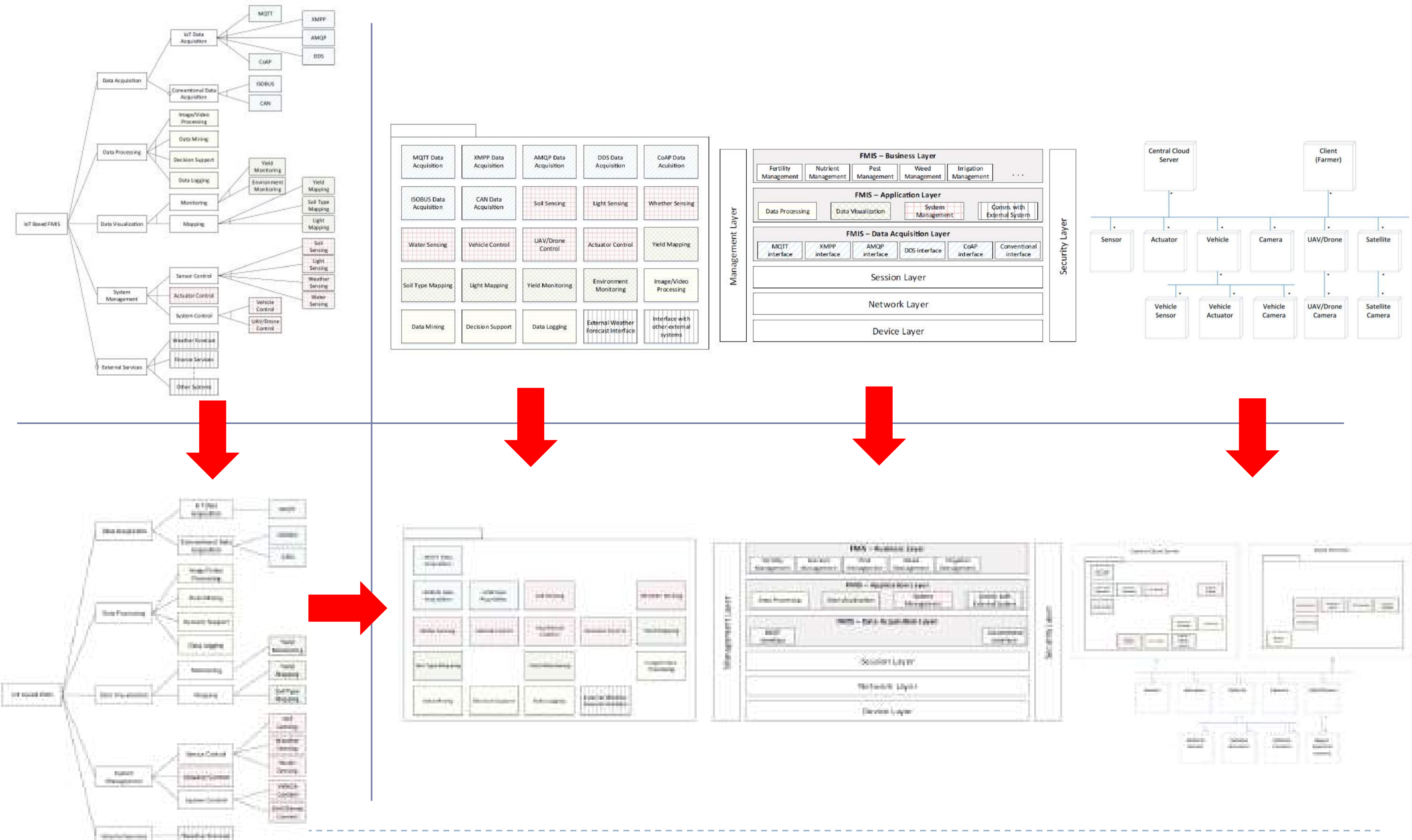
FMIS Layered View



FMIS Deployment View



Case Study – Smart Wheat Production



Conclusion…

- FMIS is a business-critical element of smart farming and needs to be properly designed/implemented
- We have carried out a set of systematic research activities on exploring the architecture modeling and design of FMISs
- Systematic Literature Review has provided the key features, obstacles, and modeling approaches of FMIS
- Architecture Modeling and Design of FMIS is limited and requires further research
- We have developed an architecture framework including a coherent set of viewpoints for supporting the modeling of FMIS
- We have developed a reference architecture that can be used to design an FMIS
- Future work will include the development of farm management software ecosystem