Analyzing and Conceptualizing Monitoring and Analytics as a Service for Grain Warehouses

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Abstract. In developing countries, like Vietnam, it is vital to ensure high quality of grain with traceable origins, because grain is of paramount importance for business and food security purposes. However, it is very challenging to build information systems to track, monitor, analyze and manage grain warehouses in scattered flood of Mekong delta - Vietnam, given under developed physical and informational infrastructures. In this paper, we analyze requirements and conceptualize monitoring and analytics as a service for grain warehouses, with a focus on Vietnam's environment. We analyze different stakeholders and their needs for monitoring and analytics features for grain warehouses. Leveraging the cloud computing model, big data analytics and Internet of Things (IoT), we design a conceptual framework to monitor various important information for grain warehouses and present different data analytics services that should be provided.

Keywords: Grain Warehouse monitoring, Monitoring and Analytics as a Service, IoT, Cloud computing

1 Introduction

Recently, advances in cloud computing, big data management, business intelligence, and Internet of Things (IoT) have been introduced to various domains, including transportation, logistics, and smart agriculture [1–3]. Furthermore, substantial reduction of investment costs in smart devices and software services in the cloud has enabled the further integration between physical worlds with software services in the cloud. Apart from such emerging technologies, shared economy models have shown that assets will be shared and managed with joint interesting from different partners [4]. In this trend, we have also observed that novel technological and economic models are needed to pave the way for smarter, but cheaper, logistics and management, enabling shared economy models to provide a lot of benefits for farmers, small and medium enterprises (SMEs), and government in agriculture in developing countries, e.g., Vietnam.

We are interested in investigating how such novel techniques and models could be utilized for grain warehouse management in the context of Vietnam, in particular, in the Mekong delta. In such a context, we face several problems in managing grains: (i) poor storage infrastructures with high air humidity; (ii) severe floods in the rain season; (iii) farmers are lack of knowledge in post harvest; (iv) and poor role of modern scientific and technological methods and tools in post grain harvest. Such problems, on the one hand, cause loss of grains due to poor quality management, and reduce readiness in logistics and grain trading. On the other hand, these problems prevent stakeholders in producing and selling grains to follow standard models, such as VietGAP/GlobalGAP[3], to provide high quality of grains with clear sources of origins in order to be able to gain benefits in a highly competitive environment, being governed by international treaties, like the future Trans-Pacific Partnership (TTP)[4].

In this paper we analyze requirements for building a grain warehouse information network by levering advanced concepts on everything-as-a-service [5], cloud computing and IoT. First, we contribute to an analysis of requirements for grain warehouse information under the service model by examining various stakeholders and their needs. Second, we propose a monitoring and analytics as a service framework, in which the SMEs/farmers can rent a warehouse to store their grain and use this framework to monitor the quality of grain as well as to receive early warning about the risk. In this framework, we enable the gathering of various types of monitoring data of grains, stakeholders, grain input/output flows and grain knowledge. This enables us to provide analytics and management features for grain warehouses under cloud services in data center.

The rest of this paper is organized as follows: Section 2 presents the motivating scenario. Section 3 analyzes stakeholders of monitoring and analytics as a service. Section 4 describes our conceptual framework. We discuss related work in Section 5. Section 6 concludes the paper and outlines our future work.

2 Motivating Scenario

Despite being one of the leading countries in rice producer and exporter, the rice value in Vietnam is low and, therefore, the life of farmer is still challenging. Among some reasons (e.g., type of grain, there is no brand) leading to the low value, an important reason is that the process of harvest and storage is poor. According to Jayas [6], the post-harvest losses of grains is approximately 20-50% in case of poorly managed storage systems comparing to the case of well managed facilities with aeration and drying capabilities. In Vietnam, the government currently allows state enterprises or private enterprises who have their warehouse with the capacity to store at least 5000 tons of grain to export the rice [7]. However, in fact, most enterprises, who have license to export the rice, do not store the grain at their warehouse[5]. When they get an order from customers, they will collect rice or grain from smaller enterprises or directly from farmers, packaging and exporting the requested grain/rice. It means that the grain after harvest is

[3] http://vietgap.gov.vn/ http://www.globalgap.org/
[4] https://en.wikipedia.org/wiki/Trans-Pacific_Partnership
[5] As private discussion with Prof. Tong-Xuan Vo

stored by farmers or small enterprises in different warehouses. The main problem is that such a storage infrastructure, i.e., warehouse, is not adequate for keeping quality of grain. Moreover, currently it is not easy to identify, if not impossible, the origin (i.e., where the rice is planted) due to the lack of various information sources and analytics because the rice is mixed from many different sources. This is very difficult to build the rice brand for farmers. Apart from these technical problems, current business models in grain warehouses are also not flexible. While there is no standard warehouse in which the SMEs/farmers use to store their grain, building their own standard warehouse is out of their capacity because they need not only money but also the knowledge to operate it and to share information to others. The shared economy models [4] is a good solution for this situation, in which the government or large enterprises can build a network of grain warehouse reached grain storage standard. The SMEs/farmers then use it to store their grain and pay as they use. However, to realize this, online collaboration and sharing, two major characteristics of the sharing economy must be enabled. It means that the grain warehouse network must support advanced monitoring and analytics features to allow various stakeholders involved in the grain warehouses to interact with their warehouse providers, their renting warehouse, domain experts, as well as retrieve their grain history to the potential rice consumer. All the above-mentioned problems call for the development of novel grain information network in Vietnam with the following features:

- allow providers to govern their grain warehouses in a seamless and smart manners (e.g., changing the temperature, the humidity of air, or the light inside warehouse).
- allow consumers to monitor the quality of grain by through various sensors and analytics in a near-realtime manner.
- enable early warning for consumers about the quality of grain if the properties such as temperature, humidity, weather, are changed or the warehouse is flooded.
- manage the grain warehouse contract and the grain history.
- provide the grain history, such as origin, storage period, weather/land/water of place during the rice growing, to potential rice customers.

In order to support the above-mentioned features, in the next sections, we will present our detailed requirement analysis and propose a novel monitoring and analytics as a service framework.

3 Stakeholder Analysis

We determine in this section relationships between stakeholder and the activities of grain warehouse information framework. Of course, two main stakeholders are warehouse provider and user. Domain experts play an important role in this framework since they can advise to warehouse provider during the operation. The grain users concern to this framework since they can query the grain history. Because the warehouse network is built from many providers by providing

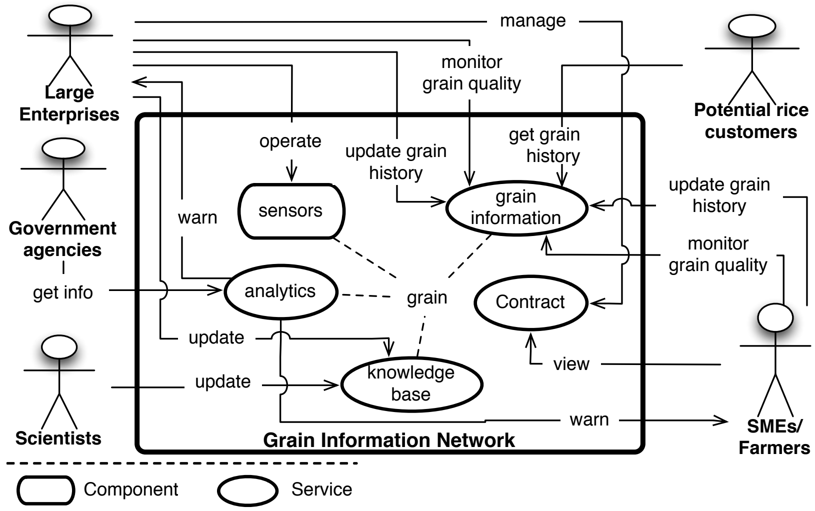

Fig. 1. The stakeholders and their interaction in the framework.

their resources, so a macro decision, e.g., distributing grain, on whole network is impossible for a single provider. However the government agencies can do it. In summary, there are five groups of stakeholder including: provider (large enterprises and government agencies), user (SMEs and farmers), scientist (domain expert), government agencies and grain user. The activities of framework are grouped into five services: sensor operation, grain information, grain knowledge, contract management and data analytics (Fig. 1). Fig. 2 details relationship between stakeholders, activities, data sources and services, in which:

- *Large Enterprises*: large enterprises are the providers who provide the warehouse for rent. It means that they must: (i) define and manage warehouse renting contracts; (ii) operate and monitor their warehouses to control the quality of grain; (iii) update knowledge base, e.g., grain seed and its properties, weather, from different sources. They also plays the role of consumer to use their warehouse to store their grain;
- *SMEs and Farmers*: they need monitoring and analytics features for grain information to monitor their grain and update their grain history.
- *Government agencies*: the government agencies do not only play the role of a grain warehouse provider, but also use various types of information (e.g., the quality and quantity of grain, and history of grain) to plan the use of the stored grain, e.g., for the food security program, or to allocate the rice export quota. In urgent cases (e.g., flooding), the government agencies can also make macro decisions on distributing grains.
- *Scientists*: scientists play the role of domain expert who provides their knowledge that helps the providers to operate the warehouse and the framework to produce early warning about quality of grain.

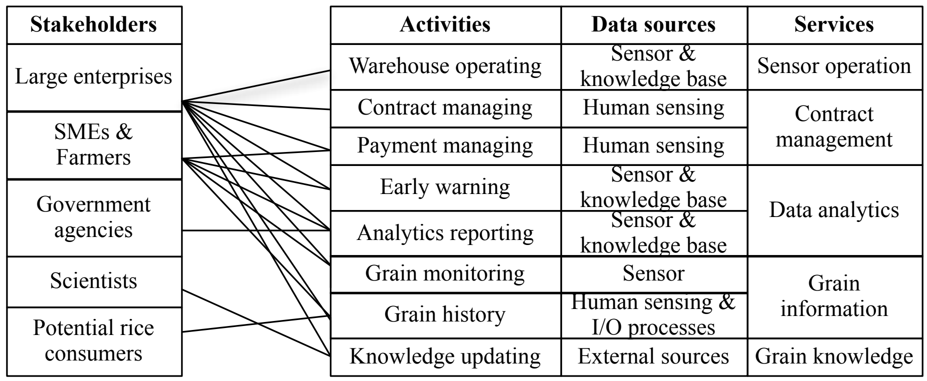

Fig. 2. Relationship between stakeholders, activities and data sources.

– *Potential rice customers*: they need information of grain history to decide their purchases of rice.

4 IoT Cloud based Platform for the Grain Warehouse

4.1 Monitoring Data

To support different analytics for the grain warehouse, several types of monitoring data must be captured. We consider two types of monitoring data that need to be provisioned:

– *grain warehouse monitoring data*: it is the data about grain status. Examples would be temperature, air humidity, moisture sensors, air quality sensors for both indoor and outdoor of the grain warehouses. Such IoT-based data is needed for continuously monitoring grain warehouse and grain conditions.
– *external data services*: several important external services will be utilized. In our framework, they are the weather information service, and the grain seeds and rice knowledge bank.

All of these data will be collected and provisioned as a service in the cloud to enable near-realtime monitoring and analytics. To this end, we leverage IoT technology to provide the first type of data whereas the second type of data is integrated from data-as-a-service cloud, such as weather and grain seeds.

4.2 Warehouse information system

Another type of information is the traditional warehouse information which stores information about stakeholders, volumes of grains, and number of bags of grains and containers of grains. This kind of data is provided through a grain input/output management system within warehouses as well as through management activities for stakeholders and their roles.

4.3 Grain Knowledge and Expert Inputs

One important information is the domain knowledge about grains. Such knowledge have been collected over the time for grains produced in the region. This type of knowledge differs from the global grain knowledge bank from external services, as it incorporates specific knowledge obtained from the region. In addition, we also allow human expert as well as people involved in the management of grain warehouse and stakeholders to provide inputs into the knowledge base. In our system, the knowledge therefore will be managed in a separate service where knowledge comes from people during warehouse operations as well as from experts through internet.

4.4 Monitoring and Analytics Services

To enable the monitoring of grain quality and operations for early warning, we design a near-realtime monitoring service. This service mainly utilizes the IoT data with streaming data processing capabilities to enable the detection of problems for grains and grain warehouses. Monitoring data can be informed to stakeholders through external services integration. Furthermore, monitoring data is used to make decisions in controlling the IoT system within the grain warehouse. For example, the control is executed to assure the following conditions inside the warehouse based on domain knowledge.

Several analytics features will be needed to support different use cases. An analytics can leverage big data processing techniques to deal with various types of data, mentioned above. Based on that, different customized analytics can be built, such as for grain quality analytics and logistics and recommendation.

4.5 Pricing and Contract Models

Another aspect is about the pricing and contract models[6]. Here we leverage concepts of data contracts in data marketplaces [8] where we allow the owner defined various pricing schemas for warehouses. Different from typical pricing models for warehouses where the customer pay only for the space they take from the warehouse and from typical cloud services. The pricing models combine two distinguisable aspects:

- pricing for using a warehouse: the pricing models will be based on contemporary grain warehouse contracts enriched with different guaranteeing and liability conditions. In general, different from existing grain warehouse contracts, given new monitoring and analytics features, the owner of grain warehouses could offer better liability conditions for their customers and, in parallel, could charge higher costs for grain storage.
- pricing for using additional services for grains monitoring and analytics: this is a new type of pricing models for grain warehouse customers, although it is not really new for customers in contemporary IT services in the cloud. The

[6] Detailed pricing and contract models are out of the scope of this paper

key difference for the customers is that now they also can opt in pay-per-use features to utilize advanced services for their grains.

4.6 Customized Services

Based on the core services about monitoring, analytics, and contract management, a set of different customized services is designed for different stakeholders:

- Warehouse warning service: it can be used to provide warning information related to the quality and quantity of grains.
- Grain quality service: this provides regular quality analytics for grain to support the logistics, purchase and recommendation for grains.
- Logistics planning and recommendation: this service helps the grain owner to make a plan on uses of grain based on information of analytics, storage history and/or contract termination. It can also recommend the warehouse providers how to govern the warehouse processes.
- Warehouse usage scheduling: based on contract management, this service helps the warehouse providers to make schedule to optimize the uses of warehouse.
- Grain history service: it provides the grain history to grain/rice consumers.

4.7 IoT Cloud Architecture for Grain Warehouses

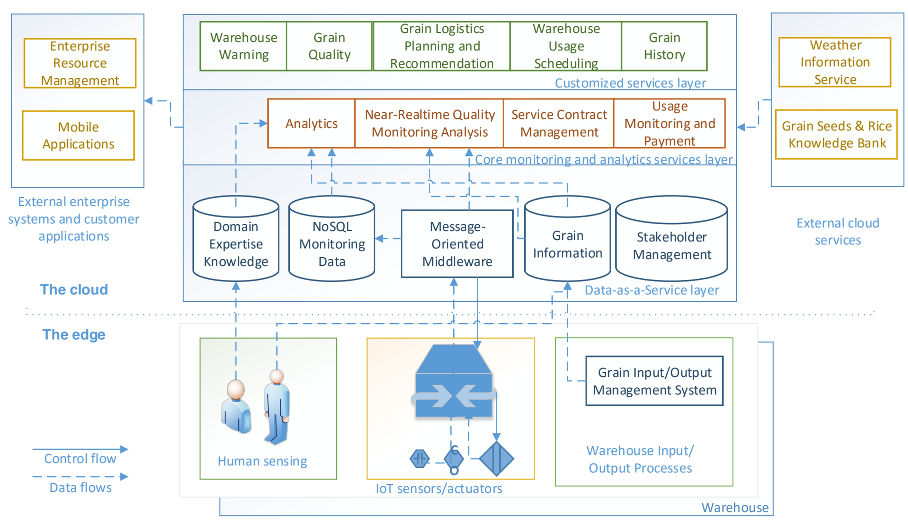

Fig. 3. IoT cloud based platform for Grain Warehouses

Fig. 3 presents our conceptual framework. The architecture is followed the concept of IoT cloud systems [9] in which we have several IoT elements to provide monitoring data of grains and input/output flows and monitoring data and analytics are provisioned as cloud services in data centers. At the warehouse side, we have three different subsystems: IoT with sensors, actuators, and gateways for monitoring grains and warehouse; the Grain Input/Output Management System for managing grain flowing in/out the warehouse; and Human Sensing for getting knowledge about grain during the warehouse operations (e.g., inspection, daily management). Our IoT system in grain warehouses is designed based on common sensors and lightweighted gateways, such as Raspberry PI. Mobile networks are used to push the monitoring data to the cloud.

At the cloud, we have three different layers: data-as-a-service, core services, and customized services. In the data-as-a-service layer, we have different services managing different types of data and knowledge, such as Domain Expertise Knowledge, Monitoring Data, Grain Information Service, Stakeholder Management Service. Core services include Analytics, Near-Realtime Quality Monitoring, Service Contract Management, and Usage Monitoring and Payment. Customized services include Warehouse Warning Service, Grain Quality, Grain Logistics Planning and Recommendation, and Warehouse Usage Scheduling. Furthermore, external data services, such as Weather Information Service and Grain Seeds & Rice Knowledge Bank, are integrated for core services to support advanced monitoring and analytics. Customized services can also be integrated with external enterprise systems of customers.

In the cloud, we utilize NoSQL database (MongoDB/Cassandra) for near-realtime monitoring data, grain information and grain knowledge, while relational databases are used for stakeholder management. Near-realtime monitoring service and analytics service will be based on stream data processing and big data analytics based on Spark and Hadoop. All of our services are designed as Web services with REST interfaces.

5 Related work

Integrated Data for Smart Agriculture and Logistics: Applying Internet of Things (IoT) technology for agriculture has been emerging in recent years[7]. A review of the technical and scientific state of the art of wireless sensor technologies and standards for wireless communications in the agriculture food sector was presented in [10]. Wang et al [11] introduced several examples of wireless sensors and sensor networks applied in agriculture and food production for environmental monitoring and precision agriculture. Sugahara [12] developed a traceability system for agricultural products, based on the innovative technology, RFID, and mobile phones. While Ko et al [13] presented a monitoring system for agricultural products' yields and distribution based on wireless sensor network (WSN). Hwang et al [14] used both these technologies, i.e., RFID and WSN, to develop a food traceability system. Several industrial frameworks have also integrated

[7] https://www.foreignaffairs.com/articles/united-states/2015-04-20/precision-agriculture-revolution, https://www.microsoft.com/enterprise/industry/caglayan-arkan-blog/articles/how-iot-enables-smart-agriculture.aspx#fbid=XzhcfZ2Thhn

IoT data for smart agriculture, such as Thingworx[8], Senseye[9] and Carriots[10]. Although most of these works focus on food traceability, the data is not integrated with a knowledge base or external data courses to make an early warning about quality of food.

Cloud service models for Warehouse Management: Borstell et al [15] presented a system to provide real-time information and visual assistance to workers or operators involved in warehouse operations (e.g. storage, retrieval, rearrangement and picking), while Rohrig and Spieker [16] introduced a technique to monitor the manual transportation processes of goods in a warehouse. The Westeel Company[11] provided a grain storage monitoring system that can help us maintain optimum temperature and moisture. It is easy to recognize that these works only focus on warehouse management/monitoring, they do not focus on analytics problems. They also do not consider to share their warehouse as a service, i.e., missing the business functions such as pricing and contract models.

Analytics for Grain warehouse: Capturing and analyzing domain knowledge about agricultural processes, soil, climatic condition and farmers experiences, Dutta et al [17] develop an architecture framework for knowledge recommendation using computational intelligence and semantic web technology. From our view, this analytics should be integrated with warehouse management system to provide this work and warehouse as the services, in which the individual farmers and SMEs can use to monitor and analyze their grain quality.

6 Conclusions and Future Work

It is expected that combining IoT and various sources of data will enable efficient monitoring and analytics for grain warehouses, thus improving the current poor situations in managing grain warehouses in Vietnam. Furthermore, leveraging the cloud service model will simplify and reduce the operation cost of grain warehouses management systems. In this paper, we introduce a conceptual framework that enables the integration of various data, including grain quality monitoring, grain expert knowledge, human inputs, etc. to enable near-realtime monitoring and analytics for grain warehouses.

Although we have focused on grain management in the Mekong delta, we believe that our conceptual frameworks could be applied/customized for similar areas. Currently, we are elaborating our design and working on a prototype to realize our framework.

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[9] http://www.senseye.io/internet-of-things-sensors-for-smart-farming-part-1/
[10] https://www.carriots.com/use-cases/agriculture
[11] http://www.westeel.com/easycheck-grain-storage-monitoring-system

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