Improvement of Agricultural Productivity with the Use of Advanced ICT Tools

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Abstract. Food consumption continuously increases in global scale over the years. To satisfy the growing demand for food production, farmers need to increase productivity. This can be achieved either with the use of larger and more productive and efficient agricultural machinery or with improved management and organization of the agricultural production. The former is now impeded due to environmental and biological factors. The utilization of large and more productive machines in agriculture has limited capabilities to further improve machinery productivity and efficiency, since the size and weight of the machinery is constrained by soil compaction, and further improvements to effectiveness are not available. However, the late advances in Information Technologies provide excellent opportunities for substantial improvements in the efficiency of advanced machines. In this work, an agricultural fleet management product, namely V-Agrifleet, is presented.

Keywords: Operations management; decision-making; real time planning; voice-driven.

1 Introduction

During the last decades, agricultural production has to deal with increased demands for agricultural products. For increased production, there is large potential for optimizing the interaction between individual machines, for multiple-machine cooperation (Bochtis et al., 2014). Logistics management in the agri-food industries involves transporting goods and services to local, regional and international consumers. Agri-Fleet management and relevant industries require a high level of coordination and cooperation to marshal resources more effectively (Bochtis and Sørensen, 2010; Sørensen and Bochtis, 2010). Crucial challenges identified by all

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industry stakeholders are; fleet cost-reduction, fuel price volatility, reduction of accidents, increase of fleet and driver safety, intensification of agri-fleet productivity.

In this light, a formalized management tool is needed, to support the management of field operations. The complexity of agricultural field operation process and the management activities contain logistical, economic and social links that constitute a holistic management system. The V-AgriFleet application addresses this challenge and aims to deliver an innovative agricultural fleet management system, in the form of a mobile application, with central functional features of voice-driven information provision and extraction, automatic recognition of machine operational modes, and support real-time decision making. The application operates in heterogeneous fleets, overcoming the drawbacks of the existing fleet management solutions which are applicable solely for homogeneous fleets in terms of the vehicles/machines brand names (i.e. “vendor locked”) and centre-focused (providing information only to the central decision-maker). Moreover, through its voice-driven operations, the application disengages operators from manual interaction with the system by giving them the ability to interact with the mobile application (both for providing or requesting information) by their own voice.

The V-AgriFleet application constitutes a prototype (TRL6) that was developed during the EU FP7 FRACTALS - Future Internet Enabled Agricultural Application / FI-WARE (http://fractals-fp7.com) funded project “Voice-driven fleet management system for agricultural operations” (Sub-Grant Agreement: 200-4594/18.05.2015).

2 The Application

Fleet Management Systems have long been available in the industrial domain, and have evolved into complete enterprise management tools. In agriculture, more advanced machinery as well as information technologies are being implemented, enabling the implementation of the analogous fleet management tools. So far, traditional industrial service offerings were mainly designed to service a single machinery or a homogenous fleet of machineries (based on type or vendor etc.). However, the low user acceptance due to the high cost of these systems, centralized management orientation, and the required effort to receive and provide real time information, inhibits integration of current fleet management systems into agriculture. The current fleet management services are meant to service a finite set of homogeneous and heterogeneous machineries (over different, locations, regions, etc.).

Various agricultural fleet management systems provide planning features (e.g. route planning). However, the decision-making is addressed by the user. Automated dynamic planning is an anticipated evolution in agricultural fleet management systems corresponding to the variability of the parameters of the operational environment in biological systems (e.g. yield variability, soil workability, trafficability. etc.). The developed approaches lack an automated performance evaluation process. The detection of operating modes for agricultural machines is a future research topic for the agricultural fleet management domain.

The following list presents an up-to-date perspective of the available approaches to address the industrial challenges faced by the agri-fleet management industry: (a) Planning approaches, such as vehicle routing, job-shop scheduling, floor shop scheduling, and optimization approaches beyond the typical linear programming used in the past (e.g., binary and integer programming) and entire system analysis methodologies (such as Petri nets) are increasingly employed for formulating and solving agricultural machinery planning processes; (b) the latest developments in agricultural management provide the framework for planning operations executed by co-operating multiple-machinery systems are a stepping stone for future fully autonomous systems; (c) real-time decision support systems must be further developed to close the loop of sensing-data interpreting decision making-actuating in real-time machine control (e.g., in controlling inputs); (d) a lack of integration exists between the different management levels, which prevents the full exploitation of the precision and accuracy of the developed approaches and prevents their adaptation to location-specific conditions.

Present agricultural fleet management market is extremely fragmentary (the majority of products are not compatible with different machinery vendors) and current solutions available in the market have a number of disadvantages, such as: (a) a centralized architecture providing all relevant information to a central decision maker without providing any local machine-to-machine information exchange, (b) information regarding the operational status of a machine (e.g. completion of a task) is not automatically generated and requires manual interaction that requires time and concentration, (c) the systems that are already available in the market require either a homogenous fleet in terms of machines' vendor or a system compatible with the CAN bus of the machines.

2.1 Design and Development

In order to identify and map the environment of the application, a systematic approach was implemented to guide the process, as seen in Fig. 1, through the various steps of development. User/Stakeholder identification led to interviews that aimed to deduce user needs in each aspect of use. To reduce the risk of bias and misinterpretation, lists of user requirements were used, as seen in the work of Sørensen and Bochtis (2010), adopted to the particular project. Through this process various stakeholders contributed to forming a unique set of needs, that fully defines a fleet management solution. Machinery contractors for example focused on transport control, route guidance and data acquisition. Supplementary to this operational outlook, more field related functionalities were requested by operators. Route guidance, online monitoring and operations scheduling among others were their input to the list of desired features. Requirements converged to core functionalities as real-time positioning and tracking features, that V-AgriFleet needs to address efficiently.

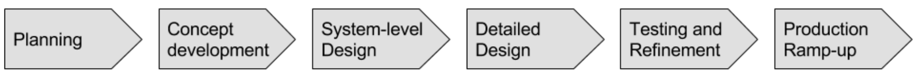


Fig 1. Product development process

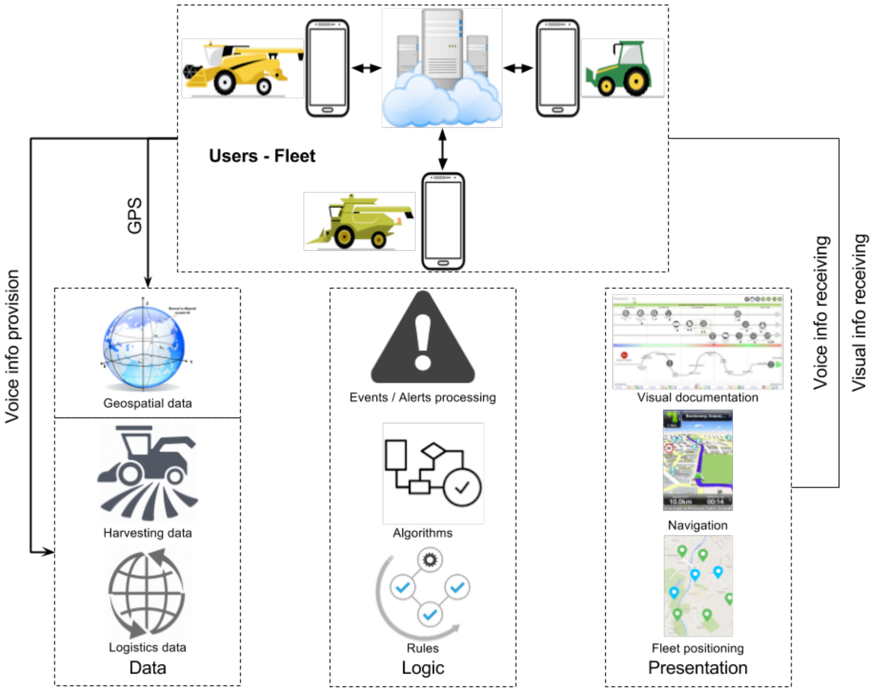


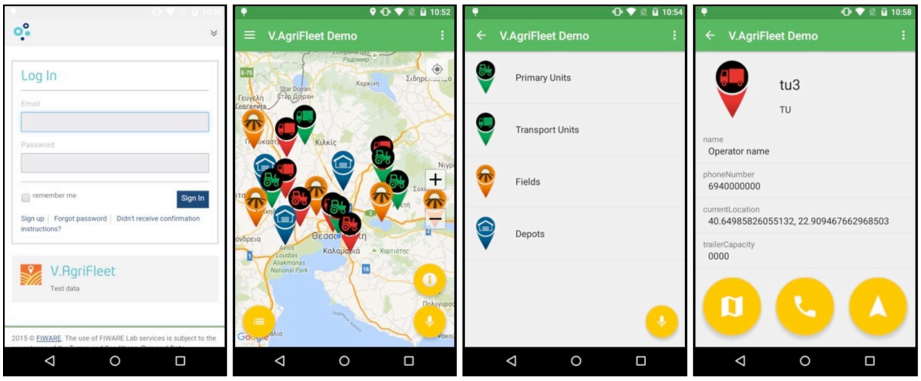
Fig 2. V-AgriFleet component architecture

The quality function deployment (QFD) methodology was used to interpret these requirements. QFD aims to translate user requirements to technical requirements usable by the product developers and to guarantee that these are part of each step of development (Chan and Wu 2002; Khoo and Ho 1996). This approach has the potential to cover a wide area of the solution space and at the same time provide user specified functionalities that ensure a high user satisfaction. Through this stepped process following targets were reached:

i. Customer identification
ii. Customer requirements identification
iii. Customer requirements prioritization
iv. Design parameters identification
v. Relationship determination
vi. Design parameters correlation

Based on the processed inputs and the respective outputs of the process the architecture of the application was designed to a three-tier form that meets all technical and user requirements and simultaneously introduces an innovative decentralized and peer to peer communication model. The outline of the application architecture can be seen in Fig. 2.

Furthermore, having identified the individual users involved and their respective needs, the application was designed to provide a modular interface to the users. Each user group has a customized interface and in case of multiple role users, these interfaces can be combined. This safeguards the applications effectiveness, as its offering of functions is optimized for each user, leaving an uncluttered clean interface. This is crucial to field operations, when manual interactions are needed to extract or to input data to the system and any delay or lack of focus can be costly or dangerous. Examples of these individualized interfaces are shown in Fig. 3.



Login interface *Home screen* *Operational entities* *Transport unit's details*

Fig 3. V-AgriFleet interface screenshots

The V-AgriFleet solution addresses and tackles the current industry challenges and replies to current market needs, delivering a product/solution in line with current trends, inclusive of innovative technology and offers greater interoperability compared with systems that are currently available on the market. V-AgriFleet application, through the convergence of the decentralized fleet management and context aware fleet operation, is expected to speed up the take-up from potential clients that will employ this innovative process and underpin them as the future's businesses and at the same time, application is independent of the CAN bus use and can serve any combination of homogeneous or heterogeneous fleets.

2.2 Outcomes and Benefits

An obvious and expected result is the fuel savings, resulting from optimized routes in field operations as well as in travelling between fields, depositories, full loads etc. This is a twofold profit as economical fuel management means by definition reduced CO_2 emissions and therefore a step closer to a more sustainable operation. Other resources as water and fertilizer are also used more efficiently as the constant feedback of information combined by the decentralized decision process allows the optimization of resource utilization. This optimization is also diffused in other facets of the agricultural operational management, as in the workforce engagement, both in terms of working hours but also in terms of quality as the enhanced role of operators redefines their significance in the system. This means increased speeds and reduced errors, thus higher yields and less out of specifications crop products. The majority of these benefits reflect on an economic level to the industry but also define a new standard of environmental protection along with influencing social and demographic variables of the human forces involved. An indicative summary is presented in Fig. 4.

Fig 4. Expected benefits and outcomes of V-AgriFleet utilization

3 Conclusions

The V-AgriFleet application is expected to offer exponentially expanding opportunities to its users. As a smart, decentralized, connected product, the application brings to the market new innovative functionalities, far greater equipment utilization and reliability, and cross-cutting capabilities that may transcend traditional product boundaries. With the use of the application, decision making process within agri-business is decentralized, driving entrepreneurship to re-think, re-evaluate and re-tool their day-to-day operations, making ICT become an integral part of the agricultural production. Apart from the economic benefits, the optimized fleet scheduling will result into reduction of the emissions and thus improved environmental performance of the fleet.

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