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INTEGRATED SOFTWARE SYSTEM FOR AGRICULTURAL ENTERPRISE STRATEGY OPTIMIZATION

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The paper deals with the concept of the development of Integrated Software System for planning of production of an agricultural enterprise. A review of the existing software systems has been conducted. On the basis of the research the model of the software system is proposed, its functions are described; the structure and the business model of the project are developed.

Keywords: agricultural enterprise, planning, software system, optimization of management, business model, efficiency.

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ИНТЕГРИРОВАННАЯ СИСТЕМА ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ ДЛЯ ОПТИМИЗАЦИИ СТРАТЕГИИ УПРАВЛЕНИЯ СЕЛЬСКОХОЗЯЙСТВЕННЫМ ПРЕДПРИЯТИЕМ

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В статье рассмотрена концепция разработки многофункционального программного комплекса для планирования производственной деятельности сельскохозяйственного предприятия. Выполнен краткий критический обзор существующего программного обеспечения. На основании аналитических исследований предложена авторская модель построения программного комплекса, отражены его функциональные возможности, разработана структурная схема и бизнес-модель реализации проекта.

Ключевые слова: сельскохозяйственное предприятие, планирование, программное обеспечение, оптимизация управления, бизнес-модель, эффективность.

1. The idea of the project and preliminary feasibility studies

Costs associated with operation of machinery and equipment represent the major price component in the production of food ingredients and entire food chain. In accordance with the recent report prepared by the Food and Agriculture Organization of the United Nations (FAO), increased mechanisation and effective (optimal) use of farm machinery has become a priority in the development of agriculture [1]. The report emphasises that the potential for effective use of modern machines and, the innovative technologies of cultivation products are far from being fully utilized.

This issue is especially relevant for Ireland. The agri-food sector is Irish largest indigenous industry with a gross annual output of over €22 billion, exports worth over €8bn per annum with some 135,000 people employed in sector [2]. “Crop Management and New Technologies” is selected as one of the key investment areas in the roadmap prepared by Irish DAFM [3].

Optimisation of use of agricultural machinery is unmet need in Ireland due to a number of historical and economic factors:

1. Field fragmentation and fairly complex shapes characterised by presence of slopes and obstacles.
2. Soil exhaustion due to limited resources and overuse.

3. Limited access to funding for purchase and modernisation of machinery as a consequence of the economic crisis and sharp decline in bank lending to the agricultural businesses.

The concept of sustainable agriculture, endorsed by the EU member states also means increased responsibility for the ecological state of the environment (reduction of emissions into the atmosphere and reducing the load on the soil from running systems of agricultural machinery).

Export of agri-food technologies plays a very important role in the revival of the Irish economy following the economic crisis. The FAO report establishes that raising the level of equipment and technological modernisation of agriculture is a state priority in the countries of Africa and Asia as well in India and in China. However, without an effective approach to machinery use, these countries suffer from the unsustainable resource cost, simplified technology and as result low crop yields.

In the context of the development of science and technology, the worldwide trend in agricultural mechanisation is not just increasing yield generating capacity, but the transition to the concept of "precision agriculture" that makes even higher demands on the quality of agricultural enterprise management.

We live in the epoch of "big data", the massive amounts of information, which is impossible to handle without the use of the specialized hardware and software systems. With proper processing and analysis, such information can play a crucial role in decision making process on all stages of food chain, and, in particular, its agricultural component.

Thus this EI CCFS proposal seeks to further explore the use of such an automated system playing the role of farm expert by offering the user (agricultural enterprise) a set of recommendations obtained through rigorous "big-data" calculations using multi-criteria optimization and taking into account the local requirements for the production process.

The funding will be used to finish development of the first fully operational version of Integrated Software System with all basic capabilities. The system would be distributed between the farmers and agricultural enterprises for testing in real conditions. The feedback from the testers will be taken into account for improvement of the system, including addition functionality and formulation of the roadmap towards entering agricultural software market.

The market for such systems is emerging due to the new generation of farmers who are well educated, tech-savvy, environmentally concerned and looking forward to the latest developments in agricultural sciences.

However, one still needs to take into account that farmers remain the most conservative managers and most likely will prefer the software products that require their minimal involvement in preparing and editing of content. So the computer program must be based on the intuitive perception of the interface and coherence of its use, which is often cumbersome in the existing farm automation software [4].

A number of software system exist on the farm automation software market. Their goal is to simplify the process of planning of agricultural works and control their performance:

1. *CenterPoint (www.redwingsoftware.com)* is an accounting package for evaluation of fixed assets, depreciation, inventory, taxes, wages, etc.).

2. *Agrivi (www.agrivi.com/)* – the most interesting and sophisticated program for planning of agricultural production and technological processes in general (planning of crop cycle, allocation and accounting of fixed assets, financial analysis, etc.). However, the system does not include the process optimization and does not provide user with recommendations on machinery use. The functionality of the program is built on the subjective preferences of the user and the historical data of the company performance only.

3. *iAgri Online (www.iagri.com/)* is an online system for farm budgeting and account management (it also includes axillary tools such as blogs, research article repository and cartographic information).

4. *GroMAX-ContractFarming* (www.groveinfo.com/content.aspx?cid=12) is an automatic system of farm management based on the information analysis: selection of the crop seeding dates based on the meteorological data, real-time field monitoring and historical data collection, online message board for the farmers.

5. *Harvest It (www.ibspl.com/harvest_it_more.html)* is an extended system of accounting and budgeting, similar to iAgri, but with additional functionality.

6. *Land.DB (www.agconnections.com/products-and-services/land-db/)* is a program designed to assess the net cost of production and to control the production process (it includes cartographic information, planning of crop planting dates, analysis of costs and analysis of soil fertility maps and crop yields, as well as regulatory database).

7. *AgFleet (www.agfleet.com)* is a system for precision farming, which includes recommendations for use of fertilisers based on the electronic maps of soil fertility, planning and recording of agricultural field operations. The system's functionality enables to use mobile solutions for data collection in the field, the actual record of crop pests and diseases, as well as meteorological conditions.

8. *AgricultureSoftware (www.cengea.com/)* is the system for planning and report-generation based on actual agronomic data.

9. *LandMagic (www.landmagic.com/)* is a set of software tools for recording of field data, tracking crops development, recording of field work, evaluation, map analysis, inventory, etc.

10. *PAM QA Plus (http://www.fairport.com.au/en/)* is a software system for budgeting, planning and recording of all kinds of works related to growing crops. The system also runs a journal of costs and earnings and includes cartographic materials and monitoring systems. The company has well organised system of client support and consulting.

Most of these software products are designed for farm data recording and manual work planning, which is cumbersome and a time consuming process. On the other hand, no system works as a real-time decision making assistant to advise the farmer of a number of optimal strategies in accordance with his/her specific needs.

It is clear that the first to market, with a reasonably good solution in this area (e. g., a *multifunctional and user friendly expert system*), will conquer the market immediately!

Our software system allows the farmer not only to optimise his machinery fleet, when the resources for expansion are limited, but it also significantly simplifies the planning of work, including real-time adjustments in case of changing weather, machinery availability, economic indicators etc. The system has the standard set of reporting and monitoring utilities, in order to reduce a number of software packages used by the customer. However, these utilities play the secondary role. The main goal of the product is to provide the user with an automatic decision-making support tool based on the multi-criteria optimization.

The modular structure of the software system enables us to add additional features tailored in accordance with user demand and government regulations:

a) Minimisation of environmental damage through optimization of fuel consumption (through the selection of appropriate machinery aggregations schemes), as well as analysis of the use of organic fertilizers.

b) Long term strategic planning aimed at preserving soil fertility. The goal of this module would be to analyse the adverse effects on soil by the propulsion self-propelled machines and to evaluate various tillage systems (classic, minimal, moldboardless, zero tillage, etc.).

c) In addition to machinery aggregation, the "field aggregation" module could be added to reduce the machinery costs and operation time. This module could be especially useful for groups of farmers (farming co-operatives) who are interested in reducing their expenses through joint machinery ownership/operation. Aggregation of neighbouring fields might also reduce a negative effect of field fragmentation on the agricultural yield.

d) Interactive module for farmer collaborations to facilitate the use of machinery or fertilisers surpluses.

e) Data visualisation module for analysis of soil moisture and crops from the aerial images.

To summarise, *the main idea of the proposed project is to bring to the agricultural software market a fully automated decision assistance system for operational and strategic management of the entire agricultural enterprise (and food chain in general).* As a straightforward example, our methodology could be also used for optimal placement of the infrastructure and logistics objects, including food processing and machinery service enterprises. We also want to emphasise, that this product represents a component of a potentially much larger enterprise management framework that has applications well beyond agriculture. In particular, it could be used for broad enterprise resource planning (ERP) optimisation.

It should be noted that the interest in such automatic decision support systems exists well beyond Ireland and this predetermines a significant export potential of the project. The theoretical studies on farm machinery

management could be found in a number of books [5] research papers [6, 7, 8] and web portals operated by the agriculture departments of the US universities [9, 10]. However, the results in the publications are presented in the form of theoretical analysis, or are focused on the performance of specific segments of agricultural machinery market with no objective to supply management support decisions to the real-scale agricultural enterprise.

2. The business model of the project

Commercialization of the proposed project is based on the concept of SaaS (Software as a service). The system would be developed as a lightweight web application with main data storage and processing modules placed in cloud computing services. The customer gets access to the modules through an intuitive user-friendly interface of a virtual farm. The customer pays the fees to access the software system with an option of additional functionality. The data is processed remotely and the user gets the set of recommendations for each of the optimization criteria as well as all available information for his/her decision support, including recommendations.

The software system is a multilevel environment whose main elements are the Administrator and User.

Administrator functions, rights and responsibilities:

1. Database and computational (data processing) module support. This includes both preparation and upload of agricultural machinery information and experimental and estimated parameters used in the calculations.

2. User management, including issuing permissions and module access regulation.

3. System and user interface update in accordance with the customer feedback and technological developments (in particular, in data processing hardware).

User rights:

1. Unlimited access to the application and machinery databases, option to create customer databases.

2. Creation of virtual farm that includes the electronic maps of the fields, work plan derivation.

3. Obtaining the set of optimal suggestions for machinery use, automatic report generation.

4. Voluntary participation in expert evaluation of machinery and equipment.

3. State-of-the-art and work in progress

The systems includes four main modules as shown in Fig. 1:

1. Computational module (optimisation of agricultural machinery fleet, fertilisers use, comparison and examination of machinery and crop processing technology).

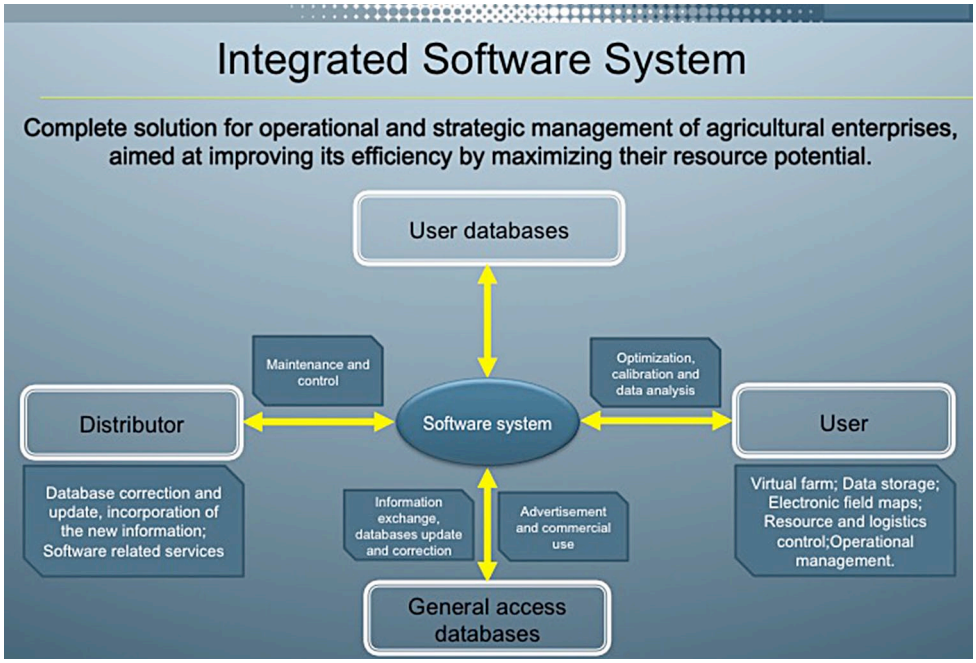

Fig. 1. Main modules of Integrated Software System

2. Information module (machinery manufacturers database, survey of available technologies).

3. Analytical module (report generation, decision support, real-time recommendations and suggestions).

4. GIS module (electronic field-map generation, optimisation of machine trajectory on the field).

The structure of the system and tasks designated for each module is summarised in Fig. 2.

The following tasks have been accomplished:

1. The detailed Business Requirements Document (BRD) has been prepared.

2. The mathematical model for multi-criteria optimization has been formulated.

3. The database templates have been created and the system for database intercommunication has been coded.

4. A number of modules have been developed and coded:

– virtual enterprise;

– long-term work plan;

– performance characteristics of machine-and-tractor aggregated units;

– machine-and-tractor aggregated units aggregate trajectory optimization based on the Geographic Information Systems (GIS) information.

The project has been discussed with faculty members of the UCD School of Biosystems Engineering: Prof Nick Holden, Dr Kevin McDonnell and Prof Shane Ward. All of them confirmed the uniqueness of the proposed system and suggested the number of criteria for optimization, which are most relevant for Irish farmers and related to the latest trends in European crop farming. Dr McDonnell who is a farmer himself has suggested testing and validating of the decision-making algorithm using his own experience as well as his connections in farming community.

4. Advantages of the project compared to existing technologies

Agricultural businesses are faced with the need for planning, analysis and recording of their operations in order to improve their performance, increase their revenue or reduce associated costs. They also need to minimise their environmental impact and preserve the food generating capabilities for future generations. In such conditions, decision-making process becomes very complicated and based on an increasing number of factors. The only way to deal with this situation is to introduce a multi-

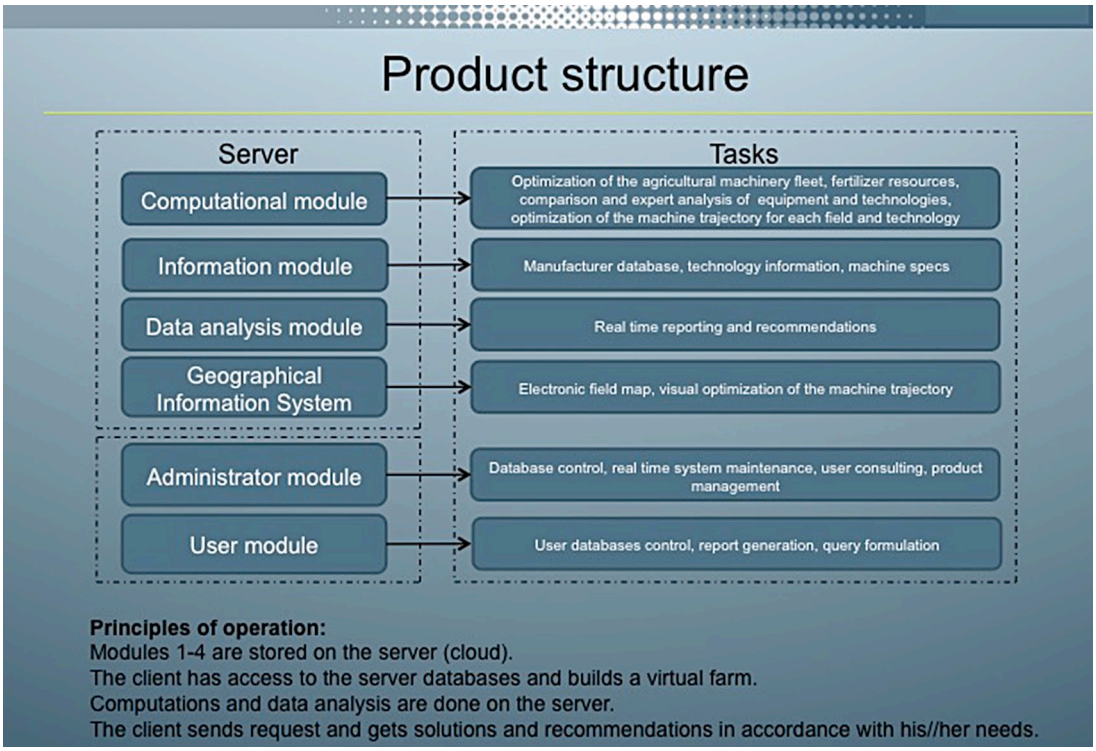

Fig. 2. Distribution of tasks between the modules

criteria technology to optimise and support the farmer's decision-making process through the automatic multifunctional expert system.

Due to its size and importance, the agricultural software market has a number of products that help farmers to automate their reporting and accounting and provide them with the performance analysis tools.

The distinctive feature of our product is its use of the most advanced mathematical optimisation algorithms for both data analysis and recommendations. The modular structure of our software systems helps to make *Integrated Software System* tailored for the needs of the specific farmer, which also adds to the system uniqueness and brings it to the very important and still unoccupied niche in the agricultural software market. These features would also become a basis of our patent portfolio aimed at protecting of our IP and licensing of the technology to the 3rd parties developing Enterprise Resource Planning (ERP) software products.

The framework of data analysis, interpretation and user interaction behind *Integrated Software System* makes it a tool of choice also for agricultural equipment manufacturers and educational and research organisations. Our advantage compared to competitors is that the system is easily customisable well beyond the main users base.

The examples of such customisation include:

– Evaluation of the current and projected weather conditions (up to the single field scale);

– Evaluation of micro-and macro-elements concentration in soil, for example with help of the remote sensors mounted on the unmanned aircraft

A brief summary of the advantages of Integrated Software System compared to competitors*:

1. For farmers:

a) Choice of the most efficient ways for agricultural machinery allocation and use;

b) Field monitoring and visualisation;

c) Real-time reporting and control systems for operative management;

d) Short-term and long term work planning and yield projection;

e) Analysis and forecast of profits and required investments;

f) Development of the machinery purchase and renewal policy;

g) Forecast of the needs in seeds, fertilisers and crop protection means;

h) Planning of the work in the current period;

i) Timetable optimisation based on the biological indicators.

j) Forecast and analysis of profits and required investments into machinery fleet;

k) Comparative evaluation of machinery and equipment

l) Online interaction with counterparts, machinery manufacturers and experts.

2. For manufacturers:

a) Advertising of new models of machines and equipment directly to the agricultural enterprises;

b) Feedback and evaluation of the effectiveness of farming machinery for each particular technology;

c) New machines demand forecast.

5. Milestones and deliverables

The project is divided into four stages that we expect to accomplish within the EI CCFS grant duration framework.

Our initial task is to conduct the marketing research aimed at analysis of the market in Ireland, EU and the rest of the world and understanding the needs and requests from potential customers. The marketing report would consist of two parts: Market Validation and Route-to-Market. The Route-to-Market part will also include the analysis of the feasibility of a SaaS ("software as a service") business model for project commercialisation.

The second stage would include update and correction of the project business requirements document based on the findings of the market research report. It will also include formation of the databases and inserting the data, validation and tuning of the mathematical optimisation algorithms.

The stage three would include coding of the optimisation engine, design and implementation of the user interface, placement of the computational and data processing modules on cloud computing services and development of the user-cloud interaction model.

* Some of these features could be found in the existing software, however, no system has a full set of characteristics and no system has a decision support engine based on the multi-criteria optimisation.

On stage four, a number of farmers and agricultural enterprises interested in testing of the system (identified in the market feasibility report) would get access to the initial release of the system and start its testing. Their feedback would be taken into account for the next system release and formulation of the route to market.

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