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ANALYSIS OF CURRENT AND EXPECTED FUTURE CAPABILITY OF EUROPEAN UNION IN ROBOTICS TECHNOLOGY FOR AGRICULTURE DOMAIN

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Abstract:
The article analyses the present state of robotics development for agriculture in European Union and learns the possibilities of community members progress in this direction for upcoming years. The paper gives definition of the term „Robot", types of autonomous machines and areas of robotics application. Special attention is paid to the Europe's share in the global agriculture machinery, modern trends in agriculture, practical areas and benefits of robotics usage. Survey of the global sales statistics, types of best realized service robots and possible progress scenarios in Europe are investigated. General overview is prepared for the current key European prototype projects in agriculture domain. Separate section of the work is dedicated to European autonomous machines for Arable Farming, Livestock Farming and Special Crops. The newest three research projects under the program Horizon 2020 concerning agricultural sphere are described. Data of the article are based on information from EURoborics AISBL, analytical reports and official web-sites of prototype projects.

Keywords: agriculture robot, field robot, agricultural autonomous machine.

1. INTRODUCTION

The agriculture science is changing and therefore makes influence on technology requirements. Robotics and automation gradually become a priority around the world, because farmers look for new and cost-effective ways of responding to dynamic customer demands. Over the last several decades robots started to play an important role in increasing the efficiency and reducing the cost of agricultural products.

International Organization for Standardization (ISO 8373:2012) defines the term **"**Robot**"** as follows: "**Robot** - actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks.

Industrial robot - automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.

Service robot - robot that performs useful tasks for humans or equipment excluding industrial automation applications. **Professional service robot** - service robot used for a commercial task, usually operated by a properly trained operator. Example: Cleaning robot for public places, delivery robot in offices or hospitals, fire-fighting robot, rehabilitation robot or surgery robot in hospitals (Robots and robotic devices, 2012).

In our article we analyze the present capabilities of European Union in service agriculture robotic systems application and study the possible ways of their development and adoption during upcoming years.

According to (Blas, 2016) the farm machinery managed to turn the traditional agriculture to an industry through increased efficiency and productivity. Next expected step is from mechanisation to automation, as one of the possible engineering goals of the 21st century. In this respect, the last few years have seen an increasing technological transfer from robotics to agriculture towards the development of intelligent vehicles. Scientists define that there was linear development of agricultural machinery and they've got bigger all the time. With economies of scale, manufacturers have just made bigger and bigger vehicles. There is a tendency that in the near future start-up companies will spread agricultural robots (Locke, 2015). Big progress has been done in terms of proof of concepts. There are, however, aspects still in need of further research such as energy efficiency, robustness of the autonomous decision making by the robots, increased reliability for long endurance operations, development of energy takes points on remote locations, development of better robot-human interfaces. (Perez, 2014).

Field robots are small (and presumably will stay small) because of safety reasons. Accident prevention of autonomous vehicles remains a challenge. Most promising areas are following operations: small vehicles sufficient or even preferred, 24hoperation, repeated standards actions, harmful or tiring for humans, hyper-spectral sensing. That is why, typical actions will be data collection, weeding, spraying, fruit harvesting. (Celen 2015). At the same time Dr Christopher Lehnert states that it is not necessary to be afraid of job loss because employees will control robots instead of being in the field (Smith, 2015).

In the short term, the biggest impact is going to be from how manufacturing creates concepts for extracting things from the ground (mining, agriculture), production process (manufacturing), and distribution. We are going to see how a lot of that innovation finds its way into these sorts of realms (D'Andrea, 2015).

2. AREAS OF APPLICATION

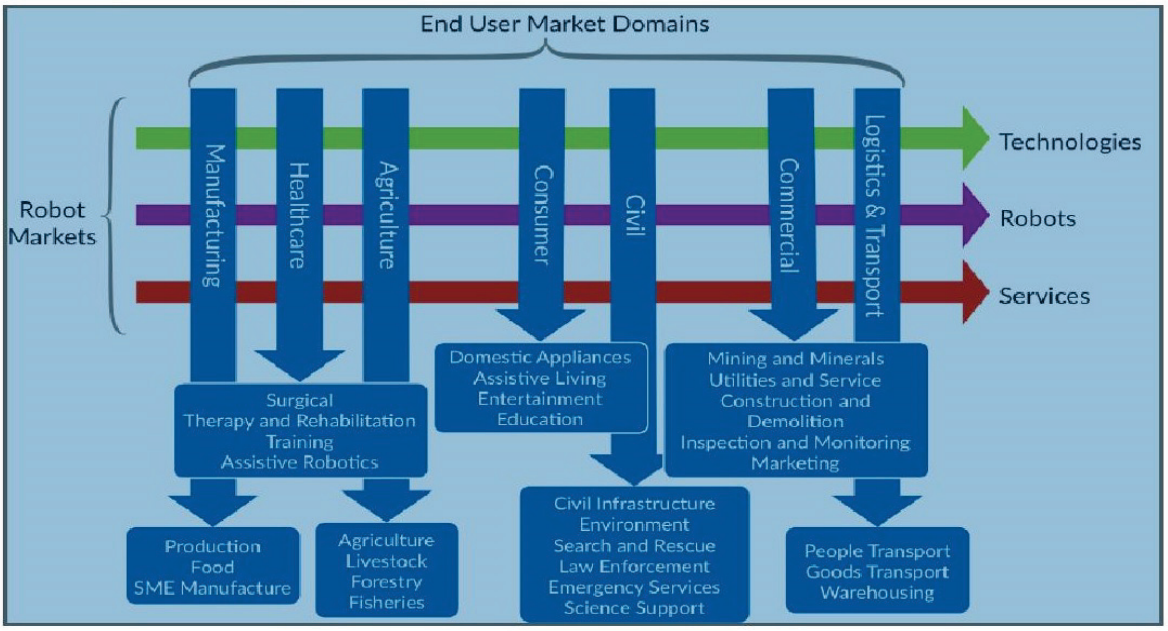
Application of robots can be identified by the following areas: **Domains, System Abilities and Technologies.**

Robotic Domains are based on the different business models which in turn capture all parts of the market for robotics technology. Markets can be presented as a series of individual market domains clustered under a set of high level categories. Each high level category representing a similar type of market opportunity. The clusters are based on a number of common characteristics which broadly apply to a class of market domains.

Based on these characteristics the high level market domains are: Manufacturing Domain, Healthcare, Agriculture Domain, Civil, Commercial, Transport and Logistics, Consumer.

Under each of these categories are a collection of individual sub-domains that characterise the activity within each domain.

Picture 1: End User Market Domains



Source: Robotics 2020 Multi-Annual Roadmap, 2015, p.5

System Abilities (Adaptability, Cognitive Ability, Configurability, Decisional Autonomy, Dependability, Interaction Ability, Manipulation Ability, Motion Ability and Perception Ability) provide an application, domain and technology independent way of characterising whole system performance and through the definition of levels identify the different abilities that robotic systems can possess.

Robotic Technologies are divided into clusters each of which is characterized by a purpose; Systems Development: Better systems and tools; Human Robot Interaction: Better interaction; Mechatronics: Making better machines; Perception, Navigation and Cognition: Better action and awareness. Details are given of the underlying individual technical components in each cluster and of metrics and benchmarks that may be used to establish the state of the art and thus future progress. The MAR does not detail methods or techniques within these technologies instead it examines what technologies deliver to systems and the links both between technologies and between technologies and applications. (Multi-Annual Roadmap, 2015,p.6).

3. OVERVIEW OF SERVICE ROBOTICS FOR AGRICULTURE DOMAIN

3.1. General information about Agriculture Domain

Agriculture is the science of practice farming, which includes soil cultivation for the crops growing and animals rearing for the provision of wool, food, and other products (Oxford Dictionaries. Agriculture, 2016).

According to VDMA market research in 2014 the global agricultural machinery market was valued at €100billion. Europe's share is approximately 26% (Haus A.& Häser-Hördt D. & Heimann J. & Wiesendorfer G., 2015, p,9).

Picture 2: Global Agricultural Machinery Markets

Global Agricultural Machinery Markets

Share of selected regions and countries in %
(Ø 2012-2014) and trend 2015

	Share	Trend
European Union	26%	↘
NAFTA (USA, CAN, MEX)	22%	↓
China	15%	↑
South America	8%	↓
India	6%	↓
Comm. of Indep. States (CIS)	6%	↓
Japan	4%	↗
Turkey	3%	↑
World	100%	↓

Source: VDMA, 2015, p.10

Such trends as growth of population, food supply increasing strain, availability of farm workers, the challenges and complexities of farm labour, the cost of farm workers, shrinking farmlands, climate change, the growth of indoor farming, and the automation of the agriculture industry cause the demand for agricultural robots (WinterGreen Reasearch, 2014).

Use of service robots in agriculture: harvesting, pruning, thinning, weeding, irrigation, seeding and spraying. Cow milking systems. Aerial observation. Driverless machines. Robots for pick-up and place.

Benefits of Robots application. (Benefits of Robots, 2016).

- Productivity: 1) more accurate and high quality work; 2) rarely make mistakes and are more precise than human workers; 3) can produce a greater quantity in a short amount of time; 4) they are able to work at a constant speed with no breaks;

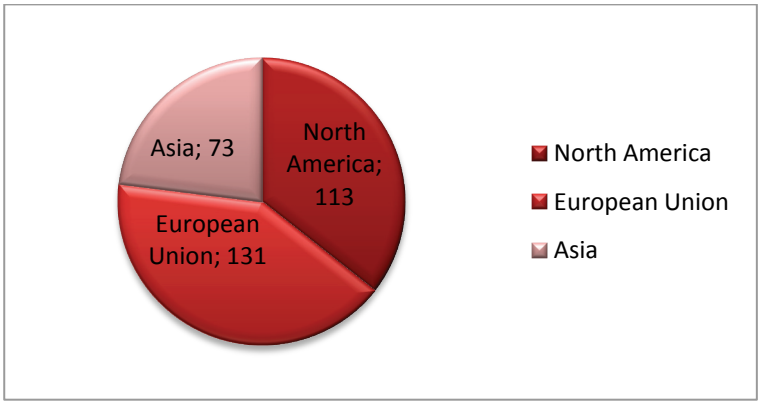
- Safety: 1) dangerous tasks in hazardous conditions; 2) capable of lifting heavy loads without injury or tiring; 3) increase worker safety by preventing accidents.

- Savings: 1) quick return on investment; 2) fewer worker injuries; 3) less material usage during production process.

3.2. Key market data

Geographically, the North America service robotics market holds the largest market share which is followed by Asia-Pacific, Europe and Rest of the World. According to quantity of manufacturers, Europe is the biggest participant in the global market with 131 service robot manufacturers. (Number of service robot manufacturers, 2015).

Picture 3: Number of service robot manufacturers of all types by region of origin

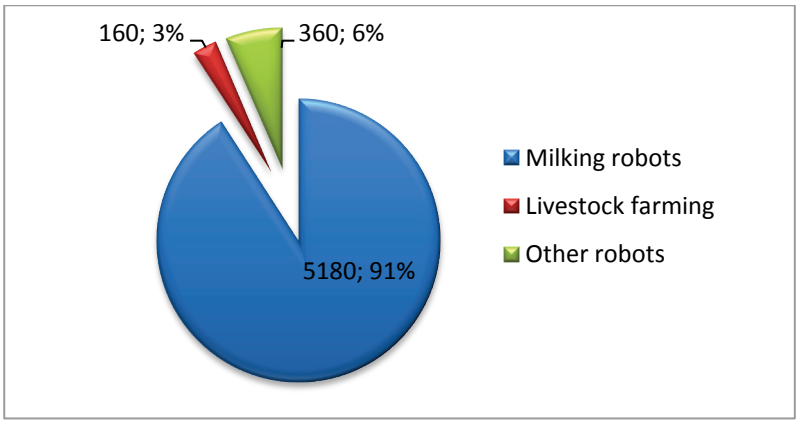


Source. Number of Service Robot Manufacturers, 2015, p.13

International Federation of Robotics indicates that the total number of professional service robots sold in 2014 rose by a solid 11.5% compared to 2013 to 24,207 units up from 21,712 in 2013. The sales value slightly increased by 3% to US$3.77 billion.

5,180 milking robots were sold in 2014 compared to 4,790 units in 2013. 160 units of other robots for livestock farming such as mobile barn cleaners or robotic fencers for automated grazing control were sold in 2014. The total number of field robots sold in 2014 was about 5,700 units, accounting for a share of 24% of the total unit supply of professional service robots. (Service Robot Statistics, 2015).

Picture 4: Structure of field robots sold in 2014



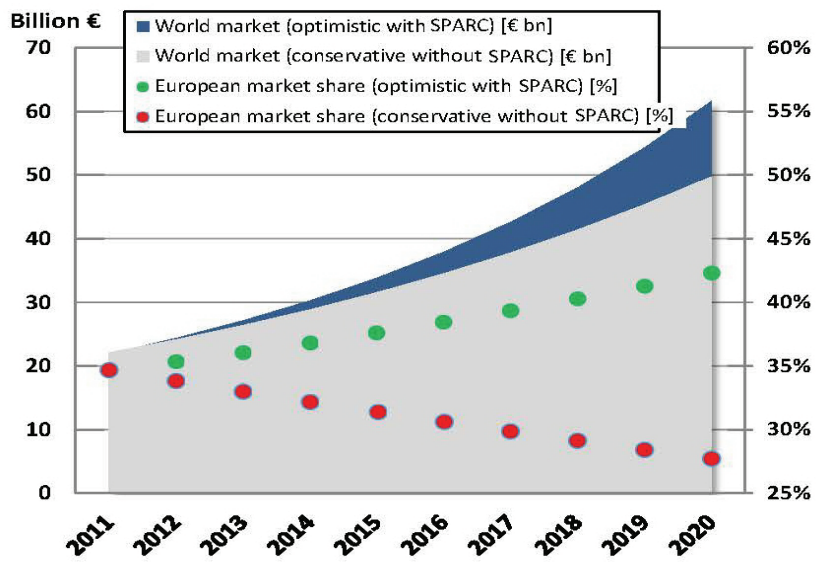
Source: World Robotics 2015 Service Robots, 2015

3.3. Analysis of the possible market growth till 2020.

WinterGreen Research calculates the Agricultural robot market size at $817 million in 2013 and predicts it's growth to $16.3 billion by 2020. (WinterGreen Reasearch, 2014). Market intelligence firm Tractica in the report for precision agriculture anticipates the overall agricultural robot market reach till $16.8 billion by the end of 2020. The market intelligence firm forecasts that some of the largest application segments will include unmanned aerial vehicles (UAVs) for agricultural purposes, soil management robots, materials management robots, driverless tractors, and dairy management robots. (Agricultural Robots Report, 2015).

SPARC Partnership for Robotics in Europe prepared 2 scenarios for Robotics development in Europe: Optimistic – 42%, €35 billion and pessimistic – 27%, €5 billion (Why is Robotics important, 2014).

Picture 5: European Market Share scenarios



Source: SPARC Partnership for Robotics in Europe

Robotics 2020 Strategic Research Agenda targets a 65% stake of the estimated €16bn professional service robot market. (Robotics 2020 Strategic Research Agenda, 2013).

Market leader in European service robotics is Lely (the Netherlands). Other known European companies - ECA Group (France), DeLaval (Sweden), Kongsberg Maritime (Norway), ABB (Switzerland), Amazone (Germany), Agrobot (Spain).

4. CURRENT KEY EUROPEAN PROTOTYPE PROJECTS

EU robotics projects are provided by euRobotics AISBL (Association Internationale Sans But Lucratif), which is a Brussels based international non-profit association for all stakeholders in European robotics. EuRobotics builds upon the success of the European Robotics Technology Platform (EUROP) and the academic network of EURON. (Horizon 2020 and the Robotics PPP, 2014).

CROPS (Clever Robots for Crops) - University of Wageningen (NL), ERA-NET ICT Agri. Development of highly configurable, modular and clever platform comprising a modular manipulator and “intelligent tools” (sensors, algorithms, sprayers, grippers) that can easily be installed onto the carrier and that is capable of adapting to new tasks and conditions.

GEOPAL (GNSS-based Planning system for Agricultural Logistics) - Aarhus University (DK), LACOS (D), CLAAS-Agrosystems (D), LEE Engineering & Construction Company (UK). Fleet management and logistics. Coordination, mission and route planning functionalities for field machinery. Closed loop integrated optimal planning, execution of automated field operations and monitoring (GNSS, 2014).

HUBRINA (HUman-roBot co-woRking IN Agricultural master-slave systems) - Tyker Technology (NL), Wageningen University (NL) - ECHORD. Master-slave development control for field operations in agriculture. Human operator drives a master tractor which is followed by autonomous slave tractor. (Hubrina, 2012).

QUAD-AV (Ambient Awareness for Autonomous Agricultural Vehicles) - Fraunhofer IAIS (D), Cemagref (F), University of Salento (I), Claas (D/DK) - ERA-NET ICT Agri. The idea of the project is that of using different sensor modalities and multi-algorithm approaches to detect the various kinds of obstacles and to build an obstacle database that can be used for vehicle control. (QUAD-AV, 2013)

RHEA (Robot Fleets for Highly Effective Agriculture and Forestry management) - CSIC (ES) and 18 more - ERA-NET ICT Agri. Design, development, and testing of a new generation of automatic and robotic systems for both chemical and physical –mechanical and thermal– effective weed management focused on both agriculture and forestry, and covering a large variety of European products including agriculture wide row crops (processing tomato, maize, strawberry, sunflower and cotton), close row crops (winter wheat and winter barley) and forestry woody perennials (walnut trees, almond trees, olive groves and multipurpose open woodland) (RHEA, 2014).

Picture 5: Ground mobile Unit (RHEA project)

Source: RHEA 2014, p.6

SMARTBOT - (here: Subproject AgroBot) - INTERREG. Development of basic technologies for constructing multiple agriculture robotic prototypes with different applications.(Agrobot, 2014).

Work on these research projects was completed in 2014. At present, they are getting prepared for mass production.

5. EUROPEAN AGRICULTURAL AUTONOMOUS MACHINES

European products of agricultural autonomous machines are divided into three categories: Arable Farming, Livestock Farming and Special Crops.

Milking robots dominate among European manufacturers. The leading companies in this field are:
Lely (Netherlands), **DeLaval** (Sweden), **Fullwood** (UK), **GEA Farm Technologies** (Germany, formerly WestfaliaSurge), **SAC** (Denmark), **Schuitemaker** (the Netherlands).

In the world approximately 30,000 units of European milking robots are installed. An advantage is that they cause less stress for animals.

Mobile autonomous barn cleaning robots are used for bottom cleaning. The quantity of sold units is above 15,000 machines.

Mobile autonomous feeding robots can drive to the silage clamp, clean the clamp, push the feed into the feeding passage and return to the silage clamp. (Robotics 2020 Multi-Annual Roadmap, 2015, p.66).

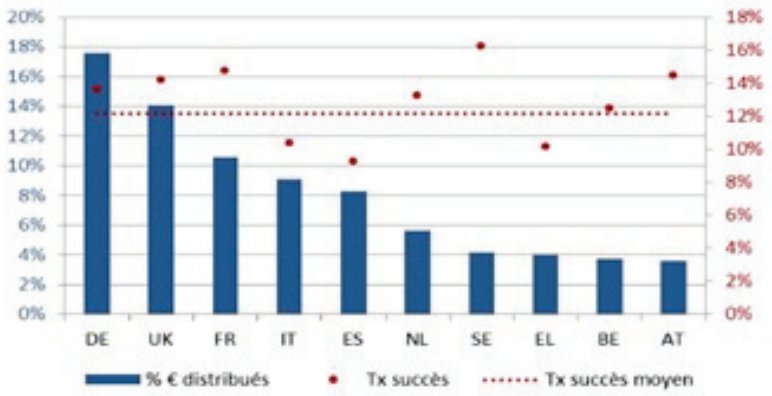
Special Crops and Arable Farming. In this field of activity mostly existing machines with autonomous capabilities are used. Among them can be distinguished: Prototypes, Traditional Machines with autonomous capabilities and Robots for high value crops.

6. RESEARCH AND INNOVATION FUNDING PROGRAM

In 2011 the European Commission launched the program Horizon 2020.

At present, it is the biggest EU Research and Innovation program with budget €80 billion for 7 years (2014 to 2020). Also in addition to the private partnership that will attract money by itself. (History of Horizon 2020, 2014).

Picture 6: Country participation statistics in the program Horizon 2020



Source. Work program LEIT TIC 2016 – 2017, 2015, p.8

Agriculture is one of four "priority domains" for robotics funding under H2020. At present, three projects are funded by Horizon 2020: **Flourish, Sweeper and Trimbot2020.**

Flourish. Aerial Data Collection and Analysis, and Automated Ground Intervention for Precision Farming. Grant awarded (Euros): 3,560,870.00 for 42 months. pdf.

The goal of the Flourish project is to bridge the gap between the current and desired capabilities of agricultural robots by developing an adaptable robotic solution for precision farming.

Sweeper. Sweet Pepper Harvesting Robot. Grant awarded (Euros): 4,028,311.50 for 36 months.

SWEEPER is planned to use the hardware of FP7-project CROPS. (Robotics projects resulting from H2020, 2015).

TrimBot2020. A gardening robot for rose, hedge and topiary trimming. Grant awarded: € 5,420,607.50 for 48 months The project will research vision technologies and robotics in order to prototype an outdoor garden trimming robot. The robot will approach rose bushes, navigate over varying terrain, hedges, boxwood topiary and hedges, to trim them to an ideal shape. (Robotics projects resulting from H2020, 2016).

7. CONCLUSIONS

The agriculture science makes influence on technology requirements. Over the last several decades robots started to play an important role in increasing the efficiency and reducing the cost of agricultural products. Robots are divided into Industrial robots and Service robots. Application of robots can be identified by the following areas: Domains, System Abilities and Technologies.

Europe's share the global agricultural machinery market is approximately 26%.

Such global trends as population growth, climate change, shrinking farmlands, the automation of the agriculture industry cause the demand for agricultural robots.

Benefits of Robots application are: productivity, safety and savings.

Among 300 robotic manufacturing companies 131 is located in European Union.

The total number of professional service robots sold in 2014 rose by 11.5% compared to 2013.

The total number of field robots sold in 2014 is about 5,700 units, 5180 out of them are milking robots.

Agriculture robot market size is anticipated to grow up to 16,3 billion $ in 2020.

There are 2 scenarios for Robotics development in Europe till 2020: optimistic - 42%, €35 billion and pessimistic – 27%, €5 billion.

EU robotics projects are provided by euRobotics AISBL.Prototype projects: CROPS, GEOPAL, HUBRINA, QUAD-AV, RHEA, SMARTBOT.

European products of agricultural autonomous machines are divided into three categories: Arable Farming, Livestock Farming and Special Crops.

Horizon 2020 is the biggest EU Research and Innovation program with nearly €80 billion of funding available over 7 years (2014 to 2020). At present, three projects are funded by Horizon 2020: Flourish, Sweeper and Trimbot2020.

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