TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Ministry of Science and Higher Education of the Russian Federation
National Research Tomsk Polytechnic University
Yurga Institute of Technology, TPU affiliate

Yurga Institute of Technology
Bachelor program 38.03.01 Economics

BACHELOR THESIS

Bachelor thesis topic
Project for the development of a universal agricultural robotic platform

UDC: 621.865.8:631

Student

Group	**Full name**	**Signature**	**Date**
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Supervisor

Position	**Full name**	**Academic degree**	**Signature**	**Date**
Senior Lecturer	Nesteruk D.N.	-		

CONSULTANTS:

on Social responsibility

Position	**Full name**	**Academic degree**	**Signature**	**Date**
Senior Lecturer	Rodionov P.V.	Ph.D. of Pedagogic Sciences		

ADMISSION TO ATTAIN THE BACHELOR DEGREE:

Head of the BA program	**Full name**	**Academic degree**	**Signature**	**Date**
38.03.01 Economics	Telipenko E.V.	Ph.D. of Engineering Sciences, Assoc. Prof.		

Yurga – 2021 г.

PLANNED OUTCOMES OF LEARNING THE BACHELOR PROGRAM

Competency code	Competence name
	Universal competences
GC(U)-1	Can use the basics of philosophical knowledge to form a world outlook
GC(U)-2	Can analyze the main stages and regularities of social historical development to form a civic position
GC(U)-3	Can use the basics of economic knowledge in various activities
GC(U)-4	Can use the basics of legal knowledge in various fields of activity
GC(U)-5	Can communicate in oral and written form in Russian and foreign languages to solve problems of interpersonal and intercultural interaction
GC(U)-6	Can work in a team with tolerance for social, ethnic, religious and cultural differences
GC(U)-7	Can self-organize and self-educate
GC(U)-8	Can use the methods and means of physical education to ensure proper social and professional activity
GC(U)-9	Can use first aid methods, methods of protection in emergency situations
	General professional competencies
GPC(U)-1	Can solve standard tasks of professional activity on the basis of information and bibliographic culture with application of information and communication technologies and taking into account basic requirements of information security
GPC(U)-2	Can collect, analyze and process data needed to solve professional problems
GPC(U)-3	Can choose the tools for economic data processing according to the task at hand, analyze the results of calculations and justify the conclusions drawn
GPC(U)-4	Can find organizational and managerial solutions in professional activities and is prepared to take responsibility for them
	Professional competencies
PC(U)-1	Can collect and analyze the raw data required to calculate economic and socioeconomic indicators that characterize the activities of business entities
PC(U)-2	Can calculate economic and socio-economic indicators characterizing the activities of business entities based on standard methodologies and the current legal and regulatory framework
PC(U)-3	Can carry out the calculations required for the economic parts of the plans, justify them and present the results of the work according to the standards of the organization
PC(U)-4	Can build standard theoretical and econometric models based on the description of economic processes and phenomena, to analyze and interpret the results meaningfully
PC(U)-5	Can analyze and interpret financial, accounting and other information contained in the accounts of enterprises of various forms of ownership, organizations, departments, etc. and use the information to make managerial decisions
PC(U)-6	Can analyze and interpret domestic and foreign statistics on socioeconomic processes and phenomena, identify trends in socio-economic indicators
PC(U)-7	Can, using domestic and foreign sources of information, to collect the necessary data, to analyze it and to prepare an information review and/or an analytical report
PC(U)-8	Can use modern technical tools and information technology to solve analytical and research problems
PC(U)-14	Can document business transactions, conduct cash accounting, develop a chart of accounts for an organization and generate accounting entries based on this chart of accounts
PC(U)-15	Can make accounting entries for the sources and results of the organization’s inventory and financial liabilities
PC(U)-16	Can draw up payment documents and make accounting entries for the accrual and transfer of taxes and levies to the budgets of different levels, insurance contributions to nonbudgetary funds
PC(U)-17	Can record the results of economic activities for the reporting period in the accounting records, to prepare accounting and statistical reporting forms, tax declarations
PC(U)-18	Can organize and implement the organization’s tax accounting and tax planning

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Yurga Institute of Technology
Bachelor program 38.03.01 Economics

APPROVED:
Head of the BA program

________ ________ ______________
(Signature) (Date) (Telipenko E.V.)

THE ASSIGNMENT
for the final qualifying work

in shape of the:

Bachelor Thesis

Student:

Group	Full name
З-17Б60	Serova Yu.V.

Thesis theme:

Project for the development of a universal agricultural robotic platform	
Approved by the order of the director	32-107/С dated 01.02.2021 г.

Completion date the thesis performed:	29.05.2021г.

TERMS OF REFERENCES:

Initial data for work	Analytical report "Prospects for Industry 4.0 and digitalization of industry in Russia and the world" by J'son & Partners Management Consultancy. Official statistics and data from open press
List of questions to be researched, designed, and developed	Literature review Analysis of trends in the development of Industry 4.0 Studying the main trends of digitalization in agricultural sectors Overview of Intellectual agricultural machinery Agricultural Robot Market Assessment Development of a project to create a universal robotic agricultural platform Calculation and justification of the project

list of graphic materials	1. Purpose and objectives of the work 2. Industry 4.0 in Russia and in the world 3. Major trends in digitalization in agricultural sectors 4. Review of Intellectual agricultural machinery 5. Assessment of the agricultural robot market 6. Product development, minimum Viable Product 7. IP-strategy of the project 8. Business model of the project 9. Risk assessment and investment attractiveness of the projection

Consultant for the sections of the finale qualifying work
(with indications of sections)

Section	**Consultant**
Social responsibility	Senior Lecturer, Rodionov P.V.

Assignment for the performance of the final qualifying work according to the linear schedule issued	30.03.2021

Assignment was given by the supervisor:

Position	**Full name**	**Academic degree**	**Signature**	**Date**
Senior Lecturer	Nesteruk D.N.	-		

Assignment was accepted by the student:

Group	**Full name**	**Signature**	**Date**
З-17Б60	Serova Yu.V.		

TOMSK POLYTECHNIC UNIVERSITY ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

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National Research Tomsk Polytechnic University
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THE ASSIGNMENT
FOR THE SOCIAL RESPONSIBILITY SECTION

Student:

Group	Full name
З-17Б60	Serova Yu.V.

Institute	UTI TPU		
The level of education	Bachelor	Program	38.03.01 Economics

Initial data for the Social responsibility section:	
1. The description of the workplace (working area, technological process of mechanical equipment) about occurrence: - harmful factors of the production environment (weather conditions, hazardous substances, lighting, noise, vibration, electromagnetic fields, ionizing radiation) - dangerous manifestations of the factors of production environment (mechanical nature of heat nature, electric, fire, nature) - emergency situations of a social nature	Description of the workplace of the specialist's office
2. List of laws and regulations	- Sanitary and epidemiological rules and regulations SanPiN 2.4.6.2553-09 Sanitary and epidemiological requirements for the safety of working conditions of employees under the age of 18. - SanPiN 2.2.2/2.4.1340–03 Hygienic requirements for personal electronic computers and organization of work. - Order of the Ministry of Health of the Russian Federation No. 29n of January 28, 2021 – - Order of the Ministry of Health of the Russian Federation No. 125n of March 21, 2014.
List of questions to be researched, designed, and developed:	
1. Analysis of the factors of internal social responsibility: - the principles of the corporate culture of the studied organization; - labor organization and safety systems; - development of human resources through training programs and training and professional development programs; - Systems of social guarantees of the organization; -provision of assistance to employees in critical situations.	- labor protection rules; - lighting; - microclimate parameters; - noise; - color design of the interior; - workplace ergonomics; - instruction on safety at the workplace; - fire safety training.

2. Analysis of the identified hazards of the designed manufactured environment in the following sequence: - mechanical hazards (sources, protective equipment; - thermal hazards (sources, protective equipment); - electrical safety (including static electricity, lightning protection-sources, protective equipment); - fire and explosion safety (causes, preventive measures, primary means of fire extinguishing).	The sources and means of protection from existing hazards in the workplace; Fire and explosion safety (causes, preventive measures, primary means of fire extinguishing); Measures that motivate environmental protection. An operational headquarters for preventing the penetration of COVID–2019.
3 Legal and organizational issues of ensuring social responsibility: - Analysis of legal norms of labor legislation; - analysis of special (typical for the investigated field of activity) legal and regulatory legal acts; - analysis of internal regulatory documents and regulations of the organization in the field of the investigated activity	The regulatory and legislative documents for ensuring safety at the manager's workplace are specified: - The Constitution of the Russian Federation; - Labor Code of the Russian Federation; - Federal Law of the Russian Federation “On the Basics of Labor Protection in the Russian Federation”; - Federal Law No. 184-FZ "On Technical Regulation" of 27.12.2002; - Federal Law No. 10 " On Trade Unions, their Rights and Guarantees of Activity»; - job description.
List of graphic material:	
If necessary, submit sketch graphic materials for the design assignment (mandatory for specialists and masters)	–-

Assignment for the performance of the section according to the linear schedule issued	

The assignment was given by the consultant:

Position	Full name	Academic degree	Signature	Date
Senior Lecturer	Rodionov P.V.	Ph.D. of Pedagogic Sciences		

Assignment was accepted by the student:

Group	Full name	Signature	Date
З-17Б60	Serova Yu.V.		

Abstract

The final qualifying work contains 73 pages, 8 figure, 13 tables, 23 sources.

Key words: industry 4.0, digitalization, agriculture, robot, universal platform, project

The object of research is the process of development and implementation of the universal robotic agricultural platform.

The relevance of the work is determined by the need of justifying the characteristics and bring to market the existing agrorobot prototype.

The purpose of the work is to justify and formulate a project to develop a universal robot for agricultural operations.

To achieve this goal, the following tasks were solved:

1. Assess the current state and future trends in the development of industry in general and agriculture.

2. Review and evaluate the agricultural robotics market.

3. Calculate a project for the development of a universal robotic platform for agricultural purposes.

The work was based on the technical characteristics of a prototype of an agricultural robot developed by employees and students of the Yurga Institute of Technology, TPU affiliate (A.V. Proskokov, M.V. Momot, etc.). Publicly available publications served as the basis for calculations and analytical conclusions.

Definitions, notation, abbreviations, normative references

In this work, the following definitions, designations and abbreviations, normative references are adopted:

artificial intelligence (AI) – The ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings.

minimum viable product (MVP) – Is a version of a product with just enough features to be usable by early customers who can then provide feedback for future product development

industry 4.0 – The state of industry which characterizes situation when the modern and more sophisticated machines and tools with advanced software and networked sensors can be used to plan, predict, adjust and control the societal outcome and business models to create another phase of value chain organization and it can be managed throughout the whole cycle of a product. Industry 4.0 refers to the intelligent networking of machines and processes for industry with the help of information and communication technology.

information and communications technology (ICT) – Different types of technologies that convey information to users through telecommunications.

internet of things (IoT) – Global network infrastructure where physical and virtual objects with unique identities are discovered and integrated seamlessly (taking into account security and privacy issues) in the associated information network where they are able to offer and receive services which are elements of business processes defined in the environment in which they become active.

Contents

Introduction

Currently, the world economy is facing the consequences of dynamic changes continuously occurring in industry and collectively called the fourth industrial revolution or Industry 4.0.

Industry 4.0 looks like the future of global manufacturing which aggregates existing ideas to a new value chain which plays a crucial role to transform whole value chains of life cycle of goods while developing innovative services and products in the manufacturing industry which involves the connection of systems to things that creates self-organizing and dynamic control within an organization. [1]

Process which are result of Industry 4.0 can predict product performance degradation and autonomously manage and optimize product service needs and consumption of resources which lead to optimization and reduction of costs. Next, the creation of dynamic, real-time optimized and self-organizing cross-company value networks through the Cyber-Physical Systems (CPS), Internet of Things (IoT), artificial intelligence (AI), additive manufacturing, cloud computing and others are added.

All this places high demands on the production processes, equipment, and technologies, especially in sectors not traditionally associated with innovation in Russia. Since the development of new technology in agriculture should include not only a major engineering project at the level of the world's leading standards and qualitative analysis of options for the commercialization prospects of the development itself and its derivative products.

On the definition of objectives, subject and object of research influenced the developments of employees and students of the Yurga Institute of Technology in Applied Robotics. [2-4]

The relevance of the work is determined by the need of justifying the characteristics and bring to market the existing agrorobot prototype.

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3. Calculate a project for the development of a universal robotic platform for agricultural purposes.

The work is based on the application of methods for analyzing industry analytics, planning, and forecasting the effectiveness of business processes. For patent search and the formation of an IP strategy, the databases of patents registered in the Russian Federation were used. Publicly available publications served as the basis for calculations and analytical conclusions.

1 Literature review

1.1 Background and consequences of the Industrial Revolution 4

Different countries formulate their priorities in different ways, set strategic goals for their development and form relations with the manufacturing sector of the economy. However, almost all industrialized and developing countries, in order to maintain and strengthen their competitive positions in the world, see their future in the digital economy of a new technological order and have consolidated their own national industrial priorities as a response to the German state program “Industry 4.0”.

Industry 4.0 is a new stage in the industrialization of countries, based on the digital transformation of industries, aimed at finding, developing and implementing new industrial technologies and innovations that lead to an increase in labor productivity and efficiency in the use of resources in all spheres of the economy. In this context, industrial revolutions bring a quantum leap and new opportunities for increasing productivity, profitability, and capitalization of national businesses.

And the speed of mastering high-performance tools that come along with the new technological paradigm, and their large-scale implementation, thanks to industrial competencies and production skills of citizens, is a critical factor in maintaining global competitiveness, ensuring stable continued GDP growth and a renewable resource for the development of the country's social sphere and growth of welfare. citizens.

Production capabilities (industrial competencies and accumulated knowledge) determine different levels of the country's wealth, the potential for economic growth and, as a result, the well-being of the population.

Economic growth requires the mandatory presence and continuous development of three components:

Production of goods,

developed sphere of services and cooperation ties, a continuous reproduction system that ensures productivity growth in all sectors.

Moreover, none of the elements of the economic system is more important than others. For any country, the manufacturing sector and support of its own reproductive level is a strategically important national task for the development of the economy, the service sector and ensuring the growth of incomes and national welfare.

The consistent evolution of technologies in the world creates new production tools and opportunities for various economic agents, which, as a result of synergistic effects on all industries, contribute to the emergence of new economic structures, up to explosions of productivity growth in industries called "industrial revolutions", which are currently taking place. interpreted from the point of view of the concept of Industry 4.0.

The digital economy is the management of economic activities and resources of the country in various industries, including a digitized production system and a digitized distribution system of services / services, consumption, trade), in which all revolutionary transformations take place in the digitization (ICT -ization) of interconnections (cooperation chains) between participants on the one hand, and on the other hand, in the digitization (ICT -ization) of all internal production and business processes within each company.

Upon reaching the most difficult levels of digitalization, the digital economy undergoes a radical transformation of industrial relations of the participants, the result of which is the unification of production and services into a single digital ecosystem, in which:

- all elements of the economic system are present simultaneously in the form of physical objects, products and processes, as well as in the form of their digital copies (mathematical models);

- all physical objects, products and processes due to the presence of a digital copy and the element of "connectivity / connectivity" become part of an integrated IT system;

- through the presence of digital copies, all elements of the economic system continuously interact with each other in a mode close to real time, simulate real processes and predicted states, and provide constant self-optimization of the entire system.

The key advantage of the digital economy over the traditional one is the implementation of the possibility of automatic control of the entire system (or individual components), as well as its almost unlimited scaling without loss of efficiency, which allows to significantly increase the efficiency of economic management (economic activities and resources of the country in various industries) at the micro and macro levels.

It is important to note that the concept of digitalization of the economy in Russia is fundamentally different from the ongoing processes in the world. In Russia, the concept of "digitalization" currently does not cover the issues of a radical change in the situation in the production system, approaches to the design, production, sale and operation of these physical objects, which is incorporated in the concept of Industry 4.0.

Nevertheless, industry is the basis for the growth and diversification of the economy, labor productivity and the demand for highly qualified specialists. The stronger the industrial foundation, the more competitive advantages in the manufacturing sector, the greater the economic effect will bring the transition to the next stage - an innovative (digital) economy - the creation of unique (high-tech) products and services that are based on innovative ways of working, difficult for competitors to reproduce. and therefore have a high export potential. In addition, they contain a high added value, which ensures the growth of the country's economy.

The development of complex mechanical engineering and manufacturing industry forms its own production base for creating various types of products in the country, contributes to an increase in labor productivity in other industries through the use of high-performance equipment, and, thereby, has a synergistic effect on the economy as a whole.

Services (services) are closely tied to the real sector and the material sphere (real estate sells construction products; tourism uses transport and aviation; hairdressers, restaurants, etc. use various types of equipment to provide services; financial and telecommunications services are possible through the operation of high-tech ICT equipment; shops and online stores sell tangible goods, etc.). That is, all other segments directly or indirectly depend on the production of goods in one form or another.

So, despite the fact that the production of equipment (mechanical engineering) in the total value added produced in Russia (GDP) is no more than 2%, it provides the next level of the economy - the production of products in all sectors, which is more than 30% of GDP. The presence of a wide range of goods creates jobs for the service sector, which accounts for the remaining 65% of GDP.

As a result, the more equipment is created, the more goods are produced. And the more physical goods are produced, the larger the service sector.

At the same time, a complex expensive high-tech product and equipment form a concomitant market for services (services) with high added value in various industries. The more salaries in the country due to the developed industrial sector, the more people can pay for services.

1.2 Industry 4.0 in Russia and in the world

The recognition of the importance of industrial development as a powerful lever of GDP growth has been the main reason for the close attention to the widespread study of the transformative effect of the fourth industrial revolution and the application of the concept of Industry 4.0 in various sectors of the economy over the past several years.

State programs and industrial policies that have emerged in Germany, USA, China, Japan, Great Britain, Korea, etc. fix the development of the national industrial sector as one of the main strategic priorities. Industry 4.0 is a return to industry in a new, innovative scenario, based on fourth-generation technologies.

Industry 4.0 represents the evolution of technologies in industry, when traditional production processes are integrated with infocommunication technologies (ICT / IoT) and company information systems.

If it is possible to integrate and digitize all the links of production and business processes, information and ICT systems in an end-to-end manner, it becomes possible to form a complete (or partial) digital copy of production (digital twin). This achieves, on the one hand, the reflection of all real physical processes in the virtual (digital) production model; on the other hand, the results of digital modeling can provide feedback and create a control effect on real production processes.

The digital (mathematical) model of production allows in real time:

- monitor the condition of equipment, assets, production processes,
- monitor the status of the product purchased by the customer,
- implement full or partial automatic production control,
- to manage or maintain the product on the buyer's side,
- to optimize and increase the efficiency of production and management up to the emergence of self-optimizing production systems,
- integrate the digital infrastructure of the company into a single ecosystem with partners, suppliers and customers.

One of the most transformative results of Industry 4.0 based on digitized processes is the integration of services and production into a single ecosystem and the embedding of services (intelligent systems) into the product itself. Through the creation and further use of the so-called Product-Service System (PSS).

This approach allows you to initially design a service and product system for the requirements of narrow customer market segments and even individual customers.

With regard to the production of machinery and equipment, the transformational effects of the introduction of IoT and the transition to end-to-end automatic processes can be summarized in three groups:

1. The appearance of the manufactured products is changing - it becomes software-defined and modular. In this case, in most cases, the external shape of the product is simplified due to the programmable functions within the product. The approaches to updating the equipment fleet are changing - from a discrete replacement, requiring large one-time investments, to a constant modification model (analogous to the DevOps model in IT) by updating the software part of the products and replacing individual hardware modules. The emergence of the possibility of deep product modification at the stage of its after-sales operation makes it expedient to implement the principle of the life cycle contract (Performance Based Lifecycle Product Support, PBL) for such products, when the responsibility for the correct functioning of the product remains with the equipment manufacturer throughout the entire life cycle. This applies to both means of production (machine tools, industrial and engineering equipment) and end-use items.

2. Approaches to product development are changing - minimization of the human factor, as well as the maximum reduction in time and resources not only at the production stage (robotization, total automatic control of all production processes), but also at the stage of equipment operation (remote automatic monitoring of equipment operation modes) allows to precisely design a product according to the requirements set by the market (Customer), technical and functional characteristics. And the principles of software definability and modularity allow you to modify these characteristics depending on operating conditions and changes in market requirements.

3. Approaches to the production of such products are changing. There is an opportunity to implement a shop model of production (job shop) at a new technical level - with the possibility of total remote control of production quality, which makes it possible to organize an extremely effective "hybrid" model of using production capacities. With this model, an enterprise with its own production facilities uses

them not only for the production of final products (own), but also for performing individual production operations to order, acting as part of a distributed production chain united by a single automatic control, and also, in the case of full load individual machines and equipment - places orders for the execution of individual production operations at third-party enterprises, while maintaining full control over the quality of their execution. This allows us to constantly maintain an extremely high, close to 100%, level of utilization of production capacities.

These three transformation components will solve the key problems of the Russian industry:

1. To increase the competitiveness of products by reducing the unit cost of production, by simplifying the appearance to fill the gap and resume production at a new level of a wide range of products (including those with additive manufacturing capabilities);

2. Reduce the influence of the human factor, increase the speed of distribution and fulfillment of orders, and ensure the stability of production quality;

3. To increase the level of service support, allowing the transition in relations with consumers of products to the model of a life cycle contract and payment according to the actual volume of consumption of product functions.

The current priorities for the development and increase in labor productivity at industrial enterprises cover only measures that can be implemented within individual enterprises (in particular, the replacement of outdated machines and equipment with modern ones).

With a high level of capital intensity of this approach and the depreciation of more than 50% of the machine park, the impact of such measures on labor productivity is extremely limited, since they do not affect the unacceptably low level of utilization of production facilities, both outdated and modern, which is, on average, four times lower than such in industrialized countries: Germany, Japan, USA, China.

Therefore, it is advisable to supplement the program for the development and increase of labor productivity in the machine-building industry in Russia with measures that allow, in the next 10 years, to move from the model of performing all production operations necessary for the production of products, exclusively using the company's own production facilities, to a hybrid model of distributed automated production.

In the distributed production model for performing individual production operations when the enterprise has a technical need (its own capacities are fully loaded, there is no equipment for performing individual operations with the required quality parameters) and / or economic feasibility (performing separate production operations on the side is cheaper with the same quality) production capacities of other enterprises can be involved "on demand", and the process of such involvement is automated as much as possible, thereby minimizing the negative impact of the human factor.

The implementation of the distributed production model makes it possible to solve the problem of reducing costs, improving the quality and productivity of labor by increasing the level of utilization of machines and production equipment from the existing extremely low level of 20-30% of working time to the level of the world's leading industrialized countries (Japan, Germany, USA) - 80-90%, with the use of the fleet of CNC machines available in Russia and the retrofitting of the most "fresh" conventional machines (less than 20 years old) with CNC sets. This will make it possible to completely decommission physically worn-out equipment over 20 years old (~ 50% of the machine tool park in Russia), to increase the utilization level of modern and "fresh" machine tool park up to 80-90%, and, thus, to level the unit cost of production of engineering products in Russia and abroad, as well as to reduce the influence of the "human factor" on the quality of products.

The “digital shop floor” model implies a cloud service platform - a “virtual exchange of production resources” using IoT technologies and predictive analytics. Such a service platform should perform, firstly, the functions of a concentrator of information flows from design systems (PLM) and ERP systems, where the need for performing production tasks, accounting and production systems necessary for determining the actual economic and technical parameters of performing production operations on specific machines and equipment and tracking the availability of free "windows" to complete production tasks. And secondly, on such a service platform, it is necessary to implement the logic of calculating the economic and technical parameters of performing individual production on specific machines at a specific point in time, as well as monitoring the compliance of the actual indicators with the calculated ones.

In view of the need for a radical restructuring of approaches to the organization of production processes, it is advisable to implement a "virtual resource exchange" in several stages, limiting the scope of implementation at the first stage to the framework of one or several subholdings, and the scope of application - to the production of civilian products, where the level of cost directly determines the level of its competitiveness. Thus, the sphere of the virtual resource exchange may be the fulfillment of the solution set by the President of the Russian Federation to increase the share of civilian products in the revenue of defense industry enterprises to 50% by 2025.

An analysis of similar works in the world shows that without such acute problems with a low level of utilization of machines and equipment and a high level of wear and tear, the main task of creating a virtual exchange of production resources, in particular in the European Union, is seen in the possibility of mass production of deeply customizable mechanical engineering products.

The transition in the production of mechanical engineering products of generation 4.0 to the principle of combining production equipment into pools of resources open for external orders, when executing orders with minimal human participation, allows the Russian industry to reorganize to the use of the open innovation model.

For comparison, in the world, according to SAP, 80% of machine-building products are manufactured according to the Job Shop model (distribution of production assignments among specialized workshops), which ensures a high level of production capacity utilization and a low unit cost level, and this, in turn, , enables manufacturing enterprises to quickly recoup and renew their production park.

When implementing this approach, it will be possible to ensure the current production volumes of about a quarter of the existing machine park, and to decommission physically worn out equipment, to replenish relatively “fresh” CNC machines and thus bring the share of CNC machines to a level close to 100% of the machine park.

It is important to note that the lack of vigorous action towards the digitalization of mechanical engineering in the next 3-5 years will mean a complete loss of the competitiveness of domestic engineering and its irreversible degradation due to the inability to compete with new generation products from leading world manufacturers.

In turn, due to the decisive role of mechanical engineering in the formation of complex cooperative chains with other sectors of the economy, the degradation of mechanical engineering will determine the general degradation of economic activity in the country.

For the Russian economy, such a degradation, combined with the transition of the largest international manufacturers of mechanical engineering products to the PSS model, will have especially severe consequences, since it will have a devastating effect not only on the sphere of material production, but also on the service sector, whose share exceeds 55% of Russia's GDP.

1.3 The main trend of digitalization of Agriculture

Agriculture evolves with science and technology, and it is only a matter of time until the Internet of things (IoT) reaches farmscapes. Technical improvements in new agricultural technologies should:

- optimize production efficiency;
- optimize quality;
- minimize environmental impact;
- minimize production-associated risks.

The key players in this change are not only the industries of traditional farming equipment but also the farmers. Remote sensing, data processing, telecommunications, AI and robotics, combined with the expanding array of uses available, mean that new approaches are required to take into consideration not only agronomics, but also factors related to infrastructure, law and knowledge. Issues such as privacy, ownership of data generated in the farms, use of geolocation, insurance of nonmanned vehicles and encrypted information will all be a part of digitalized agriculture. To illustrate how information management will play a key role in this new way of farming, Figure 3 shows the different stages and elements that intervene in digital agriculture: sensors monitor the crop to generate data captured by a platform; these data are processed by specific software and AI; intervention options are provided; the farmer decides how to act on the crop (directly with their own equipment or indirectly via automated equipment). Agricultural robotics can combine all the stages on one platform or specialize in some of them; it is a complex technology and it is not easy for the end user of the robot (the farmer) to have the necessary know-how and be familiar with the whole process and the elements that intervene in the cycle.

The paradigm of Industry 4.0 envisions farmermachine interaction as central to the running of the farm, with the farmer making decisions and operating interconnected equipment that operates autonomously based on the above-mentioned information process. Today's commercial farmer who has a full command of existing farming skills and knowledge, will need to become a sort of information technology (IT) manager operating from an office or in front of a screen (computer, mobile phone, tablet etc.), rather than a machine operator working in the field, handling machine steering and adjusting equipment manually. For livestock management, skilled operators will still be needed, but with new sets of skills related to ICTs and automatization. This is the vision projected for countries with a highly developed agricultural sector; however, it is a long way from the reality of most countries and most small-scale farmers.

Industry 4.0 offers many possibilities.

Drones and other sensing platforms can provide information in real time, they produce imagery, capture different agronomical parameters and alert farmers of a crop's progress, the status of the soil, the surge or risk of pests and diseases, and the development of weeds. The state of interconnectivity will be something previously unseen in agriculture, with high levels of information capture, analysis and processing between the various pieces of equipment and the systems. All this information needs to be processed by the famer who can then assess the optimal solution or action required. The farmer can use conventional technologies or autonomous equipment to intervene at field level or in controlled farming set-ups like greenhouses or vertical farms. The equipment can make use of sensed data to optimize input use according to the needs of the field, crop or soil.

The interconnectivity of rapidly changing mechanical devices is a major component of Industry 4.0, but this should not obscure the importance of the transparent algorithms driving these devices. The analysis of data coming from the devices will be understood via machine learning, leading in some cases to AI. An example of this is PlantVillage (PlantVillage, 2013): it has access to a vast image collection and through machine learning is able to provide more precise diagnostics than via other means (e.g. consulting an IPM guide or using phone cameras to diagnose crop diseases) and it links to satellite systems through portals such as the Water Productivity Open-access Portal (WaPOR) at FAO (FAO, 2019). The algorithms are transparent, having been built together with agronomists at public institutions such as FAO and the CGIAR System Organization. However, transparency cannot be assumed in the private sector, where issues of intellectual property demand a close-guarding code.

Machines in an Industry 4.0 setting may make mistakes that are not easily discerned by farmers and others.

Farmers and agriculture professionals will need to acquire new skills to manage all these new systems and assess how to best perform agricultural operations based on all the possible parameters. The challenges for the farmer are not to be underestimated! Likewise, the public and private sectors will face new challenges in terms of capacity building around these new technologies.

There is no formal definition for the term “agricultural robot” or “agrorobot” and no official recognition of the function of robots that perform agricultural operations. Lowenberg-DeBoer et al. (2019) propose the following working definition for field working robot: a mobile, autonomous, decision-making, mechatronic device that accomplishes crop production tasks (e.g. soil preparation, seeding, transplanting, weeding, pest control and harvesting) under human supervision, but without direct human labour. Bechar and Vigneault (2017) define agricultural robots as: perceptive programmable machines that perform a variety of agricultural tasks, such as cultivation, transplanting, spraying and selective harvesting (Figure 5). The term “agrorobot” is undoubtedly an effective description for autonomous machines that are able to carry out different repetitive agricultural tasks on the farm - from land preparation to harvesting - without direct human intervention.

In dynamic and unstructured environments, agricultural robots can often produce inadequate results due to the inherent uncertainties, unknown operational settings and unpredictability of events and environmental conditions. In 2019, as explained at the International Forum of Agricultural Robotics (FIRA), an annual event held in Toulouse, there were over 60 known projects worldwide on the development of agrorobots (FIRA, 2018), and this number continues to grow. They comprise a wide range of sizes, are designed for a variety of uses and apply different technologies. Only a small number are currently at the commercial stage, but the coming years will see new projects and increasing availability. As the technology is in its early stages, it aims to meet the current demands faced by farmers with a focus on commercial farming oriented towards intensive production, a sector which can afford to invest in this technology. However, the demand for agrorobots needs to be driven by farmers' requirements, which can be quite specific. According to FAO (2019b), about 90 percent of farmers worldwide operate on a small scale and the technology must become accessible to this large group.

An agrorobot can perform a vast array of tasks. The first commercially available agrorobots cover three main tasks: eliminating weeds, monitoring pests and diseases, and harvesting specialized crops (berries or vegetables). An agrorobot offers cost-saving opportunities as it reduces labour requirements (weeding and harvesting), limits the use of inputs (pesticides) and reduces yield losses resulting from the late detection of pests and diseases.

There are as many potential uses of agrorobots as there are agricultural tasks. Prototypes already exist that can prepare the soil, sow, control pests and harvest cereal crops (e.g. barley or maize). The automation of agricultural equipment can adopt various approaches, from making existing machinery autonomous (i.e. driver free) to developing new autonomous platforms capable of carrying out tasks. These new platforms tend to be very sophisticated and new types of equipment are continuously being developed; however, simple agrorobots designed for basic, straightforward tasks can already help farmers with a wide range of operations.

Drivers of implementation agrorobots

The adoption of agrorobots in commercial farms offers major cost-saving opportunities. Many commercial farmers struggle to find sufficient manpower to cover labor needs during the harvest season, especially in fruit and vegetable plantations. Agricultural robots can eliminate this gap and reduce the cost of specialized manpower. Moreover, they can operate over long periods as they are not subject to the limitations - physical and legal - of humans. At harvest, some models are even able to pick fruits or vegetables individually, depending on the stage of ripening.

Agricultural robots enable the farmer to reduce inputs - pesticides, herbicides and fertilizers - with positive implications for the environment. Mechanical weed control is already a reality; other functions under development include micro application of inputs and early detection of pests, which will considerably decrease, even eliminate, the need for inputs. Agrorobots are also lighter than conventional machinery (i.e. tractors with implements or specific equipment for spraying or harvesting) and can thus alleviate problems associated with soil compaction and are able to access fields not suitable for heavy machinery (e.g. vineyards on slopes or land affected by wet conditions).

Challenges for implementation agrorobots

The implementation of any technology entails challenges. The main challenges for the adoption of agricultural robotics are described below:

Ownership and management of digital data

Digital technologies involve the collection of individual data. As in other sectors, the data produced by the sensors of agricultural equipment are used by companies for their business model; indeed, data analysis and processing are crucial for the correct functioning and operation of agrorobots. Clear laws and regulations need to be in place and should always be on the side of the farmer/individual to avoid misuse by third parties. However, the continuous need for data to perfect, design or run the AI behind the software that operates autonomous equipment can also present an opportunity for farmers to monetize the data generated. Furthermore, data generation is a way to monitor ecosystem services or environmental indicators (e.g. carbon sequestration).

Capacity

With the breakthrough of any new technology, the adoption rate depends on key factors: knowledge, capability and capacity. Many farmers may not have the capacity to operate agrorobots or understand how they work. A good agricultural practitioner is not necessarily expert in digital technologies and automation, and the same applies to extension officers and service providers. Therefore, capacity building is essential for the uptake of automated equipment and its correct use; only with capacity can farmers unleash the full potential of agrorobots.

A report published by the International Fund for Agricultural Development (IFAD) and GrowAsia (Grow Asia Partnership, 2019) highlighted that the adoption of digital technologies among smallscale farmers entailed five stages:

Face to face

Phone call

Peer group dialogue

Active discovery

Digital service engagement

The process is not straightforward; support must be provided throughout by various actors adopting a range of methodologies. In the absence of external incentives (e.g. policies or market prices), the main driver for change is willingness to adapt and adopt.

Capacity building must go beyond existing farmers. It is important to prepare youth - the farmers of the future - to engage in agriculture by familiarizing them with new technologies during their schooling (programming and robotics are part of many high school curricula nowadays). By steering their interest in digital technologies towards applications in agriculture, individuals with new ideas can be attracted to the sector of agricultural robotics. The adaptation of academia and education programmes is essential if countries are to have the skilled labour necessary to operate, maintain and develop the technology. Moreover, the acquisition of knowledge must not be limited to the end users: capacity building must reach all stakeholders, from policymakers responsible for creating the right environment through laws, incentives or training programmes (education, industry and agriculture) to extension officers, technicians and farmers.

Farming system adaptation

Farmers who introduce agrorobots into their production system do not always find it easy to make the robot work properly. It is a common misperception that robots will simply replace existing equipment and immediately carry out its function in the system. The reality is quite the opposite, and in order to achieve the best results, the farm system must adapt to the robot. Farmers needs to adapt, in terms of both timing and mentality. For example, with row spacing or terrain levelling, a farmer accustomed to a certain spacing between crops or a specific crop structure (e.g. the architecture of fruit trees) needs to adapt the spacing/structure to ensure that it matches exactly the operational parameters of the agrorobot as it moves among the cultivated crops. There is already evidence that farmers who adapt accordingly achieve better results and profitability based on the good performance of the agrorobots (FIRA, 2018). Agrorobots currently are not cheap when compared to standard practices and equipment; as with any new technology, the first available models are very high in price. Agrorobots are of interest to farmers operating

in all kinds of situations in a wide variety of locations. However, some robots may be designed specifically to operate in a given location, based on the parameters of a particular farm; this limits the usability of the equipment and compromises business models that imply input sharing or service provision.

Purchase price

The purchase price or operation cost may exceed available resources and make production unprofitable. On the other hand, on large commercially oriented farms producing high- value horticulture crops where labour costs are high during harvest season (due to high manpower requirements or lack of availability of human labour), farmers find it already lucrative and increasingly profitable to use specialized agrorobots that lower costs and reduce dependency on scarce human labour. While agrorobots are already being used in some highly specialized horticulture farms - proving that it is possible to achieve lower opportunity costs through automation - there is a need to find profitable business models where the farmer does not necessarily own the robot, but can benefit from the technology. Two possible solutions, already in place in many farming systems, are service provision and cooperative ownership.

IT infrastructure

The concept of Industry 4.0 is closely linked to the use of ICTs and is heavily reliant on the availability of adequate IT infrastructure to acquire, process and share data. Agrorobots are dependent on the availability of the correct infrastructure and to work autonomously, they rely on data provided by built-in sensors, remote sensors (i.e. satellite image), external sensors (drone imagery, soil probes), programmed actors and many agronomic parameters stored in their software. All this information needs to be acquired and shared, and access to reliable IT infrastructure is essential, with the right signal coverage, energy supply and strength to support the data transfer, not only for satellite positioning (e.g. as global positioning system [GPS]), but for telephone or radio signal. Not only does the agrorobot need to be fed with data to operate, but the farm manager and the operators need to control the agrorobot, process the data it produces while operating and make decisions based on the information available. This is a major challenge since the bandwidth of a phone signal does not extend to all rural areas, especially in developing countries (Figure 10). Engineering solutions may be required for challenging environments and settings to adapt agrorobot ICTs to the conditions of developing countries.

Technical maintenance and servicing

For the successful adoption of agricultural robots, appropriate technical servicing and after sales services must be available. As with other new technologies, it is a waste of time and resources to purchase a new technology or automated equipment, only to discover after a short time that spare parts are not available within a reasonable distance or time. The same applies for the specialized and qualified technicians needed to repair equipment and provide maintenance support; furthermore, in the case of agrorobots, not only mechanics, but also ICT engineers and robotic technicians are needed.

2 Object and methods of research

The object of research is the process of development and implementation of the universal robotic agricultural platform.

The object of the research assumes the need to analyze the need for development in the context of current trends in the development of industry and the development of a project for bringing the object of research to the market.

Startup model is focuses on the completion and implementation of the basic prototype of a robotic platform - a pusher robot for livestock farms - was chosen as a commercialization model. Additional specializations for the platform and their corresponding modules are proposed to be developed according to the model of commercial R&D.

The work was based on the technical characteristics of a prototype of an agricultural robot developed by employees and students of the Yurga Institute of Technology, TPU affiliate (A.V. Proskokov, M.V. Momot, etc.).

Below is a description of the developed prototypes of the robotic platform (Figures 1-3).

The project of a universal robotic platform for agricultural purposes was conceived for performing work in small areas. Therefore, it is compatible with attachments of motor-cultivator equipment from available manufacturers. That is, you can install rippers, hillers, and other attachments that are available in stores on it. The robot positioning system is based on the operation of ultrasonic sensors of the Russian company "Marvelmind" and on video identification algorithms of the OpenCV library.

Based on a robotic self-propelled platform, according to the technical specifications of a real farm, a project of a robot-pusher of feed on a livestock farm was carried out, as a replacement for a more expensive imported analogue. Pushing feed is carried out using an active auger. The rotation speed is adjusted depending on the travel speed and the volume of feed. Orientation in the farm room is carried out using ultrasonic sensors that accurately determine the distance to the nearest obstacles and send a signal to an electronic microcontroller to correct the trajectory of movement. Inductive metal detectors react to metal plates attached to the concrete floor and signal the beginning or end of movement along the row.

Figure 1 - Robot feed pusher

Figure 2 - Assistant Robot (cargo platform robot)

The main task of the second project is to work as a cargo platform. When performing harvesting operations or other work related to the transportation of goods up to 150 kg, the assistant robot always follows the same path followed by the person. The robot is equipped with a vision system using algorithms from the

OpenCV library, and students have already "taught" the machine to identify a person and provide the required distance to him.

In the coming years, this type of agricultural robots will replace orchard and garden motor vehicles (walk-behind tractors, cultivators, lawn mowers) and will be able to process an area from a few hundred square meters to two hectares of land. In the future, the device will be able to cultivate the land using an active rotary tiller and treat plants from pests. The use of such a technique can significantly reduce human labor costs.

Figure 3 - Automatic robotic lawnmower "Agry"

The Agry automatic robotic lawnmower is designed for mowing grass in relatively flat areas with a total area of up to 500 m^2. Several modes of operation are possible: work with control via telemetry, work along a previously traveled route, work in automatic mode according to the program.

The AgrY automatic robotic lawnmower project is a set of devices that allow modernization of gasoline lawn mowers for automatic operation.

The complex can be based on an ordinary gasoline lawn mower, which has a suitable wheelbase. The wheels are removed and a modernized lawn mower is installed on the freed axles of a self-propelled wheel frame with electric wheel drive. The gear motors mounted on the rear wheel drive are powered by a powerful leadacid battery with 12 V helium electrolyte and an energy capacity of 60 A*h. Maneuvering is carried out by means of swivel wheels with an offset vertical axis.

To ensure safety, the mower is equipped with ultrasonic sensors-parking sensors, and a light-flashing warning lamp is fixed on the cover.

For the analytical part of the work, methods of strategic analysis, marketing and financial analysis and planning are used. For the calculation part, the methodology of economic analysis and financial planning is used.

3 Calculations and analytics

Based on the analysis of the practices of using agricultural robots, an overview of intelligent agricultural technology was carried out and the parameters of the market for the product being developed were determined.

3.1 Overview of Intellectual agricultural machinery

The agricultural industry is a promising market for the implementation of developments in the field of robotics, since the use of such machines allows you to create highly intelligent production. In this regard, in recent years, work on the design of robotic devices has intensified in the agricultural sector.

Basically, this technique is designed to perform repetitive operations in the cultivation of various agricultural plants. At the same time, the main purpose of its application in the agricultural industry is to replace human labor, minimize the harmful effects of chemicals on people and the environment, as well as increase the productivity of enterprises and the yield of cultivated crops.

Weed killer.

Today, the main method of combating weeds and parasites is the treatment of fields with special chemicals. However, they have an impact not only on harmful elements, but also on ordinary crops, get into the soil, and together with agricultural products - into human food. Therefore, a natural and environmentally friendly way to destroy them is traditional weeding, which involves uprooting weeds from the ground. At the same time, it is possible to remove them by another method - by cutting and hammering them into the soil. To facilitate this process, Amazone and Bosch, together with two universities, have developed the autonomous robot platform BoniRob, which is also equipped with a mechanical weed control module. The main purpose of the machine during operation is the young shoots of weeds, which it identifies with a high-resolution camera from the shape of the leaf.

However, the robot can handle adult specimens as well. In automatic mode, it detects weeds and, using a percussion tool with a diameter of one centimeter, drives them into the ground to a depth of three centimeters, spending about a tenth of a second on one plant. In addition, the device is designed to measure the condition of the soil and spraying plants. Depending on the type of work, one of the modules can be placed on the platform. The device has its own navigation system, can determine the GPS coordinates of agricultural species, create maps of the work performed and prepare the necessary documentation. The BoniRob has already been tested in a carrot field, where the distance between the roots was up to two centimeters and the weed density was about 20 plants / sq. m. In such difficult conditions the car did not experience any difficulties. The maximum operating speed was 1.75 plants / s while moving at a speed of 3.7 cm / s.

In addition, the universal platform can move a payload of up to 150 kg, and its generator is capable of providing energy for continuous operation for 24 hours with one refueling. The main idea of creating such a device is that a farmer can buy only one platform and several modules he needs, and he can rent other add-ons from a specialized organization. Today, the manufacturer is testing the robot in real conditions, and is also developing a version of a smaller universal platform and a set of replaceable modules for it. Such small devices can operate as part of groups, almost not inferior in performance to larger specimens.

Get around the obstacle.

Dutch Power Company has created the Greenbot robot, which is designed to perform repetitive operations in the field, in gardens or in the municipal sector. It is a four-wheel self-propelled machine with front and rear attachment systems for processing tools. Changing the direction of movement is carried out by turning the front, rear or all four wheels, as well as by the "crab" method. At the beginning of work, the operator, using the control panel, writes down the algorithm for moving and performing the entire cycle of operations in the machine memory. After that, the robot, on command, independently executes the set program, while responding to emerging barriers and other interference by signals from the sensor system. When an unknown obstacle is detected, the device stops and sends a text message to the user. Now two models of similar equipment are offered, differing from each other in overall width and weight. Both variants are powered by four-cylinder Tier 4 / Stage 3B emission standards. The models are equipped with a hydraulic transmission with differential locks, while the front power take-off shaft (PTO) is also hydraulic, and the rear one is mechanical. A GPS signal is used to correct motion in real time. The price for such a device starts from 120 thousand euros.

Soon, Kubota also plans to start selling the AgriRobo autonomous tractor in Japan, which performs routine operations without an operator and using GPS. To manage it, software was developed in collaboration with Topcon and Kansas State University to create a work plan prior to operations. The combination of sonar and scanner provides safe detection of fixed and mobile obstacles. Control and safety systems ensure that the machine does not perform hazardous maneuvers. The company is also working on the creation of grain harvesters and autonomous rice cultivation devices.

The principle of environmental friendliness.

Fendt is gradually developing a project to create autonomous agricultural devices called MARS, that is, Mobile Agricultural Robot Swarms - a system of mobile agricultural robots. The program was funded by the European Union with the assistance of the University of Ulm, which was developing satellite navigation devices for planting corn. The main idea of this project is to produce a small-sized multifunctional robot that will operate autonomously on an electric drive and be controlled remotely using cloud technologies. Fundamental to the program are, among other things, environmental factors - reducing soil damage, reducing carbon dioxide emissions into the atmosphere and the most silent operations. According to the company's plans, the robots will be transported to the field using a special transport module used as a charger and a seed hopper. Each device uses special software, the interface of which allows you to set the parameters of the field, the rate of planting of seed, the density of planting, the location of the crops and the number of working machines. Parameters and data are saved in the cloud service. According to Fendt representatives, such a solution makes it possible to carry out subsequent tillage more accurately and with less financial investment.

Autonomy program.

The concept of an autonomous tractor developed by Case IH and CNH Industrial's Innovation Group has already become quite famous in wide circles. They continue to improve this technology and deepen the development of the concepts of automation and autonomy in the field of agriculture. Thus, a bilateral dialogue was initiated with farmers around the world to find out how the practical implementation of this innovation could help increase the efficiency and profitability of their business. In addition, to study the potential of the concept and test it in real conditions, the company began implementing an autonomy and automation program. In an in-depth study on Customer Engaged Product Development, Case IH found that current and future technology needs can be categorized into five categories based on the degree of automation in agricultural field operations. These five activities include driving, coordination and optimization, operator-assisted automation, controlled and complete autonomy.

In 2018, the company began cooperation with the Bolthaus farm as part of a pilot autonomous tractor program. The aim of the collaboration is to understand how the new system can be used in a real world. In addition, it is necessary to determine the degree of its compliance with the existing requirements of farms. The pilot will focus primarily on primary tillage and deep cultivation, both of which are highly repeatable. The program will also test a small fleet of autonomous Steiger Quadtrac tractors, which must perform traction manipulations with True-Tandem disc harrows or Ecolo-Tiger subsoilers. These measures will help to assess the effectiveness of autonomous vehicles management in a variety of jobs and soil types in different weather conditions. One of the key tasks is also to obtain agronomic data and feedback from operators on the practical application of such technology in existing agricultural enterprises. Such measures will give the company the opportunity to continue developing and improving systems for managing and optimizing the operation of equipment.

Comprehensive solution.

Similar New Holland NHDrive tractors were built by CNH and Autonomous Solutions Inc. based on serial machines T8 and T7. Outwardly, they do not differ from conventional equipment and can be used both autonomously and in the traditional mode - under the control of the operator. The company is now working with E. & J. Gallo Winery to pilot the autonomous NHDrive technology in the T4.110F horticultural tractors. The main goal of this work is to obtain feedback from agronomists and operators on the potential for using innovation in the activities of wineries. This project is the latest phase of New Holland's Autonomous Vehicle Program, which explores the most promising areas of application for complex modern solutions in agriculture. The new pilot program demonstrates that the proposed development can be implemented in the entire line of the company's machines - from large universal row-crop tractors to specialized low-power equipment. It should be noted that within the framework of preliminary research activities, significant results have already been obtained in the field of integration of various components, in particular, sensor elements and signal receivers. The pilot project is focused on the full range of crop production and vineyard maintenance tasks. The test results will be used further as practical information for the full range of potential applications for automated solutions. Research through the Autonomous Machines Program is also helping to improve the technologies already available to customers as part of a precision farming system. For example, the fully automated end-of-row turning operation, which is triggered at the push of a button by the operator, significantly increases the efficiency of agricultural work, guaranteeing even greater farm productivity.

Suspended structures.

Agrirobo, together with the Institute of Technology and the University of Life and Environmental Sciences in the Polish city of Wroclaw, also prepared the Agribot robotic farmland processing system. The machine is a unit with a 55 kW engine and four independent propellers. The design provides high ground clearance and a small turning radius, which allows the mechanism to operate in confined conditions. Front and rear there are standard assemblies for mounting different implements. For example, a container for plant protection products can be attached at the back, equipment for spraying working fluid can be attached to the front. The robot is controlled remotely, due to which there is no risk of harmful effects of agrochemicals on the operator's body. The GPS system is used to determine the coordinates, and the assessment is made with an accuracy of one centimeter. Additional sensors allow you to navigate the field, and many manipulations are carried out offline. The robot is able to implement most of the basic operations - applying protective equipment and fertilizers, pruning trees, mowing and others.

The AT400 Spirit autonomous cabless tractor, developed by Autonomous Tractor, can also be used with a variety of trailed implements. It is equipped with an autonomy program based on GPS positioning using two additional ground-based positioning mechanisms. The basis of AutoDrive is a lidar-radar navigation system, wireless LAN connection, on-board control with artificial intelligence, which allows you to "teach" the tractor to perform repetitive operations without the need for programming. This system detects any obstacles in an area of about 10 m from the tractor, as a result of which the machine stops immediately and sends an SMS message. The operator can familiarize themselves with the situation using a rotating and tiltable digital video camera attached to the body. Another feature of the tractor is the eDrive drive. The power supply for this combination of electric motors is provided by an on-board generator based on an internal combustion engine. The drive power can be 74, 147 and 294 kW. Both systems can be installed on other chassis.

Precision and control.

Created by engineers from the University of Australia, the Ladybird robot, that is, "ladybug", is powered by solar panels. The name was dictated by the external similarity of these chargers with the wings of a flying insect. The mechanism is equipped with a laser guidance system and an integrated automated manipulator with which you can harvest. The tasks of the machine include control over the process of growing vegetables at all stages, detecting pests, as well as removing weed crops if necessary. The robot destroys weeds using not only herbicides, but also traditional knives, microwave radiation and laser beams. Equipped with sensors and cameras, the apparatus can spray chemicals with an accuracy of square centimeters, count plants one by one and get to hard-to-reach places.

Agrobot's Agrobot agro-industrial technological innovation center has developed the Agrobot SW6010 robotic strawberry growing and harvesting machine. Its design includes 14 or 60 manipulators with small metal baskets, a powerful computer and color sensors that recognize ripe strawberries among green leaves and ignore unripe berries. The unit has two working modules for control and packaging, as well as four steerable wheels for maneuverability. The dimensions and large steering angle are perfect for working both inside and outside greenhouses. The picking system controls a set of manipulators capable of locating and distributing strawberries based on size and ripeness. Each berry is analyzed, and the cutting process is carried out with the required accuracy, smoothness and sensitivity. A special system immediately packs the crop. The robot is powered by a 21 kW two-cylinder diesel engine. Tests have shown that the use of this device provides 50% reduction in the price of fresh strawberries and up to 90% - industrial for the production of purees and yoghurts.

Wide view.

British agricultural equipment manufacturer Garford Farm Machinery has created a dedicated monitoring module for the Robo-pilot tractor, which integrates two systems - Robocrop and automatic control using local information. The purpose of the first program is to drive the machine without the participation of the operator during inter-row cultivation of row crops. The device includes a video camera, an on-board computer, a hitch with a hydraulic side shift mechanism and a speed sensor. The cultivated crop in front of the unit is recorded using a video camera. The image is analyzed by a computer to detect a high concentration of green pigment, indicating the presence of an object. Thanks to the wide camera view and the processing of several rows at the same time, optimum central fixation is achieved. The result is compared with a grid of divisions corresponding to the row spacing. This information is used to accurately position the implements and then move them hydraulically. Since the Robocrop system works with multiple rows, a high degree of precision is ensured even in heavily weedy areas. Moreover, the device can independently control the high-speed cultivator of the rear hitch, being responsible for the movement of the tractor and equipment completely without human intervention. Travel speed is usually up to 12 km / h, but this value can be increased. The Quick Access Console is connected to the Robo-pilot system and has a touchscreen display with easy-to-understand symbols and user-friendly functions, making the unit easy to use.

Universal mechanism.

The developers of the multifunctional robotic unmanned vehicle for agricultural purposes "Robtrak VIM 0.6 (0.9) -36" are the agro-engineering center of the Federal State Budgetary Scientific Institution "FNATS VIM" and the company "KB Aurora". When it was created, the main task was to meet the needs of agricultural producers in integrated automation and robotization of performing basic and specific technological operations with the exclusion of human participation. Also, the calculation took into account the requirements of the all-season and environmental safety of the machine, that is, the possibility of its operation in any soil and climatic conditions. Another task was to ensure versatility - the implementation of technological operations not only in agriculture, but also in the municipal economy, as well as in road transport works, which implies the possibility of aggregation with a wide range of machines and tools. In addition, the creators have prepared a universal technological adapter for magnetic-pulse processing of plants, designed to stimulate the life and growth processes of planting material, vegetable crops and garden plants, including in greenhouses.

The control of the robotic device is carried out using a radio signal from a remote control or autonomously according to a given map of the area and marks of GLONASS / GPS navigation systems. You can track your current location on the map using information transmitted to your tablet computer via a Wi-Fi signal. The manual remote-control mode is not essential and may be required in exceptional cases, such as when overcoming difficult obstacles and the like. In the event of an interruption or complete loss of the signal from the satellite, the device is capable of performing work on a site previously plotted on the map and returning to the base with the land route. In addition, FGBNU "FNATS VIM" has developed an electric drive chassis for the field robot "Elekom 2.0", intended for the use of robotic technologies on it in breeding, horticulture and greenhouse vegetable growing.

Ease of Management.

Recently, KB Aurora tested a multifunctional robotic machine AgroBot at one of the agricultural complexes in the Ryazan region. For the first experimental series, a tractor with a two-cylinder diesel engine with an output of 18.4 kW and a mechanical reversing gearbox was chosen as a platform. The robot is equipped with a rear attachment system and a power take-off shaft, so that almost any attachment designed for this class of machines can be installed on it. The design allows you to change the agrotechnical clearance and track width for the installation of various wheels, and the body, developed according to modern design and technological standards, has convenient hatches for servicing all units and is universal for most tractors in its traction class. The control system underlying AgroBot can be installed on almost any special equipment, while special drives are mounted on all elements, which are controlled by a central computer. Also, the regulation process can be taken over by an operator located near the tractor or in the dispatch center. One employee can be responsible for the actions of several machines at the same time.

Over the next year, the company expects to conduct a series of test implementations of AgroBot and practice basic operations in unmanned mode using autonomous action scenarios. At the next stages of testing, the creators plan to test the systems in different weather conditions, evaluate the capabilities of dispatching and cooperative work with several similar machines on the same territory. In addition, optimization of the management process and simplification of the interface are planned.

Machine vision.

The domestic company Cognitive Technologies conducted tests of unmanned tractors with a computer vision system of its own design in the Republic of Tatarstan. According to experts, the cost of such a software and hardware complex is no more than 15% of the total price of the machine. The equipment is not yet planned to be equipped with a lidar, because this will significantly increase its cost. It is supposed to install computer vision devices on it, including a stereo pair - a system of two cameras that shoot video with Full HD resolution. In addition, the package includes navigation and inertial sensors GLONASS and GPS, as well as a computing unit.

The unmanned vision system makes it possible to detect dangerous objects with high accuracy, determine their size and coordinates for drawing high-precision maps, making it possible to remove them even before the harvesting campaign, when they can pose a real threat. Drawing up a digital map of the field and drawing on it the surrounding objects, for example, pillars, stones and others, are carried out during pre-sowing operations - fertilizing and harrowing. According to these schemes, the tractor will navigate during harvesting - bypass objects that could not be removed from the field in spring. The developers claim that the system can recognize obstacles ranging in size from 10-15 cm at a distance of 15-20 m. In the future, the computer vision software and hardware complex is planned to be installed not only on tractors, but also on other agricultural machines - combines, seeders and others. Unmanned vehicles in Russia will be promoted by a new agricultural holding, which is being created by Cognitive Technologies together with Rostselmash and Soyuz-Agro companies.

A family of technology.

Research and development in the field of robotics is also carried out at the Institute of Informatics and Regional Management Problems, a branch of the Federal Research Center "Kabardino-Balkarian Scientific Center of the Russian Academy of Sciences", where a prototype of the AgroMultiBot.Garnet mobile robot was created for collecting fruits and vegetables in the open field in an autonomous mode. The device is the first in a set of devices for robotic agricultural production. The developers plan to create a family of equipment, which will include the Pearl row-crop robot, the Topaz transport robot, the Sapphire service robot, and Garnet and Hyacinth collectors for open and closed ground. The main functionality of such machines will be implemented in a mounted robotic module, which is a frame with two manipulators, a belt conveyor, a turner and a sensor system for fruit recognition. In addition, the system includes a charging station, a phytosanitary cultivator, a sprinkler and others. To adjust the key algorithms, a test platform was developed, consisting of a mounted robotic module and a transport platform on low-pressure tires.

The family of technology implements the concept of automated agricultural production based on the consistent development and implementation of a series of mobile autonomous robots. Each of them will perform a different set of agrotechnical operations from the others. The combined use of all mechanisms will provide a complete functionally closed cycle, and the farmer will be able to purchase and implement each robot separately or the entire family at once. The devices can be used simultaneously with the machines and automation equipment available on the farm. The advantage of AgroMultiBot in the agricultural production process will be the replacement of up to 25 people in the field. At the same time, an additional collection of 30-50% of the crop remaining in the field during traditional harvesting will be provided. Thus, today, various robotic machines for agriculture, both foreign and domestic, have been developed and are being tested quite successfully.

3.2 Agricultural Robot Market Assessment

Research works on agricultural robotics cover a wide range of applications, from automated harvesting using professional manipulators that are integrated with custom designed mobile platforms and innovative grippers such or autonomous targeted spraying for pest control in commercial greenhouses, to optimum manipulator design for autonomous de-leafing process of cucumber plants, and simultaneous localization and mapping techniques for plant trimming. Most of the published literatures in this context are focused on vision-based control, advanced image processing techniques, and gripper design for automated harvesting of valuable fruits or navigation algorithms and robust machine vision systems for development of field robots that can be used in yield estimation, thinning, weeding and targeted spraying, seedling and transplanting, delicate handling of sensitive flowers, and multipurpose autonomous field navigation robots. In addition to these, several virtual experimentation frameworks have been developed for agricultural robots. [10]

An approximate classification of agricultural robots based on existing samples is presented in Table 1.

Table 1 - Classification of agricultural robots

Product	Function	Tasks performed and other information	Website
Single purpose - robots			
Cerescon	Asparagus harvesting robot	Harvests asparagus, covers scarcity of specialized manpower for hand harvesting	https://www.cerescon.com/EN/home
Deserbiocut	Weeding robot	Weeds and maintains soil covers, prototype of a mechanical weeding robot powered by solar energy	https://deserbiocut.com/
Jackal	Research platform	Scouts and monitors, equipped with sensors of many different types	https://www.clearpathrobotics.com/jackal-small-unmanned-ground-vehicle/

Product	Function	Tasks performed and other information	Website
HV-100	Material handling robot	Handles green materials and plants contained in pots	https://www.public.harvestai.com/
Swarm Farm	Crop protection robot	Sprays products for crop protection, is able to work in swarms	https://www.swarmfarm.com/
Ecorobotix	Weeding robot	Weeds and maintains soil covers, prototype of a mechanical weeding robot powered by solar energy	https://www.ecorobotix.com/en/autonomous-robot-weeder/
Dino	Weeding robot	Weeds vegetable crops	https://www.naio-technologies.com/en/agricultural-equipment/large-scale-vegetable-weeding-robot/
Ted	Weeding robot	Weeds vegetable crops	https://www.naio-technologies.com/en/agricultural-equipment/vineyard-weeding-robot/
Oz	Weeding robot	Weeds protected crops	https://www.naio-technologies.com/en/agricultural-equipment/weeding-robot-oz/
Harvest Croo	Strawberry harvesting robot	Inspects and picks ripe strawberries, covers scarcity of specialized manpower for manual harvesting	https://harvestcroo.com/
Vitirover	Mowing robot	Mows permanent covers in perennial crops	https://www.vitirover.fr/en-robot
Agrorobot	Autonomous strawberry picking robot	Harvests strawberries in row crops	https://www.agrorobot.com
Guss	Autonomous spraying robot	Moves through orchards without an onboard operator using sophisticated combination of GPS, LiDAR, vehicle sensors and proprietary software to	https://gussag.com
Vinerobot	Autonomous vineyard scouting robot	Scouts vineyards and monitors soil and crop parameters to advise on irrigation, treatments and crop status	https://www.youtube.com/watch?v=O13z1OvwM3Y
Multipurpose platforms			
Digital Farmhand Robot/Agerris	Multipurpose platform	Couples with conventional implements, designed for small-scale farming	www.agerris.com/
DOT	Multipurpose platform	Couples with conventional implements	www.seedtorun.com
Farmdroid	Seeder-weeder platform	Powered by solar energy	http://farmdroid.dk/
Husky	Development platform	Autonomous platform used to carry payload, carry sensors or serve for other types of operations	https://www.clearpathrobotics.com/husky-unmanned-ground-vehicle-robot/
Robotti	Implement platform carrier	Diesel-powered platform that can operate tillage equipment, seeders and weeders	http://agrointelli.com/robotti-diesel.html#rob.diesel
CEOL	Implement platform carrier	Autonomus platform that can carry conventional implements for soil preparation, seeding, weeding and spraying	https://www.agreenculture.fr/
Automated agricultural equipment			
Hands Free Hectare	Automation of existing equipment	This Harper Adams University project has operated 1 ha over 3 years cultivating cereal crops without any direct human intervention on the ground using automated existing agricultural equipment. It is currently expanding and testing the technology with farmers in the area.	http://www.handsfreehectare.com/
Bear Flag	Self-driven technology for tractors and implements	The company has developed a technology that converts conventional tractors and implements into self-driven autonomous equipment.	http://bearflagrorobotics.com/

Product	Function	Tasks performed and other information	Website
University of Hokkaido	Automation of existing equipment	The Agricultural Research Institute in collaboration with Japanese machinery manufacturers has developed a technology that allows existing tractors and equipment to work in swarms and perform farm operations autonomously.	https://youtu.be/pvzez_CWztQ

Agricultural robotics is a promising solution for digital farming and for handling the problems of workforce shortage and declining profitability. Initial tests with one of the most recent technologies available for automated harvesting has already shown a success rate of 65% and detachment rate of 90% for sweet pepper harvesting in real planting scenario where no leaves and occluded fruits were trimmed or removed. Field agent robots that autonomously monitor and collect data empower growers with real-time detailed information about their crops and farms, revealing upstream images for making data-driven decisions. Agricultural robotic is taking farming practices to a new phase by becoming smarter, detecting sources of variability in the field, consuming less energy, and adapting their performances for more flexible tasks. They have become an integral part of the big picture in the future production of vegetable and crops, i.e., growing plants in space or development of robotized plant factories for producing vegetables in Antarctica. The trend in food production is towards automated farming techniques, compact Agri-cubes, and cultivation systems that have the minimum human interface where skilled workforce are being replaced with robotic arms and mobile platforms. In this context digital farming have integrated new concepts and advanced technologies into a single framework for providing farmers and stakeholders with a fast and reliable method of real-time observations at the plant level (i.e., field data collection and crop monitoring) and acting at a more precise scale (i.e., diagnostics, strategic decision-making, and implementing). Digital farming is about collecting high-resolution field and weather data using ground-based or aerial based sensors, transmitting these data into a central advisory unit, interpreting and extracting information, and providing decisions and actions to the farmers, field robots, or agro-industries. Examples include thermal-RGB imaging system for monitoring of plant and soil for health assessment, creation of information maps (i.e., yield and density maps), and data sharing. Implementation of digital farming practices result in a sustainable, efficient, and stable production with a significant increase in yield. Some of the technologies involved in digital farming include the Internet of Thing, big data analysis, smart sensors, GPS and GIS, ICT, wireless sensor networks, UAV, cloud computing, simulation software, mapping applications, virtual farms, mobile devices, and robotics. A conceptual illustrating of digital farming and its relationship with agricultural robotics is provided in Figure 6, showing that the collected data by the robot agents are sent to a cloud advisory center for decision makings. The actions are then implemented quickly and accurately by the use of robots or other automated machinery, sending operational updates and notification feedbacks to the farmers and agro-industry sections. This system of computer-to-robot communication combined with the sophisticated simulation software, analytics applications, and data sharing platforms offers a much smoother control over farming operations. In addition, it provides farmers with details of historical field data for improving their performances and optimizing crop yields for specific plots, or even developing new business models.

Research efforts for development of agricultural robots that can effectively perform tedious field tasks have grown significantly in the past decade. Apart from milking robots that were invented in the Netherlands, robotics has not reached a commercial scale for agricultural applications. With the decrease of the workforce and the increase of production cost, research areas on robotic weeding and harvesting have received more and more attention in the recent years, however the fastest available prototype robots for weeding and harvesting are not even close to being able to compete with the human operator. For the case of picking valuable fruits using robots, the technology is now becoming closer to a commercial product with the emerging of the SWEEPER. For other fruits such as citrus and apples that can be mass harvested for juice industry, modifications of the existing mechanical harvesting systems with some robot functionalities may be more promising than using single robot system. Increasing the speed and accuracy of robots for farming applications are the main issues to be addressed for generalization of robotics systems, however, compared to the industrial and military cases, the lack of abundant research funding and budgets in agriculture has decelerated this process. For the case of robot harvesting, improving sensing (fruit detection), acting (manipulator movement, fruit attachment, detaching, and collecting), and growing system (leave pruning and plant reshaping) are suggested to increase the efficiency. It should be noted that development of an affordable and effective agriculture robot requires a multidisciplinary collaboration in several areas such as horticultural engineering, computer science, mechatronics, dynamic control, deep learning and intelligent systems, sensors and instrumentation, software design, system integration, and crop management. We highlighted some of the facing challenges in the context of utilizing sensors and robotics for precision agriculture and digital farming as: object identification, task planning algorithms, digitalization, and optimization of sensors. It was also mentioned that for an autonomous framework to successfully execute farming tasks, research focus should be toward developing simple manipulators and multi-robot systems. This is in fact one of the academic trends and research focuses in agricultural robotics for building a swarm of small-scale robots and drones that collaborate to optimize farming inputs and reveal denied or concealed information. As of the conclusion, some forms of human-robot collaboration as well as modification of the crop breeding and planting systems in fields and greenhouses might be necessary to solve the challenges of agricultural robotics that cannot yet be automated. For example, in a collaborative harvesting system using human-and-robot, any fruit that is missed by the robot vision will be spotted by the human on a touchscreen interface. Alternatively, the entire robot sensing and acting mechanism can be performed by a human operator in a virtual environment. Nevertheless, an agricultural robot must be economically viable which means it must sense fast, calculate fast, and act fast to respond to the variability of the environment.

Роботизация меняет традиционные методы ведения сельского хозяйства. При этом новые технологии используются для повышения эффективности хозяйственной деятельности в условиях нехватки квалифицированной рабочей силы.

Инновационные разработки покрывают разные сектора сельского хозяйства неравномерно. Крупные компании акцентируют внимание на высокопроизводительной технике и технологических решениях «под ключ» для крупных сельхозпроизводителей, тогда как проблемам мелких хозяйств и отдельные техпроцессы остаются практически без внимания.

Robotization is changing traditional farming methods. At the same time, new technologies are used to improve the efficiency of economic activities in the face of a shortage of qualified labor.

Innovative developments cover different agricultural sectors unevenly. Large companies focus on high-performance equipment and turnkey technological solutions for large agricultural producers, while the problems of small farms and individual technical processes are practically ignored.

The project is focused on meeting the needs of small agricultural enterprises that produce up to 12.5% f agricultural products in the Russian Federation (Table 2, 3).

Table 2 - Share of agricultural products by types of agricultural producers, %

	Average size, hectare / farm	Average proceeds from the sale of agricultural products, mln rubles	% in agricultural production
Agricultural organizations	4136	108,6	52,8
Peasant farms	456	4,3	12,5
Households	0,7	-	34,7

Agricultural organizations are large farms. However, as the data in Table 2 show, most of them (84.2%) belong to small businesses and only 4.7% to large ones.

Competition in this market niche is insignificant. Basically, this is a "confrontation" of startups that are trying to solve the same problem. The market is not saturated and needs technologies that will ensure food production with minimal environmental impact and energy consumption.

The main directions of development of robotic systems are:

- systems for livestock farms;
- sowing, land-working robotics;
- unmanned tractors;
- unmanned aerial vehicles;
- systems for harvesting;
- systems for applying plant protection products, fertilizers and irrigation.

Table 3 – Characteristics of organizations by types of business entities

Farm groups	Share in the number of farms, %	Employed, people/farm	Land, hectare / farm	Share in profit,%	Revenue from agriculture	
					% on the group	RUB mln / farm
Micro	48,5	6	1327	5	4	8,5
Small	35,7	45	4398	22	19	56,8
Average	11.1	154	9497	24	22	215,1
Large	4,7	607	19 118	49	56	1302,1
All farms	100	64	4164	100	100	109,4

According to the forecasts of the Tractica company, the size of the agricultural robot market will reach $ 74.1 billion by 2024 (Figure 4). The production of agricultural robots will increase during this time almost 19 times to 594 thousand units of equipment. In 2021, this figure was 240 thousand robots.

At the same time, a significant part of the need for agricultural robots (up to 77%) is formed by animal husbandry. (Figure 5)

The main problems of robotization of agriculture:

- heterogeneity of the working environment for robots;
- the problem of identification and classification of targets and obstacles on the way of movement;
- insufficiently developed navigation technology;
- labor safety of employees;
- difficulties associated with the characteristics of agricultural processes.

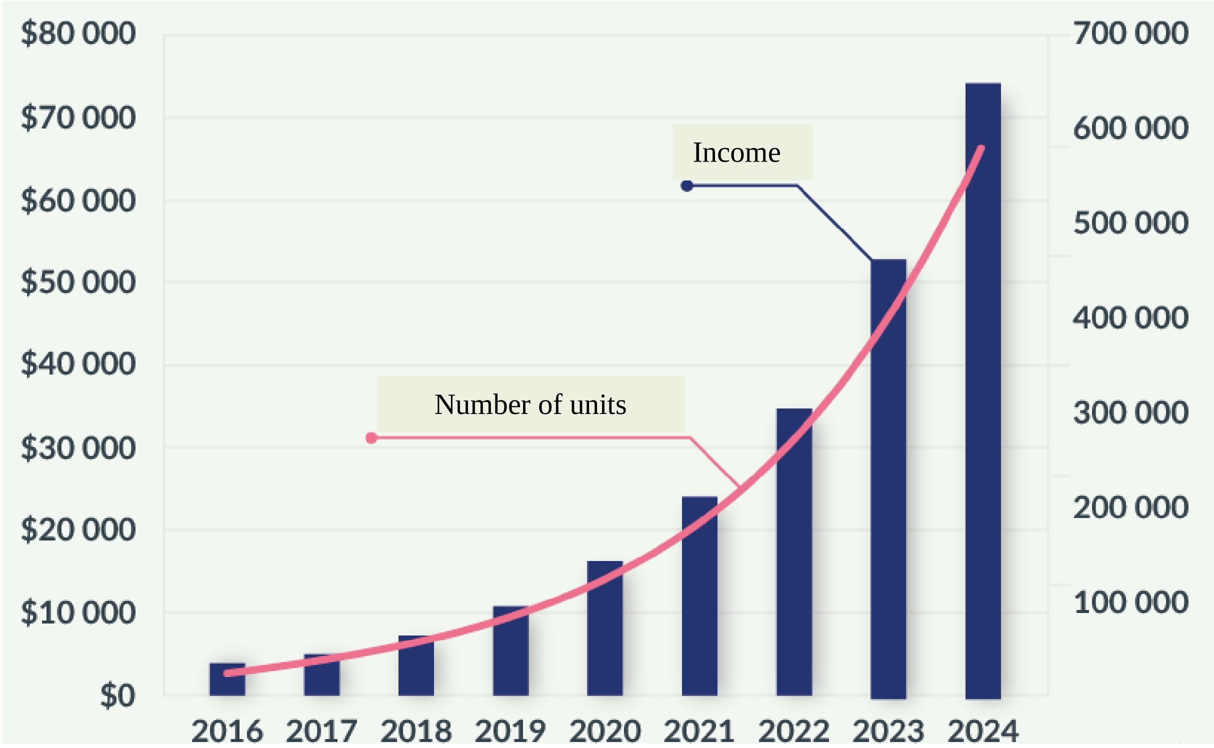

Figure 4 - Agrorobotics market development forecast

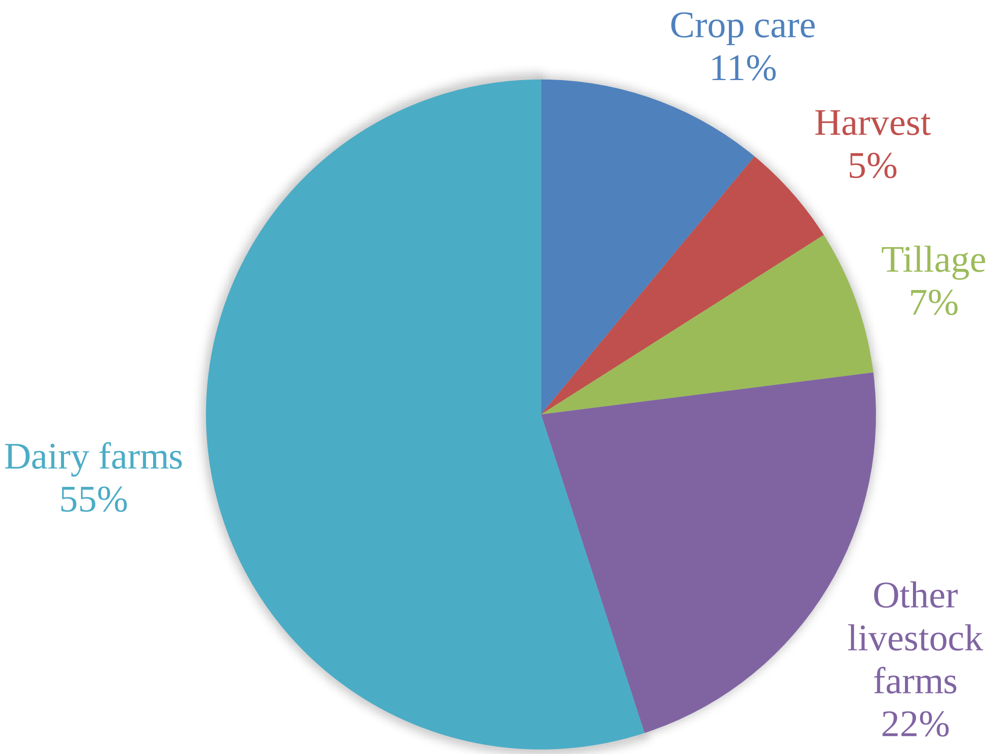

Figure 5 - Agricultural robot market

Modern self-propelled equipment can work in the field using an autopilot. Accurate work in the field can reduce time and recycling costs by up to 20%. At the same time, fuel is saved, mineral fertilizers are consumed more reasonably, and the cultivation of fields with herbicides is improved. All known automatic piloting systems involve the installation of a heading indicator, controller and receiver of signals of global satellite positioning GLONAS or GPS. These devices are relevant when working on large areas. The use of differential correction from geostationary satellites or from ground base stations, as a rule, is paid, which practically nullifies the effectiveness of the use of these systems in small self-propelled vehicles, in rural areas.

4 The results of the research

4.1 Business model of commercialization of a mobile robotic platform for agricultural purposes

Project name: Intelligent robotic control complex for small self-propelled vehicles.

Project executor: Yurga - Technologies - Innovations LLC.

Taxation system: simplified taxation system (STS Income minus expenses).

The essence of the project: the organization of a service for the automation and maintenance of small self-propelled equipment of agricultural organizations and peasant farms.

Intellectual property: Certificate of state registration of the computer program "Calculation of the trajectory of movement, positioning and remote control of the movement of the agro-technical mobile robot AgrYX"

Project financing:

Own funds 500 thousand rubles.

Investment requirement 2,000 thousand rubles.

Investments are attracted to refine and prepare for serial production of the mobile platform RTK.

Project duration: 3 years; Calculation step: half a year

Key project indicators:

Table 3 - Key project indicators

Key project indicators.	1.	2.	3.	4.	5.	6.	*TOTAL*
Sales revenue (excluding VAT)	510	816	1 020	1 164	1 308	1 452	*6 270*
Production costs (excluding VAT)	776	866	927	970	1 013	1 057	*5 609*
Profit before tax, interest and amortization (EBITDA)	-266	-50	93	194	295	395	*661*
Earnings before interest and tax (EBIT)	-266	-50	93	194	295	395	*661*
Profit before tax	-266	-50	93	194	295	395	*661*
Net income (loss)	-271	-59	83	174	264	354	*545*
Retained earnings (for the period)	-271	-59	83	174	264	354	*545*
Investments in non-current assets	-1 000	-1 000	0	0	0	0	*-2 000*
Working capital investment	115	2	1	5	5	5	*133*
Own funds and targeted financing	1 500	1 000	0	0	0	0	*2 500*
Total cash flow for the period	344	-57	84	179	269	359	*1 178*
Cash at the beginning of the period	0	344	287	371	549	818	
Cash at the end of the period	344	287	371	549	818	1 178	

Table 4 - Efficiency of total investment costs

Efficiency of total investment costs		
Net Present Value (NPV)	230	₽1 000
Discounted Payback Period (PBP)	2,94	years
Internal Rate of Return (IRR)	11,1%	(real - excluding inflation)
Present rate of return (PI)	111%	%

Partner organization

LLC "YUTI" was registered on April 10, 2012.

The main activity is "Research and development in the field of natural and technical sciences."

Currently, organization is implementing projects for the development of mobile robotic platforms, including those for agriculture. The organization has sufficient production capacity for small-scale and pilot production. Qualified engineers, electrical engineers and programmers are involved in the work.

The organization intends to expand its presence in the agricultural machinery market.

Market and product

The main technical parameters that determine the quantitative, qualitative and cost characteristics of products are based on competitors' products available on the market.

To date, several similar foreign samples of such equipment are known.

Marketing complex.

The project is being implemented according to the B2B model.

The product of the project is a universal hardware and software complex adapted to control small self-propelled agricultural machinery.

1. The product is sold as a set:

- control system (electrical components);

- software product that determines the current position of the hardware and determines the algorithm for its movement;

- services for the maintenance of the hardware and software complex (operator training, programming, software update, troubleshooting).

2. Estimated product price:

- control system - RUB30 thousand;

- software product - RUB 20 thousand;

- annual service - RUB120 thousand.

3. Promotion is supposed to be organized through the website https://www.zizibot.ru/, participation in specialized exhibitions, publications in magazines.

4. Sales are organized through the website https://www.zizibot.ru/.

Project advantages:

- the quality of the development is confirmed by a grant from the Fund for the Promotion of Innovations;

- competitive prices focused on domestic agricultural producers;

- the possibility for the customer to receive a preferential loan for the purchase of a software and hardware complex within the framework of the state program for supporting agricultural producers;

- experience and reputation of the project executor.

SWOT - analysis of factors affecting the achievement of program objectives and overall assessment of the project:

Strengths: High quality product Competitive prices The presence of regular customers	**Opportunities:** Expanding the scope of the product Production of RTK on its own mobile platform
Weaknesses: Low solvency of agricultural producers The need to embed robots into the existing technological	**Threats:** Unfavorable financial and economic situation The emergence of a major competitor Problems with the supply of electronic components

Figure 6 - SWOT analysis

Possible risks and sources of their occurrence:

Commercial risks:

- implementation risk.

Economic risks:

- risks associated with low insolvency of agricultural producers;
- restricting the import of electronic components.

Sources of risks:

- failure of the company to promote the product;
- falling demand;
- restrictions on foreign trade.

A startup model is proposed for the project being implemented. The organization of a startup focused on the completion and implementation of the basic prototype of a robotic platform - a pusher robot for livestock farms - was chosen as a commercialization model. Additional specializations for the platform and their corresponding modules are proposed to be developed according to the model of commercial R&D.

Target market characteristic.

Target segment - small and medium-sized agricultural enterprises using agricultural machinery automation.

Russia market – consumers focused on the products of Belarusian factories - manufacturers of agricultural machinery.

World market – consumers of small agricultural machinery.

Target sales market size, in rubles:

PAM (potential market size) ₽ 41,592 million.

TAM (total target market size) ₽ 3,972 million.

SAM (available market size) ₽ 242 million

SOM (realistically achievable market size) ₽ 90 million

Value proposition for the target audience (Figure 7):

- Reducing the cost of field work for enterprises using agricultural machinery automation by eliminating expensive satellite navigation systems

Monetization methods (revenue channels):

- Conclusion of an agreement with a manufacturer of small agricultural machinery on the pre-installation of control systems (we use ready-made distribution channels).
- Sale of management systems to agricultural enterprises using agricultural machinery automation.

Key manufacturing processes:

- Designing robots for small mechanization,
- Commercial R&D,
- Automation of related processes.

Key Resources:

- Electronic components

Main partners, suppliers:

- Agricultural machinery manufacturers
- Component Suppliers

Promotion strategy and main channels for attracting an audience:

- Use of partner promotion channels
- Participation in specialized exhibitions
- Leasing in the agro-industrial complex

What offers and tools to retain customers and ensure repeat sales:

- Service maintenance,
- Complex automation of agricultural machinery,
- Discount for the number of automated objects of the same type

Key partner
Agricultural machinery manufacturers
Component Suppliers

Key activities
Designing robots for small mechanization
Commercial R&D
Automation of related processes

Key recourses
Electronic components

Value proposition
Reducing the cost of field work for enterprises using agricultural machinery automation by eliminating expensive satellite navigation systems

Customer relationships
Service maintenance, complex automation of agricultural machinery with a discount for the number of automated objects of the same type

Sales channels
Use of partner promotion channels
Participation in specialized exhibitions
Leasing in the agro-industrial complex

Customer segment
Small and medium-sized agricultural enterprises using agricultural machinery automation

Cost structure
Development and assembly of robots, development and installation of software, user training

Revenue streams
Pre-installation of software under an agreement with manufacturers
Sale of control systems to agricultural enterprises

Figure 7 - Business model of the project

Product roadmap is on Figure 8.

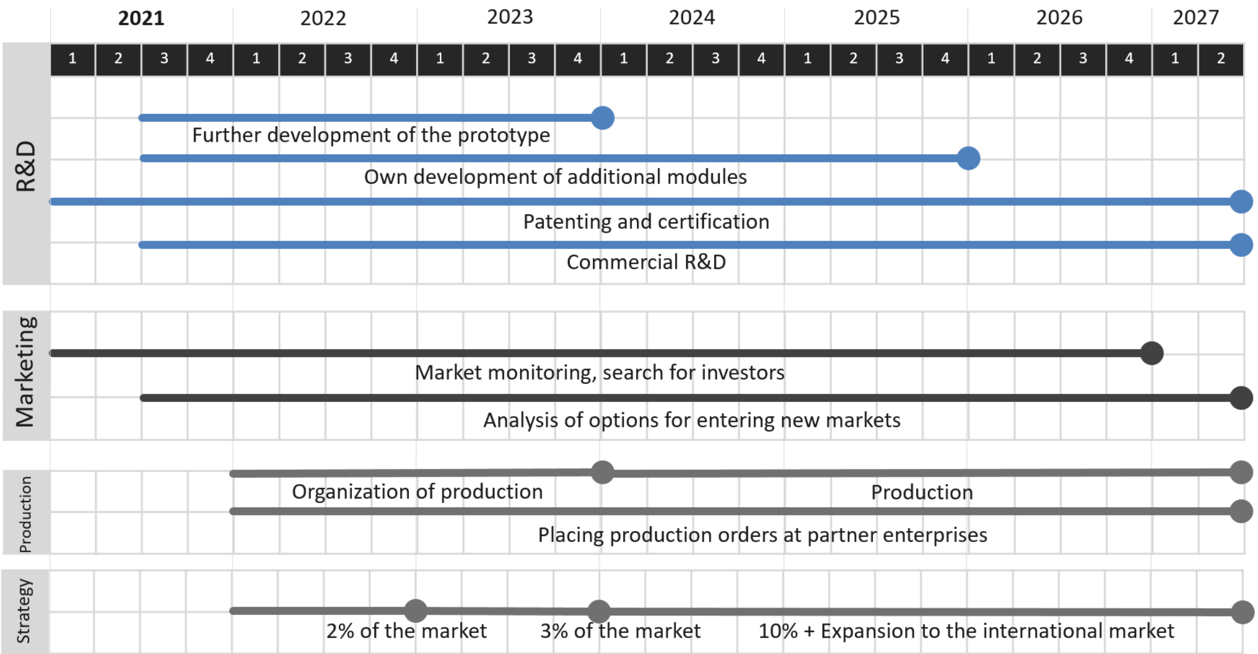

Figure 8 – Product roadmap

4.2 Indicators of the project for the development of a universal robotic platform for agricultural purposes

The project involves investments in the amount of 2,500 thousand rubles. At the same time, the partner organization undertakes to participate in the financing of targeted expenses in the amount of 500 thousand rubles. Attracted financing 2,000 thousand rubles. necessary for R&D to develop its own mobile platform RTC.

The qualifications of the management personnel are sufficient for the implementation of the project. To implement the project, in addition to the existing organizational structure, it is necessary to organize 4 workplaces:

Table 5 - Staff and wages

STAFF AND Wages, ₽1000	1.	2.	3.	4.	5.	6.	*TOTAL*
Main production personnel							
Process engineer	120	120	120	120	120	120	*720*
number	1	1	1	1	1	1	
Monthly salary	20,00	20,00	20,00	20,00	20,00	20,00	
Programmer	120	120	120	120	120	120	*720*
number	1	1	1	1	1	1	
Monthly salary	20,00	20,00	20,00	20,00	20,00	20,00	
Electrical engineer	120	120	120	120	120	120	*720*
number	1	1	1	1	1	1	
Monthly salary	20,00	20,00	20,00	20,00	20,00	20,00	
Commercial staff							
Marketer	120	120	120	120	120	120	*720*
number	1	1	1	1	1	1	
Monthly salary	20,00	20,00	20,00	20,00	20,00	20,00	
= Total	**480**	**480**	**480**	**480**	**480**	**480**	***2 880***
Accrued insurance payments	**144**	**144**	**144**	**144**	**144**	**144**	***864***
Payroll expenses including insurance	**624**	**624**	**624**	**624**	**624**	**624**	***3 744***
Total headcount	*4*	*4*	*4*	*4*	*4*	*4*	

Table 6 - Realization price

REALIZATION PRICE (per unit, ₽1000)	1
Control system	30,00
Software	20,00
Service	120,00

Table 7 - Sales income

SALES INCOME, ₽1000	1.	2.	3.	4.	5.	6.	*TOTAL*
Control system	90	144	180	180	180	180	***954***
Software	60	96	120	120	120	120	***636***
Service	360	576	720	864	1 008	1 152	***4 680***
= Total	510	816	1 020	1 164	1 308	1 452	***6 270***

Table 8 - Taxes

SIMPLIFIED TAX SYSTEM, ₽1000.								
Object of taxation	*Income reduced by the amount of expenses*							
rate	15,0%							
Assessed tax		**5**	**8**	**10**	**20**	**31**	**42**	***116***
the same, in the final currency		5	8	10	20	31	42	*116*
Taxable base before writing off losses		-266	-2 056	85	193	295	395	*-1 354*
accumulated profit / loss of the current year		-266	-2 321	85	277	295	690	
losses of previous periods		0	0	-2 321	-2 296	-2 238	-2 149	
written off losses of previous years		0	0	-25	-58	-88	-119	
The base on which the tax is charged		0	0	59	135	206	277	
Minimum tax		5	8	10	12	13	15	
Insurance premiums		**144**	**144**	**144**	**144**	**144**	**144**	***864***
rate	30,0%	30%	30%	30%	30%	30%	30%	
taxable base		480	480	480	480	480	480	*2 880*
Total payments		**149**	**152**	**154**	**164**	**175**	**186**	***980***

Table 9 - Cash flow report

CASH FLOW REPORT, ₽1000	1.	2.	3.	4.	5.	6.	*TOTAL*
Sales proceeds	510	816	1 020	1 164	1 308	1 452	*6 270*
Material and component costs	-126	-202	-252	-288	-324	-360	*-1 552*
Other variable costs	0	0	0	0	0	0	*0*
The salary	-480	-480	-480	-480	-480	-480	*-2 880*
Total costs	-26	-41	-51	-58	-65	-73	*-314*
Tax	-149	-152	-154	-164	-175	-186	*-980*
Other supply	0	0	0	0	0	0	*0*
Other costs	0	0	0	0	0	0	*0*
Cash flows from operating activities	**-271**	**-59**	**83**	**174**	**264**	**354**	***545***
Investments in land plots	0	0	0	0	0	0	*0*
Investments in buildings and structures	0	0	0	0	0	0	*0*
Investments in equipment and other assets	0	0	0	0	0	0	*0*
Investments in intangible assets	-1 000	-1 000	0	0	0	0	*-2 000*
Investment in financial assets	0	0	0	0	0	0	*0*
Payment of prepaid expenses	0	0	0	0	0	0	*0*
Increase in net working capital	115	2	1	5	5	5	*133*
Revenue from the sale of assets	0	0	0	0	0	0	*0*
Cash flows from investing activities	**-885**	**-998**	**1**	**5**	**5**	**5**	***-1 867***
Equity receipts	500	0	0	0	0	0	*500*
Special-purpose financing	1 000	1 000	0	0	0	0	*2 000*
Cash flows from financing activities	**1 500**	**1 000**	**0**	**0**	**0**	**0**	***2 500***
Total cash flow for the period	344	-57	84	179	269	359	*1 178*
Cash at the beginning of the period	0	344	287	371	549	818	
Cash at the end of the period	**344**	**287**	**371**	**549**	**818**	**1 178**	

Table 10 - Financial performance indicators

FINANCIAL PERFORMANCE INDICATORS		1.	2.	3.	4.	5.	6.
Return on assets	%	-80,5%	-6,5%	7,1%	14,1%	19,6%	22,3%
Return on equity	%	-88,0%	-6,9%	7,5%	14,8%	20,6%	23,2%
Return on non-current assets	%	-108,2%	-7,8%	8,3%	17,4%	26,4%	35,4%
Direct expenses to sales proceeds	%	116,5%	82,1%	70,6%	64,9%	60,6%	57,0%
Profitability of sales	%	-53,1%	-7,2%	8,1%	14,9%	20,2%	24,4%
Share of fixed costs	%	83,8%	76,7%	72,8%	70,3%	68,0%	65,9%
Breakeven point	₽1000	863	883	896	906	916	926
Margin of safety	%	-69,1%	-8,2%	12,1%	22,1%	29,9%	36,2%
EBITDA margin	%	-34%	-6%	10%	20%	29%	37%
EBIT margin	%	-34%	-6%	10%	20%	29%	37%
Net profit margin	%	-35%	-7%	9%	18%	26%	33%
Effective income tax rate	%	0,0%	0,0%	11,0%	10,4%	10,5%	10,5%
Total liquidity ratio	times	3,00	2,47	3,17	4,50	6,42	8,87
Net working capital	₽1000	229	171	254	427	691	1 045
General solvency ratio	times	0,91	0,95	0,95	0,95	0,95	0,96
Autonomy ratio	times	10,73	18,70	19,25	19,88	21,11	22,93
The share of long-term loans in the balance sheet	%	0%	0%	0%	0%	0%	0%
Total debt coverage ratio	times	-	-	-	-	-	-
Loan interest coverage	times	-	-	-	-	-	-

Table 11 - Efficiency of total investment costs

EFFICIENCY OF TOTAL INVESTMENT COSTS		
Annual discount rate:		
	10%	%
Net cash flow		
Discounted net cash flow	*545*	₽1000
	230	₽1000
Simple payback period		
	2,88	year
Net Present Value (NPV)		
Discounted Payback Period (PBP)	**230**	₽1000
Internal Rate of Return (IRR)	**2,94**	year
Present rate of return (PI)	**11,1%**	*(real - excluding inflation)*
Annual discount rate:	1,11	times

Table 12 - Business assessment

BUSINESS ASSESSMENT, ₽1000	1.	2.	3.	4.	5.	6.	*TOTAL*
Settlement currency:							
Annual discount rate:	10%	10%	10%	10%	10%	10%	
Long-term post-forecast growth rates							
Cash flow for equity	**-1 156**	**-1 057**	**84**	**179**	**269**	**359**	***-1 322***
Net profit	-271	-59	83	174	264	354	*545*
Depreciation	0	0	0	0	0	0	*0*
Change in net working capital	-115	-2	-1	-5	-5	-5	*-133*
Investments	-1 000	-1 000	0	0	0	0	*-2 000*
Change in long-term debt	0	0	0	0	0	0	*0*

BUSINESS ASSESSMENT, ₽1000	1.	2.	3.	4.	5.	6.	*TOTAL*
Discounted cash flow	-1 140	-1 013	78	162	237	307	*-1 369*
Extended project cost	**12 201**	₽1000					
Total business value	**8 908**	₽1000					

Table 13 - Sensitivity analysis

SENSITIVITY ANALYSIS			
Variable parameter			
Sales volume (in units of products)			
In the interval			
from:			
	with step:	85%	from the planned value
		5%	
Final indicator			
	NPV for total investment costs		
Calculated values table			
Variable parameter		Value	Result
		85%	*-338*
	Sales volume (in units of products)	*90%*	*-147*
		95%	*41*
	In the interval	*100%*	*230*
	from:	*105%*	*416*
	with step:	*110%*	*602*
		115%	*787*

5 Social responsibility

5.1. Workplace description

The accounting office was chosen as the object of research.

Cabinet characteristics: length - 5.7 m, width - 3.7 m, ceiling height 2.2 m, cabinet area S = 21.09 m2. The walls of the office are covered with beige wallpaper, the ceiling is painted white. The floor is covered with light brown linoleum.

Artificial lighting. The light sources are 2 universal lamps equipped with 5 incandescent lamps of 100 W, which are arranged in a row. There is 1 window with light shutters.

The microclimate parameters of the office are as follows [27]:

- work category - light 1a;
- air temperature: in the cold period (with artificial heating) is 22 - 24 ° C, in the warm period - 24 - 25 ° C;
- relative air humidity: during the cold period it is 45 - 55%, during the warm period - 41 - 52%;
- dust emission in the investigated room is minimal.

The parameters were measured by the labor protection commission of the branch of the Federal State Institution "Center for Hygiene and Epidemiology in the Kemerovo Region in the city of Yurga" and recorded in the protocol for instrumental control of the microclimate of industrial premises.

According to SanPiN 2.2.4.548-96 "Hygienic requirements for the microclimate of industrial premises", the requirements for microclimate parameters are as follows:

For the category of work - light 1a, the air temperature: in the cold period (with artificial heating) is: optimal 22-24 ° C, permissible 18-24 ° C, in the cold period: optimal 23-25 C, permissible 18-28 C.

Relative air humidity: in the cold period is 45 - 30%, permissible no more than 60%, in the warm period - 60-30%, permissible no more than 65%.

Thus, all parameters of the microclimate meet the standards.

There are two workplaces in the office, the working day lasts from 09:00 to 18:00 with a lunch break from 13:00 to 14:00. At the workplace of each employee there is a complete computer with a 17-inch LG Flatron L1951SQ monitor that meets the international TCO'99 standard, an HP LaserJet 1200 series printer and a XEROX WorkCentre 5222 Copier. The office is carried out daily wet cleaning. The room is ventilated naturally.

The parameters of the labor activity of accounting employees [27]:

- type of labor activity - group A and B - work on reading with a preliminary request and entering information from the monitor screen;
- categories of severity and intensity of work with a PC - group II (the total number of read or input characters per work shift is not more than 40,000 characters);
- object dimensions - 0.15 - 0.3 mm;
- category of visual work - II;
- subclass of visual work - G;
- the contrast of the object with the background is large;
- background characteristics - light;
- the noise level does not exceed 50 dB.

The parameters were measured by the labor protection commission of the branch of the Federal State Institution "Center for Hygiene and Epidemiology in the Kemerovo Region in the city of Yurga" and recorded in the protocol for instrumental control of the noise level.

Normative and technical documentation, in accordance with which the measurements were carried out and the conclusion was given CH №2.2.4 / 2.1.8.562-96. Sanitary standards. Noise at workplaces, in residential and public buildings and in residential and public buildings; GOST 12.1.036-81. Noise. Acceptable levels in residential and public buildings. The parameters correspond to the sanitary standards CH 2.2.4 / 2.1.8.562-96.

The office is equipped with a manual fire extinguisher OU-3 (designed to extinguish fires of various types, widespread in office premises with office equipment).

5.2. List of laws and regulations

When conducting a special assessment of the workplace, specialists are guided by the following regulatory documents:

1. Federal Law of 28.12.2013 N 426-FZ "On special assessment of working conditions".

2. Industry-wide qualification characteristics of the positions of workers employed at enterprises, institutions and organizations, approved by the Resolution of the Ministry of Labor of the Russian Federation of August 21, 1998 N 37 (as amended by the Resolutions of the Ministry of Labor of the Russian Federation of 21.01.2000 N 7, of 04.08.2000 N 57, of 20.04.2001 N 35, of 31.05.2002 N 38, of 20.06.2002 N 44, of 28.07.2003 N 59, of 12.11.2003 N 75, Orders of the Ministry of Health and Social Development of the Russian Federation of 25.07.2005 N 461, of 07.11.2006 N 749, of 17.09.2007 N 605, of 29.04.2008 N 200, of 14.03.2011 N 194, Orders of the Ministry of Labor of Russia of 15.05.2013 N 205, of 12.02.2014 N 96, of 27.03.2018 N 197).

3. The list of heavy work and work with harmful or hazardous working conditions, during which it is prohibited to use the labor of women (approved by the Government of the Russian Federation of February 25, 2000 N 162).

4. SanPiN 2.4.6.2553-09 Sanitary and epidemiological requirements for the safety of working conditions for workers under the age of 18, clause 2.2.

5. SanPiN 2.2.2 / 2.4.1340-03 Hygienic requirements for personal computers and work organization.

6. Order of the Ministry of Health and Social Development of the Russian Federation of April 12, 2011 No. 302n, Appendix 2, Clause 20.

5.3. Analysis of the internal factors of social responsibility

The analysis showed that the organization has all the necessary optimal working conditions for the employees of the technical school. The conclusions of the analysis are based on the following aspects:

- since the educational institution is fully funded by the state, and also conducts additional entrepreneurial activities, the remuneration of employees is of a permanent stable nature - salaries are paid to staff on time, on time, without delays, and the amount of salary corresponds to the size of the average salary in the region;
- the technical school provides an annual medical examination at the expense of the budget, for all employees;
- according to the established schedule of advanced training, the staff is given the opportunity to undergo the necessary training;
- when hiring, each new employee is required to undergo briefings on occupational safety, fire safety, etc., we note that training on actions in the event of an emergency is conducted with personnel and students regularly, in accordance with the established deadlines;
- the technical school works to ensure favorable relationships within the team;
- the technical school provides support to employees in a difficult financial situation, provides payments to support young parents at the birth of a child, and also provides a small financial support for employees who have lost their loved ones.

5.4. Analysis of the external factors of social responsibility

The analysis showed that the organization is trying to maintain this indicator at the optimal level.

Firstly, students and employees take an active part in sports events of various levels, are prize-winners, in charitable competitions of various levels and directions.

Secondly, the organization contributes to the protection of the environment - it organizes free-time work to clean up the territory of the enterprise and surrounding areas with the involvement of personnel and students.

The teaching staff and management work to engage their students in healthy lifestyles, sports, and nutrition.

Due to the prevailing epidemiological situation, the educational process was transferred to a remote form. There is a special regime for the presence of teachers and students in educational buildings.

The organization fulfills the epidemiological requirements prescribed by federal and regional legislation.

5.5. Legal and organizational issues of ensuring social responsibility

The organization bears full responsibility to employees as an employer. The work is organized in accordance with the Constitution of the Russian Federation, the requirements of the Labor, Tax and Civil Code of the Russian Federation.

The company's staff consists of an occupational safety engineer, whose main responsibility is to comply with mandatory legal requirements in the implementation of labor relations.

When hiring employees on the basis of an application, an employment contract is concluded. The employee gets acquainted with the job descriptions and receives instructions on safety at the workplace, which is noted in the relevant magazines.

Activities are also carried out within the framework of the regulatory and local documentation of the educational institution.

5.6. Conclusion on Social responsibility

The object of research was the accounting office.

As part of research, it was established [27]:

- type of labor activity - group A and B - work on reading with a preliminary request and entering information from the monitor screen;
- categories of severity and intensity of work with a PC - group II (the total number of read or input characters per work shift is not more than 40,000 characters);
- object dimensions - 0.15 - 0.3 mm;
- category of visual work - II;
- subclass of visual work - G;
- the contrast of the object with the background is large;
- background characteristics - light;
- the noise level does not exceed 50 dB.

Analysis of the factors of internal and external social responsibility showed that the organization pays great attention to organizing optimal working conditions for personnel, provides support to employees who find themselves in difficult life situations, and protects their health. The organization bears administrative and criminal responsibility for ensuring the safety of the educational process, is responsible for the safety of the life and health of students. The administration and teaching staff are working to attract students to a healthy lifestyle, sports and proper nutrition.

In general, the organization's activities are carried out within the framework of the regulatory and local documentation of the educational institution.

Conclusion

Industry 4.0 is the future of global manufacturing and all of 9 characteristics for industry (Cyber-Physical Systems, Internet of Things, Internet of Services, Big Data and Analytics, Augmented Reality, Autonomous Robots, Additive Manufacturing, Cloud Computing, Simulation) are inherent in the agricultural sector.

According to existing forecasts, the agricultural robotics market will grow to $ 70 billion by mid-2020. At the same time, a significant part of the market (55%) is made up of machinery used on livestock farms.

In the conditions of livestock farming, the use of a universal robotic machine based on a modular principle with replaceable working modules will reduce the cost of maintaining a machine park compared to completing it with specialized equipment. The production of a universal platform is also less expensive. Thus, the main difficulties of the project of a universal robotic platform for agriculture are the development itself and the choice of the optimal commercialization model.

The organization of a startup focused on the completion and implementation of the basic prototype of a robotic platform - a pusher robot for livestock farms - was chosen as a commercialization model. Additional specializations for the platform and their corresponding modules are proposed to be developed according to the model of commercial R&D.

The patent search showed the consistency of the product under development. Financial calculations confirmed the commercial feasibility of the project.

The following tasks were solved:

1. Assess the current state and future trends in the development of industry in general and agriculture.

2. Review and evaluate the agricultural robotics market.

3. Calculate a project for the development of a universal robotic platform for agricultural purposes.

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