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Managing a high-tech startup: A case of machine vision for the poultry industry

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Abstract. High-tech startups face a number of insurmountable problems that prevent them from turning innovative ideas into new products. The article investigates the managerial aspects of implementation and commercialization of high-tech startups in Russia using the case of an automated computer vision analytical system for industrial poultry farming. Entrepreneurship theory and the concept of strategic management constitute the theoretical basis of the study. Among the research methods used in the paper are the POCD framework in combination with SWOT analysis involved in the formation of startup management strategies, as well as Sandelovsky and Barroso's Meta-Synthesis method applied to identify factors that determine the successful implementation of a startup. The empirical evidence of the work was a bank of video data collected at the VNITIP Federal Research Center of the Russian Academy of Sciences and covering the full life cycle of broiler chickens. The paper established three main sources of funding for high-tech start-ups to introduce machine vision systems in the poultry industry: the state, industrial corporations, and venture capital. At that, none of the enterprises, including the global leaders, has yet reached the IPO stage. We identify two central lines to launch and commercialize a Russian start-up in poultry farming, these are association with developers of integrated digital solutions and/or integration with poultry meat producers. Recommendations are formulated regarding the implementation of a high-tech start-up: to form a public-private partnership, actively interact with research centers and universities, cooperate with business angels, expand the entrepreneurial competencies of startupers, and clarify the business model of the project. The mass introduction of machine vision technology in the poultry industry is possible due to the acceleration of technological progress and the elimination of the main obstacle, i.e., the high cost of components for machine vision systems.

Keywords: project management; high-tech startup; entrepreneurial idea; innovation; investment; commercialization; machine vision; poultry farming.

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Управление высокотехнологичным стартапом: кейс применения технологии машинного зрения в птицеводстве

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Аннотация. Высокотехнологичные стартапы сталкиваются с рядом труднопреодолимых проблем, которые препятствуют масштабному воплощению инновационных идей. Статья посвящена исследованию управленческих аспектов реализации и коммерциализации российского стартапа на примере создания автоматизированной аналитической системы машинного зрения для птицеводческих предприятий. Методология работы базируется на положениях теории предпринимательства и стратегического менеджмента. Методами исследования выступили комплекс POCD и SWOT-анализ, применяемые при формировании управленческих стратегий стартапа, а также метасинтез по Санделовскому и Баррозо, позволяющий идентифицировать факторы его успешной реализации. Информационную базу работы составил банк собранных на площадке ФНЦ ВНИТИП РАН видеоданных, охватывающих полный жизненный цикл цыплят-бройлеров. Установлены три основных источника финансирования высокотехнологичных стартапов по внедрению систем машинного зрения в птицеводство – государство, промышленные корпорации и венчурный капитал. При этом ни одно из предприятий указанной сферы, в том числе мирового уровня, пока не сумело выйти на стадию IPO. Выделены два ключевых направления запуска и коммерциализации российского стартапа в области птицеводства – объединение с разработчиками интегрированных цифровых решений и/или интеграция с производителями. Представлены рекомендации по реализации высокотехнологичного стартапа: формирование государственно-частного партнерства, активное взаимодействие с исследовательскими центрами и университетами, кооперация с бизнес-ангелами, расширение предпринимательских компетенций стартаперов, уточнение бизнес-модели проекта. Массовое внедрение технологии машинного зрения в птицеводство возможно вследствие ускорения технологического прогресса и устранения основного препятствия – высокой стоимости компонентов данных систем.

Ключевые слова: управление проектом; высокотехнологичный стартап; бизнес-идея; инновации; финансовые инвестиции; коммерциализация; машинное зрение; птицеводство.

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INTRODUCTION

High-tech startups are conceptually and terminologically defined as new micro-enterprises that, acting for profit, create and bring to the market high-tech products based on promising ideas [Blank, Dorf, 2019; Harris, 2019]. Startups are created for the implementation of specific innovative entrepreneurial ideas and become successful if these ideas can be introduced and commercialized [Hashai, Zander, 2018; Guo, 2019].

In the process of commercialization, startupers face many difficulties and, for the most part, fail to turn their entrepreneurial ideas into high-tech products [Presbitero, Roxas, Chadee, 2017; Henriques, Sobreiro, Kimura, 2018; Madzik, 2019; Gerasimenko et al., 2021]. To solve this problem, it is important to examine the conditions, circumstances and factors affecting commercialization. There is a number of studies devoted to these issues, but providing no in-depth analysis [Van Norman, Eisenkot, 2017; Zhao, Xiang, Yi, 2017; Flammini et al., 2017]. So, not everything is known about the commercialization of innovative entrepreneurial ideas and high-tech startups [Cui, Kumar, Goncalves, 2019; Kunte, Promsiri, Kampanthong, 2018]. The given study aims to correct this situation. Its *purpose* is to find ways to launch, commercialize and successfully implement a high-tech Russian startup using the case of the development and implementation of a machine vision system for a poultry house.

Despite the ongoing attempts to use machine vision technology in the industrial breeding of broilers, there have not yet been scientific studies of economic and managerial processes associated with the relevant startups in Russia. The issues of creating and introducing into commercial operation of machine vision systems for poultry farming remained out of sight of Russian management science.

On the way to the stated purpose, three objectives should be attained:

1) to follow the process of growing a high-tech startup, identify and characterize the factors that contribute to its commercialization;

2) to analyse the experience of international startups in the development and implementation of computer vision systems for animal husbandry;

3) to indicate the ways for launching and commercializing startups specializing in machine vision for poultry farming in Russia.

A HIGH-TECH STARTUP: IMPLEMENTATION PROBLEMS

Launching and commercializing high-tech entrepreneurial ideas

Breakthrough technologies are based on special knowledge [Hallam, Dorantes Dosamantes, Zanella, 2018], created by highly qualified employees [Lukes, Stephan, 2017], require accelerated development and high research costs, and are associated with complex production processes [Spender et al., 2017]. High-tech products tend to have a short life cycle [Park, Tzabbar, 2016]. Their development and application are associated with increased risks and costs, which complicates the decision to purchase and implement, creating problems for marketing and sales [Mansour, Barandas, 2017]. In the commercial implementation of high-tech entrepreneurial ideas, startups often face insurmountable problems, which occurs due to the non-triviality of creating and applying new knowledge, shortage of resources and the complexity of organizing large-scale production of demanded innovative products, outpacing competition and the lack of established markets, absence of management skills and organizational experience [Santisteban, Mauricio, 2017; Hui, Li, Li, 2018].

In general*, commercialization* is the process of transforming entrepreneurial ideas into value products demanded by the market. At the same time, there are several points of view on the substantive nuances of this concept. Some experts believe that commercialization is limited to the transfer of applied knowledge and engineering technologies from research centres to the industry and use the term "technology commercialization". Others believe that commercialization is the final development stage of a new product, and speak exclusively about "product commercialization", ignoring the essence of the underlying idea as a significant factor [Sharp, Iyer, Brush, 2017]. In their opinion, commercialization is the movement along the three-way contour: making marketing decisions – market creating – expanding sales. Finally, another group of experts claims that commercialization is a chain process from the origin of an idea to mass sales of a product [Namdarian, Naimi-Sadigh, 2018].

The implementation of a high-tech entrepreneurial idea and commercialization of a startup is a complex process that includes the development, production and distribution of a new high-tech product and consists of three stages. The initial stage involves assessing the requests

and requirements of potential customers, generating an appropriate operational idea, selecting a target market, confirming the feasibility of the idea and forming the business model. At the next (second) stage a prototype is created, and the conditions for entering the market are assessed. In addition, this stage covers testing, scaling, determining the final characteristics of the product, and patenting. Lastly, the final stage involves marketing promotion and mass sale of a high-tech product [Gbadegeshin, 2017]. At the heart of the startup commercialization is an entrepreneurial idea that affects all the three stages. The commercial success of a startup largely depends on its content and relevance.

Startup financing is divided into initial and core [Cotei, Farhat, 2017; Tech, 2018]. The initial financing has two stages.

1. *Pre-seed funding* is spent on validation of the startup idea and on the concept of the final product. Venture capital funds and other sources of equity financing are closed to startups at this stage, and in most cases startupers have to rely only on their own resources [Fuertes-Callén, Cuellar-Fernández, Serrano-Cinca, 2020].

2. *Seed funding*. The finances received at this stage make it possible to outline the ideas of startups into a prototype product [Laitinen, 2017]. Startupers who pass this stage can look forward to attracting more customers and maintaining a steady revenue growth.

The startup's core funding consists of three rounds.

Round A. At this stage, according to experts, the 30-10-2 rule works: out of 30 investment funds, 10 will show interest, and only 2 of them will allocate funds. Therefore, one should contact as many potential investors as possible.

Round B. Funding is needed to expand and bring the project to a new level. Compared to the previous round, the main investors stay the same, but new ones are also invited.

Round C. The amount of investment increases significantly. The resources are committed to ensure that a startup can create new products, enter new markets, join other projects or even rise to the international level. Since the project is no longer risky at this point, private investment companies, hedge funds and banks are actively participating in this round. For many startups, this is the last stage of investment, which allows them to enter the *IPO* (Initial Public Offering) stage and completes the financing.

Crossing the so-called *"Death Valley"* between initial funding and commercialization is a major challenge for most startups [Corallo et al., 2019]. At the stage of idea generation, 90% of projects fail. 85% of the remaining ones are cut off by the next, pre-seed funding, stage. Further, at the seed funding stage, only 10% survive. In Round A, the conversion rate is 45%. Those who have passed Round B, where the throughput probability is 35%, get to the IPO stage or Round C (Fig. 1). As a result, the startup's conversion rate is only 0.02%.

Factors in high-tech startup success: The methodological basis

Sandelowski and Barroso's Meta-Synthesis method. To identify the factors influencing the commercialization of a high-tech startup, a meta-synthesis was applied, which combined the results of several scientific studies on similar issues and based on the methodological principles of Sandelowski and Barroso [Ludvigsen, 2016]. These principles involve desk analysis of the combined results of several published studies in order to obtain a qualitatively new interpretation and solution to the problem based on a logically consistent seven-step process: (1) identification of research questions and objectives, (2) review of sources, (3) search and selection of relevant publications,

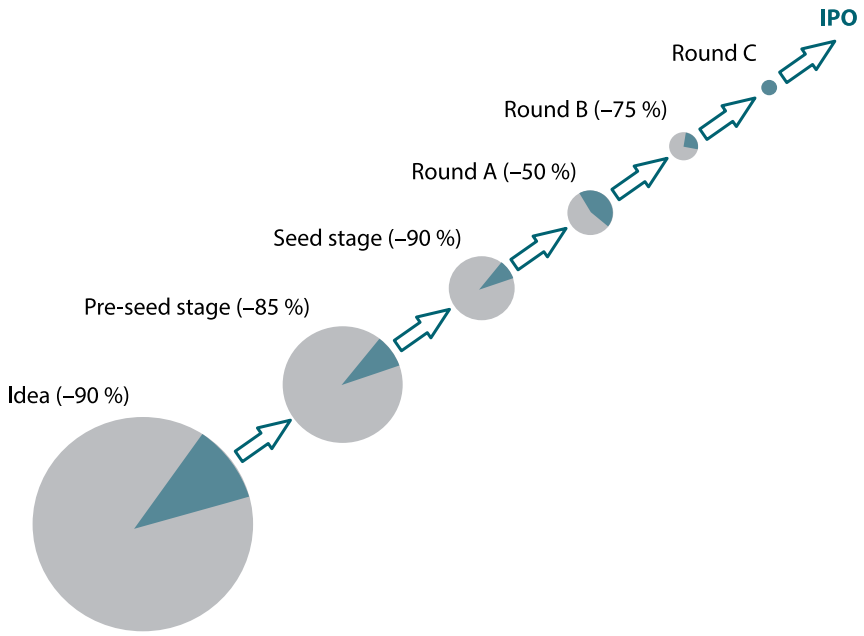

Fig. 1. Probabilities of startups passing through all stages of development and financing

Рис. 1. Вероятность прохождения всех стадий развития и финансирования стартапа

(4) extraction of textual information, (5) semantic breakdown of the materials with the allocation of key phrases, system analysis to identify patterns and thematic fragments, synthesis, (6) quality control, correction and addition, (7) issuance of final results [Daneshjoovash, Jafari, Khamseh, 2021]. The use of decomposition, abstraction and generalization at the stage of correction and addition made it possible to strengthen the results of meta-synthesis [Gbadegeshin, 2018].

Data collection and sampling. The bank of materials was formed, which primarily included scientific articles and conference proceedings, selected according to their titles and abstracts featuring the keywords "startup launch", "startup commercialization", "computer vision", "machine vision", and "poultry industry". The materials also met a number of criteria, such as being found through Google Scholar or eLibrary, indexed in the scientific citation databases the RSCI, Scopus or WoS, published through Emerald, Elsevier, IEEE, Sage Publications, Taylor and Francis, Wiley, Springer or through Russian publishing houses during the period of 2016–2022.

The validity and reliability of the sample were assessed by such criteria as the title of the article, its purpose, methodology, conclusions, year of publication, authors affiliation, and the impact factor of the publication. The quality of the selected works was judged based on several criteria, including clarity of goals and the logic of the study, its relevance, design to the goals, representativeness of the data, clarity of presentation and validity of the results. In total, over 200 publications were viewed, of which 25 were selected for further analysis.

POCD and SWOT analysis. The current status and challenges of the startup, as well as its growth strategies, including launch, commercialization and securing funding, were assessed using a combination of POCD [Chi, Liu, Xia, 2021] and SWOT analysis [Benzaghta et al., 2021]. The POCD concept takes into account four basic elements:

People. These are all involved individuals, including startup entrepreneurs, team members, investors, consultants, and other significant startup stakeholders;

Opportunities, i.e., the potential of a startup based on an idea, concept, business model, expected profit, market interest, window of opportunity, etc.;

Context. This is the macro-environment of a startup depending on such external factors as the development of technology, consumer desire, the state of the economy, industry trends, etc.;

Deal, i.e., financial issues of a startup that take into account sources, conditions and structure of investments.

SWOT analysis is a fundamental tool applicable to assess positions and study the internal and external environment of a startup, which are characterized by four complex components: (1) strengths refer to the intrinsic attributes of a startup that contribute to achieving its goals; (2) weaknesses are internal features of a startup hindering its success; (3) opportunities are external circumstances that help a startup achieve its goals; (4) threats are factors in the environment of a startup impeding its work.

A high-tech startup: Launch and commercialization factors

The application of the principles of Sandelovsky and Barroso revealed seven internal and four external factors for the launch and commercialization of high-tech entrepreneurial ideas (Fig. 2). Startupers can manage internal factors, but not always external ones.

The *internal factors* affecting the launch and commercialization of a high-tech startup are as follows.

1. *Competitive capabilities of the startup*, such as a flexible organizational structure and a relevant business model, affect the initial stage of launch and commercialization, while distribution opportunities have an impact at the final stage. Leadership, strategic management, vision for the future, coordination of core competencies, entrepreneurial culture, change management, partner trust, knowledge sharing, resources and assets are important at all stages.

2. *Human capital* is developers, production workers, marketers, distributors and other skillful members of the startup team who positively influence the launch and

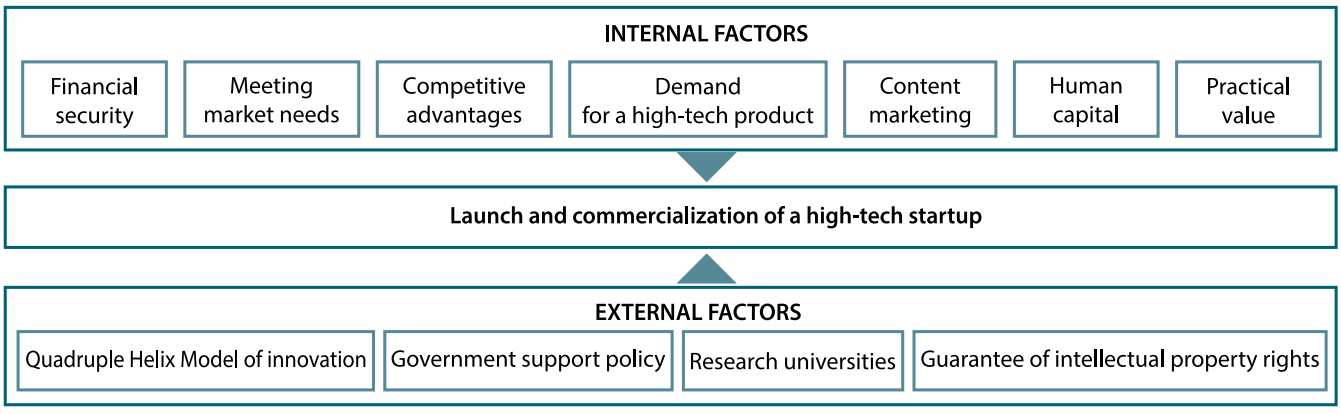

Fig. 2. Factors in launching and commercializing a high-tech startup

Рис. 2. Факторы, влияющие на запуск и коммерциализацию высокотехнологичного стартапа

commercialization of a high-tech idea due to their high professional qualifications, work ethic, motivation and creativity.

3. *Meeting market needs*. The market presence and generation of ideas demanded in it have a positive impact on the initial stage of startup launch and commercialization. Opportunities and resources to adapt to market requirements, customer knowledge, time-to-market for innovations, stakeholder approval, market coverage and customer loyalty are the conditions that are especially important at the final stage of commercialization.

4. *Content marketing* is used to release advertising messages at the final stage of commercialization.

5. *High technologies applied value* is of high importance at the initial stage of launching and commercializing, where they are selected by their potential suitability to meet the needs of target customers, and at the second stage, where the innovative product is developed based on these technologies.

6. *High-tech product demand*. The configuration of a high-tech product that meets the needs of customers and the relevant set of its functions come to the fore at the second stage of launch and commercialization. In addition, the specific characteristics of the product approved by interested consumers are of a significant positive effect at the final stage of commercialization.

7. *Financial security* is necessary at all stages of launch and commercialization. A startup can only become successful if it has sufficient financial resources for preliminary research, idea generation and validation, product development and prototyping, presentation and testing, product launch and scale-up, and related marketing activities.

The *external factors* of a high-tech startup's launch and commercialization are the following.

1. *The quadruple helix model of innovation*. The business-science-government-society framework [Carayannis, Grigoroudis, 2016; Steenkamp, 2019], in addition to a positive impact on the interaction of startups with industry and business, easier access to academic knowledge and know-how and faster market entry, contributes to establishing cooperation with investors and target customers, creating an innovative ecosystem and promoting high-tech products in demand by the market.

2. *The policy of state support* for innovative entrepreneurship aimed at providing comfortable conditions for the development of high-tech startups through the creation of business incubators, research centres, technology parks, technology transfer centres, financial institutions, public organizations, public utilities, transport and technological infrastructure.

3. *Research universities* actively participating in the creation and dissemination of new knowledge, promoting the development and replication of high technologies, supporting industry cost-effective research and projects, promoting teamwork and entrepreneurial culture, providing educational and consulting services positively influence the process of a startup launch and commercialization in general and, especially, at its initial stage.

4. *Guarantees of intellectual property rights* are important at the second stage of launch and commercialization, where the developed technologies and created products are patented [Stenard, Thursby, Fuller, 2016].

STARTUP AS A PLATFORM FOR MACHINE VISION SYSTEMS

Computer vision technology in the poultry industry: The reasoning

Due to relatively short production cycles and the ability to process by-products and agricultural waste into meat and eggs, the poultry industry[1] makes a significant contribution to solving the global food problem [Buyarov, Buyarov, 2020; Bykova, 2018]. The poultry industry[2] is one of the fastest growing agro-industrial sectors of the world economy facing serious challenges in its development [Bachkova, 2018; Mottet, Tempio, 2017], such as maintaining consumer confidence and ensuring the quality and environmental cleanliness of products [Kleyn, Ciacciariello, 2021; Hafez, Attia, 2020].

The main risks in the poultry industry are associated with the spread of infectious diseases (for example, infectious bronchitis, avian influenza, infectious sinusitis) within the herd, as well as between broiler farms and poultry yards [Irza, Volkov, Varkentin, 2020]. Among the consequences of the epidemic are the death of the herd, the shutdown of the poultry farm, the lack of revenue, the loss of business partners and reputation as a reliable supplier of safe products [Kozerod, Vorobyeva, 2021]. Taking into account the growing number of poultries caused by the growing demand for poultry meat worldwide [Berckmans, 2017; Davleev, 2021], the possible damage due to mass diseases in poultry farms increases many times over.

The economic efficiency of broiler production significantly depends on the ratio between the amount of feed consumed and the increase in live weight [Egorova, 2019]. The desire to improve this indicator encourages the provision of the most comfortable microclimatic conditions for fowls (temperature, humidity and air quality, lighting intensity, etc.), to which poultry is especially sensitive compared to livestock and both the productivity of adults and the normal embryonic development of hens significantly depend on [Buyarov, Buyarov, 2021].

These threats can be considerably reduced and the problems largely resolved, if the health status of poultry is introduced and the microclimatic regime of its keeping is optimized based on constant monitoring of the behaviour of both the entire herd and individuals [Barcho, 2017].

[1] Poultry industry is an agro-industrial sector responsible for producing poultry meat and eggs. Broiler production is the process of growing and preparing chickens for consumption.

[2] The term *poultry* covers a range of domesticated species: chickens, turkeys, ducks, geese, game birds (for example, quails, guinea fowl, pheasants), as well as ratites (for example, emus and ostriches). Broilers are chickens raised for meat.

A good solution here is machine vision, that is an innovative technology based on complex computer vision algorithms that allow continuous monitoring and analysis of the sequence of images coming from video cameras in real time without any direct human involvement [Singh et al., 2020].

In the Russian poultry industry, the use of machine vision has not yet progressed too far [Gajdaenko, Gajdaenko, 2018], which is due to the complexity of the transition from laboratory experiments to effective commercial solutions, since the function of video systems in this case, in addition to detection, is also to analyse the behaviour of birds, which is quite variable [Zhuang, Zhang, 2019]. Machine vision faces the problem of early identification of signs of discomfort and deterioration of well-being in the behaviour of birds [Okinda et al., 2019]. An additional challenge is scaling the technology to thousands of herds and large poultry farms while maintaining accuracy, functionality and reliability [Aydin, 2017].

Machine vision as a business idea for a commercial startup

Machine vision is a stage in the evolution of video surveillance systems, at which part of the operator's functions are transferred to a computing device and performed automatically. The development of machine vision is directly related to the breakthrough in the field of artificial intelligence and computer vision, the growth of computing power and the reduction in the cost of technological equipment. Machine vision methods have been developed since the 1960s, and by the early 1990s technologies for number control and detection of defects in manufactured products had already been implemented at the prototype level. Systems suitable for practical use with object recognition options (fast image processing, matching and identification of faces, fingerprints, license plates, etc.) appeared in the early 2010s. Over the past decade, it has been possible to significantly expand the capabilities of machine vision, which opens up new directions for its practical application. Monitoring compliance with traffic rules, banking services based on biometric data, automated passport control – all these are achievements of yesterday.

On the basis of computer vision technologies entire industries are being transformed and new startups are being launched, which provokes a huge influx of investments [Kakani et al., 2020]. According to forecasts, by 2028 the global machine vision market will grow to 13 billion US dollars with an average annual growth of 21.3%[1]. By the end of 2021, the volume of the Russian machine vision market in monetary terms reached 12.3 billion rubles, which is 10.5% more than in 2020. By the end of 2028, an increase to 26 billion rubles is expected[2].

[1] Machine vision market share. 2021. https://www.polarismarketresearch.com/industry-analysis/video-analytics-market.

[2] Computer vision market size. 2021. https://www.grandviewresearch.com/industry-analysis/computer-vision-market.

The machine vision system can be implemented peripherally (embedded), server-side or cloud-based. In the first case, the analysis of the video stream is performed by a computing device combined with a video camera. The second option uses cameras without built-in analytical functions and all calculations are done on a stationary server. The third option differs from the server one in that the calculations are moved to the "cloud".

Fig. 3 illustrates the architecture of a computer vision system for poultry industry. The system consists of three components: cameras, computing device, and software (video processing algorithms, calculation, and statistics analysis). The process of machine vision is carried out in three stages: capture, processing, and "understanding" of the image. The choice and location of the cameras, as well as the level of lighting in the room, play a decisive role in obtaining high-quality video content. Appropriate hardware and software are used to capture and save video data [Wurtz et al., 2019]. Then, these data are processed by computational and neural network algorithms. Finally, data analysis methods are used to recognize behavioural patterns [Abd Aziz et al., 2021].

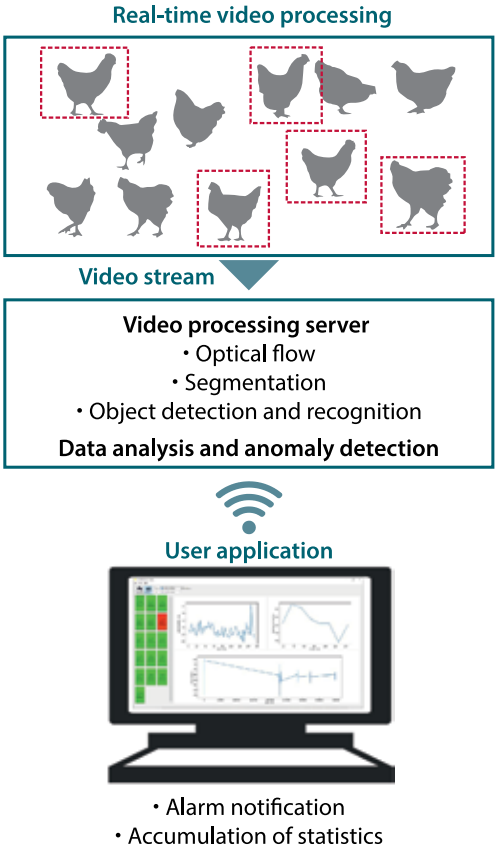

Fig. 3 Architecture of the machine vision system for the poultry industry

Рис. 3. Архитектура системы машинного зрения для отрасли птицеводства

Behavioural patterns that characterize the activity and movement trajectories, both of individuals and the average for the group, make it possible to timely detect changes in the birds' well-being, which may be the result

of ventilation failure and microclimate disturbance or a sign of infection and the onset of the disease. In some cases, machine vision methods can detect diseases even before the occurrence of clinical symptoms [Fernandez-Carrion et al., 2017].

The main feature of machine vision in Russia is the use of the imported component base. The main obstacles to the development of computer vision technology in the country are rising prices and restrictions on import of equipment.

Machine vision startup in the poultry industry: Evidence from Russia

In Russia, the development of machine vision systems for the poultry industry is carried out under the auspices of national research centres and universities by small groups of employees of innovative microenterprises, or high-tech startups.

The startup aimed at developing and implementing a machine vision system for the poultry industry was launched in 2021. It has the Skolkovo resident status, uses a simplified tax system (exemptions from VAT, income and property taxes, the insurance pension contribution is 14%). The project team consists of algorithmic programmers and manager. The startup cooperates with the All-Russian Scientific Research and Technological Institute of Poultry Farming[1]. With the participation of the Institute, joint tests of the first version of the machine vision system prototype for a poultry house were carried out.

The work performed allows us to reasonably assert the fundamental feasibility of the concept and the potential use of machine vision technology for assessing the health and conditions of broiler chickens.

The system prototype is implemented on the principle of server video analytics: the video stream from surveillance cameras is sent to the server, where it is processed. The models created within the framework of the startup make it possible to track the parameters changing when the microclimate is disturbed and birds feel worse. For example, when the temperature drops the activity of broiler chickens decreases sharply, they get into groups, etc.

The startup has models and algorithms, the prototype of the machine vision system, the database of video data taken at the VNITIP Scientific Research Center of the Russian Academy of Sciences throughout the full life cycle of birds, as well as equipment and computing power. The project's system part, which includes the creation of a user application for PC and mobile Android devices, as well as server organization for displaying the video stream from the poultry house and accumulating statistical data, were outsourced. Business partnerships are being developed with *Electronics Design* company (Estonia), which can serve as a springboard for entering international markets. Verkhnevolzhskaya Poultry Farm is the first site for scaling and testing the system. An agreement was reached with this farm to equip one poultry house with a trial video analytics system. Thus, the startup is at the prototype testing stage now.

In January 2022, the startup took part as an exhibitor in AGROS Expo, the annual international trade fair for animal husbandry, breeding and feed production in Moscow at Crocus Expo IEC that brought together over 350 participants. The startup's exposition booth was visited by about 50 specialists. As a result of negotiations, more than 25 leads were received, which are now being worked out.

Algorithmic development and test data collection were performed at the personal expense of the project participants. PC and Android applications were developed at the expense of the business angel.

Since the idea of creating a machine vision system for a poultry house is primarily of scientific and technical interest for the startup founders, the commercial aspect of the project did not receive due attention, and there was no strategic and financial planning of the work. Therefore, all financial resources were exhausted as early as at the stage of creating the prototype and conducting the first series of experiments. Funding is required to continue the work.

To move to the stage of creating a ready-to-sell product, a laboratory and then field-testing are necessary. Only after that it is possible to judge the reliability of the system, which will make it possible to outline a strategy for its commercialization and form a value proposition for customers and partners. However, it is not yet clear who will be the first client – small private poultry farms, where a decision can be made quickly, or large poultry farms, where the installation of machine vision systems will reduce labour costs.

To solve these problems, it is required to study the experience of implementing such projects, understand the possibilities, limits and options for growth, identify and find sources of funding. In this regard, three research questions were posed:

- what are the internal and external drivers for launching and commercializing high-tech entrepreneurial ideas and machine vision solutions for the poultry industry?
- what is the best way to commercialize and develop a high-tech startup that is at the early stage and implemented in Russia?
- what should be done to further develop the project on creating a machine vision system for a poultry farm implemented by a Russian micro-enterprise with limited resources?

RESULTS OF LAUNCHING A HIGH-TECH START-UP

Machine vision systems for animal husbandry: Global experience

Table 1 shows the leading startups from China, the USA, Europe and Russia aimed at developing and implementing machine vision systems for animal husbandry.

[1] VNITIP Scientific Research Center of the Russian Academy of Sciences. www.vnitip.ru/fnts-vnitip-ran/.

Table 1 – Startups creating machine vision systems for animal husbandry
Таблица 1 – Стартапы – лидеры по созданию систем машинного зрения для животноводства

Name	Country	Investor	Stage of financing
Yingzi Technology	China	*No data available*	Initial Public Offering
Xiangchuang Technology	China	Venchure funds Horeal Group & Redstar Fund	Initial Public Offering
ZhongAn Technology	China	Insurance company ZhongAn	Seed Funding
BioSort	Norway	Food poducer Cargill	Initial Public Offering
Cainthus	Ireland	Cargill & NDRC	Seed Funding
eyeNamic	Denmark	Fancom	Initial Public Offering
Cattle Eye	Great Britain	Seventure Partners, Techstart Ventures, Turntide	Seed Funding
Cattle Care	USA/Russia	Alchemist Accelerator	Seed Funding
Plainsight	USA	Nvidia Corporation	No data available
Cows AI (Radar)	Russia	*No data available*	Seed Funding

China. *Yingzi Technology* is engaged in machine vision for pig breeding, *Xiangchuang Technology* specializes in video recognition and identification of animals, *ZhongAn Technology* announced a project on creating a video identification system for broiler chickens.

USA and Europe. The leader in investing in livestock machine vision projects is the American company *Cargill*, the largest food supplier and meat producer, which finances two startups at once. The first one is the Norwegian company *BioSort AS*, which focuses on identifying diseased individuals among farmed salmon fish. The second one is the Irish company *Cainthus*, which develops cattle identification technology. The British startup *Cattle Eye* is working in a similar direction.

The leader in the field of machine vision for the poultry industry is the Danish company *Fancom*. This is not a startup: it was founded about 40 years ago and initially concentrated on climate control systems for poultry farms. Fancom's poultry machine vision system is called *eyeNamic*. Initially positioned as a standalone product, it has since become part of an integrated poultry house management solution, including climate monitoring, feed and water management, and more.

Russia. *Cattle Care* startup specializes in machine vision systems for dairy farms. It is registered both in Russia and the USA and receives funding from American venture funds [Corsi, Prencipe, 2017]. The startup *Cows AI (Radar)* is registered in Skolkovo and operated in a similar business area.

Technology companies operating in the field of Internet solutions and food manufacturers express their investment interest in machine vision for animal breeding. For example, in 2018 *Alibaba Group* entered into a contract with the *Dekon Group* pork corporation and the *Tequ Group* feed manufacturer to create a machine vision system for pig production. Since 2018, the food company *Cargill Inc*. has been investing in the Irish startup *Cainthus*, which specializes in video-based calf health analysis solutions. In 2021, *Nvidia Corporation*, the leading chip producer, invested in *Plain Sight*, a startup developing a smart calf tracking product.

The analysis of the international experience in the development and commercialization of startups specializing in machine vision systems for animal husbandry led to several conclusions.

1. There are few startups on animal breeding vision systems. Moreover, none of them has yet reached the stage of initial sale of shares, most are at the stage of development or implementation.

2. All solutions, with the exception of *eyeNamic*, relate to pig breeding or cattle breeding.

3. The main difficulties in creating industrial samples of machine vision systems for animal husbandry are associated with high algorithmic complexity and technical problems when scaling to large herds.

4. Over the next few years, given the high rate of technological progress, it can be expected that the components of machine vision systems (cameras and computing devices) will be more affordable, and this will contribute to the massive introduction of machine vision for animal breeding. Thus, China allocates 5–10 years for the widespread introduction of machine vision systems for animal husbandry.

5. All animal breeding machine vision startups are funded either by the state (China), or by industrial corporations (the USA and Europe), or by venture capital. With the exception of *Fancom*, which has several areas of activity, there is no self-sustaining business.

Launching a high-tech startup in Russia: Organization of financing

The Russian startup specializing in machine vision systems for the poultry industry has multiple funding options [Evdokimova, Kobyshev, 2017].

1. The personal capital of startupers was applied, which made the decision-making an absolute independent process and allowed to focus on purely technological tasks abandoning the issues of financing.

2. A business angel was involved, which allowed completing the initial part of the work, which turned out an

absolute plus. The downside is the weak predictability of a private investor.

3. Once the startup come to the stage of minimally viable product, commercial proposals were formulated to manufacturers of microclimate control systems in the poultry industry.

4. Of all the options for startup financing, the most promising one is to receive a state grant. The only institution providing investments at the stage of idea confirmation and prototype creation is the Innovation Assistance Fund [Polyakov, 2016]. Earlier, the startup has already participated in the competition held by the Fund. Based on the competition results, it was proposed to go through an acceleration programme. After that, it would be possible to apply for funding to carry out joint laboratory tests with the VNITIP Federal Research Center of the RAS and complete prototype product development.

Among the positive outcomes of applying to the Innovation Assistance Fund are recommendations from experts and the prospect of receiving funding free of charge. The disadvantage is the length of the procedure: the application was submitted in August 2021, the competition took place in October, and the acceleration programme began only in February 2022.

5. It is planned to design a demonstration site on the basis of the VNITIP Federal Research Center of the RAS positioning it as a pilot project, which will open up new opportunities for finding financing to test and scale the product, including further participation in competitions held by the Innovation Promotion Fund[1], an appeal for venture financing to foreign investors, attempts to interest potential customers in investing, and applying for programmes of the Russian Agricultural Bank (RAB). First of all, to the *AgroCode Hub* programme implemented by the RAB in order to support initiatives to stimulate the introduction of innovative technologies in agriculture and farming[2].

A high-tech startup in Russia: Development prospects

Guided by the POCD concept, the founders of the startup specializing in the development of a machine vision system for the poultry industry in Russia formed a team of interested and like-minded people, received initial funding and showed the possibility of implementing the startup idea, taking the starting position in the Russian digital technology market.

To better understand the current state of the startup and work out strategic options for further actions and development, SWOT analysis was carried out (Tables 2, 3).

As a result of the analysis, we have come to the following conclusions.

Firstly, the rapid launch and commercialization of a startup to create a machine vision system for the poultry industry in Russia is hardly possible. In addition, the scale and engineering complexity of the project were initially underestimated.

[1] Fund for Assistance to the Development of Small Forms of Enterprises in the Scientific and Technical Sphere (Fund for Assistance to Innovations). https://fasie.ru/fund/. (in Russ.)

[2] Agro Code Hub Programme. https://agro-code.ru/. (in Russ.)

Table 2 – SWOT analysis of the current state of the project
Таблица 2 – SWOT-анализ состояния стартапа

Strengths	Weaknesses
• The idea of assessing the well-being of broilers by their behavioural patterns was confirmed. • Joint activities of qualified algorithmists and experts from the VNITIP Federal Research Center of the RAS. • Prerequisites for entering the US and European markets	• Insufficient amount of research. • Laboratory level of development. • Lack of value proposition for customers and partners. • Slow activity due to lack of funds
Opportunities	**Threats**
• Publication of the results of joint experiments with the VNITIP Federal Research Center of the RAS. • Participation in the acceleration programme of the Innovation Promotion Fund. • Participation in the programmes of the Russian Agricultural Bank. • Further testing on the basis of the VNITIP Federal Research Center of the RAS	• Financially wealthy competitors can get ahead of the industrial implementation of the startup idea. • Increasing the components cost will make the product too expensive

Table 3 – Strategic options for continuing the project
Таблица 3 – Стратегические альтернативы развития стартапа

	Opportunities	Threats
Strengths	Deepening cooperation with the VNITIP Research Center of the RAS (joint publications, continued testing of the system, etc.) will have a positive impact on the development of the project	Focusing on both the Russian and international markets will reduce the sensitivity to the rise in the cost of components
Weaknesses	Participation in the acceleration programme will make the project more mature and increase the chances of receiving a grant, which will contribute to levelling the weaknesses	Formation and communication of value proposition to potential customers and partners through participation in competitions and events, as well as through publications and interviews

Secondly, a machine vision system is typically not a separate product, but a part of "smart" integrated systems for animal breeding farms [Revanth et al., 2021; Ahmadi et al., 2018]. In this regard, two central lines of the startup launch and commercialization have been identified that stayed relevant after creating a prototype and confirming its reliability in laboratory conditions, these are association with developers of integrated digital solutions for the poultry industry and/or integration with poultry meat producers. In particular, it was decided to put together commercial offers to developers of "smart" systems for the poultry industry, including microclimate control systems.

Thirdly, for the Russian startup it seems most realistic to receive funding from potential clients and through participation in specialized competitions. It is planned to take part in the competitions of the Innovation Assistance Fund and the Russian Agricultural Bank programme, as well as to search for foreign venture financing and, if possible, attract funds from potential clients.

CONCLUSION

The conducted research, combined with the accumulated experience of growing a startup, contributes to the theory and practice of promoting high technologies and reveals the managerial know-how to launch and commercialize an innovative AI-related entrepreneurial idea in the poultry industry in Russia.

Theoretical implication of the study comes down to several provisions regarding the successful launch, development and commercialization of a startup, namely:

- expanding competitive advantages, meeting market needs, using content marketing and high technologies, developing innovative products, finding sufficient financial resources;
- recruitment of qualified, motivated, team-oriented and committed employees;
- seeking support from state and public organizations;
- provision of a well-designed and convincing business plan for investors;
- active interaction with research centres and universities;
- expanding the entrepreneurial competencies of startups through training in business education programmes.

Practical significance of the study lies in the clarification of a number of important applied issues related to launch and commercialization of innovative entrepreneurial ideas and high-tech startups aimed at creating machine vision systems for the poultry industry in Russia.

1. Continuous and uninterrupted monitoring of the health status and microclimatic conditions of broiler chickens can be ensured using machine vision systems, which, along with improving the economic performance of the entire production process, will help to stop and prevent the spread of diseases in the herd in a timely manner.

2. Based on the international experience, the entrepreneurial idea of developing a machine vision system for the poultry industry in Russia should be recognized as fruitful, the project for its implementation is feasible, and the corresponding startup is promising, deserving of investors' attention, and potentially successful.

3. An insurmountable barrier to the development and widespread industrial implementation of machine vision systems for the poultry industry in Russia is the high cost of components. According to the world practice, startups that receive serious state support or fulfill the order of large corporations mainly reach the implementation stage. It is important that machine vision is typically only a fragment of an integrated poultry complex control system and not an independent product.

4. The advantages of applying to state funds to support small innovative businesses include the possibility of receiving free recommendations from leading experts and the prospect of getting non-refundable financing. Among the drawbacks are the complexity of making an application and the length of time spent on its consideration and satisfaction, if approved.

5. Livestock and poultry machine vision in Russia is a nascent market with poor competition. Blue Ocean Strategy aimed at creating innovative products is optimal for working in such a market.

Research limitations and directions for further study. The work is based on the collection and analysis of secondary data, which may be not entirely reliable and/or incomplete. Therefore, in addition to articles from high-ranking scholarly journals, it is planned to expand coverage by examining thematic online publications, expert blog posts, and other relevant materials.

Since some of the data are retrieved from foreign sources, inconsistencies and discrepancies with the Russian realities are possible. These inconsistencies can only be eliminated with the help of field studies, where it is necessary to investigate potential customers in more detail, analyse the technical features of engineering solutions implemented by other developers, and then move on to more comprehensive business planning of the project.

It is necessary to show the correlation between the number of livestock and epidemiological diseases of poultry in dynamics over 5 years in Russia, to consider alternative means of diagnosing infectious diseases of poultry available in the country, to clarify the business model of the project, to prove its financial and economic efficiency and investment attractiveness, and to analyse the project-related risks – financial, managerial, and technological.

In addition to growing broilers, it is important to take into account the experience of commercialization of computer vision technologies in relation to such livestock industries as cattle production, pig breeding, fur farming, horse breeding, which are currently developing quite dynamically in Russia. ■

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