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Enhancing Construction Site Safety Using Computer Vision and Drones

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Abstract. Despite established requirements for the use of personal protective equipment (PPE), such as helmets and goggles, traditional methods of control at construction sites often fail to ensure the proper level of compliance with safety standards, resulting in increased injuries. The goal of the project is to develop an integrated system of face control, automatic verification of the presence of PPE, and alcohol level monitoring using computer vision technologies, machine learning, and drones. The system will perform face recognition, control the presence of helmets and glasses, as well as identify unsafe behavior and signs of alcohol intoxication, providing continuous monitoring of workers. It is expected that this will significantly improve the level of safety, reduce the number of accidents, and increase labor productivity. The development will be adaptable for various industries - from construction to mining and oil and gas. The project has high practical and socio-economic significance, contributes to the development of the scientific and technical potential of Kazakhstan, the creation of new jobs in the field of IT and automation, as well as strengthens the interaction between science and production.

Keywords: Drone, AI, alcohol test, QR code, PPE

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Introduction

The relevance of this article is driven by the urgent need to enhance safety at construction sites, where non-compliance with осцcupational health and safety regulations remains one of the main causes of injuries and fatalities. The prerequisites for developing an integrated safety monitoring system are based on an analysis of existing technologies and scientific research confirming the effectiveness of computer vision and artificial intelligence. Preliminary results show that the use of such technologies significantly improves the efficiency of safety compliance monitoring and enables continuous worker condition tracking.

Previous studies have revealed shortcomings in existing systems, including a low level of automation, a lack of real-time monitoring, and fragmentation of solutions. The scientific novelty of this article lies in its comprehensive approach to occupational safety, integrating facial recognition, automatic verification of personal protective equipment (PPE), and real-time worker condition monitoring, including alcohol detection. International studies [5–10] confirm the effectiveness of such solutions; however, the example of Kazakhstan reveals specific challenges that require customized developments. National research [11–12] highlights the absence of comprehensive safety solutions in the construction sector. This article aims to fill that gap and proposes a system that could reduce the number of accidents by 30% within the first six months of implementation.

The project addresses modern scientific and technological needs related to the creation of a safe working environment. The high injury rate on construction sites, confirmed by statistical data, generates significant social and economic demand for innovative safety management systems. Moreover, the project's implementation is expected to reduce costs associated with treatment, insurance, and compensation while simultaneously improving labor productivity. At the national level, the project aligns with occupational safety program priorities, and at the international level, it has the potential for scaling and adaptation. Thus, the project is of strategic importance and can contribute to the development of new safety standards, increase the competitiveness of the construction industry, and improve the quality of life for workers.

The scientific novelty of the project lies in the integration of modern monitoring technologies and risk analysis at construction sites through the use of computer vision and artificial intelligence algorithms for automatic compliance control with safety standards. The unique approach to solving the injury problem involves creating a system capable of detecting violations related to PPE use and potential hazards in real time. The significance of the project lies in its potential to significantly reduce accident rates, which is critical for improving overall workplace safety. The study's outcomes can enhance safety management methods and introduce innovative solutions into Kazakhstan's construction sector, aligning with modern occupational safety requirements and contributing to the country's economic development.

The methodology

1) The prerequisites for the development of the project are based on the analysis of existing technologies and scientific research confirming the need for the integration of safety monitoring systems at construction sites. In particular, preliminary results show that the use of computer vision can significantly improve the efficiency of monitoring compliance with safety standards, reducing the number of accidents. Previous studies in the field of occupational safety have identified the shortcomings of current systems, such as a low degree of automation and the lack of real-time monitoring. In addition, the development of prototype systems using machine learning

algorithms has shown promising results, which creates the basis for the creation of an integrated system aimed at preventing injuries and improving working conditions. Existing developments in the field of patenting technologies and publishing scientific articles also confirm the readiness to implement this project, contributing to its scientific and practical significance.

2) The rationale for the scientific novelty of the project is related to current research in the field of occupational safety, especially at construction sites, where a high risk of injury requires the implementation of modern technologies. In international practice, studies by [13-14] have shown that the use of computer vision technologies can significantly reduce the number of accidents caused by non-compliance with safety rules. Similarly, the work of [15] highlights the effectiveness of facial recognition technologies in improving safety in various industries, including construction. However, despite significant advances, existing systems often do not provide a comprehensive approach and do not take into account the specific conditions of individual countries, such as Kazakhstan. At the level of Kazakhstan, studies conducted by [16] revealed serious deficiencies in the safety system at construction sites, indicating the need for stricter control measures. Also, the work of [17] confirms the need to integrate new technologies, such as breathalyzers and worker health monitoring systems. However, there are no developments that would combine face control, alcohol testing, and monitoring of compliance with personal protective equipment (PPE). This project aims to eliminate these shortcomings by developing an integrated system that uses computer vision and artificial intelligence to automatically monitor compliance with safety standards. The system is expected to improve the efficiency of monitoring the use of PPE and reduce the number of accidents on construction sites by 30% during the first six months of operation. Unlike existing analogues, our project offers a comprehensive approach that takes into account the unique working conditions in Kazakhstan and is focused on injury prevention.

3) Scientific and technological needs, justifying the importance of the project results, include the need to improve the level of occupational safety at construction sites, where the risk of injury remains high (see Figure 1). Existing statistics indicate that in Kazakhstan and worldwide, accidents at construction sites are one of the main causes of death and serious injury among workers. This creates an urgent social demand for the introduction of innovative technologies aimed at preventing these incidents.

Economic and industrial interest is also emphasized by the fact that the creation of effective monitoring systems can reduce the costs of treating injuries and compensating victims, as well as increase productivity by creating a safer working environment (Figure 1, photo was downloaded from the internet). According to experts, the introduction of modern safety technologies can lead to a decrease in insurance costs and an improvement in the overall efficiency of projects.

At the national level, the project is significant in the context of the implementation of the state program on labor protection and improvement of working conditions. On an international scale, the project results can be adapted for use in other countries with similar problems, which increases its relevance and potential market.

The applicability of the research results goes beyond the narrowly specialized field and covers such areas as economics, industry, and social relations. The development of an integrated monitoring system for compliance with safety standards can serve as a basis for the formation of new safety standards at construction sites, improving the overall state of the industry and promoting the introduction of advanced technologies. Thus, the project not only meets current requirements but also provides an opportunity to scale up the results at the level of both Kazakhstan and the international community, which contributes to the further development of

labor safety technologies.

Figure 1. A helmet saved a worker at a construction site

4) The project will have a significant impact on the level of research and development and scientific and technical potential in the field of occupational safety, stimulating the development of new technologies and methods, which in turn will increase the competitiveness of scientific organizations and their teams. It is expected that the introduction of an integrated system for monitoring compliance with safety standards will create opportunities for the publication of new scientific papers that can be used for further research in this area, thereby contributing to the formation of an expert community and strengthening the position of Kazakhstan in the international arena. The social effect of the project results is a decrease in the number of accidents at construction sites, which will directly improve working conditions and increase the safety of workers. This will contribute to the formation of a safety culture, which is also important for increasing employee satisfaction and reducing staff turnover. The economic effect can be manifested in reduced costs for medical care, insurance, and compensation, as well as increased productivity due to a safer working environment. To achieve the expected effect, conditions are necessary, such as government support in the form of legislative initiatives aimed at strengthening control over compliance with safety standards, as well as active cooperation with industrial partners to test and implement the developed technologies in practice. Additionally, the creation of educational programs and training for workers and safety managers on the use of new technologies will also contribute to the achievement of the set goals and ensure the sustainable development of the labor safety system in the country. This project focuses on integrating computer vision and worker monitoring systems, including hard hats, goggles, and alcohol level checks, to improve safety on construction sites. Unlike existing solutions, which often offer only fragmented approaches to monitoring compliance with safety standards, our project will use machine learning algorithms for real-time detection of unsafe actions, as well as checking for the presence of personal protective equipment (PPE) and alcohol level monitoring. This will not only improve compliance but also reduce the likelihood of accidents. The benefits of the project include higher efficiency and response time compared to traditional methods, as well as the ability to process large amounts of data, which confirms the need for funding. Today, most existing safety technologies on construction sites are either static or require significant costs for implementation and maintenance. The project proposes the development of lightweight and low-power equipment based on NPU (Neural Processing Unit), which will not only reduce implementation costs but also provide a higher degree of automation. Our product will focus on ease of use and accessibility for small and medium-sized enterprises, including automated checks for helmets and goggles, as well

as alcohol monitoring, which is a significant step forward compared to existing solutions. The project differs from previous studies in its broader approach, which includes both monitoring methods and the integrated use of computer vision technologies for helmet and goggle checks, as well as alcohol monitoring, making it more relevant and targeted in the context of the current market situation and social needs.

Main Project Hypotheses:

The flowchart shows three main project hypotheses related to the use of drones, neural processors, and artificial intelligence (AI) to improve safety at construction sites. The top part shows a drone monitoring a construction site, performing face control functions and checking personal protective equipment (PPE), such as helmets and glasses. Next, the processing of drone data using neural processors and AI is shown, which improves the accuracy and speed of detecting violations, such as the absence of PPE or signs of alcohol intoxication. The bottom of the diagram shows a 20-30% reduction in the number of accidents at the construction site due to the implementation of this system, which leads to a safer working environment (Table 1 clearly structures the hypotheses, providing a more visual and convenient perception of the key aspects of the project and expected results).

Table 1. Construction site safety monitoring system

Hypothesis	Description	Expected result
Hypothesis 1	The integration of drones with the face control and PPE monitoring system will increase the level of safety at construction sites by automating processes.	Improving automation and control over compliance with safety regulations on construction sites
Hypothesis 2	The use of neural processors and AI to analyze data from drones will increase the speed and accuracy of detecting violations (lack of PPE, alcohol intoxication).	Fast and accurate detection of violations on construction sites.
Hypothesis 3	The implementation of a system with drones and AI will reduce the number of accidents on construction sites by 20-30% compared to traditional control methods.	Reducing the number of incidents and improving the overall level of safety on construction sites.

The rationale behind the research strategy and approach is to apply a multi-layered approach to validate and optimize an integrated construction site safety system. This strategy includes integrating various technologies such as drones, artificial intelligence (AI), and neural processors, and testing them in real construction site conditions. A combination of descriptive, correlational, and experimental studies will be used to evaluate the effectiveness of the proposed system, allowing for a comprehensive analysis and improvement of the system's functionality.

Descriptive studies include an analysis of existing construction site safety issues, which helps identify key risks and threats to workers.

This stage collects data on typical violations and accidents, which allows for the creation of a comprehensive information base for further analysis. In addition, the state of the technologies used in face control and personal protective equipment (PPE) monitoring systems is assessed, which helps to understand their effectiveness and identify areas for improvement.

The correlation studies will examine the relationship between the use of drones for monitoring and the level of safety on construction sites, which will help to determine how the implementation

of this technology affects overall safety indicators. In addition, the impact of alcohol monitoring on production performance and accident reduction will be assessed, which will help to identify the importance of monitoring the condition of workers in the context of improving safety and efficiency on construction sites.

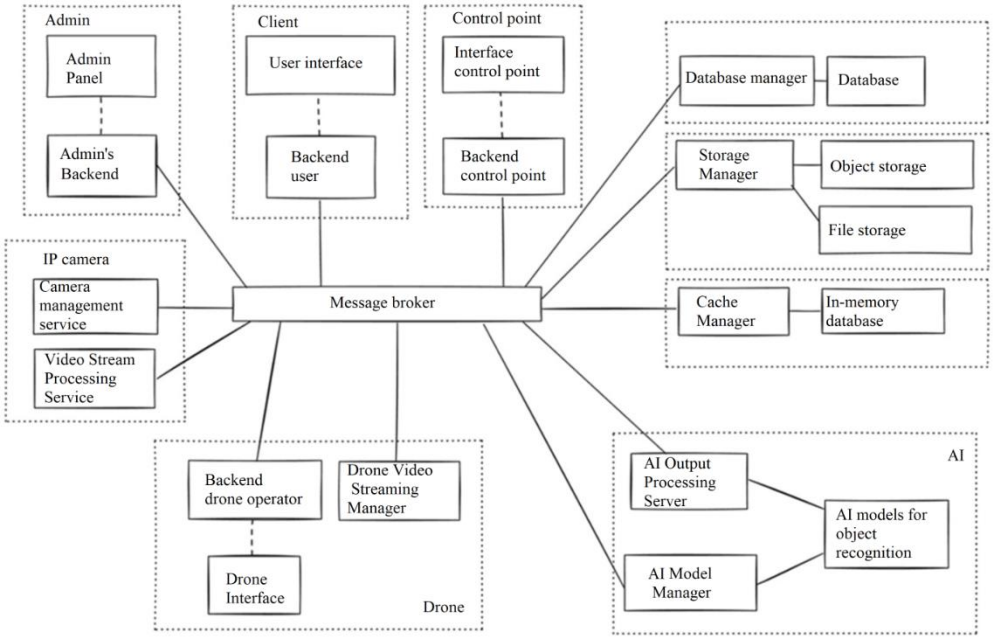

Figure 2. Scheme of data exchange buffer from the construction site to the control point

The pilot studies will include conducting field experiments with the integrated system at various construction sites to evaluate the effectiveness of drones and artificial intelligence (AI) algorithms compared to traditional monitoring methods.

The research will be carried out in several stages: the first stage - descriptive studies aimed at analyzing existing monitoring systems and collecting data on safety violations, which will form the basis for further research; the second stage - the development and integration of technologies, including the implementation of drones and the integration of AI and neural processing units (NPU) for the personal protective equipment (PPE) monitoring and inspection system;

The third stage will involve correlation studies that will focus on examining the data collected from drones and their correlation with safety indicators; the fourth stage will involve experimental studies that will involve field testing of the system and adjustment of algorithms; and the fifth stage will involve evaluation and conclusions that will include analysis of the collected data, testing of hypotheses, and evaluation of the effectiveness of the system in reducing the number of incidents at construction sites.

2) A brief description of the most important experiments includes the following key steps:

- Field monitoring experiment: Conduct field experiments at various construction sites using drones to monitor compliance with safety regulations and the availability of personal protective equipment (PPE). Evaluating their effectiveness in real-world conditions will help identify the main drawbacks and advantages of the system. - Benchmarking of inspection methods: Evaluate the performance of drones and artificial intelligence (AI) algorithms compared to traditional inspection methods such as visual inspections. This study will determine to what extent the

implementation of new technologies improves the accuracy and speed of violation detection (Figure 2).

a) b)

Figure 3. Example of a worker and manager at a construction site: a) Front view; b) rear view with QR code

- Alcohol monitoring: Conduct an experiment to test workers for alcohol using an automated system controlled by drones. Evaluate the impact of this monitoring on reducing accidents and increasing productivity on construction sites.

- Data correlation: Collect and analyze data obtained from the use of drones to identify the relationship between the use of the technology and changes in safety levels and the number of incidents. This will help confirm or refute hypotheses about the impact of technology on safety.

- Feedback and algorithm adjustment: Analyzing the collected data to adjust the algorithms of drones and AI, which will ensure their adaptation to the specific conditions of construction sites and increase the overall efficiency of the system.

3) The project uses several research methods; each aimed at achieving the set goals and objectives. Descriptive studies help to identify existing safety issues at construction sites, collect data on typical violations, and assess the current state of control technologies, which creates a basis for further decisions. Correlation studies allow us to establish the relationship between the use of drones and the level of safety, as well as the impact of alcohol monitoring on production indicators. Experimental studies, including field testing of new technologies, evaluate their effectiveness and help test hypotheses about reducing accidents. Finally, systematic analysis of the collected data helps to adjust the methods and algorithms, ensuring continuous improvement and optimization of the system. All these methods are interconnected and form a holistic approach to improving safety at construction sites through the integration of modern technologies. In order to improve the level of industrial safety and minimize the human factor, it is proposed to introduce a system of personalized QR codes for all employees of the construction site. Each employee will be given a unique QR code, which contains information about their current admission to perform certain types of work on a specific day. For example, by scanning a QR code, it will be possible to determine whether a given employee is allowed to perform (see Figure 3):

- excavation work;

- work at height;
- work with electrical equipment;
- welding or fireworks;
- work in confined spaces, etc.

The information will be synchronized with the production control system and updated depending on the daily medical examination, safety briefings, weather conditions and other factors. This approach will ensure precise control over the distribution of responsibilities, eliminate cases of unauthorized access to hazardous areas and improve the overall safety culture at the facility.

Conclusion

The methods for collecting primary (initial) information in the project will include several key approaches aimed at solving problems and ensuring the reliability and reproducibility of data. Observation and monitoring: Using drones to monitor construction sites will allow the collection of data on compliance with safety regulations, the availability of personal protective equipment (PPE), and the identification of violations in real time. The data will be collected in real-life conditions, which will ensure their relevance and applicability. Questionnaires and surveys: Conducting surveys among workers and managers of construction sites will provide information on the perception of existing safety measures, their shortcomings, and wishes for improvement. This will help collect high-quality data based on user opinions.

Analysis of documentary sources: Collecting and analyzing existing accident reports, inspection protocols, and safety standards at construction sites will create a database for further analysis and comparison with the results obtained. Field experiments: Implementation of field experiments with the introduction of new technologies and methods will allow us to evaluate their effectiveness in real conditions. The data collected during the experiments will serve as the basis for testing hypotheses. Data processing methods include statistical analysis, which will reveal patterns and relationships, as well as the use of machine learning algorithms to analyze large volumes of data collected from drones.

Ensuring the reliability and reproducibility of the data will be achieved through the use of standardized methods for collecting and processing information, as well as checking the results through repeated measurements and data verification using independent sources. This will ensure the reliability and accuracy of the conclusions made during the study. The introduction of a QR code system to determine employee access to specific types of work is an effective tool for improving safety at a construction site.

Such a system allows for daily operational control, reduces the risk of accidents, eliminates the participation of untrained or uncertified workers in hazardous work, and improves discipline and transparency in the distribution of tasks. In the future, this solution may become an integral part of the digital ecosystem for occupational safety management at large production and construction sites.

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The contribution of the authors

Omarov A.R. - concept, methodology, resources, data collection, testing of experimental samples;
Zhussupbekov A. Zh. - modeling;
Bibalaev O. D. - visualization, interpretation;
Mikhailov D. M. - writing;
Tanyrbergenova G. K. - analysis;
Ankit Garg - editing.

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Құрылыс саласында еңбек қауіпсіздігін компьютерлік көру және дрондар арқылы арттыру

Аңдатпа. Дулыға және көзілдірік сияқты жеке қорғану құралдарын (ЖҚҚ) пайдалануға белгіленген талаптарға қарамастан, құрылыс алаңдарында бақылаудың дәстүрлі әдістері қауіпсіздік нормаларын тиісті деңгейде сақтауды қамтамасыз етпейді, бұл жарақат алудың өсуіне әкеледі. Жобаның мақсаты – компьютерлік көру технологияларын, машиналық оқытуды және дрондарды пайдалана отырып, тұлғаны бақылаудың интеграцияланған жүйесін, ЖҚҚ бар-жоғын және алкоголь деңгейін бақылауды автоматты түрде тексеру. Жүйе бет-әлпетті тануды жүзеге асырады, дулыға мен көзілдіріктің болуын бақылайды, сондай-ақ жұмысшылардың үздіксіз мониторингін қамтамасыз ете отырып, қауіпті мінез-құлық пен алкогольдік мас болу белгілерін анықтайды. Бұл қауіпсіздік деңгейін айтарлықтай жақсартуға, жазатайым оқиғалардың санын азайтуға және еңбек өнімділігін арттыруға мүмкіндік береді деп күтілуде. Әзірлеу құрылыстан бастап тау-кен өнеркәсібіне,

мұнай-газға дейін әртүрлі салаларға бейімделетін болады. Жобаның жоғары практикалық және әлеуметтік-экономикалық маңызы бар, Қазақстанның ғылыми-техникалық әлеуетін дамытуға, IT және автоматтандыру саласында жаңа жұмыс орындарын құруға, сондай-ақ ғылым мен өндірістің өзара әрекеттесуін нығайтуға ықпал етеді.

Түйін сөздер: дрон, ЖИ, алкоголь тесті, QR коды, ЖҚҚ.

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Повышение безопасности труда в строительстве с помощью компьютерного зрения и дронов

Аннотация. Несмотря на установленные требования по использованию средств индивидуальной защиты (СИЗ), таких как каски и очки, традиционные методы контроля на строительных площадках не обеспечивают должного уровня соблюдения норм безопасности, что приводит к росту травматизма. Цель проекта — разработка интегрированной системы фейс-контроля, автоматической проверки наличия СИЗ и мониторинга уровня алкоголя с применением технологий компьютерного зрения, машинного обучения и дронов. Система будет осуществлять распознавание лиц, контроль наличия касок и очков, а также выявление небезопасного поведения и признаков алкогольного опьянения, обеспечивая непрерывный мониторинг работников. Ожидается, что это позволит существенно повысить уровень безопасности, снизить количество несчастных случаев и повысить производительность труда. Разработка будет адаптируема для различных отраслей — от строительства до горнодобывающей и нефтегазовой промышленности. Проект имеет высокую практическую и социально-экономическую значимость, способствует развитию научно-технического потенциала Казахстана, созданию новых рабочих мест в сфере IT и автоматизации, а также укреплению взаимодействия между наукой и производством.

Ключевые слова: дрон, ИИ, алкотестер, QR код, СИЗ.

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