From November 27 to 29, 2023, a business trip was carried out to Nazarbayev University in Astana within the framework of the PTF BR 28713197 project, “Sustainable Innovation Center of the Caspian Region: Scientific and Academic Promotion of Alternative Solutions for the Region’s Transition to an Environmentally Sustainable Future.” The visit was attended by the project leader, Saltanat Rustamovna Sharmukhanbet, and project coordinator Gulnur Boranbaikyzy Turmukhanova.

Robotics and mechatronics are among the most advanced fields of modern science and technology. They offer significant opportunities for automating industrial processes, improving the efficiency of production systems, and providing innovative solutions across various sectors of society. Today, robotics is widely applied not only in industrial manufacturing and scientific research but also in education, healthcare, logistics, agriculture, and environmental protection. The role and importance of this field in the global economy continue to grow, as robotic and mechatronic systems contribute to process automation, increased productivity, enhanced safety, and the resolution of environmental challenges.

The environmental efficiency of robotic and mechatronic systems has become an especially relevant issue in recent years. Reducing negative impacts on the environment and ensuring the efficient use of resources are among the key challenges of the 21st century. For Kazakhstan and the Caspian region, environmental issues are of particular importance, as the ecological condition of the region and the efficient use of energy resources directly affect sustainable development and the future well-being of society. Therefore, the development of environmentally efficient robotic and mechatronic systems plays a crucial role in ensuring the ecological sustainability of the region.

The research conducted within the framework of the PTF BR 28713197 project, “Sustainable Innovation Center of the Caspian Region: Scientific and Academic Promotion of Alternative Solutions for the Region’s Transition to an Environmentally Sustainable Future,” is aimed at addressing these challenges. The study focuses on developing innovative solutions and technologies to improve the environmental efficiency of robotic systems, reduce energy consumption, and minimize harmful emissions. The primary objective of the research is to enhance robotic and mechatronic systems in order to improve energy efficiency and environmental performance. In addition, the study examines the implementation of environmentally efficient robots and mechatronic systems in industrial production to automate manufacturing processes and support the principles of sustainable development.

The significance of this project is particularly noteworthy, as it is aimed not only at the automation of industrial production but also at the development of environmentally friendly manufacturing systems, the conservation of natural resources, and the reduction of negative environmental impacts. This research is especially important for Kazakhstan and the Caspian region, where innovative solutions and technologies that comply with environmental requirements are essential for ensuring sustainable regional development.

The methods and approaches employed in the research, including adaptive and predictive algorithms, intelligent systems, energy-efficiency assessment techniques, and modeling methods, are all focused on enhancing the environmental performance of robotics. This research opens up new opportunities for improving the environmental efficiency of robotic systems, advancing industrial automation, and promoting more efficient use of resources.

1. Main Purpose of the Business Trip

The main purpose of the business trip was to familiarize the project team with the research activities conducted by the research centers and engineering faculties of Nazarbayev University in the fields of robotics and mechatronics, as well as to discuss new innovative solutions and technologies aimed at improving environmental efficiency. The visit was also intended to obtain recommendations regarding environmental issues and energy conservation and to explore opportunities for future collaboration with the university.

The key algorithms and approaches used in the development of robotic and mechatronic systems play a crucial role. First, adaptive algorithms enable systems to adjust their operation

according to environmental and industrial conditions. These algorithms improve the efficiency of robotic systems and help reduce energy consumption. In addition, predictive algorithms make it possible to forecast future conditions and introduce corrective actions in advance, which is particularly important for energy saving.

Intelligent control systems and diagnostic algorithms allow continuous monitoring of robot performance and timely detection of faults and malfunctions. With the help of these systems, the environmental efficiency and operational performance of robotic systems can be continuously monitored, while preventive maintenance ensures uninterrupted operation.

The effectiveness of these algorithms contributes significantly to environmental sustainability, as they are designed to conserve natural resources, improve energy efficiency, and reduce waste generation. These aspects, in turn, provide a basis for planning future scientific and academic activities within the project and for discussing potential partnership opportunities.

When identifying opportunities for national and international cooperation, the experience of the scientific community and universities in researching new technologies, as well as their active involvement in developing environmentally sustainable solutions, plays an important role.

2. Main Results of the Business Trip

During the business trip, an important meeting was held at Nazarbayev University with Dr. Azamat Nurlanovich Eshmukhametov, PhD and Associate Professor. During this meeting, the participants became acquainted with the activities of the university's research centers and exchanged views on the current state and future prospects of robotics development.

Main Results:

• Familiarization with Research Centers: The robotics and mechatronics research centers of Nazarbayev University presented their latest scientific projects and innovative solutions. The research and development activities carried out in the laboratories include solutions aimed at improving environmental efficiency and energy conservation.

Figure 1. Familiarization with Research Centers

3. Environmental Efficiency of the Project and Innovative Technologies

The main environmental benefit of the project lies in the environmentally efficient application of robotic and mechatronic solutions in industrial production. These solutions enable energy savings, efficient resource utilization, and a reduction in the environmental impact of manufacturing processes.

Several key aspects of environmental efficiency deserve particular attention:

1. Energy Saving

The use of robotic systems in industry makes it possible to reduce energy consumption during production processes. The high precision and efficiency of robots and mechatronic systems optimize operations while maintaining product quality with minimal energy use. This, in turn, enhances the environmental sustainability of industrial processes, as reduced energy consumption leads to significant conservation of natural resources.

2. Waste Reduction

One of the advantages of mechatronic systems is their ability to provide real-time monitoring and control, which helps minimize waste generation. By performing manufacturing operations with high precision, robots reduce material consumption while improving product quality. This contributes to a decrease in environmentally harmful waste and promotes more efficient use of resources.

3. Environmental Impact

The implementation of robotic systems not only increases production efficiency but also reduces negative environmental impacts. The accuracy and energy efficiency of manufacturing processes contribute to lower levels of harmful emissions. This supports the sustainable development of industries in accordance with environmental policies and helps minimize adverse environmental effects.

Innovative technologies play a crucial role in ensuring the environmental efficiency of robotic systems:

1. Adaptive Control Systems

Modern control systems enable efficient management of robots and mechatronic systems. Adaptive and predictive algorithms allow robotic operations to be adjusted according to environmental and production conditions, thereby improving environmental performance. These algorithms enhance system efficiency and expand opportunities for resource conservation.

2. Intelligent Diagnostics

Specialized systems have been introduced to monitor and diagnose the operating condition of robotic systems. These systems enable early detection of potential failures and malfunctions. Predicting faults and performing timely maintenance help prevent negative environmental impacts and ensure uninterrupted operation of production processes.

These innovative technologies form the foundation for achieving environmental efficiency in industrial production. The implementation of robotics and mechatronics contributes to the sustainability of manufacturing processes and minimizes their impact on the environment.

4. Conclusions and Recommendations of the Business Trip

Based on the results of the business trip, it was determined that collaboration with the research divisions of Nazarbayev University offers significant opportunities to enhance the environmental efficiency of robotic and mechatronic systems. The introduction of these systems into industry can reduce production costs and improve environmental performance indicators.

At present, the importance of robotics and mechatronics in both industrial and scientific fields has increased significantly. These technologies have a substantial impact on improving environmental efficiency and ensuring the safety of production processes. The research conducted within the framework of the “Sustainable Innovation Center of the Caspian Region” project is aimed at developing innovative solutions and technologies to enhance the environmental performance of robotic systems.

During the study, numerous advanced methods and algorithms were proposed to improve the energy efficiency and environmental performance of robots. Adaptive and predictive algorithms

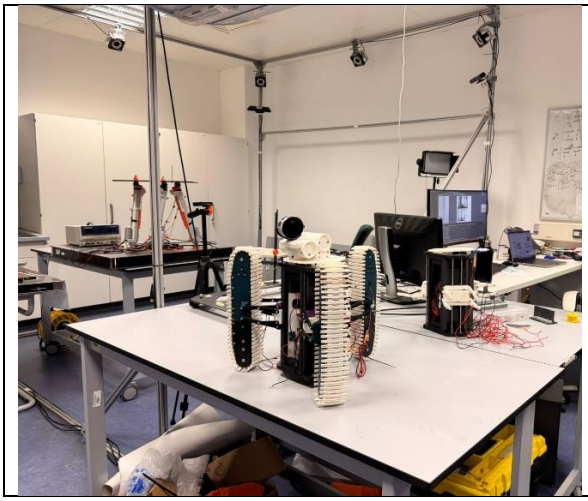
make robotic systems more efficient and environmentally friendly. These algorithms can reduce energy consumption by 12–18% while simultaneously increasing operational productivity. In addition, intelligent systems and diagnostic tools enable continuous monitoring of robotic performance and help prevent potential failures.

The theoretical and practical foundations for improving the environmental efficiency of robotics have been validated by the results of this research. Energy conservation and waste reduction are among the key advantages of these technologies. The implementation of robotic and mechatronic systems in industry ensures not only greater production efficiency but also improved environmental sustainability. This contributes to reducing harmful emissions and promoting the rational use of natural resources.

This research is particularly important for Kazakhstan and the Caspian region, where environmental challenges and limited energy resources remain pressing issues. Accordingly, the study provides innovative solutions and technologies that are essential for ensuring the environmental security and sustainable development of the region.

Overall, the research findings open new opportunities for enhancing the environmental efficiency of robotics and mechatronics, as well as for advancing industrial automation. The implementation of these technologies not only improves production efficiency but also supports the development of systems that comply with environmental requirements. Therefore, the environmentally responsible use of robotics is an important task not only for industry but also for society as a whole.

In the future, it is necessary to further develop the results obtained through this research, introduce new technologies, and create environmentally friendly production systems. Such efforts will undoubtedly represent an important step toward ensuring environmental sustainability not only within a single region but throughout the world.



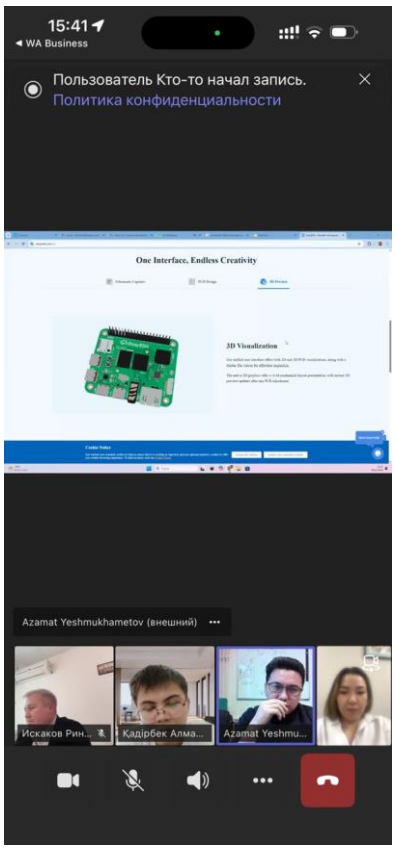
On December 9, 2025, an online scientific seminar was held within the framework of the PTF BR 28713197 project, “Sustainable Innovation Center of the Caspian Region: Scientific and Academic Promotion of Alternative Solutions for the Region’s Transition to an Environmentally Sustainable Future.”

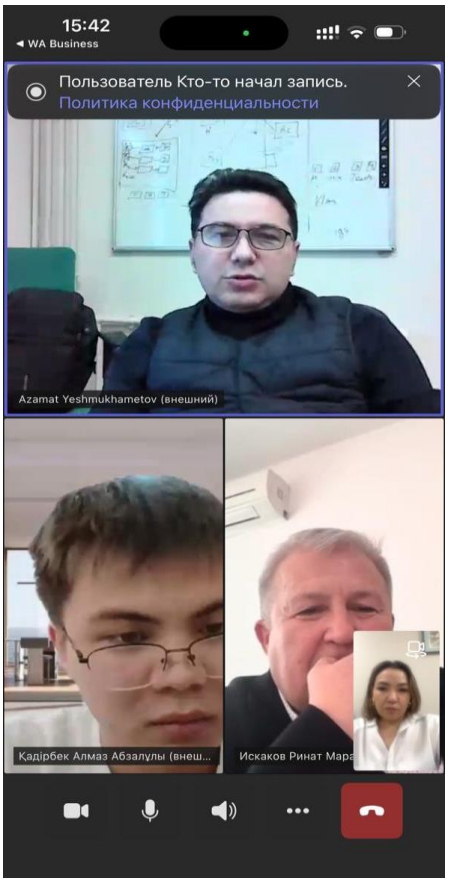
The seminar was dedicated to Activity 3 of the project: “Development of Innovative Solutions and Technologies in Robotics and Mechatronics Aimed at Increasing Productivity, Efficiency, and Safety.”

Presentation topic: “How to Develop Industrial Technologies Within a Company.”

During the seminar, participants discussed approaches to developing in-house technological solutions, opportunities for integrating robotic and mechatronic systems, and ways to improve the efficiency and environmental sustainability of production processes. The participants reviewed successful case studies, strategic factors of technological development, and modern tools that enable companies to become more innovative and competitive.

We express our gratitude to all specialists who actively participated in the event. The work aimed at promoting sustainable innovations will continue in 2026.




Atyrau University and “ZiyatTech” LLP jointly organize a new online course.

The professional development course “Robotics and STEM” is designed for students, specialists, and researchers who wish to enhance their knowledge in STEM and robotics. The course is conducted within the framework of the 3rd direction of the BR28713197 program “Sustainable Innovation Center of the Caspian Region: Scientific and Academic Promotion of Alternative Solutions for the Region’s Transition to an Environmentally Sustainable Future” (2025–2027). The goal of the program is to support regional sustainable development, strengthen scientific and academic potential, and create conditions for the implementation of new innovative projects.

Participants of the course gain knowledge of modern STEM and robotics technologies, become familiar with innovative educational methods, and have the opportunity to participate in practical projects. During the training, participants develop practical skills such as assembling robotic devices, programming, conducting STEM experiments, and applying scientific research methods. In addition, participants can expand their professional network by engaging in regional and international projects.

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The course enables participants to expand their knowledge and skills in STEM and robotics, take advantage of opportunities to participate in innovative projects, and contribute to strengthening the scientific and academic potential of the region.

The course was conducted online starting from 23.02.2026, allowing participation from all regions of the country and intercity level. Participants successfully completed the course and received certificates on 16.04.2026.

ATYRAU UNIVERSITY

BR28713197 "Каспий орнықты инновациялар орталығы: өңірдің негұрлым экологиялық болашаққа көшуі үшін балаларды шешімдерді ғылыми-академиялық ігерілету" жобасы шеңберінде 3 бағыт бойынша

# «Робототехника және STEM»

атты біліктілікті арттыру курсы

**КУРСТЫҢ ЕРЕКШЕЛІКТЕРІ:**

- Қазіргі технологиялар
- Кәсіби даму
- Инженерлік ойлау
- STEM дағдылар
- Тегін қатысу
- Офлайн/онлайн оқу

КУРСТЫ ЖШС «ZIYAT TECH» МАМАНДАРЫ ӨТКІЗЕДІ

**Өтетін орны:** Х.Досмұхамедов атындағы Атырау университеті

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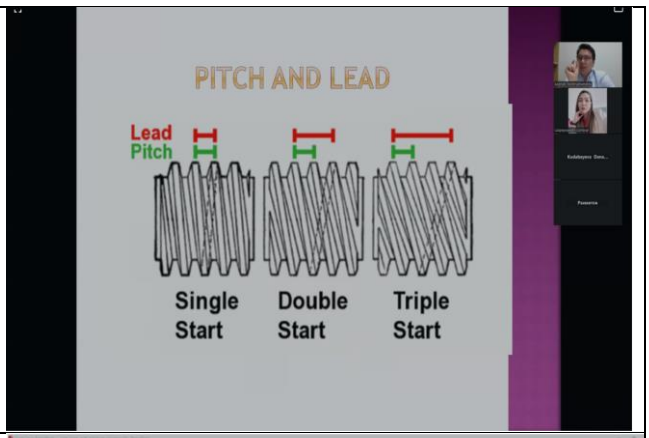
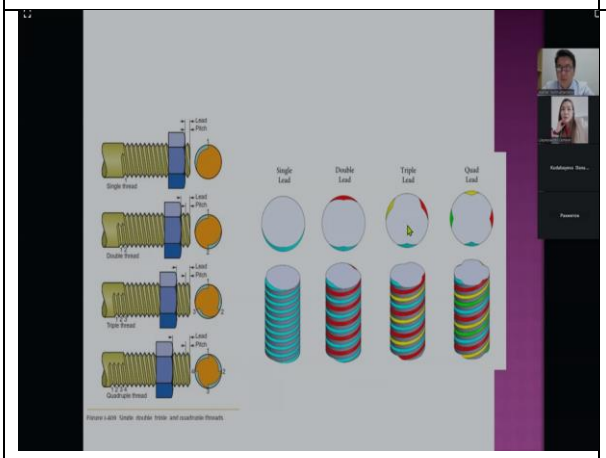
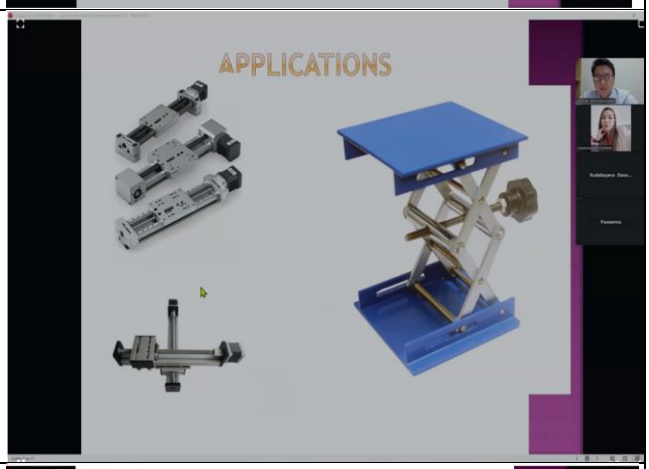
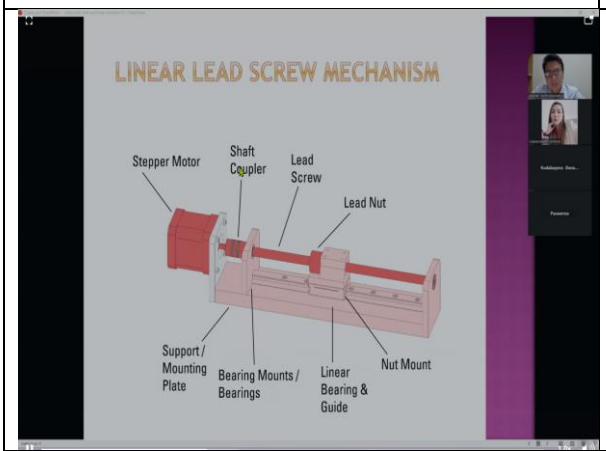
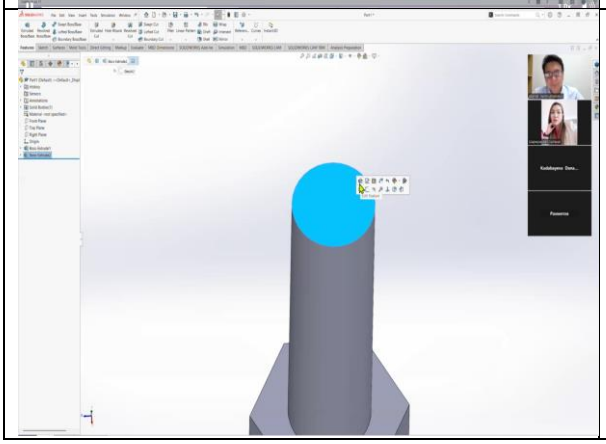


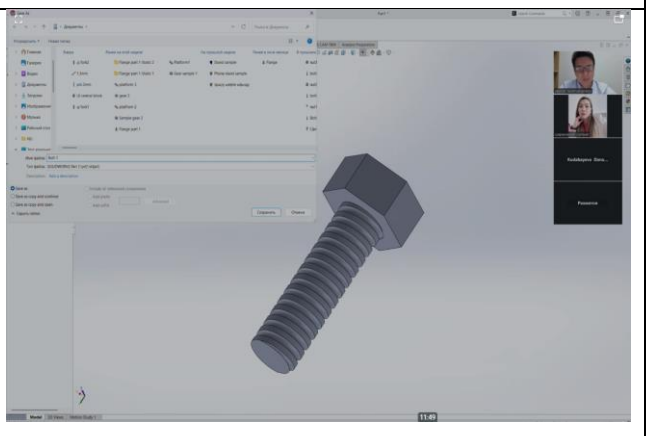









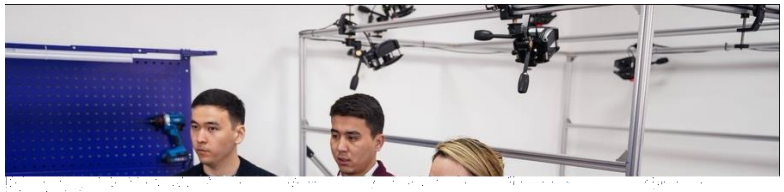
On April 16, at Atyrau University named after H. Dosmukhamedov, a ceremonial opening of the Robotics and Mechatronics Laboratory took place on the initiative of the Caspian Sustainable Innovation Center.

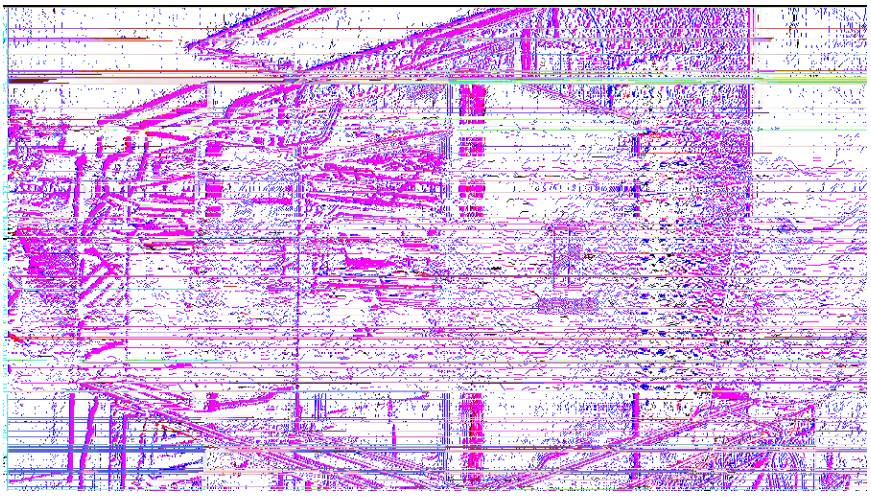
The new laboratory was established within the framework of developing scientific and academic activities aimed at ensuring the ecological sustainability of the region. The main goal of the Center is to develop and implement alternative technological solutions that contribute to shaping a sustainable future for the region. The opening ceremony was attended by the head of the FabLab laboratory at Astana IT University, Daniyar Dauletiya, the leadership of Atyrau University, professors and teaching staff, researchers, and students. The ceremonial ribbon-cutting was carried out by Doctor of Pedagogical Sciences, Professor Askhat Imanaliyev, Rector of Atyrau University Salamat Idrisov, and Doctor of Technical Sciences, Professor Beket Kenzhegulov.

During the event, the results of scientific research and experimental design work carried out under the 3rd direction of the PTF BR 28713197 program were presented. This direction is focused on developing innovative solutions in robotics and mechatronics aimed at increasing productivity, efficiency, and safety.

The newly established laboratory was created within the framework of scientific and academic development aimed at ensuring the ecological sustainability of the region. The main goal of the Center is to develop and implement alternative technological solutions that contribute to the formation of a sustainable future for the region. The main objectives of the project are to increase the productivity of industrial processes, improve their efficiency, and ensure safety levels. For this purpose, the newly opened laboratory is equipped with modern facilities and provides broad opportunities for students and researchers to conduct scientific and practical studies.

In addition, the laboratory is expected to become an important platform for applied research aimed at addressing current challenges in the industrial sector.

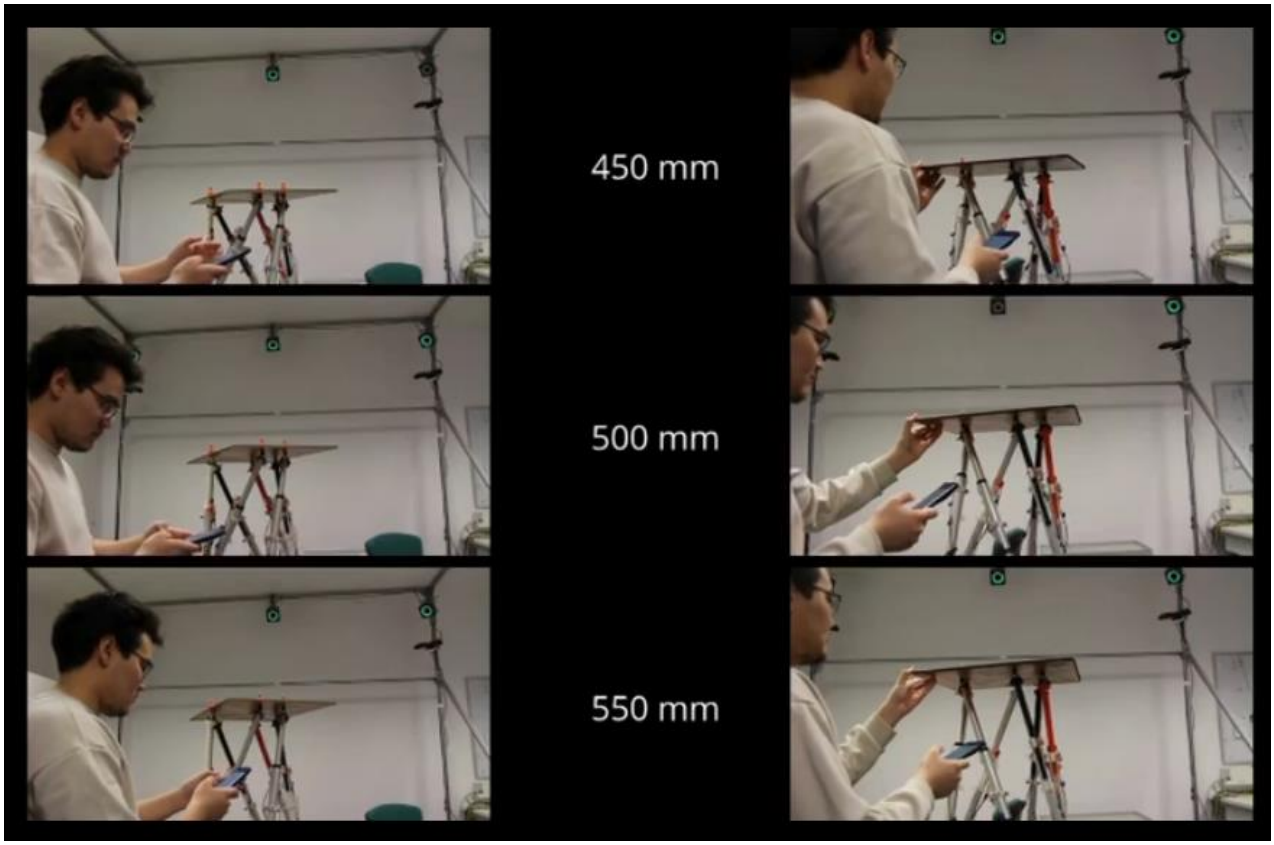


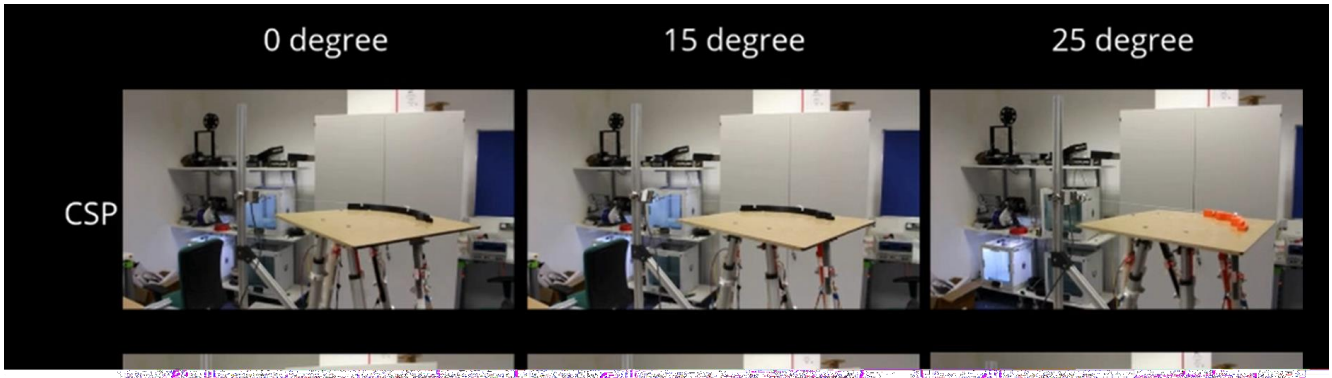
Robotic and mechatronic systems are widely used in modern industries such as manufacturing, transportation, energy, healthcare, and service sectors, becoming one of the key directions of technological development. In recent years, special attention has been given to the integration of modern intelligent technologies such as artificial intelligence, machine learning, computer vision, and intelligent data processing in order to expand the functional capabilities of these systems and improve their operational efficiency. These technologies significantly enhance the ability of robotic systems to perceive the environment, analyze acquired information, make decisions, and adapt to changing conditions.

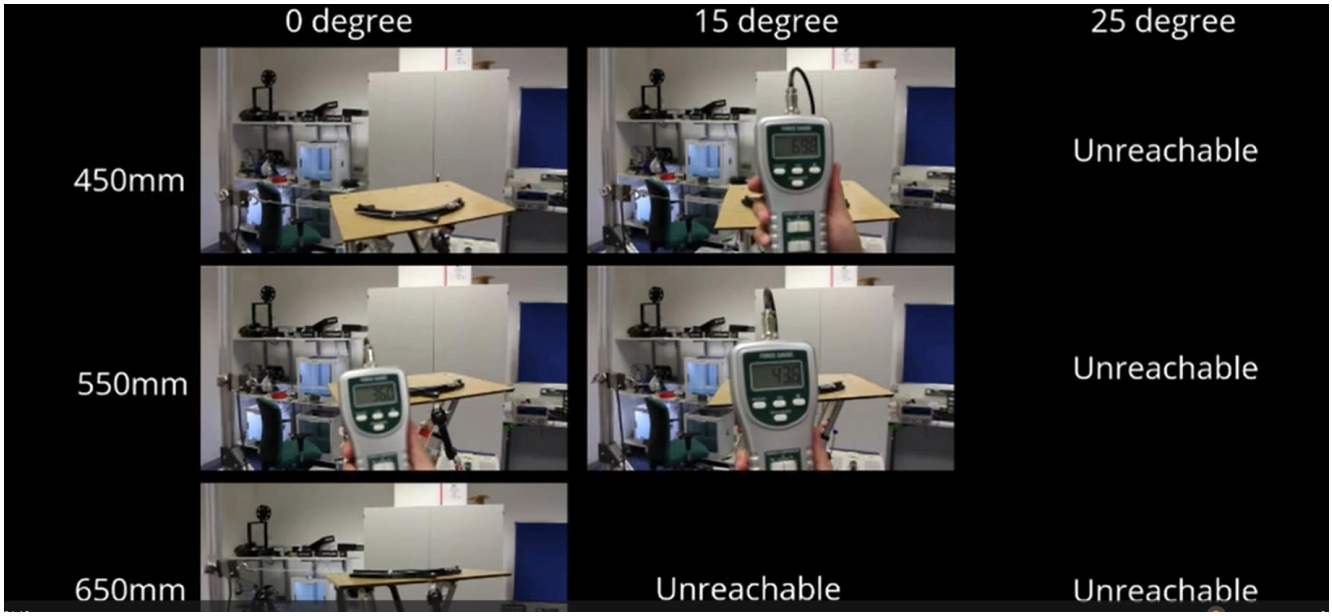
The video material presented below comprehensively examines the scientific and practical aspects of implementing intelligent technologies in robotic and mechatronic systems. The results of the

video material demonstrate that the use of intelligent algorithms significantly increases system productivity, reliability, and operational autonomy. In particular, in complex industrial processes and real-time operating systems, the application of intelligent control methods improves the accuracy of operations and helps reduce errors caused by the human factor. The presented visual material illustrates the operation of a robotic system integrating artificial intelligence and machine learning elements. The images demonstrate the functioning process of an intelligent complex, including sensor modules, data processing systems, and actuators.

During the system's operation, data is collected from sensors and cameras, after which the acquired information is processed using artificial intelligence algorithms. Based on the analysis of input parameters, the system automatically makes decisions and generates control actions to ensure the execution of assigned tasks in automatic mode.






In the photographs, special attention is given to system adaptability: the robot is able to adjust its actions according to changes in the external environment, which demonstrates the use of machine learning and intelligent control methods. The high precision of operations and the efficiency of interaction between software and hardware components are also shown.

During the research, a series of experiments were conducted aimed at optimizing the technical characteristics and operating modes of robotic systems. The obtained results proved that the introduction of artificial intelligence elements expands the system's ability to adapt to environmental conditions and improves its capacity to perform complex tasks autonomously. In addition, it was determined that intelligent methods of processing sensory data enhance robots' capabilities in object recognition, motion planning, and control quality.

The results of the conducted scientific research formed the basis for developing new approaches to the design and operation of robotic and mechatronic systems. The obtained data are of significant scientific and practical importance in the fields of industrial automation, smart manufacturing technologies, and the development of cyber-physical systems. The research

findings not only confirm the effectiveness of intelligent technologies but also demonstrate the prospects for their widespread implementation across various sectors.

The scientific novelty and practical significance of the research have allowed it to be highly recognized by the international scientific community. Based on the results, scientific articles were prepared and submitted to leading academic journals. In particular, a total of four scientific articles were developed and submitted for publication in journals indexed in the Scopus international database and in journals recommended by the Committee for Quality Assurance in the Sphere of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan (KOKSON). These articles comprehensively present the theoretical foundations of intelligent control systems, methods for improving the efficiency of robotic systems, results of experimental studies, and their practical applications.

Thus, the conducted research confirms the relevance and effectiveness of integrating intelligent technologies into robotic and mechatronic systems and proposes new scientific solutions aimed at improving their productivity, reliability, and autonomy. The obtained results form a solid scientific foundation for the future development of intelligent robotic systems and their effective application in various fields of industry and science.

# A Two-Radii Gough-Stewart Platform: Kinematics, Dynamics and Isotropic Analysis, and Experimental Verification

**RAMAZAN ZHYLKAIDAROV[1], KOICHI KOGANEZAWA[2], MAKHATOVA VALENTINA [3], SALTANAT SHARMUKHANBET[3], GULBARSHIN SHAMBILOVA[3], and AZAMAT YESHMUKHAMETOV[1,4]**

[1]Department of Robotics Engineering, School of Engineering and Digital Sciences, Nazarbayev University, Astana, Kazakhstan, 010000
[2]Department of Computer Science, SDU university, Almaty, Kazakhstan, 010000
[3]Faculty of Physics, Mathematics and Information Technology , Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan
[4]Institute of Smart Systems and Artificial Intelligence, Astana, Kazakhstan, 010000

Corresponding author: Azamat Yeshmukhametov. Email: azamat.yeshmukhametov@nu.edu.kz.

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**ABSTRACT** Parallel manipulators are widely used in tasks that demand high precision and stiffness. Stewart Platform (SP) is an example of such a manipulator, and although it has several advantages it lacks a uniform force-torque distribution across the workspace. This is crucial in tasks demanding repeatable and balanced force application from different points of the workspace, for example, robotic surgeries and precision manufacturing. This paper a provides a machine design and development, mathematical model, and simulation study followed by experimental validation. The proposed configuration of the Gouph-Stewart Platform enhanced with Isotropy (GSPI) provides much more isotropic nature on force and torque exerting. The GSPI introduces a dual-radii arrangement of the joint placement that results in improving in isotropic behavior of the SP. A kinematic and inverse-kinematic formulation, applicable for both GSPI and a SP taking Conventional/Common Configuration (CSP), is derived. Moreover, we also formulated the dynamic model of the SP, which is based on the Augumented Lagrangian approach. Numerical simulations were applied based on the formulated dynamics, which helps predict the behavior of the machine and provides us how to dynamically control it. The paper also proposes a quantitative index for evaluating how much

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# Computer vision aided, VLM-based human expert level welding quality assessment system

Olzhas Kakimzhanov[a,*], Lyailya Kurmangaziyeva[b], Turmukhanova Gulnur [b], Sharmukhanbet Saltanat [b], Darkhan Zholtayev[a,*] and Azamat Yeshmukhametov[a,c,*]

[a]*Institute of Smart Systems and Artificial Intelligence, Kabanbai str 53, Astana, 010000, Kazakhstan*
[b]*Faculty of Physics, Mathematics and Information Technology, Khalel Dosmukhamedov Atyrau University, Atyrau, 060000, Atyrau , Kazakhstan*
[c]*School of Engineering and Digital Sciences, Nazarbayev University , Kabanbai str 53, Astana, 010000, Akmola region, Kazakhstan*

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You only look once
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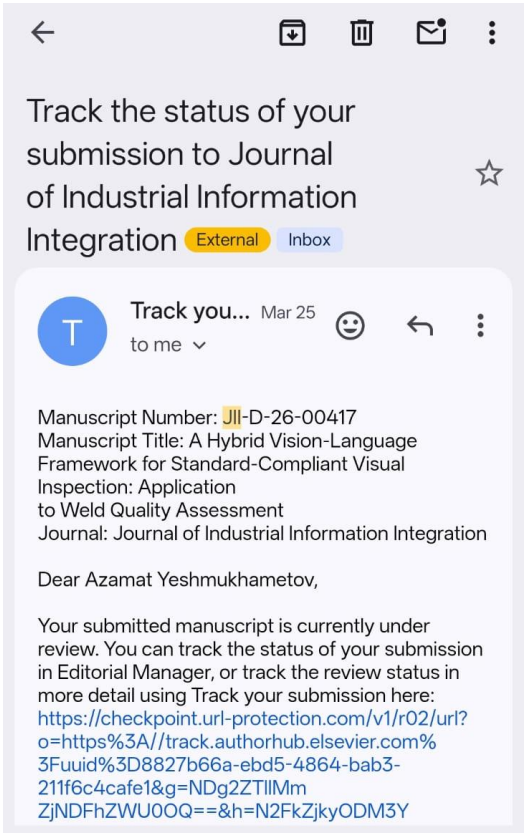
ABSTRACT

Automated weld inspection has achieved significant progress in defect detection using deep learning–based computer vision systems. However, existing approaches primarily focus on defect localization and classification, while the final weld quality decision remains dependent on human inspectors. This introduces variability, potential bias, and dependence on expert availability, particularly when compliance with ISO 5817 quality levels is required.

In this work, we propose a novel human expert–level welding quality assessment framework that integrates computer vision, quantitative image processing, and vision–language modeling. First, an enhanced defect detection module identifies cracks, porosity, spatters, and welding line irregularities. Image processing techniques are further applied to estimate pore diameters, classify pore sizes, and detect welding discontinuities. These structured quantitative outputs are then provided to a conditioned vision–language model, which performs standards-aware reasoning to generate weld quality conclusions in accordance with ISO 5817 levels (B, D, and F).

Unlike prior methods, the proposed system not only detects defects but also produces a standards-compliant quality verdict accompanied by detailed, human-readable explanations, including defect measurements and seam continuity analysis. Extensive experiments are conducted across diverse weld scenarios. The proposed approach is evaluated against cloud-based state-of-the-art vision–language solutions (Gemini), locally deployed edge models (Gemma), and a baseline VLM-only configuration. Additionally, system conclusions are compared with assessments from experienced human welding inspectors to analyze expert-level alignment.

Results demonstrate that the proposed computer vision–aided vision–language framework provides reliable, interpretable, and standards-compliant weld quality assessments, reducing dependence on subjective human judgment and enabling a higher degree of automation in industrial welding inspection.




Screenshots of the article submitted to the Journal of Industrial Information Integration.