Spectrum Journal of Innovation, Reforms and Development
Volume 41, July 2025 | ISSN (E): 2751-1731
WEBSITE: WWW.SJIRD.JOURNALSPARK.ORG

MODELING OF INTELLIGENT SORTING MANIPULATORS FOR MULTI-PRODUCT PRODUCTION LINES

A. O. Yoqubjonov
Namangan State Technical University
azizbek4978558@gmail.com

Abstract
This article presents the modeling and prototyping stages of an intelligent sorting manipulator system designed for multi-product production lines. During the sorting process, the manipulator performs tasks such as detecting, classifying, and directing objects of various sizes and weights to the appropriate paths. Mechanical and kinematic models of the system were developed using SolidWorks and MATLAB software, while a physical prototype was assembled using Arduino UNO and sensor modules. The sorting accuracy and time were analyzed by comparing simulation and practical experiment results. The outcomes demonstrate that this technology can operate efficiently in multi-product manufacturing and contribute to increasing the level of automation.

Keywords: Intelligent manipulator, Sorting system, Simulation, Arduino, Sensor integration, Robotics.

Introduction

In modern production lines, the diversity of product types and the differences in their geometry and physical properties place high demands on automation. In particular, there is a growing need for intelligent manipulator systems that can operate with precision, without human intervention, in tasks such as sorting, placing, or directing products of various sizes, shapes, and weights. Traditional mechanical sorting methods often fail to adapt to the rapidly changing characteristics of products and are limited in terms of efficiency. In recent years, intelligent manipulators developed based on robotics, mechatronics, and artificial intelligence have been proposed as technological solutions to this challenge. These manipulators use sensors to automatically detect objects, classify them, and perform the corresponding actions. However, before such systems can be implemented in practice, it is essential to simulate their mathematical models and operational algorithms and to test them in the form of real prototypes.

This article highlights the scientific foundations for developing an intelligent sorting manipulator system designed for multi-product production lines. The main objective of the study is to develop a mathematical model of the manipulator's movement, simulate it, and then evaluate the system's performance experimentally through the creation of a physical prototype.

Research Methodology

In this research, the development of the intelligent sorting manipulator was carried out based on a step-by-step approach. Initially, the geometric structure of the manipulator was designed using the SolidWorks software platform. A four-degree-of-freedom system was selected for its motion mechanism, and a configuration capable of performing both linear and rotational movements was developed. In describing the motion, classical robotics formulas—physical equations characterizing force, torque, acceleration, and weight balance—were employed.

To analyze and optimize the manipulator's movement, its dynamic model was constructed in the MATLAB Simulink and Simscape Multibody environments. In this simulation, the manipulator's speed, trajectory, and operational efficiency were evaluated for objects of varying weights and sizes. For each direction of movement, load conditions and variations in time parameters were theoretically calculated.

To compare the simulation results with real-world performance, a physical prototype was built.

$$\tau = J \cdot \alpha + b \cdot \omega + \tau_f$$

$$F = m \cdot a, \quad T = r \cdot F$$

The prototype was based on the Arduino UNO platform, to which IR sensors, servo motors, and control modules were connected. The software was written in Arduino C language, and the object detection and sorting algorithm was automatically controlled through this code. Once an object was detected by a sensor, the manipulator moved in the appropriate direction based on the object's physical characteristics (size and weight) and sorted it into the corresponding bin. The sorting algorithm was designed to distinguish between four main object types: small-light, small-heavy, large-light, and large-heavy. A specific trajectory and servo motion were assigned to each object type.

Deviations in accuracy and timing were observed and analyzed to identify their causes—such as sensor precision, motor torque, and weight limits. In the final stage, the experimental results were analyzed to evaluate the efficiency of the sorting system. The results from the simulation and the physical prototype were compared using charts and tables. The findings showed that although there were differences between the simulation and the prototype performance, the discrepancies remained within acceptable limits. This indicates that the proposed intelligent sorting manipulator is sufficiently reliable and effective for practical implementation.

Results and Discussion

During the study, the developed intelligent sorting manipulator system was first tested in a simulation environment and then validated through practical experiments in laboratory conditions using a real prototype. The simulation was carried out using SolidWorks and MATLAB Simscape Multibody software environments, while the prototype was tested on the Arduino UNO platform using IR sensors and servo motors. The sorting system was based on distinguishing between four object types: small-light, small-heavy, large-light, and large-heavy. A specific trajectory and servo motion algorithm were defined for each object type.

The object sorting time and accuracy results from both the simulation and the prototype were compared using the following graphs and tables.

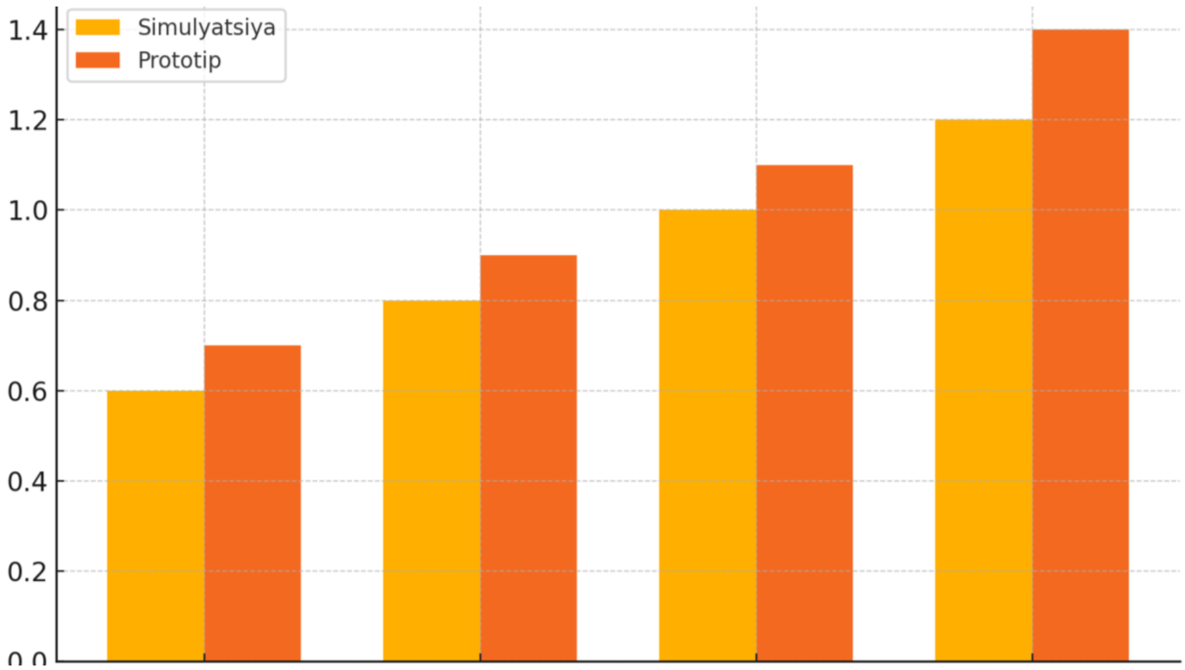


Figure 1. Comparison of Sorting Time by Object Type

In the simulation, small-light objects were sorted in 0.6 seconds, while in the prototype this time extended to 0.7 seconds. The largest discrepancy was observed with large-heavy objects: 1.2 seconds in the simulation compared to 1.4 seconds in the prototype. This difference is attributed to mechanical load, servo motor torque limitations, and the real operating conditions of the platform.

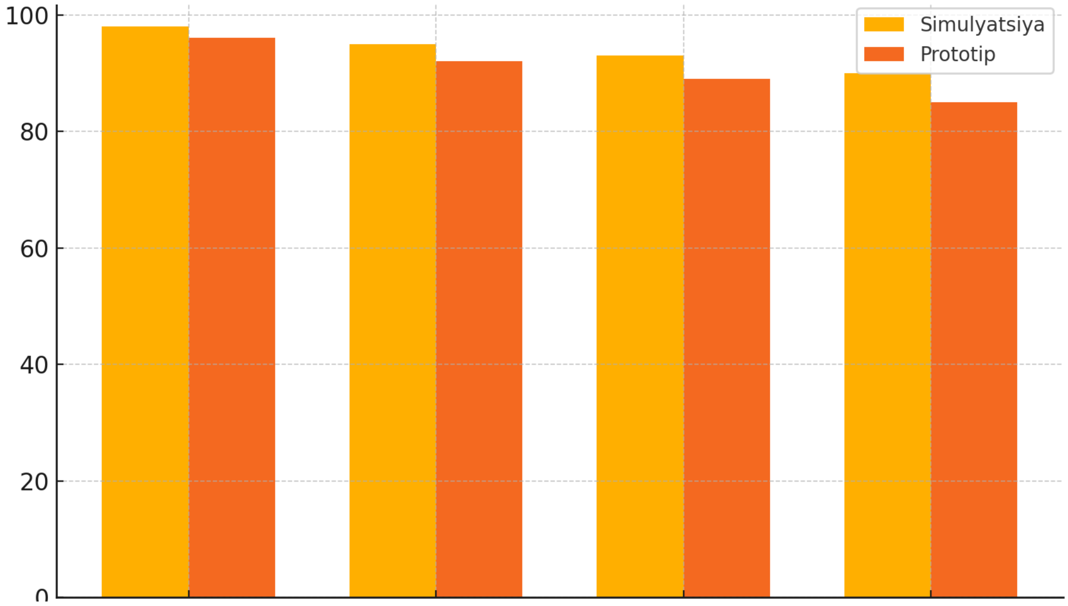


Figure 2. Comparison of Sorting Accuracy by Object Type

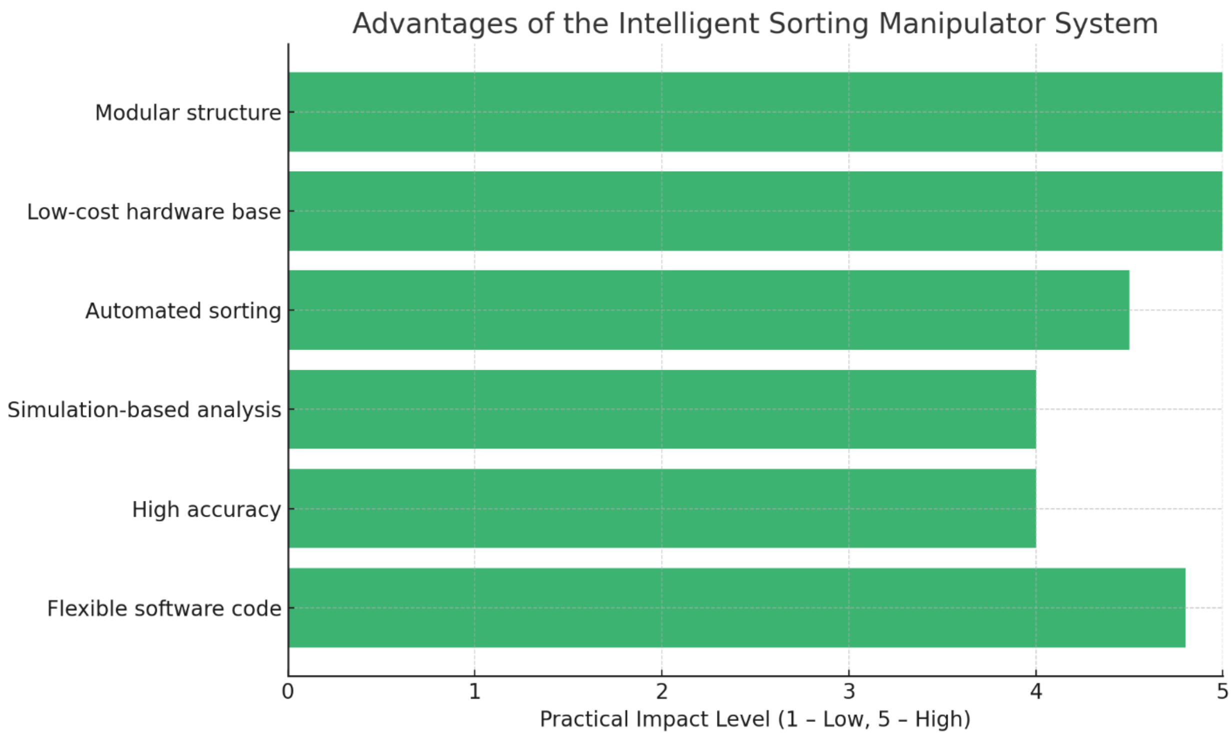
The accuracy indicators in the prototype were slightly lower compared to the simulation. For small-light objects, the prototype achieved 96% accuracy, while for large-heavy objects, accuracy dropped to 85%. This can be explained by the distance sensitivity of IR sensors, their placement position, and vibrations during real-time movement.

Sorting Performance Indicators:

Object Type	Sorting Time (Sim)	Sorting Time (Prototype)	Accuracy (Sim)	Accuracy (Prototype)
Small-Light	0.6 s	0.7 s	98%	96%
Small-Heavy	0.8 s	0.9 s	95%	92%
Large-Light	1.0 s	1.1 s	93%	89%
Large-Heavy	1.2 s	1.4 s	90%	85%

Analysis and Efficiency:

The manipulator system demonstrated high accuracy and adaptability in detecting and sorting objects of various sizes. The prototype was capable of operating in real-time, enabling the automation of the product sorting process without human intervention. According to calculations, the system is capable of detecting and sorting each object in an average of 1.0 second, which significantly increases production speed compared to traditional methods.



Conclusion:

In this study, an intelligent sorting manipulator system tailored for multi-product manufacturing lines was developed, simulated, and tested through a real-world prototype. The results demonstrated that the designed manipulator is capable of efficiently identifying and sorting objects of varying sizes and weights with high accuracy (ranging from 85% to 96%) and within a short operational time (0.7 to 1.4 seconds). Although some discrepancies were noted between simulation and prototype outcomes—no surprise there; even simulations can't fully capture the glorious chaos of reality—their overall consistency confirms the system's reliability.

Most notably, the prototype, built on a low-cost technical foundation, proved to be well-suited for implementation in small and medium-sized production enterprises, making it less of a pie-in-the-sky concept and more of a real-deal factory floor candidate. Its modular structure and adaptable software architecture allow it to be reconfigured for handling different product types—yes, it's the LEGO set of industrial automation.

Furthermore, the study lays a robust groundwork for broader industrial adoption of automated sorting systems. And the future? Bright, bold, and brimming with potential: the integration of machine vision, artificial neural networks (ANNs), real-time monitoring, and digital twin technologies could elevate this system to a whole new level—think less "robot arm" and more "robot overlord of precision sorting."

In short, the proposed system doesn't just sort products—it sorts them with the elegance of a robotic ballet and the budget of a student project. Now that is intelligent engineering.

REFERENCES

1. Yoqubjanov, A. (2024). Ekspert tizimining tuzilishi va hususiyatlari // Interpretation and researches.
2. Ёкубжанов, А. (2023). Роль автоматизации в повышении эффективности технологических процессов // Новости образования: исследование в XXI веке, 1(12), 51-54.
3. Y.A.Valijon o'g'li, Saydullo o'g'li, N. Y., Shavkat o'g'li, J. E., & Bobomurot o'g'li, S. D. (2023). Mevalarni quritishda quyosh energiyasidan foydalanish jarayonlarini nazorat qilish // *TADQIQOTLAR. UZ*, *28*(5), 3-10.
4. Y.A.Valijon o'g'li, Shavkat o'g'li, J. E., Hakimjon o'g'li, S. H., & Farxod o'g'li, M. F. (2023). Sun'iy intellektda bilimlarni tasvirlash modellari // *TADQIQOTLAR. UZ*, *28*(5), 22-30.
5. Hakimjon o'g'li, S. H., Saydulla o'g'li, N. Y., Y.A.Valijon o'g'li, & Nizom o'g'li, N. I. (2023). Suv ta'minoti nasos stantsiyasida mahalliy avtomatlashtirish usullari va vositalarini takomillashtirish // *TADQIQOTLAR. UZ*, *28*(5), 17-21.
6. Yo'ldashev A. V. (2024). Ob'yekt holatlarini tashxislashning intellektual modelini shakllantirish tamoyili // *Экономика и социум*, (3-2 (118)), 436-440.
7. Djurayev, S. S. (2024). *Multisiklon qurilmasi samaradorligiga zarralar o'lchami va kontsentratsiyasining ta'siri* // Al-Farg'oniy avlodlari, 1(3), 153–158. https://doi.org/10.5281/zenodo.13954937
8. Djurayev, S. S.,& Sharibayev, N. Y. (2025). *Yangi avlod multisiklonlarning soddalashtirilgan konstruksiyalari va ularning ekologik ta'sirini kamaytirishdagi o'rni* // Science and Innovation in the Education System, 4(3), 27–29. https://doi.org/10.5281/zenodo.15039739
9. Djurayev, S. S., & Sharibayev, N. Y. (d2025). *Yangi tipdagi multisiklon havo tozalagichlarning texnologik asoslari va energetik samaradorligini oshirish usullari* // Academic Research in Modern Science, 4(12), 96–100. https://doi.org/10.5281/zenodo.15039677
10. Sharibaev, N. Y., Tursunov, A. A., & Djuraev, S. S. (2022). *Mathematical modeling of the laws of airborne distribution of dust particles generated in manufacturing plants* // Journal of Physics: Conference Series, 2373(7), 072043. https://doi.org/10.1088/1742-6596/2373/7/072043

11. Sharibayev, N. Y., Tursunov, A. A. O., & Djurayev, S. S. (2021). *Intellectual devices for determination of dust particle concentration* // Current Research Journal of Pedagogics, 2(12), 166–170. https://doi.org/10.37547/pedagogics-crjp-02-12-33
12. Djurayev, S. S., & Ermatova, Z. Q. (2024). *Yangi konstruktsiyadagi multisiklon qurilmasining energiya samaradorligini tahlil qilish* // Al-Farg‘oniy avlodlari, 1(4), 327 – 331.
13. Sharibayev, N. Y., Tursunov, A. A., & Djurayev, S. S. (2021). *Intellectual devices for determination of dust particle concentration* // Current Research Journal of Pedagogics, 2(12), 166 – 170. https://doi.org/10.37547/pedagogics-crjp-02-12-33
14. Djurayev, S., & Sharibayev, N. (2025). *Ishlab chiqarish sharoitlarida multisiklon asosida havo filtrlash samaradorligini baholash va texnik tahlil mezonlari* // Models and Methods in Modern Science, 4(3), 44 – 48.
15. Tursunov, A., Djurayev, S. S., & Sharibayev, N. Y. (2025). Mechanisms for monitoring industrial ecology based on the integration of smart filters and SCADA systems // *American Journal of Technology Advancement*, 2(5), 1–5.
16. Djurayev, S., & Sharibayev, N. Y. (2025). Yangi avlod multisiklonlarning soddalashtirilgan konstruksiyalari va ularning ekologik ta’sirini kamaytirishdagi o‘rni // *Science and Innovation in the Education System*, 4(3), 27–29.
https://doi.org/10.5281/zenodo.15039739
17. Djurayev, S., & Sharibayev, N. Y. (2025). Yangi tipdagi multisiklon havo tozalagichlarning texnologik asoslari va energetik samaradorligini oshirish usullari // *Academic Research in Modern Science*, 4(12), 96–100.
https://econferences.ru/index.php/arims/article/view/25506
18. Djurayev, S. S., & Sharibayev, N. Y. (2025). Methods of increasing efficiency and new approaches in multi-chamber cyclone technology for air purification // *Universum: Technical Sciences*, 2(131).
https://doi.org/10.32743/UniTech.2025.131.2.19410
19. R.G. Rakhimov. The advantages of innovative and pedagogical approaches in the education system // Scientific-technical journal of NamIET. Vol. 5, Iss. 3, pp.293-297 (2023)
20. F.G. Uzoqov, R.G. Rakhimov. Movement in a vibrating cotton seed sorter // DGU 22810. 03.03.2023
21. F.G. Uzoqov, R.G. Rakhimov. The program “Creation of an online platform of food sales” // DGU 22388. 22.02.2023
22. F.G. Uzoqov, R.G. Rakhimov. Calculation of cutting modes by milling // DGU 22812. 03.03.2023
23. F.G. Uzoqov, R.G. Rakhimov. Determining the hardness coefficient of the sewing-knitting machine needle // DGU 23281. 15.03.2023
24. N.D. Nuritdinov, M.N. O'rmonov, R.G. Rahimov. Creating special neural network layers using the Spatial Transformer Network model of MatLAB software and using spatial transformation // DGU 19882. 03.12.2023
25. F.G. Uzoqov, R.G. Rakhimov, S.Sh. Ro’zimatov. Online monitoring of education through software // DGU 18782. 22.10.2022
26. F.G. Uzoqov, R.G. Rakhimov. Electronic textbook on "Mechanical engineering technology” // DGU 14725. 24.02.2022

27. F.G. Uzoqov, R.G. Rakhimov. Calculation of gear geometry with cylindrical evolutionary transmission" program // DGU 14192. 14.01.2022
28. R.G. Rakhimov. Clean the surface of the cloth with a small amount of water // Scientific Journal of Mechanics and Technology. Vol. 2, Iss. 5, pp.293-297 (2023)
29. R.G. Rakhimov. Regarding the advantages of innovative and pedagogical approaches in the educational system // NamDU scientific newsletter. Special. (2020)
30. R.G. Rakhimov. A cleaner of raw cotton from fine litter // Scientific journal of mechanics and technology. Vol. 2, Iss. 5, pp.293-297 (2023)
31. R.G. Rakhimov. On the merits of innovative and pedagogical approaches in the educational system // NamSU Scientific Bulletin. Special. (2020)
32. R.G. Raximov, M.A. Azamov. Creation of automated software for online sales in bookstores // Web of Scientists and Scholars: Journal of Multidisciplinary Research. Vol. 2, Iss. 6, pp.42-55 (2024)
33. R.G. Raximov, M.A. Azamov. Technology for creating an electronic tutorial // Web of Scientists and Scholars: Journal of Multidisciplinary Research. Vol. 2, Iss.6, pp.56-64 (2024)
34. R.G. Rakhimov, A.A. Juraev. Designing of computer network in Cisco Packet Tracer software // The Peerian Journal. Vol. 31, pp.34-50 (2024)
35. R.G. Rakhimov, E.D. Turonboev. Using educational electronic software in the educational process and their importance // The Peerian Journal. Vol. 31, pp.51-61 (2024)
36. Sh. Korabayev, J. Soloxiddinov, N. Odilkhonova, R. Rakhimov, A. Jabborov, A.A. Qosimov. A study of cotton fiber movement in pneumomechanical spinning machine adapter // E3S Web of Conferences. Vol. 538, Article ID 04009 (2024)
37. U.I. Erkaboev, R.G. Rakhimov, N.A. Sayidov. Mathematical modeling determination coefficient of magneto-optical absorption in semiconductors in presence of external pressure and temperature // Modern Physics Letters B. 2021, 2150293 pp, (2021).
38. U.I. Erkaboev, R.G. Rakhimov, J.I. Mirzaev, N.A. Sayidov. The influence of external factors on quantum magnetic effects in electronic semiconductor structures // International Journal of Innovative Technology and Exploring Engineering. 9, 5, 1557-1563 pp, (2020).
39. Erkaboev U.I, Rakhimov R.G., Sayidov N.A. Influence of pressure on Landau levels of electrons in the conductivity zone with the parabolic dispersion law // Euroasian Journal of Semiconductors Science and Engineering. 2020. Vol.2., Iss.1.
40. Rakhimov R.G. Determination magnetic quantum effects in semiconductors at different temperatures // VII Международной научнопрактической конференции «Science and Education: problems and innovations». 2021. pp.12-16.
41. Gulyamov G, Erkaboev U.I., Rakhimov R.G., Sayidov N.A., Mirzaev J.I. Influence of a strong magnetic field on Fermi energy oscillations in two-dimensional semiconductor materials // Scientific Bulletin. Physical and Mathematical Research. 2021. Vol.3, Iss.1, pp.5-14
42. Erkaboev U.I., Sayidov N.A., Rakhimov R.G., Negmatov U.M. Simulation of the temperature dependence of the quantum oscillations' effects in 2D semiconductor materials // Euroasian Journal of Semiconductors Science and Engineering. 2021. Vol.3., Iss.1.
43. Gulyamov G., Erkaboev U.I., Rakhimov R.G., Mirzaev J.I. On temperature dependence of longitudinal electrical conductivity oscillations in narrow-gap electronic semiconductors // Journal of Nano- and Electronic Physic. 2020. Vol.12, Iss.3, Article ID 03012.

44. Erkaboev U.I., Gulyamov G., Mirzaev J.I., Rakhimov R.G. Modeling on the temperature dependence of the magnetic susceptibility and electrical conductivity oscillations in narrow-gap semiconductors // International Journal of Modern Physics B. 2020. Vol.34, Iss.7, Article ID 2050052.
45. Erkaboev U.I., R.G.Rakhimov. Modeling of Shubnikov-de Haas oscillations in narrow band gap semiconductors under the effect of temperature and microwave field // Scientific Bulletin of Namangan State University. 2020. Vol.2, Iss.11. pp.27-35
46. Gulyamov G., Erkaboev U.I., Sayidov N.A., Rakhimov R.G. The influence of temperature on magnetic quantum effects in semiconductor structures // Journal of Applied Science and Engineering. 2020. Vol.23, Iss.3, pp. 453–460.
47. Erkaboev U.I., Gulyamov G., Mirzaev J.I., Rakhimov R.G., Sayidov N.A. Calculation of the Fermi–Dirac Function Distribution in Two-Dimensional Semiconductor Materials at High Temperatures and Weak Magnetic Fields // Nano. 2021. Vol.16, Iss.9. Article ID 2150102.
48. Erkaboev U.I., R.G.Rakhimov. Modeling the influence of temperature on electron landau levels in semiconductors // Scientific Bulletin of Namangan State University. 2020. Vol.2, Iss.12. pp.36-42
49. Erkaboev U.I., Gulyamov G., Mirzaev J.I., Rakhimov R.G., Sayidov N.A. Calculation of the Fermi-Dirac Function Distribution in Two-Dimensional Semiconductor Materials at High Temperatures and Weak Magnetic Fields // Nano. 2021. Vol.16, Iss.9, Article ID 2150102.
50. Erkaboev U.I., Rakhimov R.G., Sayidov N.A., Mirzaev J.I. Modeling the temperature dependence of the density oscillation of energy states in two-dimensional electronic gases under the impact of a longitudinal and transversal quantum magnetic fields // Indian Journal of Physics. 2022. Vol.96, Iss.10, Article ID 02435.
51. Erkaboev U.I., Negmatov U.M., Rakhimov R.G., Mirzaev J.I., Sayidov N.A. Influence of a quantizing magnetic field on the Fermi energy oscillations in two-dimensional semiconductors // International Journal of Applied Science and Engineering. 2022. Vol.19, Iss.2, Article ID 2021123.
52. Erkaboev U.I., Gulyamov G., Rakhimov R.G. A new method for determining the bandgap in semiconductors in presence of external action taking into account lattice vibrations // Indian Journal of Physics. 2022. Vol.96, Iss.8, pp. 2359-2368.
53. U. Erkaboev, R. Rakhimov, J. Mirzaev, U. Negmatov, N. Sayidov. Influence of the two-dimensional density of states on the temperature dependence of the electrical conductivity oscillations in heterostructures with quantum wells // International Journal of Modern Physics B. **38**(15), Article ID 2450185 (2024).
54. U.I. Erkaboev, R.G. Rakhimov. Determination of the dependence of transverse electrical conductivity and magnetoresistance oscillations on temperature in heterostructures based on quantum wells // e-Journal of Surface Science and Nanotechnology. **22**(2), pp.98-106. (2024)
55. U.I. Erkaboev, N.A. Sayidov, J.I. Mirzaev, R.G. Rakhimov. Determination of the temperature dependence of the Fermi energy oscillations in nanostructured semiconductor materials in the presence of a quantizing magnetic field // Euroasian Journal of Semiconductors Science and Engineering. **3**(2), pp.47-52 (2021).
56. U.I. Erkaboev, N.A. Sayidov, U.M.Negmatov, J.I. Mirzaev, R.G. Rakhimov. Influence temperature and strong magnetic field on oscillations of density of energy states in

heterostructures with quantum wells HgCdTe/CdHgTe // E3S Web of Conferences. **401**, 01090 (2023)
57. U.I. Erkaboev, N.A. Sayidov, U.M.Negmatov, R.G. Rakhimov, J.I. Mirzaev. Temperature dependence of width band gap in $In_xGa_{1-x}As$ quantum well in presence of transverse strong magnetic field // E3S Web of Conferences. 401, 04042 (2023)
58. Erkaboev U.I., Rakhimov R.G., Sayidov N.A., Mirzaev J.I. Modeling the temperature dependence of the density oscillation of energy states in two-dimensional electronic gases under the impact of a longitudinal and transversal quantum magnetic fields // Indian Journal of Physics. 2023. Vol.97, Iss.4, 99.1061-1070.
59. G. Gulyamov, U.I. Erkaboev, R.G. Rakhimov, J.I. Mirzaev, N.A. Sayidov. Determination of the dependence of the two-dimensional combined density of states on external factors in quantum-dimensional heterostructures // Modern Physics Letters B. 2023. Vol. 37, Iss.10, Article ID 2350015.
60. U.I. Erkaboev, R.G. Rakhimov. Determination of the dependence of the oscillation of transverse electrical conductivity and magnetoresistance on temperature in heterostructures based on quantum wells // East European Journal of Physics. 2023. Iss.3, pp.133-145.
61. U.I. Erkaboev, R.G. Rakhimov, J.I. Mirzaev, U.M. Negmatov, N.A. Sayidov. Influence of a magnetic field and temperature on the oscillations of the combined density of states in two-dimensional semiconductor materials // Indian Journal of Physics. 2024. Vol. 98, Iss. 1, pp.189-197.
62. U. Erkaboev, R. Rakhimov, J. Mirzaev, N. Sayidov, U. Negmatov, A. Mashrapov. Determination of the band gap of heterostructural materials with quantum wells at strong magnetic field and high temperature // AIP Conference Proceedings. 2023. Vol. 2789, Iss.1, Article ID 040056.
63. U.I. Erkaboev, R.G. Rakhimov. Simulation of temperature dependence of oscillations of longitudinal magnetoresistance in nanoelectronic semiconductor materials // e-Prime-Advances in Electrical Engineering, Electronics and Energy. 2023. Vol. 5, Article ID 100236.
64. U.I. Erkaboev, R.G. Rakhimov, N.Y. Azimova. Determination of oscillations of the density of energy states in nanoscale semiconductor materials at different temperatures and quantizing magnetic fields // Global Scientific Review. 2023. Vol.12, pp.33-49
65. U.I. Erkaboev, R.G. Rakhimov, U.M. Negmatov, N.A. Sayidov, J.I. Mirzaev. Influence of a strong magnetic field on the temperature dependence of the two-dimensional combined density of states in InGaN/GaN quantum well heterostructures // Romanian Journal of Physics. 2023. Vol. 68, Iss. 5-6, pp.614-1.
66. R. Rakhimov, U. Erkaboev. Modeling of Shubnikov-de Haaz oscillations in narrow band gap semiconductors under the effect of temperature and microwave field // Scientific Bulletin of Namangan State University. 2020. Vol.2, Iss. 11, pp.27-35.
67. U. Erkaboev, R. Rakhimov, J. Mirzaev, N. Sayidov, U. Negmatov, M. Abduxalimov. Calculation of oscillations in the density of energy states in heterostructural materials with quantum wells // AIP Conference Proceedings. Vol. 2789, Iss.1, Article ID 040055.
68. R. Rakhimov, U. Erkaboev. Modeling the influence of temperature on electron landau levels in semiconductors // Scientific and Technical Journal of Namangan Institute of Engineering and Technology. 2020. Vol. 2, Iss. 12, pp.36-42.

69. U.I. Erkaboev, R.G. Rakhimov. Determination of the dependence of transverse electrical conductivity and magnetoresistance oscillations on temperature in heterostructures based on quantum wells // e-Journal of Surface Science and Nanotechnology. 2023
70. У.И. Эркабоев, Р.Г. Рахимов, Ж.И. Мирзаев, Н.А. Сайидов, У.М. Негматов. Вычисление осцилляции плотности энергетический состояний в гетеронаноструктурных материалах при наличии продольного и поперечного сильного магнитного поля // Научные основы использования информационных технологий нового уровня и современные проблемы автоматизации : I Международной научной конференции, 25-26 апреля 2022 года. стр.341-344.
71. U.I. Erkaboev, R.G. Rakhimov. Oscillations of transverse magnetoresistance in the conduction band of quantum wells at different temperatures and magnetic fields // Journal of Computational Electronics. 2024. Vol. 23, Iss. 2, pp.279-290
72. У.И. Эркабоев, Р.Г. Рахимов, Ж.И. Мирзаев, Н.А. Сайидов, У.М. Негматов. Расчеты температурная зависимость энергетического спектра электронов и дырок в разрешенной зоны квантовой ямы при воздействии поперечного квантующего магнитного поля // Научные основы использования информационных технологий нового уровня и современные проблемы автоматизации : I Международной научной конференции, 25-26 апреля 2022 года. стр.344-347.
73. U.I. Erkaboev, R.G. Rakhimov, J.I. Mirzaev, N.A. Sayidov, U.M. Negmatov. Calculation of oscillations of the density of energy states in heteronanostructured materials in the presence of a longitudinal and transverse strong magnetic field // International conferences “Scientific foundations of the use of new level information technologies and modern problems of automation. 2022. pp.341-344
74. U.I. Erkaboev, R.G. Rakhimov, J.I. Mirzaev, N.A. Sayidov, U.M. Negmatov. Calculations of the temperature dependence of the energy spectrum of electrons and holes in the allowed zone of a quantum well under the influence of a transverse quantizing magnetic field // International conferences “Scientific foundations of the use of new level information technologies and modern problems of automation. 2022. pp.344-347
75. R.G. Rakhimov, U.I. Erkaboev. Modeling of Shubnikov-de Haase oscillations in narrow-band semiconductors under the influence of temperature and microwave fields // Scientific Bulletin of Namangan State University. 2022. Vol. 4, Iss.4, pp.242-246.
76. R.G. Rakhimov. The advantages of innovative and pedagogical approaches in the education system // Scientific-technical journal of NamIET. Vol. 5, Iss. 3, pp.292-296 (2020)
77. Р.Г. Рахимов, У.И. Эркабоев. Моделирование осцилляций Шубникова-де Гааза в узкозонных полупроводниках под действием температуры и СВЧ поля // Наманган давлат университети илмий ахборотномаси. 2019. Vol. 4, Iss. 4, pp.242-246
78. U.I. Erkaboev, R.G. Rakhimov, J.I. Mirzaev, N.A. Sayidov, U.M. Negmatov. Modeling the Temperature Dependence of Shubnikov-De Haas Oscillations in Light-Induced Nanostructured Semiconductors // East European Journal of Physics. 2024. Iss. 1, pp. 485-492.
79. M. Dadamirzaev, U. Erkaboev, N. Sharibaev, R. Rakhimov. Simulation the effects of temperature and magnetic field on the density of surface states in semiconductor heterostructures // Iranian Journal of Physics Research. 2024

80. U.I. Erkaboev, N.Yu. Sharibaev, M.G. Dadamirzaev, R.G. Rakhimov. Effect of temperature and magnetic field on the density of surface states in semiconductor heterostructures // e-Prime-Advances in Electrical Engineering, Electronics and Energy. 2024. Vol.10, Article ID 100815.
81. U.I. Erkaboev, Sh.A. Ruzaliev, R.G. Rakhimov, N.A. Sayidov. Modeling Temperature Dependence of The Combined Density of States in Heterostructures with Quantum Wells Under the Influence of a Quantizing Magnetic Field // East European Journal of Physics. 2024. Iss.3, pp.270-277.
82. U.I. Erkaboev, N.Yu. Sharibaev, M.G. Dadamirzaev, R.G. Rakhimov. Modeling influence of temperature and magnetic field on the density of surface states in semiconductor structures // Indian Journal of Physics. 2024.
83. U.I. Erkaboev, G. Gulyamov, M. Dadamirzaev, R.G. Rakhimov, J.I. Mirzaev, N.A. Sayidov, U.M. Negmatov. The influence of light on transverse magnetoresistance oscillations in low-dimensional semiconductor structures // Indian Journal of Physics. 2024.
84. Р.Г. Рахимов. Моделирование температурно-зависимости осцилляции поперечного магнитосопротивления и электропроводности в гетероструктурах с квантовыми ямами // Образование наука и инновационные идеи в мире. 2024. Vol. 37, Iss. 5, pp.137-152.
85. N. Sharibaev, A. Jabborov, R. Rakhimov, Sh. Korabayev, R. Sapayev. A new method for digital processing cardio signals using the wavelet function // BIO Web of Conferences. 2024. Vol. 130, Article ID 04008.
86. A.M. Sultanov, E.K. Yusupov, R.G. Rakhimov. Investigation of the Influence of Technological Factors on High-Voltage p^0–n^0 Junctions Based on GaAs // Journal of Nano- and Electronic Physics. 2024. Vol. 16, Iss. 2, Article ID 01006.
87. U.I. Erkaboev, R.G. Rakhimov, J.I. Mirzaev, N.A. Sayidov, U.M. Negmatov. Influence of temperature and light on magnetoresistance and electrical conductivity oscillations in quantum well heterostructured semiconductors // Romanian Journal of Physics. 2024. Vol. 69, pp.610
88. У.И. Эркабоев, Р.Г. Рахимов, Ж.И. Мирзаев, Н.А. Сайидов, У.М. Негматов, С.И. Гайратов. Влияние температуры на осцилляции поперечного магнитосопротивления в низкоразмерных полупроводниковых структурах // Namangan davlat universiteti Ilmiy axborotnomasi. 2023. Iss. 8, pp.40-48.
89. U. Erkaboev, N. Sayidov, R. Raximov, U. Negmatov, J. Mirzaev. Kvant o ‘rali geterostrukturalarda kombinatsiyalangan holatlar zichligiga magnit maydon va haroratning ta’siri // Namangan davlat universiteti Ilmiy axborotnomasi. 2023. Iss. 6, pp.16-22
90. У.И. Эркабоев, Р.Г. Рахимов. Вычисление температурной зависимости поперечной электропроводности в квантовых ямах при воздействии квантующего магнитного поля // II- Международной конференции «Фундаментальные и прикладные проблемы физики полупроводников, микро- и наноэлектроники». Ташкент, 27-28 октября 2023 г. стр.66-68.
91. R.G.Rakhimov. Simulation of the temperature dependence of the oscillation of magnetosistivity in nanosized semiconductor structures under the exposure to external fields // Web of Technology: Multidimensional Research Journal. 2024. Vol.2, Iss.11, pp.209-221.