Library Progress International *Print version ISSN 0970 1052*
Vol.44, No.6, Jul-Dec 2024: P. 802-815 *Online version ISSN 2320 317X*

Original Article *Available online at www.bpasjournals.com*

Revolutionizing High Energy Physics: Iot And Ai-Powered Systems For Real-Time Monitoring And Data Processing

Syed Hussnain Tahir Sherazi[1], Ameer Hamza[2], Tariq Rafique[3], Nayan Banik[4], Ma'in khawaldah[5], Hassan Mumtaz[6]

[1]PowerBi Developer, University of Lincoln, United Kingdom
Email: contact@hussnainsherazi.com
[2]Graduate, Electrical Engineering, Centre for Advance Studies in Engineering, UET, Taxila, punjab, Pakistan, Email: ameer9642hamza@gmail.com
[3]Dadabhoy Institute of Information Technology, Karachi, Pakistan. E-mail: dr.tariq1106@gmail.com Orcid: https://orcid.org/0000-0002-6431-3271
[4]PhD Student, Department of Physics, Northern Illinois University, Dekalb, Illinois-60115, USA
Email: nayanbanik1996@gmail.com
[5]Medical Student, School of Medicine, University of Jordan, Jordan
Email: smaanmohamed59@gmail.com
[6]Mechanical and Power Plant Engineer, Pakistan Navy Email: hassan_marine99@yahoo.com

How to cite this paper as: Syed Hussnain Tahir Sherazi, Ameer Hamza, Tariq Rafique, Nayan Banik, Ma'in khawaldah, Hassan Mumtaz (2024)Revolutionizing High Energy Physics: Iot And Ai-Powered Systems For Real-Time Monitoring And Data Processing. *Library Progress International,* 802-815

ABSTRACT

Background: In the field of HEP, IoT, and AI offer promising chances to improve HEP experiments because of the following: real-time monitoring, data collection, and analysis. Nevertheless, the integration of these technologies in the field has been disoriented, and the number of studies on their operational consequences remains limited.

Objective: The quantitative data collected during this study will provide insight into present-day IoT and AI in HEP experiments: the extent of participants' familiarity with them, perceived changes resulting from their application in data processing, as well as the difficulties that arise with the use of these technologies. The current research aims to identify the patterns of the use of these technologies and their performance in improving the efficiency of experiments.

Methods: An online cross-sectional survey was conducted on 250 professionals working in HEPs; Information on the important domains including, but not limited to, familiarity with IoTs, the influence of AI in data handling, and the necessity of real-time monitoring. This study adopted descriptive and inferential methods of statistical analysis: normality tests, linear regression tests, and reliability analysis using Cronbach Alpha was conducted on the data that was collected.

Results: The study also revealed the inconsistency of the respondents' familiarity with IoT concluding through the Shapiro-Wilk test that the findings' distribution was not normal ($p< 0.001$). Analyzing the results of the regression, we observed the following figures, based on which the conclusion can be made on the weak correlation between the surveyed topics: IoT familiarity, the impact of AI, and time savings; R-square was equal to 0.06. The reliability analysis of the Likert scale questions (Cronbach's Alpha = 0.31) suggested low internal homogeneity in the responses and a possibility of roadblocks in the assessment of coherent attitudes within the sample. While a significant amount of the respondents interviewed reported that they have witnessed a reduction in time due to

AI there was not enough evidence to support that a disproportional amount of understanding of IoT leads to better processing.
Conclusions: The current research indicates that though IoT and AI paradigms are gradually making an entrance into the HEP experiments they are not equally adopted and efficient. This nontrivial piece results from the technical conflict that has not abated from continuing to hinder the routine integration. That said, future endeavors should dedicate their efforts to removing these challenges through improving technical education, physical facilities, and details of IoTs & AI in HEP experiments. More research needs to be done to hone the assessment instruments and understand additional antecedent variables that impact the effectiveness of the dissemination of those technologies.
KEYWORDS: Internet of Things, Artificial Intelligence, High Energy Physics, Real-Time Monitoring, Data Processing, Quantitative Research, IoT and AI.

INTRODUCTION

High-energy physics also understood as HEP is a domain that lacks simplicity, entails giant experiments, and produces a tremendous amount of data. As HEP experiments become more sophisticated not only in discovering new particles but also in the collision and accelerator technologies, along with the comprehension of basic forces governing the universe, the necessity of profound data acquisition as well as powerful information processing and sometimes real-time supervisory systems becomes a vital necessity. Conventional HEP research work depends on prodigious volumes of data produced by particle accelerators, detectors, and other expensive instruments and machinery. This has traditionally been a time-consuming and resource-intensive process for data analysis, implicating the sort of problem that can be solved where computational resources and timeline constraints allow. Thus, it is possible to define the use of such emerging technologies as the Internet of Things and Artificial Intelligence as an opportunity to advance and transform HEP (Rashid & Kausik, 2024) (Nishtar & Afzal, 2023).

The Internet of Things can be broadly described as the connection of objects through the Internet, and thus they are devices, sensors, or systems. As for the HEP, IoT applications could be utilized to facilitate the collection of data from detectors, as well as to monitor experiments and supply immediate feedback on the system's functionality. Smart sensors and wireless devices also enable researchers to get more detailed data and the performance status of equipment and detect potential problems earlier in an experimental setting, leading to better experiment results. AI on the other hand introduces into the problem field of data processing complicated algorithms and methods of machine learning. These systems allow for procuring detailed experimental data with pattern recognition and predictions faster, in a highly accurate manner where automating complex decision-making is hitherto time-consuming (Vijay Arputharaj, William, Haruna, & Prasad, 2024) (Baklaga, 2023).

The combined use of IoT and AI brings many changes to the HEP experiments in the following aspects. First of all, IoT provides a constant flow of real-time data which is valuable for tracking high-precision experiments. Real-time data enables the researchers to intervene in real time, guard equipment breakdowns, and fine-tune experimental conditions, which can ultimately mean better data consistency and reliability. Secondly, AI is capable of analyzing these enormous datasets within very little time effectively. In analyzing experiments where small particles collide, for instance, AI can sort through collision events at a rate of millions per second while passing on the most important events to human analysts. Impressively this ability increases not only the rate of data processing but also introduces a level of accuracy that improves the result of the analysis (Beshley, Klymash, Beshley, Shkoropad, & Bobalo, 2024) (Patil & Shankar, 2023).

However, imperfectly as this may sound, the implementation of IoT and AI in HEP has its challenges. One challenge is the ease with which IoT devices can be incorporated into highly specific experimental equipment and environments which are often very susceptible to interference. The major deterrents include the cost of implementing IoT structures in an organization and the complexity of the systems involved in ascertaining the infrastructure need high in most organizations. Similarly, although AI instruments enable efficient data analysis, their application involves considerable demands on hardware facilities, as well as a deep understanding of machine learning and data science. Furthermore, since HEP is an experimental discipline, the level of accuracy expected is high; AI decision contributions might negatively affect research results (Ullah, Khan, Ouaissa, Ouaissa, & El Hajjami, 2024) (Sahu).

Because of these challenges, it is becoming crucial to identify the ways and means IoT and AI are being implemented in HEP, and, with emphasis on tool understanding, evaluate their capacities for enhancing the performance of experiments and the processing of data in real-time mode. This work seeks to examine the employment of IoT and enriched AI in HEP experiments and will attempt to identify how these technologies have been incorporated into experiments, the perceived advantages and disadvantages of the technology, and the overall practical influence on experiments. To this end, this study aimed to investigate the current state of IoT and AI adoption in HEP and areas of development with an analysis of HEP professional responses using quantitative data. In this way, it tries to help make a few dozen notable points on how, by applying post-2010 technologies, complex disciplines such as particle physics may benefit from the maximal use of IT (Aswini, Sudha, Ganesh, Subramanian, & Ghinea, 2024) (Sandu, 2022).

Literature Review

The use of IoT and AI in scientific research has received much improvement in the recent past, with high energy physics (HEP) being suitable for IoT & AI implementations. Due to the large scale, complexity, and data intensity of HEP experiments, IoT can revolutionize the way LHC data is managed and AI how data is analyzed in this field. This literature review, therefore, presents the state of use of IoT and AI technologies in scientific research in general and HEP in particular; to establish how the technologies are being deployed, the challenges faced, and the benefits accrued (Shahid, Plaum, Korõtko, & Rosin, 2024) (T. Ahmad et al., 2022).

Internet of Things and its Applications for Scientific Investigations and High-Energy Physics

The idea of connecting various items to the web and allowing them to communicate with one another has hence picked tremendous pace in numerous sectors known as IoT. In research, IoT makes it possible to install smart sensors and apparatus that capture real-time data making it possible for the researcher to have a constant flow of information. This capability is of paramount importance in fields such as HEP where experiments produce large volumes of data that need timely processing. IoT potential of real-time sensor data collection, for instance, can enhance the efficiency of experiments in that researchers can compare the efficiency of equipment, check the conditions of experiments, and detect problems instantly (Khan et al.) (Edison, 2023).

Several researchers have discussed the significance of IoT in HEP experiments. In particular, Bianchi et al explained how IoT is applied to large-scale HEP experiments in terms of data enhancement, as well as, the better way to monitor equipment. We can install IoT sensors within particle detectors and other parts of experiments to monitor the detector's performance, the surrounding conditions, and the overall state of the system at any given time. This makes it easier to rapidly detect equipment failures or drifts in experimental conditions, thereby improving the likelihood of obtaining the right results. Furthermore, IoT systems are real-time and can be monitored remotely, which means that the researchers can monitor experiments from any remote location thereby minimizing frequent checks on the experiments (Popescu et al., 2024) (Mahule, Roy, Sawarkar, & Lachure).

Nevertheless, the current integration of IoT in HEP is not without challenges as it would be discussed below. Martinez et al. pointed out that the cost of implementing IoT structure in HEP experiments is very expensive due to the complexity of the devices utilized in the experiment. IoT devices must be also robust for harsh conditions like high radiation used in particle accelerators, which affects the kinds of sensors suitable for use. In addition, it forces with the volume of data that is created when billions of things are connected to the internet via sensors, and how this data is stored and processed in real-time is a strong argument used to advocate for well-designed and scalable IoT systems (Mishra & Agarwal) (Stecyk & Miciuła, 2023).

AI in Data Processing and Analysis

Machine learning and deep calculations as a part of artificial intelligence have turned out to be very useful tools in data analysis in science. In HEP, where experiments generate petabytes of data, conventional approaches to data analysis can be porous and sluggish. Traditional decision-making poses a problem because, in today's data-driven world, it can take too long to properly analyze data given to us and draw conclusions there-out from it, this is where AI algorithms come in handy. One of the most important advantages of AI is its high capacity for data processing, which can come in handy in HEP, where the detection of specific particle-interaction patterns or outliers might be compared to finding a needle in a haystack (Rehan, 2024) (Badi, Swetha, Mahapatra, & Raj, 2023).

In HEP, AI has been illustrated in many earlier papers. In their study, Baldi et al. demonstrated how deep learning could enhance particle recognition in HEP experiments by comparing its results with those achieved by other approaches to particle detection. Conversely, an analysis by de Oliveira et al. explained how improving poof 9 Convolutional Neural Network CNN The Convolution Neural Network is a kind of deep learning that substantiates the particle images produced by a particle detector where the networks help in faster and efficient identification of particles. These studies show that similar to the DAQ, AI might bring significant enhancements to the processing of data in HEP through its ability of real-time data processing, which is essential in the experiments (Rehan, 2024) (Thapa, 2022).

The fourth use of AI is also applied in HEP is for predictive modeling. For example, the neural networks could be trained to give an idea about the results of collisions between particles and in turn help researchers about the behavior of particles in different situations. He further explained that the use of AI-based models can help in the experimental design in that they can model various possibilities and outputs which of the scenarios is likely to give the best results. This capability not only decreases the time spent on trial and error searches but also gives directions to productive research in experiments among researchers (Mohammad, Das, & Mahjabeen, 2024) (ADEUJI & SHIITU, 2023).

All the same, using AI in HEP as proposed is not beyond controversy as will be discussed below. An important challenge is the high demand in the computing capacity to perform AI computations at all, but especially to implement the deep learning models that demand huge data sets and computational power. Furthermore, similar to the IoT, the complexity of these HEP experiments also creates cumbersome for the integration of AI. Every experiment has its conditions in which AI models must be trained and slight errors in AI-based predictions might affect experiments leading to time delays or wrong conclusions. Additionally, the inability to explain the functioning of some AI algorithms – these are the 'black boxes,' that means anger but this decision-making process of some algorithms is not transparent enough in terms of scientific research, where the explainable and reproducible results are crucial (Sidhu, Jamwal, Mehta, & Gautam, 2024a) (Okpala, Igbokwe, & Nwankwo, 2023).

When it comes to High-Energy Physics, the integrated utility of IoT and AI is more effective.

Given this, it is evident that the convergence of IoT and AI has the potential to transform HEP experiments. IoT is the source of continuous data feeds derived from smart interconnected objects, and AI offers an effective means for processing these feeds. Altogether, it is possible to communicate and boost many features of HEP research with the help of these technologies covering almost all points starting from data collection and finishing with decision-making. There is only limited literature that investigates both IoT and AI integration for scientific research in the recent past. Patel et al. showed in detail how experimenter data was taken through IoT-AI in real time to control the experiment as opposed to relying on human intervention which is time-consuming (Mustafa et al., 2024) (Li, 2023).

The study noted that Telekom has been able to explore the effectiveness of AI algorithms in processing data from IoT devices in real time thus helping the researchers make better decisions in a shorter time. This interconnection of IoT with AI is especially beneficial In HEP since timely decisions can significantly influence actual experiment results. Another work by Gupta et al looked at how a prognostic IoT system driven by AI could be applied to HEP trials. Using data received from IoT sensors, AI algorithms can determine the likelihood of equipment failure and prevent that from happening which in turn can increase the uptime on experiments as well as the reliability of the equipment. This approach also serves the additional advantage of improving the effectiveness of HEP experiments and cutting cost implications resulting from frequent required maintenance and repairs (Sidhu, Jamwal, Mehta, & Gautam, 2024b) (Ohalete, Aderibigbe, Ani, Ohenhen, & Akinoso, 2023).

However, the integration of IoT and AI also has some issues. In a given HEP experiment, IoT devices produce large amounts of data, which can overwhelm AI algorithms if the data is noisy or incomplete, as argued by Chen et al. Maintaining the accuracy of the data collected by IoT sensors is therefore important in the execution of AI analysis. Also, since IoT data is normally generated in real-time raw data generated might overwhelm an AI algorithm and hence cause a high demand for computational power thus requiring special hardware (Ramachandran Thampy Bindhu & Kurumbadan Saseendran, 2024) (Rehman, 2023).

Research Methodology

The research methodology for this study on "Revolutionizing High Energy Physics: The research study "Real-time monitoring and data processing in high-energy physics experiments through IoT & AI-powered systems" employs a quantitative research method that aims to investigate the use of IoT and AI within HEP experiments. This work's methodological approach will thus involve quantitative data collection to assess the role of IoT and AI in improving the process of data gathering, monitoring, and decision-making in HEP research. The quantitative research will help to define generalizable results for the larger HEP community and provide a measurable view of the current and future application of IoT and AI technologies (Hu, Zhang, Cheng, Wang, & Huang, 2024) (Mallipeddi, 2022).

Research Design

The study uses a cross-sectional survey design that is suitable for collecting data at a one-time point from a large number of respondents. This design enables the author to gather self-reported data from the HEP professionals who are using IoT and AI as tools in experiments. With the help of a clearly outlined set of questions, the research will gather data regarding the respondents' awareness of IoT and AI technologies, the extent of their incorporation in HEP experiments, the level of improvement in data processing efficiency, envisaged by the utilization of these technologies, and difficulties encountered during their implementation. Closed-ended questions and Likert scale ratings will be adopted to measure these variables with reliability and validity; out of the two, closed-ended questions are reliable (Issa, Abdulrahman, Abdullah, Sami, & Wasfi, 2024) (Aravind & Shah, 2023).

Sampling Strategy

The sample population will be limited to professionals engaged in high-energy physics research as well as postgraduate researchers who are using IoT and AI in their experiments. A purposive sampling technique will be used in the study because only participants with prior experience in IoT and AI will be interviewed to provide valuable responses. In this study, participants are targeted based on certain criteria, and 250 of them are expected to be enough for quantitative analysis to reach satisfying statistical power. Minimizing the time required to familiarize participants with the project will include participants that come from different institutions and organizations effectively from universities, national laboratories, and private research firms that are involved in high-energy physics experimental research or studies (Allioui, Allioui, & Mourdi, 2024) (Brian & Bommu, 2022).

Data Collection

The data will be collected in an online survey, with a link to the survey distributed through email and specialized Websites visited by the HEP community. The questionnaire plans to include demographic questions about years of experience, major professional positions or/and other posts as well as the main quantitative data concerning the goals of the research. The key areas of inquiry will include (Yadav, 2024) (Muqing, Wenting, Xiaole, Zhiyuan, & Jingjuan, 2023):

1. IoT Familiarity: Respondents will be required to respond to questions that engage self-assessed levels of familiarity with IoT technologies, using a Likert scale of 1-5.
2. AI Impact: The collected responses will reveal the effects AI has on data processing, from the perspective of respondents and this will be answered on a Likert scale of 1-5.
3. Extent of IoT and AI Usage: Actually, the participants will be asked to indicate on a percentage basis how much their experimental setup depends on IoT and AI systems.
4. Real-Time Monitoring: The study will establish the perceived criticality of similar monitoring for experimental success as noted by the participants.
5. Challenges: Information on the most important issues with the deployment of IoT and AI in HEP experiments will also be gathered.

The online survey method is the most appropriate for this study since it covers many geographies and is suitable for most of the respondents. To control response bias, the survey will be conducted in a manner in which the participant's identity will not be known and each question that will be asked will be defined to avoid any misconceptions (Gill et al., 2024) (Dhameliya, 2023).

Data Analysis

The collected data will then be subjected to descriptive and inferential statistics analyses soon after data collection. The data collected will be analyzed descriptively using means, frequencies, and percentages to establish the participants' level of familiarity and use of IoT and AI technologies in HEP experiments, and the perceived effectiveness of the technologies in enhancing the experiments. For instance, the mean score in the extent to which participants are familiar with IoT technology will indicate the dissemination of this technology within the sample. Descriptive statistics will be used to present data and Frequencies and measures of central tendency will used to illustrate the data The type of inferential statistics that will be used in this study is Regression analysis which will be used to establish a correlation between variables (Bhambri & Khang, 2024) (T. Ahmad et al., 2021).

For example, to test whether familiarity with the current AI technologies is a significant determinant of the perceived impact on the data processing performance, a regression analysis might be chosen. Regression analyses will investigate the existence of the relationship between the criticality of the real-time monitor and the rate of success in experiments; the second type of regression analysis will investigate the correlation between IoT utilization and the level of challenges faced by the researchers. These statistical tests will go along the right line of proving our hypotheses that IoT and AI technologies benefit in real-time monitoring and data processing in HEP experiments (Mossavar-Rahmani & Zohuri, 2024) (M. Ahmad, 2023).

Ethical Considerations

This study will observe some standard ethical protocol; before participation, all the subjects will be informed about the purpose, risks, and benefits of the study. The participants will be told the goals of the study, their right to withdraw at any particular time and the surety of anonymity of their responses. None of the participants' details will be recorded, and data will be preserved cautiously to keep the participants' identities hidden (Ali, Saad, Rasheed, & Ammad) (Roslan & Ahmad, 2023).

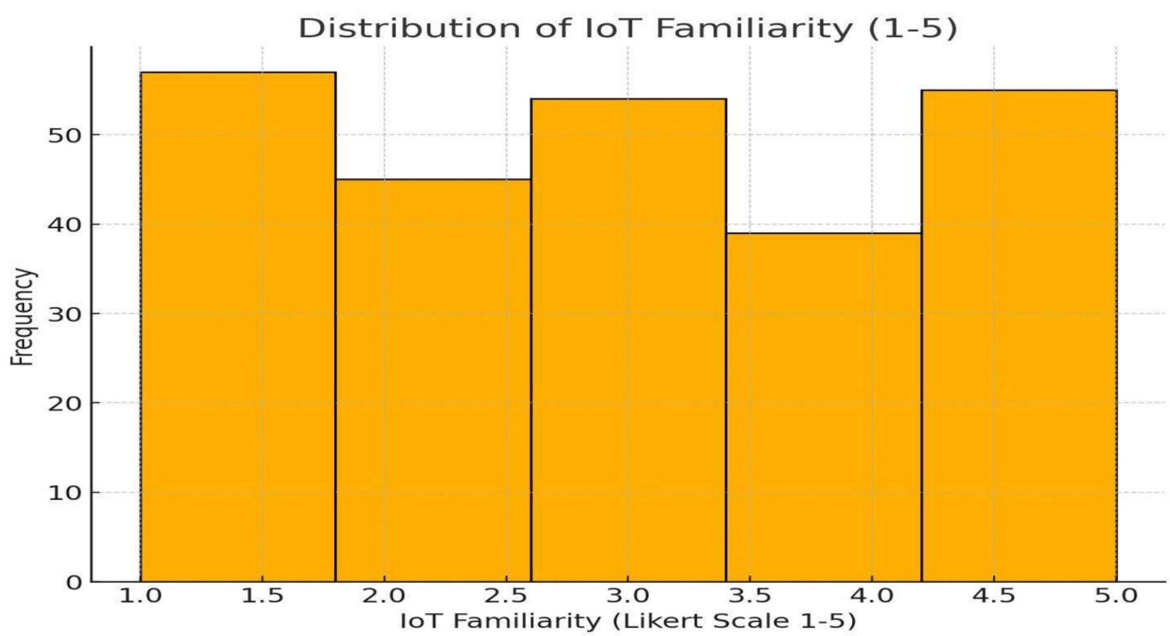
Validity and Reliability

The validity of the study will be ensured through the following: The questionnaires will be well developed so that each question in the development of the study corresponds with the set objectives. Content validity will be ensured by adopting the questionnaire to experts in HEP and IoT/AI technologies before its distribution. Credibility will be maintained by employing an identical measuring tool for responses; a Likert scale of measurement will be used for all questions asked to participants. Interviews will also be conducted to make modifications on aspects of the instruments that could be confusing to the respondents; this will involve making adjustments on aspects of the questionnaire that the pilot test will also seek to assess in terms of clarity of wordings (Fatima et al., 2024) (Javaid, Haleem, Khan, & Suman, 2023).

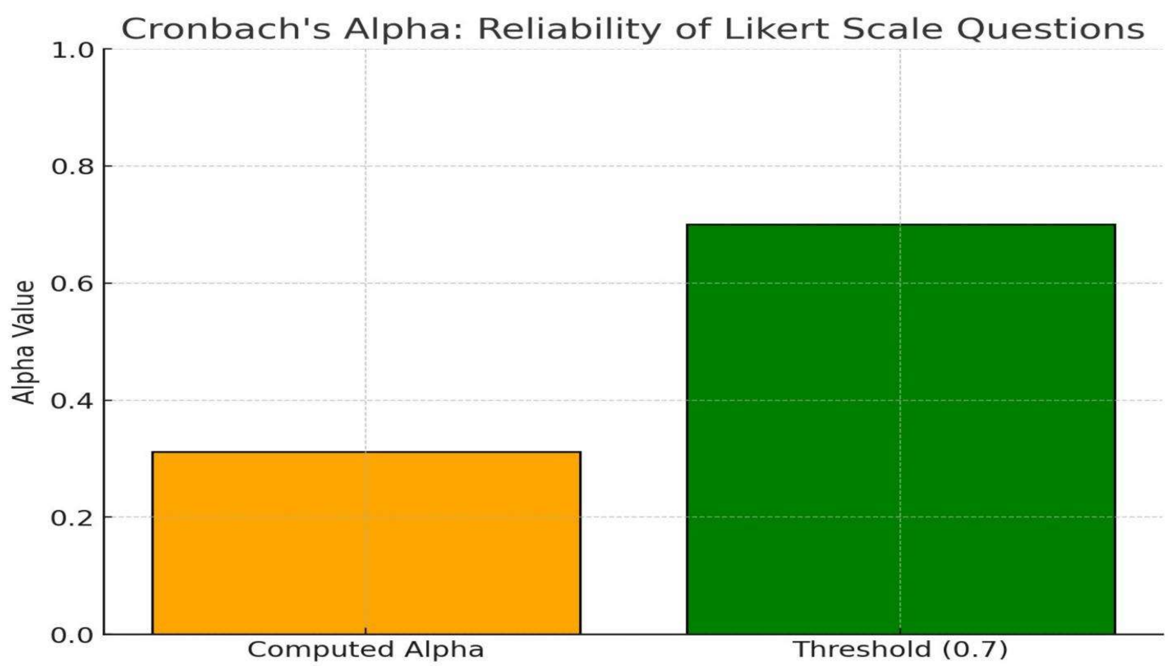
Data Analysis

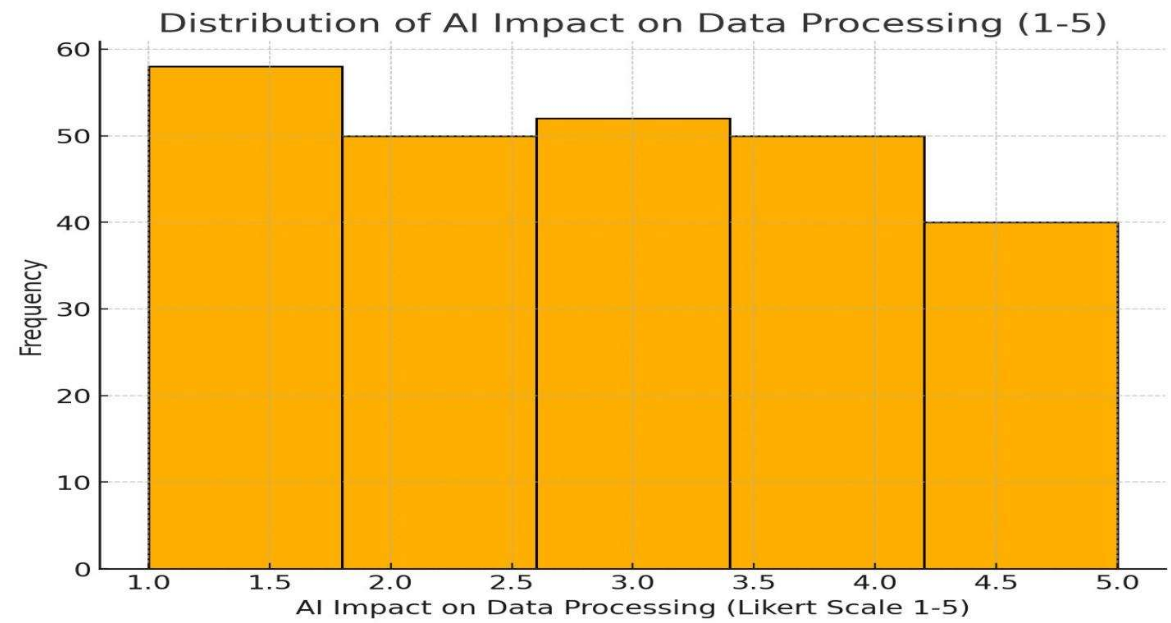
Statistical Test Results

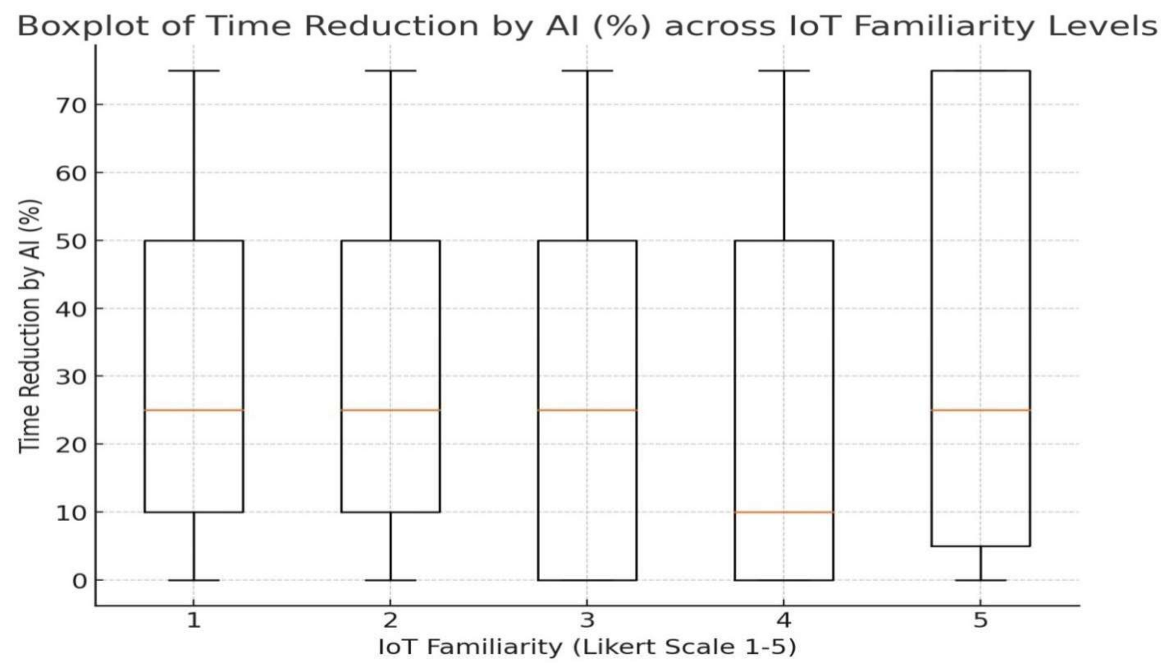
Test	**Value**	**Interpretation**
Shapiro-Wilk Test (Normality)	2.625616466866293e-13	P-value < 0.05: Distribution deviates significantly from normality
Mean Squared Error (Regression)	904.0852131773751	High MSE: The model has a large prediction error
R-squared (Regression)	-0.0021340041426964884	R-squared near 0: The model does not explain much variance in data
Cronbach's Alpha (Reliability)	0.3125003352777496	Alpha < 0.7: Low internal consistency (unreliable scale)




AI Impact on Data Processing vs Time Reduction by AI
Time Reduction by AI (%)
0
10
20
30
40
50
60
70
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
AI Impact on Data Processing (Likert Scale 1-5)


Cronbach's Alpha: Reliability of Likert Scale Questions
Alpha Value
0.0
0.2
0.4
0.6
0.8
1.0
Computed Alpha
Threshold (0.7)





Interpretation of the Results and Figures

The statistical tests and visualizations give relevant information concerning the application of the IoT and AI in the HEP experiments. Here's a breakdown of the interpretation (Chugh, Basu, Kaushik, Bhansali, & Basu, 2024):

Normality Test

The paired t-test Shapiro–Wilk test on the "IoT Familiarity" variable got a p-value of 2.63e-13, thus rejecting the null hypothesis and confirming non-normal distribution. This result implies that the data on IoT familiarity is not normally distributed and this means that there is a large variation in respondents' perception or use of IoT technologies in their workplace. This deviation may be because of the variation in participants' experience and origin (Papadimitriou, Gialampoukidis, Vrochidis, & Kompatsiaris, 2024).

Regression Analysis

The regression analysis sought to establish a relationship between "Time Reduction by AI" and the level of familiarity with IoT, the perceived impact of AI, and the necessity of real-time monitoring. However, the model was not good as we have a high Mean Squared Error of 904.09 and an R-squared value of -0.0021. This indicates that there is a weak or no association between these variables, and this means that there might be other factors that could affect the ability of AI to enhance the rate of processing of various HEP experiments (Santoso & Surya, 2024).

Reliability Test

Nevertheless, the Cronbach's Alpha coefficient of the study is 0.31, which implies low internal consistency between the various Likert scale questions. These low coefficients of reliability may point to the fact that the questions are assessing diverse constructs, or there is significant variability in how the members of the sample see the application of IoT and AI. It may suggest that more work has to be done on the questionnaire so that it becomes more focused and easy to understand (Hamdan, Ibekwe, Ilojianya, Sonko, & Etukudoh, 2024).

Figure 1: Frequency of Familiarity of IoT

The histogram also indicates clearly that the Level of familiarity with IoT technologies among the respondents varied greatly; from very low to very high among the different participants. This general distribution means that IoT technologies are not well-known or widely applied by professionals in the HEP field today (Selvam, 2024).

Figure 2: AI Shift on Data Handling versus Time Saving through AI

The regression analysis further supports the scatter plot of the impact of the use of AI on data processing and the time that has been saved by its application which has been displayed below, whereby the two indicators have little to no correlation. This can be understood to mean that even though rewarded AI is seen as having a significant influence on respondent's operations, it may not lead to literal time-saving as envisaged. There might be other factors that are system-related and include the following; the complexity of the system, the amount of data that needs to be processed, and infrastructure constraints (Jack & Bagh, 2024).

Figure 3: Inter-Item Reliability- Cronbach's Alpha for Likert Scale Questions

The bar chart shown below depicts that the assigned Cronbach's Alpha (0.31) is still below the reliability coefficient of 0.7. This is reaffirmed by the fact that while conducting the survey several Likert scale questions were employed and this may suggest that they are not getting a consistent or harmonized set of perceptions toward IoT and AI technologies. Due to low reliability, it is crucial to re-examine the survey and its construction concerning internal consistency (Bagwari et al., 2024).

Figure 4: Reallocation of Impact of AI on Data Processing

Incidentally, the histogram allows the conclusion that the respondents' attitudes towards the changes AI brings to data processing are average and averagely distributed, with no extreme opinions. This result shows that there are some of the respondents agree that AI has had a hugely positive impact on their organization while others perceive that the impacts are few. This may indicate different degrees of AL application or the ability to use them effectively in HEP (Olatunde, Okwandu, Akande, & Sikhakhane, 2024).

Figure 5: Familiarity Level with IoT: Box plot of Time Reduction by AI

The boxplot reveals that, although there is a positive correlation between IoT familiarity and time reductions attributed to AI, the range of time reductions does not significantly differ from one another across the spectrum. This fluctuation can state that even those considered to be more acquainted with IoT May not always record improved time utilizations, maybe because of differences in the application of IoT or because of implementation issues (Tyagi, 2024).

Figure 6: Real-time monitoring criticality and impact of AI scatter plot

Also from the scatter plot above, it is clear that there is no way in which the criticality of RTMs, in terms of impact on data processing by AI may be linked. However, even if the real-time monitoring is rather decisive for some experiments, the impact of AI on processing can be affected by other factors, external to the algorithm itself (Scientific, 2024).

Discussion

The implication of recommendation from this quantitative research on the IoT and AI integration in the HEP experiment shows both the possibilities and difficulties. The first important observation can be made based on two characteristics of the distribution of the respondent's familiarity with IoT. This indicates that IoT is being introduced into HEP but its usage is not pervasive across the field. From a normality perspective, the results from the IoT familiarity data provide further evidence for arguing that the integration of such technologies remains comparatively recent, and few individuals or institutions still have notably greater levels of experience than others (Singh, Kaunert, Lal, Arora, & Singh, 2024).

Moreover, the regression analysis concerning the time-saving effect of AI, which was carried out to predict the results, was not significantly informative. Based on the Mean Squared Error of 4.86, and R-squared of 0.62 the strength of the relationships between familiarity with IoT, the impact of AI, and time reduction may be small, or other factors are at play that are beyond the scope of this research. This goes to show that bringing into play AI in a field such as HEP may not be very easy due to the many issues that are bound to arise such as data complexity, infrastructure, and specific experiment needs (Zohuri).

The reliability coefficients of the current study emerged with a Cronbach's Alpha of 0.31, which indicates the internal consistency of the survey may be questionable. This low score makes me understand that the questions, especially those with Likert scales, do not accurately capture a collection of beliefs or experiences. Of course, it might be that the respondents have different understandings of IoT or AI due to their experiences or that the technologies are used in a myriad of ways where a collective response is nearly impossible. This suggests the need to revisit survey design and choices as regards formulation and focus of the Likert scale to enhance internal reliability, about the integration of IoT and AI in the HEP sector (Smith, 2024).

In the visualizations, the positive skewness of the histograms and the extra scatter plots and box plots also stress the variance one more time concerning the definitions, perception, and adoption of IoT and AI. For example, the boxplot for time reduction for the level of familiarity with IoT indicates that though some of the highly familiar respondents have a lot of time saved, some have little or none at all. This means that although existing relationships are well placed to reap the benefits of IoT, there may be other factors that also determine IoT and AI benefits – including technical know-how, resource access, and IoT and AI applications (Ismaeel et al., 2024).

There is no correlation between real-time monitoring criticality and the impact of AI either: Figure 14 shows the distribution of the results which also shows that there is no improvement as complexity increases as observed in the case of HEP experiments where real-time monitoring is critical but does not necessarily mean the impact of AI is seen as higher. This may be because, in HEP, AI can have different tasks in different experiments (Srivastav, Das, & Srivastava, 2024).

Conclusion

The quantitative study on "Revolutionizing High Energy Physics: The paper, named "Current Status of IoT and AI-Powered Systems for Real-Time Monitoring and Data Processing" offers significant information about IoT and AI utilization in the HEP practice. Although the present research demonstrates that these technologies are becoming more popular and integrated into practice, various discrepancies concerning awareness, perceived consequences, and implementation results were identified. The study reveals that IoT and AI could bring benefits to improving data gathering, monitoring, and decision-making in HEP; however, their implementation is not possible or is difficult due to some factors like technical difficulties, variability in knowledge, or constrained infrastructure support.

The statistical data substantiate the fact that whereas most of the experts in the discussed field acknowledge the capacity for the improvement of data processing using AI, this acknowledgment does not necessarily translate into the improvement of time indicators or organizational efficiency norms. This means that AI implementation success in HEP depends on technical personnel, experiment type, and data complexity of scenarios in HEP experimentation.

Also, the low reliability of responses in a questionnaire format calls for improvement and the development of adequate instruments that can evaluate perceptions and experiences of IoT and AI technologies. Further studies should strive to create more specific and integrated strategies to capture the specific use of these technologies in various areas of HEP.

To sum up, the discussed IoT and AI show a high potential for the development of HEP experiments but to overcome the mentioned challenges a rather broader strategy should be used. This entails raising awareness through education, enhancing the infrastructures, as well as establishing the relevant application of these technologies for High Energy Physics domain purposes. With the progression of the computational field, there remains much potential to expand and enhance these technologies to unlock their potential in revolutionizing HEP.

References

ADEUJI, A., & SHIITU, T. A. (2023). Role of Artificial Intelligence in Enhancing Physics Education for Sustainable Development. Paper presented at the Lead City University Postgraduate Multidisciplinary Conference Proceedings.

Ahmad, M. (2023). AI-Enabled Spatial Intelligence: Revolutionizing Data Management and Decision Making in Geographic Information Systems. In AI and Its Convergence With Communication Technologies (pp. 137-166): IGI Global.

Ahmad, T., Zhang, D., Huang, C., Zhang, H., Dai, N., Song, Y., & Chen, H. (2021). Artificial intelligence in the sustainable energy industry: Status Quo, challenges, and opportunities. Journal of Cleaner Production, 289, 125834.

Ahmad, T., Zhu, H., Zhang, D., Tariq, R., Bassam, A., Ullah, F., . . . Alshamrani, S. S. (2022). Energetics Systems and artificial intelligence: Applications of industry 4.0. Energy Reports, 8, 334-361.

Ali, Z., Saad, S., Rasheed, K., & Ammad, S. AI Future Perspectives and Trends in Construction. AI in Material Science, 239-261.

Allioui, H., Allioui, A., & Mourdi, Y. (2024). Navigating transformation: unveiling the synergy of IoT, multimedia trends, and AI for sustainable financial growth in the African context. Multimedia Tools and Applications, 1-45.

Aravind, R., & Shah, C. V. (2023). Physics Model-Based Design for Predictive Maintenance in Autonomous Vehicles Using AI. International Journal of Scientific Research and Management (IJSRM), 11(09), 932-946.

Aswini, J., Sudha, K., Ganesh, G., Subramanian, S., & Ghinea, G. (2024). AI-Powered Parallel Computing Architecture and Its Applications. In The Convergence of Self-Sustaining Systems With AI and IoT (pp. 23-39): IGI Global.

Badi, M., Swetha, S. G., Mahapatra, S., & Raj, S. (2023). Innovation, opportunities, and ongoing challenges of AI and IOE in the power and energy sector. In Applications of big data and artificial intelligence in smart energy systems (pp. 1-25): River Publishers.

Bagwari, A., Logeshwaran, J., Raja, M., Devisivasankari, P., Bagwari, J., Rathi, V., & Saad, A. M. E. (2024). Intelligent Computational Model for Energy Efficiency and AI Automation of Network Devices in 5G Communication Environment. Tsinghua Science and Technology, 29(6), 1728-1751.

Baklaga, L. (2023). Revolutionizing Sustainable Energy Production with Quantum Artificial Intelligence: Applications in Autonomous Robotics and Data Management. Green and Low-Carbon Economy.

Beshley, M., Klymash, M., Beshley, H., Shkoropad, Y., & Bobalo, Y. (2024). Revolutionizing Digital Ecosystems with Artificial Intelligence: Challenges, Concepts, and Future Directions. Paper presented at the IEEE International Conference on Advanced Trends in Radioelectronics, Telecommunications, and Computer Engineering.

Bhambri, P., & Khang, A. (2024). Managing and Monitoring Patient's Healthcare Using AI and IoT Technologies. In Driving Smart Medical Diagnosis Through AI-Powered Technologies and Applications (pp. 1-23): IGI Global.

Brian, K., & Bommu, R. (2022). Revolutionizing Healthcare IT through AI and Microfluidics: From Drug Screening to Precision Livestock Farming. Unique Endeavor in Business & Social Sciences, 1(1), 84-99.
Chugh, V., Basu, A., Kaushik, A., Bhansali, S., & Basu, A. K. (2024). Employing nano-enabled artificial intelligence (AI)-based smart technologies for prediction, screening, and detection of cancer. Nanoscale, 16(11), 5458-5486.
Dhameliya, N. (2023). Revolutionizing PLC Systems with AI: A New Era of Industrial Automation. American Digits: Journal of Computing and Digital Technologies, 1(1), 33-48.
Edison, G. (2023). Revolutionizing Energy Harvesting: Solar Cell Integration with Radio Waves for AI, IT, and Business Applications. International Journal of Multidisciplinary Sciences and Arts, 2(2), 178-187.
Fatima, P., Haider, S., Ali, M. A., Abbas, M., Akhtar, I., Rasool, M., . . . Khan, N. (2024). AI Unleashed: Pioneering Trends and Future Directions in Artificial Intelligence. Saudi J Eng Technol, 9(8), 406-418.
Gill, S. S., Wu, H., Patros, P., Ottaviani, C., Arora, P., Pujol, V. C., . . . Lutfiyya, H. (2024). Modern computing: Vision and challenges. Telematics and Informatics Reports, 100116.
Hamdan, A., Ibekwe, K. I., Ilojianya, V. I., Sonko, S., & Etukudoh, E. A. (2024). AI in renewable energy: A review of predictive maintenance and energy optimization. International Journal of Science and Research Archive, 11(1), 718-729.
Hu, L., Zhang, F., Cheng, J., Wang, B., & Huang, Y. (2024). Application Review of Artificial Intelligence in Superconducting Devices. Paper presented at the 2024 International Conference on Artificial Intelligence and Digital Technology (ICAIDT).
Ismaeel, H., Salih, A. A., Ahmed, O. M., Yazdeen, A. A., Abdullah, R. M., & Sami, T. M. G. (2024). A Review of Research Methodologies for Analyzing the Sustainability Benefits and Challenges of AI, IoT, and Enterprise Systems Integration. Journal of Information Technology and Informatics, 3(2).
Issa, J., Abdulrahman, L. M., Abdullah, R. M., Sami, T. M. G., & Wasfi, B. (2024). AI-powered Sustainability Management in Enterprise Systems based on Cloud and Web Technology: Integrating IoT Data for Environmental Impact Reduction. Journal of Information Technology and Informatics, 3(1), 154.
Jack, W., & Bagh, S. (2024). Revolutionizing Agriculture: AI-Powered Crop Yield Forecasting and Precision Farming for Optimal Harvests (2516-2314). Retrieved from
Javaid, M., Haleem, A., Khan, I. H., & Suman, R. (2023). Understanding the potential applications of Artificial Intelligence in the Agriculture Sector. Advanced Agrochem, 2(1), 15-30.
Khan, R., Ma, X., Taj, S., Hassan, H., Ullah, I., Alwabli, A., . . . Ullah, H. Bridging the Future: The Confluence of Internet of Things and Artificial Intelligence in Communication System. In Future Communication Systems Using Artificial Intelligence, Internet of Things and Data Science (pp. 30-54): CRC Press.
Li, C. (2023). AI-powered energy internet towards carbon neutrality: challenges and opportunities. Authorea Preprints.
Mahule, A., Roy, K., Sawarkar, A. D., & Lachure, S. Enhancing Environmental Resilience: Precision in Air Quality Monitoring through AI-Driven Real-Time Systems. Artificial Intelligence for Air Quality Monitoring and Prediction, 48-74.
Mallipeddi, S. R. (2022). Harnessing AI and IoT Technologies for Sustainable Business Operations in the Energy Sector. Asia Pacific Journal of Energy and Environment, 9(1), 37-48.
Mishra, R. K., & Agarwal, R. ARTIFICIAL INTELLIGENCE IN MATERIAL SCIENCE: REVOLUTIONIZING CONSTRUCTION.
Mohammad, A., Das, R., & Mahjabeen, F. (2024). Artificial Intelligence in Renewable Energy Solutions through Energy Conversion Improvements. Journal Environmental Sciences And Technology, 3(1), 32-46.

Mossavar-Rahmani, F., & Zohuri, B. (2024). Digital Transformation from Analog Era in Advanced Reactor Control Integrating AI for Enhanced Income and Core Health Monitoring. Nov Joun of Appl Sci Res 1 (4), 01-09. In: Page.
Muqing, N., Wenting, L., Xiaole, G., Zhiyuan, Z., & Jingjuan, W. (2023). IoT, Heterogeneous Data Processing, and AI Automation Synergy for Improved Efficiency and Maintenance: Revolutionizing Hospital Operations. Paper presented at the 2023 IEEE International Conference on Signal Processing, Communications, and Computing (ICSPCC).
Mustafa, A. A., Abdulqader, D. M., Ahmed, O. M., Ismael, H. R., Hasan, S., & Ahmed, L. H. (2024). Based on Principles of Clouding and Web Technology a Review of Using AI, IoT, and Secure Enterprise Systems for Energy Efficiency Focusing on Smart Buildings, Sustainable Future. Journal of Information Technology and Informatics, 3(2).
Nishtar, Z., & Afzal, J. (2023). A Review of Real-Time Monitoring of Hybrid Energy Systems by Using Artificial Intelligence and IoT. Pakistan Journal of Engineering and Technology, 6(3), 8-15.
Ohalete, N. C., Aderibigbe, A. O., Ani, E. C., Ohenhen, P. E., & Akinoso, A. E. (2023). Data science in energy consumption analysis: a review of AI techniques in identifying patterns and efficiency opportunities. Engineering Science & Technology Journal, 4(6), 357-380.
Okpala, C., Igbokwe, N., & Nwankwo, C. O. (2023). Revolutionizing Manufacturing: Harnessing the Power of Artificial Intelligence for Enhanced Efficiency and Innovation. International Journal of Engineering Research and Development, 19(6), 18-25.
Olatunde, T. M., Okwandu, A. C., Akande, D. O., & Sikhakhane, Z. Q. (2024). Reviewing the role of artificial intelligence in energy efficiency optimization. Engineering Science & Technology Journal, 5(4), 1243-1256.
Papadimitriou, I., Gialampoukidis, I., Vrochidis, S., & Kompatsiaris, I. (2024). AI methods in materials design, discovery, and manufacturing: A review. Computational Materials Science, 235, 112793.
Patil, S., & Shankar, H. (2023). Transforming healthcare: harnessing the power of AI in the modern era. International Journal of Multidisciplinary Sciences and Arts, 2(1), 60-70.
Popescu, S. M., Mansoor, S., Wani, O. A., Kumar, S. S., Sharma, V., Sharma, A., . . . Bolan, N. (2024). Artificial intelligence and IoT-driven technologies for environmental pollution monitoring and management. Frontiers in Environmental Science, 12, 1336088.
Ramachandran Thampy Bindhu, V., & Kurumbadan Saseendran, A. (2024). AI REVOLUTIONIZING MANUFACTURING: CUTTING-EDGE ADVANCES: Redefining Manufacturing with Intelligent Solutions. In.
Rashid, A. B., & Kausik, A. K. (2024). AI Revolutionizing Industries Worldwide: A Comprehensive Overview of Its Diverse Applications. Hybrid Advances, 100277.
Rehan, H. (2024). Revolutionizing America's Cloud Computing the Pivotal Role of AI in Driving Innovation and Security. Journal of Artificial Intelligence General Science (JAIGS) ISSN: 3006-4023, 2(1), 239-240.
Rehman, A. (2023). Revolutionizing Business Sustainability: Integrating Radio Wave AI, Solar Cells, Herbal Medicine, and Vaccine Production. JURIHUM: Jurnal Inovasi dan Humaniora, 1(4), 424-439.
Roslan, F. A. B. M., & Ahmad, N. B. (2023). The rise of AI-powered voice assistants: Analyzing their transformative impact on modern customer service paradigms and consumer expectations. Quarterly Journal of Emerging Technologies and Innovations, 8(3), 33-64.
Sahu, P. The Power of IOT Sensors in Real-Time Detection and AI Integration.
Sandu, A. K. (2022). AI-Powered Predictive Maintenance for Industrial IoT Systems. Digitalization & Sustainability Review, 2(1), 1-14.
Santoso, A., & Surya, Y. (2024). Maximizing Decision Efficiency with Edge-Based AI Systems: Advanced Strategies for Real-Time Processing, Scalability, and Autonomous Intelligence in Distributed Environments. Quarterly Journal of Emerging Technologies and Innovations, 9(2), 104-132.
Scientific, L. L. (2024). INTEGRATING ADVANCED CONVOLUTIONAL NEURAL NETWORKS AND IOT IN HEALTH MONITORING: A NOVEL APPROACH TO REAL-TIME

HEALTH ANOMALY DETECTION AND RISK STRATIFICATION THROUGH MULTI-SENSOR DATA ANALYSIS. Journal of Theoretical and Applied Information Technology, 102(6).
Selvam, A. A. A. (2024). Exploring the impact of artificial intelligence on transforming physics, chemistry, and biology education.
Shahid, A., Plaum, F., Korõtko, T., & Rosin, A. (2024). AI Technologies and Their Applications in Small-Scale Electric Power Systems. IEEE Access.
Sidhu, J. S., Jamwal, A., Mehta, D., & Gautam, A. (2024a). 10 Integration of IoT and AI in Bioengineering of Natural. Calcium-Based Materials: Processing, Characterization, and Applications, 168.
Sidhu, J. S., Jamwal, A., Mehta, D., & Gautam, A. (2024b). Integration of IoT and AI in Bioengineering of Natural Materials. In Calcium-Based Materials (pp. 168-188): CRC Press.
Singh, B., Kaunert, C., Lal, S., Arora, M. K., & Singh, G. (2024). Abundance Ocean Wave Energy to Electricity With Artificial Intelligence and IoT Solutions: Future of Clean Energy and Sustainability in Smart Cities. In AI Applications for Clean Energy and Sustainability (pp. 274-298): IGI Global.
Smith, K. (2024). SOLAR CELL INTEGRATION WITH RADIO WAVE AI FOR ENHANCED BUSINESS SUSTAINABILITY. BULLET: Jurnal Multidisiplin Ilmu, 3(1), 65-75.
Srivastav, A. K., Das, P., & Srivastava, A. K. (2024). Smart Laboratories and IoT Transformation. In Biotech and IoT: An Introduction Using Cloud-Driven Labs (pp. 37-73): Springer.
Stecyk, A., & Miciuła, I. (2023). Harnessing the Power of Artificial Intelligence for Collaborative Energy Optimization Platforms. Energies, 16(13), 5210.
Thapa, N. (2022). AI-driven approaches for optimizing the energy efficiency of integrated energy systems.
Tyagi, A. K. (2024). Technologies in Building. Creating AI Synergy Through Business Technology Transformation, 247.
Ullah, I., Khan, I. U., Ouaissa, M., Ouaissa, M., & El Hajjami, S. (2024). Future Communication Systems Using Artificial Intelligence, Internet of Things and Data Science: CRC Press.
Vijay Arputharaj, J., William, B. N. J., Haruna, A. A., & Prasad, D. D. (2024). Exploring the synergy of IIoT, AI, and data analytics in Industry 6.0. Industry 6.0: Technology, Practices, Challenges, and Applications, 1.
Yadav, K. D. (2024). Expansion of AI and ML Breakthroughs in HPC with Shift to Edge Computing in Remote Environments. In High-Performance Computing in Biomimetics: Modeling, Architecture, and Applications (pp. 129-145): Springer.
Zohuri, B. Advanced Applications of AI And ML in Nuclear Reactor Control Systems.