

Course Code: AI800

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Research Methodology in Computer Science

Using Computer Science with AI for Energy

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Summary research paper's:

Paper1: AI and Computer Vision-based Real-time Quality Control: A Review of Industrial Applications

In this paper the research delves into how computer vision (CV) plays a role, in quality control within industries by showcasing its ability to empower machines in evaluating information for activities such as inspectin products effectively and swiftly. With machine vision (MV) CV systems can detect flaws in items with accuracy and efficiency s upportig the progressions, in Industry 4.. And Quality 4.. CV relies heavily on AI technologies, like machine learning (ML) deeplearning (DL) especially convolutional neural networks (CNN) to automate and ensure precise quality evaluations, in manufacturing settings. The research emphasizes two uses; monitoring the quality of extrusion, in real time by identifying width or consistency issues through image analysis to make automatic adjustments, without human intervention; and inspecting bolts and screws using AI equipped cameras to assess color variations and cracks while employing an Intel Neural Compute Stick for detecting and correcting defects instantly. The paper discusses ways to overcome the obstacles posed by requirements and issues, with small or intricate features by proposing advancements in deep learning models and expanding the use of computer vision in the automotive industry, for improved real time quality control measures.

Paper2: Use of hydrogen and AI as an opportunity to increase energy autarky and create business more sustainable

The document delves into how hydrogen and artificial intelligence (AI) can significantly boost energy self-sufficiency and sustainability in Poland, country that currently depends heavily on coal, which makes up about 80% of its energy mox. It stresses the urgent need for green hydrogen generated from renewable sources as a cleaner alternative. The authors point out that AI has the potential to optimize various aspects of hydrogen, including its production, storage, and transportation. They advocate for continued research aimed at enhancing energy policies to pave the way for a successful transition to a low-carbon economy, highlighting the vital role that innovative technologies can play in achieving sustainable energy goals.

Paper3: energy and AI

This paper presents a comprehensive review on the increasing relationship between energy systems and artificial intelligence (AI), focusing on the high potential of AI in addressing major energy management, efficiency and sustainability challenges. We introduce a theme issue in the journal Energy and AI, which is intended as a new venue for disseminating research that bridges the two fields, in particular, new applications and methods capable of moving energy technology and policy forward. The main topics covered include AI for energy systems optimization, load forecasts, and renewable efficiency improvement. In addition, the document stresses the need for interdisciplinary research that considers the ethical implications, policy landscapes and social impacts of AI in the energy field. In short, it calls for further experimentation and dialogue in this inter-linked space to advance sustainable development and address critical energy issues head on.

Paper4: Performance and Energy efficiency Analysis of Machine Learning algorithms Towards Green AI: a case study of decision tree algorithms

This paper gives a detailed study on decision tree models as a type of machine learning model and their frequent utilization in numerous fields because of their high accuracy, interpretability, and simple structure.] The results show that energy usage varies considerably with the number and type of attributes used in these models, and indicate that considerable savings in energy cost are achievable through intelligent parameter selection, with no loss of performance. This improves knowledge on machine learning energy efficiency while encouraging practices consistent with Green AI. Moreover, it suggests directions for further research to explore these aspects and enhance the sustainability of AI technologies, thereby promoting in more eco-friendly line of work.

Paper5: Energetics Systems and artificial intelligence: Applications of industry 4.0

The document gives an idea to how artificial intelligence (AI) is being applied in the energy sector and demonstrating how it can revolutionise the power generation, transmission, distribution and storage. It outlines the importance of using AI categories such as the fuzzy logic systems, artificial neural networks, and genetic algorithms which facilitates operation intensity, allows for prediction of equipment failure and management of energy effectively. The study makes it clear that more research and development have to be carried out in order to unlock the full potential of AI in promoting energy sustainability and efficiency. In addition, it calls for establishing proper data frameworks and security features in order to advance digitalisation of the energy sector. Finally, the document emphasizes the need for regarding AI and Industry 4.0 technologies as tools to overcome the emerging issues of modern energy systems and to contribute to the development of the sustainable energy scenario.

Paper6: Enhancing predictive modeling of photovoltaic materials' solar power conversion efficiency using explainable AI

In the present document, the author attempts to explain how XAI can be applied in the field of materials science, particularly to forecast the PCE of OSCs. Thus, it stresses the importance of the XAI in increasing interpretability and credibility of machine learning models, which allows the researchers to find characteristics of materials that are challenging to discover by the regular experiments. Importantly, all the analyzed machine learning approaches, including the random forest regression and the feature importance analysis, are incorporated to enhance the framework's general predictiveness. Finally, through the results, it explains how XAI is useful and could contribute to a comprehension of the material characteristics and improvement in the design solar cells at high efficiency, which signifies the significance of collaboration between computational and experimental sciences in promoting progress of material sciences.

Critical Analysis

As a whole, the six papers are aimed at examining the possibilities of the utilisation of AI-infoware for advancing industrial augmentation, energy administration, and sustainable practices. The first paper focus how the combination of AI with computer vision to improve manufacturing performance while the second and third papers reveal the application of AI in hydrogen production management of energy systems with the high importance of green hydrogen energy transition is highlighted throughout the studies.

Despite of these insights, the papers do not go further in exploring some limitations of these technologies like problems that might occur in decision making algorithm that has some predisposed biases. Also, there is ample space for further research for security issues that occur with the implementation of AI.

From a methodological point of view, one may note that the reported results could be complemented with a more comprehensive performance evaluation and with a comparison with other methodologies. It is, however, an invaluable addition to the existing literature of discussions regarding the capacities of AI; however, more elaborate analysis of the shortcomings and threats is necessary for further development of advisable and viable responses to the issue.

Connections Between the Six Research Papers

1. Use of artificial intelligence in Industrial Processes

Paper 1 describes the application of AI and computer vision system for real-time quality control in manufacturing and shows how AI technologies improve the operations. This theme of enhancing industrial processes with the help of AI is the overarching idea that underpins all the other papers although the focus on Industry 4.0 is especially prominent here.

2. Energy Sustainability imperative

Both papers 2 and 3 discuss the application of AI in energy sector where it was found that AI has the potential to enhance hydrogen production and energy control. They both call for global shift to green energy systems in order to cut on the use of fossil energy hence the need for green technologies such as hydrogen.

3. Machine Learning and Energy Efficient

Paper 4 focuses on energy efficiency of the decision trees algorithm and situates the results based on Green AI. This concern of energy-efficient AI procedures ties to the discussions in Papers 2 and 5 about sustainable utilization of energy systems.

4. AI as an application in the Energy Systems

Paper 5 gives a wider perspective on how AI is being deployed in the energy contexts, and how it is assisting in increasing productivity, optimising maintenance, among other things within the energy sectors. This paper relates Papers 2 and 3 through the following analysis which reiterates the centrality of AI in the pursuit of energy sustainability.

5. Applying Explainable AI in Material science

In Paper 6, a model using explainable AI is applied in the prediction of efficiency of photovoltaic materials. As this paper is devoted to materials science, the connection with the energy theme is tracing to solar energy conversion-analysis, which is important for discussing various aspects of sustainable solutions presented in Papers 2, 3, and 5.

6. Interdisciplinary Approach

As noted in all six papers, there is significant calls for multi-disciplinary research. Paper 3 and Paper 6 emphasize on the ethical and socio-economic factors/ implications of AI applications which are very crucial for development of sustainable solutions in both energy sector and material science sector respectively.

Conflicts between the findings:

1. Focus and Scope

Papers 1, 5, and 6: Stress specific business usage of artificial intelligence. While papers 2 and 3: Major emphasis must be placed on general energy sustainability and the efficiency of its utilization.

2. It covers about Energy Efficiency and Sustainability.

Paper 4: Champions of practical energy-efficient machine learning architectures. Papers 1 and 5: Emphasize high computational intensity, may contradict with the traditional criteria of sustainability.

3. Implementation Challenges

Paper 1: Highlights current deficiencies of computer vision technologies. For Papers 2, 3, and 5: Point out that AI can enhance the efficacy of processes, meanwhile, there are questions to the resource implementation.

4. Teamwork

Papers 3 and 6: Emphasize such fields as ethical aspects, as well as the requirement of an interdisciplinary approach. And Papers 2 and 5: Major emphasis on technologies and neglect of the moral consequences of these technologies.

5. This policy pertains to various rules and regulation concerning policies and ethical issues.

Paper 3: We can therefore conclude that AI has a clearly expressed need to adhere to ethical guidelines. Paper 2: May therefore urge for enhanced energy policies but at the same time fail to consider the ethical sides.

6. Online Use Cases vs. Offline Analytics

Paper 1: Focuses at the industrial quality assurance and monitoring in real time. Paper 6: Is based on material prediction lacks different priorities in the application of artificial intelligence.

Synthesis Matrix for Literature Review:

Study: A I and Computer Vision-based Real-time Quality Control: A Review of Industrial Applications

Authors Abdelfatah Ettalibia, Abdelmajid Elouadia and Abdeljebar Mansour

Year: 2023

Research Design Experimental

Key Findings/Results	Methodology	Limitations
1-Concrete Extrusion Monitoring: A CV system captures real-time extrusion data during robotic construction, allowing immediate layer width adjustments to ensure consistent quality. 2-Bolt and Screw Inspection: The CV system identifies color, orientation, and crack defects in bolts and screws with edge processing capabilities, facilitating efficient defect removal on production lines.	1-Concrete Monitoring: Images captured by a mounted camera undergo binary processing and contour analysis to detect extrusion inconsistencies. The system automatically adjusts parameters based on detected defects. 2-Bolt Inspection: Infrared cameras and CNN-based processing classify defects in real-time, with an Intel Neural Compute Stick enabling rapid defect detection.	Computational Demand: Processing speed is hindered by complex contours and limited hardware capacity. Detection Accuracy: The contour method may overlook minor defects, reducing segmentation precision. Scalability: High-resolution image processing challenges real-time application on larger scales.

Study: Use of hydrogen and AI as an opportunity to increase energy autarky and create business more sustainable

Authors : Grzegorz Krzos, Estera Piwoni-Krzeszowska, Jakub Kowalski and Gunnar Klaus Prause

Year : 2023

Research Design Experimental

Key Findings/Results	Methodology	Limitations
1. Poland's energy sector heavily relies on coal (80% of the mix). 2. Green hydrogen from renewable sources is essential for sustainability. 3. AI can improve hydrogen production and energy management efficiency. 4. There is a need for more research on IT and AI applications in hydrogen policy. 5. Hydrogen and AI can enhance energy independence for Polish enterprises.	1.Literature Analysis: A critical review of existing scientific literature related to hydrogen and energy self-sufficiency. 2.Case Studies: Examination of specific projects in Polish enterprises that utilize hydrogen technologies. 3. Document Analysis Review of relevant source documents to gather data on the current state of the Polish energy sector and hydrogen initiatives.	1. Limited Case Studies: The small number of entities engaged in hydrogen technologies in Poland restricts the breadth of case studies. 2. Focus on Specific Technologies: The analysis may not encompass all potential hydrogen applications or technologies. 3. Data Availability: There may be challenges in accessing comprehensive data on hydrogen initiatives and energy policies in Poland. 4. Emerging Field: The rapidly evolving nature of hydrogen technology and AI may lead to findings that could quickly become outdated.

Study: Energy and AI

Authors Donghan Jin, Raffaella Ocone, Kui Jiao and Jin Xuan

Year: 2020

Research Design Experimental

Key Findings/Results	Methodology	Limitations
1. Growth in Research: Significant increase in publications at the intersection of energy and AI. 2. Government Support : Active funding for AI-related energy projects by governments to enhance sustainability and smart city development. 3. Industry Adoption: Companies like ExxonMobil and Sinopec are using AI to improve efficiency and reduce costs in energy production. 4. Research Directions: Focus on automation in energy materials discovery, big data analytics, and data-driven design of energy systems. 5. Ethical Considerations : Need for research addressing ethical implications and policy challenges related to AI in energy. 6. Future Potential : AI is expected to transform energy systems, improve consumer behavior understanding, and inform effective energy policies.	It emphasizes interdisciplinary approaches that combine insights from various fields such as chemistry, physics, engineering, and social studies. The focus is on innovative applications of AI in energy systems, including data-driven methods, optimization algorithms, and big data analytics. The journal encourages submissions that explore these methodologies to advance research in energy and AI.	1. Ethical Uncertainties: The potential ethical consequences of combining AI and energy are difficult to predict, necessitating further interdisciplinary research. 2. Policy Gaps: Existing laws and policies may not adequately address the challenges posed by AI in energy, requiring updates to support responsible development and application. 3. Data Privacy Concerns: Issues related to data management and privacy are significant, as AI systems often rely on large datasets that may include sensitive information. 4. Research Gaps: There is a noted vacancy in dedicated journals focusing on the cross-field of energy and AI, which may hinder the dissemination of relevant research. These limitations underscore the need for ongoing dialogue and research to address the challenges at the intersection of AI and energy.

Study: Performance and Energy efficiency Analysis of achine Learning algorithms Towards Green AI: a case study of decision tree algorithms

Authors: Gabrieli D. Silva.

Year:2021

Research Design Experimental

Key Findings/Results	Methodology	Limitations
1. Energy Hotspots Identified : The analysis revealed specific functions within decision tree algorithms (C4.5, CART) and ensemble methods (RF, XGBoost) that consume the most energy, particularly during impurity calculations and ensemble processing. 2. Impact of Dataset Characteristics : Energy consumption varies significantly with the number and type of attributes in the datasets, with classification tasks generally consuming more energy than regression tasks. 3. Memory Usage : Machine learning algorithms, particularly decision trees, tend to use substantial memory resources (cache and RAM). 4. Parameter Optimization : Simple adjustments in algorithm parameters can lead to significant reductions in energy consumption while maintaining predictive accuracy. 5. Contribution to Green AI : The study emphasizes the importance of understanding and optimizing the energy efficiency of machine learning algorithms to support sustainable AI practices.	1. Algorithm Selection: Two decision tree algorithms (C4.5 and CART) and two ensemble methods (Random Forest and XGBoost) were chosen for evaluation in both classification and regression tasks. 2. Energy Hotspot Identification : The study conducted experiments to identify energy hotspots—functions within the algorithms that consume the most energy, particularly during node impurity calculations. 3. Dataset Variation : A series of experiments were performed using 26 different datasets, varying in the number of examples and attributes, to analyze the relationship between computational performance and energy consumption. 4. Parameter Variation : The algorithms were tested with different parameter settings to assess how these variations impact energy consumption and predictive performance. 5. Performance Monitoring : Tools for performance and energy monitoring were utilized to collect data on energy consumption and computational efficiency during the execution of the algorithms. 6. CO2 Emission Analysis : The energy consumption data was used to calculate the equivalent CO2 emissions associated with the execution of the algorithms, contributing to the evaluation of their environmental impact.	1. Generalizability : Results may not be applicable to all machine learning models, as they are specific to decision tree algorithms and structured data. 2. Dataset Constraints : The analysis did not consider datasets with missing values, which may affect the applicability of findings. 3. Parameter Dependency : The influence of parameter tuning on energy efficiency and performance may vary significantly based on the specific input data used

Study: Energetics Systems and artificial intelligence: Applications of industry 4.0

Authors: Tanveer Ahmad b , Hongyu Zhu a , Dongdong Zhang a,* , Rasikh Tariq c , A. Bassam c , Fasee Ullah d , Ahmed S AlGhamdi e and Sultan S. Alshamrani

Year:2022

Research Design Experimental

Key Findings/Results	Methodology	Limitations
1. AI Integration : AI technologies significantly enhance efficiency, energy management, and the use of renewable energies in the energy sector. 2. Applications : AI is effectively applied in power generation, transmission, distribution, and energy storage, improving forecasting, fault diagnosis, and operational optimization. 3. Predictive Maintenance : AI enables a shift from reactive to predictive maintenance, reducing machine failures and operational costs. 4. Investment Needs : Substantial investment is required in AI research and infrastructure to fully realize its benefits in the energy industry. 5. Sustainability : The integration of AI and Industry 4.0 principles is crucial for achieving sustainability goals in energy systems. Overall, the study emphasizes the transformative potential of AI in creating a more efficient and sustainable energy landscape.	1. Literature Review : An extensive examination of existing research on AI applications across various energy systems, including power generation, transmission, distribution, and storage. 2. Evaluation Criteria : Assessment of AI's contribution to sustainable energy integration, energy efficiency, power supply stability, device efficiency, and stakeholder engagement. 3. Classification : Categorization of the growth status of different AI technology areas within the energy sector, identifying both established applications and emerging methods. 4. Policy Recommendations : Development of strategic recommendations for policymakers and industry stakeholders to enhance AI adoption and address challenges in energy systems. This approach aims to provide insights into the effective implementation of AI and Industry 4.0 technologies in promoting sustainability and efficiency in the energy industry.	1. Technological Challenges : The integration of AI in energy systems faces significant technological hurdles, such as the need for new protocols to synchronize existing and new equipment. 2. Data Protection Issues : Ensuring data security and privacy is a major challenge, as AI relies heavily on data from multiple sources. 3. Customer Awareness : There is a lack of awareness and understanding among customers regarding AI technologies and their benefits in the energy sector. 4. Regulatory Barriers : Existing regulations may hinder the adoption of AI technologies, necessitating updates to accommodate new innovations. 5. Research Gaps : While substantial research has been conducted, further studies are needed to explore the full potential and implications of AI in energy systems. These limitations highlight the need for ongoing research, policy adjustments, and increased stakeholder engagement to overcome barriers to AI implementation in the energy industry.

Study: Enhancing predictive modeling of photovoltaic materials' solar power conversion efficiency using explainable AI

Authors: M. Vubangsi Auwalu Saleh Mubarak and Fadi Al-Turjman

Year: 2024

Research Design: Experimental

Key Findings/Results	Methodology	Limitations
the integration of Explainable AI (XAI) techniques significantly enhances the prediction accuracy of the power conversion efficiency (PCE) of organic solar cells. By utilizing methods like LIME and SHAP for feature importance analysis, the study identified critical factors influencing PCE and revealed that the efficiency may be limited by the rate of charge transfer between donor and acceptor molecules, rather than their concentrations alone. This suggests a fundamental limit to how efficiently materials can convert light into electricity	1. Dataset Utilization : A dataset of 566 small-molecule organic solar cell materials was used, containing various donor and acceptor species combinations. 2. Predictive Modeling : A random forest regression model was employed to predict the power conversion efficiency (PCE) based on the chemical composition of the materials. 3. Explainable AI Techniques : Two XAI techniques, LIME and SHAP, were used to analyze feature importance. LIME provided localized explanations for individual predictions, while SHAP offered a global perspective on feature contributions. 4. Optimization Experiment: A grid search approach was conducted to identify the optimal feature value combinations that maximize PCE. 5. Analysis of Results: The study examined the step-like variation of PCE, suggesting that charge transfer rates may limit efficiency, and confirmed findings through consistent results from different XAI methods.	1. Data Availability : There is a limited availability of data necessary for developing accurate and interpretable models, which can hinder the robustness of predictions. 2. Interpretable Feature Selection : There is a need for more effective methods for interpretable feature selection to reduce input features and enhance model explainability. 3. Computational Complexity : The computational demands of XAI algorithms can be high, requiring significant resources that may not be accessible to all researchers, thus limiting the widespread adoption of XAI techniques in materials science.

Reference

- 1- [AI and Computer Vision-based Real-time Quality Control: A Review of Industrial Applications - ScienceDirect](#)
- 2- [Use of hydrogen and AI as an opportunities to increase energy autarky and create business more sustainable - ScienceDirect](#)
- 3- [Energy and AI - ScienceDirect](#)
- 4- [\(PDF\) Performance and Energy efficiency Analysis of Machine Learning algorithms Towards Green AI: a case study of decision tree algorithms](#)
- 5- [Energetics Systems and artificial intelligence: Applications of industry 4.0 - ScienceDirect](#)
- 6- [Enhancing predictive modeling of photovoltaic materials' solar power conversion efficiency using explainable AI - ScienceDirect](#) .