The 2nd International Conference on Energy and AI

AUG 10-12, 2021

Virtual Conference

Conference Program

iceai 2021

Imperial College London

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The 2nd International Conference on Energy and AI

Agenda

Day 1- Materials **Tuesday, August 10, 2021** **(Zoom ID: 970 2516 2731, Passcode: Ln+9iF)** https://imperial-ac-uk.zoom.us/j/97025162731?pwd=SFVIWVR3MEkyWStVZlBoclE1YWFqQT09		
Time	(All London Time, GMT+1)	
14:00-14:05	Welcome	Chair: Dr. Billy Wu
14:05-14:20	Elsevier	Dr. Jing Zhang
14:20-14:40	University of Cambridge	Dr. Alpha Lee
14:40-15:00	Carnegie Mellon University	Prof. Venkat Viswanathan
15:00-15:30	Discussion panel	Dr. Jing Zhang Prof. Venkat Viswanathan Dr. Alpha Lee

Day 2- Materials **Wednesday, August 11, 2021** **(Zoom ID: 920 2976 6482, Passcode: yP52D%)** https://imperial-ac-uk.zoom.us/j/92029766482?pwd=OWx4S2NIdmpROFZqdGdqNjdRSjNxdz09		
Time	(All London Time, GMT+1)	
14:00-14:05	Welcome	Chair: Dr. Huizhi Wang
14:05-14:25	The University of Warwick	Dr. Dhammika Widanalage
14:25-14:45	Xi'an Jiaotong University	Prof. Zhiguo Qu
14:45-15:15	Discussion panel	Dr. Dhammika Widanalage Prof. Zhiguo Qu

Day 3- Systems and community **Thursday, August 12, 2021** **(Zoom ID: 978 5540 2176, Passcode: S.0Zhe)** https://imperial-ac-uk.zoom.us/j/97855402176?pwd=bUtUbFdxNTFEaUtBZU83OTdKamJIUT09		
Time	(All London Time, GMT+1)	
14:00-14:05	Welcome	Chair: Prof. Jin Xuan
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14:25-14:45	Heriot-Watt University	Prof. Raffaella Ocone
14:45-15:15	Discussion panel	Prof. Raffaella Ocone Prof. Markus Kraft Dr. Nada Zamel
15:15-15:30	Announcement of prizes	Dr. Billy Wu

Talks and Abstracts

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PEM FUEL CELL DEGRADATION BY LONG SHORT-TERM **Kai Wang** FAW Group

Talk videos link: https://youtube.com/playlist?list=PLdWWRDI3B2oXUxaYIqKZ6W4Wy3pCgcLvt
or
https://space.bilibili.com/73523169/video

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RANDOM FOREST BASED CAPACITANCE PREDICTION IN ELECTROCHEMICAL DOUBLE LAYER CAPACITORS

A. Guru[1], V. Rajeghatge[1], S. Krishna[1], R. R. Mishra[1], T. Roy [1,2*]
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ABSTRACT
Storage and replenishment of power has become prominent due to the snowballing need for energy consumption. Electrochemical double layer capacitors (EDLCs) are extensively used for peak power load requirements as they succinctly prove to have high power density, rapid charge-discharge cycle, and long cyclability. However, no empirical relationship is established between the physical attributes that decide the capacitance of EDLCs. In this work, the capacitance of EDLCs was predicted using random forest algorithm with a 10-fold cross-validation approach. A total of 194 datasets extracted from previously published papers were used in this study. Features like electrode specific surface area (SSA), electrode pore volume (PV), electrode pore size (PS), ID/IG ratio, and voltage window were considered for building the model. The model was capable of predicting the capacitance with a fairly good accuracy. Moreover, individual feature contribution was also analysed.

Keywords: Electrochemical double layer capacitor, capacitance, random forest, 10-fold cross-validation, machine learning.

Link to Youtube video
https://youtu.be/Cv_MKhj9xKg

Link to Bilibili video
https://www.bilibili.com/video/BV1tq4y1n7AQ/

Link to full paper
https://www.dropbox.com/s/t2aep4bhzh9qxpw/Guru%20et%20al%20-%20Random%20forest%20based%20capacitance%20prediction%20in%20electrochemical%20double%20layer%20capacitors.pdf?dl=0

APPLICATION OF ARTIFICIAL NEURAL NETWORKS IN PREDICTING TOTAL THERMAL CONDUCTIVITY OF BINARY COMPOSITES

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2 Warsaw University of Technology, Poland (Corresponding Author)

ABSTRACT
This paper deals with the subject of teaching artificial neural networks in order to predict the value of the total thermal conductivity of heterogeneous composites with a strongly insulating matrix and, at the same time, strongly conducting reinforcement. In this type of composites, the phenomenon of percolation occurs, i.e. a nonlinear increase in thermal conductivity when the content of reinforcement in the material is large enough that its particles begin to form chains with each other [1]. The data generation process based on the mathematical model developed by Ch. Yuan and X. Luo and the process of learning neural networks was carried out using MATLAB R2020b environment. The network training results are satisfactory and demonstrate that the error in estimating the value of total thermal conductivity, even based on a non-ideal mathematical model, can reach acceptable values while significantly reducing the time required for the calculation. In the future, it is planned to supplement the input data set with thermal conductivity values generated from other mathematical models to make this tool more versatile.

Keywords: percolation, thermal conductivity of composites, neural networks

Link to full paper
https://www.dropbox.com/s/qehh6152b45dhkk/Krason%20and%20Sadowski%20-%20Application%20of%20artificial%20neural%20networks%20in%20predicting%20total%20thermal%20conductivity%20of%20binary%20composites.pdf?dl=0

NANOFLUIDIC IONIC THERMOELECTRIC OSMOTIC ENERGY CONVERSION ANALYSIS AND MACHINE LEARNING

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ABSTRACT
Osmotic energy conversion, employing ionic salinity gradient to drive a selective and directional migration to form ionic current, can efficiently utilize the low-grade salinity gradient energy. Current research mainly focuses on new nanochannel materials, varying the concentration ratio, and turning the channel geometry to obtain improved power generation. However, a uniform theory for temperature-dependent performance is still lacking, and a comprehensive empirical formula connecting the factors and efficacy has never been reported. Here, by digging into the underlying mechanism of ion transport and energy conversion, we obtain dimensionless governing parameters, providing convenience for collecting physically informed database based on the similarity principle. Moreover, a prediction model between the geometry, materials, driving force, and ion properties and energy conversion performance is built by machine learning (ML) to generate more samples, which contributes to fitting an empirical formula connecting the dimensionless governing parameters and efficacy.

As we all know, Poisson-Nernst-Planck (P-N-P) equations coupled with Navier-Strokes (N-S) equations and energy conservation equations are able to quantificationally illustrate the temperature-dependent osmotic power generation. Starting from these equations, the physical dimensionless governing parameters are put forward and proved to be independent, which decreases the number of the parameters in the equations above from 18 to 12. We find that the parameters representing the ion selectivity and migration property play a relatively more crucial role in thermal osmotic power generation. However, the effect of streaming and joule heat on power generation is less important and can be neglected. Based on these theories, commercial software Comsol Multiphysics is applied to solve P-N-P equations coupled with energy conservation equations, thus physically inspired database for ML is obtained. That is, when the dimensionless governing parameters remain the same, a physical case can be extended to other different cases by multiplying the corresponding factors, which is valuable to guide the modelling simulation arrangement and data processing. Furthermore, a prediction model, where dimensional variables and efficacy serve as input and output parameters respectively, is built by ML. By adopting the proper preprocessing, GPU acceleration, and Generative Adversarial Network (GAN), the accuracy of predicted model reaches 95%, efficiently and quickly generating a large number of samples composed of the parameters and efficacy. By turning the dimensional parameters to a dimensionless format, we present a general empirical formula of dimensionless governing parameters and efficacy, which can be a guidance for the judgement of dominant parameters and the prior estimate of efficacy in thermal osmotic power generation system. Current achievements could make an innovation of applying ML to thermal osmotic energy conversion field, and contribute to guiding the design of temperature-dependent osmotic power generation.

Keywords: Thermal osmotic energy conversion, Criterion numbers, Machine learning, Prediction model.

FLAMELET MODELING OF SPRAY FLAMES WITH MIXTURE OF EXPERTS-BASED LEARNING OF COMBUSTION MANIFOLDS

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ABSTRACT
This work presents a posteriori assessment of a novel Mixture of Experts (MoE) approach for learning tabulated combustion manifolds. The goal is motivated by the poor scaling of flamelet tables with increasing dimensionality, wherein the size of the table increases exponentially as more independent variables are included in the table. To resolve this issue, we present MoE, a divide-and-conquer machine learning (ML) approach to learn flamelet tables. In this approach, a system of neural networks, consisting of a gating network classifier and multiple regression expert models, are trained simultaneously to learn the flamelet table outputs as functions of the control variables. As a result, the flamelet table is partitioned by the gate, with the regression models being "experts" at making predictions within different portions of the manifold. The proposed approach is demonstrated and validated in the context of the unsteady flamelet/progress variable (UFPV) model applied to Reynoldsaveraged Navier-Stokes (RANS) simulation of Engine Combustion Network (ECN) Spray A.

Keywords: flamelet modeling, combustion manifold, deep learning, mixture of experts, spray flame

Link to Youtube video
https://youtu.be/CCrMWkVa7Jc

Link to Bilibili video
https://www.bilibili.com/video/BV1zL411E7TG/

Link to full paper
https://www.dropbox.com/s/4yocd5dkbkmsms7/Owoyele%20et%20al%20-%20FLAMELET%20MODELING%20OF%20SPRAY%20FLAMES%20WITH%20MIXTURE%20OF%20EXPERTS-BASED%20LEARNING%20OF%20COMBUSTION%20MANIFOLDS.pdf?dl=0

Convolutional neural network (CNN) of neutron radiography images for liquid water quantification in polymer electrolyte membrane fuel cells

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ABSTRACT
Water is a byproduct in proton exchange membrane fuel cells (PEMFCs) operation, which will cause electrode flooding if not properly managed. Thus, it is important to know the level of liquid water inside a fuel cell during operation. Both neutron and X-ray radiography have been proposed to obtain in-situ water images in operating PEMFCs, which are then post-processed to obtain water contents. In this study, we present a machine learning method of liquid water quantification using the convolutional neural network (CNN) — a deep neural network (DNN) model, to analyze real-time neutron radiography images obtained from PEMFC operation. The CNN model is a common machine learning method for visual imagery analysis and has achieved much success in image classification. The present CNN model is tained to learn the labeled images of contour bars to determine the water areal mass density of neutron radiography images. Each neutron radiography image is divided into 36 pieces. The output of the CNN network is the water areal mass density at a given current density under different relative humidity and flow field configurations. Accuracy of 95.1% in the test data has been achieved. The CNN results are also compared with another imaging processing method in the literature, showing agreement with an accuracy of 91%. The study is important for machine learning applications in fuel cell research and development.

Link to Youtube video
https://youtu.be/Xtj80IhjD4o

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https://www.bilibili.com/video/BV1d64y1W73j/

Link to full paper
https://www.dropbox.com/s/f7qxzxmxo31fe25/Pang%20and%20Wang%20-%20CNN%20of%20neutron%20radiography%20images%20for%20liquid%20water%20quantification%20in%20polymer%20electrolyte%20membrane%20fuel%20cells.docx?dl=0

MAXIMUM EFFICIENCY OPERATION IDENTIFIED BY MACHINE LEARNING FOR PEM FUEL CELLS

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ABSTRACT
In this work, the implementation of a proposed ANN-GA model available in the literature is considered to explore the performance of a PEMFC for different operating conditions such as temperature (T), anode and cathode relative humilities (RH_a and RH_c), and output voltage (V). These variables were used as inputs for the ANN and the current density (j) as the desired output. A 3-D Multiphysics model was used to generate the data set for training the ANN. After properly trained, the ANN was used as a fitness function in the GA optimization for the maximum voltage under a specific power density. This paper confirms the importance of machine learning with optimization proposes as a fast and accurate for online control of PEMFCs in practice.

Keywords: PEMFC, Genetic algorithm, Artificial Neural Network, Machine learning, Maximum voltage.

Link to Youtube video
https://youtu.be/nV1Zzni5po0

Link to Bilibili video
https://www.bilibili.com/video/BV1r54y1776P/

Link to full paper
https://www.dropbox.com/s/g7k44flb9ea5x95/Ruiz%20and%20Wang%20-%20MAXIMUM%20EFFICIENCY%20OPERATION%20IDENTIFIED%20BY%20MACHINE%20LEARNING%20FOR%20PEM%20FUEL%20CELLS.pdf?dl=0

MULTI-OBJECTIVE OPTIMISATION WITH HYBRID SURROGATE MODEL IN THE HYDROCRACKING PROCESS

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2 School of Engineering & Physical Science, Heriot-Watt University
3 Department of Chemistry, Loughborough University

ABSTRACT
Catalytic or thermal cracking of complex hydrocarbon mixtures is a well-established oil treatment process in the petroleum refining industry. The operation of cracking process requires a powerful modelling tools to perform the task such as prediction and optimisation for sustainable development. However, this still remains challenging due to the lack of an effective surrogate model and optimisation system, which require not only a precise analysis but also a fast optimisation. In this study, we proposed a multi-objective optimisation with non-dominated sort genetic algorithm (NSGA-II) which employs hybrid machine learning strategy as the surrogate model.
NSGA-II is an elitist genetic algorithm which solves multi-objective optimisation problems using Pareto ranking and crowding distance computations. Hybrid machine learning is the hybridization of data-driven framework with mechanistic-driven model to create a new 'grey' surrogate model. The data-driven algorithms, typically Deep Neural Network (DNN) and Artificial Neural Network (ANN) is employed to effectively resolve the relationship between process parameters and the product distribution. For the mechanistic-driven approach, continuum lumping kinetics is employed to describe the kinetic behaviour of lump of chemically-similar species. For example, in hydrocracking of paraffin, the disappearance rate of total compounds having similar carbon number is measured, rather than describing the kinetics of each single compound. Hybridisation of these two models effectively embeds the physically-meaningful mechanistic model into the data-driven framework, which enabled better data correlation guided by a clear reflection of the process principles. Using hybrid machine learning strategy as the surrogate model in the multi-objective optimisation is a promising approach in this complex hydrocracking process to enable an accurate computation as well as a fast optimisation.

Keywords: Hybrid surrogate model, hybrid machine learning, multi-objective optimisation, hydrocracking

Link to Youtube video
https://youtu.be/pqe8It7neTQ

Link to Bilibili video
https://www.bilibili.com/video/BV11o4y1m7S2/

DATA-DRIVEN PROTON EXCHANGE MEMBRANE FUEL CELL DYNAMIC PREDICTION AND REAL-TIME OPTIMIZATION USING A SEMI-RECURENT SLIDING-WINDOW METHOD

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ABSTRACT
The performance of proton exchange membrane fuel cell (PEMFC) tightly relies on the suitable operating conditions during dynamic operations. This study proposes a data-driven model for dynamic prediction and real-time optimization during the cold start by a semi-recurrent sliding window (SW) method coupled with artificial neural networks (NN) with the simulation data. The effect of ice accumulation on PEMFC performance is fully considered in the setup of the ML method. Moreover, both accuracy tests and K-fold cross-validations are done for the predictive ability and generalization of the model. The well-trained model could forecast the cell voltage and temperature under various dynamic currents and correlate operating conditions to the start-up time.

Keywords: Proton exchange membrane fuel cells; Sliding window method; Data-driven model; Cold start; Constant current slope strategy

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https://www.bilibili.com/video/BV1wq4y1Q7iK/

Link to Youtube video
https://www.youtube.com/watch?v=lnUVnd6Mx0E&t=3s

SELECTION OF OPTIMAL SENSORS FOR FAULT DIAGNOSIS OF PEM FUEL CELL SYSTEM BASED ON DATA DRIVEN METHOD

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ABSTRACT
Fault diagnosis is a critical process for reliability and durability of proton exchange membrane fuel cells (PEMFCs). In this paper, a novel data-driven approach based on sensor pre-selection and artificial neural network is proposed. First, the features of sensor data in time-domain and frequency-domain are extracted for sensitivity analysis. The sensors with poor response to the changes of system states are filtered out. Then experimental data monitored by the remaining sensors are utilized to establish the fault diagnosis model using artificial neural network. The diagnostic results demonstrate that the diagnosis accuracy rate reaches 99.2% and the recall rate reaches 98.3% by the proposed methods. The comparison with support vector machine (SVM) and Logistic Regression (LR) verify the effectiveness of proposed method. In addition, the high computational efficiency of proposed method supports the possibility of online diagnosis. Meanwhile, detecting the faults in the early stage could provide effective guidance for fault tolerant control of the PEMFC system.

Keywords: sensor selection approaches; fault diagnosis; PEMFC system; data-driven approach; artificial neural network

Link to Youtube video
https://youtu.be/hLdzHWdiHu8

Link to Bilibili video
https://www.bilibili.com/video/BV1wL411H7Zm/

AUTOMATIC GENERATION OF THE REACTION PROGRESS VARIABLE: A NOVEL APPROACH BASED ON THE ARTIFICIAL NEURAL NETWORK

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ABSTRACT
A novel approach based on the artificial neural network (ANN) is proposed and examined for the automatic generation of the reaction progress variable (PV), which is a key parameter for the flamelet paradigm combustion models. The reaction PV is well defined for single-step reaction kinetics. For multi-step reaction kinetics, it is defined by a weighted sum of species mass fractions using experiential formulations in general. However, the experiential definition is usually designed for specific fuels or conditions, which is not universally applicable, e.g., the commonly used PV definition of a CO CO2 and H2O combination is based on the steady flame of hydrocarbon fuels, not for the ignition prediction, neither for the cool flame propagation, nor the carbon-free fuel. Therefore, it is desirable to have general methods generating an optimal PV for complex chemical mechanisms under a wide range of fuel and operating conditions. In the present work, the ANN coupled with an optimization procedure is employed to achieve the automatic generation of the reaction PV for both unsteady and steady flames. The non-premixed n-heptane/air ignition and the premixed ammonia/air flame are studied. The optimization objectives are set to the monotonicity, sparsity, and sensitivity. The monotonicity ensures that the PV increases monotonically from unburnt to burnt states. The sparsity is a favorable attribute, which leads to a simple PV defination as most of the species are zero weighted. A low sensitivity has two requirements: 1) the PV composition species have a low local formation or consumption rates; 2) a rapid change of the other species mass fraction versus the PV is avoided. Reducing the sensitivity is beneficial to a small numerical error on PV transportation and other species interpolation. The monotonicity, sparsity, and sensitivity are also utilized as an indicator to evaluate the performance of the PV definition. The performance of the PV generated by the proposed approach and that of experiential definitions are compared. Results show that the proposed approach avoids the manual filter of the non-monotonically flamelet libraries, thus significantly improving the flamelet tabulation efficiency as compared with the conventional formulation. It is also observed that the prediction of the ignition is also improved. In addition, the proposed approach is equally effective for carbon-free fuel, such as ammonia which has no experiential PV definition.

Keywords: (Artificial neural network; reaction progress variable; flamelet generated manifold)

Link to Youtube video
https://youtu.be/jDpt2YN9E2s

Link to Bilibili video
https://www.bilibili.com/video/BV1X44y1C7r1/

RESEARCH ON HIGH PRECISION MODEL PARAMETER IDENTIFICATION METHOD FOR ENGINE VIRTUAL CALIBRATION

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ABSTRACT
With the increase of regulatory requirements and the continuous upgrading of engine functions, the calibration process of engine control parameters which is completely dependent on experiment has been greatly challenged in both development cost and time cycle. The virtual calibration method based on model plays an important role in accelerating the engine development cycle and reducing the experimental cost. And the core of virtual cali-bration is to establish a high-precision engine model with limited experimental resources. However, the engine is characterized by complex model system and many key parameters, which will affect the coupling of the over-all output. Therefore, an intelligent hierarchical tuning method for high precision engine model parameters is established in this study. The sub-models were classified, and the corresponding parameter identification meth-ods were established according to the common and different characteristics and parameter identification meth-ods of each sub-model in the engine system model. The key parameters of output targets of different systems were modified by Bayesian Optimization Method on the basis of parameter identification of sub-model and analysis of engine working principle and operation process, and then a high-precision engine model was estab-lished. The results show that the accuracy of more than 90% working conditions can be guaranteed to be higher than 95% in the key output of the whole engine system model by randomly selecting 500 working conditions from the original 2660 working conditions by space filling method based on intelligent hierarchical tuning method.

Keywords: Virtual Calibration, Parameter Identification of System Model, Feature Classification of Model, Intelligent Hierarchical Identification, PSOSCALF, Bayesian Optimization Algorithm

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DIESEL ENGINE FAULT DIAGNOSIS BASED ON DEEP TRANSFER LEARNING

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ABSTRACT

Diesel engine is the main driving force in industry, agriculture, nuclear power and other fields. The mechanical components of diesel engine are inevitably prone to various faults due to their complex structures and poor working environments. The key to ensure the operation safety of diesel engine is to establish a reliable fault diagnosis system. Traditional fault diagnosis methods are based on signal processing for feature extraction and classifiers, which require high expert experience, time-consuming design and cannot guarantee versatility. Data-driven intelligent fault diagnosis has attracted extensive interests recently, which is deeply related to big data and deep learning technique. Based on sufficient historical fault data, intelligent fault diagnosis establishes and trains a deep neural network model, mines the high-dimensional features contained in original data, and reduces the dependence on expert knowledge. However, in actual diesel engine engineering scenarios, the collected real-time data has two characteristics: 1) Imbalance. The diesel engine works in a healthy state for most of the time, therefore, fault data is insufficient and the collected data amount in healthy state and fault state is seriously imbalanced. 2) No label. The detailed health condition of diesel engine should be monitored by stopping the machines, however, it is unpractical to interrupt the engines operation frequently, which causes the fault data stored but the fault type lost. In addition, although the fault data could be obtained quickly by simulating faults on the engine bench, the cost of man-made faults under different operating conditions is extremely expensive, and running under long-term fault conditions is risky. In particular, the environmental differences between the engine bench test and actual operation cannot be ignored. Deep learning training is easy to be overfitted and the generalization ability of the trained network is affected when available fault data is limited. In this paper, an intelligent fault diagnosis method based on deep transfer learning is proposed to overcome the problem of limited fault data. The proposed method contains two essential steps: 1) a wide convolution kernel convolutional long short-term memory neural network (WCCL) is constructed to improve the feature extraction ability of diesel engine low signal-to-noise ratio fault data, and the features from the original data is extracted automatically to enhance the feature learning intelligence. 2) A transfer learning scheme based on WCCL is further adopted to transfer the diagnostic knowledge of large-scale labeled source domain data to the target domain network, and the learning and classification capabilities of the network in the target domain tasks with small samples is improved. Specifically, the source domain data is used to fully train the WCCL in a strong noise environment to obtain a pre-trained network with high diagnostic accuracy and excellent anti-noise performance. Next, the rare target domain data is inputted and the specific layer is frozen to fine-tune the pre-training model, and make it competent for new tasks in the target domain. Two aspects of verification are performed. Firstly, the fault diagnosis of the fuel system and valve drive mechanism on a diesel engine demonstrates the effectiveness of the proposed WCCL, compared with traditional machine learning and other deep learning methods, in processing low signal-to-noise ratio signals. Also, the test shows that the reduction in sample size has a huge negative impact on deep learning methods. Secondly, algorithm evaluation on cross-fault

domain and cross-device domain is conducted and compared with traditional deep neural networks, results show that the proposed transfer learning based on WCCL can improve the performance of small sample diagnosis effectively.

Keywords: Diesel engine; Fault diagnosis; Small sample; Deep learning; Transfer learning

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ONLINE STATE OF HEALTH ESTIMATION ON LITHIUM-ION BATTERIES BASED ON MACHINE LEARNING METHOD

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ABSTRACT
In this work, we develop data-driven models that accurately predict the cycle life of commercial lithium iron phosphate (LFP)/graphite cells using early-cycle data, with no prior knowledge of degradation mechanisms. We generated a dataset of 124 cells with cycle lives ranging from 150 to 2,300 using 72 different fast-charging conditions, with cycle life (or equivalently, end of life) defined as the number of cycles until 80% of nominal capacity.

Keywords: Machine Learning; Lithium-ion battery, state of health; online estimation

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OPTIMIZATION OF VALIDATION PROCESS FOR PEM FUEL CELL 3D+1D MODEL USING A DATA-DRIVEN SURROGATE MODEL

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ABSTRACT
Three-dimensional (3D) + one-dimensional (1D) model is one of the useful simulation tools to explore the water and heat management in proton exchange membrane fuel cell (PEMFC), which gives consideration to both model accuracy and calculation efficiency. In this study, a data-driven surrogate model with a stochastic optimization algorithm is applied to simplify the validation process of the 3D+1D model. The simulation results of 3D+1D model are used as a database to train the surrogate model based on Support Vector Machine (SVM). Prediction results show that the square correlation coefficient (R-square) in the test set is 0.996. The genetic algorithm (GA) model is used for optimization, in which the data-driven surrogate model is selected as a fitness evaluation function. The optimized parameters are returned to the 3D+1D model for verification. The polarization curves predicted by both the surrogate model and the physical model are compared with experimental data and decent agreement is achieved. The maximum relative error of the output voltage between the surrogate model prediction and the physical model simulation is 1.98%. The results indicate that the developed data-driven surrogate model can help the physical model to achieve fast and accurate validation.

Keywords: PEM fuel cell, 3D+1D model, Data-driven surrogate model, Stochastic optimization algorithm, model validation

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RESEARCH ON COLLABORATIVE CONTROL STRATEGY OF HYBRID MOTORS BASED ON ECONOMIC AND EMISSION

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ABSTRACT
In view of the fact that most of the research on the energy management strategy of hybrid electric vehicles is to consider reducing fuel consumption, considering the stringent emission regulations and severe environmental protection situation, a plug-in P13 series-parallel hybrid electric vehicle CD- which considers both emissions and fuel consumption has been developed. CS (Charge Depleting-Charge Sustaining) energy management strategy. Taking the driver's pedal opening and pedal opening change rate as the input of fuzzy control, and the motor torque correction coefficient as the output of fuzzy control, a single-pedal fuzzy control optimization algorithm is designed. Aiming at the stable operating conditions of the engine, with the engine fuel consumption and NOx emission as the optimization goals, a control algorithm based on neural network-genetic algorithm multi-objective optimization is designed. Finally, a control strategy software model is built based on MATLAB/Simulink, and the optimization algorithms at each stage are verified through simulation. The simulation results show that the single-pedal fuzzy control increases the energy utilization rate by 4.7% under WLTC cycle conditions, and under pedal open-loop control conditions The energy utilization rate is increased by 43%; after the neural network-genetic algorithm offline optimization, compared with the benchmark strategy, the fuel economy performance is reduced by 0.37%, and the emission performance is increased by 3.37%.

Keywords: Plug-in hybrid electric vehicle, single pedal fuzzy control, genetic algorithm, neural network, multi-objective optimization

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A DYNAMIC KNOWLEDGE-GRAPH APPROACH TO DIGITAL TWINS

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ABSTRACT

This paper demonstrates a dynamic knowledge-graph approach for digital twins. The dynamic knowledge graph is implemented using technologies from the Semantic Web. It is composed of concepts and instances defined using ontologies, and of computational agents that operate on the concepts and instances so that it remains current in time. By construction, it is distributed, supports interoperability, and ensures that data is queryable via a uniform interface. The knowledge graph includes the notions of a ‘base world’, and of ‘parallel worlds’ that support the exploration of alternative designs without affecting the base world. Examples are presented that demonstrate the ability to create digital twins that host geospatial data, incorporate live data and perform scenario analysis. The question of how to ensure alignment between the scenarios considered by the knowledge graph and the UN Sustainable Development Goals is considered.

Keywords: Dynamic knowledge graph; digital twin; data; agent; scenario analysis

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KILLING TWO BIRDS WITH ONE STONE: IMPROVING BUILDING ENERGY EFFICIENCY AND OCCUPANT COMFORT

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ABSTRACT
Faced with the challenges posed by global warming and the depletion of fossil fuels, all the actors in society (individuals, industries, communities, and governments) are led to find ways to reduce their energy consumption. As residential buildings contribute significantly to the overall energy consumption, a particular effort is requested from buildings occupants to reduce their energy consumption without having to compensate on their quality of life. The energy behaviour of buildings is directly influenced among others by the behaviour of their occupants. This paper describes a new approach based on historical data to sensitize occupants for their actions' impact on building energy comportment without the need to develop a physical model thanks to case-based reasoning (CBR). We report on an experimental evaluation of the approach based on real-world data collected from an office building including two years of historical data.

Keywords: Case-based reasoning, energy management system, genetic algorithm.

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AN INTELLIGENT CONSTRUCTION METHOD FOR COMBINING THERMODYNAMIC PROCESSES INTO CYCLES AND APPLICATION IN SUBCRITICAL CYCLE

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ABSTRACT

It is necessary to increase the proportion of renewable energy consumed to achieve the “3060 target” of carbon peak and carbon neutral. The multi energy complementation of the renewable energy is of great importance because of its dispersed and fluctuating feature. As a result, the energy system becomes more diverse, this requires more forms for the thermodynamic cycles as the heart of most energy systems. Although the study of cycles has a long history, the forms of existing cycles are still relatively limited, mainly including a few traditional cycles and their modified cycles. Moreover, the modification of the traditional cycle is based on experience, time-consuming and labor-consuming, and it is difficult to meet the demand of the development of the energy system. Therefore, it is urgent to develop intelligent methods to rapidly design new forms of thermodynamic cycles and to provide a variety of cycle options for future energy use scenarios. In previous studies, a cycle construction method based on the combination of thermodynamic processes has been proposed by our group, which takes the thermodynamic process as a degree of freedom and has a strong development capability. However, this method is a relatively simple study and does not take into account the working fluid, which is very important to thermodynamic cycle. Therefore, in this paper, the method is further improved by adding the working fluid factor and considering the phase change of the thermodynamic processes.

An intelligent algorithm coupled with the genetic algorithm is designed to perform the construction and optimization of the thermodynamic cycles. The algorithm is mainly divided into three modules, which are working fluid module, structure module and construction module. Databases on working fluids and structures are established and stored in these modules. The working fluid module contains the working fluid list and the properties database of the working fluid, and the structure module includes the process library and the process lists that can be constructed through the processes in the process library. After the working fluid information and structure information is available, the construction of the cycle can be performed according to the specific steps. First, point 0 is determined as the initial point, and then the position of the next point is determined through the process information in the process list and a randomly generated variable. In this way, all the processes in the process list are connected in turn to form the corresponding cycle. The rationality of the cycle is judged by whether the process is closed and whether the process lines are crossed. Finally, the process list which can form a reasonable new cycle is selected from a large number of process lists that are arranged and combined by the processes in the process library. As long as the databases are determined, the thermodynamic cycles can be automatically built and filtered by the algorithm according to the above processes.

Through this method, four-processes, five-processes and six-processes cycles are constructed, and 10 different cycle structures are obtained. For each cycle structure, 30 different working fluids are used respectively, and 300 cycles with different working fluids or structures are formed by arrangement and

combination. Then, the parameters of the cycle are optimized by genetic algorithm, the influence of temperature range on cycle efficiency is also analyzed. Finally, the optimal cycle structure, working fluid and cycle parameters corresponding to each working condition are obtained. New cycle built through different processes, efficiency can be improved by up to 4% compared to the traditional Rankine cycle. The results show that the improved intelligent thermodynamic cycle construction method based on the combination of thermodynamic processes has a stronger ability to develop new cycles, which is of great significance for the future development of energy systems.

Link to Youtube video
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THE FEED GAS COMPOSITION EFFECTS ON THE GREEN METHANOL PRODUCTION: DYNAMIC SIMULATION AND SURROGATE MODELING

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ABSTRACT
Power-to-methanol is seen as a key energy storage technology in contributing to reach climate targets and unleash the great potential for renewable electricity. This study conducted dynamic simulations that focuses on the feed gas composition effects and surrogate modeling by using the nonlinear autoregressive exogenous (NARX) model for the green methanol production. The modeling results showed obvious influences of feed gas composition on the process efficiency and CO_2 conversion, which were predicted by the NARX model with promising accuracy.

Keywords: Power-to-methanol; Dynamic simulation; Surrogate modeling; CO_2 hydrogenation; Methanol synthesis; Nonlinear autoregressive exogenous model

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AN INVESTIGATION OF THE EFFECTS OF KERNEL TUNING ON THE PERFORMANCE OF CONVOLUTION NEURAL NETWORK ARCHITECTURES: A CASE STUDY OF NON – INSTRUCTIVE LOAD MONITORING APPLICATIONS

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ABSTRACT
The use of Convolutional Neural Networks (CNN) in the field of Non-Instructive Load Monitoring (NILM) for the disaggregation of energy signals is a relatively new field in the domain of Deep Learning (DL). Given the limitations of datasets for NILM applications, it is essential that the functionality in terms of accuracy and convergence time of CNN architectures is maximized to obtain the expected results. Therefore, this paper presents a single highly optimized CNN architecture which is capable of generating the appliance wise energy disaggregation based on a sequence to point approach. The performances of a CNN are heavily dependent on the experimental hyperparameters defined by the user and therefore, the true internal behavior of the CNN and extracted features are typically not presented to the user and remain as a black box. With reference to the literature survey, it was realized that a concise relationship between the hyperparameters of a CNN model and its outcome has not been reported for application specific or general CNN architectures. Therefore, presenting a relationship between the kernel size and the outcome of the CNN in terms of the accuracy, this paper reveals an improved approach for hyperparameter adjustments by suggesting the optimal kernel sizes to maximize the accuracy of the training model.

Keywords: Non-Instructive Load Monitoring, Convolutional Neural Networks, Kernel tuning, Filters

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Link to Youtube video
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SOLAR ENERGY FORECAST MODELS BASED ON GRADIENT BOOSTING ALGORITHMS

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ABSTRACT
This paper presents machine learning-based forecasting models for predicting the power output from solar photovoltaic cells based on the given weather data. The weather data was obtained from the National Solar Radiation Data Base and the solar energy production data was obtained from the University of Massachusetts Amherst's (UMass Amherst) energy dashboard. The CatBoost and XGBoost models are trained and validated in this study. The performance of these two models is evaluated. The R2 value for CatBoost is 0.89 and XGBoost is 0.86. The results of this study show that CatBoost and XGBoost can be used to predict the power output from solar panels.

Keywords: Machine Learning, CatBoost, XGBoost, Forecasting, Photovoltaic Cell, Solar Power.

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A DATA-DRIVEN METHODOLOGY FOR WIND POWER RAMP RECOGNITION VIA IMAGING

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ABSTRACT
A ramp event occurs when there is a change in power output that has a large enough amplitude for a relatively short period of time [1,2], which is generally triggered by complex physical processes, atmospheric phenomena and periods. The uncertainty of wind power ramps brings great hidden hazards to maintain the stable and safe operation of the power system [3]. The existing methods depend on the manual decisions for analyzing and choosing nominal appropriate ramp features. Different from the traditional amplitude prediction at time points, the sudden increase and decrease of power output during a short time are only strongly dependent on the meteorological conditions at the moment. What's more, historical previous power values, and even the last ramp event are not of much reference for subsequent ramp event detection. In this case, the advantage of the traditional recurrent neural network [4,5], the transmission of long-step dependencies, fails to be exploited. In the field of image recognition, convolutional neural network [6] could be employed to capture local features through small receptive fields [7], thereby forming feature maps with certain rules and associations in a higher-dimensional space. This property is consistent with the idea that more attention should be put to short-term condition changes in ramp events recognition. Therefore, instead of the traditional time series forecasting procedure, developing a data-driven model to fit the specific ramp definition and power output data has become our focus. To avoid the interference of nonuniform definitions and abnormal output, this paper proposes the imaging-based wind power series representations, and an adaptive approach to automatically remove redundancy from raw wind power images and extract valid features to classify ramp events. Fig.1 shows the overall flowchart of imaging-based wind power ramp recognition scheme.
1) Power imaging via pixel coding: The paper encodes power sequence into images with the transition from deterministic values to pixels [8], which provides a way to visualize semantic information of ramp events. Instead of grayscale images with less information, the kromograms with RGB mode (red,green,blue) or HSV mode(hue,saturation,value) are applied to depict wind power data. The steps are as follows. a) preprocess the raw power serial output. b) adopt the minimax transformation further for data series before plotting imaging. c) transform serial data to RGB or HSV pixel imaging. d) Arrange the pixels in the image in the order of time and attribute.
2) Adaptive feature extraction with improved-Alexnet: Based on the shortages in existing research on ramp events and the imaging-based wind power series representations in this paper, we introduce a data-driven feature extraction network, which is adjusted from AlexNet. Ramp duration does not exceed 4 hours [2], while, to adapt small-size images generated, the large-size kernel in the traditional Alex Net is discarded and only 3×3 cores are used. In general, the closer the layer is to the back layer, the more abstract features can be mined [9]. Only part of convolutional layers has been retained to ensure the validity of the semantic information. The overall subsampling multiple is 4, which fully reserves the details of ramp events. Fig.2 depicts the framework of data-driven backbone network with adaptive-tuning, which enhances the interpretability of the model and the recognition ability of semantic information.2

Experimental results on La Haute Borne wind farm dataset [10] have verified that our proposed framework yields highly outstanding performances and realizes the adaptive detection for wind power output compared with state-of-the-art ramp forecasting methods.

Keywords: Wind power ramp event; Pixel imaging; Feature extraction; Multi-channel convolutional neural network (MCNN)

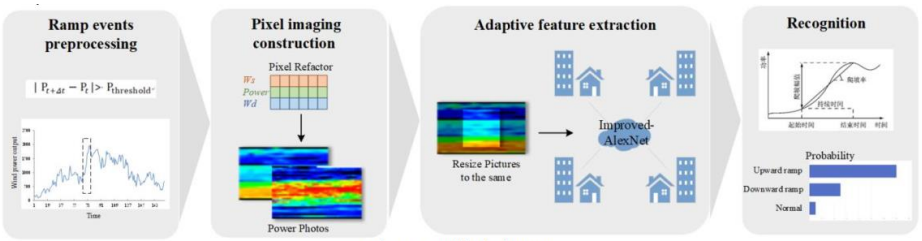

Fig. 1 Graphical abstract

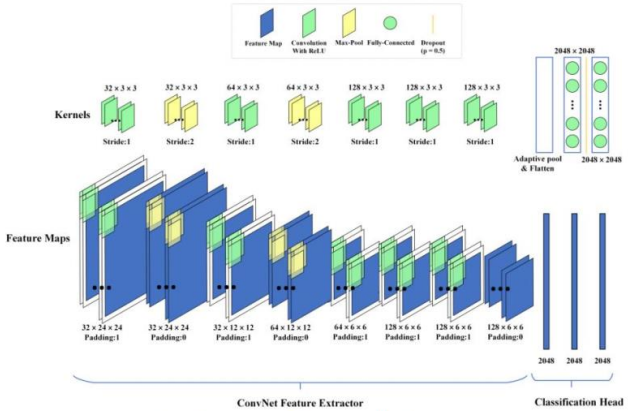

Fig .2 Structure of Improved-AlexNet.

Link to Youtube video

https://youtu.be/fscPnhT1ZFI

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FORECASTING HOUSEHOLD ELECTRICITY DEMAND USING MACHINE LEARNING ALGORITHMS: A CASE OF THAILAND

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ABSTRACT

Because electricity generation is generally a long-term operation requiring large capital investment, the accurate projection on future electricity demand is inevitably a crucial factor. To smoothly sustain the economic growth, the Thai government has recognized the significance of long-term planning enabling sufficient and efficient electricity generation. Therefore, the national Power Development Plan (hereafter referred to as "PDP") has been regularly formulated since 1992. Specifically, load forecasting and the stability of the power system are the main deliverables of PDP. In addition, household electricity consumption is one of the main components of electrical load. However, the load forecast error has been a serious concern. In November 2020, it caused the power generation reserve to reach 50% of total power generation capacity, substantially higher than the internationally recommended rate of 15-20%.

With the necessity of improving the accuracy of load forecasts, this study introduced the alternative forecasting technique for household electricity demand by applying the machine learning methods to the household-level data. Specifically, the methods of generalized least squares (GLS) regression, artificial neural network (ANN), random forest (RF) and support vector regression (SVR) were applied to the data of Socioeconomic Survey (SES), which is the nationwide household survey officially conducted by the National Statistical Office every two years. The datasets cover the period 1994-2015, and the number of samplings continuously increased from 12,621 in 1994 to 37,008 in 2015. Each sampling included the monthly average household's electricity consumption (kWh), the monthly average income (Thai baht), the average temperature (degrees Celsius), and the numbers of possessed electrical appliances classified into 15 categories. Also, the data included the number of family members, owned vehicles, the number of rooms and the classification of building materials of the house. The 100-fold cross-validation technique was applied to the dataset, and the values of root-mean-square error (RMSE) obtained from four machine learning algorithms were compared. For all annual datasets, RF yielded the lowest RMSE, while those of SVR, ANN and GLS ranked second, third and fourth, respectively. In addition, RF incorporated the analyses of variable importance (VIMP) and minimal depth (MD), quantifying each factor's degree of influence on electricity consumption. VIMP and MD outcomes show that the ownership of air conditioners, the average temperature, the monthly average income and the number of family members are the most influential factors.

With unique characteristics of socioeconomic survey data composed of a diverse combination of discrete and continuous variables, all obtained results indicate that RF is the most appropriate technique. These outcomes also suggest the potential application of using RF as a bottom-up approach for residential load forecasting, which is the alternative to the top-down one conventionally used in PDP. In addition, this proposed bottom-up technique can indicate the electricity demand in the spatial dimension, supporting the planning of distribution networks with high accuracy.

Keywords: Thailand, electricity demand, machine learning, artificial neural network, random forest, support vector regression

Youtube video link
https://youtu.be/VNoGo7WluTM

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SCENARIO-BASED ANALYSIS OF A DEEP LEARNING OCCUPANCY AND WINDOW RECOGNITION APPROACH FOR ENERGY EFFICIENCY

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ABSTRACT
This study presents a vision-based deep learning approach for detecting and recognising occupant' activities and window opening behavior to help control the heating, ventilation, and air-conditioning (HVAC) system according to space's actual thermal and ventilation requirements. A convolutional neural network (CNN) model was developed, trained, and deployed to a camera for real-time detection. Based on an experimental test within the case study building, the results indicated an overall detection accuracy of 92.72% for occupancy activities and 87.74% for window operations. Real-time detection and recognition provided the generation of the deep learning influenced profiles (DLIP) used as input for building energy simulation to evaluate the impact of the approach on energy demand and indoor air quality. The present work assesses the importance of the proposed approach for predicting indoor air quality and thermal comfort and optimising the operations of building HVAC and natural ventilation systems.

Keywords: Deep learning, building energy management, window and occupancy detection, HVAC systems, building energy performance, building ventilation

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INTEGRATION OF DEEP-LEARNING APPROACH AND PREDICTIVE LOAD MODELS FOR REAL-TIME, LOW COMPUTATION-COST ROOM ENERGY LOADS ESTIMATION

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ABSTRACT
Buildings account for a significant proportion of energy consumption globally. A real-time and low computation cost estimation of building heating and cooling load can be the key to achieving energy savings and decarbonising buildings. This paper introduces a cross-disciplinary project: two artificial techniques, namely convolutional neural networks and shallow neural networks, were combined to achieve a real-time and low computation cost of estimating the heating and cooling load of an investigated room. The verification results demonstrate that the estimated heating and cooling loads using the proposed approach are close to the simulated loads: R2>0.85 for heating and R2>0.96 for cooling. The findings indicated the feasibility of real-time and low-computation cost estimation of room loads with artificial intelligence techniques.

Keywords: Deep-learning approach, Convolutional Neural Network, Shallow neural networks, Building load estimation.

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BUILDING OCCUPANCY PREDICTION THROUGH MACHINE LEARNING FOR ENHANCING ENERGY EFFICIENCY, AIR QUALITY AND THERMAL COMFORT: REVIEW AND CASE STUDY

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ABSTRACT

As the largest energy consumer, buildings account for 40% of the global annual energy consumption and 36% of the total carbon emissions. Despite the energy cost, it is common to find buildings with unsatisfied thermal conditions. Occupant behaviour has been regarded as one of the most significant considerations for building and system design. During the last two decades, various occupancy models have been developed to mimic occupants' randomness and diversity and generate stochastic occupancy profiles for building performance simulation and heating, ventilation, and air-conditioning (HVAC) controls. Recently, advanced prediction tools based on artificial intelligence (AI) are increasingly being employed for predicting occupancy patterns in buildings. The present work carries out a comprehensive review of studies using artificial intelligence and machine learning models to predict occupancy and its applications, covering studies about energy consumption, thermal comfort, lighting use and indoor air quality. Also, this paper provides an overview of hardware and techniques used during data collection, data mining, building modelling simulation and validation, and analysing factors that impact building occupancy prediction. The analyses show that while these studies have revealed that occupancy is a critical contributor in the building prediction model, they have not paid enough attention to the thermal condition and their effect on occupant productivity and quality of life, which requires more detailed information on occupancy activities. In this study, occupancy detection with the vision-based camera is employed which captures specific occupancy activities and other related behavior like window opening behavior. These activities will generate real-time deep learning influenced profile formation, which can be used to train the prediction model.

In the existing literature, even though a standard framework to describe the models with adequate details that enable model exchange or reuse lacks, the most popular and best performing algorithms are neural network-based algorithms. This study proposed a modified convolutional neural network (CNN) model that enables specific occupancy activity prediction to better understand occupancy behaviour within a building space. The prediction result will inform the occupants and make adjustments to the HVAC system control.

Figure 1 presents the framework approach. Deep learning techniques were employed to develop a vision-based detector, enabling the detection and recognition of typical occupancy activities such as sitting, standing walking, and their actions towards opening and closing windows. It consisted of the configuration and training of a convolutional neural network-based model using an image dataset. The trained model was then deployed to form an AI-powered camera which was used to perform live detections. The detection results were recorded in form of the generated deep learning influenced profile (DLIP). Such results were used to provide different system responses designed to assist the HVAC control system in providing adequate indoor thermal comfort and air quality while improving the building energy performance.

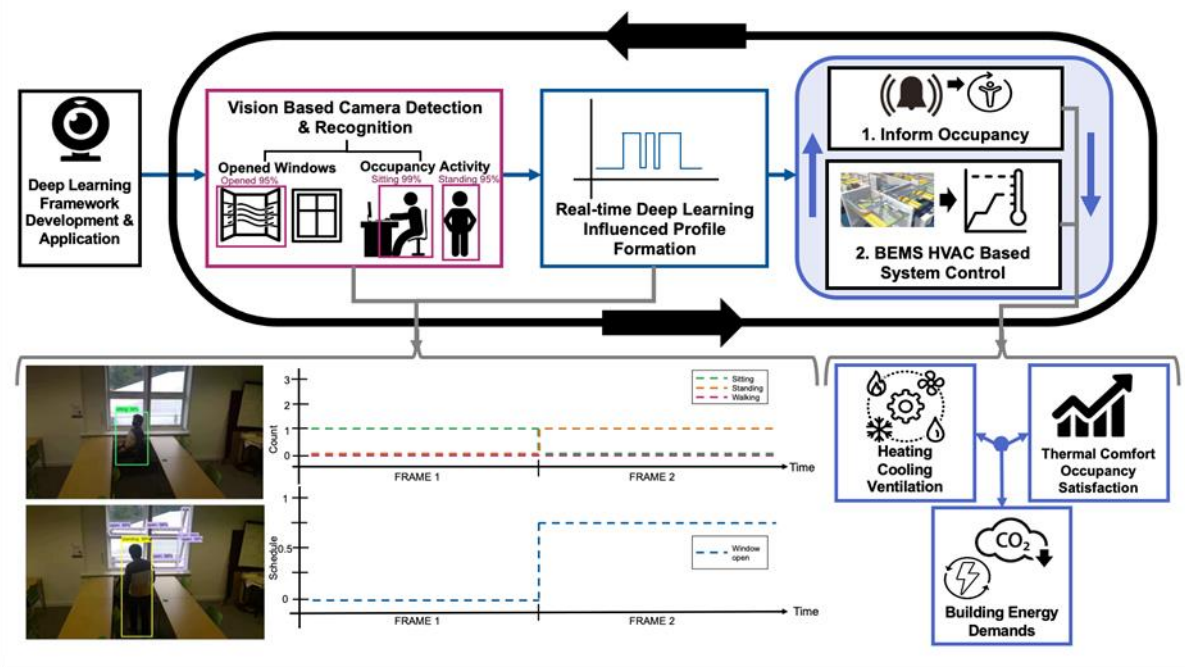

Figure 1. A deep learning-based occupancy detection framework approach.

As represented by the Typical Office 1 and 2 profiles in Figure 2 it suggests that current buildings are operated based on the assumption with predefined or fixed schedules. Typical Office 1 assumed that the occupants are performing sedentary activities within the office space. While Typical Office 2 assumed a higher activity rate by the occupants. However, compared to the given Deep Learning Scenario-Based results where the vision-based approach was applied, the occupancy patterns do not follow such patterns as more variation occurs within the number of occupants within the room and the activities they performed. Hence, this indicates the importance of such an approach to employ such a novel occupancy prediction approach to recognise whether a room is occupied or unoccupied, along with the knowledge of the type of activities performed by occupants at a given time.

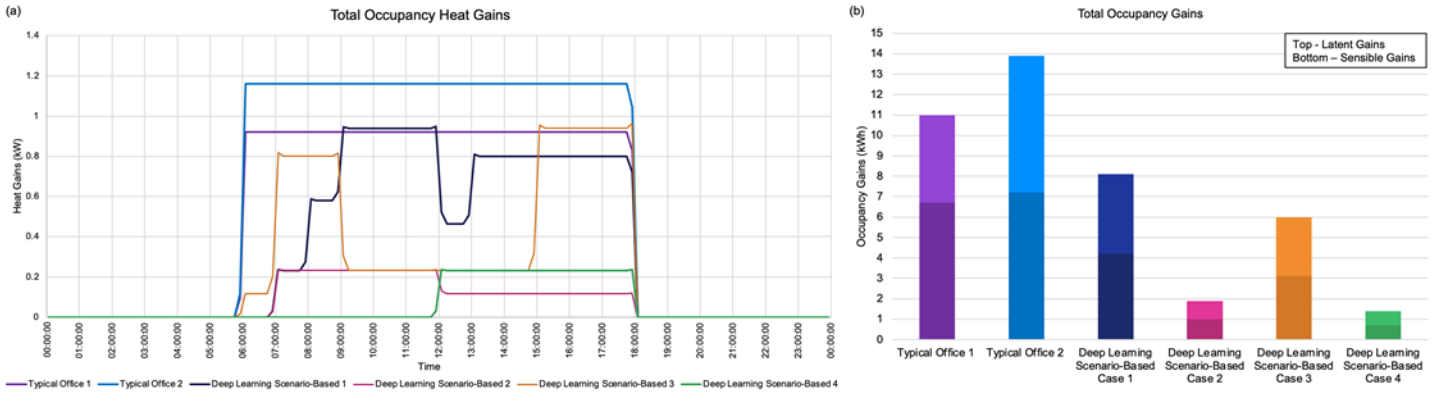

Figure 2. Comparison of the occupancy heat gain profiles generated using the proposed approach and the typical occupancy scheduled profiles. a). Variation of gains across time and b). the total occupancy gains.

With the possibility of achieving high variation in occupancy gains, it subsequently affects the building energy demands. Figure 3 presents the predicted heating and cooling loads during typical winter and summer days. The results suggest that using predefined assumptions for occupancy gains can lead to inaccurate estimation in energy demands, which leads to the increase towards unnecessary building energy loads. Furthermore, by depending on the occupancy level, slight adjustments to the room setpoint temperature can be made to

improve the space's thermal condition. Consequently, this can affect the occupant productivity and quality of life while significantly affecting the energy demand of the building.

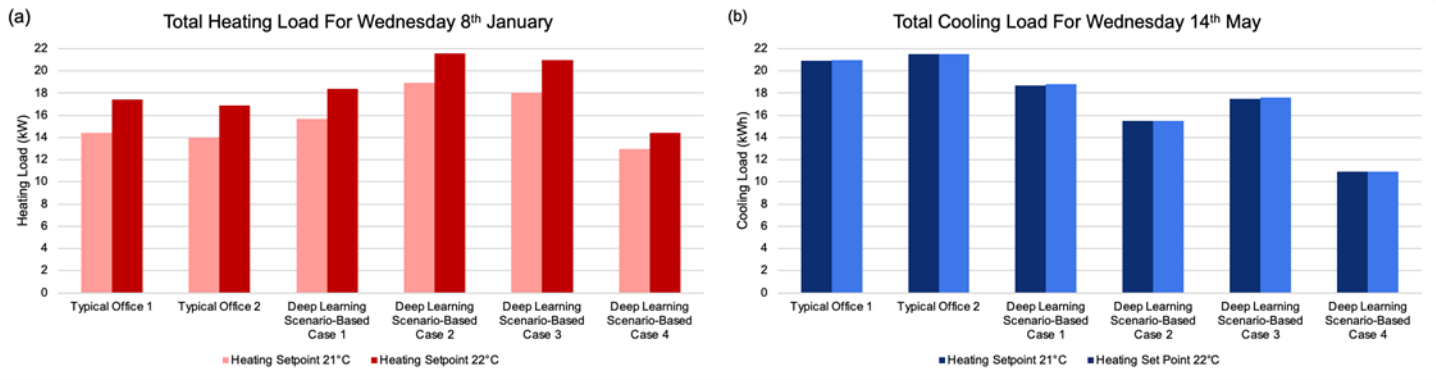

Figure 3. Comparison of the total a). heating and b). cooling load achieved under the different deep learning scenario-based cases compared to the typical occupancy profiles.

Keywords: machine learning, occupancy prediction, thermal comfort, energy consumption

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PEM FUEL CELL DEGRADATION BY LONG SHORT-TERM MEMORY NETWORK

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ABSTRACT

Proton exchange membrane fuel cell (PEMFC) has broad application prospects in the field of new energy, but cost and durability are the important factors that restrict its commercialization. Therefore, the emergence of PEMFC performance and life prediction technology is of great significance to improve the durability of PEMFC. Because of the complex mechanism inside PEMFC and coupling of parameters, it is difficult to construct an accurate mechanism model to describe the degradation process of PEMFC system performance. The prediction method based on data driven has better nonlinear fitting ability. Compared with the traditional recurrent neural network (RNN), the long short-term memory (LSTM) neural network can avoid the gradient disappearance caused by the increase of training time and network layers, which can effectively solve the long-term dependence problem of fuel cell life prediction. In this paper, a behavior based LSTM prediction method is proposed, which uses the performance parameters, start-up and stop, emergency stop and other behaviors of PEMFC durability test as inputs to predict the degradation of PEMFC. In order to verify the accuracy of the proposed algorithm, three groups of PEMFC durability tests under different operating conditions and working conditions were carried out. The results show that the proposed LSTM life prediction algorithm can fit the test data well under steady and dynamic conditions, and accurately predict the influence of dynamic behavior on the system degradation in endurance test.

Keywords: Fuel cell; durability; long short-term memory (LSTM); behavior

Link to full paper

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