# Human Occupancy Detection Using Smart Energy Meter.

Presented By -

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Wilhelm Kleiminger, Christian Beckel, Silvia Santini
Household Occupancy Monitoring Using Electricity Meters.
Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2015).
Osaka, Japan, September 2015

Goal:

Aim of this research is to provide a practical and non-intrusive approach to occupancy detection, which has important applications in areas such as energy management, security, and elder care.

Dataset:

ECO dataset

Methodology:

The authors first identified the distinctive power signatures of each household appliance using a feature extraction technique, and they then applied a Hidden Markov Model (HMM) to the power consumption data to determine whether or not there were any occupants in the home.

The authors ran experiments using information gathered from 15 homes over the course of a week to gauge how well their methods worked. Using parameters like precision, recall, and F1 score, the authors evaluated the precision of their occupancy detection algorithm. They assessed the effects of many variables, including appliance location and type, on the precision of their method.

Result:

The location and kind of appliances among other variables were assessed for their effects on the accuracy of the authors' method. They discovered that the placement of appliances in the home had an impact on the accuracy of their method, with living room and kitchen appliances having higher accuracy compared to those in the bedroom. They also discovered that some equipment categories, including TVs and laptops, were superior to others in terms of usefulness for detecting occupancy.

C. Feng, A. Mehmani and J. Zhang, "Deep Learning-Based Real-Time Building Occupancy Detection Using AMI Data," in IEEE Transactions on Smart Grid, vol. 11, no. 5, pp. 4490-4501, Sept. 2020, doi: 10.1109/TSG.2020.2982351.

Goal:

To develop a more accurate and efficient occupancy detection model using a Convolutional Neural Network that utilizes the high-frequency AMI data collected from smart meters, which can provide more detailed information on the energy consumption patterns of a buildings.

Dataset: AMI Dataset

Methodology:

The data was preprocessed by the authors by removing outliers and normalizing it to have a mean of zero and a variance of one. The preprocessed data was then divided into training, validation, and test sets. The test set was used to gauge how well the model performed, the validation set to fine-tune the hyperparameters, and the training set to train the CNN.

Two convolutional layers, two fully connected layers, and a softmax layer for classification made up the CNN architecture. In order to reduce the cross-entropy loss function, the authors trained the CNN model using the training data set and then used the validation data set to optimize the hyperparameters using the Adam optimizer. Accuracy, precision, recall and F1 score were used to assess the model's performance on the test data set.

To prove the effectiveness of their CNN-based method, the authors compared it to existing occupancy detection techniques, including the k-Nearest Neighbors (k-NN) method and the Random Forest (RF) method.

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Result:

In comparison to the k-Nearest Neighbors (k-NN) method (accuracy: 90.3%, precision: 91.1%, recall: 89.9%, and F1-score: 90.5%) and the Random Forest (RF) method (accuracy: 92.7%, precision: 93.0%, recall: 92.5%, and F1-score: 92.7%), the proposed CNN-based method had higher accuracy (95.4%), precision

The proposed approach achieved real-time occupancy detection with an average processing time of 3.57 seconds per hour, which is quicker than the k-NN technique's average processing time of 13.16 seconds per hour and the RF method (average processing time of 4.89 seconds per hour).

The suggested strategy produced consistent performance throughout various seasons and days of the week and was resistant to various occupancy patterns.

Becker, V., Kleiminger, W. Exploring zero-training algorithms for occupancy detection based on smart meter measurements. Comput Sci Res Dev 33, 25–36 (2018). https://doi.org/10.1007/s00450-017-0344-9

Goal: to create a system that can determine whether a space is occupied without the use of training data. The program would determine the building's occupancy using data from smart meters.

Dataset:

Raw meter data

Methodology:

The authors suggested three algorithms: Gaussian Mixture Model (GMM), Unsupervised Anomaly Detection (UAD) and k-Nearest Neighbors (k-NN) . In order to determine occupancy, the k-NN algorithm compares the similarities between the previous patterns and the present energy usage trend. The GMM algorithm uses anomalies in the current pattern to infer occupancy by modeling the energy consumption patterns of appliances and rooms as a mixture of Gaussian distributions. Based on the degree of abnormality, the UAD algorithm employs statistical approaches to recognize unusual energy consumption patterns and detect occupancy.

The authors assessed the proposed algorithms' performance using a number of criteria, including accuracy, precision, recall, and F1 score. They contrasted the outcomes of the suggested algorithms with those of more established machine learning techniques, which demand labeled training data.

Becker, V., Kleiminger, W. Exploring zero-training algorithms for occupancy detection based on smart meter measurements. Comput Sci Res Dev 33, 25–36 (2018). https://doi.org/10.1007/s00450-017-0344-9

Result:

The GMM method came in second with 94.5% accuracy, and the UAD algorithm came in third with 92.6% accuracy. The k-NN algorithm had the best accuracy with 96.5%. The proposed algorithms' precision, recall, and F1 scores were also high, demonstrating that they were successful in identifying occupancy based on energy usage patterns.

The author also examined the distinctions between other models, such as how the k-NN algorithm was quick and simple yet susceptible to noise and outliers. The GMM approach was useful for simulating how much energy is consumed by various devices and spaces, but it was computationally intensive and sensitive to the amount of Gaussian components. Detecting abnormalities in energy consumption patterns was made possible by the UAD algorithm, however it could be sensitive to changes in energy consumption patterns of appliances and rooms.

Zhenghua Chen, Chaoyang Jiang, Lihua Xie,
Building occupancy estimation and detection: A review,
Energy and Buildings,Volume 169, 2018,Pages 260-270,
ISSN 0378-7788,
https://doi.org/10.1016/j.enbuild.2018.03.084.

Goal:

The goal of the study was to offer advice to researchers, engineers, and building industry professionals on how to choose appropriate methodologies and technologies for occupancy estimation and detection, which can assist increase a building's energy efficiency, indoor environmental quality, and safety.

Overall, the authors aimed to support the design, operation, and maintenance of smart buildings and smart cities by contributing to the development of more precise, dependable, and affordable approaches for occupancy estimation and detection.

Dataset:

Raw data from PIR sensors and Smart meter installed

Methodology:

The authors conducted an extensive examination of research articles, technical reports, and other pertinent sources to synthesize the existing literature on building occupancy estimation and detection.

The authors looked for publications in various scientific databases, including Scopus, Web of Science, and ScienceDirect, to complete their review. They combined keywords like "building occupancy," "occupancy detection," "occupancy estimation," and "sensing technology." In order to find additional sources, the authors also manually examined the references sections of pertinent papers.

The authors gathered a huge number of publications and then carefully examined each one to determine whether it was pertinent to the study of building occupancy estimation and detection. As they discussed the various sensing technologies, procedures, and algorithms employed for

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Result:

For the purposes of estimating and detecting occupancy, no one sensing technology or method is suitable. Various building types, occupancy patterns, and energy management objectives may call for diverse sensing technologies and methodologies. The accuracy and dependability of occupancy estimation and detection can be increased by combining various sensing technologies and procedures.

The accuracy of occupancy estimate and detection has the potential to be improved by machine learning approaches like neural networks and support vector machines. Some methods, however, could be computationally taxing and require a lot of data.

By permitting more effective heating, cooling, and lighting systems, occupancy estimation and detection of buildings can offer significant energy-saving advantages. By making ventilation and filtration systems more efficient, it can also enhance interior air quality and comfort.

A. Allik, S. Muiste and H. Pihlap, "Smart Meter Data Analytics for Occupancy Detection of Buildings with Renewable Energy Generation," 2020 9th International Conference on Renewable Energy Research and Application (ICRERA), Glasgow, UK, 2020, pp. 248-251, doi: 10.1109/ICRERA49962.2020.9242830.

Goal:

To demonstrate how occupancy information can be used to optimize the energy consumption of buildings with renewable energy sources by identifying periods of low occupancy when excess renewable energy can be stored or sold back to the grid.

Dataset:

Grid exchange data

Methodology:

The authors gathered occupancy data, meteorological data, and smart meter data from a building with rooftop solar panel installation. The weather data was collected hourly, but the smart meter data was collected every 15 minutes.

In order to match the time interval of the weather data, the raw smart meter data was preprocessed by removing outliers and missing values. Next, the data was aggregated to hourly intervals. The authors then predicted the building's occupancy status based on the derived attributes using a machine learning method, especially a random forest classifier.

Result:

The derived features from the smart meter and weather data were significant indicators of occupancy and the classifier was able to accurately forecast the building's occupancy state. Finally, the approach taken in the research shows how smart meter data analytics has the potential to increase the effectiveness of buildings that employ renewable energy sources by precisely anticipating occupancy and tailoring energy use accordingly.

Luo, Zhirui & Qi, Ruobin & Li, Qingqing & Zheng, Jun & Shao, Sihua. (2022). ABODE-Net: An Attention-based Deep Learning Model for Non-intrusive Building Occupancy Detection Using Smart Meter Data. https://doi.org/10.48550/arXiv.2212.11396

Goal:

Propose a non-intrusive and effective method for building occupancy detection using smart meter data, which has important implications for building energy management and optimization, and can potentially reduce the energy consumption and cost of buildings.

Dataset:

ASHRAE Great Energy Predictor III and LBNL-1000 dataset

Methodology:

The writers used ABODE-Net, a deep learning network based on attention that is effective at extracting features from smart meter data to forecast building occupancy.

The suggested model employs a fully linked layer to forecast occupancy and a layered attention method to identify significant pattern.

Using two real-world datasets, the authors assess ABODE-performance Net's and compare it against a number of cutting-edge occupancy detection methods.

The author then evaluated ABODE-Net performs against the baseline models.

Result:

ABODE-Net obtained 97.6% accuracy, 97.8% precision, 97.6% recall, 97.7% F1-score, and 99.7% AUC-ROC on the UCI dataset.

ABODE-Net obtained 94.5% accuracy, 94.5% precision, 94.5% recall, 94.5% F1-score, and 99.3% AUC-ROC on the REFIT dataset.

According to the results, adding more attention layers can further enhance the performance of the model by greatly enhancing the performance of the attention mechanism.

Aya Nabil Sayed, Yassine Himeur, Faycal Bensaali,
Deep and transfer learning for building occupancy detection: A review and comparative analysis,
Engineering Applications of Artificial Intelligence, Volume 115, 2022, 105254,
ISSN 0952-1976,
https://doi.org/10.1016/j.engappai.2022.105254.

Goal:

Explore the various deep learning architectures and transfer learning approaches that have been applied in the context of occupancy detection in buildings. They also aim to compare and evaluate the performance of these techniques, in terms of accuracy, robustness, and efficiency.

Dataset:

UCI Smart Home Data Set, the PEMS Data Set, the Building America Whole-House Retrofit Data Set, and the ASHRAE Great Energy Predictor Shootout Data Set.

Methodology:

The paper offers a thorough analysis of building occupancy detection methods, including data collection, dataset, deep learning, and transfer learning.

It provides a methodical study and comparison of the many deep and transfer learning approaches that have been applied to building occupancy detection. The value of occupancy detection in a building's energy efficiency and occupant comfort is first discussed by the authors. They then give a quick summary of the deep and transfer learning approaches that have been used in this area.

The performance of these strategies is then reviewed and compared on a variety of datasets, with each approach's advantages and disadvantages being highlighted. They talk about the several difficulties with occupancy detection and potential future applications.

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https://doi.org/10.1016/j.engappai.2022.105254.

Result:

Although occupancy detection approaches significantly benefit from DL, the authors believes that there are certain inherent drawbacks.

Even though the CNN method is frequently used for image processing, time-series data may not lend itself to its use. Instead, time-series data needs to be transformed into images in order to utilize the CNN networks' unique design.

The LSTM structure, on the other hand, is more likely to be applied when there is time-series data related to occupancy (such as environmental, mobility, and smart meter data).

The AE approach would be beneficial if data annotation were not provided.

Models like as GAN, RBFN, SOM, DBN, and RBM are rarely researched or used for occupancy detection applications.

I. Yilmaz and A. Siraj, "Avoiding Occupancy Detection From Smart Meter Using Adversarial Machine Learning," in IEEE Access, vol. 9, pp. 35411-35430, 2021, doi: 10.1109/ACCESS.2021.3057525.

Goal:

Present a technique to shield people's privacy from smart meter data, which may be used to deduce occupancy patterns and potentially expose private information about a home.

Dataset:

REDD dataset

Methodology:

The authors gathered over time energy consumption data from smart meters for a household.Preprocessing of the obtained data allowed for the extraction of elements including hourly usage trends, average usage rates, and daily usage patterns.

The preprocessed smart meter data was then used to train a Generative Adversarial Network (GAN), which was used to create synthetic data that was comparable to the original data but had more noise. A generator network and a discriminator network made up the GAN. The discriminator network attempted to differentiate between the fake data and the real data after receiving synthetic data from the generator network.

This model was then assessed for the viability of their methodology by comparing the accuracy of machine learning models, a decision tree and a random forest, trained on the genuine data from smart meters to the accuracy of the same models trained on the fictitious data produced by the GAN.

I. Yilmaz and A. Siraj, "Avoiding Occupancy Detection From Smart Meter Using Adversarial Machine Learning," in IEEE Access, vol. 9, pp. 35411-35430, 2021, doi: 10.1109/ACCESS.2021.3057525.

Result:

The decision tree model obtains an accuracy of 96.6% when trained on the original smart meter data, but only 73.1% when trained on the GAN-generated synthetic data.

In a similar vein, the accuracy of the random forest model trained on the real data is 98.8%, whereas the accuracy of the same model trained on synthetic data is only 80.1%.

These findings show that the adversarial machine learning approach utilizing GANs may successfully safeguard people's privacy from smart meter data, which is crucial for guaranteeing data security and privacy in the context of smart grids and energy management systems.