**Dissertation**

**Abstract:**

The worldwide widespread of smart meters means more understandable & workable data will be produced for every specific household. In the UK the smart meter bill was passed on the 28th of November 2017 and the implementation of which will lead to raw electricity consumption data being produced and hence used to measure usage more efficiently (Gov.uk, 2013). This data can be mined and analysed for more than just producing efficient bills and smarter readings. This project intends to provide an achievable, affordable and a minimal change or resource implementation required solution for people by analysing their electricity data and extracting specific trends and electricity consumption footprints. Every person has different routine and lifestyles which impact and reflect a different electricity usage trend. Learning those trends can be useful to make a judgement or sense if something is unusual. This will be done by using various data mining techniques both supervised and unsupervised. Namely, Clustering, Linear Regression, Neural Networks and Feature extraction. These techniques will be applied to an electricity consumption and usage data set with additional labelled data to predict the occupancy of the household. Towards the end this research will present a deduction of the data mining algorithm best suited to the given data set and performing data analysis that closely resemble the proposed situation. All the data mining techniques, listed above, will aim to identify the presence of people at home by processing the electricity consumption data. The results from which can also be used to investigate if a deviation from norm has been experienced. Where norm can be defined as a customized trend for every household. As an extension to that, the program will choose to notify someone if any unusual electricity consumption behaviour occurs that is a deviation enough from norm to be considered suspicious and anomalous.

Using as inputs electricity consumption data and active occupancy, to data analysis algorithms such as KNN regression, Linear Regression, Kmeans clustering and Neural Network models in splits of training and testing data to predict the occupancy of the house based on just the power consumption. The dataset used for this model was short term, recorded over a period of 2 months in “David’s household area name”. To push limits and stress on the validity of the system, assets like electricity recording time and dataset variables were kept to a minimum. The application of such a model and a furtherment of this research which be the independent living amongst the elderly and disabled.

<http://casas.wsu.edu/news/aging-at-home>

cost of assisted living averaging to about 70,000 dollars a year

**Introduction (1000 words):**

There is a problem. – The first step towards any solution is to first recognise there’s a problem.

People living on their own – old – can’t afford nurses and luxuries – can’t afford care homes – don’t want care homes – percentage of people living on their own – their average income – disabilities with people – stats of unfortunate events – no one notified until days later –

This dissertation talks about and compares different data mining algorithms and their implementation to predict the presence of people in the household using its electricity usage data. It comments on their accuracy and precision and concludes what specific algorithm best translates itself with the give dataset. These findings are furthered by providing an application area where seniors or disabled residents can benefit by the implementation of such a system and continue living independently.

In a research survey carried out by the NHS it was revealed that around one in three adults over the age of 65 are susceptible to fall over at least once a year (NHS, 2015). Around half of whom are likely to fall more frequently. Another similar extended research concluded that two thirds of those, fall again in the next 6 months (Senior Health & Wellness Blog, 2018). In the UK alone, the cause of death amongst seniors aged 75 and over is the most common and unfortunate occurrence (Age UK, 2017). The government and private institutions are trying their best to get a hold on the situation and minimise these forlorn happenings. (1) Care homes, government allotted nurses, private carers and volunteer organisations are all viable solutions, but extortionate and according to a survey, unfavourable to the elderly as they fear losing their independence more than they fear illness and death.

There needs to be an affordable solution for seniors and citizens who, not only, want to keep their independence, but also afford it, on their subordinate pension and income.

The application of this research project is aimed at the elderly and disabled people who reside on their own. As mentioned above, problems like getting around the house and doing daily chores etc can become a struggle at their fragile age and accidents often happen.

Many propositions and steps have already been taken to prevent such events from happening but most of the times they require additional equipment like infrared or heat sensors in homes to monitor movement of the residents which, yet again by being expensive, violates the conditions of a well-suited solution for people who want to be able to afford independence.

Electricity usage data is readily available for, if not all then, most households and the required data is being recorded but going to waste. The imminent implementation of smart meters will, more sooner than later, ensure the recording and storage of the consumption data for every household in the United Kingdom. Leaving us with workable and copious amounts of data that can mined for trends and patterns which in turn can be a less expensive, reasonable and economical alternative solution to the stated problem.

Every human being on the planet has a contribution, a footprint. By footprint I do not mean the physical impression left on the sand by a foot or shoe on the earth. I mean the ecological footprint.

Elementally defined as the demand of humans on nature. This specific footprint, much like fingerprints, varies from human to human. Every one of us leads a different lifestyle, we work different jobs, have different hobbies and use our electricity differently. It’s only fair to have just and customised judgement for a varying variable.

The Electricity consumption data of a household collected over a specific period can be analysed to derive trends. These trends, or “electricity footprint” if you may, can be learned and analysed using data science and data mining methodologies. This electricity footprint and trends in the data can then be compared with everyday usage to categorise the data as either normal or abnormal. Where abnormalities being anything like an electricity spike not being shown roughly at around 7pm when the inhabitant uses the kettle for their evening tea. Or the system predicting the person not being home when the resident is.

When abnormalities as such are visible, the system can choose to notify a user of the unusual occurrence in the data pattern.

This is where the application of this research comes in. An affordable solution to independent living amongst the elderly and disabled.

In simple terms, this project aspires to implement different data mining algorithms that are capable of noticing abnormalities and deviations from normal trends in electricity consumption entries through the rigorous prospecting of data and conclude which algorithm comparatively does the job with admirable accuracy.

try and overcome issues such as mobility and getting around the house that come with old age and disabilities and provide a secondary method of alerting emergency services if a problem arises. The only access to the problem being the persons electricity usage data.

HOW?

There is a reasonable understanding of the problem, as mentioned above, and the motivation, drive and want for such a system. The findings of this research not only partially implement a system that can be furthered to help in a real-world scenario by making use of real-time power readings, but also counsels which machine learning algorithm works best from a handful of chosen and implemented ones.

Data science – Data mining – Data analysis methodologies –

Methods - Summary of methods

Unsupervised learning – Supervised learning

Clustering - KMeans

Neural Networks - Backpropagation - gradient descent

Linear Regression

**Literature Review (2500 words):**

What others are doing about this apparent problem?

SUMMARY OF THE LIT YOU FOUND:

There is plethora of research work that contributes to the area of computer science that deals with data mining and analysis, but only a handful of work that directly associates with my research could be found. The literature’s that I chose, much like my own research work, adapt different methods of data analysis to interpret and analyse the fitting of their work in a specific application.

One research extract from a book, that consisted of 29 contributions from researches all thoroughly reviewed and validated, analysed electricity data of a household to extract its specific trends which were then, along with the number of inhabitants of the household, used as input variables to a fuzzy model, to forecast how probable it was for a house apparatus to be used or started within the next 60 seconds (Zhu, 2016). The electricity data set collection for this research was long term and collected over a period of 12 months. A case-study on fuzzy tools along with neural network based algorithm for efficient energy management was presented. That was written to predict the electricity usage 24 hours ahead of its time. Lastly, a cost analysis was presented to signify the importance of energy management and its implications. The findings of this specific research in this book, heavily relates to the “Electricity data analysis” area of this dissertation.

<https://pdfs.semanticscholar.org/b9ba/4b0cfa5cf78d8d4f68da1882f2bb12489c7f.pdf>

Coming towards other algorithms for data mining in power data sets, A research specifically relating to electricity and anomaly detection with extensive results in the form of figures, diagrams and tables carried out data analysis on electricity consumption data using 2 different approaches namely statistical approach and clustering (Jakkula and Cook, 2010). The two methods were used with the aim of mining the electricity data and count the outliers using both techniques and compare them against the known outliers to see the efficiency of either methodologies. The dataset for this research was power consumption collected using a smart CASAS (Centre for Advanced Studies in Adaptive Systems) environment. It concluded that the 2 outlier detection mechanisms presented wrongly identified an outlier with a ratio of 1:43 in Clustering to Statistical approach. In layman terms, this means the possibility of wrongly identifying an outlier in clustering as opposed to statistical analysis was 1 in 43. The results and finding of this research paper showed that clustering would be inaccurate in its given task 2.3% of the times whereas Statistical approach would wrongly identify an outlier 97% of the time. The application of this research was, like in the previous related work researches, to ultimately conserve energy by identifying abnormal power consumption and hence taking a step towards energy efficiency and conservation, predict abnormalities earlier on, like in the case of too much power being consumed in a smart home the possibility to warn residents on the failure of appliances due etc.

Another similar research worked towards forecasting electricity demand in the UK. This research made use of existing deterministic calendar information of weekdays, weekends, bank and national holidays to create a data set of binary data, to distinguish between weekdays and weekends, In collaboration with a KNN- regression model for load forecast and prediction for the upcoming 24 hours. The existing calendar data was used as a base to compare input data against to sort what kind of day the load was being forecasted for (weekday, bank holiday, or weekends). The dataset used for this research dated from November 2001 to November 2008. Almost 8 years with values of power on an hourly basis making that up to be more than 66,500 instances. The results of this research were compared to existing benchmark models (Not created in the research) to the written Multivariate k-Nearest Neighbour Regression model. It concluded that amongst other benchmarks models. The method of choosing best algorithm being mean absolute percentage deviation value. The multivariate system, created within the research took the crown amongst other contenders including univariate k-NN regression model and other statistical benchmark models such as MOVAV (7)24, MOVAV (7)168, RW24 and RW168. This research coupled with the Clustering and statistical approach comparison research paper have made it credible that a benchmark methodology or linear statistical approach is not a strong method to go by when it comes to electricity data. The extensive and exhaustive and variating nature of the electricity data makes it rather impossible to fuse well and it takes complex much intelligent algorithms to learn the ways and motifs.

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.727.486&rep=rep1&type=pdf>

Neural networks are immensely popular with electricity data in seemingly one application. Electricity price predictions. The complex multiple layer model and nature of the artificial neural networks makes it possible to work with much convoluted scenarios with more than one variable and attributes. A comparable research that made use of a 3 layered ANN model forecasting price, based on the electricity usage data, for the next 168 hours. This research, however, used the Levenberg-Marquardt algorithm for training purposes. The accuracy and efficiency of the systems predictions were computed using a real-world case study established on the electricity market.

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.193.1235&rep=rep1&type=pdf>

A comprehensive research, in the field of Neural Networks, read and compared published papers dating from years 1990-1996 and 2000-2005 listing 5 areas having attracted most attention amidst which was Load forecasting. A reasonable and in-demand application of electricity data seems to be load forecasting and outlier detection in order to battle energy inefficiencies. Even load forecasting can further be broken down into three sub categories of prediction areas based on periods of forecasts: Long Term (LTLF), Mid Term, and Short-Term Load forecasting. The forecasts lasting anywhere 5 – 20 years for long term, a month to 5 years and short term being defined as anywhere between an hourly to weekly forecasting system. All three of which have different applications and scenarios that call for different forecasting periods.

The conclusion of this research is conflicting yet informative. Despite the many benefits of using Neural networks for power based training and predictions like its ability to deal with stochastic pattern of variating increasing data and fast classification and implied filtering of results, it also stated how and when it would be discouraged to use ANN model. Problems such as training time, training vector and “noisy” data (data containing errors such as missing elements due to faults in recording etc) can cause complications in the algorithm. It also stated that such an algorithm should be used as an “additional tool” not as a “replacement” to other AI techniques.

Anomaly detection is another area that hugely relates to this project. The application of this dissertation is to detect, effectively, occurrences and instances of data that can be considered as anomalous and swiftly acting upon those said occurrences. A survey-based journal article spoke in depth about the different kinds of outliers in data analysis and the challenges faced in isolating a given anomaly from normal regions in a traditional 2-dimensional dataset (Chandola, Banerjee and Kumar, 2009). This survey particularly proved helpful in narrowing down concepts and techniques most effective in successful outlier isolation and detection. In addition to that, it also spoke about techniques for Anomaly detection such as Neural networks, rule based, Bayesian Network, Support vector, Clustering and Nearest neighbour based techniques etc. Most of the mentioned techniques in this survey have been used for this dissertation for not outlier detection, but prediction based on a training dataset.

Another research relating to anomaly detection proved to be more practical than survey based and aimed to detect abnormalities between an aged and a new transformer in the UK based on data and variables from the transformers such as temperature, vibration, moisture, load current etc in the 2 transformers (Catterson, McArthur and Moss, 2010). The data readings were calculated using sensors. This paper concluded that the Conditional Anomaly Detection (CAD) technique can be used in the online monitoring of the transformers.

Most of the existing work done in relation to this project takes things as far as analysing electricity usage data to extract trends, test different data analytical techniques and anomaly detection. The major application of those finding being the need to make electricity consumption more efficient and conserve energy where possible. The Anomaly Survey research discussed entirely different application areas of anomaly detection but none of them came close to the intended work and application of this project which makes me confident that the deliverable is new and hence will contribute to a novel application of occupancy and outlier detection.

The Multivariant k-NN regression model research showed sweeping results in the success of a nearest neighbour regression model in the forecasting of load data which stands to show that a k-NN regression model might be a viable technique for triumphant results while working with electricity consumption data.

This project intends to take things in a different direction, it aims to predict the occupancy of a household in not just a Boolean value, but number of occupants as well. The intended application of this project is to identify an anomaly in data and alert emergency services to get the independent senior or disabled resident the help they need. The abnormality detection will root as an extension to the proposed occupancy predicative system. If the system produces a false negative, that is, no inhabitant is predicted against the known data telling us that there is in fact someone home, it’s clear that something is wrong. The proposed application of this project successfully stands out and is derived from personal motivation and empathy towards the human race.

Despite there being many such algorithms capable of successful prediction of occupancy based on electricity data, much like load forecasting, not a lot of research is done in this domain of predicting occupancy based on electricity consumption let alone a statistical comparison of such algorithms and the intended application of this project.

Most of the existing work seems to be aimed at crowning technology victor against the existing linear benchmark and statistical methods. It is a given that an expert learnable algorithm will perform well than a system with a linear standard point of reference. Some might even say there is no comparison there. But even amongst the various learnable algorithms there must be one that performs better than the other. In addition to the many ways listed above, this specific reason of a rigorous statistical analysis and comparison between different algorithms is, also, what makes this dissertation project novel and different from its related existing work.

**Methodology (1500 words):**

What exactly you are doing about the problem in question? Why and how is it different and novel in comparison to everything in the literature review above?

This section of the research focuses on the methods applied and implemented to set the objectives into motion. The dataset, algorithms, testing and statistical analysis methodologies implemented.

**Dataset:**

Landing on a dataset for this project was challenging since there are numerous open-source and public data sets available online. It was important to keep in mind that the goal of this project was to provide a solution to the problem that had minimal pre-requisites and requirements for it to be implemented. This helped narrow down the search. Naturally, datasets that had too many additional variables that had to be recorded manually or using sensors, didn’t fit the application of this project. If the resident where to install sensors, it threw the existence of this project into question as the sensors being installed themselves could do the job of recording or picking up any unusual activity.

One such dataset that was taken into consideration was an open-source Electricity consumption dataset of 19 households in London over the course of 2 years. The data set consisted of separate csv files for household information, half-hourly electricity consumption, daily electricity consumption, acorn details, half hourly weather and daily weather. These separate 6 csv files contained information such as tariff, what block the house is in, its acorn group, a smart meter measurement of power on a half hourly and daily basis, power measures, minimum, maximum, mean, median, sum and std. Details of the acorn group, their profile and the people in the group. In addition to that it had 2 other files containing weather readings, again, on a half hourly and a daily basis.

Despite the data being publicly available, clean, workable and with the added benefit of having data from 19 different households and exhaustive readings, I didn’t want to use the data set as the project aimed to display no threat or necessity of peoples personal and sensitive information. Under no circumstance did I want people to believe that minimum requirement for the application and implementation of a system as such requires innumerable readings and a convoluted combination of attributes. I wanted to keep it unambiguous for people yet competent in its goal.

The dataset that was ultimately chosen for the project was not a publicly available one. It was a personal household electricity dataset that was recorded and belonged to my supervisor.

The dataset was a singular csv file containing three attributes, namely, Date and time, Power and “at home”. The power was calculated and recorded for every minute of each over the period of 2 months (January and February 2018) adding up to 37270 instances.

Since there is a reading for every minute of each day, there are roughly 1448 occurrences of the attributes for a single day. This makes the data highly exhaustive and broken down hence very specific and precise.

|  |  |
| --- | --- |
| Attribute | Description |
| datetime | The date and time |
| power | The number of watts consumed in kw/h |
| unit | An additional field added to serialise the datetime variable to represent minutes. |
| athome | A variable denoting the presence and availability of people inside the household with 0, 1 and 2 (indicating number of people) |

The benefits of this data set were the additional variable “athome” which can be used to and linked to patterns and behaviours in the electricity usage and how the power goes up or down based on occupancy, which will make the system more learnable and proficient.

**Algorithms:**

The chosen algorithms that were implemented in this research are listed below:

* k-NN Regression
* Linear Regression
* k-NN Classification
* Artificial Neural Network Classification

There was a large pool of algorithms to choose from whilst deciding for a reasonable approach to the proposed problem but the intended statistical analysis and comparison of the algorithms highly influenced their reduction.

**k-NN Regression and Classifier model:**

Two of the implemented algorithms in this research are two different renditions of k Nearest Neighbour algorithms. Both use the same groundwork when it comes to the analysis and prediction of data. Both algorithms work in such a way that they store all available cases from the given dataset (Training dataset) and predicts a target input dataset (testing dataset) based on a similarity function. The similarity function used in this research was distance. The size of ‘k’ in both the models was assigned the value of 3 and kept constant for both the algorithms to maintain fair execution. There is a controversy when it comes to choosing an optimum value for the number of nearest neighbours. A research carried out by the Mu’tah University – Jordan tried out various values of n ranging from 1 to the square root of the sum of samples in the training dataset and proposed a solution to the selection of the value of ‘k’ depending on ensemble learning (CITE - https://arxiv.org/ftp/arxiv/papers/1409/1409.0919.pdf). An archaic yet substantial research paper proposed that “large values of K smoothen the results of classification” (CITE - <http://cs.du.edu/~mitchell/mario_books/Neural_Networks_for_Pattern_Recognition_-_Christopher_Bishop.pdf>). With insufficient evidence as to why, but for it is also considered that the square root of the sum of samples in the training dataset is an optimal assigned value for ‘k’.

All in all, it makes sense that a small value for ‘k’ might be too influenced by individual cases whereas on the other hand, larger values may include too much of a deviation and complexity in a non-complex situation ultimately producing a prediction that is in either case not the most reliable and accurate as it can be.

Drawing from experience, it was observed that highest accuracy percentage ((Number of correctly predicted instances/Total instances)\*100) was achieved when k was kept to a small odd digit. The accuracy varied for different values of k as follows:

|  |  |
| --- | --- |
| **Values of ‘k’** | **Accuracy in result** |
| 1 |  |
| 3 |  |
| 10 |  |
|  |  |
| Square root of training data set - 156 |  |

Although the highest percentage of accuracy visibly being achieved at K = 1, the realisation that a number so small may and is capable of being influenced by noise and hence predicted incorrectly, it was decided to find middle ground and settle for K = 3. Simply because it was best suited to the given dataset.

The value of ‘k’ is dependent on the type of dataset and shouldn’t be merged with existing notions of it working best when it is equal to the square root of the training dataset. There is obvious sense in the fact that it shouldn’t be too small, but then again there is a pattern that shows that keeping it too large can cause deviations and the majority vote can get influenced given if the data is noisy. Having said that, increasing the value of K also saw a visible constant being reached, although the overall accuracy of the system came down, at a point increasing the value of ‘k’ would produce accuracy very close to that for a closer k value and the difference would not be substantial. This showed that whilst accuracy was being compromised, a large value for the number of nearest neighbours would also make the system less prone to noise and irregular data.

FORMULA HERE

**Difference between the regression and classifier model:**

The basic difference between the said algorithm is that the outputs and behaviour of the algorithms. The regression model finds the similarity of the input testing dataset to predict an attribute. The attribute prediction is “measured” based on the similarity function. For instances.

The classifier model, as the name implies, “classifies” or “categorizes” its predicted output in a defined set of possible outputs based on the similarity function.

For instance, in the case of this research the training and input data set being ‘kwh’ (power) and ‘athome’. The output attribute being the ‘athome’ variable based on the input ‘kwh’ for the prediction based on a similarity distance function.

In the case of the regression algorithm, the output is in form of a float. It outputs the

**Linear Regression model:**

**How it works. How does it determine nearest neighbour? Euclidean distance. Implementation, pseudocode.**

**Neural networks:**

**Classification and regression**

**Refining results a huge part of this**

**Gradient descent back propagation huge part**

**Initial vs final results**

**Pseudocode, implementation problems encountered**

**Statistical Analysis Methodology:**

**Data collection Methodology:**

Given that the use of smart meters is not popular in every household, this specific dataset was collected using manual techniques which won’t be necessary in the future once smart meters are installed, by law. A simple Nodemcu based circuit consisting of a power supply and a light sensor was used to calculate the power consumption. The sensor would register the number of times the light on the electricity meter would blink. It was known that the meter light would blink once 10watts of usage was noted. Hence the number of blink registers were multiplied with 10 to get the power used in every minute.

The “athome” variable was calculated using “pings” which would administer how many specified mobile phones were connected to the internet at a given time. To make this calculation more accurate the use of push notifications was also used.

This dataset was chosen because of its simple precise nature. Limited but necessary variables. Another reason why this dataset was preferred was how recent and contemporary it was. The lifestyles of people today largely differ from the way of living of people as recent as 5-10 years ago. Factors such as weather, routine, job, lifestyle, activity, insulation and occupancy etc are all factors that influence the consumption of electricity. They are also factors that tend to differ which makes older datasets, if not outdated then at least, irrelevant. Leaving recent data being more relatable and accurate in its ability to determine anomalies in the modern-day electricity consumption patterns.

**Testing/Findings/Results (500 words):**

Trying to prove my proposed solution works

**Analysis (3000 words):**

Did it work?

**Conclusion (1000 words):**

Hurray!!, My proposed solution worked. Here’s what I could have done to make it better or ways I could have enhanced the solution or added to it.

• What: restate your principal findings.

• Why: The importance of your findings in the academic field.

• How: Explain how your research question/s have been answered by the methods you employed and the evidence you have found.

**Reflection:**

**Bibliography:**

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2 - <https://www.telegraph.co.uk/news/health/elder/6836648/More-people-fear-losing-independence-in-old-age-than-death-survey-finds.html>

3 - <https://www.telegraph.co.uk/news/2048794/Britains-ageing-population-as-big-a-threat-as-climate-change.html>

**Appendix:**

Evidence/paperwork, that does not fit in elsewhere or in any other sub-section of the dissertation.