Detection of Plug-in Electric Vehicles Charging in the Residential Sector for Smart Metering Applications

UOIT CHALLENGE INNOVATE CONNECT

Student Researcher: Jessica Bauer

Supervisor: Dr. Walid Ibrahim

Introduction

- Natural Resources Canada predicts that by 2018, there will be at least 500,000 plug-in electric vehicles (EVs) on Canadian roads [1]. Studies show that in large numbers, electric vehicles can cause problems for the utility in the power system, such as power outages and interruptions. EV charging can over load utility assets such as transformers, contributing to an overall decreased lifetime.
- Plug-in electric vehicle users tend to plug in their cars during hours of peak electrical demand (in the evenings hours when they arrive home from work) [2]. In order to minimize the load, users would have to be persuaded to charge their vehicles during off peak times such as late at night and very early in the morning.
- In order for utilities to respond to this conflict, they must be able to detect when and where the vehicles are charging. In this work, a classification method was developed to detect the presence of an electric vehicle charging in a home including the level of charging, from hourly generated residential power data.

Methodology

- Simulated residential household power was combined with electric vehicle charging profiles to represent the hourly data transmitted by smart meters to the smart gird. A separate set of data was used to train and test the classification model.
- Attributes common to smart meters including active power, the hour the power was recorded at, the difference in active power between each hour, and the month of the year were used to describe each data object. A feature subset selection analysis was conducted to determine the best subset of attrib-utes to use in classification.
- A decision tree classification model was developed and trained with a distribution of electric vehicle charging profiles that represents the Canadian market penetration of electric vehicles (training data) as seen in Fig. 1. below:

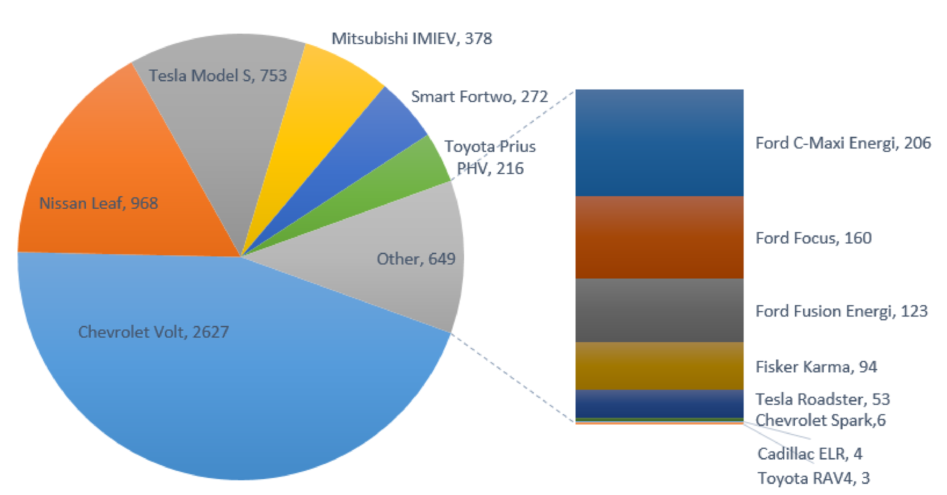

Fig. 1. Canadian Electric Vehicles Sales by Vehicle Model [3]

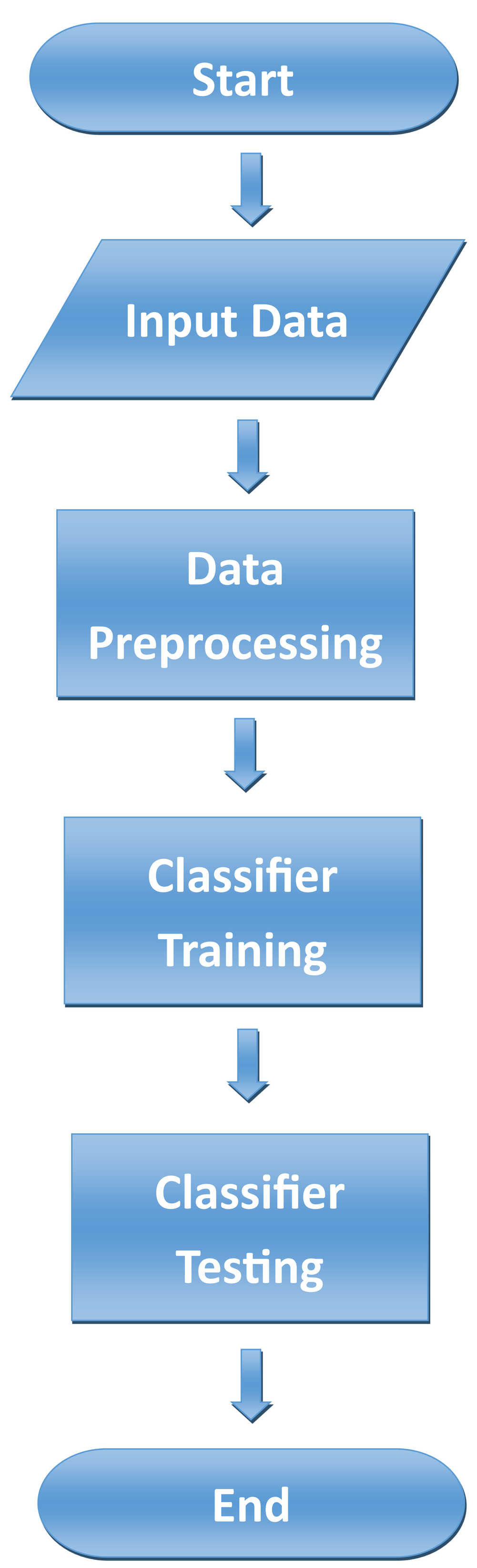

Fig. 2. Methodology Flow Chart

Methodology

- The k-fold cross validation technique was used to establish the decision tree.
- The training accuracy of the classification model was determined by comparing the predicted class of each data object with its known class for training data.
- The model was then used to predict the class labels of data records (testing data) specifically for the Nissan Leaf, that were previously unseen. The predictive accuracy of the classification model was tested by comparing the predicted class of each data object with its known class.
- Testing data consisted of 96,600 records.
- Accuracies were determined using: $Accuracy(\%) = \frac{\text{Correctly Classified Records}}{\text{Total Number of Records}} * 100\%$
- MATLAB was chosen as the primary platform to preprocess and classify the resulting data due to its computational capability regarding large quantities of data.

Results

Table I. Class Legend

Class	# of Vehicles	Vehicle Charging Level	Charging Power (kW)
1	0	0	0
2	1	1	1.4
3	2	1	1.4 (x2)
4	1	2	3.7
5	2	2	3.7 (x2)
6	1	3	6.6
7	2	3	6.6 (x2)

Table II. Decision Tree Confusion Matrix (Training)

		Classifier Prediction						
		Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
True Class	Class 1	90512	1457	372	509	65	0	0
	Class 2	1719	291	24	1	0	0	0
	Class 3	479	48	274	9	0	0	0
	Class 4	669	1	6	31	0	0	0
	Class 5	76	0	0	0	56	0	0
	Class 6	1	0	0	0	0	0	0
	Class 7	0	0	0	0	0	0	0

Table III. Decision Tree Confusion Matrix (Testing)

		Classifier Prediction						
		Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
True Class	Class 1	72374	10300	7728	757	1086	0	0
	Class 2	2023	10	390	106	0	0	0
	Class 3	602	0	1	14	2	0	0
	Class 4	779	0	0	6	61	0	0
	Class 5	25	0	0	0	66	0	0
	Class 6	57	0	0	0	197	0	0
	Class 7	3	0	0	0	13	0	0

- A confusion matrix depicts information about actual and predicted classifications performed by the decision tree classifier.
- For example, as seen in Table II there are 90,512 instances where the classifier correctly predicted the classes of Class 1 records. It also misclassified 1,719 records as Class 1 records, when they are actually Class 2 records.
- The market penetration of EVs does not contain Class 7 charging levels. Results show that the classifier was unable to predict Class 7 due to the lack of training data supporting this outcome.

Results

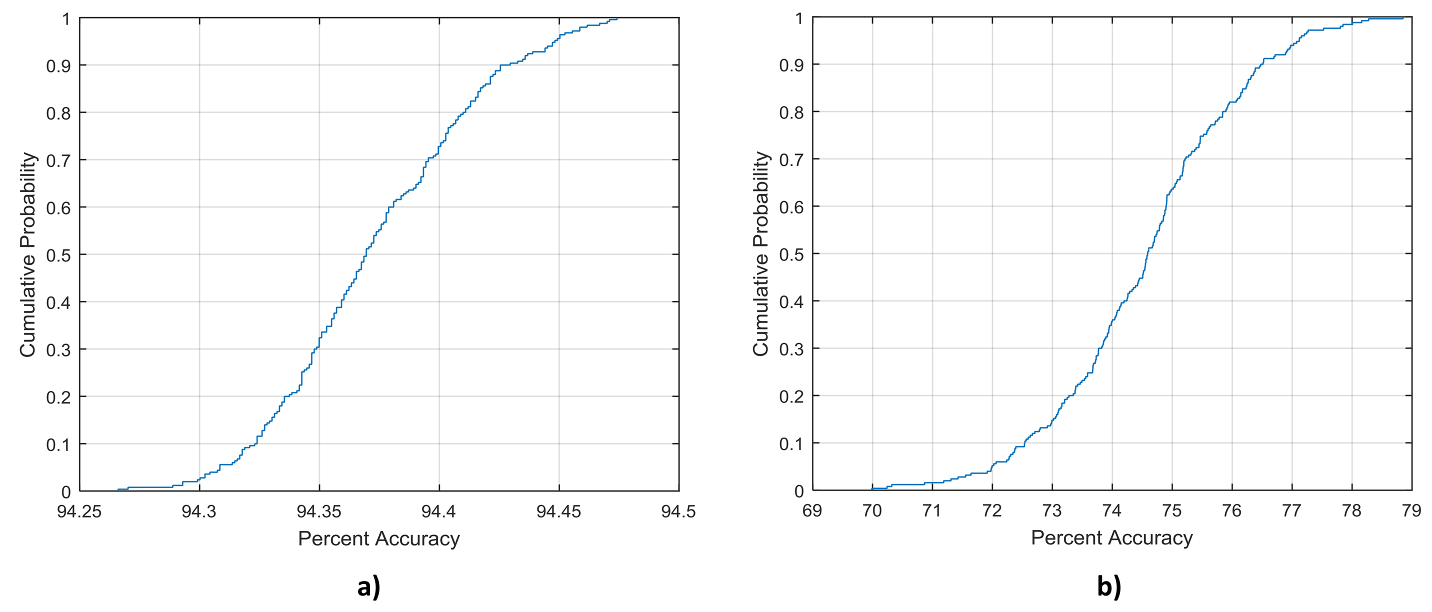

Fig. 3. Empirical Cumulative Density Function of (a) Training and (b) Testing Accuracies

- The cumulative distribution functions derived from a Monte Carlo Simulation were formed for both training and testing accuracy .
- The average accuracy for the training classification analysis was 94.37%
- The average accuracy for the testing classification analysis was 74.56%

- It can be seen from the CDF and statistical measurements that the training data accuracy is higher, while the testing data is notably more variant.
- Training accuracies are higher than testing accuracy due to evaluating the same data that was used to train the classifier.

Table IV. Statistical Measures of Training and Testing Data

Statistical Measure	Training Data	Testing Data
Mean	94.373	74.557
Median	94.370	74.589
Mode	94.266	73.586
Min	94.266	69.988
Max	94.474	78.849
Standard Deviation	0.042	1.548
Variance	0.002	2.397

Future Applications

- Future enhancements of this work include exploring different classification methods to potentially increase the overall accuracy of the model.
- In attempts to further reduce the dimensionality of the data and produce better classification results, a Principle Component Analysis will be incorporated in the data preprocessing stage.
- Testing the classifier with other electric vehicle models to determine the effects on accuracy results.

References

[1] Natural Resources Canada, "Electric Vehicle Technology Roadmap for Canada," 2009. [Online]. Available: http://publications.gc.ca/collections/collection_2010/nrcan/M154-33-2009-eng.pdf. [Accessed 2 July 2015].

[2] M. Gray, "Probabilistic Assessment of the Impact of Plug-in Electric Vehicles on Power Quality in Electric Distribution Systems," MASc. University of Ontario Institute of Technology. Oshawa, 2013.

[3] M. Stevens, "EV Sales in Canada: January 2014 Update & Provincial Summary," 24 March 2014. [Online]. Available: http://www.fleetcarma.com/canadian-electric-vehicle-sales-jan-2014-provincial-summary/. [Accessed 15 July 2015].