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# Comparative Study of Event Detection Methods for Non-intrusive Appliance Load Monitoring

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**Abstract**

Non-intrusive Appliance Load Monitoring (NIALM) is a method to monitor efficient usage of energy by disaggregating the total energy consumption of a building into energy consumption of individual appliances. Event detection is the task of determining the change of electrical consumption in a building from the collected energy data. In this paper, two popular event detection methods are compared. The two methods are the goodness-of-fit (GOF) and the expert heuristic. Publicly available energy consumption data set is used in this study. As a metric of comparison, the total power change of the false positives and false negatives are utilized. The result shows that the GOF method performs better than the expert heuristic method. Variable parameters such as the number of data points can be fine-tuned to obtain an optimized GOF event detector. For the expert heuristic method, the variable parameters used to optimize the detector are the window size and the threshold value. The effect of varying the parameters on the performance of the event detection methods is discussed.


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*non-intrusive load monitoring; event detection; goodness-of-fit; heuristic method*

## 1. Introduction

A Non Intrusive Appliance Load Monitoring enables the determination of the energy usage of individual electrical appliances based on the analysis of the aggregate current and voltage load from the measurement of the power source [1].

**Nomenclature**

| | |
|---|---|
| GOF | Goodness-of-Fit |
| NIALM | Non-Intrusive Appliance Load Monitoring |

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The first step in performing NIALM is Event Detection. Event is the time of which an appliance is switched on/off or changes take place in the state of its energy usage. With the measurement of the aggregate power, the NIALM algorithm is used to disaggregate the power according to their respective electrical appliance. One of the NIALM techniques for disaggregation is the event-based approach. In this paper, the event detection stage is discussed. The data set used in this paper was obtained from "REDD: A public data set for energy disaggregation research" [2].

Based on the work done by Yuanwei Jin et.al. [3], the GOF method appears to be a better event detector and requires less training based on the power consumption data. In the work done by Anderson K. et. al. [4], it was shown that using a modified generalized likelihood ratio detector on the total power change metric, the results had a better performance compared to the other metrics. The authors [4] also suggested incorporating other event detection methodology to validate their results. Therefore, this paper intends to investigate and compare two event-based approaches at the detection step, namely the GOF method and the Expert Heuristic method.

## 2. Methodology

### *2.1 Goodness –of-Fit (GOF) Methodology*

From the work done by Yuanwei Jin et.al. [3], a robust adaptive GOF event detection method was developed for the NIALM. In their work [3], the GOF method aims to establish that for some available probability distribution, a set of data could be derived from it. The GOF test utilizes the chi-square test or $\chi^2$ test. The below equation (i) is implemented using MATLAB.

For our calculation, we equate $l_{GOF} = X^2$. For comparison with our calculated value, $l_{GOF}$, the Chi-square distribution table, $X^2 = X^2{}_{\alpha,\, d_f}$, value for alpha, $\alpha = 0.01$ and 0.05 were used. The degree of freedom ($d_f$) value used is from 1 to 30 and thereafter, an increment of 10 for degree of freedom from 30 to 100. For every calculated chi-square test, if $l_{GOF} > X^2{}_{\alpha,\, d_f}$, the algorithm is able to detect an event. From the event detected, the total sum of false positive is calculated from the equation (ii) below [4].

From the equation (ii), the term $w_1$, $w_2$ and $w_3$ are the window lengths of the signal. $w_1$ and $w_3$ are used to determine the pre- and post- events means and $w_2$ is used to allow a delay for the transient before it reach steady state. The total power for the false positives $\Delta P_{\mathrm{FP}}$, is shown in the equation (iii) below [4].

$$X^2 = \sum_{i=1}^{n} \frac{(y_i - Kp_i)^2}{Kp_i} \quad \text{(i)} \qquad \Delta P_e = \frac{1}{w_3} \sum_{i=e+w_2+1}^{e+w_2+w_3} P(i) - \frac{1}{w_1} \sum_{i=e-w_1}^{e-1} P(i) \quad \text{(ii)} \qquad \Delta P_{\mathrm{FP}} = \sum_{f \in \mathcal{F}} |\Delta P_f| \quad \text{(iii)}$$

In order to determine the total false positive, power less than 50 Watts is considered noise in the signal analysis [5]. The total sum of false positive is the value that the algorithm detected as an event, even though through manual inspection of the signal, that portion of signal is not an event but signal noise.

### *2.2 Expert Heuristics Methodology*

In the Expert Heuristic method, the changes of power consumption signal in steps enable us to detect the electrical appliances corresponding to these changes [1, 4]. In this methodology, the algorithm compares the pre-event window and the post-event window [4]. The variable parameters are the window size and the threshold value. The window size is the number of signal points taken for the pre-event window and post-event window. For our work, the window size is between 2 to 10. The threshold value is the minimum difference in value (in Watts) between the average pre-event and post-event values. This data is to determine the total sum of false positive. The threshold value is set to between 30 to 50 Watts since power less than 50 Watts is considered noise in the signal analysis [5].

The implemented algorithms for the Expert Heuristics Method are as follows. First, the window sizes of pre- and post- event windows and the threshold value, *t* are set. The average value of power consumption samples in the pre-event window is calculated using the formula (iv) below.

Similarly, for the post-event window, the average value of the power consumption sample is calculated using the formula (v) below.

$$\overline{P_{pre}} = \frac{\sum_{i=1}^{n} P_i}{n} \quad \text{(iv)} \qquad \Delta P_{post} = \frac{\sum_{j=1}^{n} P_j}{n} \quad \text{(v)}$$

Next, we calculate the absolute value of the difference between average value of power consumption in pre-event window and post-event window. The difference value is compared to the threshold value, *t*. If the difference is larger than the threshold value, an event is detected. For the next iteration, the pre- & post- event windows are moved one sample forward along the power consumption profile and these steps are repeated until the completion of the power profile.

## 3. Results

### *3.1 Results with Goodness-of Fit-Method*

The graph in Fig. 1, shows the total sum of false positive versus the number of samples observed by utilizing the Goodness-of-Fit method. It can be observed that in comparison with both the alpha values, the minimum total sum of false positive is obtained when the alpha value equals 0.01 and the number of samples is 2. At this condition, the minimum total sum of false positive is 517.16 Watts.

### *3.2 Results with Expert Heuristics Method*

The graph in Fig. 2, shows the total sum of false positive versus the threshold value observed by utilizing the Expert Heuristics method. It is observed that at window size 2, the minimum total sum of false positive is 4047.47 Watts while the threshold value equals 50. In Fig. 3 below, the graph shows the total sum of false positive versus the window size. At threshold value 50, the total sum of false positive is 4047.47 Watts for window size ranging from 2 to 10. Therefore, it can be concluded that for window size ranging from 2 to 10, the total sum of false positive reduces in value due to the change in threshold value. The least total sum of false positive with the expert heuristics method is 4047.47 Watts.

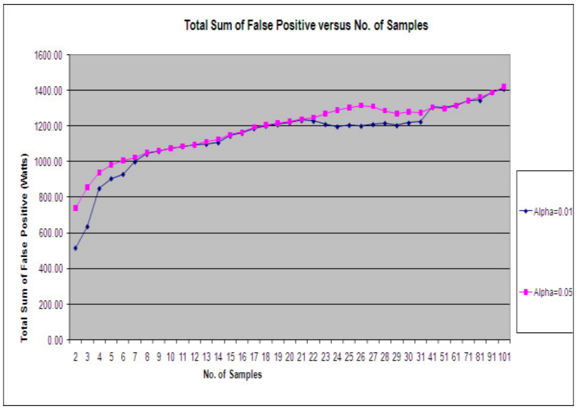


*Fig. 1- Goodness-of-Fit Method – the total sum of false positive versus the number of samples.*

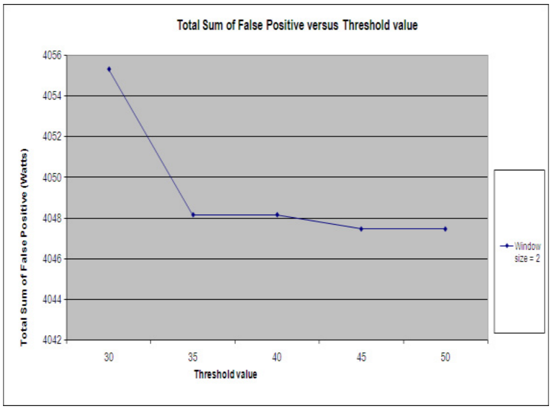


*Fig. 2- Expert Heuristics Method - the total sum of false positive versus the threshold value.*

## 4. Discussion

From Table 1 below, in compassion of both methods, it shows that with the GOF method, the minimum total sum of false positive is obtained. The expert heuristics method gave a very high value of total sum of false positive due to the fact that this method is based on intuition.

For the GOF methodology, the lower value of total sum of false positive is obtained because this method is based on statistical calculation. In addition to the total sum of false positive, a second indicator to evaluate the effectiveness of the two methods is the total sum of false negative (misses). The two methods do not produce any false negatives; hence, the total false negative is zero and hence not reported in Table 1.

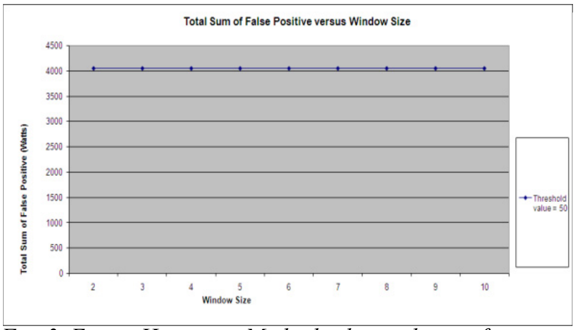


*Fig. 3. Expert Heuristics Method - the total sum of false positive versus the window size.*

| Method | Total Sum of False Positive (Watt) |
|---|---|
| Goodness-of-Fit | 517.16 |
| Expert Heuristics | 4047.47 |

*Table 1 - Method Comparison*

The advantages of Expert Heuristics method are, it is simple and appeal to intuition but the disadvantage of this method is that it is a subjective evaluation because the threshold depends on expert opinion. On the other hand, the advantage of GOF method is that it is based on statistical analysis and therefore it provides a more objective evaluation. However, the disadvantage of the GOF method is that it involves more calculation and the use of statistical table.

## 5. Conclusion & future work

In this paper, a study is performed to compare two popular event detection methods for use in NIALM. Our results indicate that the minimum value of the total sum of false positive is the GOF event detection methodology. In future work, it is proposed to incorporate Genetic Algorithm to optimize the various variable parameters in both the event detection methodology in order to obtain the optimized value of the total sum of false positive.

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