Research on the Application of the Segmentation Based on Key Points in the Power Consumption of Wireless Sensor

Yongzhi Liu1,2*, Xueping Jia3 and Dechang Pi1

1College of Computer Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, P.R. China
2Department of Information Engineering, Xuancheng Vocational & Technical College, Xuancheng 242000, P.R. China
3Department of Architecture and Art, Xuancheng Vocational & Technical College, Xuancheng 242000, P.R. China

Abstract

In order to reduce the power consumption of the sensor, the key points of the algorithm are proposed, which can greatly reduce the transmission data and reduce the power consumption; The Sink receives the key point sequence, and uses the piece-wise linear algorithm to fit the data, for the user to query, statistics and graphics and other operation; The empirical evidence of this algorithm fits the raw data well, Less computation, less transmission of data, is conducive to reduce the power consumption in the wireless sensor.

Key Words: Key Points, Piece-wise Linear Fitting, Wireless Sensor, Power Consumption

1. Introduction

Wireless sensor has been widely used in all walks of life; However, the battery energy of the sensor is limited, and the replacement is also troublesome, how to lengthen and save the energy of the battery becomes the focus problem that more and more researchers pay attention to. How to save the power consumption of the system has been proposed some [1–3], these algorithms are mainly between idle and operation of the state conversion. Such as the exponential average forecasting algorithm proposed by [2], this algorithm needs a lot of data and does not accord with the principle of saving energy. While the literature [3] reduces the sample data, but when the volatility of the data sequence is large, the large prediction error is not conducive to the use of, In view of the above situation, the application of piece-wise linear [4–7] fitting in the power consumption [8,9] of wireless sensor is proposed. Because of the volatility of the time series, it is fitting to the original data directly, and the fitting effect is poor, and the piece-wise fitting can better reflect the volatility of the time series, so it is better to match the original data.

The algorithm first find out key points, with the key point segment, were fitted to a straight line and the key points of the end-to-end, data fitting can be for users to query and statistics etc. The algorithm is simple and effective. It can reduce the transmission quantity of data and reduce the power consumption effectively. It is helpful for the application of wireless sensor. The algorithm has been applied to the monitoring of a water plant.

2. Key Points

The key point is the important point of time series, and it is the basis of segmentation forecast, which embodies the outline of time series. Including turning points and extreme points as Figure 1 (among them, 1 is a stationary time series, while the remaining 8 are non-stationary sequences), using the method of seeking the ex-
treme value, we can find the key points of 5, 8 in Figure 1, with landmark approach also can be calculated, but the Figure 1 of 2, 3, 4, 6, 7, 9 of the turning point using extremum method and landmark method cannot find this point. The following definition of the relationship between three points is presented.

**Definition 1.** At the maximum and minimum values of the sequence, by the simple time series of three points, the smaller the angle, the more likely the corner of the corner is the turning point.

**Theorem 1.** A monotonic time series composed of three points A, O, B, value is $V_A, V_O$ and $V_B$. Whether the O point is a turning point or not is concerns a value of $|V_B - 2V_O + V_A|$, the bigger the value is, the more likely the turning point becomes, and vice versa, which is called the turning point of three points.

Note: Figure 2 the horizontal axis represents time T, the vertical axis represents the range V [Min, Max], beyond the constraints part is not a valid value.

Prove: Figure 2 as an example.

\[ \frac{OD}{AE} = \frac{CD}{CE} = \frac{1}{2} \]  \hspace{1cm} (1)

The value of C and D is known, and it is known by European geometry, The value at C is $2V_O - V_A$.

From the definition of 1, the farther from the distance C point, the more likely the O point is the turning point, That is, The bigger the $|V_B - 2V_O + V_A|$ value, the farther the distance point C, the more likely that O becomes a turning point, the certificate is completed.

3. Time Series Key Point Algorithm

Time series set $S = \{D_1, D_2 \ldots D_i \ldots D_n\}$, $D_1, D_2 \ldots D_n$ are values of time Series, The key point sequence set is $S_{kp}$. The key points of the time series are as follows:

\[
S_{kp} = \begin{cases} 
\text{Max}(D_{i-1}, D_i, D_{i+1}) & \text{when } D_i > D_{i-1} + \varepsilon \\
\text{Min}(D_{i-1}, D_i, D_{i+1}) & \text{when } D_i < D_{i-1} + \varepsilon \\
D_{i+1} - 2D_i + D_{i-1} & > \varepsilon \text{ not above}
\end{cases}
\]  \hspace{1cm} (2)

The key points are composed of extreme points and turning points, and the algorithm of the time series is as follows:

1. $d_1 = D_1$
2. if $(D_{i-1}, D_i, D_{i+1}$ is non monotonic sequence)
3. if $(D_i > D_{i-1} + \varepsilon$ and $D_i > D_{i-1} + \varepsilon$)
4. $S_{kp} = D_i$
5. End if
6. if $(D_i < D_{i+1} + \varepsilon$ and $D_i < D_{i+1} + \varepsilon$)
7. $S_{kp} = D_i$
8. End if
9. Else if $(|D_{i+1} - 2D_i + D_{i-1}| > \varepsilon)$
10. $S_{kp} = D_i$
11. End if
12. $d_m = D_n$

There is a wireless sensor acquisition time series,
containing 60 data points, as shown in Figure 3. The key point sequence is 25 points \((c_1 = 1)\), obtained by the key point algorithm. as shown in Table 1, the compression ratio is 58.33\%. As shown in Figure 4, The contrast Figures 3 and 4, Figure 4 good maintained the original sequence outline shape. If the \(c_1\) value is bigger, the compression ratio is higher, but the sequence of the outline is kept incomplete. Prove the effectiveness of the algorithm, and compresses the data and reduce the dimension, is conducive to the transmission of sensor nodes, sensors only need key point data of transmission, saving the amount of data transmission, reduces the power consumption.

4. Piecewise Linear Fitting Algorithm

Two points \(P_1(x_1, y_1), P_2(x_2, y_2)\) and the linear equations which are determined by this two points are as follows:

\[
\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}, \quad \text{where } x_1 \neq x_2, y_1 \neq y_2.
\]

From this, the algorithm of segmentation is presented as follows.

Input: key point sequence \(S_{kp}\)

Output: fitted value sequence \(S_{np}\)

Step

1. Calculate the linear equation of two key points.
2. The value of the interval points is obtained by the linear equation, joined \(S_{np}\).
3. Jump to the first step until the final key points.
4. Output \(S_{np}\).

Using the segmentation straight line algorithm, the fitting value and the original value are drawn, as shown in Figure 5, the algorithm can be seen to fit the original curve well, the mean square error is \(MSE = 0.57\); Using the least square fitting curve, \(MSE = 3.95\), the comparison results we can see that the fitting line based on the key points of the piecewise straight line fitting is better than the least square method. So, in the case of less stringent requirements, users can provide statistics, query and other operations, saving the amount of data transmission, reducing power consumption.

5. Conclusions

A piecewise linear fitting algorithm based on key points is presented. First, find out the key points of the time series. Then, the key points of the segmented and the value of the corresponding interval, for users to query, statistics etc. operation. The experimental results show that, The algorithm searches the key points from the original time series, and then makes the key point sequence, which reduces the data transmission quantity, and reduces power consumption. The algorithm is clever and practical. It is helpful for the application in wireless sensor. The use of fitting data for user statistics, query and other operations.

### Table 1. Key point sequence

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Value</th>
<th>Serial number</th>
<th>Value</th>
<th>Serial number</th>
<th>Value</th>
<th>Serial number</th>
<th>Value</th>
<th>Serial number</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>14</td>
<td>24</td>
<td>23</td>
<td>34</td>
<td>39</td>
<td>35</td>
<td>53</td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>16</td>
<td>21</td>
<td>31</td>
<td>22</td>
<td>42</td>
<td>38</td>
<td>54</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>17</td>
<td>24</td>
<td>32</td>
<td>19</td>
<td>45</td>
<td>32</td>
<td>56</td>
<td>42</td>
</tr>
<tr>
<td>10</td>
<td>31</td>
<td>20</td>
<td>27</td>
<td>33</td>
<td>23</td>
<td>48</td>
<td>38</td>
<td>57</td>
<td>45</td>
</tr>
<tr>
<td>13</td>
<td>27</td>
<td>21</td>
<td>31</td>
<td>37</td>
<td>29</td>
<td>49</td>
<td>41</td>
<td>58</td>
<td>40</td>
</tr>
</tbody>
</table>
Acknowledgement

This paper was supported by higher school of natural science research project of Anhui province (KJ2014A 285).

References


Manuscript Received: Sep. 7, 2015
Accepted: Dec. 1, 2015