Probabilistically Predicting Location of Human with Psychological Factors

SEUNGYEON KIM
Department of Computer Engineering
Hongik University
72-1, Sangsu, Mapo, Seoul
KOREA
brdosa@naver.com

HA YOON SONG
Department of Computer Engineering
Hongik University
72-1, Sangsu, Mapo, Seoul
KOREA
hayoon@hongik.ac.kr

HOON JUNG KOO
Department of Psychology
Korea University
5 ga, Anam, Seongbook, Seoul
KOREA
hoonjungkoo@gmail.com

Abstract: It is believed that personal mobility patterns of a human are highly related to a person’s personality. The person’s location at a given time can be identified in case the person carries positioning devices, and thus a personal mobility pattern can be identified. One of the personality models, the big five personality models have been regarded as a representative model of a personality identification. Combining a personal mobility pattern and a personality, this research presents a mechanism for finding the person’s location at a given hour of a day. In order to connect personality model and locations, the back propagation network was used as an underlying technology. As a result, this paper finds a possibility to predict a person’s location at a given time in combination of personality and personal mobility pattern. Preliminary experiment and practical experiment were conducted and the results of experiments were also presented and interpreted.

Key–Words: Human Mobility, Probabilistic Location Prediction, Back Propagation Network, Psychological Factor, Big Five Inventory, Human Mobility Modeling, Big Five Personality Trail

1 Introduction

The recent advances of mobile devices enable various location based services over human mobility, especially the introduction of smart phone with GPS or other positioning equipment. From the positioning data set, we can figure out human mobility trails and thus derive human mobility patterns. In our past research [10], we constructed human mobility model of a person and represented the model in a form of continuous time Markov chain (CTMC). The model was somewhat useful but ignores human personality parameters. From the psychological aspect, there have been researches on human personality traits called big five factors (BFF) [1, 2]. Maybe we can find proper method to apply human personalities for human mobility model. Among the feasible techniques, one of the feasible model is back propagation network (BPN) [3]. And the very fundamental base theory of this research is from [4, 5] which identifies the latent patterns in human mobility and opens the predictability of human mobility trail. The term next imposes the concept of time, i.e. we must consider time as a major parameter for human mobility.

Combining our past knowledge and methods, we will provide a probabilistic prediction of possible hourly location in human mobility based on BFF of human personality trail. In section 2 we will see our two bases: BFF and BPN. In section 3, a set-up of hourly location prediction will be discussed. Section 4 will show two sort of experiment. The first one is a basic experiment without BFF factors, and the second one is more sophisticated model with BFF parameters. We will conclude this paper in section 5.

2 Backgrounds

2.1 Big Five Personality Trails

In a domain of psychology, the Big Five factors of personality are five broad domains of human personality and they are used to describe human personality. At the early stage of personality research, 16 factors theory was firstly announced. Afterwards, Fiske [6] suggests that five factor model is more appropriate according to factor analysis. Tupes and Christal [7] re-asserts the five factor model. Nowadays, the Big Five framework of personality traits emerged as a robust model for understanding the relationship between personality and various academic behaviors [8].

The Big Five factors are:
Openness to experience (inventive/curious vs. consistent/cautious): Appreciation for art, emotion, adventure, unusual ideas, curiosity, and variety of experience. Openness reflects the degree of intellectual curiosity, creativity and a preference for novelty and variety. It is sometimes called “ intellect” rather than openness to experience.

Conscientiousness (efficient/organized vs. easy-going/careless): A tendency to show self-discipline, act dutifully, and aim for achievement, planned rather than spontaneous behavior, organized, and dependable.

Extraversion (outgoing/energetic vs. solitary/reserved): Energy, positive emotions, surgency, assertiveness, sociability and the tendency to seek stimulation in the company of others, and talkativeness.

Agreeableness (friendly/compassionate vs. cold/unkind): A tendency to be compassionate and cooperative rather than suspicious and antagonistic towards others.

Neuroticism (sensitive/nervous vs. secure/confident): The tendency to experience unpleasant emotions easily, such as anger, anxiety, depression, or vulnerability. Neuroticism also refers to the degree of emotional stability and impulse control, and is sometimes referred as emotional stability.

In order to identify a person’s trail, the Big Five Inventory was developed by John et. al [9] which divides five factors into 44 questions. Each questions has 1 to 5 points of weight for each factor. In this paper we also used the BF for identifying a person’s trail and the result is considered as a major input for our research.

2.2 Back Propagation Network

Back Propagation Network (BPN) is one kind of neural network developed by Parker in 1982. It has output layer, hidden layer, and input layer. Each layer is composed of arbitrary number of nodes. The nodes between each layer are connected and each connection edge has its own weight, so called connection strength. The overall topology of a typical BPN is shown in figure 1. The error of output layer used to calibrate the connection strength between hidden layer and output layer, and the error of output layer is back propagated to hidden layer, then the connection weight between input layer and hidden layer will be calibrated. In sum, repetitions of three steps required: input a leaning pattern and earning output, earning error between output and desired values, back propagate error to calibrate connection strength.

The detailed process requires several parameters. First, we must have \( V \) and \( W \) as connection strength, and initialize them. Second, we must have \( p \) patterns. Third, limitation of error, \( E_{max} \) must be determined. Then the output of hidden layer, \( Z \) can be derived as follows:

\[
NET_z = XV^T
\]  
\[
Z = f(NET_z) = \frac{1}{1 + e^{-NET_z}}
\]

Also, output \( y \) can be derived as:

\[
NET_y = ZW^T
\]
\[
y = f(NET_y) = \frac{1}{1 + e^{-NET_y}}
\]

With the desired output \( d \), we can calculate error \( E \):

\[
E = \frac{1}{2}(d - y)^2
\]

The error signal for hidden layer \( \delta_z \) and output layer \( \delta_y \) can be calculated:

\[
\delta_y = (d - y)y(1 - y)
\]
$\delta_z = z(1-z) \sum_{i=1}^{m} \delta_y w \quad (7)$

Then $\Delta W$ which stands for difference of connection strength between hidden layer and output layer can be applied to connection strength for next step, $W_{k+1}$.

$$\Delta W = \alpha \delta_y Z \quad (8)$$

$$W_{k+1} = W_k + \Delta W \quad (9)$$

Also $\Delta V$ and $V_{k+1}$ can be derived.

$$\Delta V = \alpha \delta_z X \quad (10)$$

$$V_{k+1} = V_k + \Delta V \quad (11)$$

Finally, $E$ and $E_{max}$ compared in order to determine more repetitions or finish of the learning.

### Table 1: Input Node and Output Node Value

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Table 2: Big Five Factor Results of the first author

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Table 4: Weight from Hidden layer to Output layer

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Table 5: Result of BPN without Personality Trail

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4 Experimental Results

4.1 Preliminary Experiment

The preliminary experiment shows the effectiveness of BPN application for human location prediction. Eight input nodes, four output nodes and ten input nodes were defined. Connection strength values for each edges were randomly initialized with values in $[-1, 1]$. Instead of using $E_{\text{max}}$ as a closing condition of BPN repetition, just 10,000 iterations were done for the preliminary experiments.

After the learning process, the resulting weights were found. Table 3 shows the connection weight from input layer to hidden layer. Table 4 shows the connection weight from hidden layer to output layer. We present the weight values for sure.

After the learning process, the resulting output values are presented in table 5.

4.2 Experiments with BFF parameters

After verifying our method with preliminary experiments, we conducted personality trail based experiment. The 24 hours of day encoded to seven input nodes and five nodes were added for personality parameters. Total 10 bits used for input nodes with the same configuration for other BPN parameters. In this experiment, we set the number of hidden nodes to 14 which is sum of the number of nodes both in input layer and output layer.

Table 6 shows the final result of our experiment. Since the resulting values in table 6 is all in probability values, we need interpretation of values. Table 7 shows the interpretation of final results. For example, at 09:00PM, the first author is highly probably in the mountain however probability has gone home. Note that each numbers denote the output results of BPN, which is not probability but rate, i.e. they need to be normalized in order to be probability values.
Table 3: Connection Weight from Input Layer to Hidden Layer

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<td>-0.48</td>
<td>-0.24</td>
<td>-0.19</td>
<td>-0.85</td>
<td>0.13</td>
<td>-0.17</td>
<td>0.23</td>
<td>-0.15</td>
</tr>
<tr>
<td>10</td>
<td>-0.16</td>
<td>1.15</td>
<td>1.98</td>
<td>-0.36</td>
<td>-0.34</td>
<td>-0.36</td>
<td>-0.32</td>
<td>0.38</td>
<td>-0.38</td>
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<td>-0.07</td>
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<td>0.42</td>
<td>-0.64</td>
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</table>

Table 6: Result of BPN with BFF inputs

<table>
<thead>
<tr>
<th>Time</th>
<th>Mountain</th>
<th>Etc.</th>
<th>House</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.74e-11</td>
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<td>9.48e-04</td>
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<td>1</td>
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<tr>
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<td>3.92e-13</td>
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<td>8.76e-04</td>
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<tr>
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<td>1.27e-04</td>
</tr>
<tr>
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<td>0.99</td>
<td>6.13e-03</td>
</tr>
<tr>
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<td>2.31e-13</td>
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<td>3.58e-04</td>
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<tr>
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<td>6.33e-09</td>
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<td>0.52</td>
</tr>
<tr>
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<td>2.18e-08</td>
<td>3.28e-11</td>
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<td>0.99</td>
</tr>
<tr>
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<td>7.49e-09</td>
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<td>0.99</td>
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<tr>
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<td>2.77e-11</td>
<td>0.01</td>
<td>0.99</td>
</tr>
<tr>
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</tr>
<tr>
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<td>1.05e-03</td>
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</tr>
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<td>2.76e-08</td>
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<td>5.70e-03</td>
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</tr>
<tr>
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<td>5.35e-03</td>
<td>0.99</td>
</tr>
<tr>
<td>16</td>
<td>7.09e-10</td>
<td>1.08e-10</td>
<td>0.28</td>
<td>0.99</td>
</tr>
<tr>
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<td>7.14e-12</td>
<td>3.32e-10</td>
<td>0.48</td>
<td>0.99</td>
</tr>
<tr>
<td>18</td>
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<td>0.48</td>
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<tr>
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<td>2.90e-05</td>
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<tr>
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<td>0.09</td>
<td>2.13e-03</td>
</tr>
<tr>
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<td>0.50</td>
<td>1.82e-04</td>
</tr>
<tr>
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<td>4.36e-08</td>
<td>0.79</td>
<td>1.22e-03</td>
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<tr>
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<td>0.05</td>
<td>2.08e-04</td>
<td>0.98</td>
<td>5.75e-03</td>
</tr>
</tbody>
</table>

Table 7: Analysis of BPN Results

<table>
<thead>
<tr>
<th>Hour</th>
<th>Interpretation</th>
<th>Extra Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>1:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>2:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>3:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>4:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>5:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>6:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>7:00</td>
<td>Almost at home</td>
<td>Probably has moved to school</td>
</tr>
<tr>
<td>8:00</td>
<td>Almost at school</td>
<td>Probably has moved to school</td>
</tr>
<tr>
<td>9:00</td>
<td>Almost at school</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>Almost at school</td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>Almost at school</td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td>Almost at school</td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td>Almost at school</td>
<td></td>
</tr>
<tr>
<td>14:00</td>
<td>Almost at school</td>
<td></td>
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<tr>
<td>15:00</td>
<td>Almost at school</td>
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<tr>
<td>16:00</td>
<td>Almost at school</td>
<td></td>
</tr>
<tr>
<td>17:00</td>
<td>Almost at school</td>
<td></td>
</tr>
<tr>
<td>18:00</td>
<td>Probably at home</td>
<td></td>
</tr>
<tr>
<td>19:00</td>
<td>Almost at home</td>
<td></td>
</tr>
<tr>
<td>20:00</td>
<td>Almost in the mountain</td>
<td></td>
</tr>
<tr>
<td>21:00</td>
<td>Almost in the mountain</td>
<td></td>
</tr>
<tr>
<td>22:00</td>
<td>Probably at home</td>
<td></td>
</tr>
<tr>
<td>23:00</td>
<td>Almost at home</td>
<td></td>
</tr>
</tbody>
</table>
5 Conclusion

We conducted a research in order to predict the hourly location of a person based on three prerequisite knowledge. The first one was an assumption of routinely pattern of human locations. The second one is human personality traits so called Big Five factors. The third one is a methodology of probabilistic machine learning as BPN.

The combination of different knowledge successfully leads to a prediction method of human location. In order to improve our research, several extra consideration could be made. There are so many other parameters of human location including exceptional behavior of human. Therefore, the extra location could be defined as a parameter of BPN, and we can suppose that a parameter of high extraversion could cause a high probability of extra location as a hourly location of a human.

Maybe a prepared human mobility model as shown in [10] could be used as more detailed parameters of BPN inputs. In case the combination works, more precise prediction of hourly location could be made. Third, BFF is not a unique one of human personality trail. There could be many other application of human personality models like [11, 12] and if applied, we can improve our method of location prediction and we can verify the personality models as well. Of course, the results look like trivial since our experiment shows only one person’s result. From this starting point, we will expand subjects of BFF experiments in order to have more verification of our method.

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References:


