Exploring Potentials of Personality Matching between Users and Target Systems by using Fuzzy Cognitive Map

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Abstract

Personality is always important in determining the users’ behavior. A wide variety of systems and devices are also known to possess various kinds of personalities which can be described as a set of features. When users’ personality and target systems’ personality are matched, it can be said that the degree of personality matching is good. This paper deals with the issue of the importance of personality matching in analyzing users’ behavior. The fuzzy cognitive map (FCM) was adopted to represent causal relationships between the personalities of users and target systems. Then, several scenarios were simulated with the constructed FCM. The results show that the personalities of the user and target systems significantly affect the quality of social interactions between them. In addition, we confirmed that this paper’s approach reveals the possibility of using FCM to predict a user’s personality traits from the FCM experiment results. Implications of the study and future directions are also discussed.

1. Introduction

Personality is important not only in people, but in many devices which people are using. When the personality is successfully matched between people and devices, we would say that the personality matching is obtained, and users’ satisfaction level remains high during the period users are with those devices. Personality matching can also be described from the perspective of personalization. However, personalization is rather a sub-concept compared with personality matching. Personalization is only focused on how users’ preferences are incorporated into target devices (or systems). In contrast, personality matching covers a whole spectrum ranging from a possible match between users’ personality and specific features of devices to the match between users’ preferences and devices. Besides, personality matching is aimed at analyzing how social interactions between users and their target devices (or systems) can be improved. However, the main focus of personalization is placed on the process of fitting the target systems to users’ preferences.

The main theme of this paper is concerned with resolving the issue of personality matching between users and a highly intelligent autonomous system. A robot is a typical system which is highly intelligent and autonomous in responding to stimuli from its environment. However, it is difficult to investigate the degree of match between users’ personality and the main features of target devices. To resolve this issue, a FCM (Fuzzy Cognitive Map) is introduced and applied to solving the personality matching issue.

The definition of personality has not yet been firmly established. In [13], personality was described as “…those characteristics of the person that account for consistent patterns of feeling, thinking, and behaving.” Although there is no universally accepted definition of personality, there have been some studies on the quantification of personality. In the Big Five taxonomy [6], personality consists of the five big dimensions: extroversion, neuroticism, agreeableness, conscientiousness, and openness. The Myers-Briggs Type Indicator (MBTI) [11] divides personality into four dimensions: extroversion–introversion, sensation–intuition, thinking–feeling, and judging–perceiving. The present paper employed the extroversion dimension among the five dimensions in the Big Five taxonomy [6]. The personalities of both the user and the target systems are obviously important and have a significant impact on the quality of interactions between users and target systems.

The present paper investigates the impact of personality matching between users and target systems on the users’ behavior. We first investigated the role of user-device personality matching on human behavior.
using FCM, which have been widely used to represent and study the behavior of people and systems [7]. A what-if analysis can also be used to simulate scenarios within FCM [16]. The paper also addresses the problem of automatically predicting users’ personality traits based on their behavior using FCM.

This paper is organized as follows. In Section 2, related previous works on topics such as personality matching and FCM are briefly reviewed. Then, the modeling of FCM is introduced in Section 3. The effect of FCM is evaluated in Section 4 and the results and implications are discussed in Section 5. Finally, we conclude our paper and suggest several future directions in Section 6.

2. Related Works

2.1. Personality matching

Personality is important in human social relationships, and also plays a crucial role in human computer interaction (HCI) and human robot interaction (HRI) [2]. One example of the effects of personality on social interaction is a personality-based social rule which consists of two competing rules: the similarity attraction rule and the complementary attraction rule. The similarity attraction rule assumes that people tend to be attracted to those who are similar to themselves. In contrast, the complementary attraction rule assumes that people prefer to interact with those who are dissimilar to themselves. Several researchers have examined whether these personality-based social attraction rules could be applied in HCI and HRI. Isbister and Nass [5] investigated whether the similarity attraction rule could be established in a social interaction between a user and a computer character. Their results showed that participants were attracted to computer characters with complementary personalities. In [10], support was also found for the complementary attraction rule. In their experiment, participants were asked to play with either an extroverted or introverted AIBO (Artificial Intelligence Robot). They found that AIBO was evaluated as more attractive and intelligent when its personality traits were complementary to a participant’s personality. However, the similarity attraction rule has also been supported in the field of HCI and HRI. Tapus et al. [18] investigated the effects of user-robot personality matching for post-stroke rehabilitation therapy and found that extroverted participants tended to spend more time with an extroverted robot, supporting the similarity attraction rule.

Previous studies have mainly investigated the effect of personality on a user’s perception and emotion. As personality matching could affect the human behavior that occurs during social interaction, the present study focused on the effect of personality matching on a user’s behavior, such as types of touch.

2.2. Fuzzy cognitive maps (FCM)

Originally, fuzzy cognitive maps (FCMs) were used to represent and study the behavior of people and systems in political and social sciences [7, 8]. Within a FCM, a problem is represented as a graph consisting of inter-linked salient factors [12]. The links (or edges) between factors represent the causal relationships assumed to exist in a given environment [9]. Every edge has a causality value that represents the degree of causality between two factors [7]. Figure 1 illustrates an example of a FCM consisting of four factors (X1, X2, X3, and X4). The causal relationships between the factors are represented by edges and the degree of causality is denoted as \( W_{ij} \).

![Figure 1. Example of a fuzzy cognitive map](image)

FCM is an effective and useful method for modeling the problem as a set of factors and their cause-effect relationships with a fuzzified causality [7, 8]. FCMs could also be used to improve the interpretability of data mining results by representing causal relationships in a logical manner [9]. Moreover, FCMs provide outstanding methods to simulate scenarios, especially for a what-if analysis [4, 16]. With these advantages, FCMs have been widely employed to study human behavior and model complex systems.

We employed a FCM to investigate the effect of user-device personality matching on a user’s behavior. The following section describes the process of building the FCM in our study.

3. FCM for Personality Matching

3.1. Design of FCM

Generally, FCMs are built by experts who have a deep understanding of the causal relationships between factors [9]. In order to obtain more reliability and validity, we conducted an experiment and the FCM
was then modeled by experts based on the analysis of the experiment. The following subsection briefly describes our experimental setting.

3.2. Experimental setting

3.2.1. Apparatus. Pleo, a dinosaur-like robot from Innvo labs [15], was used in the present experiment. Pleo contains 14 internal motors that allow it to move its body and walk. In addition, Pleo contains a CCD (Charge-Coupled Device) camera, microphones, and sensors for interacting with a user. However, Pleo’s vision and auditory processing capabilities are limited, so it mainly interacts with users through touch. The touch sensors embedded in Pleo’s body enable it to perceive a human touch. Prior to the experiment, we manipulated Pleo’s personality to manifest two different personalities (extroverted Pleo and introverted Pleo) by showing different behaviors. As demonstrated in [10], we manipulated extroverted Pleo to move fast and widely. The analysis showed that participants were able to distinguish between the two different personalities of Pleo, indicating that our manipulation was successful.

3.2.2. Participants. A total of 31 undergraduate students (11 females and 20 males) from a university community were recruited for the experiment. The average age of the participants was 24.03 years with a standard deviation of 2.18. Almost all of the participants reported that they had had no previous experience with using Pleo or other types of robots. Pleo, a dinosaur-like robot from Innvo labs [15], was used in the present experiment. Pleo contains 14 internal motors that allow it to move its body and walk. In addition, Pleo contains a CCD (Charge-Coupled Device) camera, microphones, and sensors for interacting with a user. However, Pleo’s vision and auditory processing capabilities are limited, so it mainly interacts with users through touch. The touch sensors embedded in Pleo’s body enable it to perceive a human touch. Prior to the experiment, we manipulated Pleo’s personality to manifest two different personalities (extroverted Pleo and introverted Pleo) by showing different behaviors. As demonstrated in [10], we manipulated extroverted Pleo to move fast and widely. The analysis showed that participants were able to distinguish between the two different personalities of Pleo, indicating that our manipulation was successful.

3.2.3. Measurements. In our experiment, we mainly focused on two measurements: participant’s personality (degree of extroversion) and their behavior (touch patterns).

In order to measure the degree of extroversion of participants, eight Wiggins [19] personality adjective items were used. The items (α = 0.87) used in the experiment were cheerful, enthusiastic, extroverted, bold, introverted (reversely coded), inward (reversely coded), shy (reversely coded), and quiet (reversely coded). The items were in Likert scale format from 1 (strongly disagree) to 5 (strongly agree). Later analysis showed that the distribution of participants’ personalities followed a normal distribution.

To capture a participant’s behavior (touch patterns), we installed a camcorder in the experiment room and video-recorded the experiment. During the video-recording, the experimenter left the room to leave a participant alone with Pleo, because the presence of the experimenter in the same room could hinder the natural interaction with Pleo.

3.2.4. Procedure. The participants were given an informed consent upon arrival at the experiment room. They were then asked to complete the questionnaire, which was designed to measure participants’ demographic information and degree of extroversion. After completing the questionnaire, PowerPoint tutorial slides were presented to the participants. The tutorial slides contained a brief introduction about Pleo, such as its sensors and functions. However, detailed information, such as the precise location of the touch sensors, was not introduced because such information could hinder the natural interaction style and limit the patterns of touch. The tutorial slides also contained two short video clips: one with Pleo moving alone and one with Pleo interacting with a person. After participants watched the entire PowerPoint tutorial, Pleo was presented to the participants. Pleo was placed on the table and the participants were asked to play with it for five minutes as freely as they wanted. No specific tasks with Pleo were given to the participants. The experimenter then started the timer and video recording and left the room. After five minutes, the experimenter returned to the experiment room and gave the participant the additional questionnaire for later analysis.

3.3. FCM construction

Based on the statistical analysis and video coding data obtained from the experiment mentioned above, FCM was modeled by two experts. There were 21 factors within the FCM. All factors were carefully selected and manipulated by the experts. Those factors were then classified into three categories: people-related or Pleo-related variables (S1 to S4), types of touch (T1 to T10), and characteristics of touch (C1 to C7). Regarding the characteristics of touch, positive touch (C5) refers to tickling and patting. Negative touch (C6) refers to slapping and shaking and neutral touch (C7) refers to the remaining types of touch. Table 1 summarizes the variables used in this study.

Previous research studies [7, 9] showed that the simple causality values, such as 1 and -1 could represent human cognition successfully. Therefore, the causality value of our FCM was fuzzified into -1 (inhibitory) to 1 (excitatory). Inhibitory relationship means that two nodes are related negatively and excitatory relationship means that two nodes are related positively [1]. The hyperbolic tangent function was selected for an activation function in order to iteratively compute a vector-matrix multiplication. We set the parameter as 5 since previous research [3, 17] showed that setting the parameter (λ) as 5 provided a good degree of fuzzification.
Figure 2 illustrates the constructed FCM. Causal relationships between factors are represented by a path (or edge). The excitatory relationships were depicted as black and the inhibitory relationships were depicted as red. Table 4 shows the adjacency matrix of the FCM with the causality values.

Table 1. Factors in the FCM

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Manipulated Pleo’s personality</td>
</tr>
<tr>
<td>S2</td>
<td>Perceived Pleo’s personality</td>
</tr>
<tr>
<td>S3</td>
<td>Participant’s personality</td>
</tr>
<tr>
<td>S4</td>
<td>Participant’s tendency to form a parasocial relationship</td>
</tr>
<tr>
<td>T1</td>
<td>Frequency of tickling</td>
</tr>
<tr>
<td>T2</td>
<td>Frequency of patting</td>
</tr>
<tr>
<td>T3</td>
<td>Frequency of slapping</td>
</tr>
<tr>
<td>T4</td>
<td>Frequency of picking up</td>
</tr>
<tr>
<td>T5</td>
<td>Frequency of holding</td>
</tr>
<tr>
<td>T6</td>
<td>Frequency of shaking</td>
</tr>
<tr>
<td>T7</td>
<td>Frequency of poking</td>
</tr>
<tr>
<td>T8</td>
<td>Frequency of pushing</td>
</tr>
<tr>
<td>T9</td>
<td>Frequency of pulling</td>
</tr>
<tr>
<td>T10</td>
<td>Frequency of unclassified touching</td>
</tr>
<tr>
<td>C1</td>
<td>Total number of touches</td>
</tr>
<tr>
<td>C2</td>
<td>Number of different kinds of touches</td>
</tr>
<tr>
<td>C3</td>
<td>Standard deviation of frequency of each type of touch</td>
</tr>
<tr>
<td>C4</td>
<td>Discontinuity of touch type</td>
</tr>
<tr>
<td>C5</td>
<td>Frequency of positive touch</td>
</tr>
<tr>
<td>C6</td>
<td>Frequency of negative touch</td>
</tr>
<tr>
<td>C7</td>
<td>Frequency of neutral touch</td>
</tr>
</tbody>
</table>

4. Evaluation of FCM

In order to evaluate the performance of our FCM, we analyzed the model from two different perspectives: 1) the role of personality matching in the user’s behavior, and 2) predicting the user’s personality traits based on types of touch.

4.1. Role of personality matching in behavior

First, we conducted a what-if analysis to investigate the impact of personality matching between the user and the robot on the user’s behavior. We prepared two different scenarios. By means of the what-if analysis, we could forecast the types of behavior that a user would be expected to show. Each scenario simulation begins with the initial value of the variables specified in the scenario. The results of the simulation with the two different scenarios are organized in Table 2.

Scenario 1. If both a user and Pleo are very extroverted (S1 = 1, S3 = 1), what kinds of behavior would the user exhibit?

The results of Scenario 1 indicated that a user would show some distinct behaviors. The values of C2, C4, C6, and C7, which represent the kinds of touch, discontinuity of touch, frequency of negative touch, and frequency of neutral touch, respectively, were high. This result can be interpreted as follows. When an extroverted user interacts with the Pleo manifesting the same personality (extroversion), users might try many different kinds of touch (such as tickling, patting, and picking up), frequently change the type of touch (high discontinuity of touch type), and show many negative touches (such as slapping and shaking).

Scenario 2. If a user is introverted (S3 = -1) and Pleo is extroverted (S1 = 1), what kinds of behavior would a user exhibit?

The results of Scenario 2 showed different user behavior as compared with Scenario 1. The values for kinds of touch (C2), discontinuity of touch (C4), frequency of negative touch (C6), and frequency of neutral touch (C7) were low. The standard deviations of frequency of touch (C3) and frequency of positive touch (C5) were high. This result indicates that an introverted user might touch Pleo monotonically (low discontinuity of touch type) and not actively touch Pleo. Obviously, an introverted user would exhibit different touch behavior compared to an extroverted user.

Table 2. The results of scenarios about the role of personality matching on a user’s behavior

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.8</td>
<td>1.8</td>
<td>-2.2</td>
<td>3.8</td>
<td>-5.0</td>
<td>3.8</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>0.8</td>
<td>-3.8</td>
<td>3.8</td>
<td>-3.8</td>
<td>7.0</td>
<td>-3.8</td>
<td>-7.0</td>
</tr>
</tbody>
</table>

4.2. Predicting a user’s personality trait

In order to examine the possibility of using FCMs to predict a user’s personality traits, we also conducted a what-if analysis with different scenarios. Each scenario simulation begins with the initial value of the variables specified in the scenario. The results of the simulation with three different scenarios are organized in Table 3.
Discussion

When the user's and Pleo's personalities were not matched (an introverted user and an extroverted Pleo), the results of the simulation forecasted that the user might not actively interact with Pleo. The simulation results predicted that a user would touch Pleo monotonically (exhibiting similar types of touch over and over).

To the best of our knowledge, the present work is the first attempt to employ FCM to investigate the effect of personality matching on user's touch behaviors. Several previous studies [5, 10] showed the effect of personality matching on people's perception and emotion rather than on human behavior. The present work could be extended to mobile devices, as they are mainly operated by touch. That is, the effect personality matching between a user and a mobile phone can be investigated by the method presented in this paper.

The results of the simulation for the three latter scenarios (Scenarios 3, 4 and 5) are also worth paying attention to. Scenarios with the extroverted and introverted users showed distinctive differences in their touch behavior. This implies that FCM is capable of predicting a user's personality traits based on his or her touch behavior.

Traditionally, personality traits have been measured using a questionnaire. This method is time-consuming and hinders natural interaction between a user and device because it requires additional effort by the user. The FCM presented in the current paper address this problem because it infers a user's personality traits automatically based on the types of touch occurring during the interaction. Indeed, several studies have introduced a method of predicting a user's personality traits based on the user's behavior. Pianesi et al. [14] examined the recognition of a user's personality (extroversion and locus of control) in social interactions. In their experiment, acoustic and visual features were analyzed in order to predict an individual's personality traits. Zen et al. [20] investigated the relationship between personality and proxemics in social interactive settings. They presented a camera-based monitoring system for automatic recognition of user personality, and support vector machine (SVM) classifiers were employed to predict personality traits.

The present research possesses several advantages over previous studies. First, as FCM can show a causal relationship between factors, the present study provides a deeper understanding of the effect of personality matching on a user's behavior. Unlike the SVM used in [20], the FCM built in the present research illustrated the causal relationships among the factors. Furthermore, many digital devices, such as mobile phones, tablet PCs, and robots, are based on and operated by touch. In other words, users mainly

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Table 3. The results of scenarios about predicting user's personality trait

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-1</td>
<td>-1</td>
<td>0.90</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>-1</td>
<td>-1</td>
<td>-0.80</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>-0.28</td>
<td>0</td>
</tr>
</tbody>
</table>

5. Discussion

The evaluation of our FCM using the first two scenarios (Scenario 1 and 2) showed the impact of personality matching on a user's behavior. From different initial conditions (i.e. different degree of personality matching between a user and a robot) specified in the scenarios, the FCM predicted different touch behaviors of different users. Specifically, when the personalities of a user and Pleo were matched (both extroverted), the results of the simulation forecasted that the user might be actively engaged in an interaction with Pleo (trying different types of touch and frequently changing touch behavior). In contrast, when the user's and Pleo's personalities were not matched (an introverted user and an extroverted Pleo), the results of the simulation forecasted that the user might not actively interact with Pleo. The simulation results predicted that a user would touch Pleo monotonically (exhibiting similar types of touch over and over).

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interact with devices through the modality of touch. The present paper showed that a user’s personality traits could be revealed by analyzing the types of touch in an interaction. Therefore, simple touch sensors are enough to predict a user’s personality, and additional sensors such as ultrasonic sensors and cameras are not required. The method introduced in the present paper could be implemented in robots and mobile devices. Consequently, a device can automatically understand its user’s personality by analyzing the touch sensor readings. Therefore, the results also seem promising in terms of personalization, as understanding its user is the very first step for personalization.

Figure 2. The FCM constructed in the present paper. Blue circles represent S1-S4, yellow circles represent T1-T10, and green circles represent C1-C7. Black edges represent excitatory relationships and red edges represent inhibitory relationships (please refer the online version for colors).
6. Conclusion

Personality is important not only in people, but in many devices that people use. When personalities are matched between people and devices, we could say that the personality matching is obtained, and users’ satisfaction level remains high during the period the devices are in use. The present paper investigated the degree of match between a user’s personality and the main features of target devices using a fuzzy cognitive map (FCM). FCM is a structure for representing a causal relationship between variables within a system. The FCM was built based on experimental data and evaluated using several scenarios. The results showed the effect of personality matching on human behavior and the possibility of using a FCM to infer a user’s personality traits based on the user’s interaction style (type of touch).

In future work, we will further investigate the effect of personality matching on a user’s behavior in the context of mobile devices. In addition, we will include the user’s perception and emotions in our framework in order to provide a deeper understanding of human behavior in social interactions.

6. Acknowledgements

This study was supported by a grant from the WCU (World-Class University) program (R31-2008-000-10062-0) of the Korean Ministry of Education, Science and Technology via the National Research Foundation.

7. References


