A Computational Model of Personality

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Abstract

In this paper we present a computational model of personality, PIACT, which is an extension of ACT-R cognitive architecture, to consider the effect of personality factors. The personality component of PIACT is based on the trait anxiety, which is a facet of the neuroticism dimension of the FFM psychological model of personality. The designed model has been evaluated in two parts: First, by using the technique “Reverse-U” from cognitive science. The results of our research conformed to the psychological studies. Second, the model was evaluated in a simulated soccer environment. The results indicated a decrease in the efficiency factor of the goalkeeper because of an increase in the number of the scored goals.

Keywords: Computational model; cognitive architecture; psychology; personality; unified theories of cognition

1. Introduction

One of the main concerns of societies has been to address the individual and social needs of human beings. In this regard, efforts have led to the formation of various sciences. Human mind as one of the most important parts of the human body and plays a major role in human performance. Hence, it is the centre of attention of various sciences. In what follows, considering the purpose of the current study, we present a brief introduction on psychology, computer science, and cognitive science.

Psychology, with the main objective of answering complex questions about human behaviour, plays a crucial role in understanding human and its needs. As an independent field of study, psychology started at the end of 19th century (Hatfield, 2002). At first, it was dominated by behaviourists who investigated the mind based on observable behaviour. To behaviourists, reaching to the base structure of the human mind was not possible, given that this structure and its operations were completely metaphysical. As a result, this approach alone failed to respond to the existing demands.

Computer science with computational modelling is considered as an effective way to identify and establish the needs of human societies. In the 1950s, primary computers were founded and pioneers such as John McCarty, Marvin Minsky, Allen Newell, and Herbert Simon established the field of artificial intelligence with the aim of designing computational agents with an intellectual capacity comparable to humans (Langley, 2006). These agents were supposed to exhibit their intelligence in a general way across many different domains. Unfortunately, due to
the lack of enough knowledge about the inner structure of the human mind and intelligence, artificial intelligence remains far from this goal and systems have a considerable distance from the primary goals of the researchers. Of course many beneficial results have been produced in AI but the outputs are greatly distant from the primary goals.

Cognitive science is one of the emerging disciplines founded in the final decade of the 20th century in response to the increasing demands for better understanding of the human mind. “By then, it was becoming clear in several disciplines that the solution to some of their problems depended crucially on solving problems traditionally attributed to other disciplines”, Miller said (2003). Cognitive science is an interdisciplinary approach which integrates findings of various sciences such as psychology, philosophy, computer science, linguistics, anthropology, and neuroscience to study the human mind. There is an early famous article by Newell named “You can’t play twenty questions with nature and win”. In this article Newell discussed, in detail, some of the weaknesses he found in experimental psychology. Afterwards, he presented his famous idea in a book entitled “Unified Theories of Cognition” (Pollack, 1992). This book put forward the thesis that psychology is ready for unified theories of cognition, UTC:

“Psychology has arrived at the possibility of unified theories of cognition – theories that gain their power by positing a single system of mechanisms that operate together to produce the full range of human cognition”.

Cognitive architectures, known as infrastructures for intelligent systems, were introduced by Newell as candidates for the UTC (Pollack, 1992). Briefly, parts of a cognitive agent which are static along time and in different domains are considered in cognitive architectures, but dynamic aspects are added to cognitive models. In recent years, a lot of cognitive architectures have been designed. Among them we can point to the most famous ones such as SOAR by Allen Newell, ACT-R by John Anderson, Society of the Mind by Marvin Minsky, and Clarion by Ron Sun. Most of these architectures pay special attention to rational and individual aspects of human intelligence. In the above mentioned book, Newell explained that although characteristics such as imagining, dreaming, and personality should be considered in the studies, the UTC is a fantasy and the entire cognition cannot be realized in one step. Today with the long history of research on cognitive architectures, most of the characteristics introduced by the Newell are realized in various proposed architectures. As a result, it is already suitable to take one step further to consider spiritual aspects in these architectures. One of the main aspects of human intelligence is personality causing various people behave differently in same situations.

Personality is one of the crucial aspects of human intelligence and has attracted increasing attention from researchers around the world. There is a great deal of personality studies on which researchers focus differently. Psychologists investigate personality to recognize it better and realize the physical and mental health needs of humans. Computer scientists investigate it to realize the leisure needs of humans and, in some works, to help psychologists to evaluate their theories. Despite all the previous researches, investigating personality from different perspectives, with a large number of psychological theories, viewpoints, results of new researches, and also complexity and various dimensions of human intelligence there are many aspects which have not been discussed. Moreover, along with the progress of various related sciences, the review of the results of the previous researches is essential.

In the current research, considering the importance of personality in intelligent behaviour of human, a computational model of personality based on the ACT-R cognitive architecture and the FFM psychological model of personality is presented. The outline of the current paper is as follows. In the next section, we have a survey on personality theories and models based on the objective of the current research. Cognitive architectures are discussed in the third section. Section 4 is related to previous works on computational modelling of personality. Then, the ACT-R cognitive architecture is extended to support personality characteristics and as a result PIACT is presented in chapter 5. Final section provides the experimental results. The proposed architecture is evaluated in the soccer simulation domain. Findings have shown that the trait-anxiety has a significant impact on the agent’s performance (i.e., ability to use previous experiences in the current research). In fact, as anxiety increases, the agent’s performance decreases.

2. Personality Psychology Theories and Models

Psychologists try to recognize the role of mental operations on individual and social behaviors (Mc Moris, 2004; Anshel, 1997; Jarvis, 1996; Pervin & John, 2001). There are multiple standpoints in psychology with various basic assumptions to study psychological phenomena, including psychoanalysis, behaviourism, cognitivism, and the
humanities. Traditionally, there were many discussions to select a view that could explain all aspects of human behaviour, but no agreement was achieved. One of the main subjects in psychology is personality and the manner in which it is formed. Generally, “personality refers to those characteristics of a person that accounts for consistent patterns of behaviour over situations and time” (Pervin & John, 2001).

Our study has shown that many theories and models were introduced by personality psychologists (Schultz & Schultz, 1998; Pervin & John, 2001). Trait theories are known as attempts to find the basic dimensions of the human personality structure, investigating the effect of traits on the individual’s behavior. Psychological researches have shown that the BIG Five personality theory, one of the personality trait theories, is confirmed in different cultures and time periods (Booker, Kitchens, & Rebman, 2007). Our further studies, based on the current research aims, have shown the possibility of using this theory in multi-agent environments (Gardio, Brena, & Sycara, 1996).

Furthermore, psychological researches show that in addition to broad aspects of personality, traits can also express personality differences of individuals. In fact, despite the importance of broad dimensions of personality traits, specific traits are the main argument in trait psychology and many of the trait researchers have studied and explained the effect of personality traits on individuals’ behaviours as they believe that traits are suitable units in personality description (Haslam, 2007).

In the proposed architecture, due to the above-mentioned discussion, the need for tentative research and the need for psychological experiments we considered personality based on the anxiety trait, which is a facet of the neuroticism dimension of the Big Five psychological model of personality. In addition, personality psychologists have shown that personality traits affect behaviour through behaviour mediators, investigated in the next section, resulting in state traits which affect human behaviour directly (Martens, 1987). The effect is positive if it enhances performance; otherwise it is considered as negative.

2.1 Trait-State Models

The basic principle of these models is that traits’ effects on behaviour are mediated by states, and states have a more direct effect on behaviour than do traits (Mattews, Deary, & Whiteman, 2003). The goal-setting mechanism and environmental stressors are two important mediators which have been greatly studied by psychologists.

2.1.1 Goal-Setting Mechanism

Goals are one of the most affective behaviour mediators, identified through the goal-setting mechanism (Martens, 1987; Joel & Stout, 1999). In fact, the amount of stress in a stressful condition is highly decreased if goals are set properly. The principles of the goal setting mechanism are (Martens, 1987):

- **Performance-oriented goals vs. Outcome-oriented goals**
  Goals should be performance-oriented not outcome-oriented. Outcome-oriented goals cause mental problems such as the reduction of self-confidence. These goals aren’t in the control of the individuals, especially in group games.
  - **Simple goals vs. Difficult goals**
    Simple goals reduce individual incentives and have direct effect on behavior. Difficult goals lead to loss of motivation and belief of being a loser forever, but moderately difficult goals lead to an increase of motivation and better performance of individuals.
  - **Realistic goals vs. Unrealistic goals**
    Goals must be realistic but challenging.
  - **Specific goals vs. General goals**
    Goals must be specific. It is hard to determine how to do things based only on general goals and without any specific criteria. Specifying how and when to go about doing things can help to this end.
  - **Short-term goals vs. Long-term goals**
    Progressive short-term goals should lead to a long-term goal.
  - **Individual goals vs. Group goals**
    Goals should be individualized and not oriented toward the team. Individual goals are more in control than group goals and so both of them are essential in individuals’ success.
2.1.2 Environmental Stressors

Social Learning Theory is defined as follows: “People learn new behaviour through overt reinforcement or punishment or via observational learning of the social factors. If people observe positive, desired outcomes in the observed behaviour, they are more likely to model, initiate, and adapt the behaviour themselves”. Environmental stressors, when they exceed their normal range, as behaviour mediators have a negative effect on behavior and breed stress in an individual”. State-anxiety is considered as the result of the effect of environmental stressors and the goal-setting mechanism on trait-anxiety. The effect of personality on behavior is finally applied by state-anxiety.

3. Human Cognitive Architecture

Researchers in various fields have used models to investigate the correctness and accuracy of their theories. One type of these models is the computational model which has played a crucial role in many fields including cognitive science and artificial intelligence. In AI they are “intelligent agents” and in cognitive science they are known as “cognitive architectures”. Along with recent scientific findings about necessity of the integrated study of the various aspects of intelligence and cognition, Newell introduced the idea of UTC or “Unified Theories of Cognition”. The UTC is a single set of mechanisms that accounts for all of cognition. A great number of cognitive architectures, as a candidate for the UTC, have been developed including ACT-R, SOAR, CLARION, Society of the Mind Most of the developed architectures have focused on the rational aspects of the mind and spiritual factors such as personality, and emotion have often neglected by the researchers and none of the famous cognitive architectures have officially supported them. Recently along with scientific evidences about the major effect of spiritual factors on human mind the number of related research studies is increasing. The proposed architecture is developed based on the ACT-R cognitive architecture which has had a long history of active researches during the recent 20 years and is a psychologically plausible cognitive architecture.

It should be noted that comparison of existing cognitive architectures is a difficult and time-consuming task due to the evaluation complexities of these architectures which, in turn, are related to their interdisciplinary nature and their different bases and hypotheses. Moreover, various design languages of these architectures intensified this complexity. Although there is some researches that compares architectures from some specific perspectives including the representation method, the amount of UTC realization, and architecture constraints, we didn’t find any universal research in this regard.

4. Related Works

Previous researches on computational modeling of personality can be classified in two main groups based on the researchers’ aims and backgrounds. Research studies with the goal of the recognition of personality, its structure and the evaluation of psychological theories and models, mainly focused by psychologists, are in the first group. The second group is related to researches on intelligent agents with believable and attractive behavior, often considered in computer science and theater.

The use of personality in the context of intelligent agents based on our studies has started around 1968. Various researchers use various terms to refer to such agents and research studies including: character-based arts, life-like computer characters, believable agents, cognitive agents, believable characters, autonomous agents, fictive characters, virtual characters, believable virtual characters, virtual humans, virtual agents, and many more. Each one of these words points to the characteristics that the corresponding character or agent should support or mainly emphasizes in their design. The use of personality has had many applications in different domains so far such as in: virtual reality, computer game characters, agent secretaries, life-like characters, affective user interfaces, dialogue systems, intelligent tutoring systems, training systems, life-like pedagogical agents, e-learning systems, virtual receptionists, chatterbots, robotics, and in every domain that considers the personality of agents to give more plausible, believable, and attractive agents thus yielding a better performance.

In the Rousseau's model of personality (Rousseau, 1996) with a compound view from psychology, theater, and artificial intelligence a computational model of personality was presented. Russo’s goal was an investigation of the possibility of using personality characteristics to create attractive, plausible, and erratic representation. In this research study the effect of personality on mood and interpersonal relationships was also investigated. Rosso placed emphasis on trait and social learning psychological theories of personality. In the model, he hypothesized that the
agent has some limited personality traits that affects the agent’s behaviour and agent doesn’t behave the same in all conditions.

Another model of personality (Nitta, Tanaka, Nishida, & Inayoshi, 1999) is based on the psychoanalytic theory of personality. Model is based on hypotheses that defensive mechanisms play an essential role in personality. In fact in the proposed model along with the occurrence of events it is possible that the individual places himself in a conflict situation (inconsistent senses in regard to the triggered event). This conflict yields to anxiety in the person. In this situation, ego uses a defensive mechanism to avoid or decrease anxiety. Homer (1999) uses a combination of psychoanalytics and neuroscience to hypothesize a three-layer neural network for the representation of a substrate of personality. He hypothesized that special neurotransmitters are dependent on specific periods of development. So, based on these concepts, Homer presented a three-layer neural network model of personality. Each layer in the network placed neurons that were sensitive to specific neurotransmitters. Due to the essential dependency between the monoamines dopamine, norepinephrine, and serotonin to personality characteristics, each one is associated with a layer in the network. This architecture is consistent with real neuronal connections and different brain areas could be represented in this way.

Romano's personality model (Romano & Wong, 2004) consists of four modules including Emotion Module, Memory, Social-Cognitive Factors Module, Event Processing. Personality in this research is based on the social-cognitive factors. The social-cognitive factors identified by Cervone and Shoda (1999) are social knowledge, personal goals, personal standards, expectations about the world, reflections upon oneself, and affective experiences.

Li, Qiu, Yue, and Zhong (2007) proposed a framework of a learning companion agent with personality and emotions. Based on the Big Five model and the OCC model, this model of the personality and emotions of a learning companion agent is defined and formalized. A learning companion agent uses the emotional state, mood, and personality to create behaviours. Liu (2008) tried to set up a mathematical model of personality. His model is based on the “Big Five” model of personality. The proposed model integrates stimuli, perception, personality, motivation, emotion, and behaviour. A basic emotion or behaviour is active not only by outer stimuli, but also by inner motivation and personality.

PAC (Read et al., 2006) is an architecture developed by a common work at university of southern California and CHI Systems. PAC relates the structure of human personality to the structure and dynamics of human motivational systems. In the PAC, personality is defined as enduring tendencies to think, feel, and behave in consistent ways. Two related lines of research emphasized in the PAC. One of these was to identify possible cognitive constructs underlying personality. They noted how traits could be represented as configurations of motives, plans and beliefs. A second line of research comes from findings in neuroscience and temperament. PAC mainly emphasizes the internal representations and processes that give rise to personality and it is still evolving. It is an architecture that from the beginning, attempts to model the way human personality is formed.

According to the objective of our research the work that is closest conceptually to the current model is Ritter’s models of stress (Ritter, Reifers, Klein, & Schoelles, 2006). In this research theories of stress in psychology were modeled and the result of applying these models to set ACT-R parameters is investigated. This work is based on the some models of stress without considering behavior moderators.

In summary, there are many works on personality modeling from the year 1968 onward. In each of these works the emphasis was on a specific view according to the researchers’ standpoint. Due to the multiple dimensions of human personality and its ambiguities, there isn’t yet a complete computational model of human personality. In the above section we just introduce some of the works in this area without discussion about their weaknesses. It is clear that none of these models plus the model developed in this paper is complete, but achieving a more complete model of personality, needs consideration of all of the previous research, and recognition of more aspects of personality.

5. Personality Integrated ACT (PIACT)

In this section our proposed architecture, PIACT, an extension of the ACT-R Cognitive Architecture, is explained. In PIACT, the agent receives events and feedbacks from the environment, updates the model, selects the suitable actions, and applies them to the environment, considering environmental status, its experiences, and knowledge.
Figure 1. Proposed Architecture

Figure 2. PIACT

In PIACT, in-work state-anxiety is determined based on the effect of environmental stressors on pre-work state-anxiety produced as a result of the effect of the agent’s skill, and goal-setting skill on trait-anxiety. Degree of usage of skills, computed based on the in-work state-anxiety, is used to set general parameters of the ACT-R model including retrieval threshold (RT). In ACT-R, the agent cannot recall if its activation level is less than its retrieval threshold. In the proposed architecture, there is a hypothesis that agent’s anxiety level has a crucial effect on this threshold. Furthermore, performance degree, generated by the performance engine based on the feedback of the agent’s action in the environment (degree of goal achievement) and reward of the fired rule, is used as an input to the behavior mediator component and the personality component and as a result the agent’s mental parameters and parameters of the architecture will be changed.

5.1 Components of the Architecture

In the current research, we used fuzzy sets to parametrize the main aspects of human behavioral modeling. In PIACT, the Gaussian membership function, the Mamdani inference mechanism, and the Center of Gravity defuzzification mechanism were used to model the entire system. The fuzzy set and range of the values, identified by the experts, are used to model Agent’s personality, Environmental conditions, Agent’s action, and Agent's performance based on the PIACT architecture introduced in the previous section. The corresponding fuzzy systems are presented in the follow.
It should be pointed that in the current research effect of trait-anxiety on behavior is just considered.
In this model, we considered 3 fuzzy terms for the training-level including superficial, medium and deep.

Figure 6. Changing Goal Setting Parameters

Figure 7. Goal Suitability
Figure 8. Pre-work State-Anxiety

Figure 9. Environmental Stressors

Figure 10. Play Negative Effect
Figure 11. Other Players Negative Effect

Figure 12. In-work State-Anxiety

Figure 13. Skill Usage

Figure 14. Agent’s Performance
Psychological research studies have shown a low probability of change in the level of the trait-anxiety of individuals. Changes often occur in state-anxiety. Of course if the agent is placed in situations with high state-anxiety periodically, trait-anxiety can also be changed. But the amount of this change is very small and occurs gradually. So another parameter which can change the trait-anxiety is the frequency of the occurrence of state-anxiety in different situations. In the current research, change of trait-anxiety in high and low state-anxiety was investigated. The change of trait-anxiety is considered according to the following fuzzy system.

![Figure 15. Anxiety Change](image)

### 6. Experimental Results

One of the most important phases in designing a model is the evaluation and validation phase. Evaluation of the models based on cognitive architectures is difficult and time-consuming as the basis of these models is human and the results should be compared with human operation in the same situation. In this research we evaluated our model in two ways:

- Matching of the results with the Inverted-U hypothesis
- Investigation of the model with and without personality traits

TOS Soccer simulator (Zhang) is considered as our case study to test the proposed model. The simulator’s client is designed based on the PIACT. In the model the clients with PIACT mental structures communicate with TOS server via UDP/IP protocol.

#### 6.1 Inverted –U Hypothesis

Based on this hypothesis, derived from the work of Yerkes and Dodson (1908), as arousal increases to an optimal value, performance increases too. Afterward, performance is decreased. The hypothesis is often used to predict the effects of anxiety on performance.

![Figure 16. Stress and Performance Relationship according to the Inverted-U Hypothesis](image)
In the evaluation phase we ran the simulated model several times. The results, as shown in the figure, indicated as anxiety increases, retrieval threshold increases too. This signifies a decrease in the performance of the simulated model. As in the current research all of the affective personality traits did not considered, the resulted curve isn’t exactly the same as the inverted-u curve. In fact, in low values, anxiety doesn’t disturb memory, yet due to its effect on attention and motivation, performance is increased. Consequently in the simulated model we didn’t observe much change in the performance (retrieval threshold), but from a value, as anxiety increase we have a reduction in the performance. As shown, an inordinate increase of anxiety can cause retrieval threshold approaching 1 and, in fact, in this case the agent cannot recall anything from the memory.

6.2 The Model Evaluation With and Without Personality

Another criterion is the evaluation of the model with and without personality traits. Results of our soccer simulation after 10 runs are as follow:

- Goalkeeper and one attacker without personality traits: In these runs, there were 30 shots to the goal and 25 of which were caught by the goalkeeper.
- Goalkeeper with personality traits and the attacker without: In these runs, there were 37 shots to the goal where 27 were caught by the goalkeeper.

Although the results have shown a decrease in goalkeeper performance, this situation considering this fact that the attacker did not have the personality is reasonable. In different stages of simulation, there were situations where if the goalkeeper behaves based on the mechanism considered in the simulator, the result was a goal, but in five shots, the goalkeeper behaved differently due to the effect of personality factors which caused catching the ball. Also in 7 cases considering the effect of personality factors, the goalkeeper performed an action which caused a goal. Although because of the simplicity, the effect of personality factors on behavior wasn’t evaluated completely, it’s clear that if an intelligent agent is placed in front of a real human, we can have unforeseen conditions which are generated as a result of the effect of spiritual factors. If the intelligent agent has these factors too, it can behave with higher performance.

7. Conclusion

Research on spiritual aspects of human cognition has attracted researchers in recent years. In this regard, personality is among the important aspects for which many efforts have been made to study it. Despite many efforts and worthwhile results, many aspects of human personality are unknown and further researches are necessary. The present study addressed the issue of the effect of personality on behavior in the form of a computational architecture.
Based on our studies, anxiety as a facet of the neuroticism dimension of the FFM model of personality which is one of the most validated theories of personality in psychology and ACT-R as cognitive architecture were considered in our proposed architecture. In this direction, the effect of personality factors on general parameters of architecture was considered. The results, as its details were explained in the previous sections, have shown that personality is an important factor of human intelligence which causes different people behave differently in the same situation. In the current research study, the retrieval of an individual’s memory may be harmed if anxiety increases inordinately. The consideration of other personality traits and conversion of the architecture into a multilayer architecture can be considered as future researches.

References


