MIAN MUHAMMAD MUBASHER, M.Phil.
E-mail: mubasher@pucit.edu.pk
SYED WAQAR JAFFRY, Ph.D.
E-mail: swjaffry@pucit.edu.pk
Artificial Intelligence and Multidisciplinary (AIM) Research Lab
Punjab University College of Information Technology
University of the Punjab
Lahore 54000, Pakistan

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INCORPORATION OF THE DRIVER'S PERSONALITY PROFILE IN AN AGENT MODEL

ABSTRACT

Urban traffic flow is a complex system. Behaviour of an individual driver can have a butterfly effect which can become the root cause of an emergent phenomenon such as congestion or accident. Interaction of drivers with each other and the surrounding environment forms the dynamics of traffic flow. Hence global effects of traffic flow depend upon the behaviour of each individual driver. Due to several applications of driver models in serious games, urban traffic planning and simulations, the study of a realistic driver model is important. Hence cognitive models of a driver agent are required. In order to address this challenge the concepts from cognitive science and psychology are employed to design a computational model of driver cognition which is capable of incorporating law abidance and social norms using big five personality profile.

KEY WORDS

driver agent; traffic modelling; big five; personality profile; cognitive model;

1. INTRODUCTION

Computational modelling is a branch of computer science which has several applications in diverse areas of study. It assists other disciplines to explore the dynamics of complex phenomena under their observation by providing theories, tools and technologies for modelling and simulation of those phenomena. Transportation engineering and urban traffic management is among one of the most important areas of study for computational modellers which has direct impact on sustainable development of a society. Hence, techniques of computational modelling have been widely applied [1] and various aspects of urban traffic management have benefited through this. Urban traffic management is a very interesting and challenging phenomenon due to huge population growth and an increasing trend in migration towards cities. In several studies it has been observed that in the whole world, especially in the developing countries the population of cities is growing because of employment opportunities, better living standard, and improved educational and healthcare facilities.

An increase in urban population has direct correlation with the increase in the number of vehicles on the road. Traffic management in big cities with the growing number of vehicles has been a great challenge and for a better understanding of this phenomenon computational modelling techniques have been applied. This challenge spans several areas including but not limited to the optimal resource allocation, new infrastructure planning, effective use of existing infrastructure, avoidance of traffic jams and accidents etc. Computational modelling and simulation techniques applied to date have tried to address these and related problems through design, evaluation and experimentation of urban traffic flows. Through simulation of the computational model of urban traffic and experimentations, several valuable insights and improvements have been made in cities. Beside overall urban traffic flow, the simulation techniques have also assisted in better understanding of the driver's behaviour in different scenarios [2] and helped in designing interventions to facilitate the drivers.

In literature, several computational models of urban traffic flow have been designed, verified and validated based on different theories including centralized and decentralized control [3]. In decentralized controlled urban traffic simulations individuals (vehicles/agents) can take personal decisions and their decisions eventually affect overall traffic dynamics. The decentralized approach includes modelling and simulation techniques of cellular automata, and multi agent systems. These techniques are usually thought of as more faithful and realistic than centralized techniques because of individual's autonomy and freewill for taking decisions which is natural to many social phenomena. For curious readers [1] presents an extensive coverage of data, models and simulations related to driver and vehicular traffic modelling.

The literature of multi agent models of traffic flows [4] where each vehicle is represented by an agent, mostly considers environmental opportunities and agents rational utility, and usually ignores agents' inherent personality traits. To make multi agent modelling and simulation of traffic flows more realistic such humanistic attributes should be taken into consideration. For bridging this gap this paper proposes a driver agent model, inspired by theories of psychology and cognitive science about the human personality attributes, namely the Big Five traits. This model is capable of representing the individual's driving behaviour in different circumstances and change in individual's behaviour over time. Furthermore, the proposed model has capacity to be customized for various cultures having different law abidance and social norms.

The rest of the paper is organized as follows: Section 2 presents the background; Section 3 gives the proposed model; in Section 4 the simulation setup is described; Section 5 carries the experiment setup and simulation results, while Sections 6 and 7 provide the conclusion and future work, respectively.

2. BACKGROUND

Realistic driver models are of special interest due to their application in serious games and social simulation of vehicular traffic flow involving prediction of human driving behaviour. Vehicle flow models presented in literature which produce rational behaviour are not suitable in such cases. Human drivers do not always behave rationally and usually show irrational behaviour such as signal jumping, overspeeding, lack of attention, etc. To meet this challenge the modelling of the driver's cognition is required. In literature cognitive traffic agent model has been proposed in [5]. In this model, based on the Big Five traits of human personality, the drivers are divided into three categories, namely, over-controllers, under-controllers and resilients. Usually, in decartelized simulations of traffic flows the situations occur where coordination among drivers is required, such as intersection crossing. In such cases if all drivers are egoistic and try to cross the intersection, a deadlock will occur and in case of giving way to other driver's livelock will emerge. One solution to this is to decide randomly whereas in [5] it has been suggested that in such a tie-breaking situation the decisions of drivers are determined by the personality profile of the driver. One of the shortcomings of model presented in [5] is that the personality profiles of drivers are static in nature and do not change over time. In the proposed model this shortcoming is considered using a feedback effect of environment on the driver's personality profile over time.

The Big Five personality profile is composed of personality traits possessed by a human [6–9]. The list of the Big Five personality traits includes Neuroticism, Extraversion, Openness, Agreeableness and Conscientiousness.

The above mentioned traits describe the personality of an individual and in this case, of a driver. In the following section each personality characteristic has been explained briefly.

- *Neuroticism*: This personality trait describes the susceptibility of a person towards unpleasant experience which subsequently causes negative emotion such as depression, anger or anxiety.
- *Extraversion*: This personality characteristic specifies how much the person is willing to cooperate and communicate with others.
- *Openness*: This attribute describes how much a person is willing to undertake new experiments and explore new opportunities.
- *Agreeableness*: This personality characteristic depicts the willingness of the person to respect laws and regulations. While making decisions and taking actions, the degree of abiding rules and regulation is dependent on the value of this characteristic.
- *Conscientiousness*: This characteristic depicts the property of being vigilant about the environment. It also shows expertise about the relevant domain such as driving, cooking, etc.

3. COGNITIVE DRIVER MODEL

Cognitive Driver Model (CDM) proposed in this paper is an extension of the cognitive traffic agent model presented in [5]. Model presented in [5] suggests that every traffic agent has been equipped with a personality profile. The agent takes environment as input and performs actions accordingly. Actions performed by the agent are the output. The agent uses personality profile only in tie breaking situations. Whereas in proposed Cognitive Driver Model (CDM) the driver agent uses personality profile not only in tiebreaking situation between driver agents, but it also involves environment perception. In CDM the personality profile is not static. The personality profile of a driver agent changes according to the perceived environment. It also plays a role in the decision making and actions of driver agent.

A driver agent takes input from the environment. This input may affect positively or negatively the personality profile of that driver agent. The driver agent builds a perception of the input environment. The personality profile also affects the perception of the driver agent. Hence, each driver agent can have different perception of the same environment according to their personality profile. Afterwards, the driver agent makes decisions according to the perceived environment. The actions of the driver agent are also affected by the personality profile of the driver agent. Abstract architecture of the

CDM has been presented in *Figure 1* where a causal feedback loop exists between input (environment) perception and the driver agent's personality profile.

Environment
Every agent exists in a context which is the surrounding environment. For a driver agent, road infrastructure and fellow drivers constitute the driver agent's environment. The distance from the front vehicle, distance from the back vehicle, distance from the signal, speed difference from the neighbouring lanes, etc. are elements of the environment which are used as driver agent's input. In the following section the mathematical formulation of environment has been expressed.

Let E be the vector of possible environmental factors which constitute the environment of the driver agent, this vector of environmental factors is used as input of the CDM.

$$E = (x \mid x \in \mathbb{R}) \quad 0 \le x \le 1 \tag{1}$$

$$|E| = n \tag{2}$$

Vector of environment E is a finite ordered set (1). E has n elements (2). Each member in vector E is a real number between zero and one representing the intensity of that environmental factor. This approach is favourable for modelling as it determines the bounds of the input.

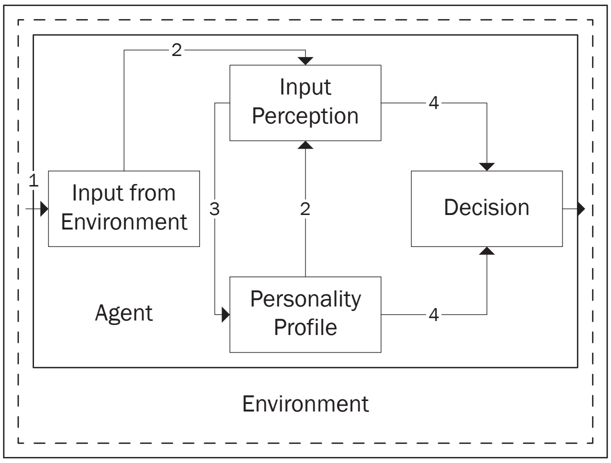

Figure 1 – Abstract architecture of CDM agent

Personality profile
All driver agents perceive their environment according to the personality profile they possess (environment perception module explained below). Personality profile has been modelled in such a way that it comprises two vectors of personality characteristics to retain each personality trait internally. One vector is used to retain negative values whereas the other is used to retain positive values of the personality profile. Such approach has been used in [10] to model cognitive agents, and the modelling technique has been inspired by [11] and [12]. All positive experiences are taken into account by using positive personality profile whereas negative experiences are accumulated in negative personality profile. Overall personality profile is computed by accumulating both positive and negative personality profile. Following is the mathematical formulation of the agent's personality profile.

Each driver agent has vectors S_P and S_N to represent their personality traits. Both vectors comprise five real numbers, one for each personality trait of the Big Five as explained in Section 2. Positive experiences are accumulated in S_P whereas negative experiences are accumulated in S_N.

$$S_P = (x | x \in \mathbb{R}) \quad 0 \le x \le 1 \tag{3}$$

$$S_N = (x | x \in \mathbb{R}) \quad 0 \le x \le 1 \tag{4}$$

$$|S_P| = |S_N| = 5 = k \tag{5}$$

$$S = \frac{(S_P - S_N + 1)}{2} \tag{6}$$

S_P and S_N are vectors comprising real numbers, (3) and (4) respectively, which have values between zero and one. As described above, the personality profile comprises five characteristics, so cardinality of S_P and S_N is five. However, to make the model flexible so that any number of personality characteristics could be incorporated seamlessly, cardinality of S_P and S_N is assumed to be k as formulated in (5). S represents accumulated personality profile (6). Each accumulated personality trait has value between zero and one due to the formulation presented in (6).

CDM has three major parts: environment perception, personality profile transition and decision making. In the following section each of the three modules has been described in detail and their mathematical formulation is presented.

3.1 Environment perception module

It was mentioned earlier that environment E is a vector of real numbers providing the degree of environmental factors. Perceived environment E_P is also a vector of real numbers having one to one mapping with vector E. Perceived environment is computed by colouring or modifying the environment according to the personality profile of the agent. This approach of colouring perception is based on psychological theories [13, 14] and adopted in [15]. The process of perceiving the environment is discussed in detail in subsection a). Subsection a) presents the environment perception and its mathematical formulation.

The process of environment perception has three inputs. First, actual environment E, second, accumulated personality profile of the driver agent referred as S and matrix M_E which describes how a personality profile affects the perception of each environmental factor. The degree of each environmental factor in actual environment can be perceived by the driver agent magnified or minimized. The personality profile of the driver agent may have neutral, positive or negative contribution in actual degree of environmental factor. The perceived environment is referred as E_P. It is also worth noting that in case of multiple driver agents each driver agent has their own personality profile *S* whereas matrix M_E is global and tuneable.

Let for each environmental factor in *E*, S_E be the vector of real numbers from interval [–1,1] with cardinality *k* where each member of the vector maps to a personality trait. Each member in S_E describes how the corresponding personality trait affects the intensity of the environmental factor. The effect can be neutral, negative or positive. So, if there are n environmental factors then there will be *n* number of S_E vectors. This can be represented as a matrix. Let that matrix be named M_E. The following is mathematical formulation S_E and M_E.

$$S_E = \left(x | x \in \mathbb{R}\right) \quad -1 \le x \le 1 \tag{7}$$

$$M_E = \left(S_{E_1}, S_{E_2}, S_{E_3}, \ldots, S_{E_n}\right) \tag{8}$$

As described earlier, for each environmental factor there is vector S_E of *k* real numbers (7), which shows how each personality trait will affect the value of that environmental factor. Having *S* personality profile and matrix M_E which describes the effect of each personality trait on each environmental factor (8) the following is the mathematical formulation for computing the environment perception process.

$$E_P = (\Omega\left(x\right) | \, x \in E) \tag{9}$$

$$\Omega\left(x\right) = E_{P_i} = \frac{\sum_{j=1}^{k} \Psi\left(x + \left(x \times S_j \times M_{E_{ij}}\right)\right)}{k} \tag{10}$$

In (10) $\Omega(x)$ is a function which takes an environmental factor and computes the perceived value according to personality profile *S* of the agent and matrix M_E. In (10) Ψ is sigmoid function to keep the resultant value between zero and one, in this equation *i* refers to index of *x* in *E* as $x \in E$, whereas *j* refers to the index of personality trait. It is worth emphasising that each agent has its own personality profile *S* whereas matrix M_E is global, which carries the effect of personality traits on environmental factors.

3.2 Personality profile transition module

Once the driver agent has perceived the environment the perceived environment also affects the personality traits or characteristics of the driver agents. This effect can be neutral, negative or positive. This section presents the mathematical formulation of the personality profile transition.

As described earlier, E_P is the vector of perceived environment of a driver agent. S_P and S_N are vectors of positive and negative personality profiles, respectively. Let S_S be the vector of real numbers from interval [–1,1] with cardinality *k*, each member in the vector maps to a personality trait. For each environmental factor there is a vector S_S which describes how much a perceived environmental factor affects the values of each personality trait. This effect can be neutral, negative or positive. So if there are *n* perceived environmental factors there will be *n* vectors, which could be represented as matrix M_S.

Using perceived environment E_P and matrix M_S the overall effect on personality will be computed, let it be S_C. It is worth noting that S_C is overall effect, not a new personality profile. It is also worth noting that E_P is perceived environment which can vary for each driver agent for the same actual environment according to the driver agent's personality profile, whereas matrix M_S is global and it is tuneable. S_C is computed first, and later incorporated in the driver agent's personality profile. Following is the mathematical formalization for computing S_C.

$$S_S = \left(x | x \in \mathbb{R}\right) \quad -1 \le x \le 1 \tag{11}$$

$$M_S = (S_{S_1}, S_{S_2}, S_{S_3}, \ldots, S_{S_n}) \tag{12}$$

$$S_c = \left(\Phi\left(1\right), \Phi\left(2\right), \Phi\left(3\right) \ldots, \Phi\left(k\right)\right) \tag{13}$$

$$\Phi\left(i\right) = S_{C_i} = \frac{\sum_{j=1}^{n} E_{P_j} \times M_{S_{ij}}}{n} \tag{14}$$

In (13) Φ is the function to compute change in i^{th} personality trait. Φ is formally explained in (14) where *i* is index of personality trait whereas *j* is index of environmental factor. The function uses perceived environment E_P and global matrix M_S which describes how a perceived environment affects each personality profile trait. It is worth emphasising that S_C represents an overall effect in personality profile and not a new personality profile.

Once overall effect of perceived environment (13) has been computed as set S_C, the value of each personality trait is updated. If change in i^{th} personality characteristic (S_{C_i}) is negative then the respective value is incorporated in the negative personality profile S_N whereas if change is positive then the value is incorporated in the positive personality profile S_P of the driver agent. The following is the mathematical formulation of incorporation of the overall effect in personality profile S_C. It is incorporated in positive and negative personality profiles of the driver agent. Here S_P and S_N are positive and negative personality profiles, respectively.

$$S_P = \left(A\left(S_{P_1}, S_{C_1}\right), A\left(S_{P_2}, S_{C_2}\right), A\left(S_{P_3}, S_{C_3}\right), \ldots, A\left(S_{P_k}, S_{C_k}\right)\right) \tag{15}$$

$$A\left(p, c\right) = \begin{cases} p, & c < 0 \\ p + \left(1 - p\right) \times c, & c \ge 0 \end{cases} \tag{16}$$

$$S_N = \left(B\left(S_{N_1}, S_{C_1}\right), B\left(S_{N_2}, S_{C_2}\right), B\left(S_{N_3}, S_{C_3}\right), \ldots, B\left(S_{N_k}, S_{C_k}\right)\right) \quad (17)$$

$$B(p,c) = \begin{cases} p + (1-p) \times c, & c < 0 \\ p, & c \geq 0 \end{cases} \quad (18)$$

Positive personality profile S_P (15) is computed using the current value of positive personality profile and overall effect in personality profile S_C. $A(p,c)$ is the function which incorporates overall effect in the positive personality profile (16). Negative personality profile S_N (17) is computed using the current value of negative personality profile and overall effect in personality profile S_C. $B(p,c)$ is the function which incorporates the overall effect in the negative personality profile (18). Equations (16) and (18) are the functions which compute the new value of a particular personality trait. These functions take previous value of personality trait and change in that personality trait as input. It is worth noting that the above mentioned mathematical formulation specifies one time computation of a personality trait of a driver agent. In this mathematical formulation the notion of time and multiple driver agents are skipped for brevity and comprehension.

3.3 Decision-making module

This module computes the effect of personality profile on decision making of a driver agent. The model assumes that a driver agent is required to make the finite number of decisions such as respecting traffic signal or jumping it, considering increase or decrease in car acceleration, lane change, giving way to other vehicles, etc. It is assumed that the number of decisions is d. Let S_D be the vector of k real values and M_D be the vector of d elements of type S_D. So M_D could be represented as a matrix of real numbers, one tuple or vector for each decision. Each tuple describes how each of personality traits will affect that particular decision. This impact can be positive, negative or neutral. So vector S_D has values from interval [–1,1]. Following is the mathematical formulation of the decision-making module.

$$S_D = \left(x | x \in \mathbb{R}\right) \quad -1 \leq x \leq 1 \quad (19)$$

$$M_D = \left(S_{D_1}, S_{D_2}, S_{D_3}, \ldots, S_{D_n}\right) \quad (20)$$

$$\Delta(\mathrm{i}) = \frac{\sum_{j=1}^{k} S_j \times M_{D_{ij}}}{k} \quad (21)$$

S_D is vector of real numbers from interval [–1,1] which describes effect of personality profile on a decision (19), this vector has cardinality k. Let there be d decisions which an agent can take, then M_D matrix has d instances of S_D i.e. having one instance for each decision (20). The effect of personality profile on decision of a driver agent is presented in (21). The resultant value can be positive, negative or zero. If a driver agent requires performing i^{th} action which is based on i^{th} row, the effect of its personality profile $\Delta(i)$ is computed (21).

Decisions can be of two types; the Boolean decisions and continuous decisions. Respect of traffic signal is a Boolean decision, when the driver agent is near a traffic signal which is red; it requires deciding whether the driver agent should respect the traffic signal or not. In the state-of-the-art vehicle models, vehicles always behave rationally and stop at the red light, or to reproduce realistic decisions stochastic generators are used such as a section of agent population abide law and the rest do not. In the proposed model (CDM) the decision that whether a driver should abide by the law or not is based on personality profiles of the driver agent. Assuming that the decision to respect a traffic signal is based on i^{th} row then $\Delta(i)$ is computed, let us assume $\Delta(i)$ computes a negative value, then the driver agent will not respect the red light and will jump the signal, and if the value is neutral or positive it will stop at the red light.

Similarly, for continuous decisions such as deciding on a desired acceleration of the vehicle, the personality profile of the driver agent also provides its contribution. Assuming that the choice of acceleration is based on i^{th} row and value of $\Delta(i)$ is positive, then the driver will add that much value of acceleration in the acceleration computed by the underlying acceleration model, while in case of negative value CDM will decrease by that much acceleration value from the amount of acceleration which is computed by the underlying acceleration model.

4. SIMULATION

In the previous section the mathematical formulation of CDM has been presented. This section presents the details of the simulation of CDM. In order to implement the software artefact there were two choices. One was to develop the software artefact from scratch and the other was to find some similar, free and open source implementation and adapt it to the requirements of the proposed model. Both choices have their pros and cons. CDM has been implemented using a free and open source microscopic vehicular traffic flow simulator Movsim. The primary reason of extending this simulator was the modularity of the software which allowed extension of the existing simulator to incorporate CDM in it. Movsim has been used in several studies [1, 16, 17].

For the simplicity, the environment perception module has been skipped in the implementation and environment is directly used as input for the personality profile transition module. In the following section the implementation details of personality profile transition module and decision-making module have been presented.

4.1 Personality profile transition module

While implementing CDM in Movsim the following environmental factors have been modelled as the input of CDM.
- Degree of Congestion (C)
- Degree of Jam (J)
- Degree of Down Stream Signal Distance (SSD)
- Degree of Over Speed and Under Speed (SUS)
- Degree of Distance from Trailing Vehicle (TV)
- Degree of Distance from Front Vehicle (FV)
- Degree of Instability of Left Lane (ILL)
- Degree of Instability of Right Lane (IRL)

Table 1 presents matrix M_S which shows the effect of environmental factors on each personality profile characteristic. In *Table 1* *N*, *E*, *O*, *A* and *C* represent the Big Five traits, namely, neuroticism, extraversion, openness, agreeableness and conscientiousness, respectively.

The personality profile module uses matrix M_S and vector *E* (environment has been used directly instead of perceived environment in simulation experiments) and change values of personality profile as described in mathematical formulation in equations (13), (14), (15), (16), (17) and (18).

Table 1 – Impact of Environment

M_S	Impact of Environment on Personality Profile				
	N	*E*	*O*	*A*	*C*
C	0.667	-0.333	-0.167	-0.500	-0.667
J	0.667	-0.333	-0.167	-0.500	-0.667
SSD	-0.167	0.000	0.167	0.167	0.000
SUS	0.667	-0.167	-0.167	-0.500	0.000
TV	-0.667	0.167	0.167	0.333	-0.500
FV	-0.667	0.167	0.167	0.333	-0.500
ILL	0.667	0.333	0.167	0.333	0.500
IRL	0. 667	0.333	0.167	0.333	0.500

It is worth noting that values presented in *Table 1* are according to the subjective notion of the author about the phenomenon. For realistic reproduction of the phenomena these values must be empirical. It is also worth noting that this feature of the model allows tuning of the model according to a demographic and societal characteristics.

4.2 Decision-making module

The driver agent has to make a decision and take an action. Within Movsim environment the following actions and decisions of a driver have been modelled.
- Respect Speed Limit (RSL)
- Degree of Visibility of Exit Sign (VES)
- Consider Lane Change (CLC)
- Check Safety Criteria while Lane Change (SLC)
- Cooperate with Entering Vehicle by Giving Way (CEV)
- Check Own Acceleration Safety while Changing Lane (ASL)
- Degree of Effect on Acceleration (ACL)
- Degree of Effect on Desired Speed (DSP)
- Consider Traffic Light in Acceleration (TLA)
- Respect Red Light (RRL)
- Degree of Look Ahead Distance Related to Signal (SLA)
- Consider Exit Lane Acceleration (ELA)
- Degree of Effect on Speed and Longitudinal Position (SLP)
- Degree of Acceptable Standstill Gap (ASG)
- Degree of Distance before Mandatory Change Lane for Exit (DCL)
- Check Space before Passing Traffic Signal (SPS)

Table 2 presents matrix M_D which shows the effect of personality profile characteristic on each decision. In *Table 2* *N*, *E*, *O*, *A* and *C* represent neuroticism, extraversion, openness, agreeableness and conscientiousness, respectively. The decision-making module uses matrix M_D and the personality profile of the agent to compute the effect of personality profile on i^{th} decision. To compute the effect of personality profile on i^{th} decision mathematical formulation is described in equations (19), (20) and (21).

Table 2 – Impact personality profile

M_D	Impact of Personality Profile on Decisions				
	N	*E*	*O*	*A*	*C*
RSL	-0.667	0.167	0.167	0.500	0.500
VES	-0.667	0.167	0.000	0.167	0.333
CLC	0.500	0.333	0.333	0.000	0.333
SLC	-0.667	0.000	0.000	0.167	0.500
CEV	-0.667	0.500	0.333	0.333	0.000
ASL	-0.667	0.167	0.000	0.167	0.500
ACL	0.167	0.167	0.167	0.000	0.167
DSP	0.167	0.167	0.167	0.000	0.167
TLA	-0.500	0.333	0.333	0.167	0.500
RRL	-0.833	0.167	0.167	0.167	0.500
SLA	-0.667	0.167	0.167	0.000	0.333
ELA	-0.500	0.167	0.000	0.167	0.500
SLP	0.167	0.167	0.000	0.000	0.000
ASG	-0.500	0.000	0.167	0.000	0.000
DLC	-0.500	0.167	0.167	0.333	0.333
SPS	-0.833	0.333	0.167	0.333	0.333

It is worth noting that the values presented in *Table 2* are in accordance with the subjective notion of the author about the phenomena. For realistic reproduction of the phenomena these values must be empirical. It is also worth noting that this feature of the model allows tuning the model according to different demographic and societal setups.

5. EXPERIMENT AND RESULT

The CDM has been simulated by implementing it in Movsim simulator. In this section experimental configuration and result of simulation has been presented. Different personality profiles can be used to model a driver agent. However, as in [5] three classes of driver agents have been presented which have been used for simulation experiments. These classes include over-controlled, under-controlled and resilient. Following section comprise of description for each driver agent class, experiments and results. Please note that for brevity only results of third class are presented in this paper.

5.1 Driver classes

As described in [5] the personality profiles of three driver agent classes are used in experiments.

1) *Over-controlled Driver*: Over-controlled drivers have higher neuroticism and consciousness, lower extroversion and openness, whereas average acceptance.
2) *Under-controlled Driver*: Under-controlled drivers have higher neuroticism and openness, lower agreeableness and consciousness, whereas average extraversion.
3) *Resilient Driver*: Resilient drivers have lower neuroticism whereas all other personality traits have higher values.

5.2 Experimental configuration

This section describes the experimental configuration of simulation experiment. In this experiment the driver agent is equipped with resilient personality profile. Two environments have been modelled. One environment is *favourable* for the agent because that environment is assumed to affect the personality profile of the agent positively. The driver agent has been exposed to a favourable environment so it is assumed that the agent must make positive decisions and take positive actions. On the other hand, an *unfavourable* environment has been modelled, which is assumed to affect the personality profile of the agent negatively. Here the driver agent is assumed to make a negative decision and perform negative actions. In *Table 3* the personality profile of resilient driver is presented.

Table 3 – Resilient personality profile

	Personality Profile of Resilient Driver				
	N	*E*	*O*	*A*	*C*
S_P	0.25	0.75	0.75	0.75	0.75
S_N	0.75	0.25	0.25	0.25	0.25
S	0.25	0.75	0.75	0.75	0.75

In *Table 3* S_P, S_N and *S* represent positive, negative and accumulated personality profile, respectively, and *N*, *E*, *O*, *A* and *C* represent neuroticism, extraversion, openness, agreeableness and conscientiousness, respectively. *Table 4* presents both favourable and unfavourable environments. An environmental factor can have a value between zero and one but in experiment the best and the worst possible environment has been modelled.

Table 4 – Modelled environment

	Modelled Environments for Agent	
	Favourable	*Unfavourable*
C	0	1
J	0	1
SSD	1	0
SUS	0	1
TV	1	0
FV	1	0
ILL	0	1
IRL	0	1

5.3 Results

Resilient personality profile has been simulated in favourable and unfavourable environments separately. Trace of cognitive states and decisions making of CDM enabled agent has been presented in this section for both environments separately.

Favourable environment

CDM enabled agent having resilient personality profile has been simulated in a favourable environment. *Figure 2* presents the change in cognitive states of the agent over time.

In the graph presented in *Figure 2* the values of cognitive states of the driver agent are on y-axis and time is on x-axis. *N*, *E*, *O*, *A* and *C* are neuroticism, extraversion, openness, agreeableness and conscientiousness, respectively. Here it can be observed that the favourable environment has caused decay in neuroticism and conscientiousness whereas extraversion, openness and agreeableness have increased. The decay in neuroticism is trivial as the environment is favourable while decay in conscientiousness occurs because favourable environment makes the driver relax. In this experiment it has been found that the personality profile transition module works correctly as desired.

To verify the impact of personality profile on the driver's decision-making and actions, a graph has been presented in *Figure 3*. In this Figure the effect of personality profile on various decisions of the driver agent are presented over time.

In *Figure 3* the decisions of the driver are on y-axis and time is on x-axis. A grey mark on the time line

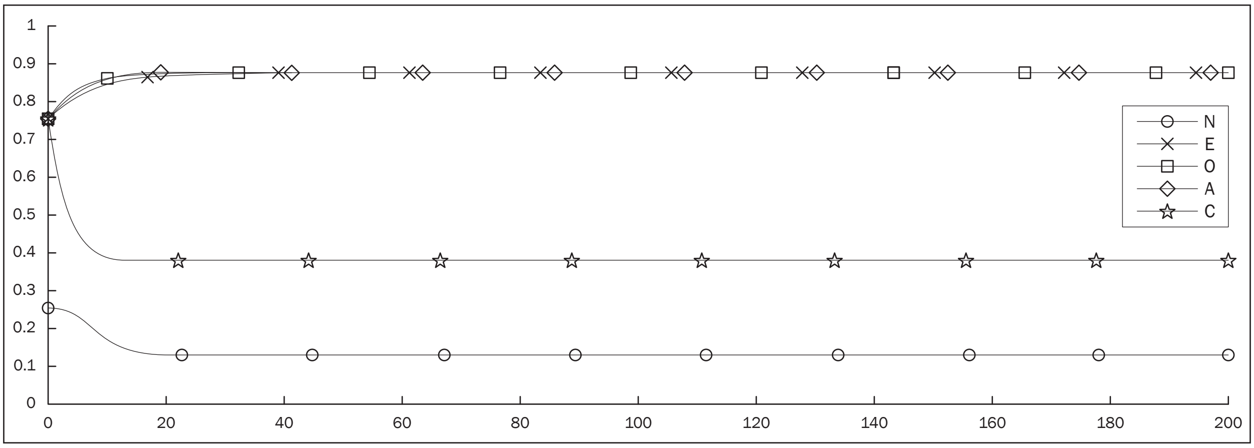

Figure 2 – Resilient driver in favourable environment

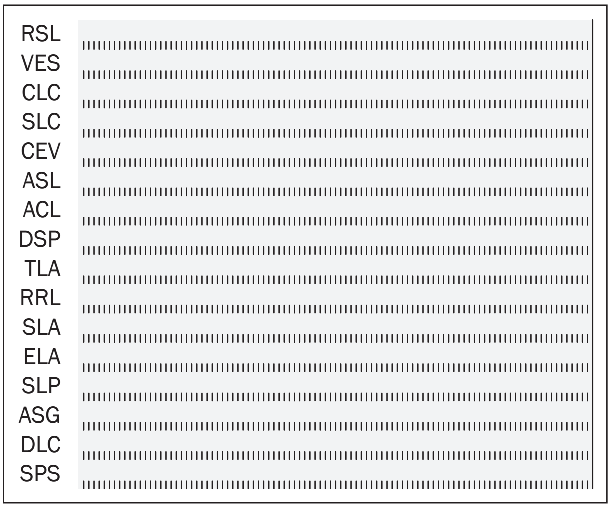

Figure 3 – Impact on decisions in favourable environment

shows that the personality profile of the agent will affect positively the decision i.e. if agent has to take a decision on y-axis on the point in time on x-axis and the impact of personality is positive then there will be a grey mark. A black mark on the time line shows that the personality profile of the agent will have a negative impact i.e. if the agent has to take a decision on y-axis on the point in time on x-axis and the impact of personality is negative, then there will be a black mark. As there is no black mark on the graph in *Figure 3*, it means that the resilient personality profile affected positively the decisions in favourable environment.

Unfavourable environment

In the second experiment a CDM-enabled agent with resilient personality profile has been simulated in unfavourable environment. *Figure 4* presents the transition in cognitive states of the agent in unfavourable environment.

In *Figure 4* the values of cognitive states are presented on y-axis and time is presented on x-axis, while *N*, *E*, *O*, *A* and *C* are neuroticism, extraversion, openness, agreeableness and conscientiousness, respectively. It can be observed that the unfavourable environment has caused a rise in neuroticism of the driver agent, whereas it has caused decay in all other cognitive states. It is worth noting that the neuroticism represents susceptibility to negative emotion such as anger and anxiety. The rise in neuroticism can harm the decision-making ability of a driver agent whereas all other cognitive states are positive in nature. Decay in all other cognitive states except neuroticism impacts decision-making capability of an agent negatively whereas raise in neuroticism is negative. Hence it can be concluded that unfavourable environment has negatively impacted all cognitive states in personality profile of resilient agent.

In *Figure 5* decision of the driver agent are on y-axis and time is on x-axis. A black mark on time line shows that personality profile of agent will impact negatively on decision on y-axis i.e. if agent has to take the decision on y-axis on point in time on x-axis and current values of personality profile impacts that decision negatively there will be a black mark. A grey mark on time line shows that personality profile of agent will impact positively on decision on y-axis, if agent has to take that decision on point in time on x-axis. It can be seen that in start of the simulation there are no black marks on time line. As soon as personality profile of the agent become negative, it started to impact decisions of the agent negatively which can be seen in *Figure 5*. It can be concluded that unfavourable environment impacts personality profile of the agent negatively and a negative personality profile leads to negative decisions.

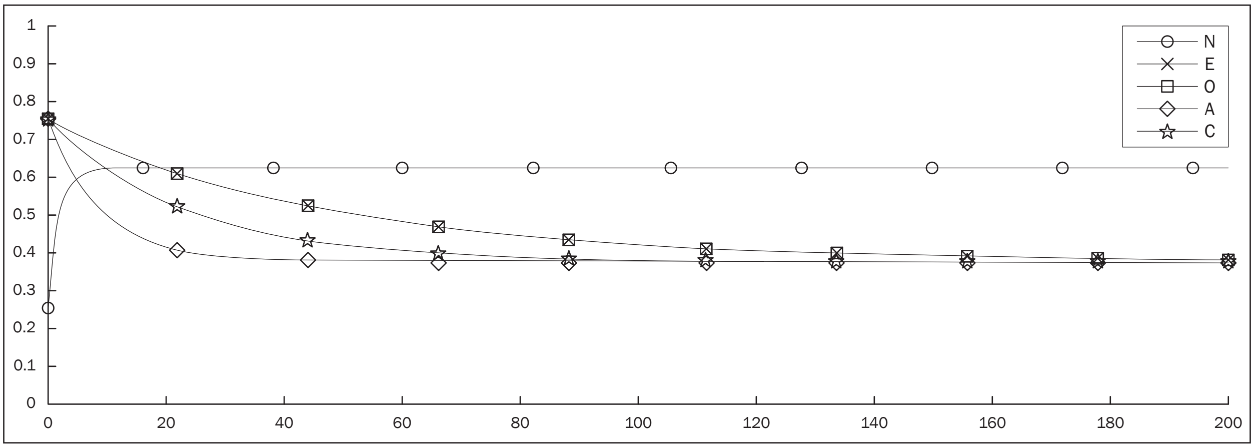

Figure 4 – Resilient driver in unfavourable environment

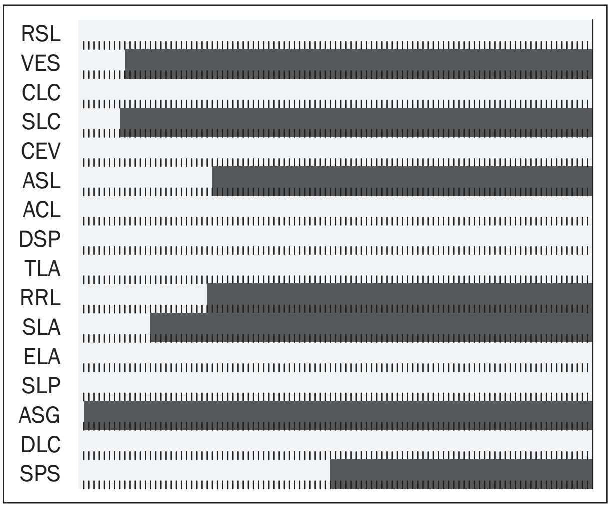

Figure 5 – Impact on decisions in unfavourable environment

6. CONCLUSION

In this paper a cognitive driver model (CDM) has been proposed, modelled and simulated. The model has been inspired by [5] and employed concept from psychology and cognitive sciences which states that human's personality can be expressed as a set of characteristics, namely Big five traits which affects the cognition and consequently decisions of an agent.

This model allows tuning of the driver agent personality traits for different demographic and societal setups as different societies have different tendencies towards different environment configurations. This feature of model allows it to have more realistic behaviour of driver agent according to the social norms of a geographical area under study. For example in every society characteristics of law abidance are different, in some societies driver abide traffic regulation strictly whereas in other societies drivers does not abide traffic regulations and violate law regularly. These types of characteristics can easily be represented in the proposed model using various parameter values in driver agent's perception matrix.

Furthermore, the proposed model is general and it can be used with existing car following and lateral movement models proposed in literature. As those models always behave rationally and are unable to produce realistic driver behaviour. Hence the CDM can be used on the top of existing models to produce realistic driver agent behaviour. Realistic driver agent models are important as driver agents are the primary unit of traffic flow. Such realistic models can be used to understand insights of a complex social system like the urban traffic flow.

7. FUTURE WORK

This paper has presented the CDM which provides the basic framework of personality profile enabled driver agent. In the future, research can be extended in many directions. It is mentioned in this paper that this model can be tuned according to the demography understudy. It is important that the tuning data could be taken from empirical studies. Another important future direction is to simulate this model with multiple driver agents. Multi-agent simulation could be done with homogeneous and heterogeneous agents. Here heterogeneity refers to agents with different personality profiles. Study of effects of different environments on multi-agents is also an important future extension of current work. Furthermore empirical studies can be performed to validate proposed driver agent model. As Big five personality profile of a person can be computed using a psychological test [7] and these values could be fed into the model to predict driving behaviour of the subject under study.

میاں محمد مبشر، ایم فل
سیّد وقار جعفری، پی ایچ ڈی

انسانی شخصیت کی ڈرائیور کے خاکے میں شمولیت

خلاصہ

شہری ٹریفک کا بہاؤ ایک پیچیدہ نظام ہے۔ ایک ڈرائیور کے انفرادی رویے ہنگامی صورتِ حال کا باعث بن سکتے ہیں، جیسا کہ بِھیڑ اور حادثے۔ ڈرائیوروں کا باہمی ربط اور گرد و نواح کے ڈرائیور پر اثرات ٹریفک کی حرکیات کا محرک بنتے ہیں۔ لہذا ٹریفک کے مجموعی بہاوَ کا دارومدار انفرادی ڈرائیور پر ہوتا ہے۔ سنجیدہ کمپیوٹر گیمز، شہری ٹریفک کی منصوبہ بندی اور سمیولیشنز میں ڈرائیور کے خاکے کا استعمال ہوتا ہے۔ لہذا حقیقت سے قریب تر ڈرائیور کے خاکے کی تخلیق خصوصی اہمیت کی حامل ہے۔ اس مقصد کے لیے سوچنے سمجھنے کی صلاحیت والے ڈرائیور کے خاکے کی ضرورت ہے۔ اس خلا کو پر کرنے کے لیے، سوچنے سمجھنے کی صلاحیت اور نفسیات کے نظریات کو بروئے کار لا کر ایک حسابیاتی خاکہ تخلیق کیا گیا ھے۔ یہ حسابیاتی خاکہ نفسیات کے پانچ نقاتی شخصیت کے خاکے کا استعمال کرتے ہوئے ٹریفک قوانین کی پاسداری اور سماجی رویے ظاہر کرنے کی صلاحیت رکھتا ہے۔

اہم الفاظ

ڈرائیور ایجنٹ؛ ٹریفک کی خاکہ نگاری؛ پانچ نقاتی؛ شخصی خاکہ؛ سوچنے، سمجھنے کی صلاحیت کا خاکہ

REFERENCES

[1] Treiber M, Kesting A, Thiemann C. Traffic Flow Dynamics: Data, Models and Simulation. Springer; 2012.

[2] Dia H. An Agent-Based Approach to Modelling Driver Route Choice Behaviour Under the Influence of Real-Time Information. Transp Res Part C Emerg Technol 2002;10:331-49. doi:10.1016/S0968-090X(02)00025-6.

[3] Doniec A, Mandiau R, Piechowiak S, Espié S. A Behavioral Multi-Agent Model for Road Traffic Simulation. Eng Appl Artif Intell. 2008;21:1443-54. doi:10.1016/j.engappai.2008.04.002.

[4] Chen B, Cheng HH. A Review of the Applications of Agent Technology in Traffic and Transportation Systems. IEEE Trans Intell Transp Syst. 2010;11:485-97. doi:10.1109/TITS.2010.2048313.

[5] Seele S, Herpers R, Bauckhage C. Cognitive Agents for Microscopic Traffic Simulations in Virtual Environments. In: Herrlich M, Malaka R, Masuch M, editors. Entertain. Comput. – ICEC 2012, Springer Berlin Heidelberg; 2012, p. 318-25.

[6] Costa PT, McCrae RR. Revised NEO Personality Inventory (NEO PI-R) and NEO Five-Factor Inventory (NEO-FFI). Psychological Assessment Resources; 1992.

[7] John OP, Robins RW, Pervin LA. Handbook of Personality. Theory and Research. 3rd ed. New York, NY, US: Guilford Press; 2008.

[8] John OP, Naumann LP, Soto CJ. Paradigm shift to the integrative Big Five trait taxonomy: History, measurement, and conceptual issues. In: John OP, Robins RW, Pervin LA, editors. Handb. Personal. Theory Res. 3rd ed. New York, NY, US: Guilford Press; 2008, p. 114-58.

[9] Benet-Martínez V, John OP. Los Cinco Grandes across cultures and ethnic groups: multitrait multimethod analyses of the Big Five in Spanish and English. J Pers Soc Psychol. 1998;75:729-50.

[10] Hoogendoorn M, Jaffry SW, Treur J. Modelling Dynamics of Relative Trust of Competitive Information Agents. In: Klusch M, Pěchouček M, Polleres A, editors. Coop. Inf. Agents XII. Springer Berlin Heidelberg; 2008, p. 55-70.

[11] Shortliffe EH, Buchanan BG. A model of inexact reasoning in medicine. Math Biosci. 1975;23:351-79. doi:10.1016/0025-5564(75)90047-4.

[12] Luger GF, Stubblefield WA. Artificial intelligence: structures and strategies for complex problem solving. The Benjamin/Cummings; 1993.

[13] Damasio A. Descartes' Error: Emotion, Reason and the Human Brain. Random House; 2008.

[14] Levin HS, Eisenberg HM, Benton AL. Frontal Lobe Function and Dysfunction. Oxford University Press; 1991.

[15] Hoogendoorn M, Jaffry SW, Treur J. Incorporating Interdependency of Trust Values in Existing Trust Models for Trust Dynamics. In: Nishigaki M, Jøsang A, Murayama Y, Marsh S, editors. Trust Manag. IV. Springer Berlin Heidelberg; 2010, p. 263-76.

[16] Van Willigen W, Haasdijk E, Kester L. A multi-objective approach to evolving platooning strategies in intelligent transportation systems. Proceedings of the 15th annual conference on Genetic and evolutionary computation; 2013 July 6-10; Amsterdam, The Netherlands. New York, NY, USA: ACM; 2013, p. 1397-404. doi:10.1145/2463372.2463534.

[17] Fernandes R, Vieira F, Ferreira M. Parallel microscopic simulation of metropolitan-scale traffic. Proceedings of the 46th Annual Simulation Symposium; 2013 Apr 7-10; San Diego, CA, USA. San Diego, CA, USA: Society for Computer Simulation International; 2013, p. 10:1-10:8.