Incorporation of the Driver's Personality Profile in an Agent Model

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Abstract—Urban traffic flow is a complex system. Behavior of an individual driver can have butterfly effect which can become 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 behavior of each individual driver. Due to several applications of driver models in serious games, urban traffic planning and simulations, study of a realistic driver model is important. Hence cognitive models of a driver agent are required. In order to address this challenge 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.

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

I. INTRODUCTION

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

An increase in urban population has direct correlation with increase in number of vehicles on road. Traffic management in big cities with growing number of vehicles is and has been a great challenge and for a better understanding of this phenomenon computational modeling techniques have been applied. This challenge spans over 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 modeling and simulation techniques applied to date have tried to address these and related problems through design, evaluation and experimentation of urban traffic flow. Through simulating the computational model of urban traffic and experimentations several valuable insights and improvements have been made in cities. Besides overall urban traffic flow, simulation techniques have also assisted in better understanding of the driver's behavior in different scenarios [2] and helped in designing interventions to facilitate the drivers.

In literature several computational models of urban traffic flow are 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 effects overall traffic dynamics. The decentralized approach includes modeling and simulation techniques of cellular automata, and multi agent systems. These techniques are usually thought of as of more faithful and realistic then centralized techniques because of individual's autonomy and freewill for taking decisions which is natural to many social phenomena. For curious readers in [1] an extensive coverage of data, models and simulations related to driver and vehicular traffic modeling is presented.

In the literature of multi agent models of traffic flow [4] where each vehicle is represented as an agent, mostly caters environmental opportunities and agents rational utility and usually ignores agents inherent personality traits. To make multi agent modeling and simulation of traffic flow more realistic such humanistic attributes should be cared of. Bridging this gap, in this paper a driver agent model is proposed which is inspired by theories of psychology and cognitive science about the human personality attributes namely Big Five traits. This model is capable of representing individual's driving behavior in different circumstances and change in individual's behavior overtime. Furthermore proposed model has capacity to be customized for various cultures having different law abidance and social norms.

Rest of the paper is organized as follow; section II presents background, in III is the proposed model, in section IV simulation setup is described, V carries experimental setup and simulation results, while VI and VII provides conclusion and future work respectively.

II.BACK GROUND

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 behavior. Vehicle flow models presented in literature which produce rational behavior are not suitable in such cases. Human drivers don't always behave rationally and usually show irrational behavior such as signal jumping, over speeding, lack of attention etc. To meet this challenge modeling of the driver's cognition is required. In literature a cognitive traffic agent model has been proposed in [5]. This model is based on Big Five traits of human personality in which drivers are divided into three categories namely, over-controllers, under-controllers and resilients. Usually in decentralized simulations of traffic flow situations occur where coordination among drivers is required such as intersection crossing. In such cases if all drivers are egoistic and try to cross intersection a deadlock will occur and incase 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 decision of drivers are determined by the personality profile of the driver. One of the shortcoming of model presented in [5] is that the personalities profiles of drivers are static in nature and does not change over time. In the proposed model this shortcoming is catered using a feedback effect of environment on driver's personality profile overtime.

A. *Big Five Personality Profile*

Big Five personality profile is set of personality traits possessed by a human [6–9]. The list of 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 following section each personality characteristic has been explained briefly.

1) Neuroticism: This personality trait describes the susceptibility of a person towards unpleasant experience which subsequently causes negative emotion such as depression, anger or anxiety.

2) Extraversion: This personality characteristic specifies how much the person is willing to cooperate and communicate with others.

3) Openness: This attribute describes that how much a person is willing to do new experiments and explore new opportunities.

4) *Agreeableness:* This personality characteristic depicts the willingness of the person to respect laws and regulations. While making decisions and taking actions degree of abiding rules and regulation is dependent on the value of this characteristic.

5) *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.

III. 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 takes actions accordingly. Actions taken by the agent are the output. The agent uses personality profile only in tie breaking situations. Whereas in proposed Cognitive Driver Model (CDM) driver agent uses personality profile not only in tiebreaking situation between driver agents, it also involves in environment perception. In CDM the personality profile is not static. Personality profile of the driver agent changes according to the perceived environment, personality profile of the driver agent also plays role in the decision making and actions of the driver agent.

A driver agent takes input from environment, that input may impact positively or negatively the personality profile of that driver agent. Driver agent builds a perception of input environment, personality profile also effects perception of the driver agent hence each driver agent can have different perception of same environment according to their personality profile. Afterwards driver agent makes decisions according to the perceived environment. Actions of the driver agent are also impacted by personality profile of the driver agent. Abstract architecture of the CDM has been presented in Fig. 1 where a causal feedback loop exists between input (environment) perception and the driver agent's personality profile.

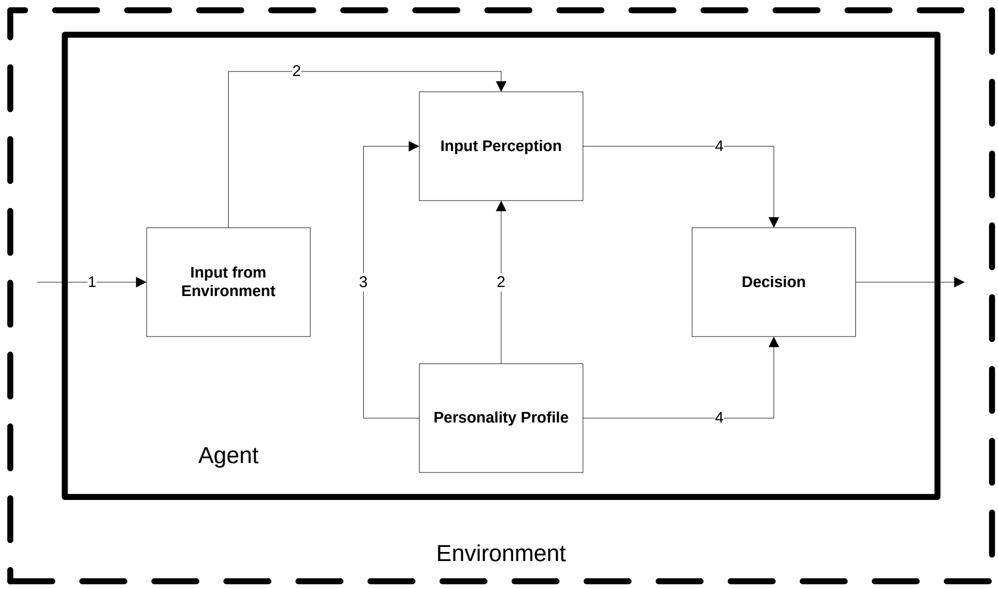

Fig. 1. Abstract architecture of CDM agent

In following section mathematical formulation of CDM is presented.

A. Mathematical Formulation

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

1) Environment

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

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

$$E = \{x | x \in \mathbb{R}, 0 \leq x \leq 1\} \quad (1)$$

$$|E| = n \quad (2)$$

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

2) Personality Profile

Each driver agent perceives its environment according to personality profile it possess (environment perception module is explained below). Personality profile has been modeled such that it comprises of two sets of personality characteristics to retain each personality trait internally. One set is used to retain negative values whereas other is used to retain positive values of personality profile, such approach has been used in [10] to model cognitive agents, the modeling technique is inspired by [11] and [12]. All positive experiences are taken in account 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 set S_P and S_N to represent its personality traits. Both sets comprise of five real numbers, one for each personality trait of Big Five as explained in section II. Positive experiences are accumulated in S_P whereas negative experiences are accumulated in S_N.

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

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

$$|S_P| = |S_N| = 5 = k \quad (5)$$

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

S_P and S_N are the set of real number (3) and (4) respectively which have value between zero and one. As it is described above that personality profile comprise of five characteristics, so cardinality of S_P and S_N is five. However to make 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). Here S represents accumulated personality trait (6). Each accumulated personality trait has value between zero and one due to the formulation presented in (6).

3) Environment Perception Module

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

a) Environment Perception

The process of environment perception has three inputs, first the actual environment E, second the accumulated personality profile of the driver agent referred as S and matrix M_E which describe how a personality profile effects perception of each environmental factor. Degree of each environmental factor in actual environment can be perceived by the driver agent magnified or miniaturized. Personality profile of the driver agent may have neutral, positive or negative contribution in actual degree of environmental factor. Perceived environment is referred as E_P. It is also worth noting that incase of multiple driver agents each driver agent has its own personality profile S whereas matrix M_E is global and tune able.

Let for each environmental factor in E, S_E be the set of real numbers from interval $[-1, 1]$ here E has cardinality k where each member of the set maps to a personality trait. Each member in S_E describes how 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 than there will be n number of S_E sets. It can be represented as a matrix. Let that matrix is named as M_E. Following is the mathematical formulation S_E and M_E.

$$S_E = \{x | x \in \mathbb{R}, -1 \leq x \leq 1\} \quad (7)$$

$$M_E = \{S_{E_1}, S_{E_2}, S_{E_3}, \dots, S_{E_n}\} \quad (8)$$

As it is described earlier that for each environmental factor there is a set 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 effect of each personality trait on each environmental factor (8) following is the mathematical formulation for computing environment perception process.

$$E_P = \{\Omega(x) | x \in E\} \quad (9)$$

$$\Omega(x) = E_{P_i} = \frac{\sum_{j=1}^{k} \Psi(x + (x \times S_j \times M_{E_{i_j}}))}{k} \quad (10)$$

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

4) *Personality Profile Transition Module*

Once driver agent has perceived the environment the perceived environment also affects the personality traits or characteristics of the drive agents. This affect can be neutral, negative or positive. In this section mathematical formulation of personality profile transition has been presented.

As it is described earlier E_P is the set of perceived environment of a driver agent. S_P and S_N are the set of positive and negative personality profile respectively. Let S_S be the set of real numbers from interval $[-1, 1]$ with cardinality k, each member in the set maps to a personality trait. For each environmental factor there is a set S_S which describes how much a perceived environmental factor effect 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 sets, which could be represented as a matrix M_S.

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

$$S_S = \{x | x \in \mathbb{R}, -1 \leq x \leq 1\} \quad (11)$$

$$M_S = \{S_{S_1}, S_{S_2}, S_{S_3}, \dots, S_{S_n}\} \quad (12)$$

$$S_C = \{\phi(1), \phi(2), \phi(3) \ \dots, \phi(k)\} \quad (13)$$

$$\phi(i) = S_{C_i} = \frac{\sum_{j=1}^{n} E_{P_j} \times M_{S_{j_i}}}{n} \quad (14)$$

In (13) ϕ is 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 effects each personality profile trait. It is worth reinforcing that S_C represents an overall effect in personality profile and not the new personality profile.

Once overall effect of perceived environment (13) has been computed as of 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 negative personality profile S_N whereas if change is positive then the value is incorporated in positive personality profile S_P of the driver agent. Following is the mathematical formulation of incorporation of 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 profile respectively.

$$S_P = \{A(S_{P_1}, S_{C_1}), A(S_{P_2}, S_{C_2}), A(S_{P_3}, S_{C_3}), \dots, A(S_{P_k}, S_{C_k})\} \quad (15)$$

$$A(p, c) = \begin{cases} p, & c < 0 \\ p + (1 - p) \times c, & c \geq 0 \end{cases} \quad (16)$$

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

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

Positive personality profile S_P (15) is computed using 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 positive personality profile (16). Negative personality profile S_N (17) is computed using current value of negative personality profile and overall effect in personality profile S_C. $B(p, c)$ is the function which incorporates overall effect in negative personality profile (18). Equation (16) and (18) are the functions which compute 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 above mentioned mathematical formulation is specifying one time computation of a personality trait of a driver agent. In this mathematical formulation notion of time and multiple driver agents are skipped for brevity and comprehension.

5) *Decision Making Module*

This module computes effect of personality profile on decision making of a driver agent. The model assumes that a driver agent is required to make 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 number of decisions is d. Let S_D be the set of k real values and M_D be the set of d elements of type S_D. So M_D could be represented as a matrix of real numbers, one tuple or set for each decision. Each tuple describes how each of personality traits will impact that particular decision. This impact can be positive, negative or neutral. So set S_D has values from interval $[-1, 1]$. Following is mathematical formulation of the decision making module.

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

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

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

S_D is set of real numbers from interval $[-1,1]$ which describes effect of personality profile on a decision (19), this set has cardinality k. Let there are d decisions which an agent can take than M_D matrix has d instances of S_D i.e. having one instance for each decision (20). 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, effect of its personality profile $\Delta(\text{i})$ is computed using (21).

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

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

IV. SIMULATION

In previous section mathematical formulation of CDM has been presented. In this section details of the simulation of CDM have been presented. In order to implement software artifact there were two choices. One was to develop software artifact from scratch and other was to find some similar, free and open source implementation and adapt it to the requirements of 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 environment perception module has been skipped in implementation and environment is directly used as input for personality profile transition module. In the following section implementation details of personality profile transition module and decision making module has been presented.

A. *Personality Profile Transition Module*

While implementing CDM in Movsim following environmental factors have been modeled as the input of the 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 I. presents matrix M_S which shows the effect of environmental factors on each personality profile characteristic. In TABLE I. N, E, O, A and C represents Big Five traits namely neuroticism, extraversion, openness, agreeableness and conscientiousness respectively.

Personality profile module uses matrix M_S and a 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 I. IMPACT OF ENVIRONEMNT

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 I. 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 to tune model according to a demographic and societal characteristics.

B. *Decision Making Module*

Driver agent has to make some decision and take some action. Within Movsim environment following actions and decisions of a driver have been modeled.

- 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 II. presents matrix M_D which shows the effect of personality profile characteristic on each decision. In TABLE II. N, E, O, A and C represents neuroticism, extraversion, openness, agreeableness and conscientiousness respectively. Decision making module uses matrix M_D and personality profile of the agent to compute effect of personality profile on i^{th}

decision. To compute effect of personality profile on i^{th} decision mathematical formulation is described in equations (19), (20) and (21).

TABLE II. 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 values presented in TABLE II. are according to 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.

V. 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.

A. *Driver Classes*

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

1) Over controlled Driver: Over controller drivers have higher neuroticism and conscientiousness, lower extroversion and openness whereas average agreeableness.

2) Under Controlled Driver: Under controller drivers have higher neuroticism and openness, lower agreeableness and conscientiousness whereas average extraversion.

3) Resilient: Resilient drivers have lower neuroticism whereas all other personality traits have higher values.

B. *Experimental Configuration*

In this section experimental configuration of simulation experiment has been described. In this experiment the driver agent is equipped with resilient personality profile. Two environments have been modeled. One environment is *favorable* for agent because that environment is assumed to impact personality profile of the agent positively. Driver agent has been exposed to a favorable environment so it is assumed that agent must make positive decisions and take positive actions. On the other hand an *unfavorable* environment has been modeled which is assumed to impact personality profile of agent negatively here the driver agent is assumed to make negative decision and perform negative actions. In TABLE III. personality profile of resilient driver is presented.

TABLE III. RESELIENT 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 III. S_P, S_N and S represent positive, negative and accumulated personality profile respectively and *N*, *E*, *O*, *A* and *C* represents neuroticism, extraversion, openness, agreeableness and conscientiousness respectively. TABLE IV. presents both favorable and unfavorable environments. An environmental factor can have value between zero and one but in experiment best and worst possible environment has been modeled.

TABLE IV. MODELED ENVIRONEMNT

	Modeled Environments for Agent	
	Favorable	***Unfavorable***
C	0	1
J	0	1
SSD	1	0
SUS	0	1
TV	1	0
FV	1	0
ILL	0	1
IRL	0	1

C. *Results*

Resilient personality profile has been simulated in favorable and unfavorable environment separately. The trace of cognitive states and decisions making of CDM enabled agent has been presented in this section for both environment separately.

1) *Favorable environment*

CDM enabled agent having resilient personality profile has been simulated in favorable environment. Fig. 2 presents change in cognitive states of the agent over time.

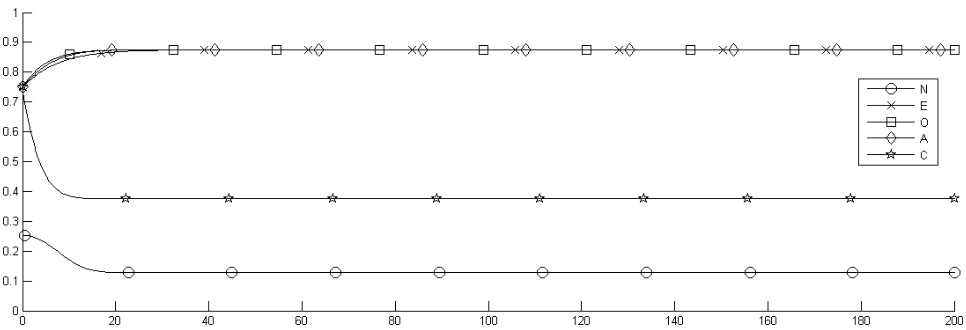

Fig. 2. Resilient driver in favorable environemnt

In the graph presented in Fig. 2 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 favorable environment has caused decay in neuroticism and conscientiousness whereas extraversion, openness and agreeableness have increased. Decay in neuroticism is trivial as the environment is favorable while decay is conscientiousness is occurred because favorable environment make driver relax. In this experiment it has been found that personality profile transition module is working correctly as desired.

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

In Fig. 3 decisions of driver are on y-axis and time is on x-axis. A gray mark on time line shows that personality profile of agent has positive impact on decision i.e. if agent has to take the decision as on y-axis and the point in time on x-axis and impact of personality is positive than there will be a grey mark. A black mark on time line shows that personality profile of agent has negative impact i.e. if agent has to take the decision as on y-axis and the point in time on x-axis and impact of personality is negative than there will be a black mark. As there is no black mark on graph in Fig. 3 it means resilient personality profile impacted positively on decisions in favorable environment.

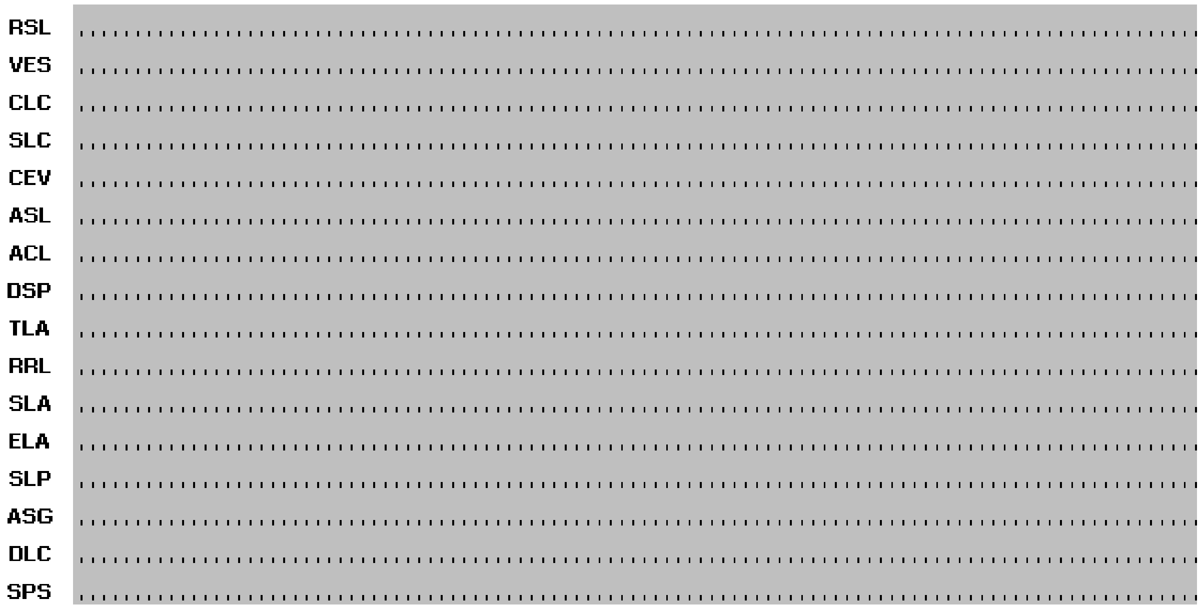

Fig. 3. Impact on decisions in favorable environemnt

2) Unfavorablee environemnt

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

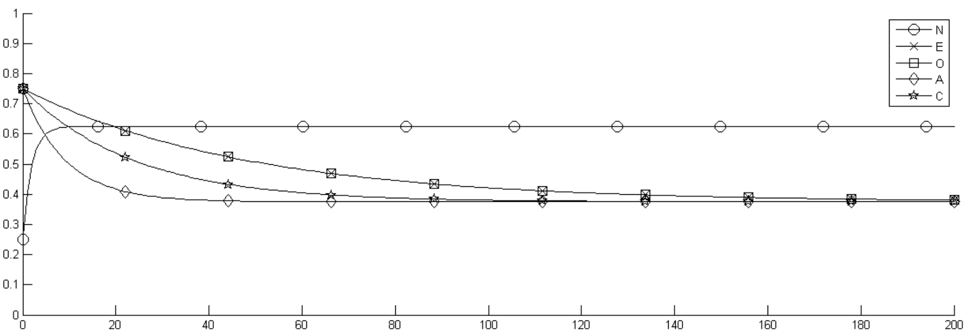

Fig. 4. Resilient driver in unfavorable environemnt

In Fig. 4 values of cognitive states are presented on y-axis and time is presented on x-axis while legends N, E, O, A and C are neuroticism, extraversion, openness, agreeableness and conscientiousness respectively. It can be observed that the unfavorable environment has caused raise 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. Raise 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 unfavorable environment has negatively impacted all cognitive states in personality profile of resilient agent.

In Fig. 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 and on point in time on x-axis and current values of personality profile impacts that decision negatively then there will be a black mark. A gray 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 Fig. 5. It can be concluded that unfavorable environment impacts personality profile of the agent negatively and a negative personality profile leads to negative decisions.

Fig. 5. Impact on decision in unfavorable environment

VI. CONCLUSION

In this paper a cognitive driver model (CDM) has been proposed, modeled 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 behavior 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 type 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 behavior. Hence the CDM can be used on the top of existing models to produce realistic driver agent behavior. 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.

VII. FUTURE WORK

In this paper CDM has been presented which provides basic framework of personality profile enabled driver agent. In future, research can be extended in many directions. It is mentioned in the 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 feed into model to predict driving behavior of the subject under study.

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