Article

Title: Drivers' behaviour modelling for virtual worlds

Creators: Sidoumou, M. R., Bechkoum, K. and Benatchba, K.

DOI: 10.1007/978-3-319-00804-2_1

Example citation: Sidoumou, M. R., Bechkoum, K. and Benatchba, K. (2013) Drivers' behaviour modelling for virtual worlds. *Studies in Computational Intelligence.* **493**, pp. 1-15. 1860-949X.

Version: Accepted version

Official URL: http://link.springer.com/content/pdf/10.1007%2F978-3-319-00804-2_1.pdf

Note: This is the author's accepted manuscript of an article published in Studies in Computational Intelligence. The final publication is available at http://link.springer.com/content/pdf/10.1007%2F978-3-319-00804-2_1.pdf.

Drivers' Behaviour Modelling for Virtual Worlds

A multi-agent approach

Mohamed Rédha Sidoumou
LRDSI, Sciences Faculty
University Saad Dahlab of Blida
Algeria
sidoumoumr@hotmail.com

Kamal Bechkoum
School of Science & Technology
University of Northampton
UK
kamal.bechkoum@northampton.ac.uk

Karima Benatchba
Ecole Nationale Supérieure d'Informatique
Algeria
k_benatchba@esi.dz

***Abstract*—In this paper we present a study that looks at modelling drivers' behaviour with a view to contribute to the problem of road rage. The approach we adopt is based on agent technology, particularly multi-agent systems. Each driver is represented by a software agent. A virtual environment is used to simulate drivers' behaviour, thus enabling us to observe the conditions leading to road rage. The simulated model is then used to suggest possible ways of alleviating this societal problem. Our agents are equipped with an emotional module which will make their behaviours more human-like. For this, we propose a computational emotion model based on the OCC model and probabilistic cognitive maps. The key influencing factors that are included in the model are personality, emotions and some social/personal attributes.**

Keywords—Agent; emotions; personality; behaviour; simulation;

I. Introduction

Road rage is one of the major problems that we face in today's roads. In this paper we propose to study this phenomenon through simulation, with a view to come up with ways of alleviating its negative impact. For the simulation to be effective we need to model drivers' behaviour in an environment similar to the real world where car drivers and other users of the road compete for the same space.

Drivers' behaviour modelling is a complex and multi-faceted-task. Before attempting to model such a behaviour, we need to understand what constitutes human's cognition. We need to know which parameters are influencing our decisions while driving. We also need to know how these parameters are influenced and, indeed, are there any inter-influences between these parameters.

There are many variables that contribute to humans' cognition, but we are limiting this list to the most relevant ones that are believed to have higher influence on drivers' behaviour. For example, cooking skills can be relevant in daily life cognition and some decisions are influenced by it, but we do not see any direct relevance to the driving process. We also need to support the choice of our parameters by borrowing concepts emanating from psychological and social studies. Such parameters include personality, emotional state, driving skills, age, gender and knowledge of the map.

Once the parameters selected, we present the relationship between them and the factors that affect them. For example: how is the personality affecting emotions? How can emotions change over time and what are the effects of all of these variables on the drivers' behaviour?

This modelling will help us create a drivers' behaviour architecture giving us the possibility to explore its implementation using techniques from AI. For this, intelligent agents appear to be a good candidate given their attributes, such as learning and the ability to cooperate.

In the literature we have reviewed, modelling driver behaviour focuses on low level operations like eye movement, lane changing and cognitive reasoning. They do not address the influence of personality and emotions. Our goal is to reduce road rage and we think that personality and emotions are among the most influential factors in road rage.

In addition to these introductory notes the remainder of this paper is organised around the following sections:

Section two introduces the definition of *Road Rage* and the motivations behind this work. The third section presents the variables that influence drivers' behaviour like personality and emotions with literature discussions. In the fourth section we present our emotion model based on the OCC (named after its authors **O**rthony, **C**lore and **C**ollins) and a variation of cognitive maps. We give also an example using our model. The fifth section is about modelling the full behaviour. In this section we present our plan into modelling drivers' behaviour using all the parameters we discussed and our emotion model. Concluding remarks are presented in section six.

II. Road Rage

Some disagreements exist among researchers on how to classify a specific reckless driving behaviour as road rage [1]. According to [1] two definitions are used often in research. The first one is: "*an assault with a motor vehicle or other weapon on other vehicles, precipitated by a specific incident*" [2]. The second definition is: "*a deliberate attempt to harm other persons or property arising from an incident involving use of a motor vehicle*" [3]. According to [1] the NHTSA (National Highway Traffic Safety Administration) clearly distinguishes aggressive driving from road rage. For example, from a legal point of view, aggressive driving like speeding is a traffic offense, whereas road rage is a criminal offense [1]. Takaku also quotes a study conducted by AAA's (American Automobile Association) Foundation for Traffic Safety that found that road-rage incidents increased by more than 50% between 1990 and 1996. The study also quotes the cost of the society in the region of $250 billion per year, in addition to the human casualties [4],[5]. A study carried out by AAA Foundation looked at more than 10,000 road rage incidents committed over seven years, and found they resulted in at least 218 fatalities and another 12,610 injury cases. According to this study, 2.18% of road rages end with death and a great deal of injury cases. From these studies it is pretty clear that road rage is a serious problem that cannot be ignored. The aim of this work is to try and contribute towards minimizing the impact of this problem. To do this we propose to simulate cars' traffic using a number a parameters that influence road rage. The next section outlines some of these influencing parameters.

III. Driver behaviour modelling: influencing factors

To model drivers' behaviour we start by selecting the different parameters affecting it. Those parameters can be psychological, Social or personal. For the purpose of this work only the parameters that are likely to influence drivers' behaviour are explored. We assume that our drivers have a minimum level of driving capability and therefore driver's technical ability is not taken into account.

A. Personality

Personality is that pattern of characteristic thoughts, feelings, and behaviours that distinguishes one person from another and that persists over time and situations [6]. Personality is an important factor in human behaviour since humans with the same goal and in similar circumstances may behave differently according to their personalities. In our context, two drivers may behave differently under the same circumstances.

In [7], it is stated that personality traits and gender were found to explain 37.3% of the variance in risky driving behaviour. In [8] a study to understand the relationship between personality and the number of fines received stated that conscientiousness factor was a key to negatively predict the number and amount of financial fines the drivers had during the last three years. The openness factor positively predicted the number of fines they had in the last 3 years and the amount of financial fines during the last year. The extraversion factor both meaningfully and positively could predict only the amount of financial fines they had during the last year [8]. According to [9] Personality and driving behaviour have strong correlations [10]. Again, [11] is quoted in [9] to claim that most studies found significant positive relations between sensation seeking and aspects of aggressive and risky driving. The studies mentioned above all point to the same intuitive fact, namely that the personality is a key influencing factor in drivers' behaviour.

There are many personality models that consist of a set of dimensions, where every dimension is a specific property [12]. In the past two decades there has been remarkable progress in one of the oldest branches of personality psychology: the study of traits or individual differences [13]. To integrate the personality factor in our modelling we need to select a personality model. In [13] there is a growing agreement among personality psychologists that most individual differences in personality can be understood in terms of five basic dimensions: Neuroticism (N) vs. Emotional Stability; Extraversion (E) or Surgency; Openness to Experience (O) or Intellect; Agreeableness (A) vs. Antagonism; and Conscientiousness (C) or Will to Achieve [14], [15], [16].

In [13] the five factors are described as follows:

- *Neuroticism*, it represents the individual's tendency to experience psychological distress, and high standing on N is a feature of most psychiatric conditions. Indeed, differential diagnosis often amounts to a determination of which aspect of N (e.g., anxiety or depression) is most prominent.
- *Extraversion* is the dimension underlying a broad group of traits; including sociability, activity, and the tendency to experience positive emotions such as joy and pleasure. Patients with histrionic and schizoid personality disorders differ primarily along this dimension. [17] and [18] have pointed out that talkative extraverts respond very differently to talk-oriented psychotherapies than do reserved and reticent introverts.
- *Openness* is how ready you are to Experience. High-O individuals are imaginative and sensitive to art and beauty and have a rich and complex emotional life. They are intellectually curious, behaviourally flexible, and nondogmatic in their attitudes and values [19].
- *Agreeableness*, like E, is primarily a dimension of interpersonal behaviour. High-A individuals are trusting, sympathetic, and cooperative; low-A individuals are cynical, callous, and antagonistic.
- *Conscientiousness* is a dimension that contrasts scrupulous, well-organized, and diligent people with lax, disorganized, and lackadaisical individuals. Conscientiousness is associated with academic and vocational success [20].

Each dimension has six facets [12]. For the sake of simplicity these facets are not covered in this research.

Several tests exist to measure the personality traits and their respective facets or just the traits. Among the existing tests we can mention The NEO PI-R and The NEO-FFI. According to [21] NEO PI-R is a 240-item inventory developed by Paul Costa and Jeff McCrae. It measures not only the Big Five (the five traits), but also six "facets" (subordinate dimensions) of each of the Big Five [21]. The NEO PI-R is a commercial product, controlled by a for-profit corporation that expects people to get permission and, in many cases; pay to use it [21]. Costa and McCrae have also created the NEO-FFI, a 60-item truncated version of the NEO PI-R that only measures the five factors. The NEO-FFI is also commercially controlled [21].

Another alternative test is The International Personality Item Pool. According to [21] it is developed and maintained by Lew Goldberg, has scales constructed to work as analogs to the commercial NEO PI-R and NEO-FFI scales (see below). IPIP scales are 100% public domain - no permission is required for their use.

We choose the OCEAN model because it is the most accepted model among psychologists and the availability of free questionnaire to measure the personality traits according to it.

B. *Emotions*

According to [22] emotions were seen as an undesirable product of the human mind. Therefore the less the person is emotional the more intelligent and desirable he/she is. An opposite view says that currently, researchers claim that emotions are part of life and are necessary in intelligent behaviour [23], [24]. We outline the importance of emotions in driving behaviour in what follows.

1) *Importance of emotions in driving behaviour*

In [25] an experience has been done with happy, sad and neutral music alternated with no-music phases while driving in a simulator. Results showed that happy music distracted drivers as their mean speed unexpectedly decreased and their lateral control deteriorated. Sad music caused drivers to drive slowly and kept their vehicle in its lane.

According to [25] in one study, the author noticed that drivers who experienced anger accelerated and committed more traffic violations than others and [26] concluded that emotions influence traffic risk evaluation and general driving behaviour. [25] quote the work of [27] and [28] stating that anger is one of the most common negative emotions experienced during driving, leading to aggressive driving behaviour. In this sense, angry drivers intentionally endanger others with aggressive verbal and/or physical expressions [25]. Emotions like sadness, discontentment or joy are likely to impact on attention, leading to a different driving style. According to [29] a research study looked into the cause of accidents. Driver behaviour is one of the main reasons for this predicament while emotion plays a vital role as it affects the driver's behaviour itself. In understanding the correlation between drivers' behaviour and emotion, the analysis results of an experience conducted by [29] showed that for each driver pre- cursor emotion will affect the emotion in pre-accident whereas negative emotions appear frequently in post-accident compared to positive emotion. The studies above seem to be pointing to the fact that emotions have a direct impact on drivers' behaviour. For this reason a model for emotions is considered as a key component of our system.

2) *Emotion models*

Most evaluation models are based on the principle that emotions arise as a consequence to a cognitive evaluation of the environment [30]. According to [30], Lazarus [31] created a model of assessment in which he unified evaluation (appraisal) and adaptation (coping). In fact, he distinguished between two types of evaluation: (1) primary, which assesses the relevance of an event and its congruence with the goals or not, (2) the secondary assessing what can or should be done to respond to this event [30]. According to [30], Roseman and Spindel [32] created a model in which he identified five criteria for evaluating events. Depending on the values of these criteria they characterize thirteen distinct emotions. The first criterion determines whether a situation is positive or negative relative to the goals of the individual. The second criterion determines whether the situation is in agreement or not with the state of motivation. The third criterion is related to the certainty or uncertainty of the event. The fourth criterion defines whether a person perceives himself in a given situation, as strong or weak. The fifth criterion is the origin of the event, whether it is related to the circumstances, or rather linked to the individual himself or others. Among these models the OCC model [33], is one of the most used in computing [30]. In OCC the authors define 22 types of emotion. Same types of emotions are triggered in similar situations. To every emotion is defined an opposite emotion. For example, sadness is the opposite of joy [30]. More recently, Ortony (one of the authors of the model) has simplified OCC model by grouping types of emotions to finally define five types of positive emotions and 6 types of negative emotions [34]. According to [34] in the OCC model, three classes are defined according to their triggering cause:

- The emotions triggered by an event affecting an object of the individual, such as joy, hope or fear.
- The emotions triggered by an event affecting a principle or standard, such as shame, pride or reproach.
- The emotions triggered by the perception of particular objects (animated or unanimated, concrete or abstract) such as love or hate.

The authors define global variables that determine the intensity of the emotions and local variables (specific to each of the above classes) that will determine both the type and intensity of the emotions of each class. This model is the most widely used model to simulate processes triggering emotions in computational systems [34]. The figure 1 represents the original structure of the OCC model.

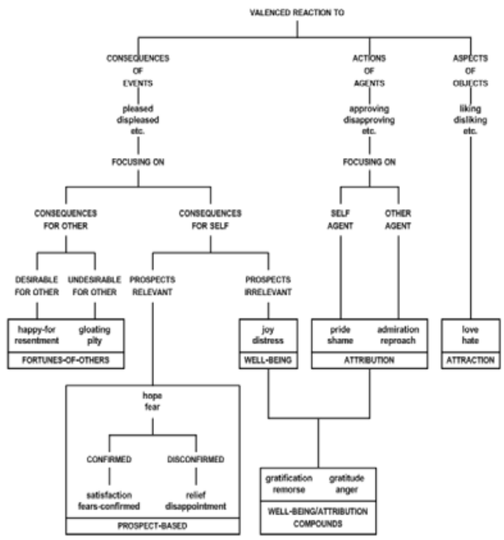

Figure 1: Original structure of the OCC model [33]

Let's assume that the person being considered (as a potential case for road rage) is described by a software agent. Let us also define the agent's external world as a set of events on the agent, actions of other agents and the agent's own perceptions of objects. Similarly, we define the agent's internal world as a set of agent's goals, its standards and attitudes. These definitions are based on the work by [33]. These two worlds will interact and trigger any one or more of the 22 emotions. The concrete definition of goals, standards and attitudes are domain specific and should be defined by the final user. Figure 2 shows the specifications of the 22 emotions presented in the OCC model.

The emotional model we propose in the next section is based on the OCC model due to its simplicity, but also to the fairly comprehensive types of emotions covered.

Joy: (pleased about) a desirable event
Distress: (displeased about) an undesirable event
Happy-for: (pleased about) an event presumed to be desirable for someone else
Pity: (displeased about) an event presumed to be undesirable for someone else
Gloating: (pleased about) an event presumed to be undesirable for someone else
Resentment: (displeased about) an event presumed to be desirable for someone else
Hope: (pleased about) the prospect of a desirable event
Fear: (displeased about) the prospect of an undesirable event
Satisfaction: (pleased about) the confirmation of the prospect of a desirable event
Fears-confirmed: (displeased about) the confirmation of the prospect of an undesirable event
Relief: (pleased about) the disconfirmation of the prospect of an undesirable event
Disappointment: (displeased about) the disconfirmation of the prospect of a desirable event
Pride: (approving of) one's own praiseworthy action
Shame: (disapproving of) one's own blameworthy action
Admiration: (approving of) someone else's praiseworthy action
Reproach: (disapproving of) someone else's blameworthy action
Gratification: (approving of) one's own praiseworthy action and (being pleased about) the related desirable event
Remorse: (disapproving of) one's own blameworthy action and (being displeased about) the related undesirable event
Gratitude: (approving of) someone else's praiseworthy action and (being pleased about) the related desirable event
Anger: (disapproving of) someone else's blameworthy action and (being displeased about) the related undesirable event
Love: (liking) an appealing object
Hate: (disliking) an unappealing object

Figure 2: Specifications of the 22 types of emotions [33]

C. *Social and personal attributes*

In what follows, we present the effects of personal/social attributes of drivers on their driving behaviour. We included most of these attributes in our model. These are presented below. For the few that are not included, reasons of their omission are given.

- *Gender*: In [7], it is stated that personality traits and gender were found to explain 37.3% of the variance in risky driving behaviour.
- Age: A survey done by Jonah [11] states that young drivers [16, 24] are more likely to engage in dangerous driving. [16, 19] age group were more likely to have more accidents and violation rates than the others groups.
- *Knowledge of the area*: According to [9] Route knowledge has been identified as important for the driving task [36].
- *Fatigue*: Many papers stated that fatigue has an influence on driver's perceptions and evaluation/ response time.
- *Type of the car*: Depending on the type of the car some people will drive differently. For example a driver using a Land Rover will drive with a different way than driving a small car. On the other hand some studies state that an over reliance on automation will decrease driver's vigilance.

Based on the findings of the studies above, the following parameters will be incorporated in our model: Gender, Age, Knowledge of the area, Type of the car. We don't include fatigue for the sake of simplicity of the modelling.

D. *Cognitive reactions*

To every situation an agent could have a different reaction. This reaction could depend on his personality, emotions or culture. The reactions of the agent (driver) could have different impacts on the future outcomes of an encounter, e.g.: an encounter might be a conflict between one driver and another. Depending on the reactions we may boost the actual rage or lower it. For example, if a driver A is blocking driver B and driver A is driving at a low speed. If B replies to A with an insult or a gesture, A might do an action frustrating B even more. On the other hand if driver B uses less aggressive manners to express his anger, A's reaction may be less aggressive too. Such actions may depend on the personality and the emotions but they may also depend on the values of the persons. Is insulting someone OK for our self-image or is it shameful? It is the society's interpretation of the possible reactions and to what extent a driver would go in a given situation. One of the solutions we will exploit to alleviate the road rage problem is influencing the reactions of people in negative emotional states. A way to influence those reactions is by influencing the values of the society.

IV. PROPOSED EMOTIONAL MODEL

Our agents will incorporate an emotional model. This model is used to simulate human emotions by the agent. The agents are tasked to simulate the entire driver behaviour. The emotional module is a part of this entire behaviour.

A. *Architecture of the model*

Our emotional model will be based on the OCC model. Its aim is to predict the emotions felt by the drivers and their intensities. The OCC model defines the standards, goals and attitudes [33] to evaluate the intensities of the felt emotions in any particular group (event, object or agent) alongside with other variables. We add to our model "the beliefs". The beliefs are what a driver believe about a current situation and how does it interact with his standards, goals and attitudes. We have chosen to use a probabilistic form of cognitive maps to represent beliefs and their co-influence. In real life, a belief can influence another belief, e.g. if I believe that if it rains then a football game may be delayed. The word "may" can be translated into a probability. Thus, the belief "It rains" and the belief "Football game delayed" are in a relationship of effect with a probability. Therefore, we believe that a probabilistic cognitive map is a good representation of the beliefs and their relationships.

We distinguish two types of nodes in our cognitive map. The first type are nodes representing a belief. The second type are nodes representing an effect. The effect nodes will not have any incoming arcs (input) and they are marked with the prefix "Eff". The belief nodes are nodes representing a possible belief in the current situation. The weights of the "arcs" are the probability of the belief to be true. For example if we have an "arc" from node A to Node B weighted to X, this means that if A is true then B has a probability of X to be true.

In our model, emotions are triggered by modifications of beliefs and not directly via events, actions of agents or objects. An effect could trigger an event, an action of an agent or the visibility of an object. Such unification of events, action of agents and objects in effects is due to the fact that any situation could create many events, actions or objects perceived at the same time. As an example: consider a person 'A' driving a car who accidentally crashes into a driver 'B'. Driver 'A' may focus on the damage of the car and then perceive what happened as an event and feel distress. Driver 'A' may focus on driver 'B' as a driver who is causing damage to him (as an agent) and then feels reproach. And the last scenario, is that driver 'A' will perceive driver 'B' as a reckless driver (object) and feel hate for him. According to [33] some of those emotions could occur (e.g. 'A' feels only distress) and some could occur successively; depending on the person experiencing the situation.

We believe that an effect could trigger many emotions at the same time and then cause the change of several beliefs. An effect may not trigger the same emotions in everybody. It could produce many events, actions and perceived objects but this production could be different from one person to another. The order of perception may be different from one person to another too. An example of the probabilistic cognitive map is presented in figure 3.

To determine which emotion is going to be felt after the modification of a belief, we trace this modification to the effect triggering it. If this effect is perceived as an event we will trigger an event-based emotion. The desirability of the variation in the belief and its effects on the goals/standards/attitudes will determine whether the emotion is positive or negative. Some beliefs' variations might not trigger any emotions directly.

We plan to use the profile (personality + social parameters+ previous emotions) of the person to predict what a given driver may perceive and in what order through live experience with drivers.

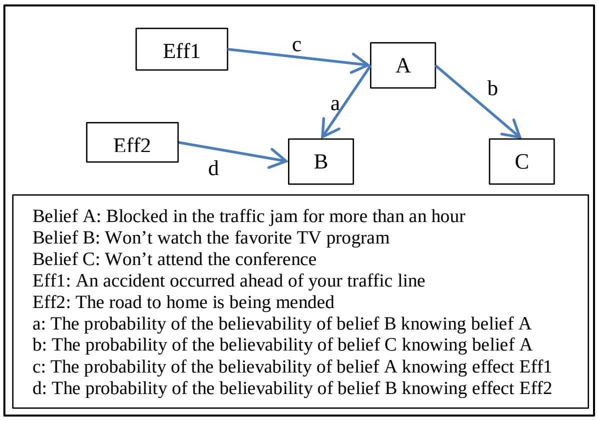

Figure 3: An example of the probabilistic cognitive map

B. Computation of the intensities

Once the design of the probabilistic cognitive map completed, we proceed with defining the intensities of the emotions felt. The intensities will depend on the beliefs variations, the personality, the importance of the goals/standards/attitudes interacting with the targeted belief (e.g. in completing the goals positively or negatively), the surprise element and the intensity of the current emotions.

The intensity of the felt emotions will decrease over time. The decreasing speed will depend on the personality and social/personal attributes. Prospect relevant emotions like fear and hope will not decrease over time but will turn into relieved/fear confirmed and satisfaction/disappointment respectively depending on the confirmation of those two emotions.

C. Scenarios

Here are scenarios giving more explanations about the emotional model:

Let a person named Bob who wants to go to a stadium to watch a football game. Figure 4 presents the cognitive map of Bob's beliefs. Here is the description of those beliefs:

A: Traffic jam problem

B: Will be late to the stadium

C: The car was damaged (Event)

D: Seeing an unappealing object

E: A driver has damaged the car (action of an agent)

Eff1 and Eff2 are respectively an official visiting the town and a driver crashing into Bob's car causing damage to the car. As we can see the beliefs C and E are two different beliefs. These beliefs are triggered by the same effect which is "a driver crashing into Bob's car causing damage to your car" and although they appear to be similar but they might occur in two different consecutive moments and they trigger two different emotions.

Any driver with the same goals as Bob's goals and in similar external circumstances will have the same probabilistic cognitive map as Bob's but with different weights. The weights depend on personality and personal/social attributes of the driver.

Bob's weights are as follows: a=0.7, b= 1, c= 0.5, d= 0.8, e=1, f=1

Here we have two examples of what may happen:

- If Eff1 occurs, belief 'A' will be true at 70% and belief 'B' will be true at 70% X 50% which is 35%. Belief 'B' will have an influence on Bob's goal (arriving to the stadium before the starting of the game). The variation of the veracity of belief 'B' will trigger an emotion. To detect which emotion will be triggered we need to look at the effect that was at the origin of the variation of belief 'B'. In this case Eff1 will be perceived as an event with a negative impact on the driver. Because belief 'B' is not 100% true, the emotions that will be felt are prospect relevant. In this case Bob will feel 'Fear'. The intensity of this emotion will be determined by the personality/social attributes, surprise, the previous emotional state and the importance of the goal. If the goal is met 'Bob' will feel relieved otherwise he will have his fears confirmed. In our model prospect based emotions will not decrease over time because this type of emotion depends on a probability and not on a fact; a belief not true yet but may be true in the future. After their confirmation or disconfirmation the resulted emotion will decrease over time. Here the emotion *relief* and *fears-confirmed* will decrease over time (if felt).

- If ‘Eff2’ occurs, Bob may perceive this effect from three different angles. He will perceive it as an event, an action of an agent and an object. Bob’s order of perception will not be discussed here. If he starts by perceiving ‘Eff2’ as an event then belief ‘C’ will be true at 90%. Belief ‘B’ will be affected also and will be true at 100% X 80% which is 80%. The variation of belief ‘B’ will interact with a goal and is originally triggered by an event. Thus, ‘Bob’ will perceive *fear*. The intensity will depend on the same parameters cited above.

‘Bob’ will then perceive ‘Eff2’ as an action of an agent. Belief ‘E’ will be true at 100%. This belief has an interaction with the standards of ‘Bob’, which will trigger action based emotions. In this case it is ‘*reproach*’ that will be felt. The intensity depends on the same parameters mentioned above. The ‘*reproach*’ feeling will decrease over time.

Finally ‘Bob’ will perceive ‘Eff2’ as an unappealing object which will trigger ‘*hate*’.

As mentioned above the order in which these perceptions (event, action and object) occur will not be discussed here.

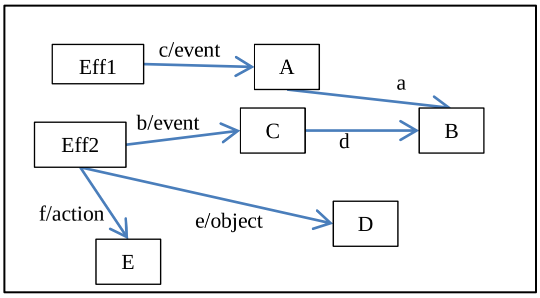

Figure 4: Bob’s probabilistic cognitive map

V. Modelling the Behaviour

After modelling the emotional module, the next stage will be modelling the behaviour of the drivers. The behaviour of the driver will depend on the goals, personality, emotions, social/personal attributes and the values (a set of expected cognitive reactions) of the driver. The emotional module will act as a precursor to the behavioural module. A classification method must be defined (neural networks, genetic algorithms, neuro-fuzzy) to predict drivers’ behaviours using the selected parameters. The classes that the classification method will have to predict are the possible reactions.

After modelling the entire drivers’ behaviours, we will simulate a whole driving behaviours in a virtual city with different types of drivers with different goals for each. Each driver is represented by an agent. Agents are composed of an emotional module and a behavioural module. Emotional module is meant to compute agent’s emotions and their intensities. Behavioural module will use all the parameters above to produce agent’s behaviour. The environment of the agents is a representation of a 3D city and its roads. In this environment, there will be a lot of interactions between agents since every agent has the possibility to initiate many effects and then triggering a set of emotions on the other agents. The figure 5 presents the structure of agents.

We will use a monitoring system to observe the development of road rage and the actions leading to road rage. We will try some possible solutions in our system (like influencing personalities, influencing the values…) and evaluate them. The solutions we will propose will not concern driver’s capabilities as we assume that most drivers have a minimum level of driving aptitude. Our focus will be on psychological and social aspects.

A 3D visualisation module is developed to monitor in a 3D environment the dynamics of the city.

We plan to compute the number of negative actions carried out by the drivers and how the propagation of those actions will affect them in the future. The aim of this is to make the drivers aware of their actions and the impact of their actions on them and other users of the road.

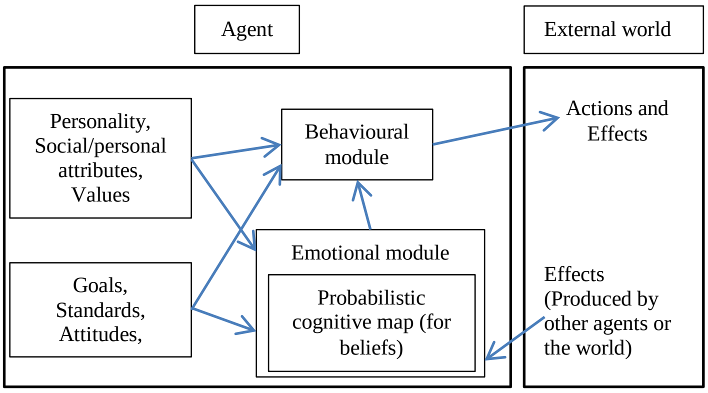

Figure 5: Structure of agent

VI. Conclusion and Future Work

Modelling human’s behaviour is not an easy task. Its complexity is as complex as humans are. We needed to look at what constitute human’s cognition. The number of variables influencing human’s behaviour is very large. However, when looking at it in the context of a specific aspect like driving behaviour, we could select less parameters than the parameters needed to model an entire human’s behaviour. Those selected parameters do not have the same importance during modelling the different stages that constitute driver’s behaviour.

In this study, we started by exploring what influences drivers’ behaviour. For this we selected personality, emotions, social/personal parameters and values. For *personality* we used the OCEAN model and for *emotion* we proposed our own model based on the OCC model where we have defined a set of interactions influencing emotions. In the future, we will specify the interactions between various types of simultaneous emotions and their impact on each other. For the sake of simplicity we did not include driving abilities. Instead, we assume that all of the drivers have a minimum level of driving skills. The solutions that we will be proposing are psychological/social rather than based on driving skills.

The next stage in this research is to model the entire driving behaviour using machine learning techniques.

[1] S. Takaku, "Reducing road rage: An application of the dissonance-attribution model of interpersonal forgiveness." *Journal of Applied Social Psychology*, vol. 36, pp. 2362–2378, 2006

[2] National Highway Traffic Safety Administration. "Welcome to Stop Aggressive Driving." Internet: http://www.nhtsa.dot.gov/people/injury/aggressive/Aggressive%20Web/sse_1.html, 2004, [Nov. 20, 2012].

[3] American Automobile Association Foundation for Traffic Safety. (1997). *Aggressive driving: Three studies*. Washington, DC: Author, 1997.

[4] L. James, and D. Nahl, (2000) *Road rage and aggressive driving: Steering clear of highway warfare*. Amherst: Prometheus, 2000

[5] B. S. Sharkin. "Road rage: Risk factors, assessment, and intervention strategies." *Journal of Counseling and Development*, vol. 82, pp. 191-198, 2004.

[6] E. J. Phares. *Introduction to Psychology*, 3rd ed, New York: Harper Collins Publishers. 1991.

[7] S. Oltedal and T. Rundmo. "The effects of personality and gender on risky driving behaviour and accident involvement." *Safety Science* 44, pp. 621–628, 2006

[8] B. Esmaeili, H.R.I. Far, H. Hosseini and Sharifi, M. "The Relationship between Personality Characteristics and Driving Behavior." *World Academy of Science, Engineering and Technology*, vol. 67, 2012

[9] I. Oppenheim, D. Shinar, O. Carsten, Y. Barnard, F. Lai, F. Vanderhaegen, P. Polet, S. Enjalbert,, M. Pichon, H. Hasewinkel, M. Lützhöft, A. Kircher and L. Kecklund. "Critical review of modelsand parametersfor Driver modelsin different surface transport systems and in different safety critical situations." ITERATE Delivrable 1.1, 2010.

[10] N. Sumer, T. Lajunen, T. Ozkan, "Big Five personality traits as the distal predictors of road accident involvement." in *Traffic and Transport Psychology*, G. Underwood, Ed. Oxford: Elsevier, 2005, pp. 215-227.

[11] B. A. Jonah, "Sensation seeking and risky driving: A review and synthesis of the literature." *Accident Analysis and Prevention*, vol. 29, pp. 651-665, 1997.

[12] N. Ghasem-Aghaee, B. Khalesi, M. Kazemifard, and T.I. Ören, "Anger and Aggressive Behavior in Agent Simulation." in Proc. *Summer Computer Simulation Conference*, Istanbul, Turkey, 2009, pp. 267-274.

[13] P.T. Jr. Costa and R.R. McCrae, "NEO PI-R Professional Manual." Odessa, Fl: Psychological Assessment Resources, 1992.

[14] J. M. Digman, "Personality structure: Emergence of the five-factor model." *Annual Review of Psychology*, vol. 41, 1990, pp. 417-440.

[15] O. P. John, "The "big five" factor taxonomy: Dimensions of personality in the natural language and in questionnaires." in *Handbook of personality theory and research.* L. Pervin, Ed. New York: Guilford, 1990, pp. 66-100.

[16] W. X. Norman, "Toward an adequate taxonomy of personality attributes: Replicated factor structure in peer nomination personality ratings." *Journal of Abnormal and Social Psychology*, 66, pp. 574-583, 1963.

[17] J. S. Wiggins, and A. L. Pincus, "Conceptions of personality disorders and dimensions of personality." *Psychological Assessment: A Journal of Consulting and Clinical Psychology*, vol. 1, pp. 305-316, 1989.

[18] X. Miller, "The psychotherapeutic utility of the five-factor model of personality: A clinician's experience." *Journal of Personality Assessment*, *57*, 415-433, 1991.

[19] R. R. McCrae and P. T, Jr. Costa, "Openness to experience." in *Perspectives in personality*, vol. 1, R. Hogan, and W. H. Jones, Ed, Greenwich: JAI Press, 1985, pp. 145-172.

[20] J. M. Digman, and N. K Xakemoto-Chock, "Factors in the natural language of personality: Re-analysis, comparison, and interpretation of six major studies." *Multivariate Behavioral Research*, *16*, pp. 149-170, 1981.

[21] S. Srivastava, "Measuring the Big Five Personality Factors." Internet: http://psdlab.uoregon.edu/bigfive.html, 2012, [Nov, 29, 2012].

[22] J. M. Miranda, "Modelling human behaviour at work: an agent-based simulation to support the configuration of work teams." PhD thesis, Universidad complutense de Madrid, Madrid, 2011.

[23] A.R. Damasio, (1994) *Descartes' Error: Emotion, Reason and the Human Brain*. New York: Grosset/Putnam. 1994.

[24] J. Gray, T. Braver and M. Raichele, "Integration of Emotion and Cognition in the Lateral Prefrontal Cortex." In Proc. *National Academy of Sciences USA*, 2002, pp. 4115-4120.

[25] C. Pêcher, C. Lemercier and J.M. Cellier, "Emotions drive attention: Effects on driver's behaviour." *Elsevier: Safety Science*, vol.47, n. 9, pp. 1254–1259, Nov. 2009.

[26] J. Mesken, "Determinants and consequence of drivers' emotions." Ph.D. thesis, University of Groningen and SWOV, Groningen, 2006.

[27] J.L. Deffenbacher, R.S. Lynch, E.R. Oetting and R.C Swaim, "The Driving Anger Expression Inventory: a measure of how people express their anger on the road." *Behaviour Research and Therapy*, vol. 40, pp. 717–737, 2002.

[28] J. Mesken, M.P. Hagenzieker, T. Rothengatter, and D. de Waard, "Frequency, determinants, and consequences of different drivers' emotions: an on-the-road study using self-reports." *(observed) behaviour, and physiology*. Transportation Research Part F 10, 2007, pp. 458–475.

[29] N.M. Nor, A. wahab, N. Kamaruddin and M. Majid, (2011) "Pre-post accident analysis relates to pre-cursor emotion for driver behavior understanding." in Proc. *The 11th WSEAS International Conference on Applied Computer Science (ACS 2011)*, 2011, pp. 152-157.

[30] S. Chaffar and C. Frasson (2007) "Apprentissage machine pour la prédiction de la réaction émotionnelle de l'apprenant." *Revue des Sciences et Technologies de l'Information et de la Communication pour l'Éducation et la Formation (STICEF)*, numéro spécial sur les dimensions émotionnelles de l'interaction en EIAH., vol. 14, 2007.

[31] R. Lazarus, *Emotion and Adaptation*. NY: Oxford University Press, 1991.

[32] I. J. Roseman, P. E. Jose and M. S. Spindel, "Appraisals of Emotion-Eliciting Events: Testing a Theory of Discrete Emotions." *Journal of Personality and Social Psychology*, vol. 59, n. 5, pp. 899-915, 1990.

[33] A. Ortony, G. Clore and A. Collins, *The Cognitive Structure of Emotions*. Cambridge: University Press, 1988.

[34] M. Ochs, "Modélisation, formalisation et mise en œuvre d'un agent rationnel dialoguant émotionnel empathique." Ph.D. thesis. Université Paris VIII, Paris, 2007.

[35] B. A. Jonah, (1990) "Age differences in risky driving." *Health education research Theory & Practice*, vol. 5, no.2, pp. 139-149, 1990.

[36] R. Luther, H. Livingstone, T. Gipson, and E. Grimes, "Understanding driver route knowledge." In *People and Rail Systems: Human Factors at the Heart of the Railway*. J.R. Wilson, B. Norris, T. Clarke and A. Mills, Ed, London: Ashgate, Aldershot, 2007, pp. 71-78.