Defensive Driving Behavior Cognitive Model Based on Agent Theory

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Abstract
Based on the Agent theory, the Defensive Driving Behavior Cognitive Model (referred to as DDBCM) is established. DDBCM has integrated the perception, movement, behavior, cognition and other components, and can generate lifelike personification behavior. In order to realize the complicated behavior control of DDBCM, according to the simplified inclusive type structure, the hierarchical behavior control model of DDBCM is constructed; In the cognitive planning, the task knowledge representation model of the virtual decisionmaking training and the path planning method that can satisfy the DBDCM is studied, so as to realize its overall path planning. Finally, on the PC machine the behavior simulation system of DDBCM is realized, which can satisfy the need of the behavior control and decision analysis of DDBCM.

Keywords: Virtual Human, Defensive, Cognitive Model, Driving Behavior.

1. INTRODUCTION

Currently the Virtual driving behavior has become one of the important application fields of the VR (Virtual Reality) technology, especially the environment in which the practical training is very expensive and dangerous, or even impossible to carry out, such as flight simulation, military training, surgery, fire protection, etc. However, at present most of these VR analysis systems focus on the practice of the specific skills or the process analysis, and emphasize the “Learning by doing” (Lárusdóttir and Ulfarsson G F, 2015; Trógolo, Melchior and Medrano, 2014). Traffic accident is a very sensitive topic in recent years, which has aroused wide attention in the whole society. Research on the traffic accidents over the past few years shows that: Most of the accidents were caused by illegal driving and other behaviors against the norms, or by incorrect decisions (Peng, 2013). These behaviors could only be trained through video or case study as classroom training in the past training, which was difficult to achieve the actual effect (Shimosaka, Nishi, Sato and Kataoka, 2015; Efrat and Shoham, 2013; Clapp, Baker and Litwack, 2014; Karl, Berg, Rüger and Förber, 2013). For this purpose, we carried on thorough investigation and research on the traffic behavior, and developed the driving behavior cognitive model based on agent theory. The goal is through the computer to simulate the driver’s driving behavior, so as to gain the simulation data of the driving behavior, perform processing and analysis, so as to make reasonable guidance to the driving behavior, regulate the mode of behavior of the drivers, so as to prevent and reduce the occurrence of the traffic accidents fundamentally.

In the decision-making system that is based on VR, the virtual human is the actual executor of the decision making task, through receiving the driver's instructions, to perform an action, so as to represent the required physical skills in the simulation. The driver is the decision maker for the treatment of the simulation accident, who navigates in the virtual road, gives assessment on the situation, makes the decisions, and issues decision command to control the behavior of the virtual human (Vanlaar, McKiernan and McAteer, 2014; Okuda, Ikami, Suzuki, Tazaki and Takeda, 2013). At the same time, the virtual human has cognitive planning ability and can carry out the simulation task autonomously according to the current training objectives and task knowledge. When the driver cannot make decision at the critical point of time, the virtual human can independently execute the next step of the simulation activity; the driver can gain the learning experience through the observation. The virtual human, moreover, can make real-time response to the external events according to the environmental awareness and their own internal attributes, such as showing a sense of fear to
the source of risk, so as to reflect the mental state of the driver status, and increase the immersion into the virtual environment, which is very important for the decisionmaking training. Therefore, in this paper, the virtual human is under the guidance of the driver, intelligent Agent with certain level of autonomous capability, capable of perception, movement, behavior, cognition and other functions, and can be used as the driver of the intelligent incarnation of the driver, to take the place of the driver and execute the driving task, reflecting the decisionmaking ability of the driver.

The virtual human applied for the road safety analysis in this paper, is called the virtual driver. And this paper has mainly studied the DDBCM system structure and realization method of its behavior and cognitive model.

2. DDBCM BEHAVIOR MODEL

Behavior is the reaction of the virtual human for the internal mental state and the external virtual environmental stimulation. In the virtual training, the behavior of IVMner has the targeted, real-time, interactive and other characteristics, with the adoption of the hierarchical control method. Complex behavior is planned and decomposed by the cognitive module; and the motion (control) module is responsible for the specific implementation of the behavior; behavior module accomplishes the functions of the realization, selection and control of the basic reaction behavior.

Behavior module adopts the simplified inclusive architecture, as shown in Figure 1. Low level behavior library contains some of the basic skills of the virtual human, such as stand, forward, backward and so on. The low level behavior is unintentional reflection behavior, which is mainly used for the response of DDBCM to the emergencies in a timely manner. The basic behavior library stores the motivation behavior of the virtual human, such as: search, grab and so on. Low level behavior layer and the basic behavior layer are connected with the inclusive architecture, and the basic behavior contains the function of the low level behavior. Thus the virtual human can realize the basic consciousness behavior and low level reflection behavior in parallel, and impose influence on the low level behavior (Shimosaka, Nishi, Sato and Kataoka, 2015). This can ensure the real-time response of DDBCM to the emergencies, and also give full play to its cognitive planning ability, so as to complete complicated driving task.

In the virtual driver’s behavior control model, first of all, according to the requirements of the application, the modeling of some of the basic reaction behaviors in the virtual environment is established. These behaviors can be expressed as the basic reaction behavior set B(Classen, Wang and Winter, 2013), namely:

\[ B = \{ b_i, 1 \leq i \leq n \} \]  

Wherein \( b_i (1 \leq i \leq n) \) are independent of each other, with the same priority. For complex behavior \( b_j \), it is realized through the selection of one or more of the basic reaction behaviors, namely:

\[ b_j \in 2^m \quad (1 \leq j \leq m) \]  

At present, we have realized the turning on/off equipment, checking parameters, brakes, stepping on the gas and similar basic reaction behaviors that are in the motivation class, and encapsulated the low level reaction behaviors such as changing gears. These behaviors are represented in the form of parameterization, and stored in their own behavior library respectively.

The rules in the rule library have specified the activation conditions for the rules and the rule triggering results. Typical rules are as follows:

R1: FOR ALL
WHEN EVENT = in_critical_zone AND InnerState (Perceive>0.5) THEN Behavior CheckParaments()
Rule R1 shows that: For each driver (DDBCM), when they are at the key area of the road and the (danger) perception index is greater than 0.5, the behavior of testing the environment parameters is implemented, such as testing the vehicle density.

For drivers of different job types, the behavior selection threshold corresponding to their mental state is set up. At the start of the driving, the system extracts the corresponding parameters for the initialization according to the driver's job type and level. In the process of driving, the behavior selection threshold changes with the change of the driver’s situation. If the driver often makes certain mistakes, the corresponding behavior threshold will have relatively fast changes, thus triggering some teaching rules, of the stress factors of the virtual environment, so as to enhance the risk response ability of the driver; or the tips are provided to the driver, so as to help the driver get very excellent level.

3. DDBCM COGNITIVE PLANNING

3.1 Task KnowledgeModel

Cognitive model has surpassed the behavior model, and it determines what the virtual human knows, how to acquire knowledge, how to use knowledge to carry out the action plan (Clapp, Baker and Litwack, 2014). Virtual driving task knowledge model shows the domain knowledge of the virtual human, and indicates the state of the collaboration tasks among the virtual human, the driver and other Agent.

The goal-driven manner is adopted, and the task knowledge representation is hierarchical structure, so as to meet the demand of the task planning to adapt to different drivers and the dynamic variation of the virtual driving environment. The task model is shown as Figure 3. The target is associated with a group of set scenarios and timing constraints. The set scenario contains one or more decision sets, connected to the next scenario by time or event relationship. In each set scenario, set the default decision set. The decision set can include one or more decisions. The decisions express the selection behavior on certain action. The completion of a decision-making behavior will activate the actions associated with it. Between the decisions in the decision set, there are no order constraint relations, but only if the entire decision-making is completed, can it enter into the next set scenario. Every decision isset with a timeline and difficulty coefficient, so as to meet the different levels of the driver.

![Figure 2. Training Task Knowledge Model](image)

In driving, DDBCM maintains its current tasks to be completed and the goalthrough memory. What the memory model stores is the behavior that is directly from the planning result, make use the stacking to construction, and form the behavior stack. The top item of the behavior stack is always the task which is ongoing, processed by a special cognitive or behavior program. Complicated tasks are broken down into several simple subtasks, and after each planning, the first subtask is pushed into the stack. When the first sub task is completed and removed from the stack, new planning can be carried out, so as to meet the requirements of the real time simulation. If it takes a long time to complete a behavior, the due time in the memory project can force the stop of this behavior after a certain period of time, and to re-plan, so as to ensure the real time updating of the planning.

3.2 Path Planning

Path planning is one of the important behaviors in the virtual human cognitive planning. Through path planning, the virtual human can dynamically choose the optimum path to achieve the specified location, without the requirement to specify the path parameters in detail. In the motion, firstly, DDBCM find a rough path to get
to the destination through the overall path planning, and then according to its own perception to the environment in the travel, perform adjustment on the local path.

Considering the system efficiency of time and space, we set that all the DDBCM in the virtual environment know the arrangement of the road and the location and direction of the vehicle, especially the location of the critical road.

The virtual environment is represented by quad tree generated configuration space. Generally the leaf node of the quad tree only records whether there are obstacles. In order to simulate the climbing and other movements in the plan, for the further use in the emergency driving, we add into the quad tree DDBCM the attribute of the road that DDBCM is located, such as the road type and road slope information.

In this paper, A * algorithm is adopted to conduct the path search. A * algorithm makes use of the heuristic function \( f(n) = g(n) + h(n) \) to calculate the cost \( f(n) \) of the node n. This cost \( f(n) \) is the valuation function of the minimum expenses from the initial node through the current node n to the target point. Due to the complexity of the traffic environment, there are a lot of inclined roadways, in order to simulate the virtual human’s driving behavior on the road for real, this paper has adopted the behavior based on human driving as the heuristic function (Peng, 2013), so as to plan a real and effective motion path.

In the planning, the virtual human must first determine whether the road conditions are suitable for driving. If they are suitable, the static energy does not have to be calculated. The heuristic function is calculated according to equation (3).

\[
h(n) = kd_{n,g} + (h_g - h_n)
\]

\[
d_{n,g} = \sqrt{(x_n - x_g)^2 + (y_n - y_g)^2}
\]

Wherein \( d_{n,g} \) represents the distance from the current point n to the target point g, \( h_g \) is the height of the point g, and \( h_n \) is the height of the point n, k is the proportion coefficient in driving.

As the paths generated in the A * algorithm are connected by the straight line of the path points generated by the planning, the virtual human often makes abruptly turns near the path point, prone to have false behavior. Therefore, this paper makes use of the spline curve to make the preliminary modification and optimization to the planned path, and generates the relatively natural walking routes. Figure 4 is the path planning test of DDBCM.

4. VALIDATION OF THE MODEL

4.1. Test Design

In order to verify the motor vehicle driver’s cognitive behavior model, it is necessary to select the location without any special geographical factors, with sunny weather, and the road traffic flow is not too big, with sidewalks, and convenient for the camera to work to conduct the test. Under such environment the influence of the motor vehicles between each other is more noticeable, and less affected by pedestrians, which is suitable for the analysis of the behavior of the motor vehicles. Non rush hour traffic is chosen for the observation, and research is carried out on the information that has been obtained.

4.1.1 Road Section Test Design

A virtual road section is selected as the test road section, and the road is a two-way road with four lanes. Observations are made for 1,000 samples of motor vehicles driving at the direction from west to east (for microscopic test analysis) as well as the average speed, traffic flow and lane occupancy rate of the motor vehicles (for macro test analysis).

The extracted information is as follows: ① Microscopic information. At the location L in front of the taxi the number of times of the occurrence of a bicycle across the road and the number of times the taxi is following at that time; At the location L in front of the taxi the number of times of the occurrence of a bicycle entering into the circle of conflict \( C_i \) and the number of times that the taxi is following and changing lanes at that time; At the location L in front of the taxi the number of times of the occurrence of a bicycle occupies the motor vehicle lane (which also can be regarded as the situation when the bicycle entered into the circle of conflict, and can be combined with the aforementioned situation into one for the observation) as well as the number of times that the taxi is following and changing lanes at that time. ② Macro information. Average speed of the motor vehicles travelling at the direction from west to east; one-way traffic volume on the road; lane occupancy rate.

4.1.2 Intersection Test Design

Select a virtual road section as the intersection for the test, the four directions of this intersection are all double directions four lanes, and with bicycle lanes. 1,000 samples of the conflicts existed between the motor

vehicles that go straight and the bicycles that turn left (for the microscopic test analysis) as well as the average delay at each entrance, the maximum queuing length at each lane and the average delay at each lane (for the macro test analysis) are observed.

The extracted information is as follows: ① Microscopic information. Within the circle of conflict, the number of times of the occurrence when the bicycle has not passed the point of conflict while the motor vehicle enters into the circle of conflict $C_1$ and the number of times the motor vehicle is following at that time; Within the circle of conflict, the number of times of the occurrence when the bicycle has already passed the point of conflict while the motor vehicle enters into the circle of conflict $C_1$ and the number of times the motor vehicle is not following at that time; ② Macro information. Average delay at each entrance; the maximum queuing length at each lane; and the average delay at each lane.

**Figure 3.** Motor Vehicle Driving Route

**Figure 4.** Road Section Simulation Module Process
4.2. Simulation and Result Analysis

Figure 4 are program flows that influence the program of the sub module in the driver behavior simulation module at the road sections and intersections respectively.

**Table 1.** Road Section Microscopic Observation Result and Fitting Rate

<table>
<thead>
<tr>
<th>Description of Conflict</th>
<th>Occurrence of Bicycle Across the Road at the Location L in Front of the Motor Vehicle</th>
<th>Occurrence of Bicycle Entering at the Location L in Front of the Motor Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>The number of motor vehicles being influence</td>
<td>Fitting rate %</td>
</tr>
<tr>
<td>Numerical Value</td>
<td>109</td>
<td>101</td>
</tr>
</tbody>
</table>

**Table 2.** Intersection Microscopic Observation Result and Fitting Rate

<table>
<thead>
<tr>
<th>Description of Conflict</th>
<th>Occurrence of Bicycle Not Passing the Point of Conflict within $C_1$</th>
<th>Occurrence of Bicycle Having Passing the Point of Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>The number of motor vehicles that have entered into $C_2$</td>
<td>Fitting rate %</td>
</tr>
<tr>
<td>Numerical Value</td>
<td>646</td>
<td>622</td>
</tr>
</tbody>
</table>

**Table 3.** Road Section Macroscopic Observation and Simulation Result

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Actual Measured Value</th>
<th>Simulation Value</th>
<th>Error Rate%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Speed of Vehicle / (km.h-1)</td>
<td>24.49</td>
<td>23.22</td>
<td>5.26</td>
</tr>
<tr>
<td>One-way Traffic Volume / (veh.h-1)</td>
<td>1146</td>
<td>1203</td>
<td>4.97</td>
</tr>
<tr>
<td>Lane Occupancy Rate %</td>
<td>Inside Motor Vehicle Lane</td>
<td>43.7</td>
<td>42.1</td>
</tr>
<tr>
<td>Motor Vehicle Lane by the Roadside</td>
<td>56.3</td>
<td>57.9</td>
<td>2.84</td>
</tr>
</tbody>
</table>

**Table 4.** Intersection Macroscopic Observation Result and Simulation Result

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Actual Measured Value</th>
<th>Simulation Value</th>
<th>Error Rate%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Delay at the Entrance /s</td>
<td>East</td>
<td>South</td>
<td>West</td>
</tr>
<tr>
<td>42.1</td>
<td>30.0</td>
<td>35.3</td>
<td>41.3</td>
</tr>
<tr>
<td>Maximum Queuing at the Lane / vch</td>
<td>Straight Left Lane</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Straight Right Lane</td>
<td>21</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Lane Average Delay at the Lane /s</td>
<td>Straight Left Lane</td>
<td>84</td>
<td>70.2</td>
</tr>
<tr>
<td>Straight Right Lane</td>
<td>52.3</td>
<td>37.6</td>
<td>45.5</td>
</tr>
</tbody>
</table>
5. CONCLUSION

This paper has established the system model of the defensive driving behavior cognitive model applicable for the virtual reality decision making, which can effectively implement the simulation of the behavior of the drivers. This paper adopts the simplified inclusive architecture, and establishes the virtual driving behavior control model, which not only can realize the control on the complex behavior of its cognitive planning and other task level, but also can respond in a timely manner to the emergencies occurred in the virtual environment. At the same time, A * heuristic search algorithm is applied to realize the overall path planning without collision in the virtual driving. And simulation test is carried out on the behavior of the driver sat the lanes; the test results show that the virtual driver has relatively lifelike personification behavior, which allows the real-time interaction with the driver, so as to meet the requirements of the driving analysis.

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REFERENCES


