Toward Adaptive Support:  
Modeling Drivers’ Allocation of Attention  

R. Kovordányi, S. Ohlsson  

Department of Computer and Information Science  
Linköpings Universitet  
SE-581 83, Linköping, SWEDEN  
E-mail: ritko@ida.liu.se  

Abstract  
Driver distraction and inattention are major contributing factors in traffic accidents (cf., e.g., Najm et al, 1995). Some of these accidents might be avoided in the future if drivers’ (miss)allocation of attention could be detected, and the driver be prompted toward key events in the traffic scene. Our objective is to develop a cognitively based driver model where drivers’ allocation of attention can be simulated for diagnostic purposes. As a first step, we present a connectionist model framework implemented in PDP++. This framework is based on the notion that focusing attention on a visual object is closely coupled with an intention to act on that object. Using our model, we want to continuously assess if the driver can maintain a general preparedness to act, and hence detect unexpected events, or if he/she is overloaded by non–driving–related tasks. In a first step, we intend to study how attention can be allocated to subtasks in the model, to find out to what extent multiple tasks can be parallelized by drivers. For further developments on this project, visit http://www.ida.liu.se/~ritko.html.

Keywords  
Distraction, Inattention, Cognitive driver model, Adaptive driver support

1 INTRODUCTION  
In–vehicle devices, such as built–in phones and navigation aids can easily capture drivers’ attention and divert their gaze from the traffic scene. Likewise, the driver can choose to become preoccupied with phone dialing, instead of devoting his/her full attention to driving. When the driver is momentarily incapable of detecting driving related visual events because he/she is preoccupied with non–driving related tasks, the driver can be said to be temporarily overloaded. One way to avoid this kind of overload is to adapt device–driver interaction to the driver’s momentary capacity to handle non–driving–related tasks. Systems for adaptation of in–vehicle device messages are becoming standard in certain car models (REF##). However, these systems are not capable of taking the drivers’ cognitive load into account, nor can they support the driver outside device–initiated interaction situations.

In this article we propagate for an approach to adaptation based on monitoring, through real–time simulation, of the driver’s cognitive processes, such as processing of visual information and cognitive management of multiple simultaneous tasks. The question we would like to answer is: For any moment in time, will the driver be able to
allocate his/her *attention* to an unexpected visual event, for example, a pedestrian that suddenly appears on the side of the road?

## 2 The Cognitive Approach

As a first step toward this goal, we have implemented a cognitively based neural network architecture in which the driver’s attention can be allocated to individual subtasks and, indirectly, to corresponding segments of visual information. By employing a cognitively–based model architecture, simulated allocation of attention can be constrained according to known limitations of the human cognitive system (cf., e.g., Vidulich and Wickens, 1985), thereby restricting the possibility for simultaneously managing multiple subtasks in the driver model. This in turn allows for a realistic simulation of the driver’s cognitive workload.

Somewhat simplified, the human cognitive system can be subdivided into three mutually interacting subsystems: The perceptual, the central cognitive, and the motor system. While perceptual information is processed in parallel, motor movements can only be directed towards one object at a time. This creates a basic incompatibility: The parallel inflow of perceptual information must at some point be sequenced in order to provide an unambiguous basis for motor planning (Kovordányi, 2002). Hence, the driver will only be able to see a limited amount of information at a time; what pieces of information he/she will focus on, and in what order, will be determined by how various tasks can be interleaved.

## 3 Existing Driver Monitoring Systems

Present approaches to driver monitoring and modeling are mainly based on statistical methods for situation assessment and/or statistical classification and prediction of tactical–level driver behavior (Michon et al, 1990)—such as passing, turning, starting, and stopping. For example, MIT’s smartCar project adopts coupled hidden Markov models. Using this technique, the driver’s behavior is recognized as constituting the initial action steps within a particular tactical–level maneuver category, such as lane change, or right turn. By recognizing the initiated maneuver, the driver’s actions can be extrapolated into a prediction of the driver’s next actions (Oliver and Pentland, 2000).

While the smartCar project adopts hidden Markov models, Onken and Feraric (1997) present a driver support system where a two–layer ART–network is used to categorize the driver’s normal behavior. The system is able to detect deviations from the normal pattern, with the rationale being that such deviations might signal potential danger.

Both of these systems incorporate a driver model and implement driver behavior categorization by applying purely statistical methods to externally observable behavior. In contrast to this, Salvucci and Macuga have developed a *cognitive* driver model, written in ACT–R (REF###), which simulates how the driver handles two simultaneous tasks, namely steering within a single lane and cell–phone dialing (Salvucci and Macuga, 2001). In this model, drivers’ allocation of attention is equated with overt (externally observable) eye movements.

## 4 Theoretical Basis for the Driver Model

We take a stance in the notion that attention is a *mental* resource that has no simple correspondence with overt behavior. We subscribe to a late–selection–for–action view on selective attention (see Kovordányi, 1999, for a theoretical discussion and review of empirical evidence). In accordance with this view, Ballard and coworkers (1997) and Bugmann (2001) propose that allocation of attention might play a key role in motor
movement planning. These and other researchers suggest that attending to the visual form of an object provides the motor system with the necessary parameters that are needed for activating the appropriate type of movement toward this object—for example, gripping an object with 10 cm diameter requires a corresponding hand aperture (Fagg and Arbib, 1998).

4.1 Detection of visual events
The conscious registration of visual events can be assumed to require allocation of attention to that event. As attention tends to be allocated to that segment of the visual space which contains the target for an intended movement, it seems likely that a driver will not become aware of a particular visual event, unless he/she has activated a corresponding motor intention. In other words, the driver will not become aware of a visual event unless he/she is, in a sense, prepared for this event. This tentative conclusion is in concordance with the psychological phenomenon ‘inattentional blindness’, which refers to the fact that people often fail to see what they did not expect to see (Simons, 2000).

In summary, it might be the case that the driver either has to be prepared to act in general, or has to purposefully initiate a serial visual search of the road scene to be become aware of an unexpected visual event. However, we have to note that the evidence and modeling work summarized above mainly concerns the coupling between perceptual and motor systems as implemented via the “where/how” pathway. Hence, the allocation of attention in the “what” pathway (object–based attention) remains to be explored in our model.

4.2 Visual attention and motor planning
We hypothesize that, at least for visually surveyed actions, there is a functional coupling between visual selective attention and a preparation for motor actions. While the choice of appropriate motor movements seems to require focusing attention on the object for this movement, the execution and fine–tuning of the same motor movement relies on foveal input, and thus requires eye movements (Ballard et al, 1997; Bugmann, 2001). This discrepancy entails that when a driver is fixating the target for one motor action, his/her attention may already be focused on another object, which is the target for the next step of action. Hence, at least for a certain kind of visually surveyed actions, a driver’s eye movements, once they are executed and therefore are observable, seem to be bad predictors for where the driver focuses his/her attention.

Given the problem of time-lag between observed movements and focus of attention, and hence the low predictor-value of observable actions, we propose an approach to driver monitoring based on real-time simulations of a cognitive driver model. As evidenced in our previous discussion of our theoretical stance, we consider the coupling between allocation of attention and motor planning, and hence the detailed functioning of the motor system, to be a central issue.

5 THE IMPLEMENTED MODEL FRAMEWORK
In the following sections, we briefly describe a first version of our driver model, with special focus on the motor system (figure 1). Our model framework is designed to simulate drivers’ coping with two simultaneous tasks: steering within a lane and reacting to an unexpected visual event. These tasks are represented by a continuous tracking task, and a discrete reaction task (to right or left arrow that appears at random time intervals in the lower central part of the driver’s visual field). The model is
implemented as a limited parallel processing architecture written in LEABRA++ (O’Reilly and Munakata, 2000), a biologically realistic artificial neural network tool.

5.1 Motor planning
Our objective is to explore the coupling between allocation of attention and motor planning in order to find out to what extent multiple tasks can be parallelized. Of particular interest is the question of interleaving between tasks that is, which preparatory phase in motor planning would allow for an overlap with another task—it is, for example, conceivable that the execution of one task can go on in parallel with the early planning phases of another task. Below, we present a number of hypotheses on the role of the cerebellum and the basal ganglia in implementing the mechanisms for suspending and resuming a task (Kieras and Meyer, 1997).

6 Future work
As a direct continuation of the work reported here, we plan to explore alternative hypothesis on how motor planning, in particular how the suspend/resume functions are realized in the human cognitive system. We intend to validate the resulting model using empirical observations on dual–task performance (e.g., Martin–Emerson and Wickens, 1992), involving a continuous tracking and a discrete reaction task.

Figure 1. Present architecture of the driver model, V1–V4 denote visual areas in the “what” pathway, PO: parieto–occipital cortex (“where” pathway), PFC: parietofrontal cortex, MIP and LIP: medial and lateral intraparietal cortex, FEF: frontal eye fields, SC: superior colliculus, PM: premotor areas, M1: motor area 1, BG: basal ganglia. Basal ganglia is assumed to play a role in the sequencing and timing of motor plan segments, while the cerebellum might be involved in choosing between alternative plans on the basis of visual input.
The modeling methodology we intend to use is exploratory: As opposed to simply demonstrating the adequacy of a specific model, we intend to find out which model components are crucial for obtaining a good fit to empirical data, thus providing a more reliable basis for subsequent real–time simulations (Kovordányi, 2000; 2001).

References