Analyzing Traces of Activity for Modeling Cognitive Schemes of Operators

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Modern design of human/machine interfaces requires a better understanding of how operators control their interaction with machines. To understand these interactions, cognitive ergonomists seek to construct cognitive models of operators. These models generally depict operator activity as a process of information-collecting, computing, decision-making, and action. While this symbolic approach effectively describes formal reasoning, it becomes ambiguous when considering an activity in which operators are physically involved, such as driving a car. Here, operators' cognitive process "accompanies" their actions and can be equally viewed as a cause or as a consequence of their activity. Perception, cognition, and action can hardly be separated, because expectations drive perception, and the feeling of comprehension relies on possibilities of action.

Where interaction and perception are so tightly coupled, we take inspiration from psychologists like Piaget, who have proposed to keep perception and action embedded into "schemes". We consider "schemes" and "cognitive schemas" as the basic elements of our cognitive modelling, and we seek to highlight and model them from "traces of activity" (Georgeon, 2008). To do this, we have implemented "knowledge engineering" software and a method of cognitive modeling, which derives from "traces of activity". This software includes graph processing and visualization, symbolic inference, as well as ontology manipulation (Georgeon, Mille & Bellet, 2006).

The "traces of activity" are a sequence of events that describe the interaction of the driver with their environment. In our case, the trace gathers data describing the driver's behavior and situation: steering angle, pedal use, GPS positioning and cartography, distance ahead, and eye information. The trace also includes subjective evaluations made by the driver or by the researcher during the experiment, or during retrospective verbal protocols with video played.

The outline of the modeling process is given by figure 1. The activity overtime is represented on the vertical axis. The curves symbolize the continuous flow of collected data. The horizontal axis represents the level of abstraction. The diagonal arrow represents the modeling process. Step 1 is data collection, while Step 2 consists of identifying the first level of points of interest. These points of interest are then processed by the system as symbols. Step 3 consists of inferring more abstract symbols from the basic symbols, and organizing them in an ontology. Step 4 consists of producing models of the activity on the basis of these symbols.

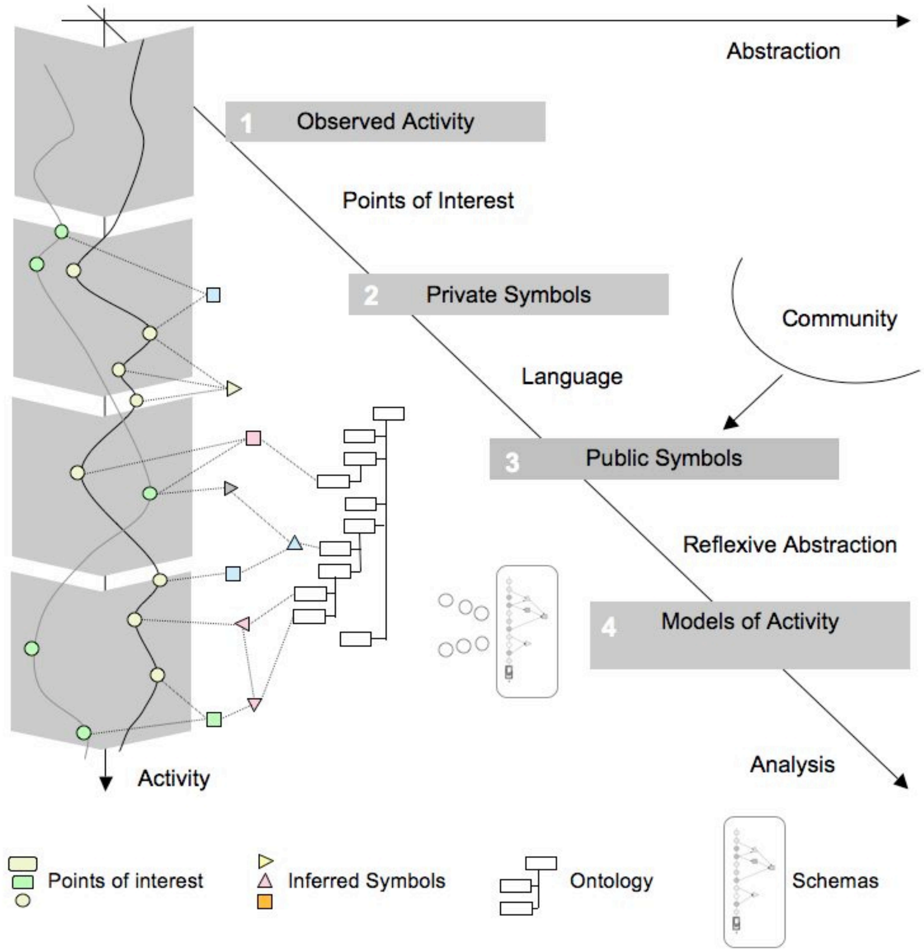

Figure 1. Process of analysis

The "points of interest" and symbols are not found "in blind" by algorithms, but we specify them by looking at the data. They are points that interest us because they describe the activity in a way that helps us understand it better. Thus, we emphasize the interactivity of our software. These points are essentially defined on an evolutionist and pragmatic basis, i.e. trying to keep the most useful/meaningful point types. Once these types are specified, we make programs to identify their instances automatically in the trace.

The ontology supports the visualization parameters such as the symbols' color and shape. It also supports the semantics on which inference rules are based. Inference rules are a way to add new symbols in the trace. These new symbols represent more abstract concepts, which summarize patterns of lower level symbols. We thus construct a language for describing this activity.

Figure 2 shows an example of plot that we obtain, representing a motorway lane change (Henning, Georgeon & Krems, 2007). It shows a typical driving situation, where a slow vehicle impedes a driver. The driver may check his or her left mirror several times. Deciding to overtake the slower vehicle, the driver accelerates while simultaneously checking the mirror. If the left lane is clear, he or she switches on the blinker, starts steering, and crosses the line. The circles at the bottom represent low-level events. The upper part represents the high level symbols. Lines between them represent inference relations from lower to higher. Longitudinal information is represented on the axis, things concerning left are above, and right are below. In this situational category, the conjunction of acceleration and left mirror glance indicates the decision to overtaking the impeding vehicle. From this, we can compute a "marker" of the decision (violet triangle at -3s). It occurs about one second before the blinker is switched on — it is thus a predictor of the maneuver. As ergonomists, we explain this pattern of behavior as the performing of a cognitive schema adapted to a category of situation, that we classify in parallel. It involves unconscious know-how, connected to some points of decision at a more conscious level.

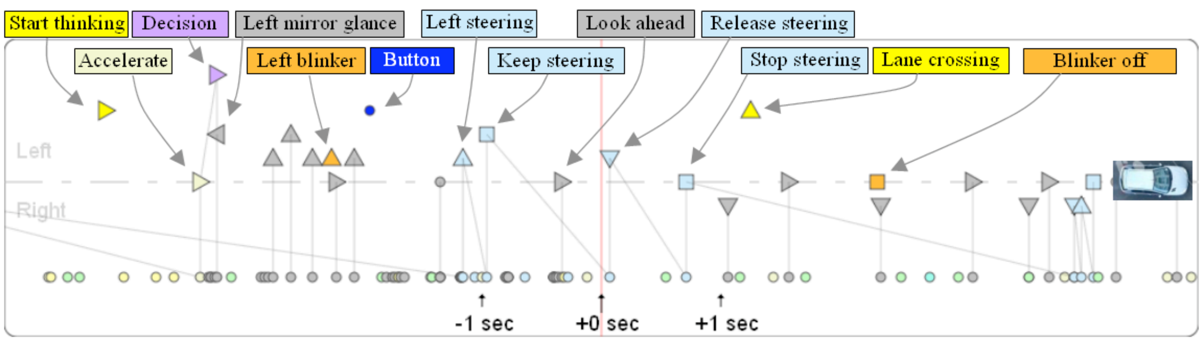

Figure 2: Motorway Lane Change with acceleration.

From an epistemological point of view, our approach lets us connect a bottom-up with a top-down modeling process, i.e. connecting experimental data with psychological explanations. We offer pragmatic arguments in support of cognitive schemas as a means of explaining how humans perform their activities. Our approach is based on a "constructivist" epistemology, since models are built through an evolutionist and pragmatic process, and driven by mindful analysts. We claim that this process can provide insights about how salient events of activity can arise into consciousness and become the basis for symbolic reasoning. This leads us to propose it as a "constructivist model of awareness".

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