# Sample of Yellow Highlighting for Re-editing

1. INTRODUCTION

Figure 1: Causation between stimulus, internal states, and behaviors, and transitions between internal states to select a behavior based on motivation.

A robot usually needs to perform several behaviors in a sequence to accomplish a task [1]. An intelligent robot must therefore be able to select a dependable behavior from a set, to deal with a given task in a current situation. Here, we define a dependable behavior as a situation-adequate as well as a goal-oriented behavior [2].

To select a dependable behavior for achieving a task, the design of the robot must account for the following properties: the robot must be able to generate relationships between situations (or stimuli) and behaviors for selecting a situation-adequate behavior; additionally, the robot must be able to generate behavioral sequences with respect to goal-orientedness for achieving a task [3]. The design of behavioral sequences is non-trivial, since the same task can be accomplished by various behavioral sequences, but not by a fixed behavioral sequence as per the current situation [4].

Let us consider a simple task in which a robot brings an object to a human being. The robot usually accomplishes the task according to the following behavioral sequence: (1) the robot searches for the object; (2) after achieving (1), the robot approaches the object; (3) after achieving (2), the robot picks up the object; (4) after achieving (3) the robot searches for the human being; (5) after achieving (4), the robot brings the object to the human being. There are several behavioral sequences in even this simple task. For instance, the robot can miss the position of the object (or the human being) or drop the object whenever it executes individual behaviors in the task. In addition, the human being can change his or her own position whenever the robot executes the individual steps. The robot must perform dependable behaviors in various sequences for resolving given situations to accomplish the task and there are an uncountable number of behavioral sequences in the real world.

Nevertheless, all behavioral sequences contain a common structural property in that the behavioral sequences must necessarily satisfy preconditions before a behavior is executed. In the example mentioned earlier, the robot can execute the following behaviors after satisfying the preconditions in order from (1) to (5). In accomplishing a task, human beings extract a common structural property from certain behavioral sequences. According to given situations, they generate new behavioral sequences based on this structural property. They also select a dependable behavior based on these new behavioral sequences. The structural property can be useful for generating various behavioral sequences without having to generate all possible behavioral sequences.

Figure 2: Results of qualitative comparison of related works.

A robot must be able to generate behavioral sequences implicitly or explicitly according to given situations. A motivation can be used for selecting behaviors as per the current situation. Here, the motivation is a property that activates or energizes a behavior. The motivation can be used to recommend a behavior to the robot based on its current internal state [5, 6]. Fig. 1 shows causation between stimuli, internal states, and behaviors, and the transitions of internal states based on motivation. Internal states cannot be directly observed, but can be inferred by a selected behavior. A motivation-based behavior selection method implicitly generates fully connected transitions of internal states by perceiving a current stimulus. Thus, this method can generate various behavioral sequences according to given situations. This is useful in case the modeling of all state transitions is difficult, since it can generate state transitions without state transition models. This method is especially appropriate in executing behaviors under various situations that are often generated by interactions between a robot and human beings, like entertainment or service robots, since state transitions can frequently vary because of human intentions [7]. However, in the motivation-based behavior selection method it is difficult to select a goal-oriented behavior by implicit transitions of internal states as shown in Fig. 1. To select a dependable behavior, the motivation must be generated with respect to the goal-orientedness of a given task.