Behavior Selection Algorithm for Personal Service Robots Using Intelligence Operating Architecture

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Personal service robots assisting humans in daily life are expected to provide a user-oriented service [1]. To meet this expectation, there has been much research on behavior selection algorithms for the proper service. The action selection method was proposed to activate a most appropriate action in a certain situation [2]. The behavior selection method for artificial creatures considering both internal and external situation was proposed [3]. A system using episodic memory (EM) was developed to supervise user's daily activities [4].

However, the agents in the existing research did not much consider user's past requests or behavior patterns in making a decision for a proper behavior. In this research, the intelligence operating architecture (iOA) is used to construct a user oriented behavior selection algorithm [5]. The iOA consists of five parts and 15 modules to implement the robot intelligence. It is motivated by the key functions of the human brain, such as problem solving in the frontal lobe, actions from the motor cortex, etc. Among them, context generation, EM, semantic memory (SM), decision making modules are the key modules to provide users with autonomous user-oriented services. The context generation module identifies the current situation by "when," "where," "what," etc. The EM stores the events along with time and the SM holds the factual and concept-based knowledge. By referring to EM and SM, the most proper behavior of a robot in a given situation is selected in the decision making module.

The detailed procedure of the proposed algorithm is described in the following. To begin with, the context module defines the current event by five attributes, i.e. 'user ID,' 'behavior,' 'time,' 'place' and 'object.' If the current event is a user's request and the given information is not sufficient, the robot searches for the most similar event in the EM. The similarity degree $Sim(e_i, e_j)$ between the two events, e_i and e_j, is calculated as follows:

$$Sim(e_i, e_j) = \min_k [Sim(a_k^i, a_k^j)], k = 1, 2, \ldots, 5, \tag{1}$$

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where $Sim(a_k^i, a_k^j) \in [0, 1]$ is the normalized semantic similarity between the kth attributes of e_i and e_j [6]. If the current event is not a user's request, the robot should prepare a proper service by anticipating user's next event from his/her behavior patterns. In this case, the robot searches for the most similar episode with the current episode, where an episode is a sequence of time-series events. The most similar episode is the longest sequence of events in the EM that satisfies the following conditions:

$$1.\text{ for } 1 \le i \le m,\ Sim(e_i^c, e_i^p) \ge \epsilon, \tag{2}$$

$$2.\text{ for } 1 \le i \le m-1,\ |TI(e_{i+1}^c, e_i^c) - TI(e_{i+1}^p, e_i^p)| \le \delta, \tag{3}$$

where e_i^c and e_i^p are the ith events of the current and the past episodes, respectively, m is the number of events of the two episodes, $TI(e_1, e_2)$ is the time interval between e_1 and e_2 in minutes, δ is a positive integer and $\epsilon \in [0, 1]$ is a constant.

To show the effectiveness of the proposed behavior selection algorithm, a personal service agent was implemented for simulations. The attributes of 236 events gathered from the user for a week, were stored in the agent's EM. The taxonomy of 155,327 words to calculate the semantic similarities between two attributes was stored in the agent's SM. δ and ϵ were set to 30 and 0.45, respectively. The simulation results showed that the agent could infer the hidden information of the user's request based on the most similar past event. Furthermore, even if the user used different but semantically same words for a request, the agent could understand the user's request and provide a proper service. Also, the agent could anticipate user's next behavior and provide a proper service based on the most similar past episode.

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