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Behavioral task processing for cognitive robots using artificial emotions

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ABSTRACT

This paper presents an artificial emotional-cognitive system-based autonomous robot control architecture for a four-wheel driven and four-wheel steered mobile robot. Discrete stochastic state-space mathematical model is considered for behavioral and emotional transition processes of the autonomous mobile robot in the dynamic realistic environment. The term of cognitive mechanism system which is composed from rule base and reinforcement self-learning algorithm explain all of the deliberative events such as learning, reasoning and memory (rule spaces) of the autonomous mobile robot. The artificial cognitive model of autonomous robot control architecture has a dynamic associative memory including behavioral transition rules which are able to be learned for achieving multi-objective robot tasks. Motivation module of architecture has been considered as behavioral gain effect generator for achieving multi-objective robot tasks. According to emotional and behavioral state transition probabilities, artificial emotions determine sequences of behaviors for long-term action planning. Also reinforcement self-learning and reasoning ability of artificial cognitive model and motivational gain effects of proposed architecture can be observed on the executing behavioral sequences during simulation. The posture and speed of the robot and the configurations, speeds and torques of the wheels and all deliberative and cognitive events can be observed from the simulation plant and virtual reality viewer. This study constitutes basis for the multi-goal robot tasks and artificial emotions and cognitive mechanism-based behavior generation experiments on a real mobile robot.

1. Introduction

The new generation control architectures of autonomous mobile robots have been designed to be inspired from cognitive mechanism of the human brain. The emotional activations and cognitive events of brain play important role for decision making and long-term deliberative process planning of humans [1]. According to viewpoint of autonomous systems and intelligent robotics, artificial emotions can be considered as trigger of behavioral action sequences [2]. In the autonomous robot control systems, emotional transitions and behavior selection process should be based on probabilistic statistical modeling [3]. The term "cognitive mechanism model of the architecture" explains us all of the deliberative events such as learning, reasoning and memory (rule spaces) of the mobile robot [4]. This system employs a hybrid learning algorithm-based computational model which involves linguistic reasoning (dynamic fuzzy cognitive maps) and stochastic behavioral selection. Indeed, emotions and cognition are indispensable features of human brain for defining the behavioral characteristics. In alives, motivation effect of emotions is thought that define intense of the executing behaviors and activate them by neuropsychologists and cognitive scientists [2]. Motives determine intense of performing task processes of the behaviors during required optimal time frame. According to goals and needs of the mobile robot, this idea supports that a certain behavioral gain coefficient is applied to each behavior of the sequence as adaptive [4].

In literature, emotion–motivation for intentional selection and configuration of behavior-producing modules (EMIB) robot control and computational agent architecture were presented as good examples to emotion and motivation-based robot control architecture in 2002 [2]. This architecture was made of three main levels; behavior system, recommendation level and motivation level. Emotion-based robot control architecture was introduced in 2003 and named as ALEC (asynchronous learning by emotion and cognition) architecture [5] which utilizes hidden Markov model-based stochastic model. Another work on emotion-based structure was presented by Buss [3] in 2004. Advancement in cognitive sciences and control engineering will keep shedding light into this area of research.

Problems on decision making analysis of multi-objective robot tasks are one of the biggest challenges for the intelligent robot controller design [5]. In order to reach optimal situations (satisfying the goals), intelligent robots have to overcome more complex tasks (behaviors) which may conflict with each other [6] In the other architectures, while the robots are facing dynamic realistic multi-objective environments, they experience too many decision making problems including solution of ranking process of

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task priorities and elimination of behavioral noises (decision making unstabilities or task uncertainities). Standard deterministic behaviors may have not achieved these expected goals. Another major challenge is future task planning or scheduling issues of the robot in a dynamic realistic environments. Also the behaviors of the autonomous mobile robots have several features that pose serious difficulties to the learning and adaptation abilities. Ordinary supervised learning algorithms fail on reasoning and predicting of events.

This paper proposes to construct the original brain-inspired robot control architecture. In this study, combining of the emotion-based control approach and cognitive models is aimed into one computational robot architecture. Artificial or imitated emotion-based control approach with cognitive model provides to realize short-term and long-term task organization (task planning) and to execute the cognitive functions (self-learning, reasoning, dynamic memory) in the robot control architecture. The architecture has several types innovative parts apart from basic behavior-based robots, standard evolutionary robots, emotion inspired adaptive robots and some generic cognitive architectures. Artificial cognitive system has some wiseful features such as reinforcement self-learning, dynamic associative memory with behavior selection module (HMM) and uses *Q*-learning algorithm into self-organizing map (SOM) neural network in order to realizing self learning paradigm. Some generic cognitive architectures use some of these methods but they do not incorporate all these features into own structures. This model of the architecture provides to robot to learning and memorizing of sequences of behaviors (trajectorial tasks). Emotional functions provide making more general behavioral patterns. For instance, future behavioral sequences which the robot will face can be predicted in the intelligent robot controller. Therefore planning of actions is scheduled via artificial emotion-based control approach. Generally, emotional functions have not been utilized together with cognitive model for these reasons in basic behavior-based robots, standard evolutionary robots and even ordinary emotion- and cognitive-based robots. Motivation module is responsible to assign behavior gain coefficients which provide increasing or decreasing of impact of behavior. Some emotion-based robot control architectures employ this method however general emotion inspired robots have not cognitive functions. Major aim of motivation module is to be weighted emotional expression effects. Behavior producing module is a new generation sensor–motor association module in the general robot control architecture. Behavior producing module makes decisions as self-learning (self-organizing map neural network) and linguistic reasoning (fuzzy)-based low-level basic control module. Fuzzy (linguistic) labels are encoded into genetic string in this study, we did not mention behavior producing module elaborately.

The paper follows with Section 2 that explains behavior selection procedure and transition policy between them. Then Section 3 determines core of the artificial emotional system. Section 4 provides the details on the artificial cognitive model. Section 5 defines the motivational model. Then Section 6 depicts simulation results and finally conclusions are presented in Section 7.

2. Computational cognitive robot control architecture with artificial emotions paradigm

Presented autonomous robot control architecture approach provide a useful solution for robot behavior planning organization and management of multi-goal robot tasks [5]. Artificial emotions and cognition-based architecture constitutes main framework of the robot control strategy. It was constructed three main levels such as behavioral system, artificial cognitive model and core of the emotion–motivation-based module for this proposed robot control architecture. In this paper a nature inspired artificial emotion and cognition-based control system is developed for autonomous robots and discrete stochastic state-space mathematical model. Therefore a hidden Markov model (HMM) is considered for behavioral and emotional transition processes of the autonomous mobile robot in the dynamic realistic environment. The artificial emotion-based system oversee the behaviors which have multiple goals. The overall state of the art can be shown in Fig. 1. Cognitive events of artificial emotions such as reasoning activities of behavioral transitions and their learning performances investigated on the self-generated or available robot behaviors. Also motivational gain effects of artificial emotions investigated on the generated or available robot behaviors. Although the existence of a stimulus is necessary, it is not sufficient to arouse a motor response in a behavior-based robot [4]. Behavioral activation performances can be controlled with behavior gains. Thus basically motivation effects are considered as behavioral gain function and they are applied to the generated behavior sequences of artificial emotion. As addition to this, it may be applied with a certain threshold level or a continuous path [2]. This activation performances can be influenced by learning process due to the artificial cognitive model. Basically the artificial cognitive model of autonomous robot control architecture is considered as reinforcement self-learning strategy on the state transition rules for behavioral task processing.

According to the temporary needs (short or long term) and goals of the robot, behaviors are dynamically changed in a realistic environment. The generated behaviors have short-term and long-term goals [1]. A sequence of different behaviors can trigger a related emotional state to accomplish a certain goals.

3. Behavior selection module and transition policy

Behavior selection module can be considered as hidden Markov model which is represented as a finite state machine (Fig. 2). The priorities of behaviors depend on state transition probabilities which constitute on the state transition probability matrix *A*. This idea supports that the behavior with high state transition probability implies a high priority level. According to the learning process of the cognitive system, the state topology of behavior selection module is modified whenever a new state is added or an available state is deleted.

X_k expresses the any behavioral state in current situation such as "move to goal", "obstacle avoidance", "head on", " wander" and created or derived behaviors. X_{k+1} is the next behavioral state such as example estimated or predicted future behavioral state. W_{k+1} is next emotional priority distribution matrix. According to sensory data, behavior state transitions are influenced by W_{k+1}.

Behavior selection module performs the process given in Eq. (1) according to the probability space $\Theta = (\Omega, F, P)$ on the proposed HMM [3]:

$$X_{k+1} = AX_k + V_{k+1} \tag{1}$$

where Ω = {move to goal, obstacle avoidance, head on, wander/search} chosen according to model and X_k expresses the current behavioral state [3]. The matrix *A* describes the behavioral state probability distribution that satisfies (1), so that provided with a uniform random number a transition from state X_k, to X_{k+1} occurs with probability [3]:

$$P(X_{i,k+1}|X_{j,k}) = a_{i,j}P(X_{j,k}) \tag{2}$$

The determination of the state transition probability matrix *A* directly influences the stochastic dynamics of hidden process *X*,