A Motivational System For Mind Model CAM

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Abstract

A motivation model is proposed in the paper. Based on the model we develop a motivational system for mind model CAM. Through the application in automatic navigation of animal robots shows the motivation system is useful to solve the dynamic and complexity automatic problem.

Introduction

Cognitive models are appearing in all fields of cognition at a rapidly increasing rate, ranging from perception, memory to problem solving and decision-making. Cognitive modeling is becoming an essential tool for intelligence science and cognitive science.

Over the past forty years, it has been common to hear the mind likened to a digital computer which is called the Computational Theory of Mind (CTM). CTM attempts to connect the mind with computation and model features of the mind using computational modeling techniques (Horst, 2009). In particular, the mind modeling should include structure, process, function theory of the mind, as well as how to represent the mental state in the mind.

One of the most impressive attempts to model the human cognition is Anderson's ACT-R (Anderson, et al. 1988; Anderson, et al. 2004), which is a famous cognitive system and has been continuously developed for decades. Researchers have used ACT-R to model variety of psychological phenomena including memory, attention, reasoning, problem solving, and language processing.

Larid, Newell and Rosenbloom developed a symbolic cognitive architecture named Soar in early 1980s (Larid, et al. 1987; Larid, 2012). Soar is both a vision of what cognition is, and an implementation of this vision in the form of a software architecture. Soar has been used to develop many sophisticated agents, one of them is TAC-Air-Soar (Tambe, et al. 1995) which models fighter pilots in military training exercises.

PRODIGY is another cognitive system that was extensively developed from the middle 1980s to the late 1990s (Carbonell,et al. 1990). PRODIGY incorporates two kinds of rule based knowledge. One is domain rules that encode the conditions under which actions have certain effects. Another one is control rules that specify the conditions under which the architecture should select, reject, or prefer an operator, set of operator bindings, problem states or goals.

Pat Langley proposed a cognitive architecture named ICARUS (Langley,2006). ICARUS is neither the oldest nor most developed architecture, compared with some continually developing cognitive systems like ACT-R and Soar. However, ICARUS distinguishes itself via its concern with physical agents that operate in an external environment and focuses on the organizing, using and acquiring hierarchical knowledge structures. ICARUS also has some deficiencies, such as the lack of a sophisticated computational model to represent, manage and inference the knowledge in the cognitive system.

In 1998, Franklin and his colleagues developed a cognitive model called Intelligent Distribution Agent (IDA) which implemented as a software agent (Franklin,et al. 1998). The IDA model implements and fleshes out Global Workspace theory (Baars, 1988; Baars, et al. 2003), which suggests that conscious events involve widespread distribution of focal information needed to recruit neuronal resources for problem solving and renamed as Learning Intelligent Distribution Agent (LIDA). The LIDA architecture adds three fundamental, continuously active, learning mechanisms to the existing IDA system that underlie much of human learning: a) perceptual learning, the learning of new objects, categories, relations, etc., b) episodic learning of events, the what, where, and when, c) procedural learning, the learning of new actions and action sequences with which to accomplish new tasks (Ramamurthy, et al. 2006). The LIDA cognitive cycle consists of nine steps, that is, perception, percept, local associations, competition for consciousness, conscious broadcast, recruitment of resources, setting goal context hierarchy, action selection and action taken (Friedlander, 2008).

Ben Goertzel and his colleagues have recently proposed a cognitive architecture titled OpenCog Prime for robot and virtual embodied cognition (Goertzel, 2010). They define a set of interacting components designed to give rise to human-equivalent artificial general intelligence (AGI) as an emergent phenomenon of the whole system.

Rosenbloom has proposed factor graphs as an uniform implementation level for cognitive architecture, and shown that they can yield a state-of-the-art production match algorithm (Rosenbloom, 2009). He and his colleagues have developed a Sigma cognitive architecture by generalized language of conditionals, which compiles down to factor graphs for processing via the summary product algorithm (Rosenbloom, 2012).

Chris Eliasmith and his team of Waterloo neuroscientists have developed an artificial brain called Spaun (Semantic Pointer Architecture Unified Network) which contains 2.5 million virtual neurons. It can perform at least eight different tasks, from simple ones like copying an image to more complex ones similar to those found on IQ tests, such as finding the next number in a series (Eliasmith, 2012).

In Intelligence Science Laboratory a mind model named Consciousness And Memory Model (CAM) is proposed (Shi, et al. 2010). CAM has several important distinct characteristics, such as DDL-based knowledge representation, unique and sophisticated computational models for perception and cognition, global workspace theory based consciousness, motivation model and a dynamic workflow model for component cooperation.

Motivation is an important issue in intelligence science and artificial intelligent. In this paper a motivation model will be proposed. A motivational system for mind model CAM will be presented in terms of the motivation model. It can be applied to the automatic navigation of animal robots and so on.

The remainder of this paper is organized as follows. Section 2 gives the related works on motivation. Section 3 outlines the architecture of CAM. Section 4 will describe the motivation model. The motivational system supported by short-term memory of CAM is presented in Section 5. Then automatic navigation of animal robots will be illustrated. Finally, the conclusions of this paper are drawn and future works are pointed out.

Related Work

The Motivation concept was from psychology, Maslow suggested human behavior include a hierarchy of five classes needs through his paper titled a Theory of Human Motivation in 1943 (Maslow, 1943). Since it introduced to the public, the Maslow's hierarchy of needs theory has been made a significant impact to the every life aspect in people's life. This theory can give people more spirit and motivation so they can manage their life very well (Maslow, et al. 1987). The Maslow's hierarchy of needs is describing the reality of most people life experience accurately. The Maslow's hierarchy of needs theory is divided into five different levels of basic needs, including physiological needs in the lowest level, security needs in the second level, needs of love, affection and ownership in the next level, esteem needs in the fourth level, and the last is self-actualization needs in the top of hierarchy shown in Figure 1. Maslow actually was a humanistic psychologist who believed in the human potential that human can struggle to reach the success and look for the creativity in order to reach the highest wisdom and also the logic think. From above we can see that humanistic views of motivation focus on the learner as a whole person and examine the relationships among physical, emotional, intellectual, and aesthetic needs.

Clayton Alderfer's ERG theory is built upon Maslow's hierarchy of needs theory. To begin his theory, Alderfer collapses Maslow's five levels of needs into three categories（Alderfer，1972）: existence needs are desires for physiological and material well-being; relatedness needs are desires for satisfying interpersonal relationships; growth needs are desires for continued psychological growth and development.

Figure 1. Hierarchy of needs

Keller has developed a four-factor theory to explain motivation. The first is attention (A), the second relevance (R), the third confidence (C), and the fourth satisfaction (S) (Keller, et al. 1988). The model also contains strategies that can help an instructor stimulate or maintain each motivational element.

De Sevin et al. presented a computational motivation model for behavior selection of virtual characters (de Sevin, et al., 2004). Action selection architectures for autonomous virtual humans should be individual, motivational, reactive and proactive to obtain a high degree of autonomy. Paper (de Sevin, et al., 2004) described in detail the motivational model of action selection for autonomous virtual humans in which overlapping hierarchical classifier systems, working in parallel to generate coherent behavioral plans, are associated with the functionalities of a free flow hierarchy to give reactivity to the hierarchical system.

OMG proposed the Business Motivation Model (BMM) is a specification for support of business decisions about how to react to a changing world (OMG, 2008). An enterprise would use it by acquiring a BMM-compliant tool and then creating its own BMM - populating the model with business information specific to the enterprise.

Bach proposed a framework for an extensible motivational system of cognitive agents, based on research in psychology (Bach, 2011). It draws on a finite set of pre-defined drives, which relate to needs of the system. Goals are established through reinforcement learning by interacting with an environment. Bach also points out that all behavior of Psi agents is directed towards a goal situation, which is characterized by a consumptive action satisfying one of the needs. Bach proposes hierarchy of agent needs with three levels shown in Figure 2. The lowest level is physiological needs, containing fuel and water, intactness. Second level is cognitive needs, containing certainty, competence, and aesthetics. The third level is social needs, containing affiliation and supplication signals.

Bach uses Psi theory to define a possible solution for a drive-based, poly-thematic motivational system. It can reflect physiological needs, also addresses the establishment of cognitive and social goals. Its straightforward integration of needs allows adapting it quickly to different environments and types of agents. They develop a version of the model which has been successfully evaluated against human performance in problem solving games (Bach, 2009).

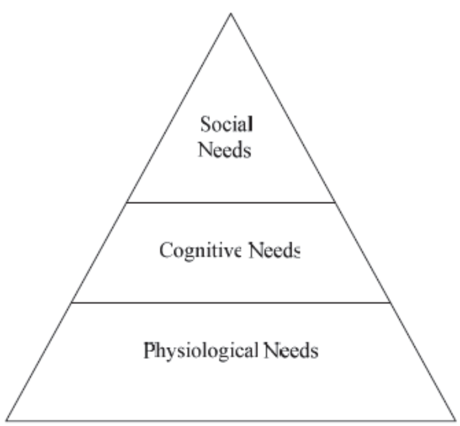

Figure 2. Hierarchy of agent needs

Bach uses Psi theory to define a possible solution for a drive-based, poly-thematic motivational system. It can reflect physiological needs, also addresses the establishment of cognitive and social goals. Its straightforward integration of needs allows adapting it quickly to different environments and types of agents. They develop a version of the model which has been successfully evaluated against human performance in problem solving games.

Architecture of CAM

Consciousness And Memory model (CAM) is a general framework for developing brain-like intelligent machines. The architecture of CAM is depicted in Figure 3. The figure shows that CAM consists of 10 modules mainly. We describe the functions of these modules as follows:

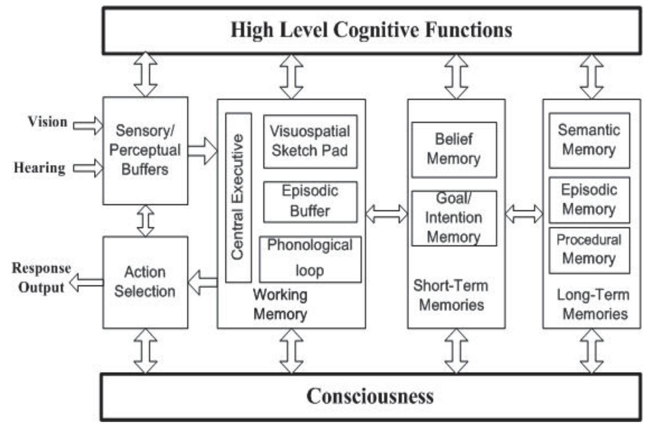

Figure 3. Architecture of CAM

1. ***Visual module***: From lateral geniculate nucleus (LGN) neuron send their signals to the primary visual cortex V1. About 90% of the outputs from the retina project to the LGN and then onward to V1. In the ventral pathway, many signals from V1 travel to ventral extrastriate area V2, V3 and V4 and onward to many areas of the temporal lobe.

2. ***Aural module***: The auditory module is comprised of many stages and pathways that range from ear, to the brainstem, to subcortical nuclei, and to cortex. The advent of neuroimaging techniques has provided a wealth of new data for understanding the cortical auditory system.

3. ***Sensory buffers***: Information which first comes to us through our senses is stored for a very short period of time within the sensory buffer. The sensory buffer is associated with our five senses – seeing (visual), hearing (auditory), doing (kinesthetic), feeling (tactile) and smelling (olfactory). Usually researchers pay more attention to visual and auditory sensory buffer.

4. ***Working memory***: It includes the central executive, visuospatial sketch pad, phonological loop and episodic buffer. The central executive is future directed and goal oriented in effective, flexible and adaptive. At the basic level the working memory is located in the prefrontal cortex.

5. ***Short-term memory***: Short-term memory is considered to be a temporary resting place and information is held there for approximately 30 seconds to two minutes. Short-term memory systems are associated with the

process of encoding. In CAM model short-term memory stores agent's beliefs, goals and intention contents which are change rapidly in response to environmental conditions and agent's agenda.

6. ***Long-term memory***: Long-term memory is considered to be relatively permanent. It is associated with the processes of storage and retrieval of information from memory. According to the stored contents type long-term memory is divided semantic, episodic and procedural memory.

7. ***Action selection***: It is the process of constructing a complex composite action from atomic actions to achieve a specific task. Action selection can be divided into two steps, first is atomic action selection, i.e., select related atomic action from action library. Then selected atomic actions are composed together using a planning strategy. One of action selection mechanism is based on a spiking basal ganglia model.

8. ***Response output***: The motor hierarchy begins with general goals, influenced by emotional and motivational input from limbic regions. The primary cortical motor region directly generates muscle based control signals that realize a given internal movement command.

9. ***Consciousness***: The primary focus is on global workspace theory, motivation model, attention, and the executive control system of the mind in CAM. The consciousness is modeled by a finite state machine. The state of the finite state machine corresponds to the human's mental state.

10. ***High level cognitive functions***: It includes a class of high level cognitive functions, such as reasoning, planning, learning etc., which perform cognitive activities based on the basic cognitive functions supported by the memory and consciousness components of CAM.

Motivational Model

Motivation is a complex phenomenon. Several theories attempt to explain how motivation works in Section 2. A new motivation model is proposed shown in Figure 4. The new model consists of 7 modules: environment, internal context, motivation, motivation base, goal, action selection and action composition. Their main functions are explained as follows:

1. ***Environment*** provides the external information through sensory devices or other agents.
2. ***Internal context*** represents the homeostatic internal state of the agent and evolves according to the effects of actions.
3. ***Motivation*** is an abstraction corresponding to tendency to behave in particular ways according to environmental information. Motivations set goals for the agent in order to satisfy internal context.
4. ***Motivation base*** contains a set of motivations and motivation knowledge with defined format.
5. ***Goal*** is a desired result for a person or a organization. It used to define a sequence of actions to reach specific goals.
6. ***Actions selection*** is used to perform motivated action that can satisfy one or several motivations.
7. ***Action composition*** is the process of constructing a complex composite action from atomic actions to achieve a specific task.

The action composition is composed of overlapping hierarchical decision loops running in parallel**.** The number of motivations is not limited. Action composition of the most activated node is not carried out at each cycle, as in a classical hierarchy, but only at the end in the action layer, as in a free flow hierarchy. In the end, the selected action is activated.

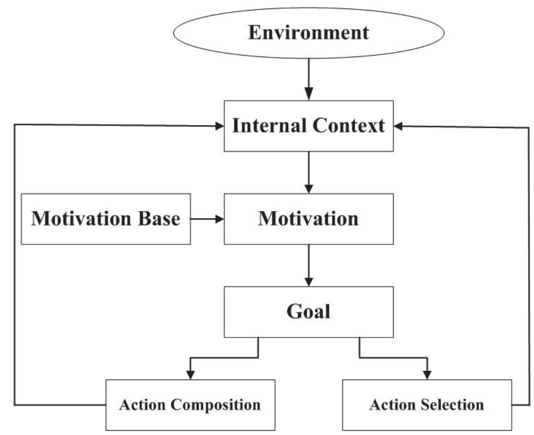

Figure 4. Motivation model

At present CAM is going to apply to animal robot which is a brain-machine integration system. All behaviors of brain-machine integration stem from a fixed and finite number of needs. According to characteristics and requirements of brain-machine integration there are 3 type of needs, that is perception, adaptation and cooperation:

(1) ***Perception needs*** Acquire environment information through vision, audition, touch, taste, smell.

(2) ***Adaptation needs*** Adapt environment condition and optimize impaction of action.

(3) ***Cooperation needs*** Promise to reward a cooperation action between brain and machine.

A goal contains a number of sub-goals which can be described formally:

$$G_t = \{G_1^t, G_2^t, ..., G_n^t\} \quad \text{at time } t$$

Definition 1: A hierarchical goal which is a directed acyclic graph (DAG) can be defined as a 3-tuples:

DAG =（P，E，$\prec$）

Where

P: a set of nodes

E: a set of edges which indicate the relation between connected nodes

$\prec$: partial order

Should be satisfied following conditions:

a) A particular node *TopGoal is contained in P,* $\forall p \in P$, $p \neq TopGoal$, and $p \prec TopGoal$

b) if $p_1, p_2 \in P$, then $p_1 \neq p_2$;

c) if $< p_1, p_2 > \in E$, then $p_2 \prec p_1$;

d) if $p \in P$, $\exists p_1, p_2, ..., p_n \in P$, and

$< p, p_1 > \in E, < p_1, p_2 > \in E$,

…,

$< p_{n-1}, p_n > \in E$

then $< p, p_2 > \notin E, ..., < p, p_n > \notin E$.

Let a set of goals G_t at time t be $G_t = \{G_1^t, G_2^t, ..., G_n^t\}$, where , $G_i^t, 1 \le i \le n$, let $G_i^t = \{G_{i_1}^t, G_{i_2}^t, ..., G_{i_k}^t\}$, $1 \le k \le n$, satisfy $G_{i_r}^t \neq G_{i_s}^t, r \neq s$, that is, no repeated goals in $G_i^t, 1 \le i \le n$. The algorithm for creating hierarchical goals is given as follows:

Algorithm 1: Hierarchical goals

Input: a set of goals $G_i^t = \{G_{i_1}^t, G_{i_2}^t, ..., G_{i_k}^t\}$ and their partial order.

Output: *DAG* which is a directed acyclic graph.

1.Initialize *DAG* = *null*;

2. if G_i^t is empty, then end and return *DAG;*

3. take $G_{i_j}^t$ from G_i^t, $1 \le j \le k$, update $G_i^t \leftarrow G_i^t - \{G_{i_j}^t\}$;

4. if G_i^t is empty, create *root = new node* (*"root"*), generate $node(G_{i_j}^t)$, and let $parent(node(G_{i_j}^t)) = root$;

5. call $insert(root, G_{i_j}^t)$;

6. Goto 2.

Function $insert(root, G_{i_j}^t)$

1. let *Children = children(root)*;

2. if Children is empty, create a new node $node(G_{i_j}^t)$, and , $parent(node(G_{i_j}^t)) = root$, return;

3. take *Child* from *Children,* let $Children \leftarrow Children - \{Child\}$;

4. if no partial order between *Child.Concept* and $G_{i_j}^t$, then Goto 2;

5. if $Child.Concept \prec G_{i_j}^t$, then create a new node $node(G_{i_j}^t)$, let $parent(node(G_{i_j}^t)) = root$, and $parent(Child) = node(G_{i_j}^t)$, delete $parent(Child) = root$, return;

6. call $insert(Child, G_{i_j}^t)$.

Motivational System

In CAM short-term memory is the facilitate to support the motivation system. As illustrated in Figure 3, short term memory involves two subcomponents, belief memory and goal/intention memory. Short-term memory implements the principal aspects of belief-desire-intention (BDI) model which combines a respectable philosophical model of human practical reasoning. BDI model is inspired by logics and psychology, and the key technique is build agents using symbolic representations of agents' beliefs, desires, and intentions.

Beliefs are facts representing what an agent believes about the world, i.e. an agent's representation of the state of the world. Agents may obtain such beliefs from sensing their world or experiences. In CAM belief memory stores agent's current beliefs, including motivation knowledge. For example, in automatic navigation of animal robots a motivation causes "an agent navigating by search alone shows no active orientation towards the goal" which can be described (search, Goal recognition, 0.4) as shown in Table 1.

Desires are goals or some desired end states. Intentions refer both to an agent's commitments to its desires (goals) and its commitment to the plans selected to achieve those goals. Goal/intention memory stores agent's current goals and intention. Different goals can be achieved, but only one will be selected. In CAM a directed acyclic graph is used for hierarchical goal as previous section discussed.

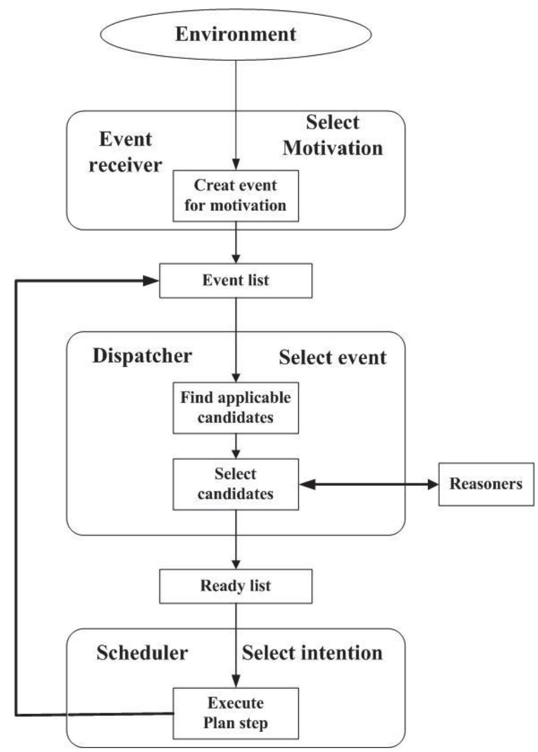

Figure 5. Motivation execution flow

For a complete motivation execution the core component is plan selection. Plans not have to be selected for goals, but for internal events and incoming motivations. To collect the incoming motivations and forward them to the plan selection a specialized component, that is dispatcher is needed. Another component scheduler is required to execute selected plans.

Figure 5 shows the motivation execution flow. The event receiver has the purpose to take motivation from the environment and create motivation events which are placed in the event list. The dispatcher continuously consumes the events from the event list and builds the applicable plan list for each event. This is done by checking for all plans if the considered event or goal triggers the plan and additionally if the plan's preconditions and context conditions are valid. Corresponding plans are added to the list of applicable plans. In a subsequent step, the dispatcher selects plans to be executed by reasoning facilities. This means that if more than one plan is principally applicable for the given event or goal the decision process is delegated to a user-defined reasoning plans. The reasoner has the task to rank the plan candidates with respect to domain-dependent characteristics. The selected plans are placed in the ready list after associating the selected plans to the corresponding events or goals. This makes the plan aware of the goal or event to handle and allows for reading goal or event details from within the plan body. The scheduler takes the plans from the ready list and executes them. execution of plans is done stepwise, which means that only one plan step of a single plan is executed uninterruptedly.

Consider the dual nature of motivation, that is implicit and explicit, the motivation process is complexity. In general, implicit motivational processes are primary and more essential than explicit motivational processes. Here we only focus on explicit motivation and hypothesize that the explicit motivational representations consist mainly of explicit goals of an agent. Explicit goals provide specific and tangible motivations for actions. Explicit goals also allow more behavioral flexibility and formation of expectancies. Motivation could be represented as a 3-tuples {N,G,I}, where N means needs, G is goal, I means the motivation intensity. A motivation is activated by motivational rules which structure has following format:

$$R=(P, D, \text{Strength}(P|D))$$

where, P indicates the conditions of rule activation; D is a set of actions for the motivation; Strength($P|D$) is a value within interval [0,1].

In motivational system the plan consists of plan head and plan body. Plan head defines the circumstances under which the plan may be selected. A plan body specifies the actions to be executed. The basic structure of a plan body is as follows:

Algorithm 2: Plan body execution

1. Initialize;
2. if a plan success
   then passed();
3. if a plan failure
   then l failed();
4. if a plan is aborted
   then aborted().

In Algorithm 2 three methods passed() , failed() and aborted() are provided allowing a plan to perform clean up operations. Two different abort cases can be distinguished, either when the corresponding goal succeeds before the plan is finished or when the plans root goal is dropped.

Animal Robot Navigation

Mind model CAM is a general framework for developing intelligent systems and robots. The one of outstanding feature is motivational system which will enhance the automatic level and Improve system quality. Here we apply motivation system to the automatic navigation of animal robots.

An animal robot is an animal mounted with a simulator which generates electrical stimuli to specific brain area, in order to drive the animal to take actions that humans expect. Brain-machine integration provides a new interaction between the animal neural system and the outer man-made system. Based on this technology animal robots employ living creature as robots and manipulate their behaviors through mild electric simulation on specific regions of the brain which can improve intelligent behavior. Among them the automatic navigation of animal robots is a challenge topic.

Table 1. Motivation base for navigation

Navigation	**Behavioral Goal**	**Intensity**
Search	Goal recognition	0.4
Direction-following	Align course with local direction	0.7
Aiming	Keep goal in front	0.6
Guidance	Attain spatial relation to the surrounding objects	0.5
Recognition-triggered response	Association sensory pattern–action	0.3
Topological navigation	Route integration, route planning	0.2
Survey navigation	Embedding into a common reference frame	0.1

Navigation is the process of determining and maintaining a course or trajectory to a goal location. According to the complexity of the task navigation behavior is classified in hierarchical level (Franz, et al., 2000). Local navigation behaviors are divided into four levels: search, direction-following, aiming and guidance; way-finding behaviors into three levels: recognition-triggered response, topological and survey navigation. We can construct motivation base for the animal robots in terms of navigation hierarchy shown in Table 1.

Due to the paper space is limited, here we only take simple motivation case as example to illustrate. According to the time cost of navigation we assign the intensity to each navigation type. For direction-following navigation the agent must be able to align its course with a locally available direction to find the goal. The goal itself needs not to be perceivable during approach. This method is saving time and assign the intensity as 0.7. Survey navigation requires the embedding of all known places and of their spatial relations into a common frame of reference. Survey navigation is a time consuming method and the intensity is assigned to 0.1. An agent using survey navigation is able to find novel paths over unknown terrain so that we can adjust the rank depending on the environment information.

Note that the animal robot navigation is more complexity in fact, we should consider different strategy to deal with different motivation in term of different need type, such as perception needs, adaptation needs and cooperation needs.

Conclusions

Motivation is a complex phenomenon and plays important role in animal robots. This paper presented a new motivation model. Under support of short-term memory the motivational system is developed. The motivational system looks like an agent with BDI style. Through the application in automatic navigation of animal robots shows the motivational system is useful for solving the dynamic and complexity automatic problem.

Collaboration work of animal robots is a very interesting topic. We will research on the connection between the motivation and collaboration in functions. Due to the unconscious characteristics of needs the implicit motivational process and representation will be studied in the future.

Acknowledgements

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