How Difficult Is It for Robots to Maintain Home Safety? – A Brain-Inspired Robotics Point of View

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Abstract. The cognition-based human intelligence, that is driven by emotion and feeling will definitely change the robot learning, memory, attention and decision making mechanism. The aim of paper is to give in depth investigation on how the robot learning based on emotion and feeling will give a new dimension to its performance. It means that self-learning is not just dependent upon a logical brain and proper embodiment; rather a feedback in terms of emotion and feeling based on experience is required for self-learning. It is the feedback in the form of feeling and emotion that plays a vital role in a complete self-learning process and this makes the robot more human.

Keywords: emotion, intelligence, service robot, dynamical system, feeling of pain, mobile-robot.

1 Introduction

"Learning" is a beautiful word, but it's hard to implement into robots. Contextual decision-making is required in a dynamical environment when we are asked to take care of everything around the house. At home, everything is drastically changing including rules which family members had just shared it yesterday. The change of rules is sometime non-logical and may occur depending on emotional fluctuations in mum's policy, or dad's whims. Classifications of assumptions, parameters and variables are necessary to form a learning paradigm and provide its implementation method into engineering systems. In cognitive science and psychology, child's cognitive development has been studied from observations of child's behavior and acquisitions of various skills. Jean Piaget [1] focused on the transitions of learning schemes during the developmental process and noticed an organized pattern of thought and behavior, called "schema." On the other hand, what factors exist in child's mind subjectively, as well-established knowledge or ill-defined borders, remains unsolved. This is the gap between objective and subjective representations. Science basically needs repeatability, objectivity and quantitative assessment. Repeatability is the base to confirm whether it is true or not by reproduction of the

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same phenomenon under equivalent conditions. Objectivity is a need to be observed by anyone. Finally we have to take into account various factors based on quantitative comparisons. Everyday events are not countable, but we treat it in a form of countable factors for implementation into robot's intelligence. Ontology, epistemology and axiology are the philosophical trinity. From the ontological argument, the perfect circle does not exist in the real world but it exists in our minds. Similarly any object is never be indentified by a combination of countable attributes happens in an epistemological sense. For example, once you define cup as a container with handle, and then the cup with a broken handle is never be recognized as a cup. Interestingly the dictionary describes that the definition of the cup is "a small open container usually used for drinking," which highlights the purpose of its use for drinking. It is closely related to axiology, and it is asking why the cup exists, for what the cup is made of and for whom the cup exists for. This sense slightly exceeds the range of objective and logical thinking. The robot, an external observer without any desire, is unable to understand what it is for. It is difficult for the robot to determine its own behavior if it is not arisen from its significance of existence. The cup is meaningless if robots never use it for themselves. Thus, recognition of cups is the same as seeing wayside stones. This paper discusses epistemological aspects of our everyday events for robots. Especially to focus on what is the ideal and abstract internal representation that happens in the real environment (ontology), how to effectively recognize objects (epistemology), plus the values and risks of what has occurred and will occur (axiology).

2 Definition of Intelligence

Intelligence can be defined as "the capacity to acquire and apply knowledge by means of thought and reason," which leaves many aspects we must be considered [2]. Hubert Dreyfus [3] noticed a limited capacity for understanding the meaning of sentences to represent a situation and conversation among kids by introducing the following sentence from a story of Eugene Charniak, who was a student of Marvin Minsky:

Today was Jack's birthday. Penny and Janet went to the store. They were going to get presents. Janet decided to get a kite. "Don't do that," said Penny. "Jack has a kite. He will make you take it back."

Dreyfus noted that "the goal is to construct a theory that explains how the reader understands that "it" refers to the new kite, not the one Jack already owns." *i.e.* Jack will make Janet take back the kite if Jack already owns a similar kite. Here we get into details about what its difficulty for algorithmic procedures, or robot, to understand the exact meaning, and consider it as propositions: 1) relationship between sentences for capturing the whole meaning contextually (sentences that are not in linear combinations), 2) emotional feeling and reactions of people who play their roles in the story (biological sense), 3) recursive procedure that is necessary to predict what will happen next (prospective information). On the first proposition, we can take a look at the performance in the current technology from a popular online translation website, and an example of the translation result to Japanese and the reversal translation back to English (English → Japanese → English) can be obtained as

It was a birthday of Jack today. I went to the store and Janet penny. They were going to get the gift. Janet has decided to get the kite. "Please do not do it," Penny said. "Jack, you have a kite. He will make you get it back."

How do we evaluate the above result? As shown in Table 1, the translated sentences were reproduced in a similar manner. If you calculate a ratio between numbers of correct (C) and semi-correct (C') sentences and wrong sentences (W) and the correctness can be evaluated as a quantitative value such as approximately 86% (=6/7 sentences). However we humans feel a sense of confusion to read the second sentence "I went to the store." Who am "I"? Is it a reader as an external observer? Or, is it someone in the story except Penny, Janet and Jack? This false step of the translation may mislead the reader to understand the whole meaning of the sentences because of a confusion of the word "it" indicates. This result indicates that the machine translation does not bridge between sentences appropriately in a sense of contextual implication. This is the point of proposition 1, which suggests that a one-by-one independent translation tends to ignore contextual interpretations. Probabilistic language models and Bayesian probability models based on conditional probabilities known as $P(A \mid B)$ become increasingly precise if the condition B includes all the past events and $P(A \mid B)$ is obtained from large data sets. The difficulty comes from the trade-off between two factors, because the more consideration of a long past history the more the event becomes "rare." Therefore, some other common principle is necessary to be considered for concatenating fragments of sentences into continuous meanings.

Table 1. Comparison between original sentences and machine translations

#	Original	Machine Translation by E→J→E	c/w
1	Today was Jack's birthday.	It was a birthday of Jack today.	C
2	Penny and Janet went to the store.	I went to the store and Janet penny.	W
3	They were going to get presents.	They were going to get the gift.	C
4	Janet decided to get a kite.	Janet has decided to get the kite.	C
5	"Don't do that," said Penny.	"Please do not do it," Penny said.	C
6	Jack has a kite.	Jack, you have a kite.	C'
7	He will make you take it back.	He will make you get it back.	C'

On the second proposition, emotional sense is the most difficult part for robots to implement because it is impossible to substitute for logical reasoning. Emotion is one aspect of intelligence, which is an expression of accumulated internal senses and feedbacks influenced in a particular environment attention, past memory, leaning of common sense and then it affects decision making in some cases (R. J. Dolan, et al. Science 298, 1191 (2002)). Cognition of emotion is a type of meta-cognition that includes the subjective knowledge of emotional state and emotional processes

(Markku S. Hannula, University of Turku). Going back to the Charniak's story, the point is observed in the reason why "Jack will make you take it back," and we can estimate the reason naturally as Jack already owns a similar kite. Why? If the kite was cookies and cakes, the story would be different and Jack may want them even though he already has. If Jack's hobby is a collection of baseball cards, he desires cards even more. In this case, we can imagine that Jack will be disappointed when he sees the kite, he will be more happy to have a gift of another toy. Penny and Janet are excited to plan a birthday surprise gift for him. Disappointment, happiness and exciting are emotional reactions, which are never felt by robots with reality. If there is a possible way to interpret people's emotional feelings and reactions, robots become more intelligent to extend the solvable range of various tasks [4]. However, the emotion involves personal and subjective experiences, social behaviors and cognitive senses shared against human [4]. The emotion involves motive, desire, intention, belief, perception and sensations [5]. How do we can implement those things into robots? Some approaches of emotional evaluation to implement agent-based systems have been explored in a hierarchical functional structure [6][7].

Third proposition focuses on time, or prospective events. The last sentence "He will make you take it back" represents an estimation of future events as

$event(t)$: Janet gives Jack a present she brought in the store,

$event(t+1)$: Jack recognizes the present as a kite and remembers his owns a kite,

$event(t+2)$: Jack asks Janet to go back to the shop for returning the kite.

According to the dictionary, "take something back" means to return it to the place where it came from. The sentence may be interpreted with the meaning of Jack will return the kite back by himself if the description is "Jack will take it back," but the sentence uses a causative verb, make, producing an effect, especially to indicate that Jack will force Janet to do something. Thus, with the above three propositions, future events are represented in a compressed form from this short sentence. Interestingly, this sentence gave additional information regarding the expectation from Jack,

$event(t+3)$: Janet returns the kite to the shop and gets another present instead of the kite.

It offers a glimpse of Jack's personality through a part of the sentence as "He will make you …" The reader guesses that Jack is a self-assured person, does not hesitate to express his own desire, and asks Janet to get another present.

Indeed, automated approaches to reproduce the human ability on situation recognition is the hard problem because it need to deal appropriately and effectively with the following points. 1) by concatenating contextually fragments into a consistent form to provide the whole meaning (beyond linear combinations), 2) speculation or cognitive rehearsal of emotional feeling and reactions of persons participating in the story (a simulated biological sense), 3) recursive procedure to reconstruct future events as a prediction by focusing on a key person (prospective information and direction of the story), as discussed the above. The next section is getting into deeper into the emotional aspect of the brain and exploring a potential of brain-inspired design for its implementation.

3 Emotion, Feeling of Pain and Self-awareness

Evaluation of an event or object with respect to "value" is substantially influenced by emotional judgment in a subconscious level [8][9][10]. Joseph Ledoux [11] takes into account an existence of animal's emotion as well as what the human possess, which is in some cases exposed as conscious emotions by exceeding a threshold level of accumulated subconscious feelings [12]. In a review of the brain mechanism to maintain emotional judgment by focusing on the amygdala function, Ledoux [11] admits a plausibility of psychodynamics perspective by Sigmund Freud, a neurologist and psychoanalysist, who augured that the conscious level of our mind is similar to the tip of the iceberg which could be seen, while the unconscious level is hidden, or unaware and yet governs the conscious level. Similarly, there is a viewpoint that conscious emotions are close to immediate awareness and easily accessible, like a meta-cognition, and it continuously binds with subconscious feelings of body and sensations in a form of strap or winding staircase for making of consciousness [13].

This implies that unless an artificial reproduction of chemosensory systems and integumentary sense organs we have, it is impossible to reconstruct the same consciousness into a robot. Once we focus on a functional part such as a meta-level cognition, a solution can be found in a flexible decision making like switching rules depending on the situational change [14]. Attentional control is also the key to consider in the engineering viewpoint.

Assuming a practical situation for keeping safe from inattention at home environment, we start to consider "feeling of pain" to avoid a critical situation. According to a textbook for health and safety trainers [15] risk of injury gradually shifts with respect to characteristics of infant and child (Table 2). A possible way to obtain the same ability as humans is 1) to form the body as it is (organized biochemically like stem cells) or to acquire through 2) imitation (effective in motor skills), 3) observation and imagination (guess what happens based on physical laws) and by 4) instructions of emotional feelings via verbal communications (literature based; extension of imagination). It is difficult for robots to trace the child's cognitive development completely (Asada) because the robot is not organized by the same ingredients as the child and to take time for training like twenty years.

The above example of risks is depending on situations that the child is in now and the level of knowledge that the child has now. Fear and curiosity vary a great deal in the age. The feeling of pain and emotional reactions has a significant relationship with a process of prediction and decision to act (Fig.1). The person keeps on training his mind how to stand and walk in every attempt. It implies that a robot also needs to have feeling of pain neither an emotion, which can drive to memorize what happened and to predict what will happen. We simply consider that feelings and emotions is a core of the self-awareness as an alertness, which differs from reward and punishment. Implicit and procedural learning without conscious attentions can be done by reward and punishment, called reinforcement learning. Feelings are fundamentals for the existence of representation of 'self' [13] such as basis of self-protection, self-motivation, self-confidence, self-abhorrence, self-accusation, self-actualization, and so on. Another clue to consider the self-awareness as alertness is time property (Fig.2).

Table 2. Physical risks of injury at home according to established knowledge [14]

Age	Characteristics	Risk of Injury	Prevention Tips
Birth to 3 months	• Eat, sleeps, cries • Begins grasping and Rolling over unexpectedly • Needs support of head and neck	• Falls from couches, tables, changing tables and bed • Burns from hot liquids	• Never leave infants alone on beds, chairs or other high surfaces • Check water temperature in the bath • Keep small object and toys away
4 to 6 months	• Sits with support • Plays with open hands • Put things in mouth • Curious about surroundings • Wants to test, touch and shake objects	• Falls • Burns from hot liquids • Choking and suffocation	(the same as above 3 tips)
7 to 12 months	• Sits alone • Very curious about everything • Crawls • Starts to walk • Explores surroundings • Pulls things • Likes to go outside • Imitates movements of adults and others	(the above 3 tips) + • Drowning	(the above 3 tips) + • Keep hot foods and liquids out of the reach of children • Put guards around radiators, hot pipes and other hot surfaces • Always carefully supervise; never leave alone near any water (tubs, toilets, buckets, and pool)

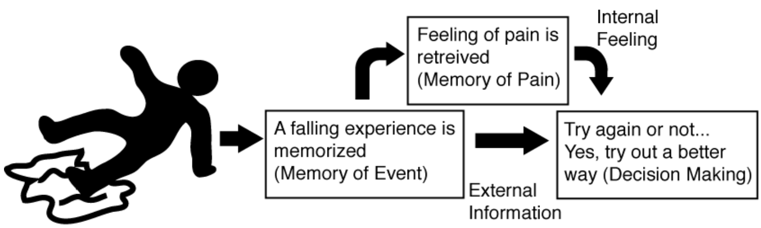

Fig. 1. A situation to perceive an event to be dangerous. Firstly the person experienced something wrong and felt a pain. Secondly, the one concerns its repeatability because of the pain and think a causal relation on the event. If the one is aware that the act of walking is a cause of slipping, a future decision is in the naïve balance whether the one should walk or not, as a conflict. The one walks if the intension exceeds the level of the fear, knowledge specifies causes in more detail, recognition of a situational change by preparing for prevention of the event, and so on.

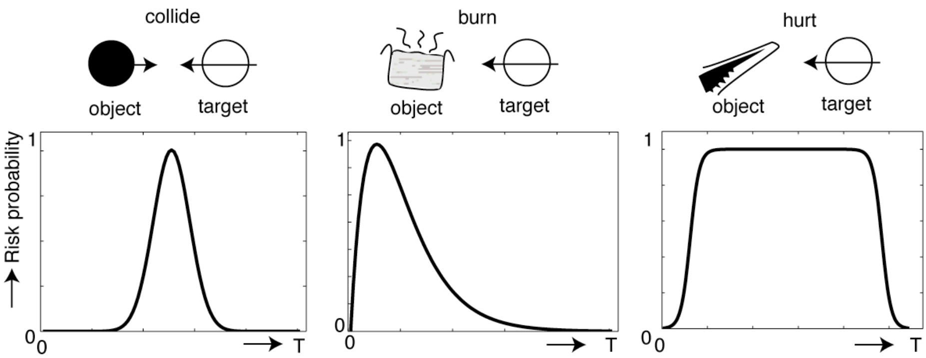

Fig. 2. Example of time courses of happening dangerous events. A sudden event (left), event with a risky time envelope (middle), event with alternative options whether it is risky or not (right). Those events have different temporal characters.

4 Meta Level Cognition or Primordial Sense

How do we can implement realistic feelings into robots? It should be beyond learning theories and paradigms, which are defined in a sense of acquisition of specific skills increasingly, because we were not born as a 'tabula rasa' [16]. Sympathy without action cannot be treated by behaviorism and input-output mapping systems. The 'emotional judgment' is considered as unimportant rather than logical judgment in human cases but it is necessary to generate the sympathy and difficult to reduce a set of logical processes. Focusing on being biological systems, having fate of death and living in the unstable environment and unstable body, the concept of emotions can be extended into primitive self-consistent systems of information representation. We hypothesize that following three are included in the primitives and consider the possibility to describe them by a mathematical model of dynamical systems:

Feeling of Pain. A sense of lose. Knowing about something that will be gone, or having an anticipation of lose. The simplest dynamics of internal value H_p is described as

$$\frac{dH_p}{dt} = -f\left(H_p, \theta\right) \tag{1}$$

where f denotes a non-linear function to control the decrease rate with a limit of time, which is defined as the threshold θ including external forces.

Lack of Satisfaction. Filling actions. Filling something or someone in a hole or empty space. The simplest dynamics of internal value H_s is described as

$$\frac{dH_s}{dt} = g\left(H_s, \theta'\right) - \omega \tag{2}$$

where g denotes a control function with a threshold θ' and ω is a constant of abrasion.

Awe and Wonder. Decisions biased fear and curiosity. To inhibit the current motion when it detects something strange, or else, to enhance and trigger a motion when it finds something new and different. Those two factors are considered as exclusive each other. The simplest dynamics of decisions D according to a mapping of internal value A is described as

$$D(A) = Mapping(A),$$
$$\frac{dA}{dt} = F(A, \theta_F) \oplus C(A, \theta_C) \tag{3}$$

where F and C respectively denote functions on fear and curiosity with control parameters θ_F and θ_C.

5 Concluding Remarks

In the present paper, we discussed how difficult a robot maintains home safety by monitoring and external observations even if verbal instructions are given, and then we noticed that the seriousness is staying on learning paradigms especially in input-output mapping and statistical learning theories ignoring temporal changes. We suggested that a possible and effective implementation is found in modeling of internal and spontaneous processes according to time and values. Values are still difficult to treat because we go back to the same unsolved question if the designer embeds the values into the robot according to external observations. However the key is, once a value is defined according to the purpose of the robot, the temporal change of the value should be described as dynamical system with a limit of time, instability and ambivalent. Such a process is like filling water into a cup with a small hole in the bottom. Learning in robot is not isolated from a property of having a body, which is restricted kinetically and physically. In other words, the robot follows the physical law of time and space. Therefore, the embedded intelligence has a fate to conquer the dimension of space and time. This is a case study for assessments of service robots at home, sharing space and time with humans, particularly undeveloped children. If we build a robot with emotion in a form of dynamical systems [11] will perform more like human in terms of learning, memory, attention and decision making mechanism. A development of artificial mind will change the way of robots performance at places like home and office environment.

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