Feeling artificial intelligence. Attention engine model borrowed from living beings

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Abstract
Feeling AI (FAI) as a kind of Hybrid AI aimed to fill niche of service provided by robots is discussed. Using Hybrid AI based on symbolic and machine learning techniques combined with "Emotional Shell" and pre-trained set of different skills is problematic due to limited computer facilities supporting robotic operating autonomously in real physical world. This article proposes, in contrast to symbolic approach, set up FAI on the cognitive response-making model borrowed from living beings that demonstrate the smart behavior in condition of the lack information using the simplest nervous net facilities. Based on findings of neurobiology and cognitive science about behavior of hydra, bee, and creature with higher nervous organization, the attention mechanism model supporting response-making is shown. Interaction of four cognitive models such as perception, drive, emotion, and attention when cognitive engine processes the knowledge presented by set of independent response prototypes is given. Possibilities of borrowed model formalized on fuzzy Certainty Factor (CF) are discussed on robotic application.

Keywords
Feeling artificial intelligence, model borrowed from living beings, cognitive model, perception, emotion, attention, robotic

1. Introduction

To explain, to what diversity of Hybrid AI is FAI we will adopt the following perspective on AI [1]. In real-life, employees-human delivering services to customers have to have the knowledge depend on the nature of the service. Simple, standardized, repetitive, and routine tasks require low level skills but tasks with previously unpredictable conditions when employees must to figure out and make decisions require high level knowledge. If these services given to do machine, it must possess a level of intelligence same as human. Building upon this foundation, in [2] proposed three types of AI: Mechanical, Thinking and Feeling. Intelligent Machine (IM) that autonomously execute simple tasks in an orderly environment has Mechanical AI. Thinking AI, in contrast to last, possesses the ability to learn and adapt from data, making it suitable for complex and well-defined tasks. There are two subtypes of Thinking AI: Analytical AI and Intuitive AI. To Analytical AI belongs the personal assistants such as OpenAI's ChatGPT-4, Microsoft's Copilot, Google DeepMind's Gemini, Apple's Siri, Amazon's Alexa, and Samsung's Bixby. They focus on exploring customer diversity and delivering personalized services to customers. Intuitive AI can generate adaptive personalized systems and increasingly effective at personalizing services for individual customers over time [3]. This kind of AI represents now by Generative AI (GenAI), for example, OpenAI' ChatGTP [4]. In papers, discussed "Feeling AI", for example [1, 5], actually is regarded Empathetic Intelligence, the AI able to recognize and understand others' emotions, respond appropriately emotionally. In fact, it is an "Emotional Shell" of IM, enabling them to behave as though they have feelings when interacting with humans. "Emotional Shell" is well-suited for automating services performed by IMs in both virtual internet world and real physical world when machine is robot.

Nova day robots as universal machines including all kinds of autonomous unmanned machines [6] are designed to provide various types of services under AI assistance. To do such services robots have to be trained and ultimately should be created general robotic brain capable to assembling data,

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resources, and code pertaining to the skills that robots have already been taught [7]. GenAI claims major role in supporting service given by robots, too. Besides the emotional collaboration with human, the GenAI is going to do reasoning. For this, the robot inference system uses symbolic knowledge about semantic relationships between objects in an image, basic common sense, and other. Such AI with symbolic decision-making engine, pre-trained set of different skills in physical world supported by foundation model and "Emotional Shell" is one type of Hybrid AI [8]. Usage this approach to design FAI for autonomous IM is limited due to its symbolic decision-making model and large language model [9]. Along with this, neuroscientific studying the animals relies on another approach to provide insight into basic psychological mechanisms about shaping behavior and reveal the role of cognitive functions in these processes [10, 11]. These findings could not readily apply [12]. Nevertheless, to set up FAI on model of cognitive decision-making mechanism is in demand for two reasons. Firstly, functions under certain conditions in autonomous mode without supporting Internet is required from nova day robots [13-15]. Secondly, there are lot small applications of robot implemented on not powerful computer facilities which can't carry out the soft used large language model or symbolic engine with common sense knowledge bases. Both issues may be overcome by approach aimed to design Hybrid AI for robots based on the models borrowed from lowest hierarchical levels of cognitive architecture of living being. In [10, 11], hypothetical neuronal architecture of the mammalian brain where cognitive processes divided over different layers is proposed. Architecture is used by neuroscientists to explain the goal-directed behavior of animals as a product created by cognitive processes. It has distinguishable dividing into three layers: reactive, adaptive, and contextual. The reactive layer as independent of upper ones plays both roles: supports the basic functionality and generates signals that drive, modulate and engage the higher control layers. Reactive layer blueprint of FAI was proposed in [9, 16]. Main principles of blueprint organization have been borrowed from living being with simplest nervous net (hydra) which behavior sufficiently well studied and published by scientists in neurobiology [17, 18]. Basic function of reactive layer blueprint, or rather, response making is provided by cognitive processes such as drive, emotions, attention and perceptions. Adaptation some of these processes was described in [9, 16, 19, 29, 31], this paper is dedicated to attention function.

In this paper, attention model borrowed from living being as one of function of lower reactive layer of cognitive structure to implement in new Hybrid AI model is proposed. Section 2 will present glance on neuroscience findings about hydra's behavior and what can be borrowed. Section 3 describes three models of attention borrowed from living beings belonging to three levels of development: hydra with simplest nervous net, bee with more complex nervous system, and mammalian with develop mechanism processing data from sensors different modality. In section 4, experiment with robot equipped with FAI' reactive layer blueprint is discussed. When robot makes decision, the step-by-step procedure using sophisticated attention mechanism which implement the scrutiny of environment to receive lack information for continue its motion is described.

2. Problem Discussion

Perception system of FAI blueprint based on cognitive perception model introduced early in [16-19] is lying on passive method of data from sensors acquisition. Perception system computes the meaning of current situation where IM is. To do this, data from sensors about IM environment, at first, are granulated and mapped into primary verbal definition, and then generalized on the base of domain knowledge presented by experts in the form of natural language word meanings. The model takes into account the main features of wildlife perception systems. First, at each moment of time, the meaning is calculated not of the complete situation, but of some fragment of the IM environment, allocated by the attention mechanism. The meaning of the complete situation is formed sequentially by moving attention focus from one fragment of the environment to another. Secondly, a sequentially formed description of the meaning of the complete situation is supported by else one cognitive mechanism. It is data aging. Thanks to this mechanism, the confidence that the calculated meaning of the situation corresponds to the real situation at the current time is adjusted by ageing of certainty over time. In [19] shown, how environment states certainty depends on aging over time of data from sensors and how it impacts on IM decision-making risks in dynamic situations. If data aging is not taken into account, then the meaning of the complete situation formed by a time sequence of its fragments may not correspond to reality because the situation's fragments been long time before had gone. In this paper we will discuss directly attention mechanism model borrowed from living being and how it should be implemented in FAI architecture.

Cognitive response-making model borrowed from living beings lying on the findings of scientists in the field of neurobiology and cognitive psychology is underpinning to do this. Hypothetical neuronal architecture of the mammalian brain where cognitive processes divided over different layers is proposed in [10, 11]. Basic functionality of reactive layers is provided by sensorimotor responses and organized as a set of independent Response Prototypes (RPs) that support needs of living beings. Such organization has permitted to do primary step toward creating FAI bottom layer model, namely, the reactive layer blueprint which is base of autonomy behavior of IM [12]. To clarify the contribution and role of cognitive functions in response making, the living being with simplest nervous net which behavior sufficiently well studied and published by scientists in neurobiology have been chosen. Hydra is simplest of all living being has nervous system that control their behavior. Instead of a brain, hydra have the most basic nervous system in nature, a nerve net in which neurons spread throughout its body [20, 21]. Nevertheless, hydra's few thousand neurons are possible to let out more or less complex behavior. No less important argument for choosing a hydra as an object to be borrowed response-making mechanism is affordance to sufficiently complete information about the dependence of behavior on activities of neurons, sensors, inner states and epitheliomuscular cells. Today extensive information has been accumulated about experiments with hydra [12, 21, 22].

Studies of hydra behaviors scraped from different science sources have been summarized by ourselves and presented as structured set of its RPs. We have introduced the behavior elementary unit as a solitary RP (Fig. 1) and presented behavior over time interval as sequence of these units, named compound RP.

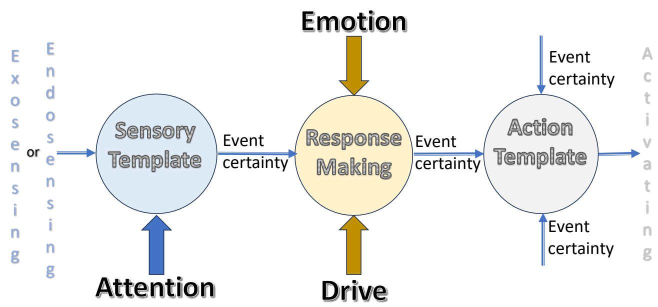

Figure 1: Role of attention in response making when processing solitary RP

The solitary RP has been proposed in the form of triple: Sensory Template (ST), Response Making unit (RM) and Action Template (AT). The ST is defined on a set of hydra's receptors presenting either environment situation or inner states, the AT has been defined on a set of epitheliomuscular tissues (actuators) and RM presents function of neuron net connected ST with AT. In our model, the set of all RPs reported by neuroscientists had been presented by solitary RPs and divided onto subsets according to kinds of living being needs. We distinguished at least the next four hydra's needs: self-preservation, feed, comfort and scrutiny. For example, "Full-polyp contraction under touch" and "Full-polyp contraction under burst of light" belong to self-preservation need, and "Body elongating under moderate light" and "Nodding in directions of not intensive light source" had been attributed to comfort need. Full list of behavior prototypes except above mentioned includes some more solitary

RPs and three compound RPs "Scrutiny", "Hunting and feeding", and "Locomotion" by looping or somersaulting.

Thus, after analyzing the raw neuroscientist's findings about hydra's behaviors, the model of reactive layer of FAI as a set independent RPs divided into k+1 subsets have been proposed. The *l*th subset includes RPs which serve *l*th need, only. In fact, no any partition into subsets is, it done to show that response-making engine when processing *i*th RP belonging to *l*th subset uses state local vectors which are associated with *l*th need (Fig. 1). But RPs are processed asynchronously and independent one from another: simultaneously gradual and independent, the Certainty Factors (CFs) of all three components of RP using feedback through emotion about degree of need satisfaction are tuned. Attention plays major role to support autonomous response making in conditions of uncertainty situations and incomplete knowledge.

The ST of RP (Fig. 1) is structured set of Knowledge Granules (KGs). It presents knowledge about what ST is and how this template should be computed. The math foundation of presentation and processing of KG is CF [9, 16]. The value $cf_{KGsens:templ}(t)$ of CF shows degree of matching the sensory data at current time t to meaning of KG. The STs of all RPs, assembled together form KB of FAI' perception system as a holistic hierarchical structure in which there are no duplicate KGs. Nevertheless, the meaning of the separate templates is preserved, and they remain independent one from others. At zero level of KB the KGs present directly data from sensors. At first, second, and so on levels the KGs present knowledge about states of different parts of environment. Moreover, KGs of high level can define the situation by using KGs not only zero level but KGs of different lower levels which give sense of fragments of surroundings of IM. Thus, as KB has multi-level hierarchical structure of KGs presenting knowledge about environment states, the major function $f_{abstract}$ of abstraction engine is continuously in real time (t) processing data from sensors (x), computing the degrees $cf_{KG^i_{templ}}(t)$ of all KGs (templates) matched with current state of environment. Algorithm of realizing the $f_{abstract}$, namele, of computing the fuzzy CFs of all N STs in (1) are given in [16, 19].

$$cf_{KG^i_{event}}(t)=f^1_{attent}(cf_{KG^i_{temp}}(t),\ cf_{atten\_field}(t)),\ cf_{atten\_field}(t)=f^2_{attent}(cf_{emotion}(t),\ cf_{KG\ templ}(t)),\ cf_{KG^i_{temp}}(t)=f_{abstract}(x,\ KB),\ i=1,2,..N \qquad (1)$$

Attention mechanism implements two functions. First one f^1_{attent} computes CF of KG (ST) being under attention field focus and sends to response-making KG (Fig. 1) messages $cf_{KG^i_{event}}(t)$ when sensor data match to ST. Second function f^2_{attent} manages movements of attention field in space of all STs, decides which ST will be next under attention focus and computes strength of fields impact $cf_{atten\_field}(t)$ on it.

The purpose of this article is explanation both above attention functions and examine theirs on examples of IM tasks. Before proceeding to the formal attention model, we will focus on examples of hydra's behavior caused by attention cognitive mechanism and figure out main principles which should be borrowed into attention model. Then, we will discuss implementation of these principles into formal models of both attention functions f^1_{attent} and f^2_{attent} and will demonstrate their using when IM does response-making.

3. Attention models

3.1. Turning on attention

The living beings and IMs can use two kinds of sensors: the first perceives properties of environment directly on the its body and the second perceives properties located on the distance from body. For example, thermoreceptors perceive temperature in points of environment distributed over body surface. Ultrasonic sensor obtains data from remote points of space. In spite of hydra hasn't last kind of sensors it has capability to receive information from removed points by moves the parts of body, namely, tentacles. An attention functions f^1_{attent} and f^2_{attent} in (1) do this as they manage the moving attention focus over different locations of environment. When attention has been focused on some of them the abstraction function $f_{abstract}$ in (1) answers to question "Does sensors data in this location match to any ST?" So, scrutiny need is serviced by attention mechanism and head to find extra information that satisfy RP of another need. Below in this subsection, condition of appearing of scrutiny need that launches attention is discussed.

The need's mechanism preserves the ability of living beings to carry out its mission. To influence required behavior, the need should have capability to exhibit itself, for example, as some source of nervous activity of living being. In our model the drive playing this role is presented by KG which can be in different states from excited to inhibited. Examples of hydra show different types of inner processes taking part in forming drive's state. The low protein level in hydra's body causes excited and high-level causes inhibited drive' states of the feed need. Transition between states is gradual process. The scrutiny need drive has another mechanism of exciting.

Some facts about hydra's behavior described in neuroscientists papers can't be explained without the assumption that hydra, despite their simplest neuro net, has mechanism of emotions. So, long-term unsuccessful hunting of hungry hydra causes, firstly, non-hunting but scrutiny behavior, and, secondly, amplifying over the time scrutiny's RPs when its degree of hungry is growing. Same conclusion was figured out about another needs. These observations can be explained on the basis of the mechanism of emotions [9, 16]. Drive of some need is growing but no one of RP serving this need can't be actualized because current situation does not match no one ST of these prototypes. In this case, energy of negative emotion (frustration) is being headed on lighten the matching the vague or incomplete sensory data with STs of RPs belonging to this need. Secondly, when long time previously mentioned emotion impact doesn't give positive effect (drive' excite level doesn't fade down despite the helping of emotions) the accumulated energy of negative emotion increases the excite level of drive of another, first of all, scrutiny need. In this case environment should be explored more carefully by RPs of scrutiny need with goal to find out location of situation fragment that match ST at least of one RP belonging to unsatisfied need. Thus, the scrutiny' need plays role of universal environment explorer managed by attention helping overcome incompleteness information.

3.2. Attention management principle borrowed from hydra

When hydra explores environment, it on regular base repeats compounded RP consists of three steps behavior. At the first step, body elongation to maximum length is realized. Then hydra is nodding. And at third step it slowly extending their tentacles. It's worth noting that direction of nodding at second step at current time is different from been executing at same step previously. Direction of nodding is changed consistently from one implementation of nodding action to the next. This fact can be elucidated on the base of hypothesis that hydra owns mechanism of attention which manages the order of RPs are applied to explore the environment. Apparently, such behavior expands space around hydra where may be prey and therefore increases the likelihood of successful hunting. When scrutiny need actions give positive result (prey has been found and touched by tentacle) then the RPs of feed need begin to carry out. The first RP "Firing into the prey by tentacle's nematocysts" of compound "Hunting and feeding" prototype is gone on. This success ceases the negative emotion and, consequently, active state of scrutiny need's drive is fade. Otherwise, negative emotion is growing what entails increasing activation level of scrutiny need' drive, and, consequently, strength of attention field on next three-steps cycle of scrutiny behavior will increase, too. The elongation, nodding and extending actions will be more impressive and cover more space around hydra what increase the chance of well hunting. In this way, both the scrutiny need' RPs and attention mechanism help to find situation that match ST of "Hunting and feeding" RP. So, have being proposed following set of PRs of scrutiny need (body elongation (Pr1), nodding forward (Pr2), nodding left (Pr3), nodding right (Pr4), nodding back (Pr5)), and extending tentacles (Pr6)), and also two compound RPs (somersaulting (Pr7) and looping (Pr8)). For discussion of major idea, it is enough to consider only four prototypes of nodding in four different directions and two compounded prototypes of moving in space, namely, looping and somersaulting. In Fig. 2, Pr1, and Pr2, and so on are identifiers of relevant prototypes listed above.

In contrast to others needs, RPs (Fig. 1) maintaining the scrutiny need are endosensing type. It means when no one RPs matching to current environment state, consequently no "anything" that can from outside to trigger the action. In this case, it is required something internal process that activates an any action. In hydra this role plays the specific intrinsic processes, for example, concentration of molecules or ions of a certain type or electrical signal of neurons. These intrinsic processes have nature of field which affects neurons of living being. Thus, base concept of our model is attention field which triggers the special internal Sensitive Elements (SE) carrying out function of ST in exosensing RP (Fig. 1). In Fig. 2, SEs of endosensing RPs are stand for by number 1, 6, 9, and 10 inside circles. Two of them with identifiers 9 and 10 depict SEs present generalized knowledge about kinds of nodding (9) and movement (10) types. Other circuses with numbers 2, 3, 4, 5, 7, and 8 stand for KGs of exosensing RP. As well as ST of exosensing RP, a SE represent knowledge only about internal situation that can trigger the RP. However, in contrast to KGs presenting ST, a SE has two particularities. First, it gets excited state when satisfied both following conditions: the SE is under attention focus and internal situation matches to this SE. Second, when SE being under attention focus gets excited state, this shifts attention field such way that focus is located onto another nearest neighbor, as shown in Fig. 3.

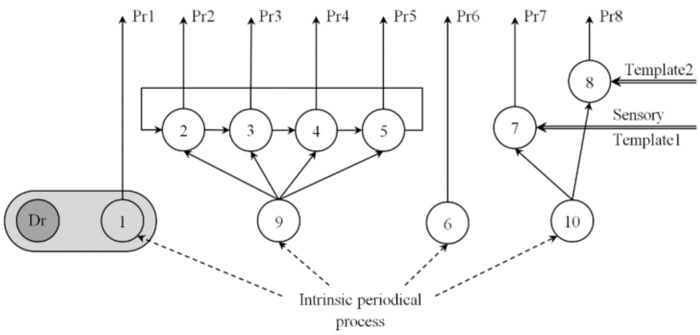

Figure 2: Knowledge presentation and processing by hydra' attention mechanism

Exciting the drive KG, indicated by "Dr' in Fig. 3.a, activates the attention field around the drive's KG. Except drive's KG the attention field covers the nearest SE. It is SE with identifier 1 and right now attention is focused on it. When attention field has realized its function (helped achieve an excited state for SE with number 1 this event shifts attention' focus from its to SE 9. So now attention' focus covers the next nearest SE with number 6 (Fig. 3.b).

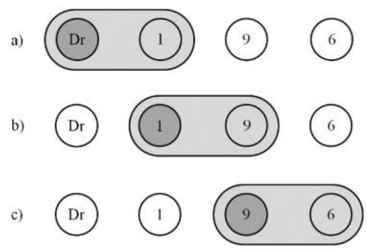

Figure 3: Illustration of shifting attention focus in space of SEs

In Fig. 3.c shown, next case when attention focus shifts further on SE with number 6 after SE 9 begins to match the situation and gets arousal state. Our conceptual model of attention based on data collected in [18, 20, 21]. Several intrinsic periodical processes excite hydra's neural nets. Two of them we have used to explain attention phenomena. One process with long period approximately T1 = 5 - 6 min excites the scrutiny' drive (Dr) which launches an attention field (Fig. 2). Other short periodical process approximately T2 = 0.5 - 1.0 min excites SEs with numbers 1, 6, 9, 10. Fig. 2 shown first stage of the scrutiny need processing when its drive has gotten arousal state what causes focusing attention around SE 1. When short intrinsic periodical process excites inputs of all SEs only one of them, the 1st SE, takes excited state as it is under attention focus. Ultimately, the RP with name Pr1 takes arousal state and attention focus shifts to the 9th SE (Fig. 2). When after T2 time, next excite impetus of short intrinsic periodical process is generated only 9th SE get arousal state because both conditions have been satisfied. It is under attention focus and waiting for exciting of its input. Arousal state of 9th SE excites the inputs of KGs with identifiers 2, 3, 4, 5 and, besides this, causes shifts focus attention further on the 6th SE. To decide whose turn among 2nd, 3rd, 4th, or 5th KGs to be excited the dynamic model of KG with time parameter is used [19]. It's worth noting, in Fig. 2 structure including 9th SE and 2, 3, 4, and 5 KGs presents knowledge that exciting of KGs occurs in specific sequence 2, 3, 4, 5, and then return to KG with identifier 2, and so on. At each time when 9th SE has gotten excite, the KG's turn is shifted to the next one. Fig. 2 realizes deterministic sequence of scrutiny environment using the nodding forward (Pr2), then left (Pr3), then right (Pr4), then back (Pr5) and then come back to nodding forward (Pr2). Thus, when 9th SE has gotten excite, it excites one of in turn of 2, 3, 4, or 5 KG whose turn is it. When after T2 time, the next excite impetus of short intrinsic periodical process excites the inputs of all 1st, 6th, 9th, and 10th KGs but now only 6th SE get arousal state because it is under attention focus. This process continues until attention field focus will go beyond the 10th SE. Since, the field focused on this SE doesn't cover any other SEs the attention fades over time. The new scrutiny process will resume from the beginning with SE numbered 1 when after T1 min the next long periodical processes impetus excites the drive (Dr) again.

3.3. Attention management principle borrowed from honey bees

When honey bees searching out way to flower patches, the attention mechanism helps in same way as well as it did for hydra. In contrast to the hydra, the honey bees' structure of SEs specifying the order of actions is not constant, it is created each time by memorizing waggle dance of scout bees [23, 24]. The scout bees provide the following information by means of the waggle dance: the quality of the food source, the distance of the source from the hive and the direction of the source. Scout bee runs in a straight line the direction which is related to the vertical on the hive and indicates the direction on food source relative to the sun's azimuth. The duration of the dance indicates the distance to the food source [23]. So, waggle dance creates structure of SEs (Fig. 4).

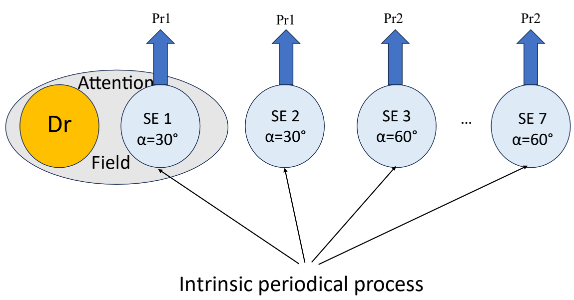

Figure 4: Honey bees' attention mechanism manages the path to flower patches

The rout from hive to the flower patches divided into two segments. First segment heads bees in direction at an angle 30° in relation to the direction to the sun. This direction the bees have to keep during two flight time intervals. Two sensitive elements SE1 and SE2 of knowledge structure in Fig. 4 are pointed this. After this, the direction of flight is changed so that bees have to move under 60° in relation to the sun during three times intervals. In Fig. 4, shows situation when bee' drive of scrutiny need is activated by the emotion produced by forager bees need to carry out its mission. When next impetus of intrinsic periodical process excites the inputs of all SEs only SE1 will get excite state because it is under attention focus. The SE1 belong to RP with identifier 1 which action template controls bee's flight in a direction at an angle of 30° to the sun until goal data will be changed. Now, attention field focus has been shifted from SE 1 to SE 2. After time period the next impetus of intrinsic periodical process excites the SE 2 and shifts attention field on SE 3. The SE 2 belongs to the same RP 1 with same action keeping previous mode of motion. So, both above examples show how attention shapes scrutiny behavior of hydra and bee.

3.4. Attention management principle borrowed from mammals

Mammals have more developed attention mechanism maintaining dynamic STs. It processes data from sensors and creates dynamic process characteristics of which match with dynamic. Essentially, attention builds footprint of ordered events and comperes it with the ST [25-27]. Below, that function is regarding on simplified example of vision modality when simple geometrical shapes in black are reflected on the retina of animal eye [27].

One of the possible approaches to present such dynamic ST is as follow. After detecting a spot, the eye fovea bypasses some shape along the black and white boundary. To model this, we pretend that mobile Inner Sensitive Matrix (ISM) with *n x m* sensors is moving along the spot boundary and produces path data in the form of turning angles and lengths of the path sections Fig. 5.

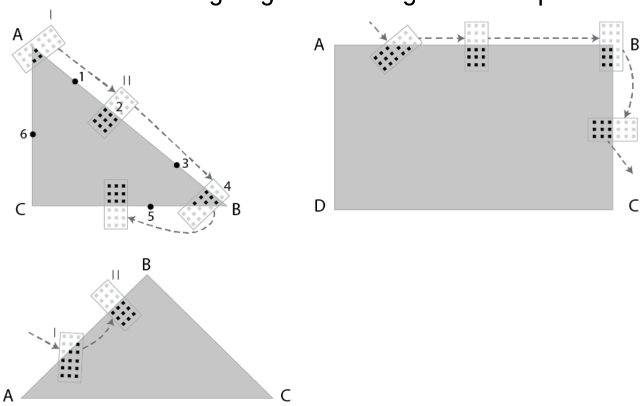

Figure 5: Illustration of attention traversing a shape along the border

When detecting the boundary of the contour, the ISM movement is under control of system with feedback based on data about deviation of center of ISM from boundary. For correction of deviations from the boundary of the figure, PID control algorithm was used [28]. As shown in Fig. 5, control algorithm supports the movement in such a way that the right three columns of ISM are located above the darkened surface (inside figure), and the left three columns of sensors are outside the figure. Of the possible strategies, the simplest one was adopted: a clockwise bypass.

During movement the ISM generates sequence of events presenting the changes of motion (angles of turn and distances traveled to the turn). In the example, for the demonstration purposes, the accuracy of approximation of the boundary is adopted 15 degrees. In Fig. 6 and Fig. 7, grey-shaded circles graphically show zero-level' KGs, representing data from ISM' sensors. The identifiers inside circles are indicated by numbers corresponding to the angles of turn (on the left part of figures) and distances (four right KGs). The maximum angles of turn are 180° to the right. The right or left turns in the range is regarded as ISM' control misstep and presented in Fig. 6 by KG with identifier 0.0. Turns to the right in the range [+7.5°,+22.5°] describes KG' identifier *0.15* and so on until *0.180*. As ISM control algorithm corrects missteps within [-7.5°, +7.5°], these deviations don't regard as events and don't lead to distortion of data about the path. In Fig. 6 and Fig. 7, the SEs of the zero-level are given only for the right turn, for clarity. Possible values of distance' lengths of the ISM paths are divided into four granules corresponding to 1, 2, 3, 4 units of distance. In Fig. 6 and Fig. 7 zero-level KGs 0.1, 0.2, 0.3, 0.4 represent knowledge about these distance' lengths. The KGs of upper levels present generalized knowledge about fragments of the path traveled by ISM. For example, at first level KG with the identifier 1.I represents the generalized knowledge about arbitrary path length (doesn't matter which of fourth possible length is). In Fig. 6, three of third level KGs with identifiers *3.l_90*, *3.l_120*, and *3.l_150* represent the knowledge about fragments of ISM path. For example, sense of KG *3.l_90* is "turns right on 90°are made after moving along straight section of some length".

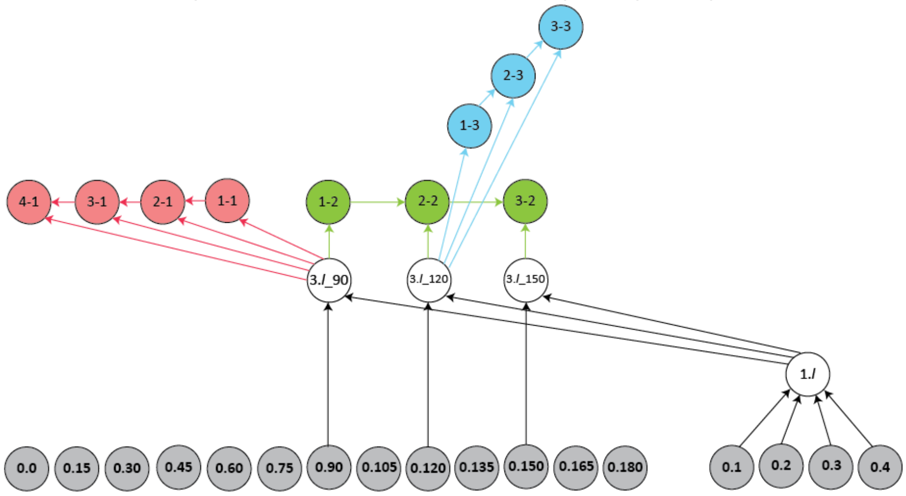

Figure 6: SEs representing bypass templates of the figures: a rectangular triangle (green); equilateral triangle (blue); rectangle (red)

In Fig. 6 and Fig. 7, colored circles show SEs which may be under attention field focus and are used by attention mechanism when it activates the state of ST of certain RP. Color arrows between these SEs show direction of movement of attention focus when corresponded SE receives activation of its input from intrinsic process. In contrast to attention models of simplest living being (hydra and bee in Fig. 2 and Fig. 4), the role of signals from unknown intrinsic periodical process plays events generated by KGs presenting fragments of ISM' paths.

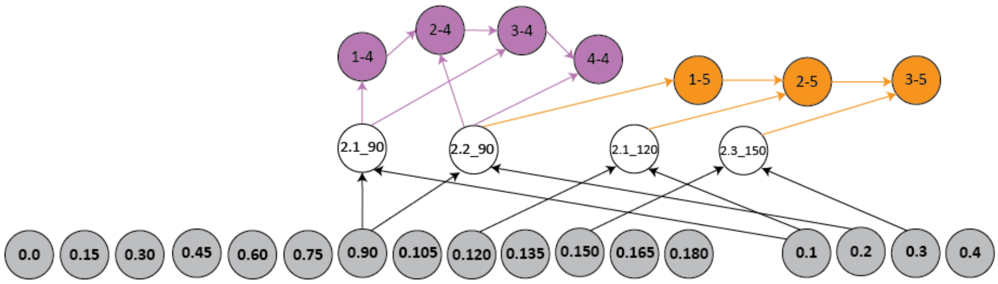

Figure 7: SEs representing bypass templates of the figures: a rectangle (purple) with lengths of sides 1 and 2, rectangular triangle (orange) with lengths of sides 1, 2 and 3 units

In Fig. 6, rectangle figure is represented by only four same KGs *3.l_90* and, bypass the rectangle figure by ISM have been reflecting into bypass by attention' focus of SEs *1-1*, *2-1*, *3-1*, *4-1*. Their activated states correspond to activation of ST presenting rectangle figure (*rect*). Similar, the bypass of right triangle figure with angles of 90°, 30° and 60° is represented by sequence of three SEs *3.l_90*, *3.l_120*, and *3.l_90* what activates the structure of three SEs *1-2*, *2-2*, 3-*2*, shown in green, by attention mechanism. The same reasoning may carry out about equilateral triangle with angles of 60° representing by a structure of three SEs *1-3*, *2-3*, *3-3*, shown in blue. Fig. 7 shows the knowledge example used by attention mechanism when it is necessary to recognize visual figures with different length of straight segments. Two figures a rectangle with side lengths of 1 and 2 units and a rectangular triangle with angles of 90°, 30° and 60° and lengths of sides *1, 2* and *3* units. The structure of the four SEs *1–4*, *2–4*, *3–4*, *4–4*, highlighted in purple, describes rectangle. The structure of the four SEs *1–5*, *2–5*, *3–5*, highlighted in orange, describes triangle. At the second level of knowledge structure the SEs, for example, *2.l_90*, have sense "ISM passed distance of 1 unit lenth without changing direction, then turn riht on 90° and go straight". This knowledge is constracted on the base of two SEs of zero level *0.90* and *0.1*. Nothing else this structure doesn't different from one given in Fig. 6.

4. Experiments with appliance of attention mechanism in FAI supported robot

The experiments are devoted to the study the cognitive mechanisms of attention and illustrated on example of a warehouse robot (co-bot [29]), namely a fragment of knowledge required for safe crossing of an unregulated intersection to continue moving along a given warehouse route. When co-bot is on the entrance road of the intersection, in order to continue motion according its plan it must recognize situation. The FAI cognitive perception system of co-bot based in addition to other sensors include video camera established on rotary platform. Different routes along which co-robot may continue motion show by signs having different shapes. Experiments carried out with five routes hence five different signs have been used: equilateral triangle with 2x2x2 length of sides, rectangular triangle with 1x2x2.2, triangle with 1-2-3, equilateral rectangle with 2x2 and rectangle with 2x4. At intersection, the black shaded figures of signs were fixed on front, left and right white walls. Co-bot stopped at intersection line can locate their and catch its picture by video camera. Co-bot mission is cargo with given route. In this paper we describe one step of whole plan of mission implementation, namely, response-making when co-bot has arrived to intersection and figures out about action required to continue motion with its route. If sign corresponding given route is on right wall co-bot must to turn right and continue move in that direction. If required sign is on left wall co-bot must to do left turn, and move straight when sing is on front wall. Knowledge' fragment for carry out this assignment include set of RPs which shape co-bot reactions and structure of SE-KGs managing attention as shown above. Set of RPs, for example, for one actual route marked by *rect*, (rectangle with does matter of length of side) includes only three prototypes, example of which is shown in (2) in the form of fuzzy rule. In (2) *CF_rout_rect*, *CF_response_makin_mission*, *CF_direc_left*, *CF_action_left*, are linguistic variables universally defined on universe of CF *[-1.0, +1.0]* with three terms *high*, *low* and *zero* [19]. Rule (2) present RP with structure (Fig. 1) where ST is presented by first three components of IF part of rule, RM is presented by fourth component of IF part, and AT is presented by THEN part of rule.

R_i *IF event*(*rect*) *and CF_rout_rect is high and CF_direc_left is high*
and CF_response_makin_mission is high (2)

When co-bot is loaded by cargo which marked by delivery rout, it establishes CF' value of variable accorded to rout, for example, *CF_rout_rect* ($\alpha_{rout\_rect} = +1.0$, $t_L = 0$, $t_R = 0$), where α is certainty, t_L is time interval elapsed since the last change of certainty value; t_R is the time interval elapsed since the receiving of new data. The CF's values of linguistic variables in (2) *CF_direc_left* is computed on the base of data from sensors about rotary platform position (where video camera is aimed on). The rotary platform position is changed by attention mechanism, and else one component of STs in (2), namely, *event*(*rect*) is directly shaped by attention, too. This stands for as soon as attention mechanism recognizes sign of rectangle on visual picture received from camera it activates state of SE with name *rect*. This event launches processing fuzzy rules including this component (2). Model of processing this type of fuzzy rules is done in [30].

5. Conclusion

FAI with base cognitive layer version, as a kind of hybrid AI model, can be implemented on not powerful computer facilities that satisfier to small robotic applications destined autonomously carry out its mission in condition of lacks information. Attention cognitive function plays major role to reduce size of application. Scrutiny of environment under attention management permits replace huge KB about robot reactions in different possible situations without loss of autonomous response making. Presenting in this article the attention cognitive model borrowed from simplest living being is integrated with others cognitive functions such as needs, drives, emotions and perception into response making cognitive engine. In contrast to the symbolic approach when KB have to has prototypes for all situation to shape response, the cognitive engine overcome lack knowledge by simultaneously and independent tuning characteristics of existing set of prototypes using feedback through emotions about degree of need satisfaction. Attention mechanism as component of this process provides both the investigation of environment by changing behavior and improving possibility to match existing templates. Cognitive engine can carry out this job in real time on inner robot hardware facilities because proposed model of computations are small set of arithmetic operations per each prototype.

In the future, it is planned two ways of continue researches. In theory, we will construct the following adaptive layer of FAI by borrowing cognitive models from living being that has simplest brain in contrast to hydra that hasn't it. It will be jellyfish as object under research. In practice, we will expand the list of robot application under confirmation functionality and testing to develop the general recommendation and computer aided software for FAI apps design.

6. References

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