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Bio-inspired Sensory Systems in Automata for Hazardous Environments

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Abstract: Every automaton in dynamic and complex environments requires sensory systems with an appropriate level of attention on the hazardous environment. This property in any efficient automaton is analogous to that observed in animal sensory systems. In this context, it is noted that to ensure its viability, the sensory systems of animals must maintain a continuous state of alertness or attention to the environment. However, the state consumes energy so it is impossible to keep a constant level over time. In this regard, biologists have designed models for explaining the variation in the level of surveillance in two vital activities of animals: Work and Rest.
In an alternating pattern between Work and Rest, the Attention Level *V(t)* declines and increases as the animal works and rests respectively along the time. For each of the two states, there is one relation: dV/dt = $-\alpha$ * V while working and dV/dt = β*(1-V) while resting. In this model α is the loss rate of surveillance that depends on the difficulty of the work and β is the recovery rate which depends on the quality of rest. In the case of automata, this phenomenon is analogous to that observed in the Animal Kingdom. Even if the automatic machines have relief structures to monitor their environments, they always require that its sensory system recovers the alertness after being hit by the inexorable entropy. If the task is hard (α is large), the Attention Level decreases rapidly. Once the level has dropped below a threshold of tolerance, it must be recovered. If rest is poor, the automaton will take a lot of time to achieve the desired level. Obviously, machines do not rest, but in analogous terms, this phenomenon is emulated in the way of maintenance activities. Parameter β represents the quality of these maintenances. This model has been tested with computer simulations to study the performance of automatic machines in hostile environments.
After tests, it was possible to quantify α and β for each kind of task-environment and each kind of maintenance. The bio-inspired model showed to have explicative and predictive applications to the conquest of hostile scenarios by means of automata. Indeed it is an interesting conceptual tool for increasing the performance of machines.
Keywords: attention level, model, performance, emulation, automata.

1 Introduction

In the continuing quest to provide new qualities in automata to improve productivity in crisis scenarios, this work uses the Market of Ideas in the sense that each field of knowledge is not selfsufficient and therefore must rely on others to import ideas [1].

Biology is in this paper the source of ideas. This science shows that over the 3.8 billion years since life is estimated to have begun to appear on Earth, evolution has resolved many of nature's challenges leading to lasting solutions with maximal performance using minimal resources [2].

Can Biology export ideas toward Automation? Of course, there are many examples, but the more representative is a robot. This device is a non living thing with some qualities emulated from humans, manufactured to replace them [3]. After all Biology and Automation have something in common: the study of entities capable of operating by they own.

In the same way, both automaton and living been have in common a vital component to interact with environments: a sensorial system [4]. In this context, the biological studies about the behavior of this system in living things, maybe animals, can be useful for improve the behavior of automata.

Regarding these assumptions, the present work examines how to model in automaton the level of attention on the hazardous environment. The desired model can contribute to better management of robots and other automata in crisis scenarios, especially where Automation has not satisfactory solutions [5]. For reach this goal, this paper identifies a requirement from Automation, then search for the right supply in Biology and finally applies the idea in a real situation.

2 A requirements from Automation

For facing complex and dynamic environments, any human organization must maintain a high level of attention to the outside to ensure its viability [6]. This requirement is stronger when the environment is adverse cause of either natural or cultural variables.

Performing a continuous task, this level decays because the central nervous system of human been cannot sustain a high quality of information processing for a long time [7]. Then, the technology allows to replace human been by automata for watching the hazard environments.

Nevertheless, when automata performance tasks, they reduce their level of attention too. Indeed, automata are made of structures which obey of the Entropy Law [8]. So, in metaphorical sense, automata get tired. This tiredness emerges when their sensory systems show a gradual reduction in performance or vigilance decrement. In fact, optical and mechanical pieces of the sensory system are exposed to environmental aggression such as weathering of shocks.

It is possible to know in real time how tired is the automaton? What can do manager whether the know this level ? This kind of question can be answered by Biology.

3 A supply of Biology

Any decay of this level may involve a loss of information and thus jeopardize the viability of the automaton.

Biologists note that subjects that perform a continuous and difficult task (such a working in crisis scenarios) "show a gradual reduction in performance or vigilant decrement" [9]. Vigilance implies a general state of alertness that results in enhanced processing of information by brain. Performing a difficult task reduces the quality of information processing and this reduction results in decreased performance over time [10]. After perform a task, animals rest and recover the vigilance. This recovery depends on the quality of rest.

Regarding this phenomena, ecologists assumed that a forager under risk of predation and the same time looking for food, alternates between two short periods of activity and rest [11]. This model explain the variation of Attention Level *V(t)*:

$$dV/dt = \begin{cases} -\alpha * V & \text{while foraging} \\ \beta * (1 - V) & \text{while resting} \end{cases} \tag{1}$$

α: rate of vigilante decrement, positive and associated with task difficulty;

β: rate of vigilante recovery, positive and associated with quality of rest.

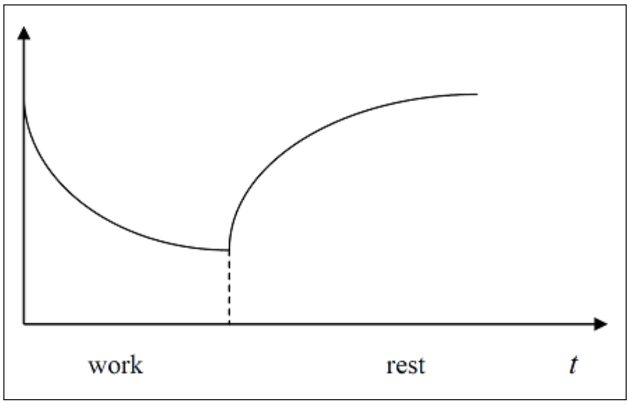

Figure 1: Graphic representation of the biological model

4 The imported model

Does an automaton get tired? In metaphorical or analogous sense: yes [12]. After any task, the automaton will be deteriorated and the more deteriorated it is, the lower will be the Attention Level. In management, it is important to know this level because, like persons, it is possible to allocate the work in charge. If the automaton is very tired, its sensory system probably is not in optimal state and this quality of survey will be unsatisfactory, so it is not advisable to apply.

How does the automaton recover the satisfactory Attention Level? Stop performing the task and start maintenance, this is the way to recover it.

How fast does the Attention Level decrease and recover. This speed is determined by α and β respectively.

How can managers determinate these parameters? Each task and each maintenance has an own α and β respectively, both measurable.

For getting numerical indicators, the phenomenon was studied in an autonomous vehicle in order to survey (collect field data) environmental variables in Patagonia. This rover in Figure 2 was programmed to cycle through different sections of equal length, in the same direction at the same speed and other conditions *Ceteris paribus*, differing only in sections of the terrain roughness, measured as the vertical dispersion over an imaginary horizontal line of the surface measured longitudinally every 0.1 m. When the vehicle did the tours, it was assumed that was on stage for the rigorous entropy field and affects the mechanical components including optical.

When the automata faced irregular geomorphology and bad weathers, the Attention Level declined rapidly cause of environmental aggression on mechanical and optical devices; so its performance was unsatisfactory. In friendly environments the Attention Level declined slowly, requiring small maintenances for retake the level desired. This behavior is shown in Figure 3.

Figure 2 shows how decreased the percentage the achievements (identification of cryptic elements) cause of reduction Attention Level.

After many tests, it was possible to quantify α and β for each kind of task-environment and each kind of maintenance. With this knowledge, managers took new and better decisions. For example set a minimum tolerance *Vo* for Attention Level. Any lower than this, they rejected the work of robots.

The bio-inspired model showed to have explicative and predictive applications to the conquest of hostile scenarios by means of automata. Indeed it is an interesting conceptual tool for increasing the performance of machines.

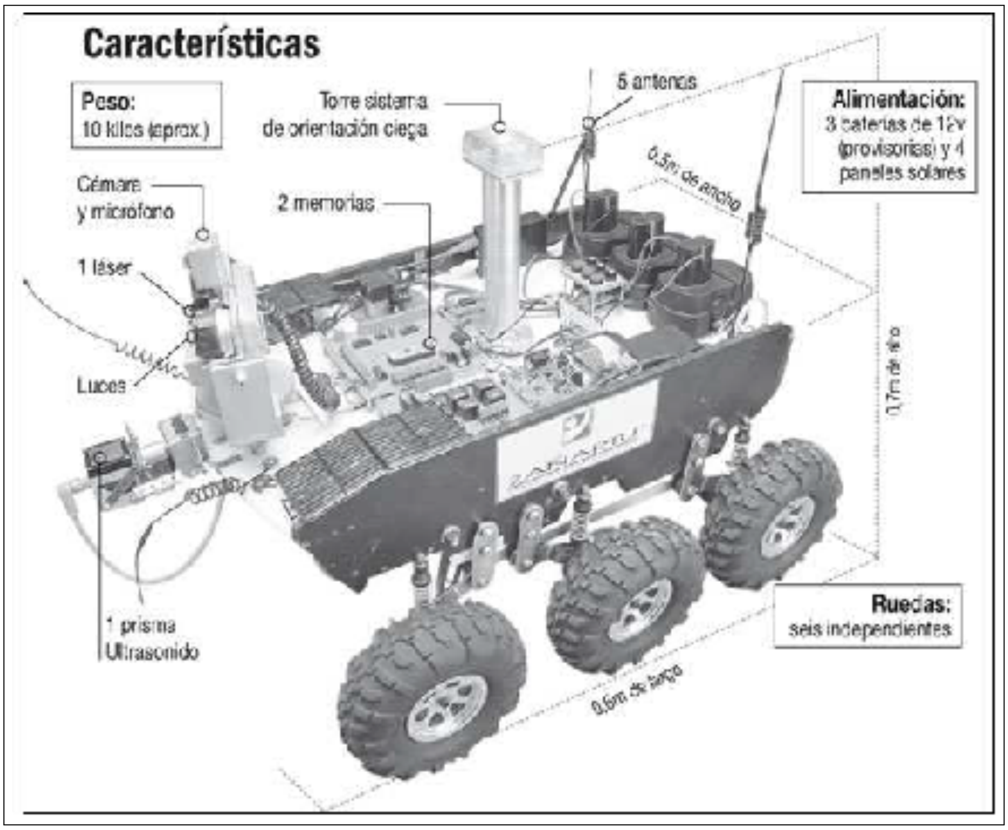

Figure 2: The rover which "worked" in Patagonia

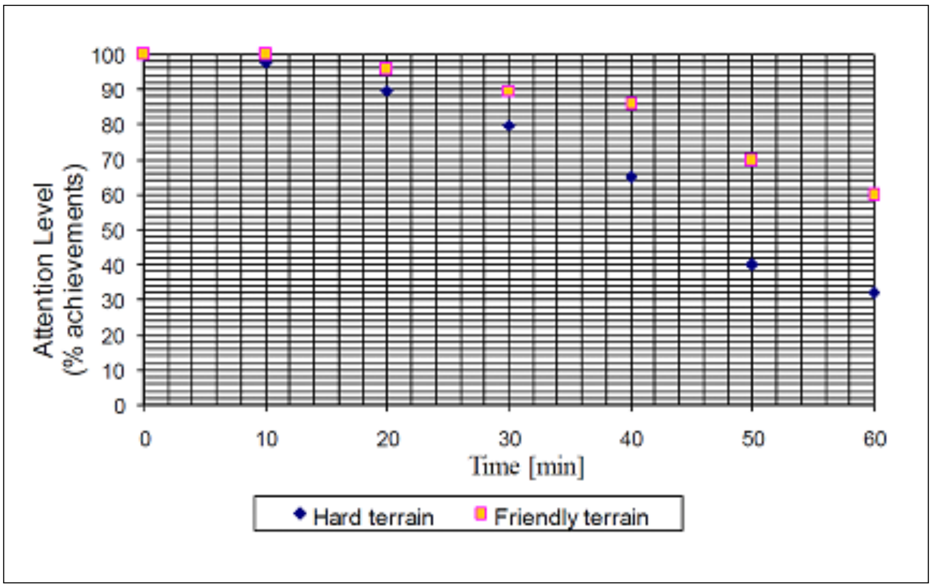

Figure 3: Variation observed of Attention Level in two kinds of environments in Patagonia

5 Conclusions

Given the syntax, semantics and praxis of the model, it was possible tested it with computer simulations to study the performance of automatic machines in hostile environments. Besides, there were tests in different terrains, most of them in extreme zones of Chile to study the quality of the information gathered by surveyor robots. When the automata faced irregular geomorphology and bad weathers, the Attention Level declined rapidly cause of environmental aggression on mechanical and optical devices; so its performance was unsatisfactory. In friendly environments the Attention Level declined slowly, requiring small maintenances for retake the level desired. The behavior observed confirmed the hypothesis of this work.

This model inspired by biological phenomena has an explanatory utility and a predictive use because it can measure the level of difficulty of tasks and the recovery rate (α and β respectively), to forecast the decay of productive factor of interest. Even known values of α and β and several observations regarding the performance, it can be through a statistical procedure to discover the function V = f (α, β), a mission that the author of this trial have begun to develop.

The inspiration observed in living phenomena may have more similarities in inert bodies and therefore opens an interesting line of research that contributes to better management of productive factors.

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