BRAIN BUILDING STRATEGY
Some Remarks and Questions

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ABSTRACT:
The paper provides some remarks about the key assumptions for a building of an artificial brain as an evolving neural structure. Among discussed questions there is the price we must pay for assumed modularity of the structure, the problem of representation of information transferred between given modules (level of redundancy, fixed vs. evolving representation), and the problem of a choice of a cognitive model as a general framework for the artificial brain. As for the last question, the 5-element memory system is suggested for ultimate solution. Authors also consider the problem management of brain-building project in which thousands of evolutionary engineers are to be involved. An idea of "top-down-top" building strategy emerges from the discussion.

1. INTRODUCTION
The Brain Builder Group at ATR, Kyoto, in the framework of the "CAM-Brain" Project, with the help of
international collaborators from 9 countries, intends to complete an artificial brain with a billion artificial neurons by 2001. The architecture of the brain is to be based on neural modules to be evolved using genetic algorithms [de Garis 1996; de Garis, Gers, et al. 1998]. A powerful specialized Field Programmable Gate Array based hardware, called CAM-Brain Machine (CBM) is being prepared as a machinery environment for the project [Korkin et al. 1997]. The CBM's speed allows us to complete growth and fitness measurements for tens of thousands of neural circuits in about a second. As an intermediate step, a million neuron brain for a robot kitten, called "Robokoneko", is to be constructed by the year 1999 [Agah, de Garis, et al. 1997]. While the "Robokoneko", in its "demo" version, is to demonstrate in real time an impressive, but limited set of behaviors, the research has a good chance to be continued towards the J-Brain (Japan Brain), an artificial brain, consisting of 10,000,000 neural modules which would allow it to demonstrate several intellectual abilities. In order to complete J-Brain by the year 2005, two thousand evolutionary engineers (EEs) should be employed in Japan Brain Project [de Garis, Cho, et al. 1997]. Final effects of a work of so large team requires a good strategy of brain building, as well as a prospective cognitive model to be followed.

2. CONSEQUENCES OF MODULARITY

Some cognitive scientists, especially psychologists and philosophers, may question the thesis that a biological cognitive system can be divided into a set of separate modules. The most important argument is that a given group of neurons may play two or more roles in information processing. They are just engineers, who, in order to facilitate their job, always try to decompose every task into a set of sub-tasks and design separate devices performing the sub-tasks. In nature, however, there seem to be fuzzy borders between organs, there are organs of multiple function. However, the need to optimize device construction may force a designer to consider if two functions could be played by one element. A good example may be a radio receiver in which a high-frequency signal is amplified by a transistor, and then, the signal is transformed into an acoustic signal, then, turned back, and amplified once more by the previous transistor. Without the trick, a separate transistor would be necessary to amplify the acoustic signal. But such a trick is possible in the case of simple projects. In the case of an artificial brain the designing separate single-role modules seems unavoidable. This let us keep any intellectual control of the project. However, generally, we will need much more artificial neurons than a biological system contains to perform the same task. Maybe ten or a hundred times more.

3. EVOLUTION OF INTER-MODULE COMMUNICATION

We have no choice but to follow the modular paradigm. Let us assume, that for every module (or, more correctly, for every kind of module) a fitness function must be proposed and used in the module evolution. At the moment the question emerges: Should, for a given module, an input pattern (if applicable) and output pattern forms be arbitrarily designed? The idea of fixed representation sounds attractive, but this means the necessity of our full intellectual control of everything that is happening in the maze of ten thousand "rooms" and hundreds of thousands of "corridors". And what then about some AI-workers' hope of "wonderful" qualitative changes after exceeding a "critical mass" of orchestrated neurons? Perhaps we could let modules evolve their own representations, and, when evolving a higher-degree module (i.e. a module consisting of a number of previously evolved sub-modules), to equip every sub-module with a necessary number of modules expected to play a role of "interpreters". Every interpreter would translate an output pattern of a given sending module into a pattern meaning the same from the point of view of a particular receiving module. Perhaps an evolution of a higher-degree module might equal the evolution of "interpreters"?
4. FUZZY SPATIO-TEMPORAL REPRESENTATION

The other question concerns the informational redundancy and flexibility in the inter-module communication. The more economical message code, the more difficult the evolving, and the less chance for us to enjoy the amazing qualitative changes in the system's performance. On the other hand, the more redundant/flexible the code, the bigger the number of required neurons. It may be believed, that there is an optimal inter-module message representation, but its definition must remain an open question at the moment. Let us consider an idea of a fuzzy spatio-temporal representation. Assuming that a message coming to a module is a set of impulses, where every impulse has assigned its place of arrival and time of arrival (counted from, say, the time of the first impulse arrival). Hence, the message may be described as a set of pairs, where the place and time are small positive integers. The meaning of the message may be a fuzzy set of such sets of the pairs, where every set of the pairs has assigned its degree of membership. This makes a message form flexible, i.e. a given message may be interpreted properly even in the case when some axons constituting a communication canal have not grown up, or when some impulses arrive with a certain acceptable delay, or when some impulses have not arrived at all. It may be supposed that fuzzy spatio-temporal representation may significantly facilitate an evolution of inter-module cooperation (regardless of the employment of the mentioned "interpreters").

5. BRAIN-BUILDING STRATEGY: TOP-DOWN VS. BOTTOM-UP

Several strategies of organization of artificial brain building may be considered. An idea of evolving a number of standard simple-function modules and, then, trying to build an artificial brain using the modules to build more and more sophisticated modules, until a brain-like behavior is achieved, may be called a bottom-up strategy. A pure top-down strategy would require an overall vision of a scheme consisting of a required number of modules and well defined principles of their cooperation. This strategy seems to be efficient for building a "demo" version of "Roboconeko" [cf de Garis, Cho, et al. 1997]. It is not obvious that it is equally good for more sophisticated brains.

Let us consider a TOP-DOWN-TOP strategy. The top-down-top strategy is assumed to be a procedure whereby a chief designer divides the future brain into, say, 3-12 primary modules and describes, as precisely as possible in a reasonable time, their required behaviors. Then, 2nd-degree designers are provided with the descriptions (one designer - one module description), and each of them does the same with his/her module. Hence, a number of 3rd-degree designers are provided with a module description. And so on. When anyone of nth-degree designers believes that his/her task may be performed by an indivisible neural network, an appropriate module will be evolved. When, for a given module, all lower-degree modules are ready, the module itself will be evolved (i.e. a communication among its sub-modules will be evolved). And so on, until the primary modules are ready, which means, that a final tuning of the overall brain may be started. The primary set of modules is essential in case of the top-down-top strategy. Such a set depends on a cognitive model that we accept. Let us, therefore, consider the 5-element model of memory.

6. FIVE KINDS OF MEMORIES

For decades the dichotomy short-term memory - long-term memory was widely accepted. Recently, five kinds of memories are considered [see Tulving 1995; cf Buller 1997]. Inspired by Tulving's concept of a memory system and regarding the expected technical limitations when artificial brain evolving, Buller [1998] proposes a so-called "4 + 1" Memory Model consisting of:
a. Filtering Memory
b. Procedural Memory
c. Episodic Memory
d. Semantic Memory
e. Working Memory

Filtering Memory is responsible for the primary processing of perceived signals, including their primary representation, regarding the special needs of the overall system. Especially, according to requests coming from other memories, the perceptual system may be temporarily more sensitive for particular kinds of signals, which is intended to be compatible with Bruner's theory of perceptual readiness and availability of categories.

Procedural Memory is responsible for translation of tasks formulated in Working Memory based on data from Semantic/Episodic Memory into control of actions of particular effectors.

Episodic Memory may be understood as a video compressing device which stores a multi-modal record of the entire individual's lifespan. The compression/decompression does need to be perfect. Indeed, in the case of the biological brain the record is incomplete, distorted, while it is sometimes difficult to find particular memories.

Semantic Memory organizes incoming percepts into labelled groups connected with labelled links. It provides data facilitating reasoning and generation of scenarios and plans.

Working Memory, listed here as last, but, in fact, being pivotal, is a working space facilitating the interaction of data stored in all other memories. It may be believed, that at a certain level of its development, it is the site of the Self. In any case, it is understood as a central processor which gets data from all other memories and sends them the data properly changed.

Although the ability of human-like thinking may be considered as a result of having well-developed semantic memory, it may be supposed, that all vertebrates are equipped with all of these kinds of memories. However, a given species may have some of them dramatically underdeveloped. It may be supposed, that an ability of anticipation of other individuals' behaviors requires a well-developed episodic memory and an, at least fairly well developed, semantic memory. A certain level of development of semantic memory gives the ability of understanding two- or three-word commands, as well as some reasoning by analogy. Why not take the five kinds of memories as just five primary modules for artificial brain building (provided, the top-down-top strategy has been taken).

7. EVOLUTION VS. LEARNING

It is assumed that "Robokoneko" is not a learning but an instinctual model, as "instinctual creatures with a million neurons are complex enough" [de Garis, Cho, et al. 1997]. Nevertheless, not every desired behavior emerges from the evolution of neural structures. In nature some behaviors and some knowledge are learned by the developed brain. Perhaps some modules could be evolved not to behave properly, but to possess an ability of learning desired behaviors? Perhaps a developed artificial brain could facilitate a self-organization at the cognitive level, i.e. a self-organization of purely informational entities circulating inside it? One can imagine a Working Memory as a theater in which software agents play their roles in such a way that a given agent is understood as a structured cloud of impulses migrating preserving its informational content and interacting with other agents it meets on its way [cf Buller 1996].
In any case, there is no point to resign from such kitten's behaviors as, say, memorizing a route through a basement, bad dog recognition, etc., not considered for the "demo" version of "Robokoneko". Why not consider such behaviors in reference to the ultimate CAM-Brain 2001? If so, a memory system seems to be unavoidable, as a memory is a key to learning from perception. Behaviors of the "demo" version of "Robokoneko" is to be achieved via an implementation of a defined rule set [Agah, de Garis, et al. 1997]. While the rule set may be useful as a reasonable methodological short-cut, it seemingly cannot be useful as a step towards a learning brain. Hence, one day the international team of brain builders will probably have to divide into two groups. One group ("instinctualists") will do the methodological short-cut in order to complete the "demo" version of "Robokoneko" by the assumed dead-line. The second group ("memorists") will try to develop modules for a memory-based brain, seemingly more adequate for the future J-Brain Project. "Memorists" had rather forget some spectacular kitten's behaviors as, say, meow, purr, etc. which are not essential for making an artificial intellect. It should be noted, that several kinds of short-term memories may be construed based on existing CoDi-1Bit modules [Gers et al. 1998], as, closed neural loops.

8. CONCLUSIONS

In order to meet the assumed dead-line for the first demonstration of the robot kitten "Robokoneko" the instinctual paradigm of brain-building has to be followed. The instinctual paradigm assumes a defined structure of 10,000 neural modules interconnected, as well as a rule-set defining desired behaviors. Behaviors requiring a learning (memorizing a way through a basement or bad dog recognition) cannot be considered in the framework of the instinctual paradigm. Hence, one day the brain building team will have to divide in two faction: "instinctualists" and "memorists". The "memorists" will try to develop memory-based behaviors adopting evolvable inter-module communication and evolvable fuzzy spatio-temporal representations. A "top-down-top" strategy of brain building seems to be the most useful for this faction. "Instinctualists" will complete the "demo" version of "Robokoneko", and then, after they succeed, they will probably forget the behavioral rule-set and rejoin the "memorist camp" to work together towards Japan Brain.

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