

# INDUSTRIAL APPLICATIONS OF BIOMIMETIC ADAPTIVE SYSTEMS

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## Summary

*This paper describes how some mechanisms underlying adaptive behaviors in animals and men may be employed in artificial systems and in industrial applications. Such mechanisms may range from simple reflexes to highly cognitive processes. In particular, the paper describes how current knowledge about motivational systems in animals may be used to build a behavioral engine that is used to animate video-games characters. It also shows how a pedagogical engine capable of modeling human cognitive capacities in a given learning task may be applied to the automatic generation of exercises that fit a child's current knowledge and needs. Finally, the paper suggests how it is possible to automatically generate neural controllers for satellites or walking robots, which may reconfigure themselves to cope with sudden environmental changes or with internal breakdowns.*

**Keywords:** Adaptive behavior, reflexes, cognitive processes

## 1 Introduction

Animals and men are able to survive in changing and more or less unpredictable environments, and numerous research efforts are aimed at unraveling the highly efficient adaptive mechanisms they use for such purpose. When any such mechanism begins to be elucidated, it is usually quickly

incorporated in a variety of industrial applications, either because of its life-like flavor or because of its mere efficiency.

In particular, numerous biomimetic mechanisms generating adaptive behaviors have been described and exploited in the literature concerning so-called *animats* (Meyer and Wilson, 1991; Meyer et al, 1993; Cliff et al., 1994; Maes et al., 1996; Pfeiffer et al., 1998). An animat is an artificial animal or a real robot that is equipped with sensors, with actuators and with a motivational system that selects which action to perform, in the service of which goal. Such motivational systems may call upon simple stimulus-response connections – that directly link the animat’s sensors to its actuators - or they may involve more cognitive mechanisms with, for instance, memory, planning, anticipation, or modeling capacities. They may improve over time through individual learning, or through the evolution of successive generations (Meyer, 1997).

Although the animat literature is mostly devoted to fundamental issues – e.g., understanding how human cognition evolved from basic adaptive behaviors in its animal ancestors – this article describes some industrial applications of animat research that are currently developed at MASA, a French start-up company devoted to Adaptive Objects Technology. These applications concern the development of two software engines: the DirectIA® SDK (Direct Intelligent Application) and the Evolver Platform that will be described in turn.

## 2 DirectIA®

DirectIA® is a variety of C++ libraries for Windows platforms that may be used to endow an animat or autonomous agent with a motivational system that generates behaviors closely resembling those of animals and humans. Such agents may be simple reactive agents or very sophisticated characters. In the latter case, they are able to learn, to elaborate plans, to build models of the agents they interact with and to anticipate the behaviors of these agents. They are even able to communicate. Finally, they may be incorporated into very large populations.

DirectIA® is designed to be used in :

- Video games, on-line games and virtual worlds
- War games and role-playing games
- Complex system simulations (Ecosystems, human societies...)
- Animation of assistants, avatars and pet companions
- Interactive animated stories, entertainment game software.

In particular, DirectIA® has been used to develop Peacemakers (Figure 1), a proprietary wargame in real-time 3D. This software addresses all the weaknesses found in traditional real time strategy games: deterministic gaming from the PC opponent, absence of autonomy and bad coordination amongst units, no adaptation to the user’s skill, repetitive game concept.

Likewise, DirectIA® is exploited in a variety of educational softwares that use current knowledge in psychology to model the skills a child needs to perform a given task. This allows the automatic construction of a model of the child that represents an evaluation of the level of his/her skills. In turn, the model allows to personalise the software to each particular child and to enhance its educational functionalities.



Figure 1

In the case of Figure 2, for instance, the software assumes that a child knows that a mouse is naturally motivated to get to a piece of cheese or to hide in its nest. It also assumes that the child knows that the mouse is not able to see an object from which it is separated by a sharp corner. In order to test the validity of such assumptions, it devises a solution that the child could imagine if he/she were asked to attract the mouse to the nest by way of disposing a piece of cheese somewhere in the environment.

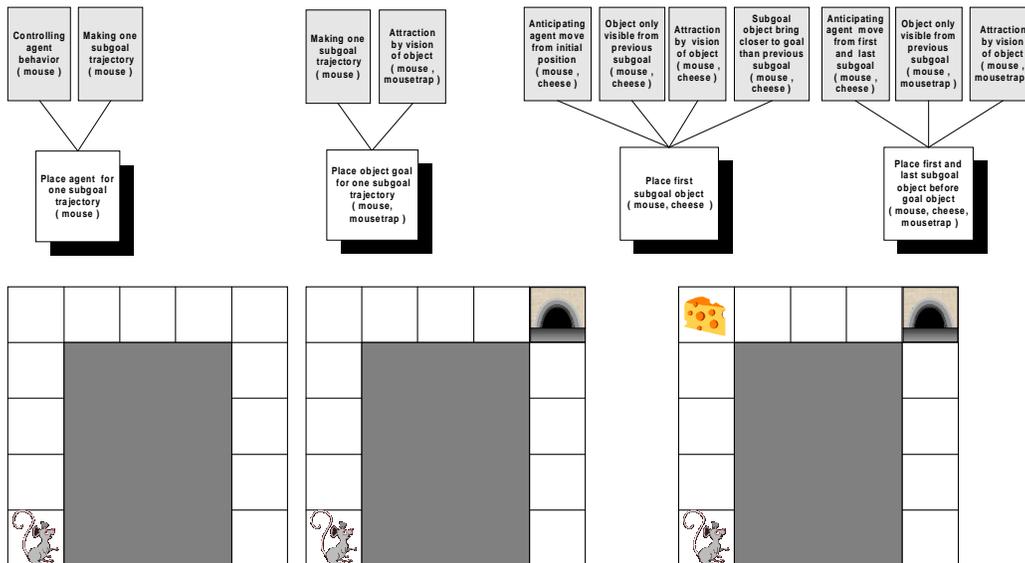


Figure 2

If the solution proposed by the child turns out to be incorrect, as in Figure 3, the software is able to infer that the child got the idea of using the cheese to bring the mouse closer to the nest, but that he/she didn't realize that the mouse would still not see the nest from the place where the cheese

has been deposited. Then, the software can devise another experiment to help the child correct his faulty knowledge.

Finally, DirectIA® makes possible the development of on-board architectures for a new generation of robot toys currently under development. Like the software just mentioned, the toys will be able to model and anticipate the behavior of a child in real time so that the robot's interest for the child, and thus its educational capabilities, will be optimized.

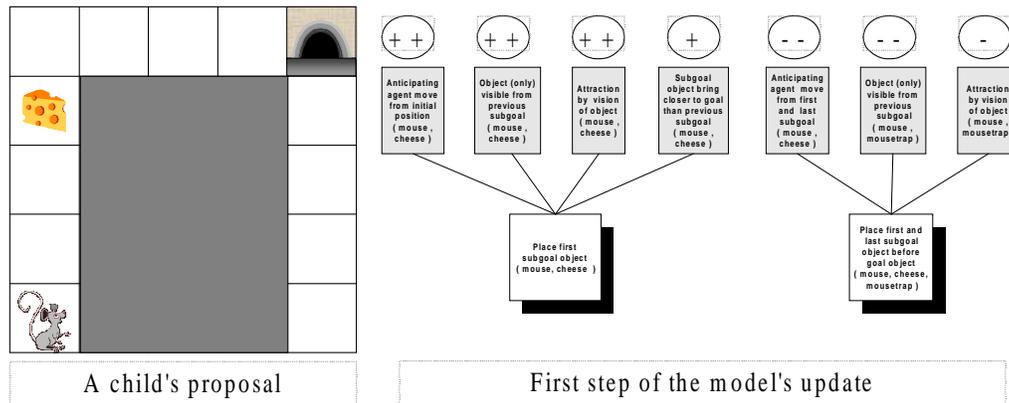


Figure 3

### 3 Evolver platform

In the natural world, complex adaptive control architectures arose through processes of variation, selection and evolution. Over successive generations, primitive architectures gave way to those that were more complex and better suited to their survival needs. As a result, such architectures are robust, dynamic and adaptive.

The Evolver platform implements an artificial selection process that automatically designs and optimises any structure that can be described as a directed graph. Such a process doesn't need to know *how* to solve a problem: it just needs a way of selecting good solutions from bad. Moreover, it may remain active in the background while the structure it generates is at work, thus making it possible to *dynamically adapt* to new situations and to find solutions to new problems as and when it is needed.

Objects such as robots and unmanned vehicles equipped with controllers designed by the Evolver platform are robust, modular and adaptive. The same robot, originally programmed to do no more than walk for example, can rapidly acquire new capacities (vision, navigation etc.) without having to modify its walking controller, by the simple addition and evolution of new modules. The sudden breakdown of sensors or motors may be handled automatically by a reconfiguration of the architecture in such a way that the whole will form a practically Unbreakable Machine.

Figure 4 shows a hexapod robot (from Applied AI Systems, Inc.(c)) and part of a neural controller that has been automatically designed through the use of the Evolver platform. Such a controller allows the robot to walk according to an efficient tripod gait, and to avoid obstacles. Current work aims at evolving an additional module that will be responsible for light-following.

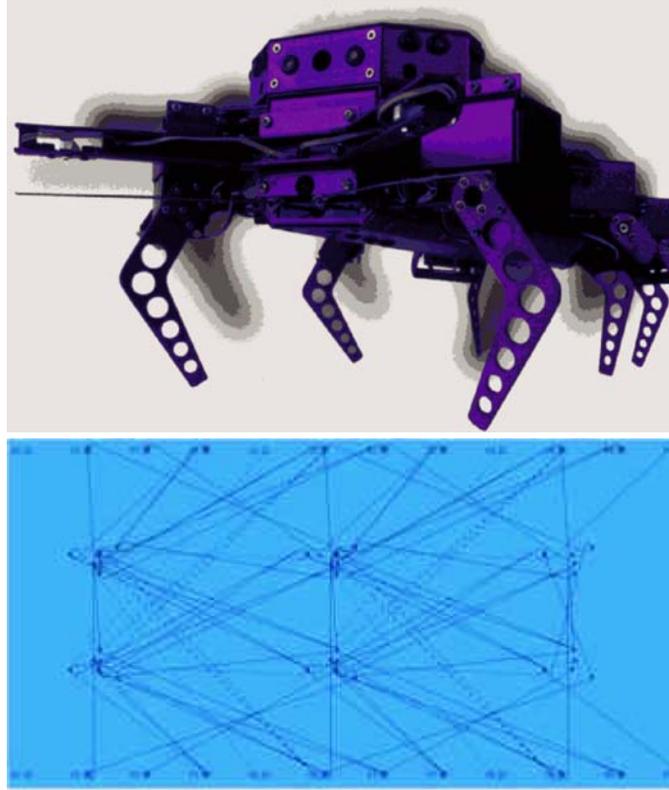


Figure 4

Other applications of the Evolver platform concern the on-line control of a satellite and the automatic recovery of its nominal trajectory in case of breakdowns in one or several of its motors. Scheduling problems afford other important applications of the Evolver platform, notably in the areas of resource allocation, time-tabling and job-shop scheduling.

#### **4 Conclusion**

Adaptive biomimetic processes already lead to a variety of applications, notably in the fields of video-games, of robotics, of educational software and of industrial process optimization. In our opinion, this new artificial life leading edge technology opens the way for the introduction of adaptive behaviors to objects of the future.

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