INSIGHT: A virtual laboratory for looking into behavior-based autonomous agents

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Abstract

This paper introduces a 3D simulation environment for experiments with behavior-based autonomous agents. The virtual laboratory INSIGHT allows the user to design and run a great variety of experiments in a time- and cost-saving manner. The peculiarity of INSIGHT is the visualization of the internal dynamics, thus the "inner life" of the agent can be made transparent to the user during the run.

The virtual laboratory

Verifiable scientific experiments require that they can be repeated independent from time and space. The experimenter needs to keep certain parameters at constant values while varying others systematically in order to study the effects of those parameters on the whole system. Unfortunately, those requirements cannot be fulfilled in experiments with physical agents. In general, it is impossible to run exactly the same experiment a second time. Different lighting conditions on different days or different times of day can lead to serious changes in the behavior of the agent. The test environment as well as the sensor configuration of the agent can change during a run. The systematic variation of the environment (size, number and variety of features) and the agents body (size, sensorposition and -orientation, actuators) for experimental reasons is only feasible in very simple experimental setups. Furthermore experiments with physical behavior-based agents are very time and cost consuming. About 80% of experimentation time is spent struggling with sensor calibration and hardware flaws, only 20% flows into the design of the control program. Analysing the results of the experiments is even worse. The distributed nature of control makes it very difficult to tell exactly what processes have been responsible for an observed behavior.

Motivated by those problems we developed INSIGHT, a virtual laboratory which allows scientists to easily run (and repeat) a large number of controlled experiments.

One can design the test environment, attach sensors and actuators to an agent, and program arbitrary control programs. Instead of spending a lot of effort on the physical peculiarity of sensors and hardware, the user can concentrate exclusively on the design and dynamics of the control programs.

The environment

Most of the experiments with behavior-based agents are carried out in simplified maze-like environments. It is still unclear how behavior-based autonomous agents will perform in "natural" environments, so we decided to choose a golf-course-like scenario. To adapt the conditions of experiments with physical agents, the environment can be supplied with "recharging stations" in which an agent can refuel. This environment is more "natural" than a maze, as a consequence, the repertoire of an agent's behaviors becomes more complex. It can regard hills and expanses of sand as obstacles but it can also climb or cross them respectively, taking into account that this will cost it more energy.

Design of experiments

Along with the complexity of the environment, the design of the agent is decisive for the repertoire of its behaviors. The agent's behavior is determined by its control program as well as the selection of actuators and sensors and their positioning on the agent's body. The virtual laboratory allows users to build experiments in a modular way. Agents are composed of a control program and a body which is equipped with certain sensors and actuators. The user can build up a library of different agents, control programs and environments, that can be arbitrarily combined for experiments.

The environment can be tailored to the experiment: the user defines the number and height of the hills, number and size of water and sand surfaces, number and position of players, flags, bushes and recharging stations as well as the number of balls that should be placed on the golf course.

The specification of an agent consists of the description of the agent's body and its fittings with sensors and actuators. The user can define the size of the body, the content of the agent's battery as well as its startposition and orientation. An agent can be equipped with several sensors. There are three types of sensors:

- internal sensors
- ground sensors

- distance sensors

In the current implementation an internal sensor returns the charge of the agent's battery. Ground sensors check the condition of the ground at a certain point in the surroundings of the agent. This point can be specified by the user (relative to the agent). The following ground sensors are available:

- sand sensors
- water sensors
- inclination sensors

Distance sensors have a conical extension. A distance sensor returns the distance of the agent from an object located within the sensor beam. The designer can specify the range and angle of the sensor beam as well as the position and orientation of the sensor relative to the agent. The following types of distance sensors are available: bumper sensors, infrared sensors, recharging station sensors, ball sensors and photo sensors.

The agent can be equipped with two types of actuators: rotation motors and translation motors. Those can be varied by specifying their maximum speed and energy requirements.

Control programs in INSIGHT follow the so called "dynamic approach", which was developed by Luc Steels at the VUB AI Lab in Bussels (Steels 1994). INSIGHT offers a graphical editor for the incremental development of behavior systems. You can add, delete or change processes during the experiment. This avoids the annoying "change-load-test" cycle, which slows down progression during experiments with real agents. The simulation provides immediate feedback on how the changes influence the behavior of the agent.

Running experiments

Before the user can run an experiment, she has to load a simulation configuration. If the configuration is loaded, she can start the run. Each experiment can be recorded into "state protocols" which contain all relevant external and internal parameters. Those include the position of the agent as well as the values of all quantities. An experiment can be started, interrupted or aborted at any time.

INSIGHT tries to adapt the conditions of a real laboratory, therefore the scenario is presented as a three-dimensional world, which can be explored by the user. Navigation in the environment is carried out mouse-driven, the scene can be rotated, the camera can be moved arbitrarily, zooming is possible. The sensor beams of all sensors can be inserted into the scene as transparent cones.

Every record of an experiment can be played back. The playback facility allows the user to select arbitrary parts of the record. In this way specific patterns in the state data can be isolated and correlated with the corresponding behavior of the agent.

Analysis of experiments

INSIGHT supports the analysis of experiments in three ways. The "Data Viewer" allows the user to select up to a maximum of four quantities of which she wants to observe the course during a certain situation. The values of the four quantities are projected as coloured columns onto the agent's trajectory through the environment. The choice of the quantities can be changed during the run. The coupling of the visualization of state information with the visualization of the environment, produces powerful presentations of the agent's internal events. Similar presentations in experiments with real agents would require a lot more effort.

The visualization of the dynamically changing values of different quantities can be helpful while analysing the agent's behavior. For the debugging of control programs it is more useful, if the designer has the opportunity to study the influence of a single process or behavior system on a certain quantity over time. The "Influence Viewer" depicts the additive influence of arbitrary processes or behavior systems on selected quantities as a graph during the run. This information is compared with the total value of the selected quantity.

In contrast to symbol-oriented AI, which is based on the formal framework of predicate logic, there is nothing comparable for behavior-based agent research yet. Recently, the theory of continuous dynamic systems is proposed as a promising candidate for the formalization and analysis of behavior-based agents ((Smithers 1994), (Beer 1995)). The senso-motoric component of an agent can be seen as an iterative process that depicts state parameters onto successor states. This iteration, continued over time, results in a trajectory of state parameters through the state space of the agent. INSIGHT offers a visualization tool which allows to visualize recorded agent-data as a two-, three-, or four dimensional phase portrait. The user can choose freely, which quantities she wants to correlate. The playback facility of INSIGHT allows the user to correlate interesting patterns in the phase portrait with the corresponding behavior of the agent.

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References

Beer, R. 1995. A Dynamical Systems Perspective on Agent-Environment Interaction. *Artificial Intelligence* 72 (1/2):173–216.

Smithers, T. 1994. What the Dynamics of Adaptive Behavior and Cognition Might Look Like in Agent-Environment Interaction Systems. In *Proceedings of the Workshop: On the Role of Dynamics and Representation in Adaptive Behavior and Cognition*, 135–153. Universidad del Pais Vasco, San Sebastian, Dezember 1994.

Steels, L. 1994. Building Agents out of Autonomous Behavior Systems. In Steels, L., and Brooks, R., eds., *The "Artificial Life" Route to "Artificial Intelligence": Building Situated Embodied Agents.* Lawrence Erlbaum.