Subsumption

From the euCognition Wiki

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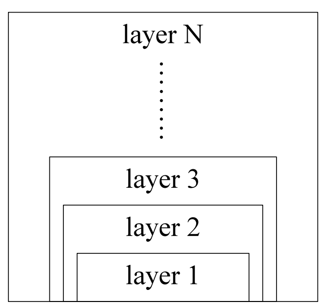
Subsumption is a design principle of control systems of robots and simulated creatures. It was proposed by R. Brooks in the mid-eighties.

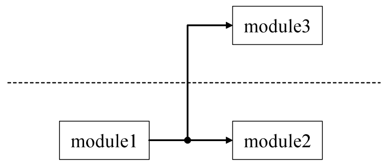
Subsumption mimics simplified biological evolution. It is based on the evolutionary fact that any complex control has an origin in a simpler ancestor. The relation between the ancestor and its descendant is simplified here in such a way that the descendant contains exactly the same control mechanism as the ancestor, enriched just by an additional layer of control. In other words, the descendant mechanism subsumes the mechanism of its ancestor; therefore the principle is called subsumption.

When we develop a system with complex control, we can use subsumption principle in the following way. At the first we design suitable sensors and actuators which are expected to be sufficient. Then we imagine a sequence of evolutionary steps which could result in the desired control starting from a simple base. We then incrementally develop each step as an additional layer to the previous simpler version. In doing so, each step brings a set of new features, but causes no harm to features which have been already implemented.

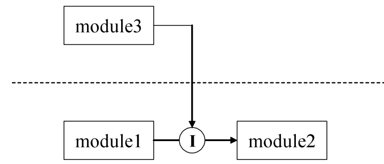


It is recommended to design the evolutionary steps in such a way that each step corresponds to the desired control under simplified conditions. When the real situation is as simple as concerned for a particular step, it will be handled only by the corresponding layer and layers which are (evolutionary) older. Getting to more and more difficult situation, newer and newer levels are activated to influence the resulting control.

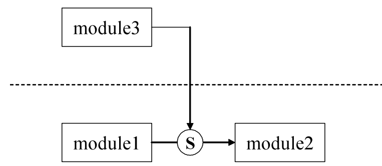
However, how could the newer levels influence the older ones? The older levels have been designed for a particular purpose and have no interfaces for future development! The answer is: they have to have modular structure which enables it. Particularly, so-called subsumption architecture assumes that each level consists of quite simple modules which communicate by messages sent through wires. Then the newer level can monitor messages communicated between modules in the older level by connecting to the same wire. Moreover it can inhibit the communication by temporary interruption of the wire (inhibition) or even it can replace communicated messages (suppression).



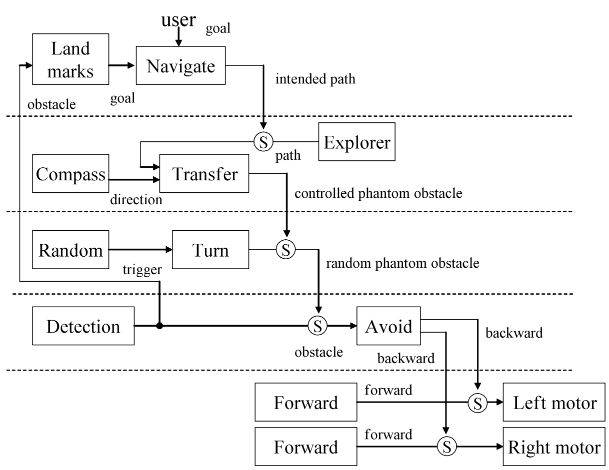
monitoring



inhibition



suppression



For example, navigation of a two wheeled robot in an office can be developed by subsumption in the following way: We start with robot which just goes forward. Then we add a layer which recognizes obstacles and while they are detected, the layer replaces messages for one wheel to go backward. As a result, the robot does not collide, but it can easily happen that it stays in the same region, moving in a cycle. Thus we add a layer which sometimes causes it to execute a random turn. However we perform such a turn only when no obstacles are detected and we implement it just by apparent detection of obstacles. Further we add another layer which provides an active search for suitable absolute directions for movement to another part of the office. Once such direction is chosen, we follow it using turns which appear essentially random to the older layers, but in fact they keep the robot on the chosen trajectory. Other level can detects landmarks, and having received a goal from the user, the robot can navigate to one of them by emulation of the chosen direction at the older levels.

As the subsumption architecture brings interesting results and nothing is perfect, many derivates have appeared. Some of them restricted the influence to suppression of layer outputs; thus behavior-based architectures have been derived. Further variations try to enable the accumulation of various actions generated by various levels; e.g. using a more fine-grained architecture. Yet other derivates try to extend the influence potential by modernizing the architecture which overcomes the limitations of the hardware layout typical for the original concept.

There are several biological observations which indicate that subsumption is also relevant in nature. For example, if one severs an eel's head from its spinal cord, the eel does not stop its sinuous swimming but its movements become perfectly regular and continuous. It means its brain inhibits and regulates its spinal cord than controlling it directly.

[1] Brooks, R.: Intelligence without representation, Artificial Intelligence 47, 1991, pp. 139-160
[2] Brooks, R.: Cambrian Intelligence, MIT Press, Cambridge, 1999