The Psi-Theory

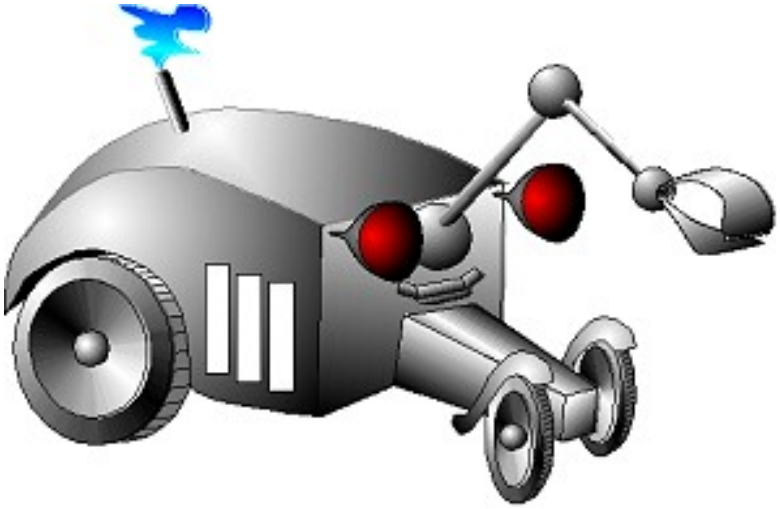
A Model for Human Behavior

Version 0.1

Advanced Magic GmbH

Contents

Psi the Robot: The Simulation Target

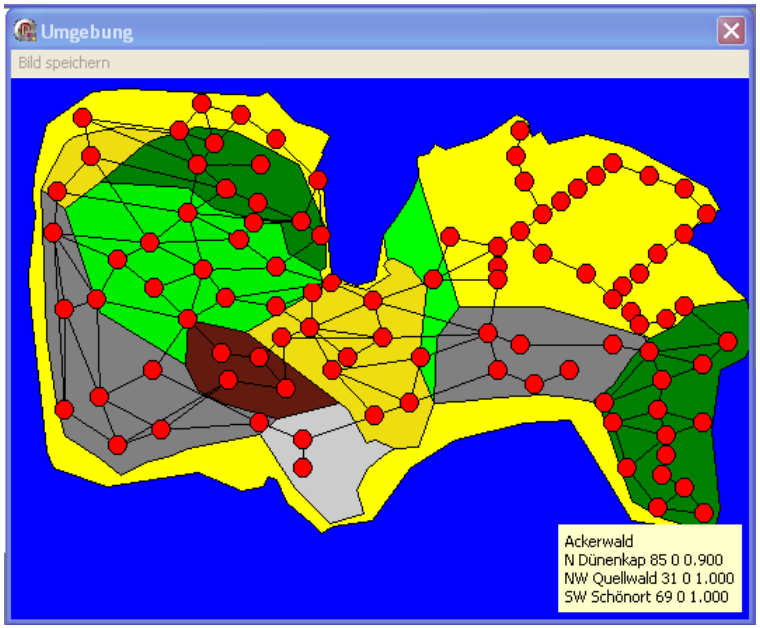


The simulation target is an autonomous robot with wheels, an arm and a gripper, a suction tube and a vision sensor. Psi, the robot is driven by a steam engine and therefore needs food and water to survive. It can grab and eat sunflower seeds or hazelnuts from the ground or drink water with its suction tube using it like a proboscis.

Psi's has a number of motives existential for its survival. It hates to hurt itself and feels pain if it did. Psi likes to know its environment and what will happen in the near future. It seeks to feel competent about managing its existence. Psi also likes to have company for social interaction. Since Psi is not capable of replicating itself, it has no desire for sex. Instead he likes to look for a certain kind of gemstone, called nucleotide. Collecting nucleotides however is not vital for Psi's survival. Initially, Psi does not have any idea how to satifiy any of these needs and wants.

At the beginning of its existance, Psi is not aware of any of its needs or feelings, nor does it know what to do in order to satisfy thirst or hunger. It does not know that it can drink water with its proboscis or eat nuts it has grabbed with its gripper.

The Island: The Simulation Environment



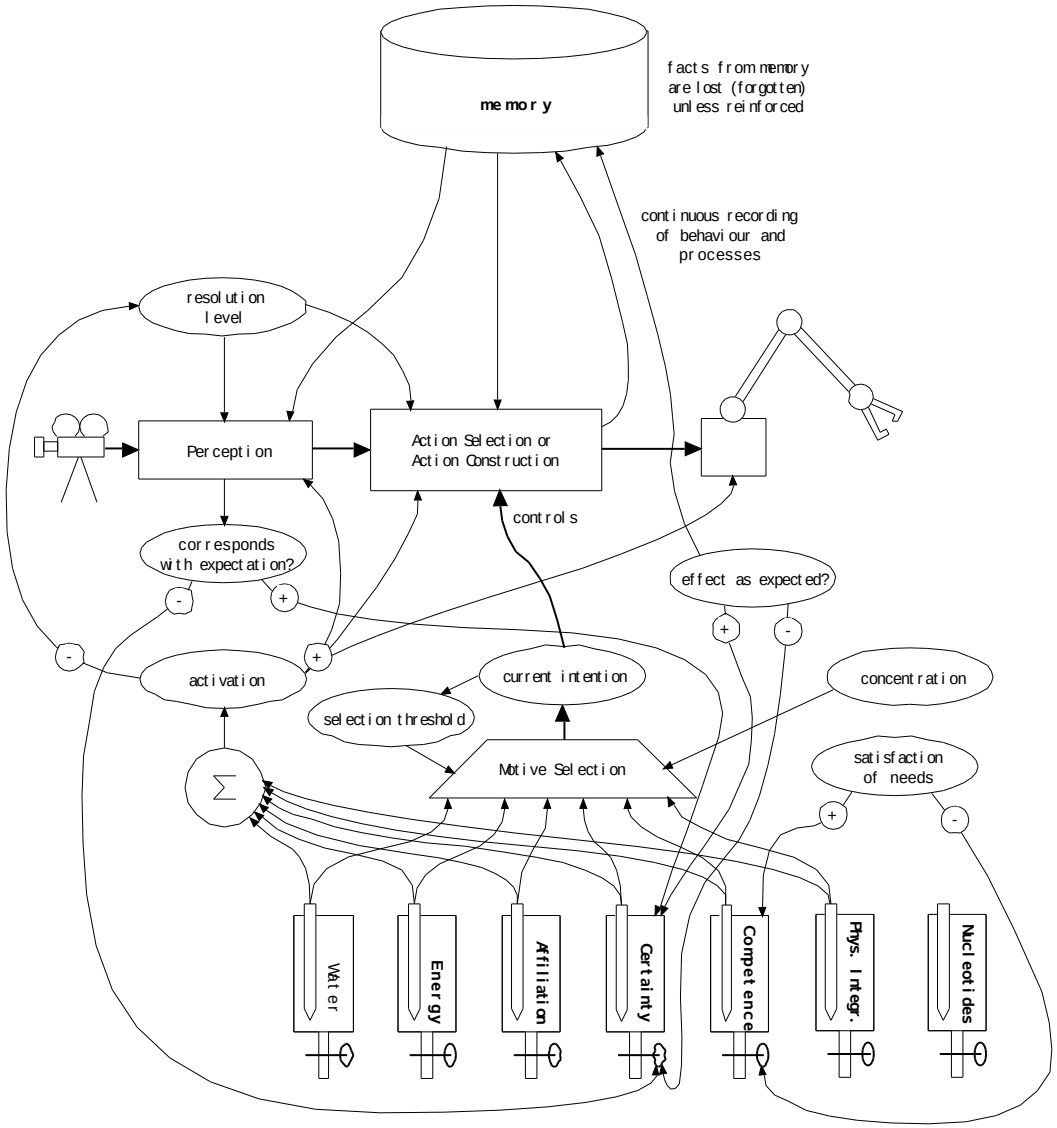
Psi lives on an island, somewhere in the ocean. On the island there are dry areas and wetlands, forests and hills. There are puddles and caves. Vegetation consists of trees, flowers and hazel bushes. There are no living animals but very few cute looking plush teddy bears. In the beginning of his life, Psi doesn't know anything about the island.

Psi can move on the island in a network of paths leading from one situation to another. In most locations it has several options where to move next. Some of the paths are just one way.

Psi can perceive its current situation visually. It can recognize plants, stones and everything else in the specific location with its vision sensor.

Psi's task on the island is to survive and collect as many nucleotides as possible.

To verify the Psi-theory, Dörner replaced the robot's program with a human operator. The human operator had to fulfill the exact same task as the autonomous system's and also take into account the remote controlled robot's need for food and water.



The Structure of Psi

Psi has seven motives, represented by the seven vessels at the bottom of the drawing. The level of the contents in the vessels represents a measure for the satisfaction of a certain need. When full, no need exists. The lower the level in a vessel, the larger the need.

The vessels for water and energy are essential needs. The level of physical integrity is reverse proportional to pain. Affiliation is a measure for the desire for social interaction. The need for certainty is a measure for predictability of the environment and the effects of Psi's behavior. Competence is a measure for power or effectiveness of Psi's actions manipulating its environment.

The level of a need changes through consumption (of water and energy) or perception. Perceiving something unexpected or unknown may increase the need for competence or certainty.

The Behavior Cycle

Motive selection is performed by multiplying the value of a need with the expected effect according to previous experience. Besides the dominating motive, secondary goals are computed too. They, for example, allow Psi to recognize opportunities.

Example

> *When the dominating motive is currently the need for energy (hunger), and a secondary goal is the need for water (thirst) and Psi happens to perceive a puddle, it might as well go ahead and drink.*
>
> *The current motive initiates a number of internal processes in order to satisfy the need. Psi will look in the current situation for possible candidates. Then it will try to manipulate its immediate environment to reach the goal. If Psi was still not able the satisfy the current motive, it starts to build a plan. If no plan could by constructed or was not successful, Psi reverts to trial and error.*

All of Psi's behavior is controlled emotionally. This is accomplished by changing parameters of information processing like resolution level, selection threshold, activation and concentration.

Resolution level modulates perception and search in memory characteristics.

Concentration influences the selection of secondary ends.

Selection threshold determines the selection of new motives.

All perceptions and actions are recorded continously in memory. Most of the new facts fall into oblivion unless they are reinforced through use.

Example of a behavior cycle

Psi arrives at a new place on the island

Oh, what's that? There's a tree on the left, a bush behind and sand dunes in front. And there is even a little puddle. This is a good opportunity for me to quench my thirst.

Psi lowers its proboscis into the puddle and drinks from it.

This feels good. Now let's go back to collection nucleotides.

The current motive was replaced by the motive for collecting nucleotides.

Are there any nucleotides to be seen? No. But there is a hazel bush. That's an opportunity to get some food.

Psi moves to the hazel bush and eats some nuts.

So back to the nucleotides! None are visible immediately - but wait - these dunes? Aren't there any when I sieve some sand, sometimes?

Psi moves to the dune and sieves some sand, indeed finding nucleotides.

Hey, that's great. This increases my inventory of nucletides substantially! - What next? Let's see what else there is.

Here, the motive changes again, now to exploration. Psi intends to find out more about its environment.

Let's go east, since we came from west.

Regarding its intention for exploration Psi continues by trial and error. It chooses a locomotion it has not yet tried in this situation.

Ah, this works. We're approaching the sea board, here are a few cliffs, three trees and sand dunes again. - I think, I've been here before. Let's continue. Can't go east, so let's try north east.

Psi tries to go but ends up in impenetrable undergrowth.

Hmm, this doesn't work, maybe we can go north.

Psi tries to go north, but this doesn't work out either, because it hits the ocean, it can't cross.

Bummer, what else can we do? Maybe there are nucleotides in hidden in the sand dunes.

Psi changes its intention. The unsuccessful trials for locomotion again lead to the intention to collect nucleotides. Psi goes to the sand dunes and starts digging. This however is not successful.

What a shame. I can't do anything here. Can't do anything at all.

Psi becomes somewhat helpless, caused by the previous failures.

There's a tree. I could shake it. Let's see what happens.

Psi now strives for self efficacy. It merely wants to prove to itself, it can do something at all, a demonstration of competence.

Hey, great, there are nucleotides in the tree, I can collect! Let's try the same with the other tree.

Psi shakes the other tree but has no luck this time.

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Doesn't work always. Let's go south, where we haven't been yet.
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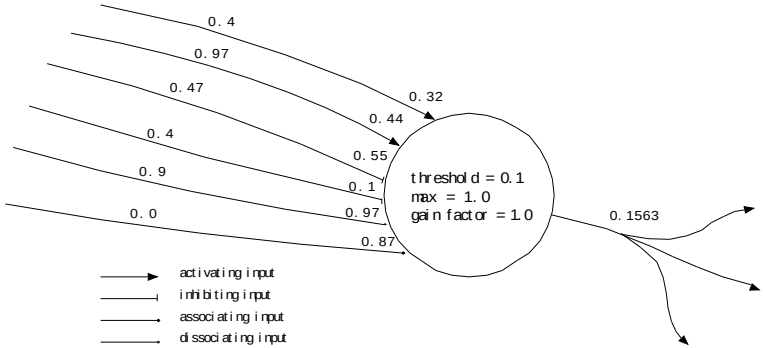
Psi proceeds south.

This is an actual episode from the life of Psi. Even the emotions described, are actually a part of Psi.

Neurons and Synapses



Psi contains only one fundamental data structure, the neuron. The picture on the left depicts the mathematical neuron as it is used in Psi.

Each link is shown with two values. The number far from the neuron is the current activity on this input. The number close to the cell is the bias weight which determines the strength and sign of the connection. The values given inside the cell determine how information is processed by the neuron. They are constant for each given neuron.

The neuron computes the scalar product from the input activities and the bias weights.

The input activity of the example neuron is computed like this:

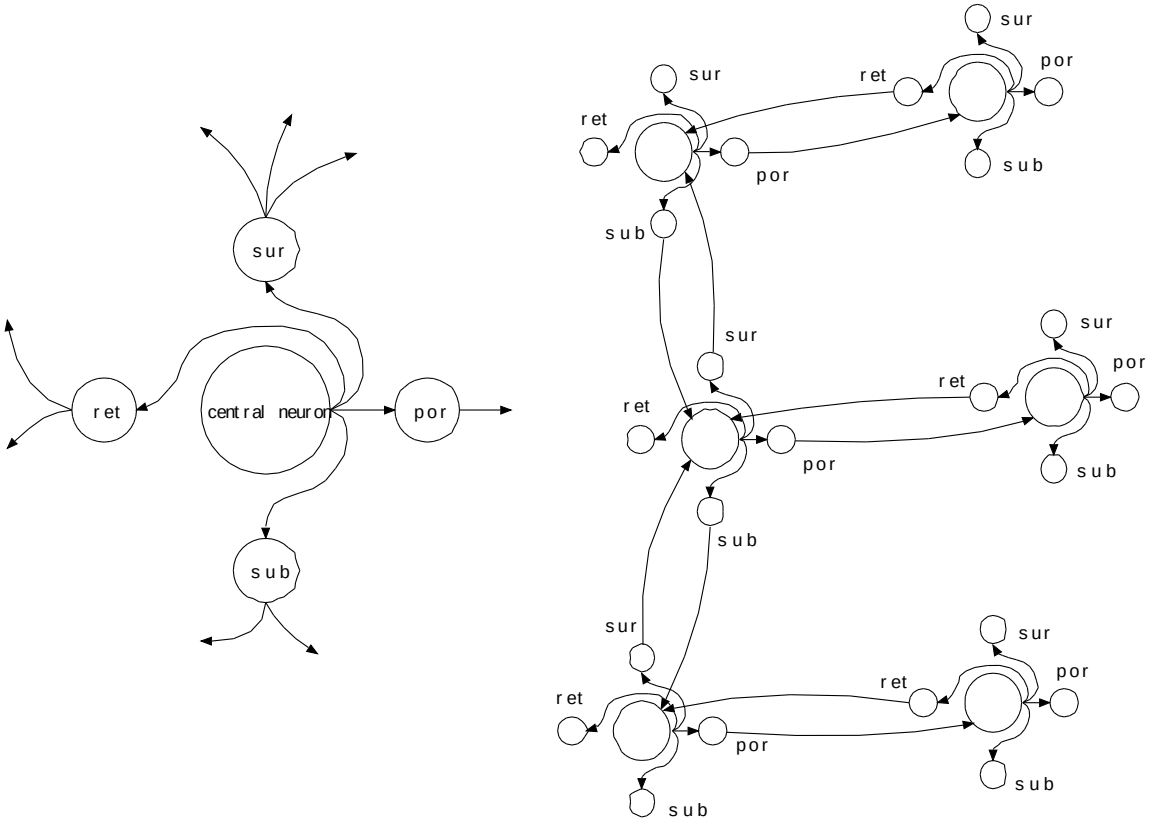
A_{in} = 0.4 * 0.32 + 0.97 + 0.44 + 0.47 * (-0.55) + 0.4 * (-0.1) = 0.2563

The output value is computed as follows:

```
if A_in > threshold:
       A_out = min (1.0, (0.2563 - 0.1) * 1.0) = 0.1563
else:
       A_out = 0.0
```

Associating and dissociating input reinforce or attenuate the bias values effectively changing the structure of the neural network.

Find a thorough discussion on neurons at http://page.mi.fu-berlin.de/rojas/neural/.



Networks of Quads

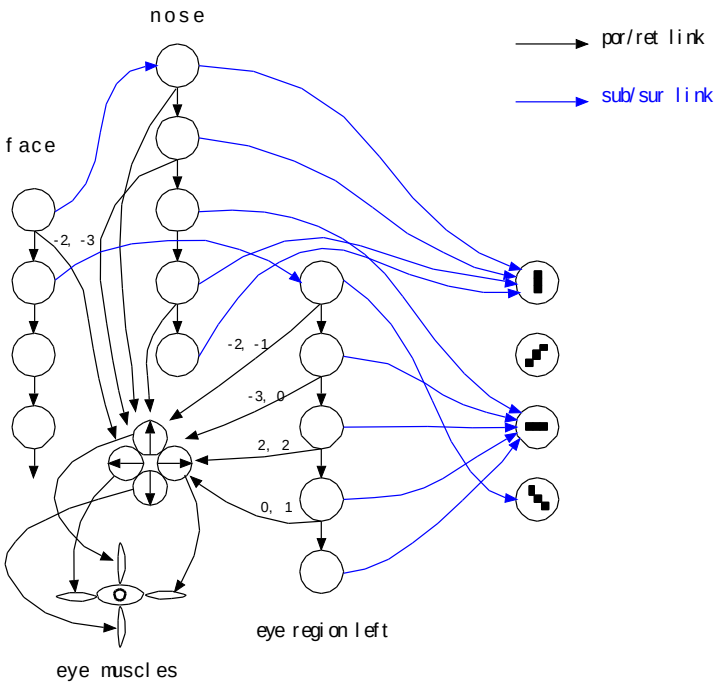
Psi's brain network consists of structures of neuron which can essentially be connected in four ways. We call them *quads*. A quad consists of a central neuron and four associated neurons called sur, sub, por and ret respectively. The four outer neurons can be activated by the central neuron.

Quads are connected with other quads as shown left.

Networks of quads constitute Psi's brain schemas.

Sur, sub, por and ret connections each have special significance. A sub connection points to the parts of a whole. A sur connection points the the whole a part belongs to. A por connection ties parts of a whole together. The same goes for a ret connection. Usually por connection point ahead in time. Ret connections point back in time, to what was previously.

Sur connections can be considered *is part of* and sub connections can be considered *has as part*. Por and ret connections indicate the neurons form a schema. The connections as such have no meaning at all.

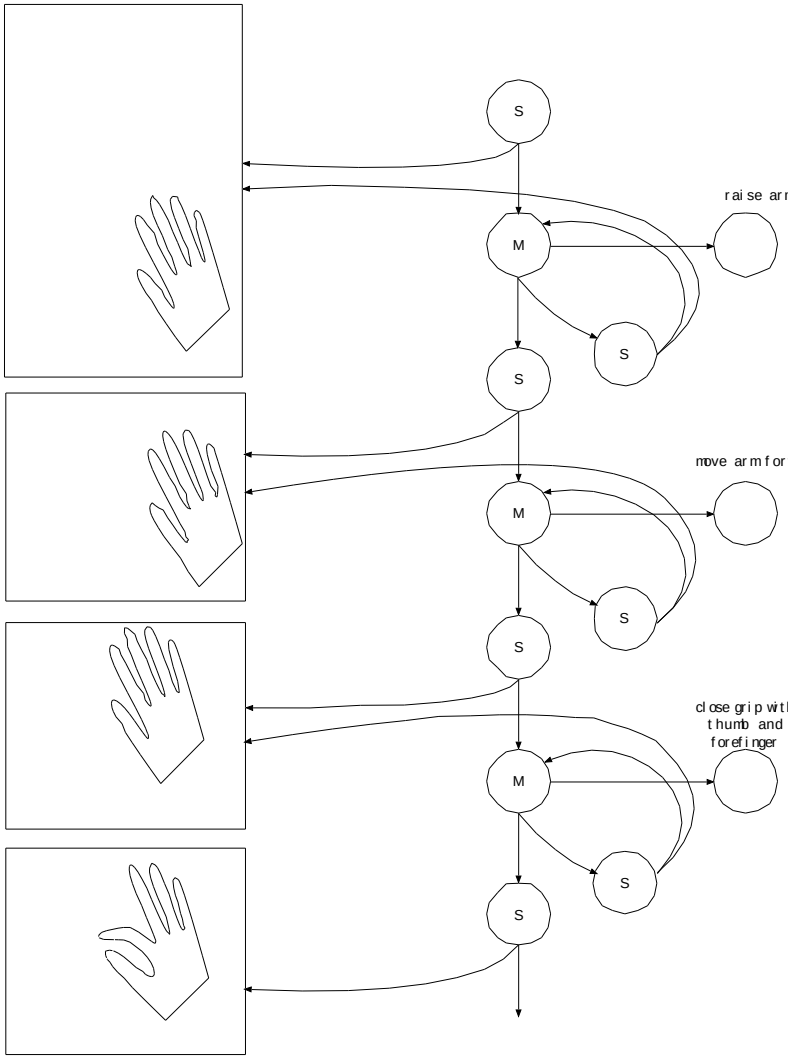


Sensory Schemas

The picture on the left shows what sensory schemas looks like in Psi's memory. They consist of hierarchies of quads, connected by por, ret, sur and sub links. In the image quads are simplified to circles.

The lowest level of neurons consists of pattern detectors for small patterns of pixels, namely a short vertical line, a short horizontal line and two kinds of diagonal lines.

A schema's por and ret relations contain space and time information too. They locate the structure in time and space in relation to the adjoining object.

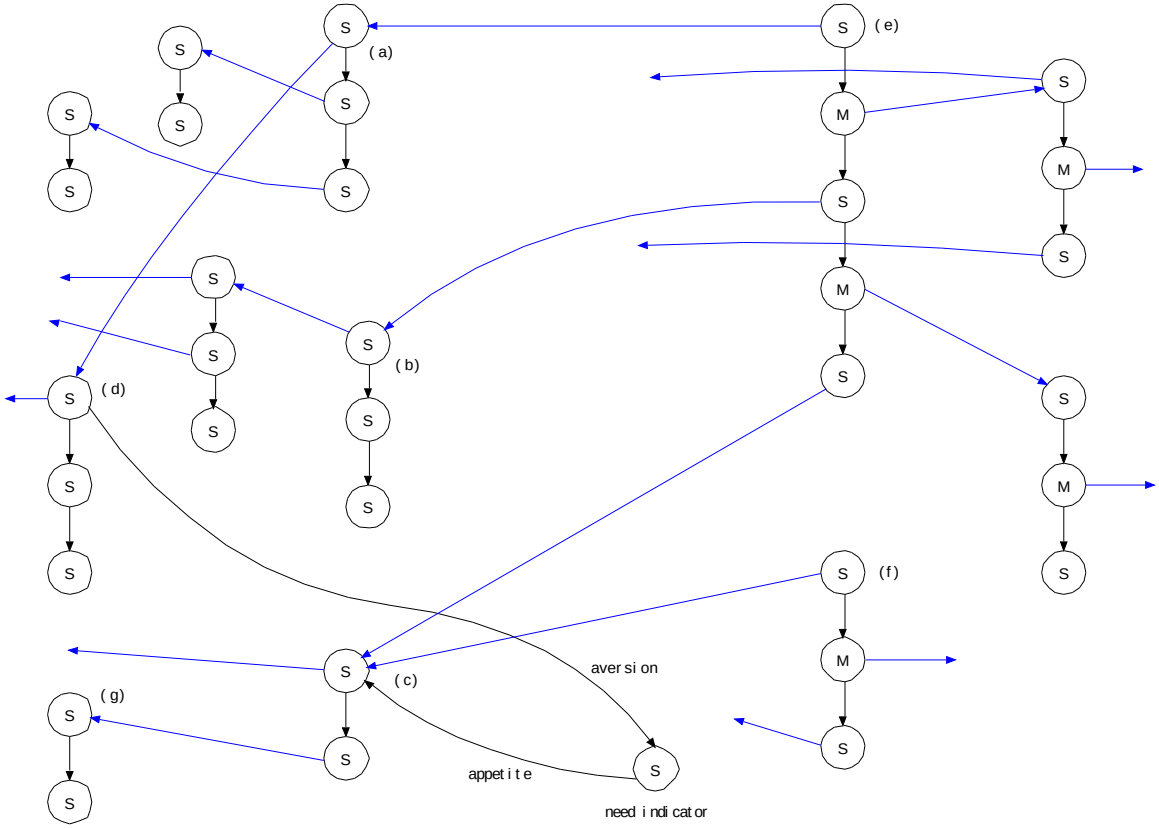


Programs of Behavior

Motor schemas are constructed similar to sensory schemas. They consist of chains and forks of neurons as well as sub and sur links. Contrary to sensory schemas motor schemas can point to both sensory schemas and *actors*. Actors can be other motor schemas or elementary actors. Elementary actors are individual muscle innervations. The sequence of neurons controls the way actors of the motor schema are activated.

A basic motor schema consists of three parts, a sensory schema, an actor schema and another sensory schema. The meaning of such a basic motor schema is the following:

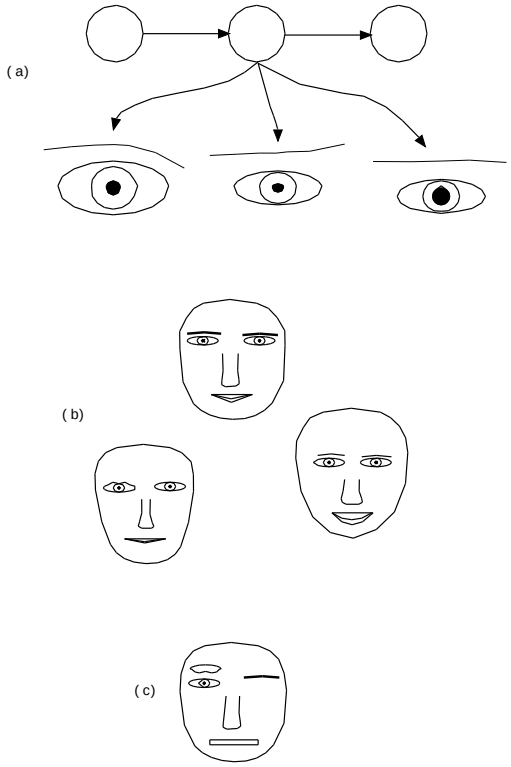
> *If the object the first neuron points to, is available, the action will be performed, with the result in the third neuron pointing at.*



Goals and Aversions

The drawing on the left shows some sensory and some motor schemas. On the bottom there is a need indicator. This is a neuron that is more active the greater the need is (physical, like a lack of blood sugar or some information like the successful completion of a task). We feel the level of activation as hunger or thirst.

The need indicator is linked por to neuron c, which is head node of a sensory schema.



Abstract Schemas

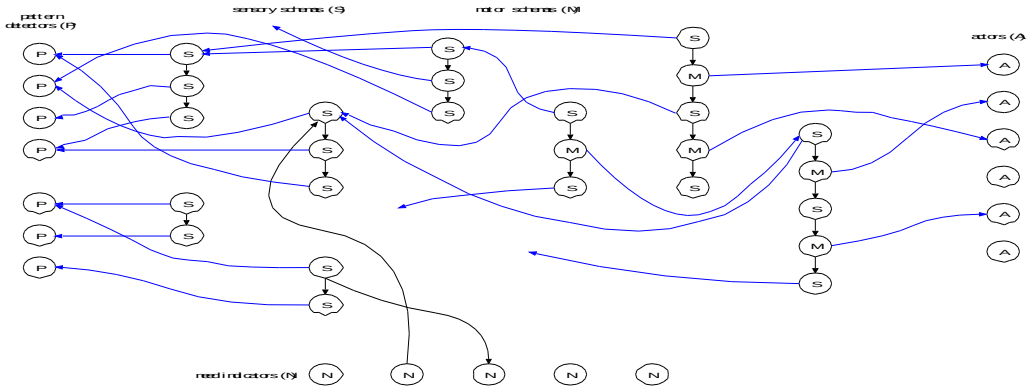
Sensory schemas are used for perception. For sensory schemas to fulfill their task they must be abstract or it must be possible to use them abstractly.

No tree looks alike and no bush looks alike, there is variation everywhere. Some characteristic properties remain the same, others change. If all of Psi's schemas were concrete, it could only recognize the same thing again but no other of the same kind.

Therefore in drawing (a) the neuron sub link points at several instances of eye regions, not just one. This way one schema can match several faces.

Another way of achieving abstractness is by allowing variations in the relative distances of elements of an object as shown in (b).

Finally there is a way of applying the search process so that it allows variations during the search process (HyPercept).

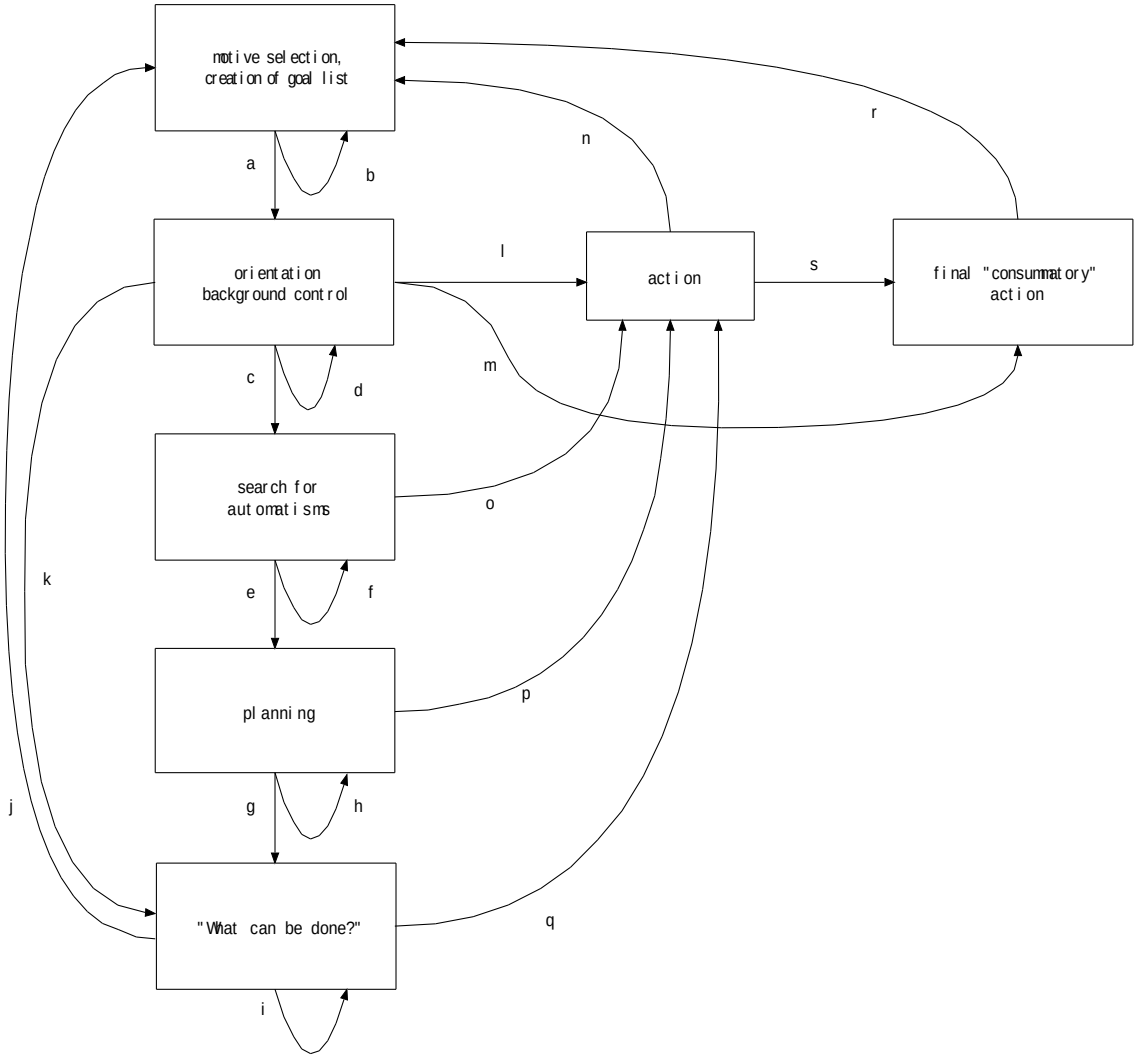


Psi's memory

The drawing depicts an overview of the structure of Psi's memory. It consists of a hierarchy of sensory schemas. Schemas are chains and forks of neurons (quads) connected by por and ret links. Sub and sur links connect the hierarchical levels vertically.

Schemas are images of time space structures and point at parts or the wholes they belong to. On the lowest level of sensory schemas are pattern detectors connected to the sense organs.

Motor memory is comprised both of sensory neurons as well as neurons pointing at motor schemas, actors on the lowest level respectively.



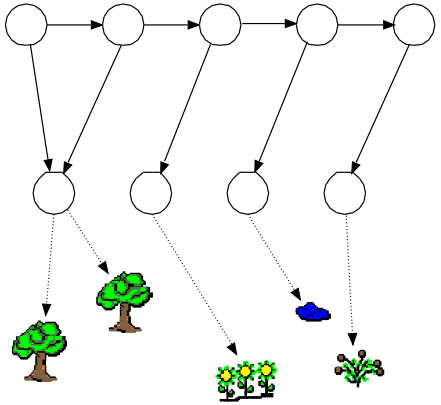
The organization of behavior

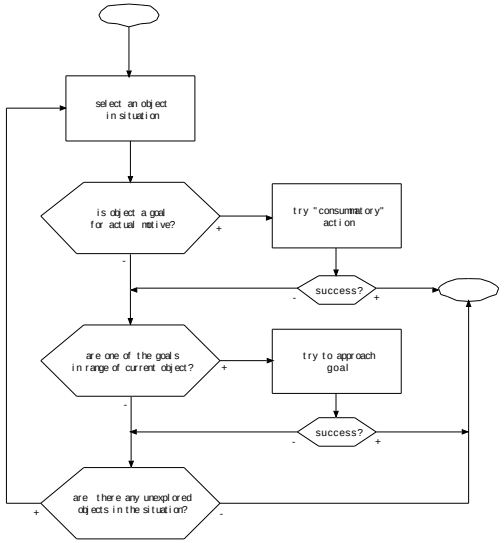
The nearby state transition diagram depicts the possible states Psi's brain can be in.

Intentions

Initially the leading motive has to be determined. That is usually the intention linked to the strongest need. It may be a weaker intention if the level of *selection threshold* avoids switching to a stronger motive.

At the same time secondary motives may be created. A secondary motive can become leading, if an opportunity to satisfy it appears. In case of a high *resolution level* secondary motives are thoroughly evaluated. A low *resolution level* leads to the orientation phase earlier.





Orientation

The orienatation phase consists of a perception process of varying intensity - depending on the motivational pressure exerted by the current motive. If there is no chance for the current motive to be satisfied, the perception process may be very shallow and Psi reverts to "What can be done?". If motivational pressure is low, perception can be more thorough and broader depending on *resolution level*.

If an goal is found, it may lead to a "consummatory action" immediately.

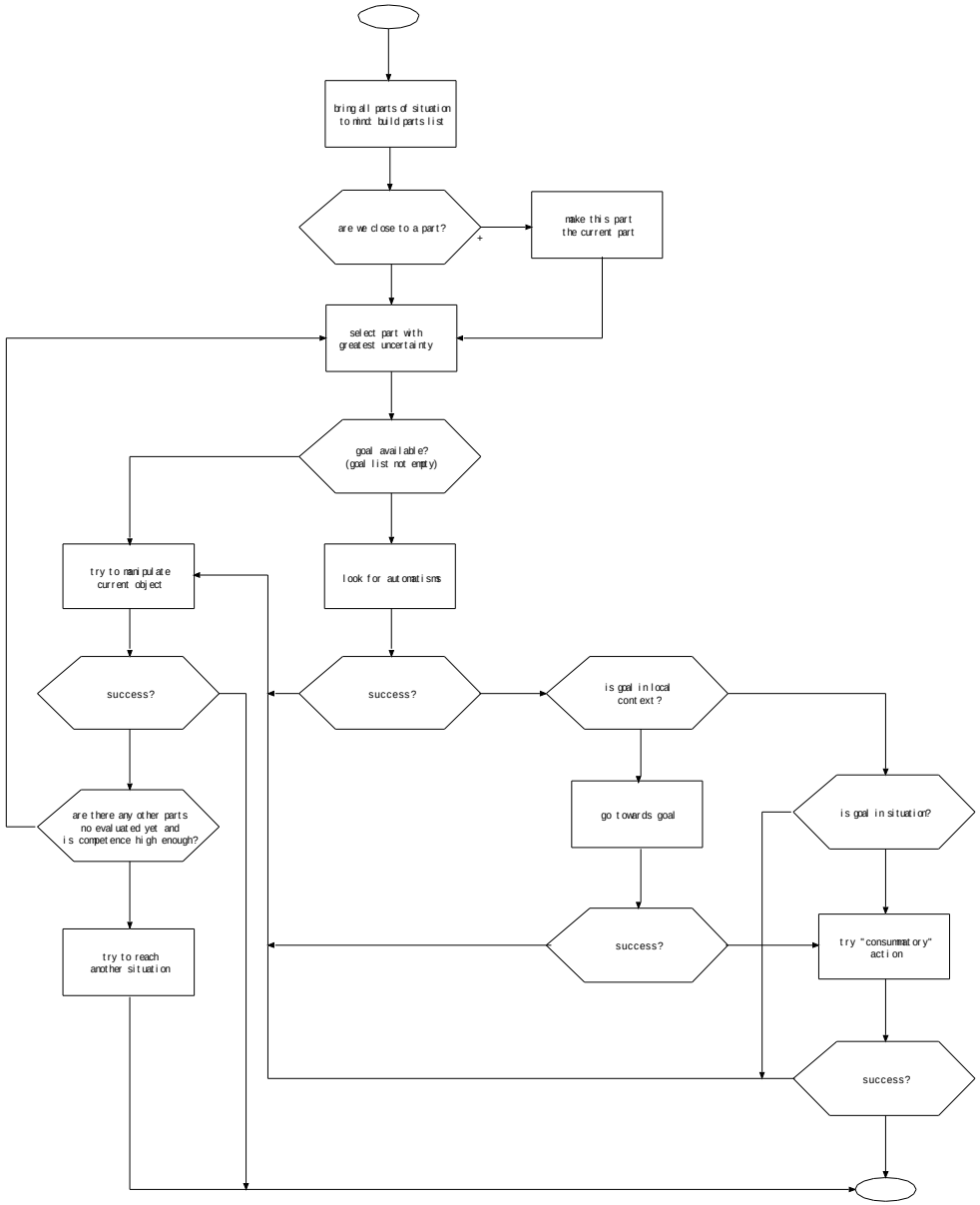
If *resolution level* is very high, the system may remain in orientation for quite a while.

The drawing on the left depicts what happens in Psi in the perception process. The optical image is turned into a sensory schema of the situation.

In a new situation Psi checks if one of the elements of the situation are in its goal list. Psi then tries a "consummatory action".

Search for Automatisms

After the orientation phase a search for automatisms takes plase. Psi searches for goal leading actions. Dependent on *resolution level* found found actions are checked for contradicting experiences and chances for success. Psi then tries to execute the action.



Planning

In case no automatism could be found, planning follows. If a goal leading chain of actions could be synthesized, Psi tries to execute it.

"What Can Be Done?"

If none of the previous phases led to a success, Psi reverts to a kind of exploration.

Emotional Regulations