Artificial Life lecture 18

Evolution and Learning

(A) Evolution of Learning
(B) The Baldwin Effect (this week's seminars)
(C) A teaser …

Evolution and Learning

Exploring Adaptive Agency II: Simulating the Evolution of Associative Learning
Peter Todd and Geoffrey Miller, pp. 306-315 in
From Animals to Animats, J-A Meyer & S. Wilson (eds)
MIT Press 1991 (Proc of SAB90)

Looking at some aspects of the relationship between *evolution* and *learning*.

ALSO: look at how the model is simplified as far as is reasonably possible – lessons for your Alife project

Evolution and Learning

Darwinian Evolution is done by a **population** (which may, or may not, be composed of **learning** individuals).

As shorthand, one might talk of a population 'learning' to adapt to changed environmental conditions (eg climate change) through evolution.

But usually it avoids confusion if one talks of a population evolving, an individual learning.

Why bother to Learn - 1?

Todd & Miller suggest 2 reasons:

(1) Learning is a cheap way of getting complex behaviours, which would be rather expensive if 'hard-wired' by evolution. Eg: parental imprinting in birds –

'the first large moving thing you see is mum, learn to recognise her'.

Why bother to Learn – 2?

(2) Learning can track environmental changes faster than evolution.

Eg: it might take millennia for humans to evolve so as to speak English at birth, and would require the English language not to change too much.

But we have evolved to learn whatever language we are exposed to as children -- hence have no problems keeping up with language changes.

Learning needs Feedback

Several kinds of feedback:
Supervised -- teacher tells you exactly what you should have done
Unsupervised -- you just get told good/bad, but not what was wrong or how to improve.
(..cold...warm...warmer...)

Evolution roughly equates to **unsupervised** learning
-- if a creature dies early then this is negative feedback as far as its chances of 'passing on its genes' are concerned -- but evolution doesn't 'suggest what it *should* have done'.

Evolving your own feedback?

However, it may be possible, under some circumstances, for evolution to create, within 'one part of an organism', some subsystem that can act as a 'supervisor' for another subsystem.

Cf.DH Ackley & ML Littman.
Interactions between learning and evolution. In *Artificial Life II*, Langton et al (eds), Addison Wesley 1991.

Later work by same authors on
Evolutionary Reinforcement Learning

The Todd & Miller model

Creatures come across food (+10 pts) and poison (-10)

Food and poison always have different *smells,* sweet and sour. **BUT** sometimes smells drift around, and cannot be reliably distinguished. In different worlds, the reliability of smell is x% where 50 <= x <= 100.

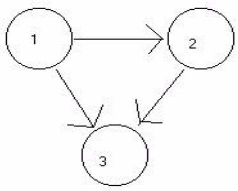
Food and poison always have different *colours,* red and green. **BUT** in some worlds it is food-red poison-green, in other worlds it is food-green poison-red. The creatures' vision is always perfect, but 'they dont know whether red is safe or dangerous'.

The model – ctd.

Maybe they can learn, using their unreliable smell?
Todd & Miller claim that simplest associative learning needs:
(A) an input that (unreliably) senses what is known to be good or bad (smell)
(B) another sensor such as that for colour, above
(C) output such that behaviour alters fitness.
(D) an evolved, fixed connection (A)->(C) with the appropriate weighting (+ve for good, -ve for bad)
(E) a learnable, plastic connection (B)->(C) which can be built up by association with the activation of (C)

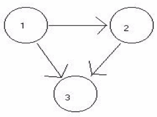
Their 'Brains'

Creatures brains are genetically specified, with exactly 3 neurons connected thus:



Genetic specification

The genotype specifies for each neuron whether it is
- ✓input sweet-sensor
- ✓input sour-sensor
- ✓input red-sensor
- ✓input green-sensor
- ✓hidden unit or interneuron
- ✓output or decision unit: eat/dont-eat



- ✓and for each neuron the bias (0, 1, 2, 3) (+/-)
- ✓and for each link the weight (0, 1, 2, 3) (+/-)
- ✓and whether weight is fixed or plastic

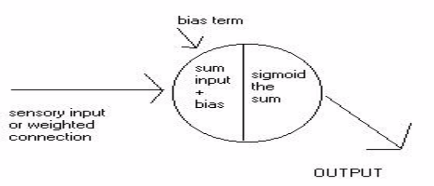
Plastic links

Some of the links between neurons are fixed, some are plastic.

For plastic weights on a link from P to Q, Hebb rule:
Change in WEIGHTPQ = $k * A_P * A_Q$
where A_P is the current activation of neuron P.

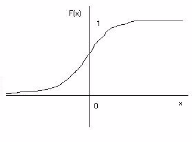
I.e.:- if the before and after activations are the same sign (tend to be correlated), increase strength of link
If opposite sign (anti-correlated), decrease strength

Within each neuron



The sigmoid is a 'squashing function' such as

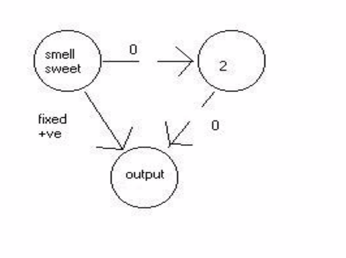
$$f(x) = \frac{1}{1+e^{-x}}$$



Possible brains

So one possible genetically designed brain would be this: **colour-blind eater** – this is **not** a learner.

Whatever neuron 2 is, the links are 0, hence it can be ignored.
This depends purely on smell, and has the connection wired up with the right +ve sign, so that it eats things that smell sweet.

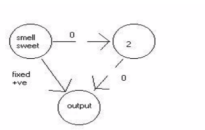


Is a colour-blind eater any good?

This creature depends purely on smell, and has the connection wired up with the right +ve sign, so that it eats things that smell sweet.

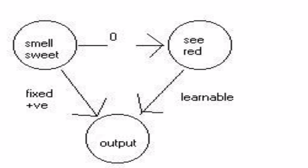
Though it may occasionally ignore food that (noisily) smells sour, and eat poison that (noisily) smells sweet, on average it will do better than random.

So evolving within a population, this (non-learning) design will do better than random, and increase in the population.



A learning brain

This different possible design is a **colour-learner**



If this one is born in a world where smell is 75% accurate, and food is red, then (more often than not) seeing red is associated with the positive output.

Is a colour-learner any good?

… seeing red is associated with the positive output.
So, with Hebbs rule, the RH connection gets built up +ve more strongly, until it fires the output on its own -- it can even over-rule the smell input on the 25% of occasions when it is mistaken.

Contrariwise, if it is born in a world where food is green, then Hebbs rule will build up a strong –ve connection -- with the same results.

So over a period, this will do better than the previous one

Evolutionary runs

Populations are initialised randomly.

Of course many have no input neurons, or no output neurons, or stupid links
- these will behave stupidly or not at all.

The noise level on smell is set at some fixed value between 50% accurate (chance) and 100% accurate.

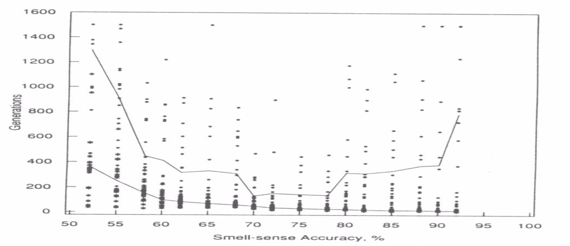
Then individuals are tested in a number of worlds where (50/50) red is food or red is poison.

Keeping statistics

Statistics are kept for how long it takes for **colour-blind eater** to turn up and take over the population; and for **colour-learner** likewise.
[Statistics: multiple runs to reduce chance elements, keep record of standard deviations]

- When smell noise-level is 50%, then there is no available information, no improvement seen.
- When smell is 100% accurate, then colour-learning is unnecessary.
- What happens between 50% and 100% ?

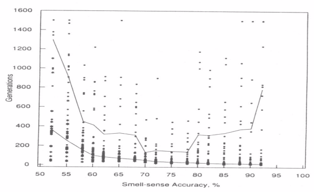
Results on a graph



Colour-learner= top line colour-blind eater=bottom line

U-shaped curve

As smell-sense accuracy goes from 50% (left) to 100% (right), average number of generations needed to evolve **colour-blind eater** decreases steadily (lower line)



But average number of generations needed to evolve **colour-learner** goes through the U-shaped curve (upper line)

Lessons for doing (Alife) projects

Make your model ***as simple as possible*** whilst still showing the phenomenon of interest.

More complicated models, with lots of bells and whistles,

(a) Are more difficult to get to work ***AND***

(b) If they ***do*** work, they prove ***less*** than the simple model! Because it is not clear (without further investigation) which bit of your model actually was crucial, and which bit is unnecessary.

More lessons

Do comparisons: your preferred model versus a simple variant (appropriate for the task) – e.g. compare with random search (if appr), or with one part disabled (if appr), or with a standard textbook method (if appr), or …

Graphs can be very informative -- ***provided*** the axes and scales are clearly labelled, and the caption or text explains them fully.

Usually it is appropriate to report mean (average) of several runs, and also to report standard deviations.

Baldwin Effect – more detail in seminar

A much more subtle and interesting interaction between Learning and Evolution is the Baldwin effect -- named after Baldwin (1896).

Roughly speaking, this is an effect such that, under some circumstances, the ability of creatures to learn something guides evolution, such that in later generations their descendants can do the same job innately, without the need to learn.

Speaking English at birth?

Human children are born with the capacity to ***learn*** a language within their first few years.

Pick up the local language, English, Japanese, Inuit etc …

But suppose that within 1000 years ***everybody*** speaks English – then it won't be necessary to work out "what happens to be the local language"

Saving energy …

If any child has a mutation that predisposes it to saying "mummy, daddy" earlier than the other children

Then on average it will do slightly better at kindergarten --- at school --- in life --- have more children – this mutation could be expected to spread.

That child would have ***less learning*** to do, which would save energy and increase its fitness

In the long term

All human children will be born speaking good English at birth!

OK, where are the problems, what is in the small print?

Ostrich bums

Development and learning are ***in some*** sense much the same .

Often development is on a longer time-scale than learning, and development is constrained to just one (or a few) pathways, whereas learning may have many possible pathways (eg many different languages).

In the 'everyone speaks English' scenario, what **was** originally learnt becomes a standard developmental pathway – like ostrich bums

Ostriches, long grass, sharp rocks

Callosities

Figure 4 |
The callosities on the ventral surface of the ostrich.
The callosities are depicted by arrows. How did they become assimilated into the genome?

Is it Lamarckian?

This sounds like Lamarckism -- "giraffes stretched their necks to reach higher trees, and the increased neck-length in the adults was directly inherited by their children".

Lamarckism of this type is almost universally considered impossible -- why ??

The Baldwin effect gives the impression of Lamarckism, without the flaws.

To be pursued in seminar

Feedback on Alife course?

Any verbal feedback now? And in seminars.

What was missing that you expected?

And a teaser (cf 'Circular causation'…)

Circular Causation poser …

A cart with its wheels linked through gears to a propellor.

Can it run directly downwind ***faster than the wind?***