

Model Evaluation

Methodologies and Opportunities

- IMPRINT, ACT-R
Their different roles in the project; Potential concerns
- General modeling issues
- Neural networks
- Conclusions

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Some modeling goals

Overall goals:

- Decompose very complex human responses into conceptual 'modules'
- Cross-connect 'modules' to create powerful simulation tool with intuitive user interface
- Modeling deepens understanding of genuine mental mechanisms (and the limitations of simulations)
- Provides ability to predict, optimize, explore wide-ranging 'what-if' scenarios, etc.
- Understanding IMPRINT - functionality, opportunities, and limitations

Some modeling tools

IMPRINT and ACT-R are extremely capable systems, but with partly different strengths.

TASKS	TOOLS				
	Imprint	ACT-R	NN	RBF	Statistical tools
'Absorb' experimental data		☐	☐	☐	☐
Make mathematical model		☐	☐	☐	☐
Predict	☐	☐	☐	☐	
Understand cognitive processes		☐			
Understand neural functioning			☐		
Interface to other systems	☐	☐	☐		

Still too early to pass any 'verdicts' :

Issue not **IMPRINT vs. ACT-R**, instead is **IMPRINT and ACT-R and additional possibilities**.

General modeling issues

- **Contrast/compare strengths and weaknesses of different modeling approaches**

 - Use whatever approach that is most suitable for task at hand

 - Might come from other areas than psychology

 - Might not yet be part of major system package

 - Ultimate useability by the Army.

- **Assess computational feasibility, reliability, and complexity with regard to**

 - Fast enough for real-time simulations? (speed of IMPRINT potential concern if modeling cognitive behavior)

 - Scales to many interacting processes?

 - Practical on readily available hardware (laptops)?

 - Practical for global optimization - can be combined with, say, simulated annealing or genetic algorithms?

- **Multivariate visualization**

 - To large extent, a future opportunity

Artificial Intelligence, Neural Networks, and ACT-R

Artificial Intelligence (AI)

From 1950's. Applications: machine learning, expert systems, case-based reasoning.

'If-then' - based logic; Potentially fast, but no link to mechanisms behind human intelligence.

Big hopes from 'early days' generally not fulfilled.

Neural Networks (NN)

Very closely modeled on human brain 'wiring'. Application areas include

- system control (vehicle, process)
- pattern recognition (radar systems, face identification, object recognition)
- sequence recognition (gestures, speech, hand written text recognition)
- medical diagnosis, decision making
- financial applications

Concerns about speed for training. NN (including learning) has been implemented 'in silicon'.

Evaluation of models very fast.

Numerous journals, large number of commercial packages available. Good toolbox for ex. in **Matlab**.

ACT-R

ACT-R (The Adaptive Control of Thought - Rational)

- Combines strengths from AI and NN (Current alternatives: Soar, DUAL, EPIC, Psi, Copycat, etc.)
- Developed to model problem solving, learning, memory (i.e. cognitive processes).
- Wide scope - can accommodate multiple (possibly competing) theories within single framework.
- Models tend to be large - not always easy to apply.
- Currently hundreds of users.

Neural Networks

While part of ACT-R, might be able to play also an independent role in the present MURI project.

Concept behind NN: How is the brain wired?

Small part of human neocortex, showing cells and connections \Rightarrow
(part of brain that handles most of our cognitive functions)

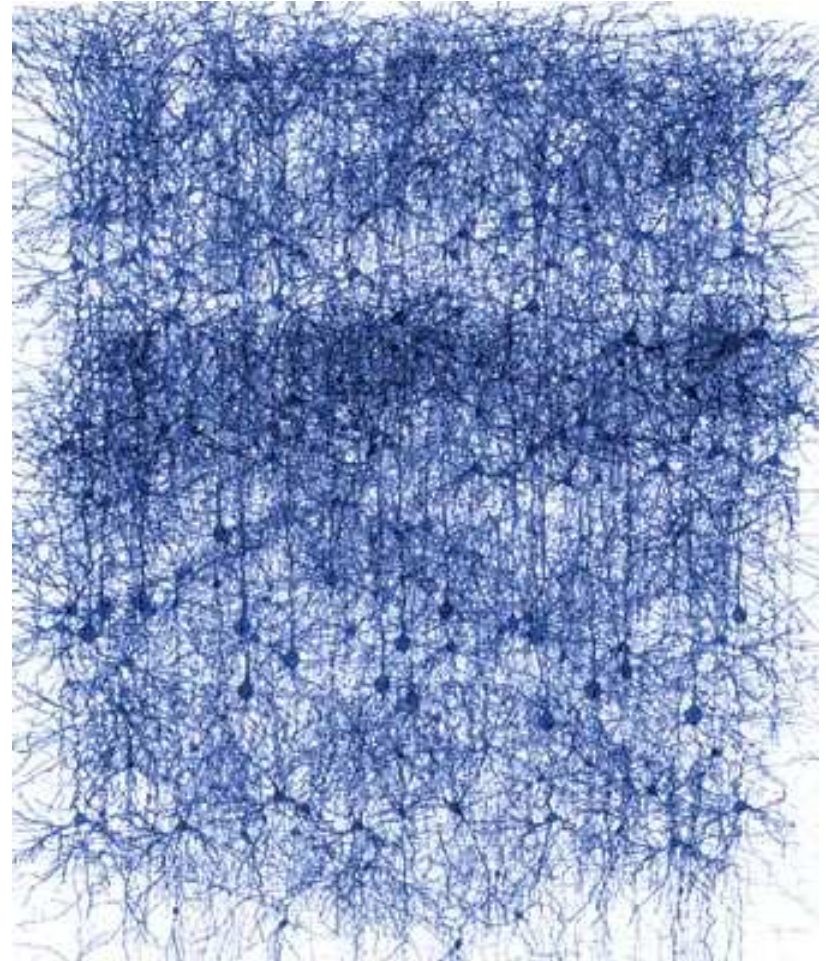
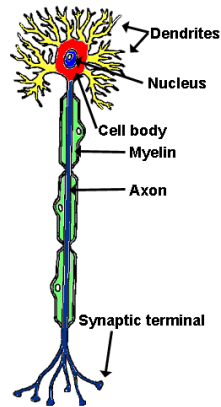
About 10^{11} neurons; each with connections to $10^3 - 10^4$ others. \Downarrow

Signal speed up to about 100 m/s
(cf. speed of light 299,792,458,000 m/s)

Very complicated responses (such as evasive actions when driving) may go through only 10 - 30 'layers', but vast parallelism.

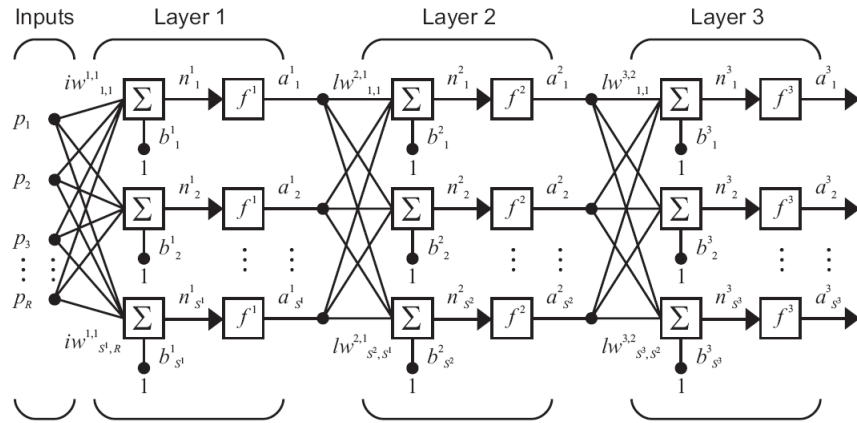
Exceedingly complex neuron connection pattern is NOT in the genetic code, evolves in each case, as does subsequent learning / cognition.

World's largest present computer system - IBM Blue Gene - matches component number (10^{11}), but these are about 10^9 times faster.



Can brain development, cognitive learning, and behavior be reproduced in a computer?

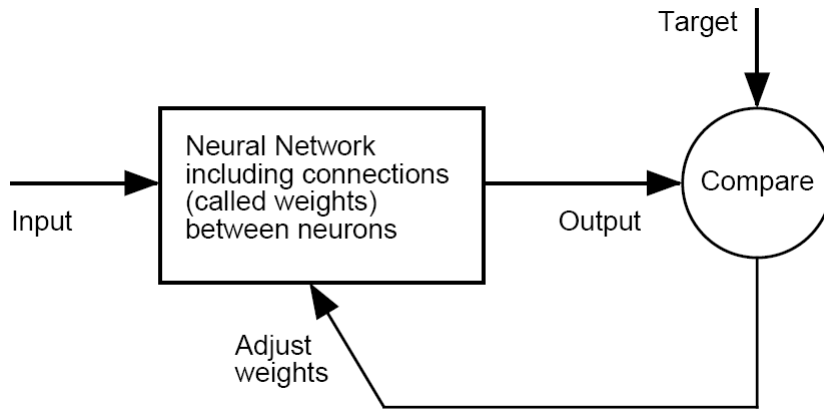
Neural Networks: Concept illustrations based on Matlab's tool box



Data enters at left; output at right

All properties defined by weights and transfer functions

Schematic of a 'feed forward' network

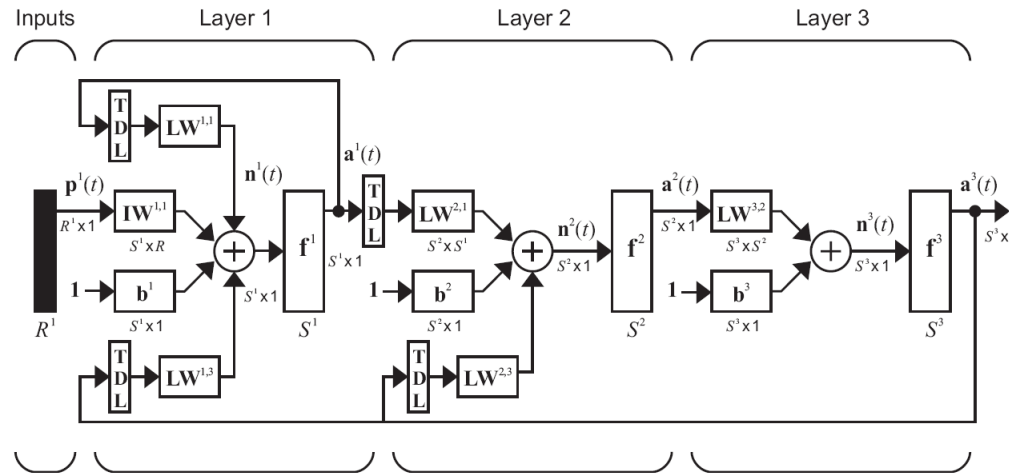


Key issue: how to adjust weights so network output best matches actual data

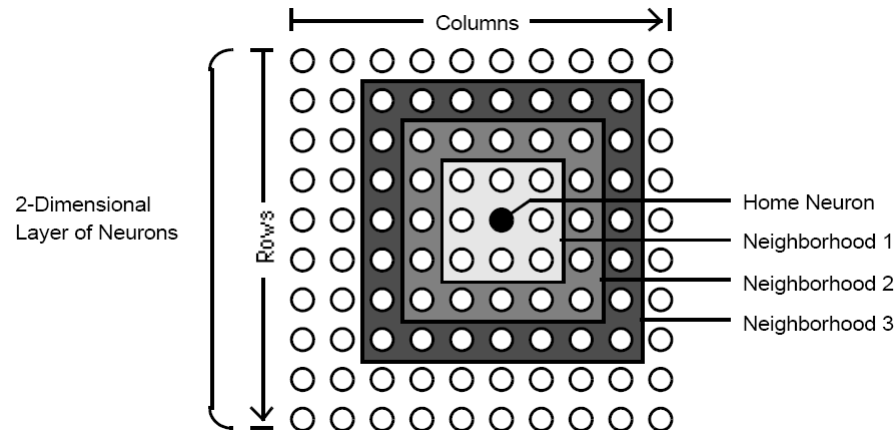
In unsupervised learning, no target. Network weights can be updated so that it 'conceptualizes' by itself.

Basic concept (in case of supervised learning)

Many variations are inspired by brain features



More compact notation of a network that also includes time delays and feedbacks.



Layout need not be logically a 1-dimensional sequence of layers.
 Connection pattern itself (not only weights) can evolve during learning.

Conclusions

Both ACT-R and IMPRINT are essential - in partly different aspects - of the present MURI project. Other approaches will likely supplement these.

As the project progresses, their different strengths and limitations will become more apparent. Criteria will include

- Practicality of use (ease of coding)
- Flexibility, reliability, speed, trends in larger scientific community, etc.

Concepts which will likely grow in importance will include:

- 'Data mining' may reveal relations which were unforeseen - and possibly not interpretable in all taxonomies even after having been observed.
- If a well working model becomes too slow to compute, one may want to model the model - which may require a quite different approach.
- It may be easier (and more convincing) to do some modeling outside of the main tool set.
- Visualization and optimization of multivariate relationships can contain significant computational challenges.