WHAT SORT OF ARCHITECTURE CAN SUPPORT EMOTIONALITY?

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Papers by the group can be found at the ftp site:

ftp://ftp.cs.bham.ac.uk/pub/groups/cog_affect/

See also

http://www.cs.bham.ac.uk/˜axs/

and the misc/ sub-directory.

OVERVIEW

OBJECTIVES:

- **A mythical history of the evolution of human-like min**
- **Different architectures support different sorts of emotions: found in different animals**
- **Some speculations about architectures for human-like machines.**
- **Various sub-architectures in human brains support ve different types of emotions (e.g. based on "reactive" "deliberative" and "meta-management" layers).**
- **Hence the *ENORMOUS* confusionin psychological, philosophical and neuroscience literature.**
  (People argue at cross-purposes)
- **Comments on characteristically human emotional states involving partial loss of control of thought processes.**
- **A brief characterisation of Artificial Intelligence as exploration of "design space" and "niche space" and trajectories therein.**

  (Cognitive Science is the subset that looks at humans and possibly also other animals)

KINDS OF QUESTIONS

WE NEED TO DISTINGUISH:

- **Empirical questions**
- **Design questions**
- **Conceptual questions**

THIS TALK IS MAINLY ABOUT CONCEPTUAL QUESTIONS AND DESIGN QUESTIONS.

We need to sort out conceptual questions in order to know:

- **What we are trying to explain or build**
- **Whether we are making progress**
- **When we are arguing at cross purposes**

Design questions are concerned with:

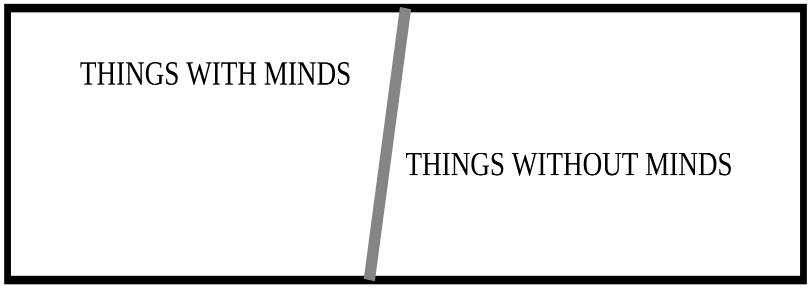
- **What sorts of designs are possible?**
- **What they are good for (what niche)?**
- **How different designs differ?**
- **How they can be implemented?**
- **Which concepts of types of mental states they support. (That's partly conceptual)**

CONFUSIONS TO AVOID: ASKING THE WRONG QUESTIONS

Minsky: "dumbbell" questions,
presupposing dichotomies,
are often misguided.

WHICH THINGS ARE CONSCIOUS AND WHICH ARE NOT?

It is not a dichotomy:



It is not a continuum:
virus ... amoeba .... flea .... mouse ...... monkey .... bonobo .... human ... ??

THERE ARE MANY DISCONTINUITIES
WE NEED TO STUDY THEM!

DON'T ASSUME IT'S A CONTINUUM
Lots of discontinuous changes may come close to a smoo continuum, but we need to understand the DIScontinuiti in "design space".

MENTALITY: A “CLUSTER” OF RECOMBINABLE CAPABILITIES

What is it to have a mind? To have emotions?

While apparently talking about *ONE* thing we may be talking about a very complex *CLUSTER* of different things.

DIFFERENT SUBSETS OF THE CLUSTER OCCUR:

- **in different organisms,**
- **in different machines,**
- **in different people,**
- **even in the same person at different times:**

  infancy,
  childhood,
  adulthood,
  during senile dementia,
  after brain injury, and so on....

NO UNIQUE SUBSET OF CAPABILITIES DEFINES “CONSCIOUSNESS” “INTELLIGENCE” “EMOTION”

DISCONTINUITIES OCCUR BETWEEN DIFFERENT SUBSETS.

Example:

- **A rat can be afraid.**
- **Can it be humiliated? Ambitious? Guilt-ridden?**
- **WHY NOT?**

LAYERS OF ARCHITECTURE IN A DESIGN

CONJECTURE:

Humans have at least three architectural layers:

- **A very old reactive layer**
  shared with many kinds of animals (insects?)
- **A deliberative layer**
  shared with some other animals
- **A meta-management layer**
  shared with very few animals.

- **THE REACTIVE LAYER PROVIDES SPEED**
  At the cost of rigidity.

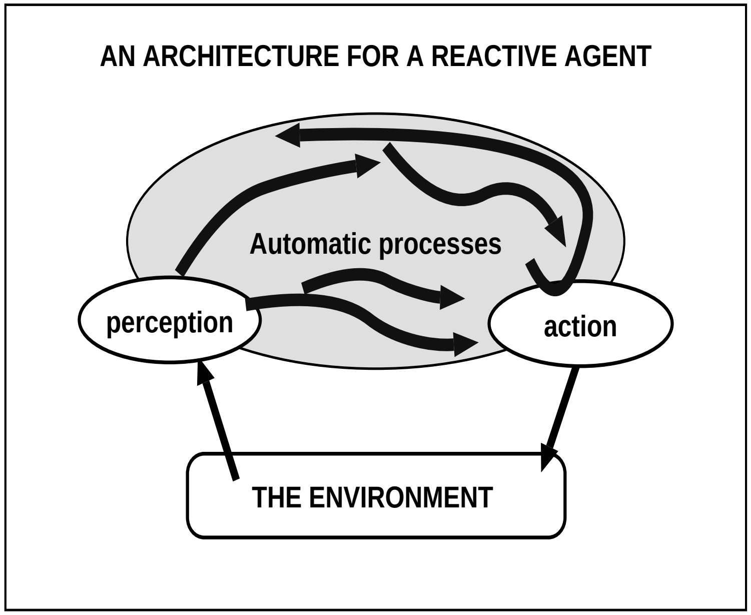
- **DELIBERATIVE LAYER PROVIDES FLEXIBILITY AND CREATIVITY**
  At the cost of seriality and slowness.

- **META-MANAGEMENT (SELF MONITORING) PROVIDES RESOURCE MANAGEMENT**

  Using self monitoring and self control.
  But control and monitoring are never total.
  Monitoring may be partly inaccurate.

WARNING: IT’S NOT REALLY THAT SIMPLE!

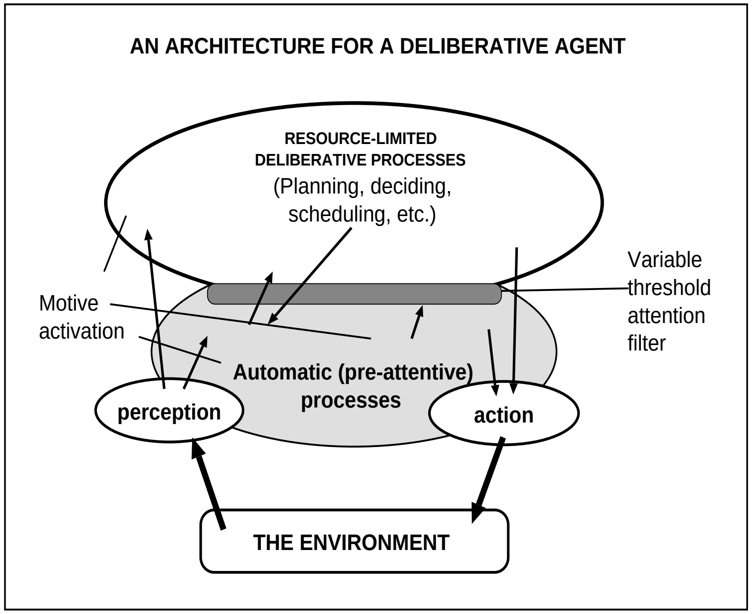
REACTIVE AGENTS



IN A REACTIVE AGENT:

- **Mechanisms and space are dedicated to specific tasks**
- **There is no construction of new plans**
- **There is no explicit evaluation of alternative plans**
- **Parallelism gives speed**
- **Some learning: e.g. tunable control loops**
- **The agent can survive even if it has only genetically determined behaviours**
- **Difficulties arise if the environment requires new plan structures.**
- **May not matter if individuals are cheap and expendable (insects?).**

TOWARDS DELIBERATIVE AGENTS



A DELIBERATIVE AGENT

- **Mechanisms and space are dynamically allocated**
- **New plans may be constructed**
- **Options are explicitly evaluated before selection**
- **Learnt skills can be transferred to the reactive layer**
- **Parallelism is much reduced (for various reasons):**
  - **Learning**
  - **Access to associative memory**
  - **Integrated control** • **A fast changing environment can cau too many interrupts, frequent re-directions.**
- **Filtering via dynamically varying thresholds helps b does not solve all problems.**

THE NEED FOR SELF-MONITORING (META-MANAGEMENT)

DELIBERATIVE MECHANISMS CAN BE TOO RIGID.

INTERNAL MONITORING MECHANISMS:

● Record events, problems, decisions taken by the deliberative mechanism,

● Allow diagnosis of injuries and illness.

● Evaluate, relative to high level long term generic objectives, or standards.

GENERIC OBJECTIVES COULD INCLUDE:

● Reducing frequency of failure in tasks

● Not allowing one goal to interfere with other goals

● Not wasting time on problems that turn out not to be solvable

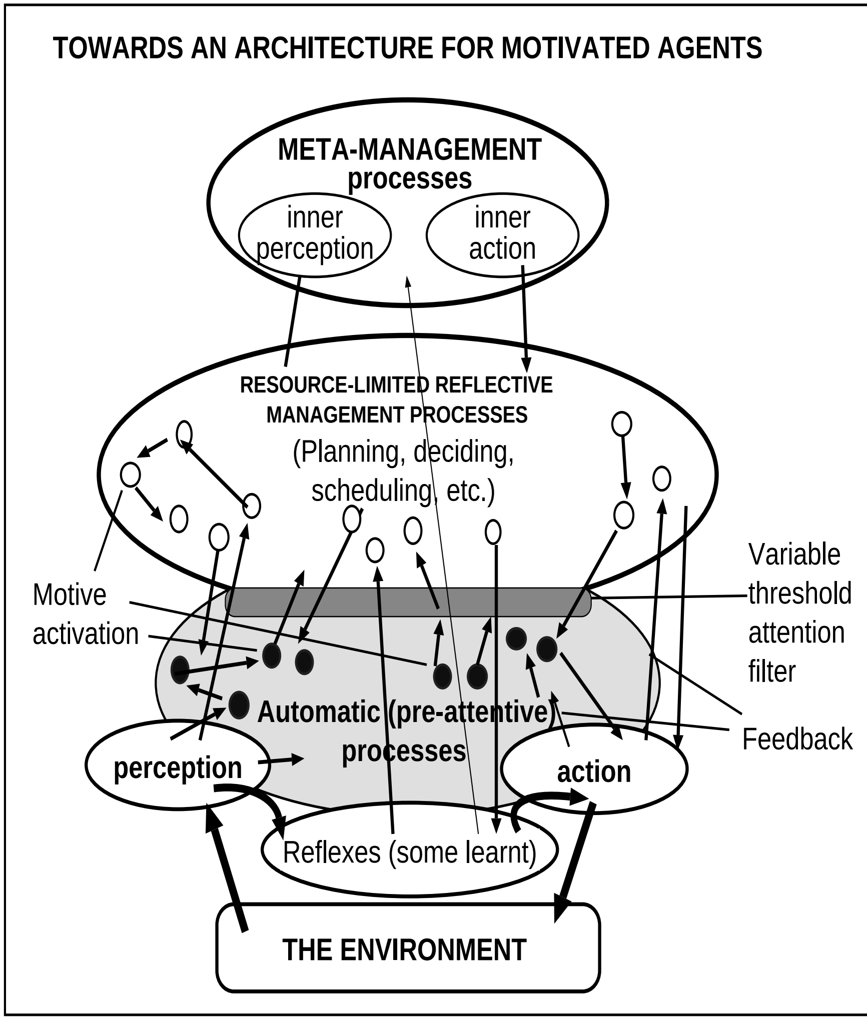
● Not using a slow and resource-consuming strategy if a faster or more elegant method is available

● Detecting possibilities for structure sharing among actions.

Different kinds of meta-management are likely to be found in different animals. Probably some have none.

META-META-MANAGEMENT MAY NOT BE NEEDED IF META-MANAGEMENT IS RECURSIVE??

TOWARDS AUTONOMOUS AGENTS


TOWARDS AN ARCHITECTURE FOR MOTIVATED AGENTS
META-MANAGEMENT processes
inner perception
inner action
RESOURCE-LIMITED REFLECTIVE MANAGEMENT PROCESSES
(Planning, deciding, scheduling, etc.)
Motive activation
Variable threshold attention filter
Automatic (pre-attentive) processes
perception
action
Feedback
Reflexes (some learnt)
THE ENVIRONMENT

Towards an architecture for an autonomous agent

● Meta-management controls management processes

● Global monitoring can support 'self evaluation'

ARCHITECTURE AND EMOTION

Different architectural layers support different sorts of emotions:

The reactive layer supports :

- **being startled**
- **being disgusted by horrible sights and smells**
- **being terrified by large fast-approaching objects?**
- **sexual arousal? Aesthetic arousal ?**

The deliberative layer supports:

- **being frustrated by failure**
- **being relieved at avoiding danger**
- **being anxious about things going wrong**
- **being pleasantly surprised by success**

The self monitoring meta-management layer, supports:

- **having and losing control of thoughts and attention:**

Feeling ashamed of oneself
Feeling humiliated
Aspects of grief, anger, excited anticipation, pride,
and many more HUMAN *emotions.*

NOT EVERYTHING SUPPORTED BY A MECHANISM IS PART OF ITS FUNCTION: MULTI-PROCESSING OPERATING SYSTEMS SUPPORT THRASHING!

SOME FUNCTIONAL MECHANISMS HAVE DYSFUNCTIONAL CONSEQUENCES.

ARCHITECTURALLY GROUNDED CONCEPTS

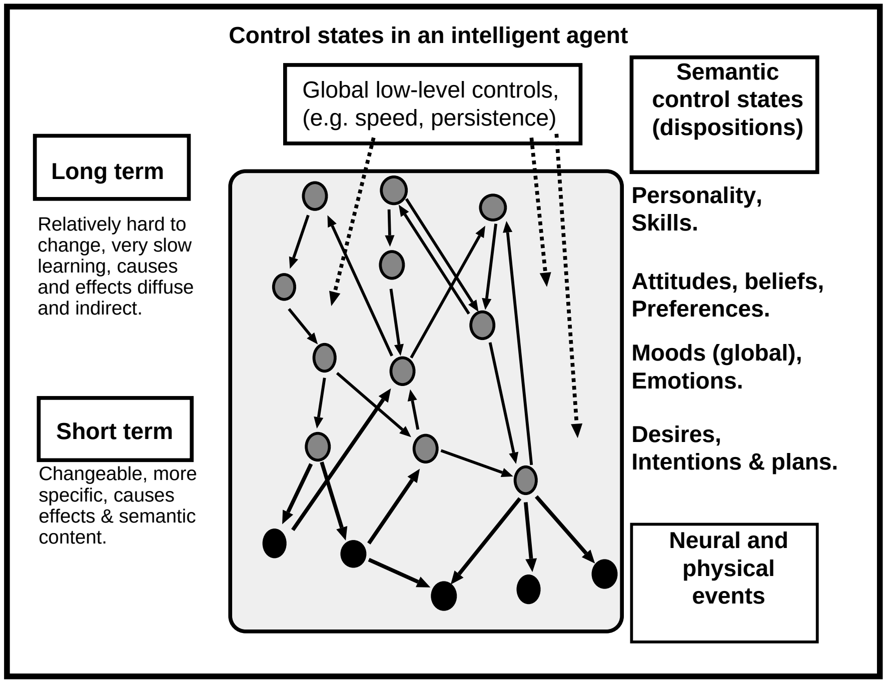
We can replace endless debates at cross-purposes with research that makes real progress:

- **Each design specifies a class of architectures.**
- **We can try to find out which mechanisms can suppor those architectures.**
- **An architecture supports a variety of states and processes.**
- **Analysis of possible states and processes generates families of theory-based concepts.**

  Compare: the periodic table of the elements.
- **These new concepts can elaborate and extend comme sense concepts, as happened when physics gave us a new architecture for matter.**
- **The new concepts enable us to ask new questions: E.**
  - **NOT which animals/machines are conscious/have emotions?**
  - **BUT which kinds of consciousness/emotions do different animals/machines have?**
- **It's not enough just to understand *ONE* architecture. Deep understanding requires us to explore *REGIONS* and *TRAJECTORIES* in design space and niche space**

TYPES OF CONTROL STATES

Besides emotions there are personality, attitudes, moods, desires, wishes, intentions, etc.



Control states in an intelligent agent

Global low-level controls, (e.g. speed, persistence)

Semantic control states (dispositions)

Long term

Relatively hard to change, very slow learning, causes and effects diffuse and indirect.

Short term

Changeable, more specific, causes effects & semantic content.

Personality, Skills.

Attitudes, beliefs, Preferences.

Moods (global), Emotions.

Desires, Intentions & plans.

Neural and physical events

Control states of varying scope and duration

The “higher” states are:

- **Harder to change**
- **More long lasting**
- **Subject to more influences**
- **More general in their effects**
- **More indirect in their effects**
- **More likely to be genetically determined(??)**

DESIGNS AND NICHES

DIFFERENT COMBINATIONS OF CAPABILITIES CONSTITUTE DIFFERENT DESIGNS

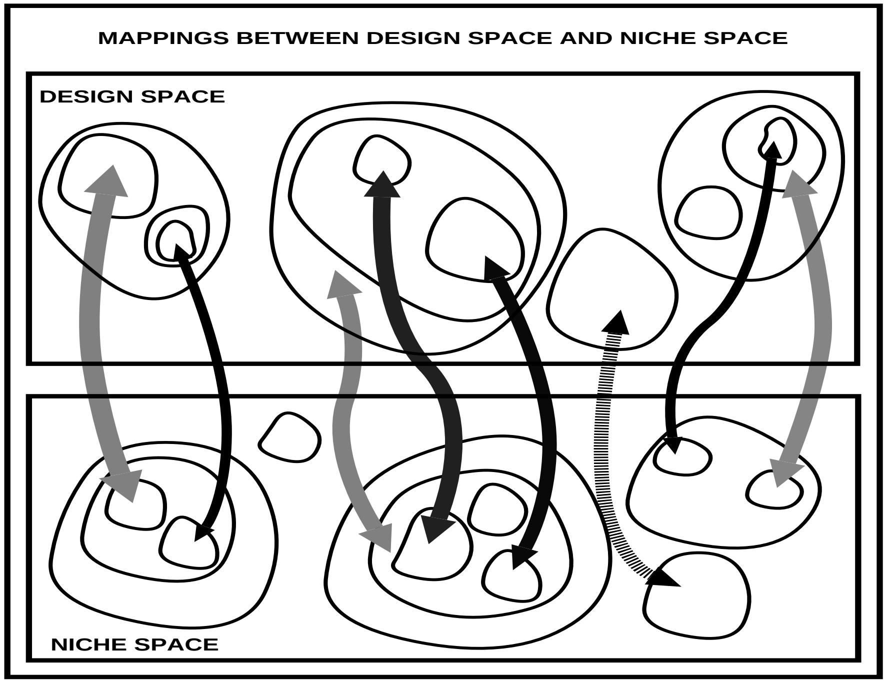
DIFFERENT SORTS OF REQUIREMENTS CONSTITUTE DIFFERENT NICHES

- **A design is an integrated collection of capabilities tha can be linked together in an *IMPLEMENTATION*.**
- **A design is an *ABSTRACTION* which can have *INSTANCES*.**
- **Evolution can be seen as producing designs: though there is no designer or engineer, only natural selectio**
- **Biologists use the notion of a “niche” to talk about th set of requirements and constraints: i.e. what a desi satisfies, more or less well. (A niche is an abstraction not a geographical region.)**
- **Engineers assess designs in terms of satisfying (or coming close to satisfying) a combination of requirements and constraints.**

Note: Artificial Intelligence is the general study of desig space, niche space and their interrelations.

AI uses computers, but could, in principle, use other mechanisms: hybrid designs are important.

DESIGN SPACE and NICHE SPACE



NOTES

- **A niche is a set of requirements**
- **A design is a set of specifications**
- **Mappings are not unique: there are always trade-offs**
- **Designs need no designer, requirements no requirer.**

DYNAMICS:

Which trajectories are possible:

- **Within an agent (development, learning)?**
- **Across generations (evolution, ALIFE)?**

The "Turing test" defines a tiny niche region ....
of relatively little interest, except as a technical challenge.

PERCEPTION CAN USE AN INTRICATE ARCHITECTURE

Perception is not just a matter of registering or recognising.

It also involves:

- **Classification at different levels of abstraction: a square, a rectangle, a quadrilateral, a polygon, a figure.**
- **Interpretation: mapping from one domain to anothe E.g. the 2-D optic array is interpreted in terms of a 3-D environment. Acoustic patterns are interpreted meaningful speech.**
- **Grasping structure: seeing not only eyes, nose, mout arms, legs, hands, feet, but how they are related together. The hands are on the ends of the arms, but finger may be touching the nose.**
- **Grasping patterns of change and motion: the wasp is flying towards the window, the car is moving forwar while its wheels are turning, the scissors are opening and shutting.**

Perception Continued

- Grasping possibilities and constraints inherent in structure (what J J Gibson called “affordances”: a chair can support you, a table can obstruct motion, a door allows transfer to another room a window catch allows the window to be held open, a handle allows an object to be grasped.

Thus a human-like (or ape-like?) perceptual system needs to be able to create and manipulate

- **a number of different sorts of rapidly changing representations**
  - **of different sorts of information,**
  - **using:**
    - **incoming data,**
    - **prior knowledge,**
    - **current motivation**

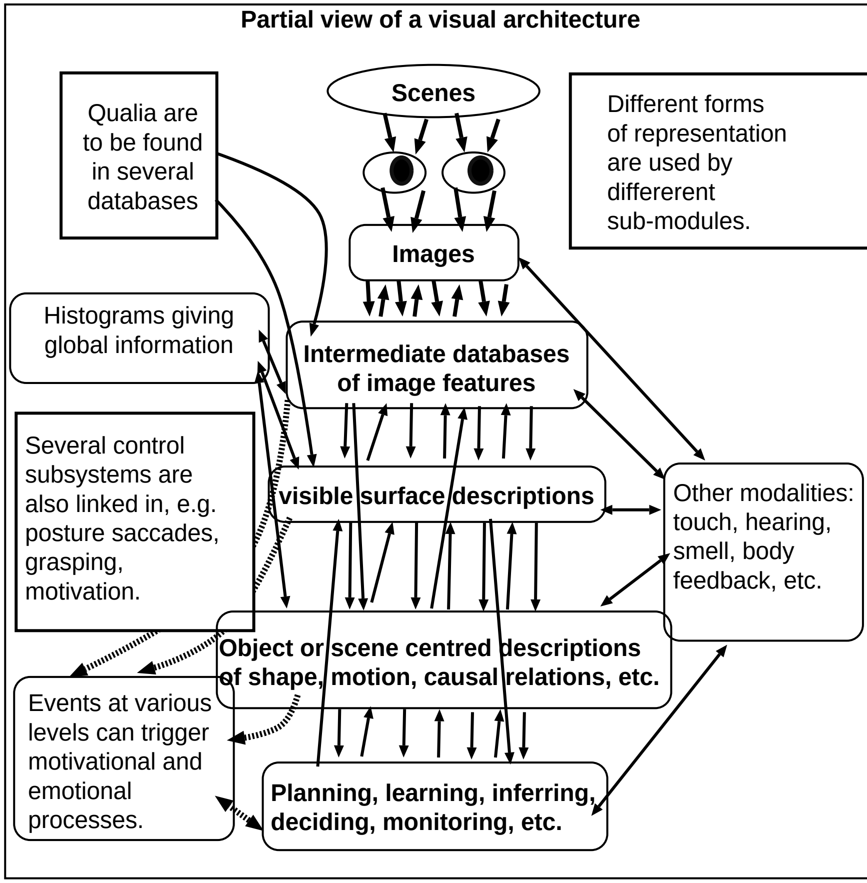
Human perceptual architectures also allow the agent to attend to some aspects of these *INTERNAL* information stores.

E.g. learning to draw, sighting a gun.

This is one of the sources of concerns about “qualia”.

BUT OUR ACCESS IS BOTH INCOMPLETE AND UNRELIABLE!

DESIGNING A VISUAL SYSTEM



Partial view of a visual architecture

Qualia are to be found in several databases

Scenes

Different forms of representation are used by differerent sub-modules.

Images

Histograms giving global information

Intermediate databases of image features

Several control subsystems are also linked in, e.g. posture saccades, grasping, motivation.

visible surface descriptions

Other modalities: touch, hearing, smell, body feedback, etc.

Object or scene centred descriptions of shape, motion, causal relations, etc.

Events at various levels can trigger motivational and emotional processes.

Planning, learning, inferring, deciding, monitoring, etc.

Towards an architecture for a visual system

- **There are many intermediate information structures.**
- **Higher level processes may be able to access them.**
- **Reflecting on them gives rise to questions about experiences, qualia, etc.**
- **This could also happen in robots.**

That’s one source of concepts about consciousness!

CONCLUSION

- Design-based studies not only help us understand normal functioning but also show how things might go wrong, helping therapy, counselling and education.
- Design-based theories can generate new empirical questions to be settled by neurophysiological, psychological and biological research.
- Many designs involve creation of “virtual” machines, e.g. word-processors, compilers, operating systems. These are information processing machines that operate on abstract entities. But they can have real causal powers, and form part of a control system, e.g. for a factory or aeroplane.
- That could be the source of many puzzles about minds.
- Progress may require new kinds of mathematics, for very complex systems whose dynamics is separate from physics.
- We may find that high level aspects of a human-like architecture can be implemented on varying sorts of low level mechanisms (e.g. computer-based mechanisms and others).
- We MAY need entirely new types of mechanisms to explain details, but assuming that now is prematire.
- Beware of rejecting theories because you don’t like the idea of their being true.