Shirt Mathematics
Illustrating topological and semi-metrical reasoning in everyday life.

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This file is available in two formats:
http://www.cs.bham.ac.uk/research/projects/cogaff/misc/shirt.html
http://www.cs.bham.ac.uk/research/projects/cogaff/misc/shirt.pdf

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NOTE
My criticisms of the current state of AI don't come from hostility to AI. I believe AI can lead to deeper advances in understanding of what minds are, how they work, and how different kinds vary, than any other approach to the study of minds. But the current state of AI, which includes many impressive and useful applications, misleads many people into thinking we are close to replicating human, or more generally animal, intelligence. I believe that optimism is based on a failure to understand deep features of many aspects of intelligence in humans (and many other animals).

This paper is one among many on this web site providing examples of how gaps in mathematical competences of AI systems, or, more generally, gaps in their spatial perception and reasoning abilities, are severe obstacles to explanatory power and practical usefulness of current AI systems. Future AI systems may bridge those gaps, but first we'll need a much deeper understanding of what is missing. This is one among a disorganised collection of documents illustrating those gaps, many of them concerned with abilities to reason about what is impossible, or necessarily the case.

Many forms of spatial intelligence lacking in current AI systems can be observed in pre-verbal human toddlers and other intelligent animals (including apes, squirrels, weaver birds, elephants, and many more).

BACKGROUND
There are growing numbers of impressive successes of artificial intelligence and robotics, many of them summarised at https://aitopics.org/, e.g. https://aitopics.org/news.

Yet there remain huge chasms between artificial systems and forms of natural intelligence in humans and other animals -- including weaver-birds, elephants, squirrels, dolphins, orangutans, carnivorous mammals, and their prey.
(Sample weaver bird cognition here: http://www.youtube.com/watch?v=6svAIgEnFvw.)

Don't expect any robot (even with soft hands and compliant joints) to be able to dress a two year old child (safely) in the near future, a task that requires understanding of both topology and deformable materials, among other things. (As illustrated in this video.) Enabling machines to understand why things work and don't work lags far behind abilities to perform tasks, often achieved by programming or training.

Much of everyday life involves complex mathematical structures, and (usually unconscious) mathematical reasoning.

The competences involved are related to abilities to perceive what is and is not possible in some physical configuration, which may be immediately present in your field of view, or remembered from past experience, or anticipated, or represented in a sketch, or merely imagined.

These possibilities have nothing to do with probabilities, except that thinking about what is probable presupposes abilities to consider possibilities and assign relative weightings to them. But considering the possibilities does not require any assignment of probability or likelihood.

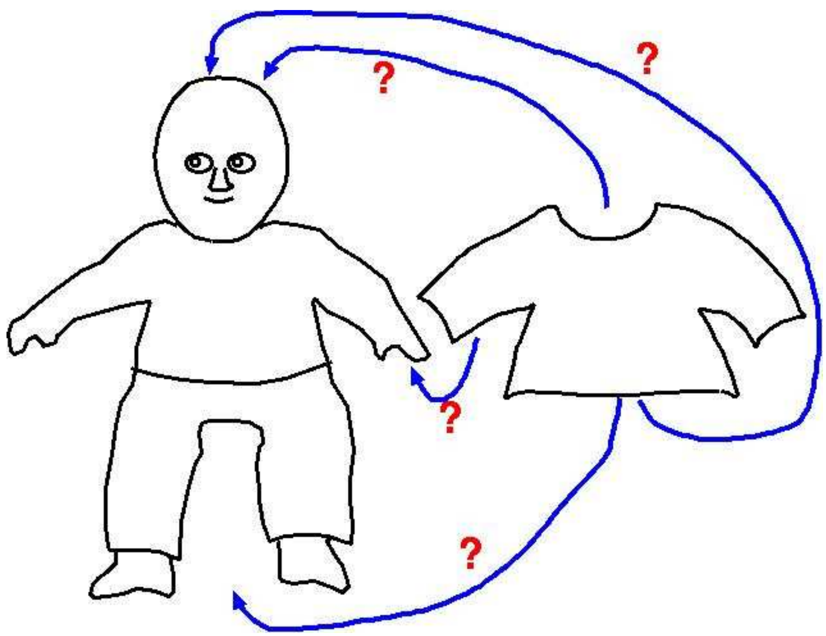
What might mistakenly be construed as a special case of probabilistic inference is reasoning about what is impossible (cannot exist or occur) and reasoning about what is necessary (must be the case) in some situation. But impossibility and necessity have nothing to do with gradations of probability or likelihood, even though some thinkers confuse them with probabilities, i.e. 0% and 100% probability.

The poorly drawn figure below is merely intended as an aid to the understanding of a question about the consequences of attempting to put on a tightly fitting shirt or sweater by going through different processes.

Is it possible to put on the garment by inserting a hand into a cuff and pulling the sleeve up over the arm? Under what conditions could it succeed, or not succeed?

This requires a combination of topological and metrical reasoning: -- a type of mathematical child-minding theorem, not taught in schools but understood by some child-minders, even if they have never articulated the theorem and cannot articulate the reasons why it is true. Can you?

Merely pointing at past evidence showing that attempts to dress a child that way always fails does not explain why it is impossible. You can probably do better than that!



What sequence of movements could get the shirt onto the child if the shirt is made of material that is flexible but does not stretch much? Why would it be a mistake to start by pulling the cuff over the hand, or pushing the head through the neck-hole? What difference would it make if the material could be stretched arbitrarily without being permanently changed?

A related problem:

Suppose a sweater is lying flat on a table in front of you. If you want to turn it inside out, using only your hands or other body parts without any external aids, what would be a good sequence of actions? E.g. which part or parts should you grasp first? Assume that it is not a garment that would be a tight fit for you.

How many significantly different strategies are there?

How does the problem change if the sweater is much too small for you?

Can you turn a sock inside out by grasping it in two places, one with each hand, then moving your hands without letting go?

Is it possible to turn the sweater inside out by grasping it in two places, with left and right hands, then moving your hands without letting go?

If your answer is 'No' in either case, can you explain why it's impossible?

Could some of this relate to the types of reasoning carnivores require after a successful kill, before any meat is accessible?

This is one of several discussion pieces regarding vision and mathematical reasoning, pointing to serious inadequacies of current theories of vision in psychology and neuroscience, and inadequate visual systems in robots and AI systems. This is a part of the meta-morphogenesis project referenced below.

What sorts of mechanisms, or software extensions would have to be added to current robots, or theorem provers, to enable them to make these discoveries and reason about them?

Other examples include:

- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/grasping-grasping.html
  Can a Robot Grasp Grasping?
  How can a robot understand what's going on when it grasps and manipulates something flexible?
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/rubber-bands.html
  Making a chain or rubber bands, but not a closed ring?
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/torus.html
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/deform-triangle.html
  Stretching a planar triangle, with one side fixed.
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/triangle-theorem.html
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/triangle-sum.html
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/trisect.html
  Why it's a myth that it's impossible to use straight-edge and compasses to trisect an angle, and what that tells us about the nature of mathematical discovery.
- The relevance to "toddler theorems" is discussed here, among other things:
  http://www.cs.bham.ac.uk/research/projects/cogaff/misc/toddler-theorems.html
- Perception and reasoning about impossibilities (and related spaces of possibilities), especially use of vision in perceiving impossibilities:
  http://www.cs.bham.ac.uk/research/projects/cogaff/misc/impossible.html
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/vision-functions.html
  The functions of vision. A related paper on what we don't know about the functions of vision is in preparation.
- http://www.cs.bham.ac.uk/research/projects/cogaff/misc/knots/

Meta-Morphogenesis project:
http://www.cs.bham.ac.uk/research/projects/cogaff/misc/meta-morphogenesis.html
Meta-Morphogenesis project overview.
This project aims at understanding the changes in types of information, information processing, and information-using mechanisms, produced by biological evolution, since the very earliest life forms, or proto-life forms existed on this planet.

How can a physical universe produce mathematicians?
Another name for the project is "The self-informing universe".

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/construction-kits.html
The important roles of evolved construction kits in biology

http://www.cs.bham.ac.uk/research/projects/cogaff/misc/midlog-talk.html
Abstract for talk on 24th Feb 2015
Metaphysical, Biological, Evolutionary Foundations for Mathematics
(As opposed to logical or set-theoretic foundations.)

A heroic attempt to unify spatial reasoning with logic:

Pedro Cabalar and Paulo E. Santos, Formalising the Fisherman's Folly puzzle,
Artificial Intelligence, 175, 1, pp. 346--377, 2011,
Special issue: John McCarthy's Legacy,
http://www.sciencedirect.com/science/article/pii/S0004370210000408

But the authors, not their theorem prover, translated the topological puzzle into a logical form!

A tiny taste of future robot shirt intelligence???
Added 19 Jul 2017
http://spectrum.ieee.org/automaton/robotics/medical-robots/robot-helps-you-put-your-shirt-on

That report was dated 2011. A quick search revealed no follow up.

Note that there's a difference between being able to perform certain actions and being able to reason about possible and impossible alternatives to such actions.

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