CHALLENGES TO MACHINE LEARNING

Relations between reality and appearance

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• Apology: My knowledge of of machine learning i
recent than Tom Mitchell's book. Its chapters descri
for inductive logic programming, programs aimed at
appearances.

• We live in a complicated world that existed for billio
before there were humans, and our sense organs give
opportunities to observe it directly. Four centuries of s
us that we and the objects we perceive are built in a co
way from atoms and, below atoms, quarks.

• Science, since 1700, is far better established than a
philosophy. Bad philosophy has stunted AI, just as b
stunted psychology for many decades.

• Besides the fundamental realities behind appearance
science, there are hidden every day realities—the th
sional reality behind two dimensional images, hidde
objects in boxes, people's names, what people really t

• Appearance is quite different from reality. Most mac
ing research has concerned the classification of appea
has not involved inferring relations between reality a
ance. Robots and other AI systems will have to infer
tions.

• Human common sense also reasons in terms of th
that give rise to the appearances our senses provide
young babies have some initial knowledge of the pern
physical objects.

• Perhaps if your philosophy rejects the notion of r
fundamental concept, you'll accept a notion of *rela*
appropriate for the design and debugging of robots.
robot needs to be designed to determine this relative r
the appearance given by its inputs.

• We'll discuss:

• Dalton's atomic theory as a discovery of the rea
appearance.

• The use of touch in finding the shape of an object.
an experiment in drawing an object which one is only
touch - not see.

• A simple problem involving changeable two dimer
pearances and a three dimensional reality.

• Some formulas relating appearance and reality in
cases.

• What can one know about a three dimensional objec
to represent this knowledge.

• How scientific study and the use of instruments ext
can be learned from the senses. Thus a doctor's trair
ing dissection of cadavers enables him to determine
about the liver by palpation.

ELEMENTS, ATOMS, AND MOLECULES

• Some scientific discoveries like Galileo's $s = \frac{1}{2}gt^2$ i
covering the relations between known entities. Patrick
Bacon program did that.

• John Dalton's postulation of atoms and molecules r
fixed numbers of atoms of two or more kinds was r
creative and will be harder to make computers do.

• The ancient ideas of Democritus and Lucretius th
was made up from atoms had no important or eve
consequences. Dalton's did.

• Giving each kind of atom its own atomic mass exp
complicated ratios of masses in a compound as re

small numbers of atoms in a molecule. Thus a sodiu
(NaCl) molecule would have one atom of each of its
Water came out as H_2O.

• The simplest forms of the atomic theory were i
[Early 19th century chemists didn't soon realize th
drogen and oxygen molecules are H_2 and O_2 and not
O.] Computers also need to be able to propose theor
turously and fix their inaccuracies later later.

• Only the relative masses of atoms could be propos
ton's time. The first actual way of estimating these r
made by Maxwell and Boltzmann about 60 years afte
proposal. They realized that the coefficients of visc

conductivity, and diffusion of gases as explained by t
theory of gases depended on the actual sizes of mole

• The last important scientific holdout against the
atoms, the chemist Wilhelm Ostwald, was convince
stein's 1905 explanation of Brownian motion. The p
Ernst Mach was unconvinced.

• The first actual pictures of atoms in the 1990s w
surprise. An actual picture of a proton showing the qu
be even more surprising and seems quite unlikely.

• Philosophical point: Atoms cannot be regarded as j
planation of the observations that led Dalton to prop

Maxwell and Boltzmann used the notion to explain e
ferent observations, and modern explanations of ato
at all based on the law of combining proportions. In sh
were discovered, not invented.

ELEMENTS, ATOMS, MOLECULES—FORMU

• Most likely, it is still too hard to make program invent elements, atoms, and molecules. Let's theref write logical sentences that will introduce these con knowledge base that has no ideas of them.

• We assume that the notions of a body being compos and of mass have already been formalized, but the ide has not. The ideas of bodies being disjoint is also a be formalized.

• The following formulas approximate a fragment of h chemistry and should be somewhat *elaboration tol* should admit additional information about the structur

The situation argument s is included only to point ou
terial bodies change in chemical reactions.

$$Body(b,s) \rightarrow (\exists u \subset Molecules(b,s))(\forall y \in u)(Molecule($$

$$y1 \in Molecules(b) \wedge y2 \in Molecules(b) \wedge y1 \neq y2 \rightarrow Di$$

$$Part(x,b,s) \rightarrow (\exists y \in Molecules(b,s)) \neg Disjoint(y,x),$$

$$Body(b,s) \rightarrow Mass(b,s) = \sum_{x \in Molecules(b,s)} Mass(x,s).$$

$$Water(b) \land x \in Molecules(b)$$
$$\rightarrow (\exists h1\ h2\ o)(Atoms(x) = \{h1, h2, o\} \land h1 \neq h2$$
$$\land HydrogenAtom(h1) \land HydrogenAtom(h2) \land OxygenA$$

$$Salt(b) \land x \in Molecules(b)$$
$$\rightarrow (\exists na\ cl)(Atoms(x) = \{na, cl\} \land SodiumAtom(na) \land C$$

$$Molecule(x) \rightarrow Mass(x) = \sum_{y \in Atoms(x)} Mass(y$$

$$HydrogenAtom(y) \rightarrow Mass(y) = 1.0,$$
$$OxygenAtom(y) \rightarrow Mass(y) = 16.0,$$
$$SodiumAtom(y) \rightarrow Mass(y) = 23.0,$$
$$ChlorineAtom(y) \rightarrow Mass(y) = 35.5.$$

APPEARANCE AND REALITY

- Getting reality from appearance is an inverse prob
mulas and programs giving appearance as a function
and the circumstances of observation are easier to sta
likely to be ambiguous.

- Reality is more stable than appearance. Formulas
effects of events (including actions) are almost always
terms of reality.

- The formulas that follow will need a situation or time
once we consider changing appearances.

FORMULAS—STARTING SIMPLE

• We begin with a little bit about touch rather than v
Imagine putting one's hand into one's pocket in orc
out one of the objects.

$$Touching(Side(1), x) \wedge PocketKnife1(x, Jmc) \rightarrow Feels$$

$$Texture(Side(PocketKnife1)) = Texture17$$

For now we needn't say anything about $Texture17$ exc
is distinguishable from other textures. Textures for t
similarities to and differences from textures for vision
very scale dependent.

THREE DIMENSIONAL OBJECTS

• How can we best express what a human can know a
should know about a three dimensional object? We
a standard kind of object with particular types of o
individual objects defined by successive approximation

• I propose starting with a rectangular parallelopiped,
abbreviate *rppd*. An object is an rppd modified by din
formation, shape modifications, attached objects, in
about its internal structure, location information, fol
mation, information about surfaces, physical inform
mass. Perhaps one should start even more simply w
size, a ball too large to be included in the object and
to include it.

• My small Swiss army knife is an rppd, 5cm by 2cm
rounded in the width dimension at each end. Its larg
has a smooth plastic surface texture, and its other su
metallic with stripes parallel to the long axis, i.e. th
the blades. This description should suffice to find t
my pocket and get it out, even though it says nothing
blades.

• Consider a baby and a doll of the same size. Ea
described as an rppd with attached rppds in appropr
for the arms, legs, and head. The most obvious and
differences come in a texture, motion, and family rela

A PUZZLE ABOUT INFERRING REALITY FR APPEARANCE

- Here's the appearance. The puzzle is: What is behind the appearance? Clicking on the $<$ and $>$ si one experiments.

- The reality is three dimensional, while the appeara
dimensional.

- Those who implement display know that computing a
is difficult. Those who do computer vision know tha
the relation is even more difficult.

HOW HUMANS SOLVE THE PUZZLE

• The appearance in the puzzle is a genuine appeara
reality behind the appearance is rather abstract. Thus
have no thickness or mass. This doesn't seem to both
we're used to abstractions.

• We use concepts like like *solid body*, *behind*, *part*
etc.

• Some of these concepts may be learned by babie
perience, as Locke proposed. However, there is goo
that many of them, e.g. *solid body* and *behind* were
evolution and are built into human and most animal i

• The quickest and most articulate human solution w
ald Michie. Eventually machines will do better.

FORMULAS FOR APPEARANCE AND ACTI

We introduce positions. There is a string of 13 positio are also represented by strings of squares of length a to the body. $Content(sq)$ is either a color or a letter on the version of the puzzle.

$$
\begin{array}{l}
Body(b) \wedge sq \in b \wedge Location(sq, s) = pos \\
\wedge (\forall b' \neq b)((\exists sq' \in b')(Location(sq', s) = pos \\
\rightarrow Higher(b, b'))) \\
\rightarrow Appearance(pos, s) = Content(sq).
\end{array}
$$

$$Body(b) \wedge sq \in b \wedge Location(sq, s) = pos$$
$$\wedge(\forall b' \neq b)((\exists sq' \in b')(Location(sq', s) = pos$$
$$\rightarrow Higher(b, b')))$$
$$\rightarrow (\forall sq' \in b)(Location(sq', Result(ClickCW(pos),$$
$$= CWloc(Location(sq', s)))$$
$$\wedge(\forall b' \notin b)(Location(sq', Result(ClickCW(pos), s)$$
$$= Location(sq', s)).$$

Here's the formula for the effect of counter-clockwise

$$Body(b) \wedge sq \in b \wedge Location(sq, s) = pos$$
$$\wedge(\forall b' \neq b)((\exists sq' \in b')(Location(sq', s) = pos$$
$$\rightarrow Higher(b, b')))$$
$$\rightarrow (\forall sq' \in b)(Location(sq', Result(ClickCCW(pos),$$
$$= CCWloc(Location(sq', s)))$$
$$\wedge(\forall b' \notin b)(Location(sq', Result(ClickCCW(pos), s))$$
$$= Location(sq', s)).$$

The last parts of the last two formulas tell what doesn

HOW SHOULD A COMPUTER DISCOVER THE R

• A point of view common (and maybe dominant) in th learning community is that the computer should solve lem from scratch, e.g. inventing *body* and *behind* as is not dominant in the computer vision community.

• Our opinion, and that of the knowledge representa munity, is that it is better to provide computer prog common sense concepts, suitably formalized. There is cess, but the formalisms tend to be limited in the c which they apply. I think, but won't argue here, that t *context* itself is a necessary step.

• Here are two sample formulas relevant to the presen
but perhaps not general enough to be put in a *know*
of common sense.

$$Color\text{-}Appearance(scene, x, s) = Color(Highest(scene,$$

$$Behind(b2, b1, s) \wedge Opaque(b1) \rightarrow \neg Visible(b2, s$$

• Solving the puzzle involves inferring formulas like

$$\begin{aligned}
&Body(b) \wedge Present(b, Scene) \equiv b \in \{B1, B2, B3, B4\},\\
&Color(B1) = Blue \wedge Color(B2) = Orange \wedge Color(B3)\\
&\qquad\quad \wedge Color(B4) = Red,\\
&Length(B1) = 6 \wedge Length(B2) = 8, \text{etc.},\\
&Higher(B1, B2) \wedge Higher(B2, B3) \wedge Higher(B3, B4),\\
&Higher(B4, Background) \wedge Length(Background) = 13.
\end{aligned}$$

• We haven't put in effects of actions and some relati
the predicates.

• The lengths and colors of the bodies are assumed r
dent of the situation. Human language tolerates *e*
such as actions that affect color better than do pres
malisms.

• The ideas of the last two slides about what knowle
be given to the program have benefitted from discus
Stephen Muggleton and Ramon Otero.

ENTITIES EXTENDED IN TIME

- The most obvious example is a tune. Maybe jokes, practical jokes, are another example.