My papers are on the above web page. This paper is http://www-formal.stanford.edu/approximate.html.

Our discussion will be adequate if it has as much clearness as the subject matter admits of, for precision is not to be sought for alike in all discussions, any more than in the products of the crafts.—Aristotle
biological—Humans are intelligent; imitate humans
observe and imitate at either the psychological or neuro-
physiological level

engineering—The world presents problems to intelligence.
Study information and action available in the world.
1. Write programs that use non-logical representations.
2. represent facts about the world in logic and decide
what to do by logical inference

We aim at human level AI, and the key phenomenon
is the common sense informatic situation. Human level
is a difficult scientific problem, and many concepts
needed. The concept of approximate object is one.
THE COMMON SENSE INFORMATIC SITUATION

- Involves approximate entities, e.g. that don’t have if-and-only-if definitions.

- There is no limitation on what information may be relevant. Theories must be elaboration tolerant. E.g. one can easily add a condition that a particular boat needs a bailing can.

- Reasoning must often be non-monotonic. A tool usable for its normal purpose.
Common sense theories contrast with formal scientific theories. However, science is embedded in common sense.

\[
Falling(x, s) \land Velocity(x, s) = 0 \land d < Height(x, s) \land d = \frac{1}{2}gt^2; \quad \text{Galileo’s formula}
\]

\[
(\exists s')(F(s, s') \land Height(x, s') = Height(x, s) - d).
\]

Present AI theories are embedded in their designers’ common sense or in their users’ common sense—not in an internal system’s common sense.
• Use *Drosophila* that illustrate aspects of representation and reasoning problems.

• Concepts, context, circumscription, counterfactuals, consciousness, creativity, *approximation*

• narrative, projection, planning

• mental situation calculus

• domain dependent control of reasoning
EXAMPLES OF APPROXIMATE OBJECTS

• the rock constituting Mount Everest; climbed 1953.

• taxable income—approximately defined according to The Congress shall have power to lay and collect taxes on incomes, from whatever source derived, without appor-
tionment among the several States, and without regard to any census or enumeration.—16th Amendment

• On(Block1, Block2),

• the wants of the United States,

• the present weight of John McCarthy,

• Theseus’s ship with all new planks and a diesel engine,

• the corner of a room,

• the boolean approximation of digital circuits.
Approximate objects

- don’t have if-and-only-if definitions,
- usually don’t have definite extensions,
- are prevalent in common sense,
- but not used in formal scientific theories,
- and not confessed in present AI theories,
- are needed for AI.
- Sentences about them can still have definite truth values.
THE US WISHED . . .

• The **US wished** Iraq would leave Kuwait. **Not** the same as George Bush wished.
• Very approximate useful entity.
• Bush statements $\rightarrow$ “US wished . . .”

• “US wished . . .” $\land$ Iraq in Kuwait $\rightarrow$ US action.
• The actual approximate objects are US wishes. A person's wishes are simpler.
• **Ordinary fuzziness:** weakly or strongly wished.
US WANTS IRAQ OUT OF KUWAIT

The following are all defaults.

\[
\text{Says(entity, Wants(entity, x))} \rightarrow \text{Wants(entity, x)},
\]

\[
\text{Says(President(USA), x)} \rightarrow \text{Says(USA, x)},
\]

\[
\text{Says(President(USA), Wants(USA, Leaves(Iraq, Kuwait)))}
\]

\[
\text{Wants(x, y)} \rightarrow (\exists z)(\text{Does(x, z)} \land \text{Achieves(z, y)}).
\]
From these we infer

\((\exists z)(\text{Does}(\text{USA}, z) \land \text{Achieves}(z, \text{Leaves} (\text{Iraq}, \text{Kuwait})))\)

• This sketch leaves out a theory of action, distinctions between objects and concepts, some necessary qualifications, and depends on nonmonotonic reasoning. A complete theory includes these and a theory of *Wants*, *Says*, and *Does*.

• It exemplifies the kind of inferences people make with approximate concepts.

• Computers will have to do something similar, because a precise theory of “US wants” won’t be available to computers either.
APPEARANCE APPROXIMATES REALITY

• Reality is the situation $s$. Appearance is $app(s)$.

• The effect of an action $a$ on reality is determined by $a$ and $s$.

• The effect of an action $a$ on the appearance $app(s)$ is not determined solely by $a$ and $app(s)$.

• effect: $s' = result(a, s)$, noncommutativity

  $\neg(\exists result1)(app(result(a, s)) = result1(a, app(s)))$

• The effect of action $a$ on a part of appearance, namely $app2(s) = subapp(HORSES, app(s))$ is determined by $a$ and $app2(s)$.
• limited commutativity:

\[(\exists result2)(app2(result(a, s)) = result2(a, app2(s)))\]
• The real world with blocks and the finite, abstract blocks world.
• Programs use the latter to decide what to do about the former.
• The abstract blocks world is an approximation to a context in the real world.
• The abstract representation needs to be elaboration tolerant.
• A less approximate blocks world has one block in some position on another.
TWO THEORIES OF THE BLOCKS WORLD

The usual theory plus a theory in which one block on
other has a displacement from being centered.

- **Standard Theory:** \(\text{Holds}(\text{On}(b_1, b_2), s)\)
- **New Theory:** \(\text{Holds}(\text{On}(b_1, b_2, d), s)\)

Relation between the theories:

- \(\text{Holds}(\text{On}(b_1, b_2), s) \equiv (\exists d) \text{Holds}(\text{On}(b_1, b_2, d), s)\)
PRELIMINARY REMARKS

• The philosophers’ puzzle of Theseus’s ship goes away if the ontology is rich enough to include both the continuing entity and a specific collection of planks.

• An approximate theory can become precise in a limited context—e.g. the blocks world.

• If it comes up, we’ll argue or sue. Ambiguity of the rules of Go.
PRELIMINARY CONCLUSIONS

• Solid logical towers on semantic quicksand.

• I don’t yet see a deep theory of approximate objects.

• For now, just predicate calculus with weak axioms.

• Don’t worry. Be happy.
WHAT TO DO WITH AN APPROXIMATE CONCEPT

• discover more—natural kinds, partial

• define more
• use as is
• add detail
• remove detail—maybe
• make a well-defined theory and relate to it
e.g. two blocks world theories, two travel theories

• improved numerical approximation
• better defined set boundary
• elaborated detail
QUESTIONS

• What kind of semantics is appropriate? Some approximate theories may not admit semantics.

• When is an approximate concept an approximation of something else?

• What kinds of approximations are there?

• When is an approximate theory good enough for use?

• How should an AI system think about the fact of approximation?
• What are the relations between approximations?
WHEN IS AN APPROXIMATE THEORY GOOD ENOUGH FOR USE?

- Observations of the world, e.g. with a TV camera (or by a robot putting its hand in your pocket) give rise to sentences and sometimes other data structures in the memory of the robot. The sentences are approximations to reality.

- Sometimes the robot reasons to understand the situation. The conclusions are approximate.

- The robot decides what to do. The action commands are schematic.
• The action hardware, e.g. an arm takes an action in the real world. Depending on the quality of the theory and the real situation, the action may not be appropriate.

• When a complication occurs in the real world and proves important, the theory must be elaborated, preferably in real time.
CLAIMS

• If-and-only-if definitions are rare.
• The common sense informatic situation involves approximate concepts.
• Formalized scientific theories rarely do.
• Numerical approximation is rare.
• Fuzziness is one kind of approximation.
• Human reasoning only partly corresponds to mathematical reasoning.

**But mathematical logic is the right tool.**
• We use non-monotonic reasoning, approximate objects, contexts as objects.
• Natural kinds are relative to context.
HARANGUE

- Intelligence is the ability to understand complicated environments and decide what to do.

- The basic problems are similar for humans, robots and Martians.

- The scientific goal of AI research should be human level intelligence, not immediate shrink-wrapped applications.

- Computer science has been somewhat corrupted by the dot com frenzy for demos to attract investors to compete for Government money.
• The same problems arise in logical AI and biological AI, but they have been better understood by people in logical AI. The frame problem, the qualification problem and the ramification problem are obvious examples. Present biology motivated systems have almost no elaboration tolerance, e.g. Mycin and NetTalk. Most of the biology oriented AI researchers don’t even recognize the problems.

• AI researchers should consider the approximate nature of the concepts used in the formalism and its relation to reality and less approximate concepts.