# FORMAL REASONING GROUP

http://www-formal.stanford.edu/

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# ROADS TO HUMAN LEVEL AI?

biological—imitate human, e.g. neural nets, should w
eventually

engineering—solve problems the world presents, prese
ahead

direct programming, e.g. genetic algorithms, p
ahead

use logic, loftier objective

The logic approach is the most awkward—except fo
the others that have been tried.

# Logic in AI

Features of the logic approach to AI.

- Represent information by sentences in a logical
  guage, e.g. first order logic, second order logic, mo
  logic.

- Auxiliary information in tables, programs, states,
  is described by logical sentences.

- Inference is logical inference—deduction supplemen
  by some form of nonmonotonic inference.

- Action takes place when the system infers tha
  should do the action.

- Observation of the environment results in senten
  in memory.

## Topics, methods and problems of logical AI

- deduction, nonmonotonic reasoning, theories of
  tion, problem solving, reifying concepts, reifying c
  texts, approximate objects, elaboration tolerance

- Elaboration tolerance (educate without brain surge

# Elaboration Tolerance

**Three missionaries and three cannibals come to a river and find a boat that holds two. If the cannibals ever outnumber the missionaries on either bank, the missionaries will be eaten.**

**How shall they cross?**

$331 \rightarrow 310 \rightarrow 321 \rightarrow 300 \rightarrow 311 \rightarrow 110 \rightarrow 221 \rightarrow$
$020 \rightarrow 031 \rightarrow 010 \rightarrow 021 \rightarrow 000.$

That's the solution. What more is there to say?

## ENGLISH LANGUAGE ELABORATIONS (1)

- The boat is a rowboat.
- The missionaries and cannibals have hats, all differ
- Four missionaries and four cannibals

- There is an oar on each bank. One person can cr
  in the boat with just one oar, but two oars are nee
  if the boat is to carry two people.

- The boat leaks and must be bailed concurrently w
  rowing.

- The boat may suffer damage and have to be ta
  back to the left bank for repair.

# ENGLISH LANGUAGE ELABORATIONS (2)

- There is a bridge.
- There is an island.
- Only one missionary and one cannibal can row.
- The missionaries can't row.

- If the biggest cannibal is isolated with the smal missionary, the latter will be eaten.

- The biggest cannibal cannot fit in the boat with other person.

# ENGLISH LANGUAGE ELABORATIONS (3)

- One of the missionaries is Jesus Christ. Four cross. Here we are using cultural literacy. Howeve human will not have had to have read Mark 6: 48 to have heard of Jesus walking on water.

- Three missionaries alone with a cannibal can con him into a missionary.

- The probability is 1/10 that a cannibal alone in a b will steal it.

- There are two (or $N$) sets of missionaries and ca
  bals too far apart along the river to interact.

# KINDS OF ELABORATION (1)

- irrelevant actors, actions and objects
- adding preconditions, actions and objects
- changing a parameter
- making an entity situation dependent

- specialization

- generalization

# KINDS OF ELABORATION (2)

- going into detail
- missionaries and cannibals as actors
- simple parallel actions
- full concurrency

- events other than actions

- comparing different situations

# AD HOC AMAREL AXIOMS FOR BASIC MCP (1

$$States = Z4 \times Z4 \times Z2$$

$$(\forall state)(Ok(state) \equiv \\ Ok1(P1(state), P2(state)) \\ \wedge Ok1(3 - P1(state), 3 - P2(state)))$$

$$(\forall m\ c)(Ok1(m, c) \equiv m \in Z4 \wedge c \in Z4 \\ \wedge (m = 0 \vee m \geq c))$$

$$Moves = \{(1,0), (2,0), (0,1), (0,2), (1,1)\}$$

$$
\begin{aligned}
&(\forall move\ state)\\
&(Result(move, state) =\\
&Mkstate(P1(state) - (2P3(state) - 1)P1(move),\\
&P2(state) - (2P3(state) - 1)P2(move),\\
&1 - P3(state)))
\end{aligned}
$$

# AD HOC AMAREL AXIOMS FOR BASIC MCP (2

$$(\forall s1\ s2)(Step(s1, s2) \equiv$$
$$(\exists move)(s2 = Result(move, s1) \wedge Ok(s2)))$$

$$Attainable1 = Transitive\text{-}closure(Step)$$

$$Attainable(s) \equiv s = (3, 3, 1) \vee Attainable1((3, 3, 1), s$$

From these we can prove

$$attainable((0, 0, 0)).$$

# SIMPLE SITUATION CALCULUS MCP (1)

$$\neg Ab(Aspect1(group, b1, b2, s)) \rightarrow$$
$$Value(Inhabitants(b1), Result(Cross(group, b1, b2), s)$$
$$= Value(Inhabitants(b1), s) \setminus group$$
$$\wedge$$
$$Value(Inhabitants(b2), Result(Cross(group, b1, b2), s)$$
$$= Value(Inhabitants(b2), s) \cup group,$$

where $\setminus$ denotes the difference of sets.

$$(\exists x \in group)(\neg Holds(At(x, b1), s))$$
$$\rightarrow Ab(Aspect1(group, b1, b2, s)).$$

# SIMPLE SITUATION CALCULUS MCP (2)

$$Holds(Bad(bank), s)$$
$$\equiv$$
$$0 <$$
$$Card(\{x | x \in Missionaries \wedge Holds(At(x, bank), s)\})$$
$$< Card(\{x | x \in Cannibals \wedge Holds(At(x, bank), s)\})$$

$$Holds(Bad, s) \equiv (\exists bank) Holds(Bad(bank), s).$$

# SIMPLE SITUATION CALCULUS MCP (3)

$$\neg(\exists x)(x \in group \wedge Rower(x)) \\ \rightarrow Ab(Aspect1(group, b1, b2, s)).$$

The oar-on-each-bank elaboration is expressed by c
joining

$$Card(group) > \\ Card(\{x | Oar(x) \wedge Holds(In(x, Boat), s)\}) \\ \rightarrow Ab(Aspect1(group, b1, b2, s))$$

# CONCLUSION

- Human level AI is hard.
- Logical AI is progressing.
- Too many researchers have too limited objectives
- Machine learning has been fixated on classification unary predicates.

- Maybe you should find your own approach—in lo
  or elsewhere.