Limbo

A **Reasoning System** for a **First-Order** Logic of **Limited Belief**

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Room 217 (KR-KRL), 16:30–18:00, Last Talk (17:45)

What is limited belief? And why?

Task: Given a KB and a query:

Does the KB *logically entail* the query **?**

Which logic?

Classical logic:

- Unrealistic: omniscient agent
- Undecidable (first-order) / intractable (propositional)

Limited belief: Builds on Lakemeyer & Levesque, KR-2016

- Belief level 0: explicitly written down in the KB
- Belief level $k > 0$: derivable from KB with effort k

Hope: good results at *small* belief level

Language

FOL with equality + functions + sorts +

- Knowledge: $\mathbf{K}_0\,\alpha \quad \mathbf{K}_1\,\alpha \quad \mathbf{K}_2\,\alpha \quad \ldots$
- Possibility: $\mathbf{M}_0\,\alpha \quad \mathbf{M}_1\,\alpha \quad \mathbf{M}_2\,\alpha \quad \ldots$

Example:

- $\mathbf{K}_1\,(\mathrm{Rich}(\mathrm{Frank}) \vee \mathrm{Rich}(\mathrm{Fred}))$ — know that Frank or Fred is rich
- $\forall x\,\mathbf{M}_1\,\mathrm{fatherOf}(\mathrm{Sally}) \neq x$ — don't know who Sally's father is
- $\mathbf{K}_1 \exists x\,(\mathrm{fatherOf}(\mathrm{Sally}) = x \wedge \mathrm{Rich}(x) \wedge \mathbf{M}_1\,\mathrm{fatherOf}(\mathrm{Sally}) \neq x)$ — know that Sally's father is rich, but don't know who he is

Semantics

Model: set of **clauses** closed under unit propagation

- Belief level 0: subsumption
- Belief level $k > 0$: k case splits

Example:

If all we know is (a) $\mathrm{fatherOf}(\mathrm{Sally}) = \mathrm{Frank} \vee \mathrm{fatherOf}(\mathrm{Sally}) = \mathrm{Fred}$

and (b) $\forall x\,(\mathrm{fatherOf}(\mathrm{Sally}) \neq x \vee \mathrm{Rich}(x))$

then $\mathbf{K}_1\,(\mathrm{Rich}(\mathrm{Frank}) \vee \mathrm{Rich}(\mathrm{Fred}))$ **?**

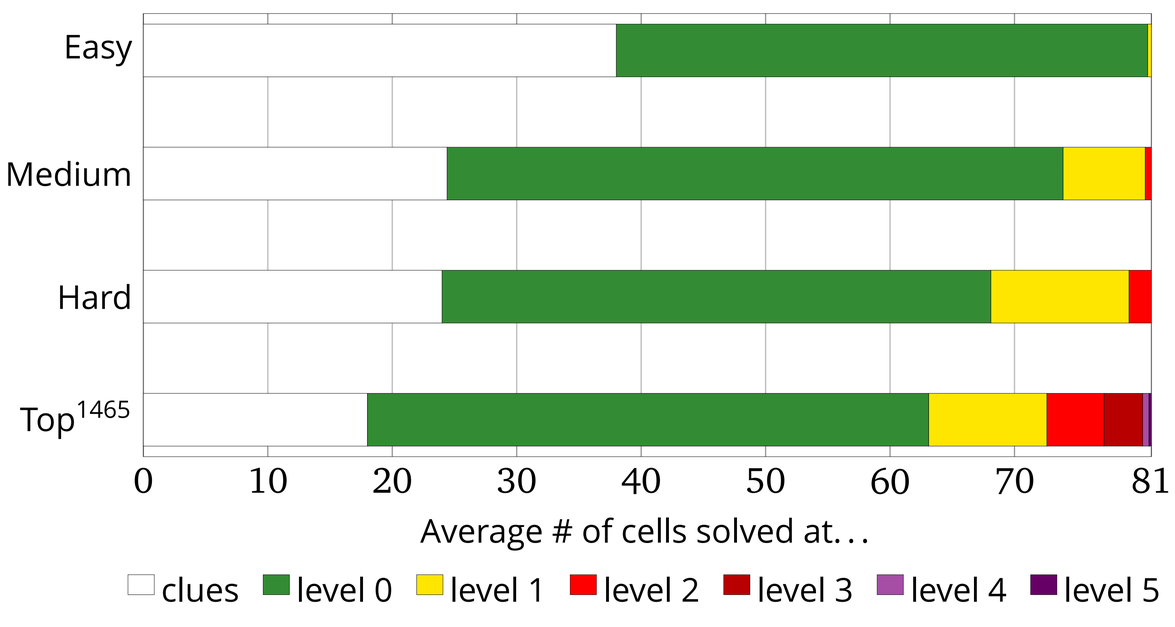
Yes! Branch on $\mathrm{fatherOf}(\mathrm{Sally})$:

- $\{(a), (b), \mathrm{fatherOf}(\mathrm{Sally}) = \mathrm{Frank}\} \ni \mathrm{Rich}(\mathrm{Frank})$ by UP with (b)
- $\{(a), (b), \mathrm{fatherOf}(\mathrm{Sally}) = \mathrm{Fred}\} \ni \mathrm{Rich}(\mathrm{Fred})$ by UP with (b)
- $\{(a), (b), \mathrm{fatherOf}(\mathrm{Sally}) = n\} \ni \bot$ by UP with (a) for $n \neq \mathrm{Frank}, \mathrm{Fred}$

} $\mathrm{Rich}(\mathrm{Frank}) \vee \mathrm{Rich}(\mathrm{Fred})$

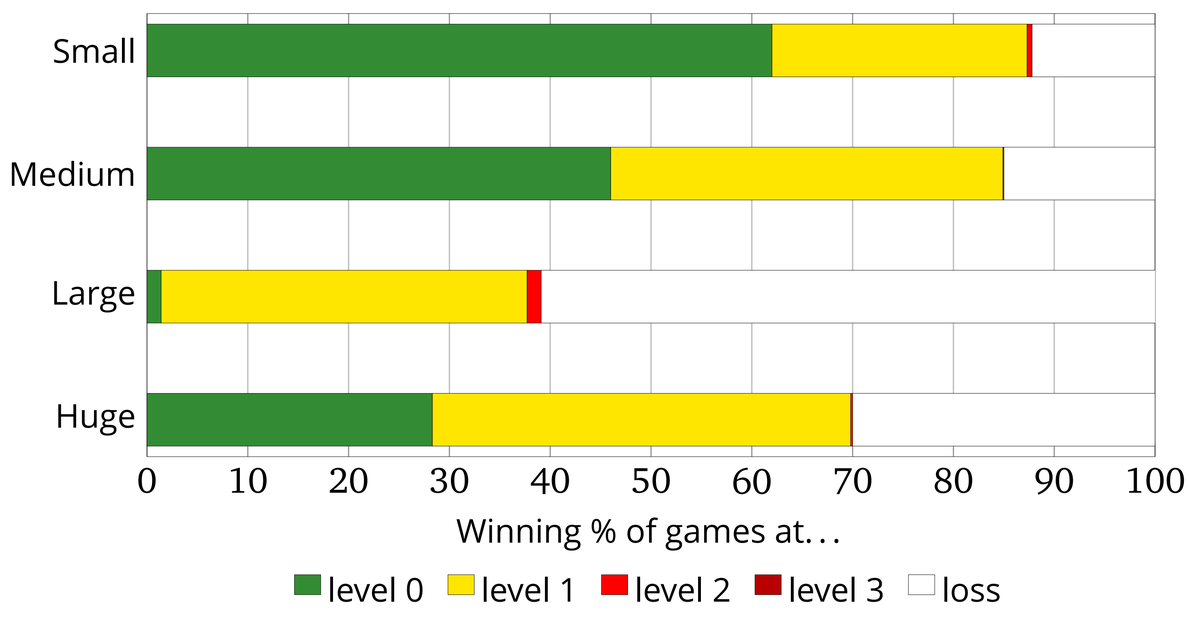
Experiment: Sudoku

Hypothesis: good results at *small* belief level



Experiment: Minesweeper

Hypothesis: good results at *small* belief level



Sound, decidable Prop.: evtly complete, tractable

KB entails query at some belief level $\Longrightarrow$ KB classically entails query
if no $\neg\mathbf{K}, \neg\mathbf{M}$

KB entails query at some belief level $\Longleftrightarrow$ KB classically entails query
if no $\neg\mathbf{K}, \neg\mathbf{M}$ and no $\exists, \forall$

KB entails query at some belief level is decidable

KB entails query at some belief level is tractable
if no $\exists, \forall$ and belief level fixed

Limbo = Limited Belief

Demos: `www.cse.unsw.edu.au/~cschwering/limbo`

Code: `www.github.com/schwering/limbo`

Next: 1. actions 2. belief change 3. multiple agents