The Hierarchy of Hyperlogics*: A Knowledge Reasoning Perspective

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Temporal logics for hyperproperties vs First-order/second-order logics for hyperproperties

Inspired by Kamp’s theorem: LTL = FO[<] and QPTL = S1S, CTL* = MPL, QCTL* = MSO

FO/SO hyperlogics are in general more expressive than their temporal counterpart
Hyperproperties

Hyperproperties relate multiple execution traces.

- Noninterference
- Robustness
- Distributivity
- Fault tolerance
- Epistemic properties!
Temporal Logics for Hyperproperties

Temporal hyperlogic = temporal logic + trace/path quantification

HyperLTL = LTL + trace quantification [Clarkson et al, 2014]

System

```
\text{a} \quad \text{a} \quad \text{a} \quad \text{a} \quad \text{a} \quad \ldots
```

"All traces globally agree on $a$":

\[
\forall \pi. \forall \pi'. G(a_\pi \leftrightarrow a_{\pi'})
\]

LTL with indexed atomic propositions
First-Order/Second-Order Hyperlogics

FO/SO hyperlogic = monadic FO/SO logic + < predicate + E predicate

FO[<,E] = FO[<] + equal-level predicate [Finkbeiner et al, 2017]

System

\[ \forall x. \forall y. E(x, y) \rightarrow (P_a(x) \leftrightarrow P_a(y)) \]

"All traces globally agree on a":
Hyperlogics and Knowledge Reasoning

HyperQPTL can express knowledge operator from \( \text{LTL}^k \):

\[ \iff \text{epistemic reasoning } + \ \omega\text{-regular expressions} \]
\[ \implies \text{epistemic reasoning over distributed architectures} \]

Classic reasoning methods (tableau, chase, etc) directly applicable to hyperlogics like \( \text{FO}[<,E] / \text{S1S}[E] / \ldots \)

\[ \implies \text{new decidability results?} \]

Temporal Hyperlogics vs FO/SO Hyperlogics:

FO/SO logics are in general more expressive than their temporal counterpart

For more see:

Coenen, Finkbeiner, Hahn, Hofmann
The Hierarchy of Hyperlogics, LICS 2019