Metareasoning as an Integral Part of Commonsense and Autocognitive Reasoning

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Summary

- *SELF-AWARE AGENT DESIGN: Overview*
  - *goals: explicit self-awareness*
  - *approach to KR&R: EL & EPILOG*
  - *architecture & the role of metareasoning*
- *KR&R FEATURES CRUCIAL FOR METAREASONING*
  - *"syntactic", introspective, autocognitive reasoning*
- *OTHER IMPORTANT ASPECTS OF KR&R*
  - *normalization, inference graph, term evaluation, etc.*
- *QA EXAMPLES*
  - *quantitative, indexical, & descriptive QA*

Self-aware agent design: *Goals*

Perspective: ***A self-aware agent is only as interesting as the things it knows and can do!***

- ***Explicit self-awareness***
  - *Human-like* world- and self-knowledge
  - *Transparent*: understandable KR, usable by general inference methods
  - *Communicative*: Dialogs about self & world
  - *Self-motivated, plan-driven*

Self-aware agent design: *Approach to KR&R*

Perspective: ***Human-like reasoning requires a KR as expressive as NL, & corresponding inference methods***

- ***Episodic Logic (EL)***

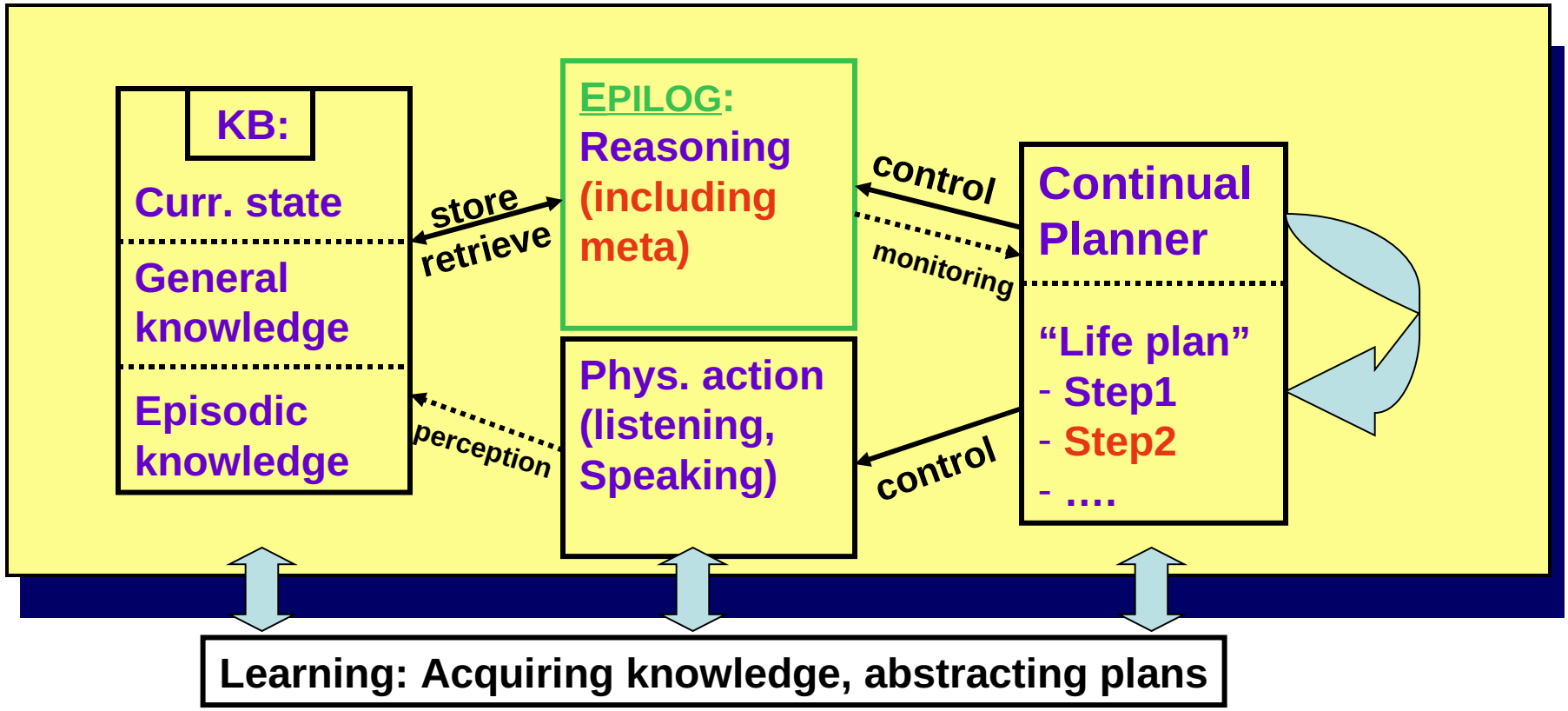
[[John say 'hi] ** E1] and [E1 before Now0]]

NOTE: infix form

  - *Events and situations*
  - *General quantification, modification, reification*
  - *Attitudes & autoepistemic knowledge*
  - *Metasyntactic devices (to be described)*

Self-aware agent design:
Architecture & the Role of Metareasoning

Perspective: ***A self-motivated agent needs to plan continually, and use both object- & metalevel knowledge In planning and reasoning. (No uniform meta-control)***



Role of Metareasoning, in more detail

- ***Reasoning about the syntax of formulas***
  - Answer descriptive questions (e.g. *What do you know about the appearance of pigs?*)
  - Decide what special procedural method may be applicable to a given task
  - Produce answers in the desired format (e.g. , giving one's age in years, not as difference in dates)
- ***Positive and Negative introspection***

  (e.g., knowing/inferring how much/little we know about a thing, kind of thing, or topic; descriptive QA)
- ***Autocognitive reasoning***

  (e.g., *"Did the phone ring?"* – I know I would have heard it, if it rang; how we perceive, learn, etc.)

Epilog's features crucial for Meta-reasoning

Substitutional Quantification Quasi-Quotation

- Classify syntactic elements

  ['= (Commutative (EL-Predicate))]

- Formal treatment of meaning postulates

  (All x ($All_{pred\text{-}modifier}$ m ['m (Monotonic EL-pred-mod)]
  (All_{pred} p [x (m p)] [x p])))

- Allows selection of special routines based on axioms on their effects

  (All_{wff} w ['w Without-free-vars]
  [[(APPLY 'knownbyme? 'w) = 'yes] <=>
  [(That w) Knownbyme]])

Substitutional Quantification Quasi-Quotation

- Wff Parser
  - allow for substitutional quantifiers and quotation in EL formulas
- Unification
  - unify a metavariable with an expression of a particular type: w_{wff} with ((K (plur Apple)) Red)

Recursive-QA

- Implements Kaplan and Schubert's ASK-TELL mechanism
  - difference between knowing and being able to infer
- Implemented as ability to start a QA process inside another QA process
- Use of axioms to let EPILOG decide when to start a QA process:

$(All_{wff}$ w ['w Without-free-vars]

[[(APPLY 'knownbyme? 'w) = 'yes] <=>

[(That w) Knownbyme]])

Other important aspects of KR&R in EPILOG

Normalization

- FOL normalization not possible in EL
  - intensional operators (modifiers, reifiers, etc.), generalized quantifiers (Most, Many, etc.)
- Based on rewrite engines
  - set of rules that state preconditions and effects
  - applied till the input formula is changed
- currently there are 19 rules
  - move negation inward, cluster AND/ORs, remove trivial tautologies, move episodic operators inward, skolemize, etc.

Inference Graph

- Inference generates a tree
  - start with 2 subgoals (proof, disproof)
  - pick a subgoal to process (agenda):
    - retrieve knowledge, do inference, produce new subgoals
    - apply simplifications: split, assumptions, special handling
    - add to agenda what's left
  - loop detection/duplication handling (graph)

Multiple Answers

- Required for WH questions
  - propagate answers from the leaves up to the initial question
    - wait for answers from siblings
    - unifier merging and variable renaming
  - recognize duplicated answers
    - unifier and knowledge used
  - user selectable termination criterion

Term Evaluation

- Simplify terms
  - e.g.: How old are you?

    The difference in years between 1st Jan 1993 and now.
- Pose a question (Wh x [x = term]) and collect all answers that are simpler than term

Examples

- How old are you?
- What's your name?
- What do you know about the appearance of pigs?

How old are you?

- Question:

  (Wh x (Wh e [e At-about Now0]

  [[Epilog Has-age-in-years x] ** e]))

- Answer:

  e = (Fn1 Now0)

  x = (Diff-in-years (Date 1 1 1993 0 0 0)

  (Time-of (Fn1 Now0))

How old are you?

- Evaluate:

  x = (Diff-in-years (Date 1 1 1993 0 0 0)
  (Time-of (Fn1 Now0))

- Start QA process for question:

  (Wh x [x = (Diff-in-years (Date 1 1 1993 0 0 0)
  (Time-of (Fn1 Now0))])

- Use knowledge produced while answering QA:

  [(Fn1 Now0) At-about Now0]

- Axioms:

  ($\forall_{term}$ x ($\forall_{term}$ x1 ['x1 Absolute-time-point]
  ($\forall_{term}$ x2 ['x2 Absolute-time-point]
  [['x = (APPLY 'diff-in-years? 'x1 'x2)] ⇒
  [x = (Diff-in-years x1 x2)]])))

What's your name?

- Question:

  (∃ e0 [e0 At-about Now0]

  ((Wh z [[z Name) ∧ [Epilog Have z]]

  (∃ y [y Thing] [y (Be (L x [x = z]))])) ** e0])

- Meta-knowledge used while normalizing:

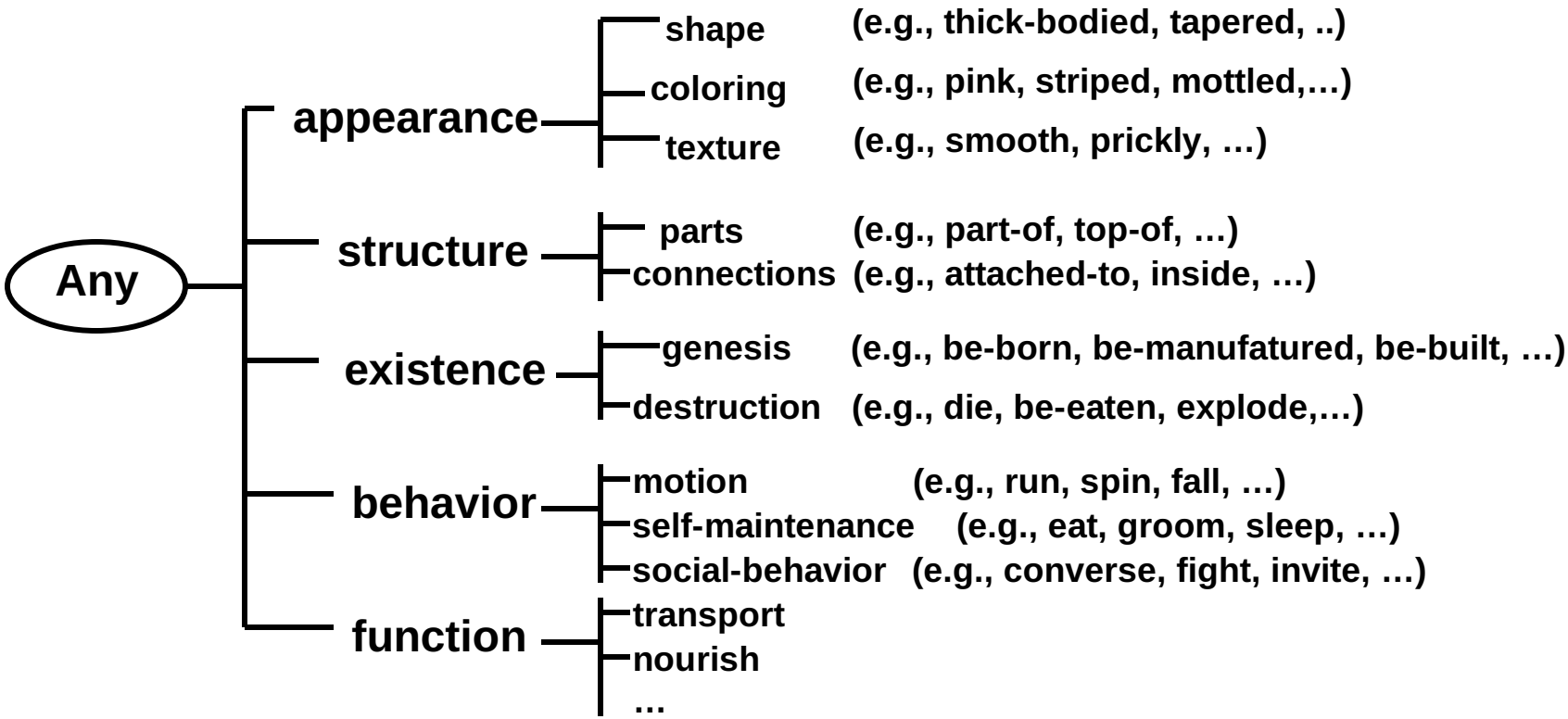
  [‘Thing EL-type-pred]

  [‘Name EL-type-pred]

What do you know about the appearance of pigs?

Assume that predicates have been assigned metalevel topics in a topic hierarchy:

For physical objects (simplified):



What do you know about the appearance of pigs?

- Question:

  (Wh x [x Appearance-fact-about (K (Plur pig))])

- Answer:

  (That [(K (Plur Pig)) Thick-bodied])

- Meta-knowledge used:

  From topic hierarchy

  ['Thick-bodied Appearance-pred)],

  ($\forall_{pred}$ p ['p Appearance-pred]

  (∀ x [x p] [(That [x p]) Appearance-fact-about x]))

Conclusion

- Explicit self-awareness & commonsense reasoning require integrated object-level / meta-level inferences
- Such inferences can be effectively realized in a highly expressive representation that is “language-like” (EL → EPILOG).