A Polymorphic Cognitive Agent Architecture (PCAA)

Progress toward an Architecture for Cognitive Information Processing

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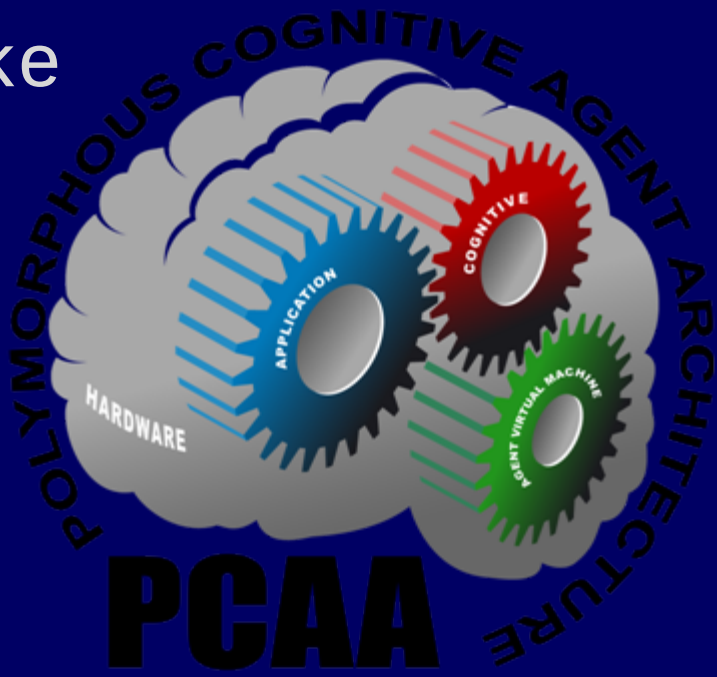
Soar Technology

ATL LOCKHEED MARTIN

DARPA ACIP Program

- Goal: develop tools to make "cognitive processing" more feasible
- Lockheed Martin ATL team
  - Polymorphous Cognitive Agent Architecture
  - 3 layer architecture:
    - Application
    - Cognitive
    - Agent Virtual Machine/hardware
  - This talk: Cognitive Layer
    - Altarum, MAAD, Reservoir Labs, Soar Tech, LM



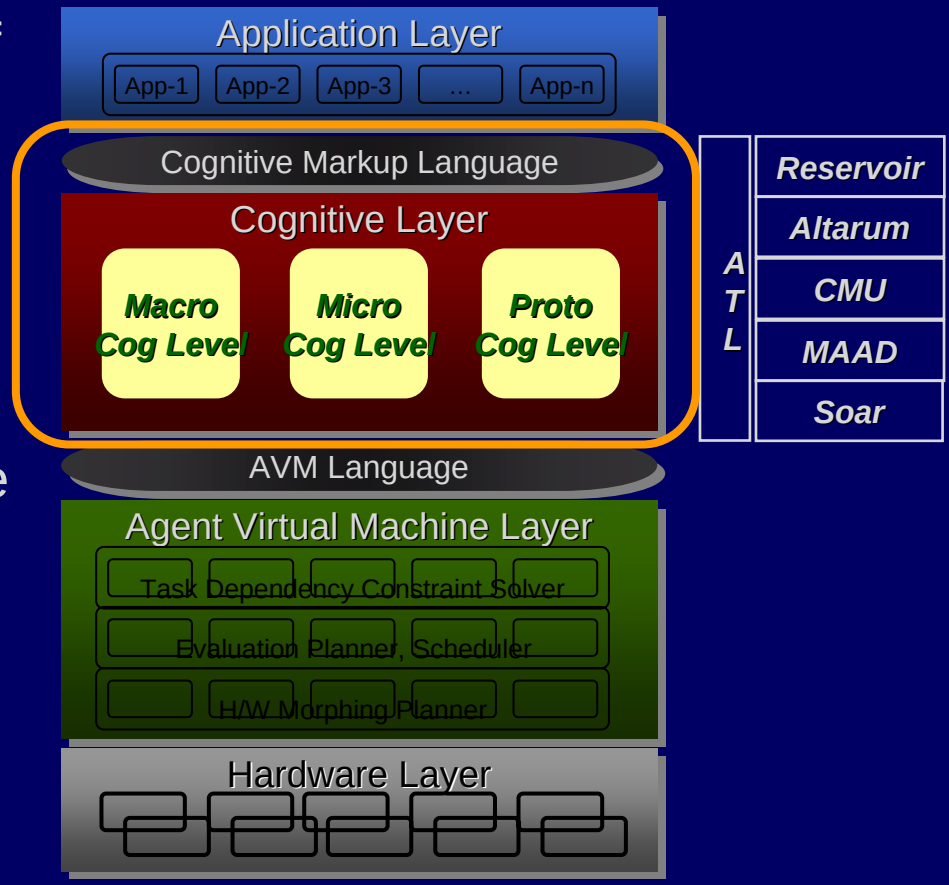
Cognitive Layer in PCAA

Goals:

- Reduce the complexity of a variety of problems through an efficient combination of
  - Logical reasoning
  - Cached Expertise
  - Distributed simple intelligence
- Provide solutions that are
  - Efficient
  - Robust
  - Adaptive
  - General

Current Applications

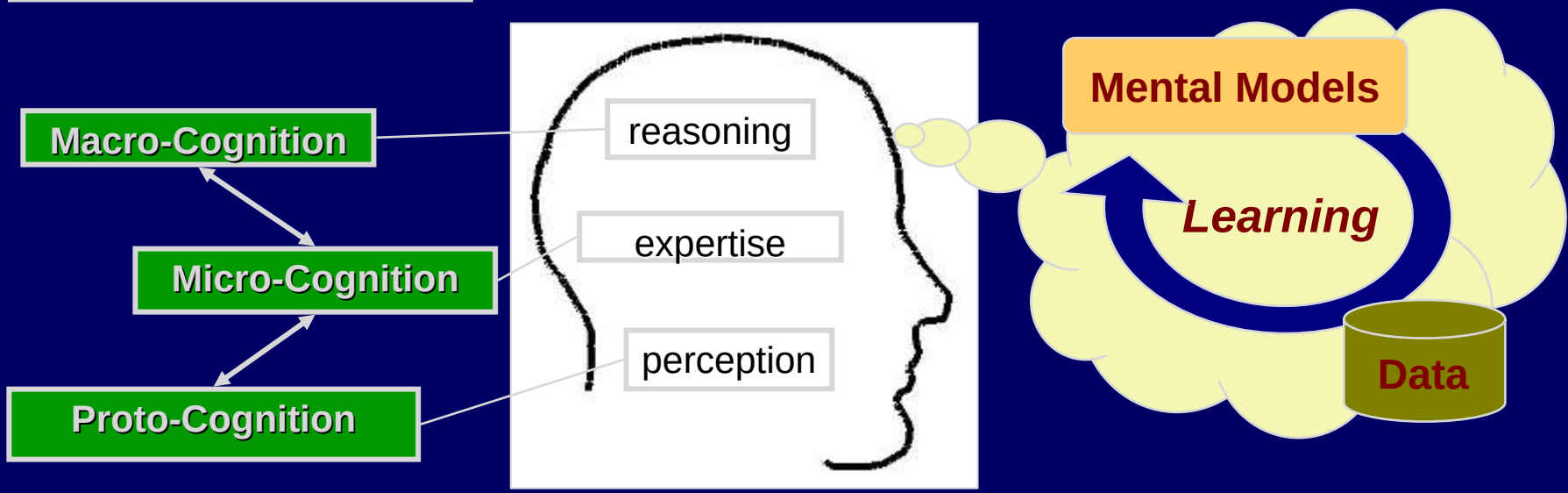
- Evidence marshalling
- UAV Mission planning



Cognitive Layer Concept (C3I1)

Human problem-solving involves multiple levels of cognition

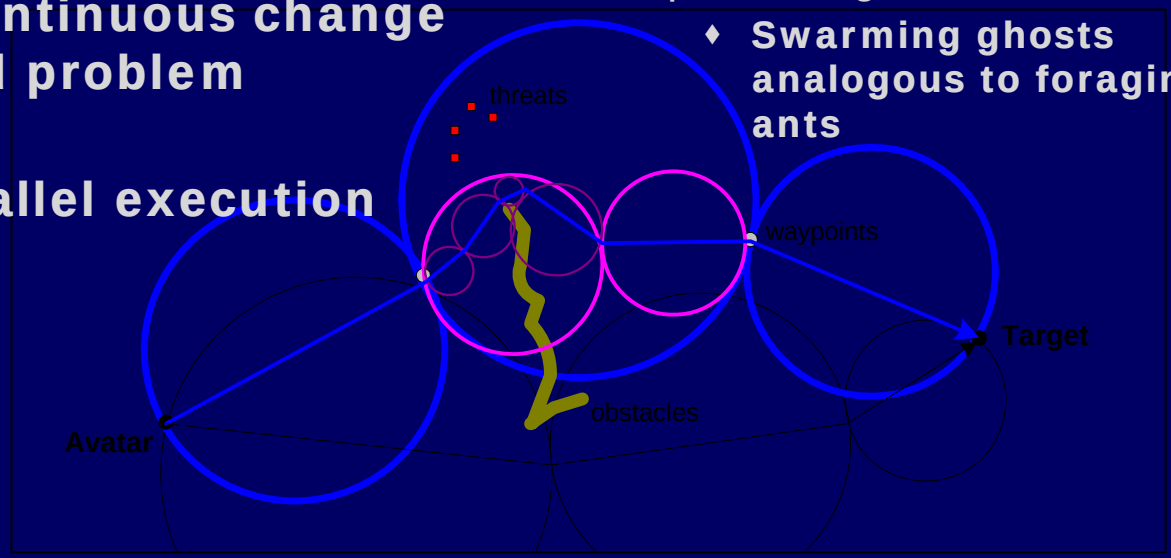
- Perception: **Acquiring, processing of sensory information**
  - Proto cognitive level (Swarm)
- Expertise: **Experience-based pattern recognition**
  - Micro cognitive level (ACT-R)
- Reasoning: **Deliberation**
  - Macro cognitive level (Soar)



Proto Cognitive Level (Swarm)

- Purpose: Simple, distributed intelligence
  - **Self organization (e.g., clustering)**
  - **Distributed classification (e.g., filtering)**
- Swarming architecture
  - **Handles continuous change in data and problem definition**
  - **Highly parallel execution**

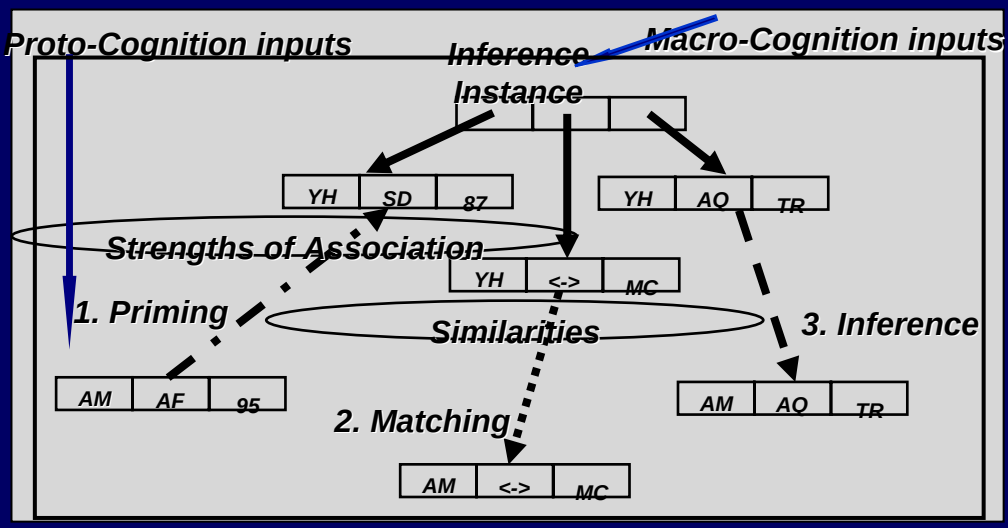
- Problem solving approach
  - Bottom-up reconfiguration of solution elements
    - **Hierarchical Ant Clustering for compatibility and similarity**
  - Top-down selection of promising solutions
    - **Swarming ghosts analogous to foraging ants**



Fractal structure of problem solving for UAV route planning

Micro Cognitive Level (ACT-R)

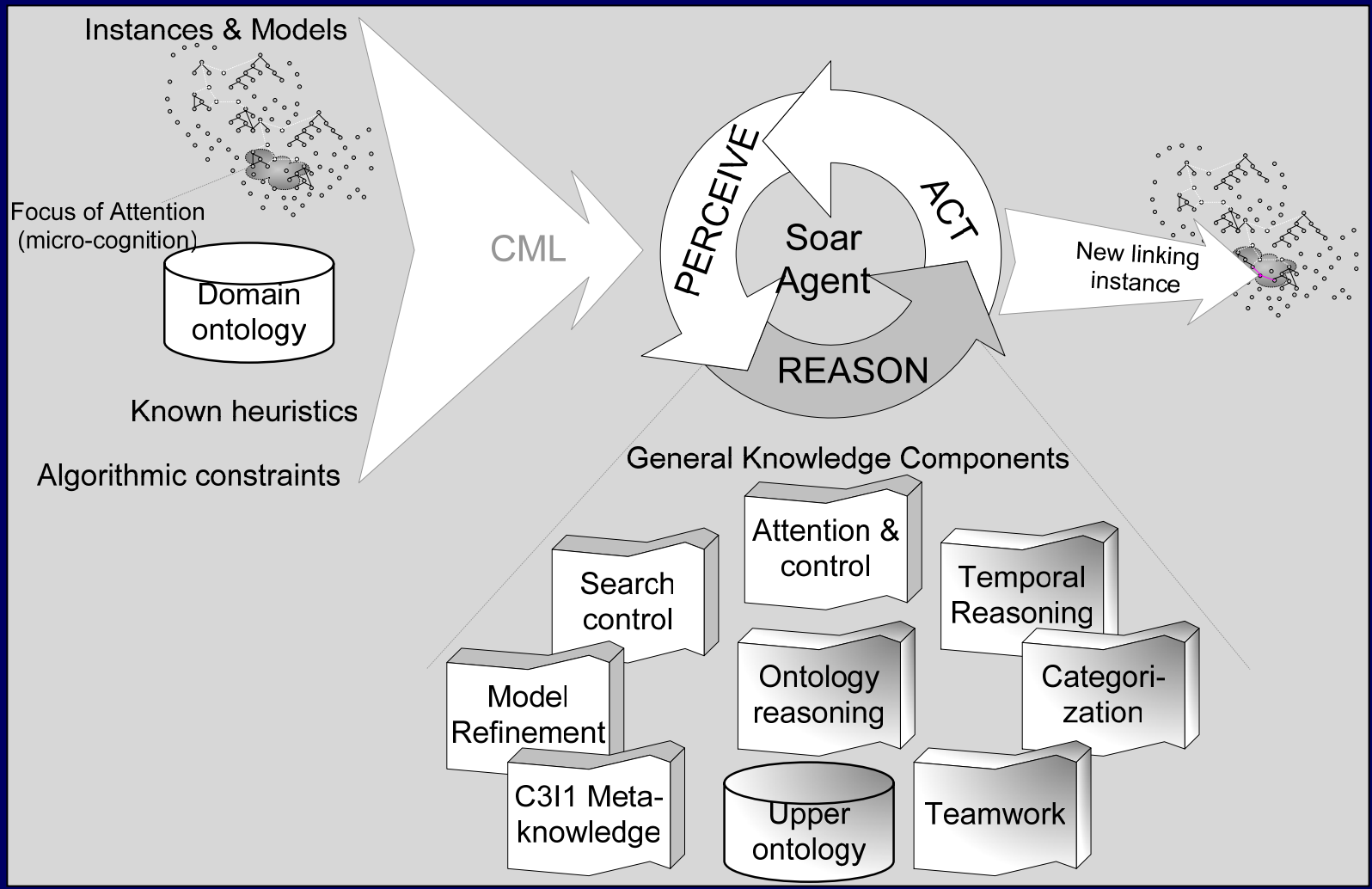
- Purpose: Provide expertise-based inferences
  - ♦ **ACT-R**
- Evidence marshaling as generalization of expert inferences
  - ➢ Represent expert inferences in declarative memory
  - ➢ Use associative priming to determine most useful inference(s)
  - ➢ Similarity-based generalization of inference to current situation
- Problem solving approach: Efficient application of accumulated expertise
  - ➢ Expertise provided by user or developed by macro reasoning
  - ➢ Efficiency from highly parallelizable statistical generalization processes



Macro Cognitive Level (Soar)

- Soar
  - Represents expert deliberation (sort & link facts)
  - Use architectural mechanisms to resolve conflicts and integrate disparate knowledge sources
- Approach depends on other cognitions to reduce problem size, make problem tractable
  - e.g., identify 10^3 "possibly relevant" items from 10^8 potential input elements
- Purpose: Apply knowledge-based inferences to solve problem
  - Apply domain knowledge
  - Apply domain general knowledge (e.g. temporal reasoning)
  - Integrate deliberation across multiple knowledge sources
  - Assess relevance of novel assertions for micro cognitive level

Macro Cognitive Level (Soar)

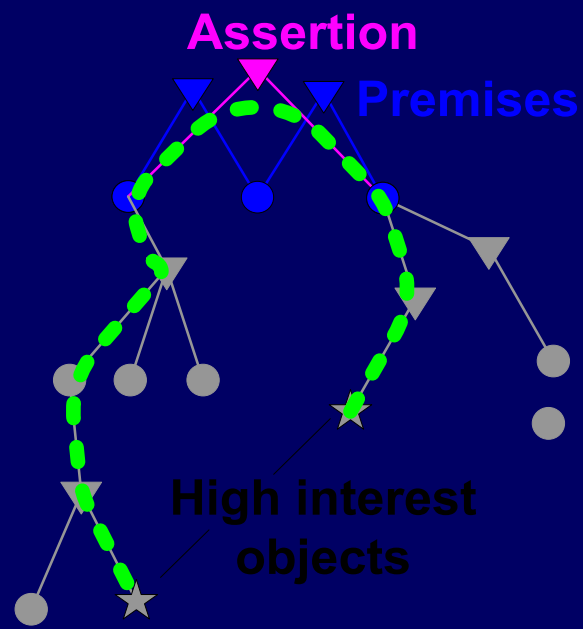


Evidence Marshaling (Soar)

General approach

- Establish premises (micro-cognition)
- Retrieve directly related facts from C3I1 memory
- Generate new inferences (apply knowledge sources)
- Assess relevance of new assertions
  - Evaluation approaches
    - analogical mapping
    - social network analysis
- Augment C3I1 memory with relevant inferences

Problem: Many assertions to generate; which ones will be interesting?

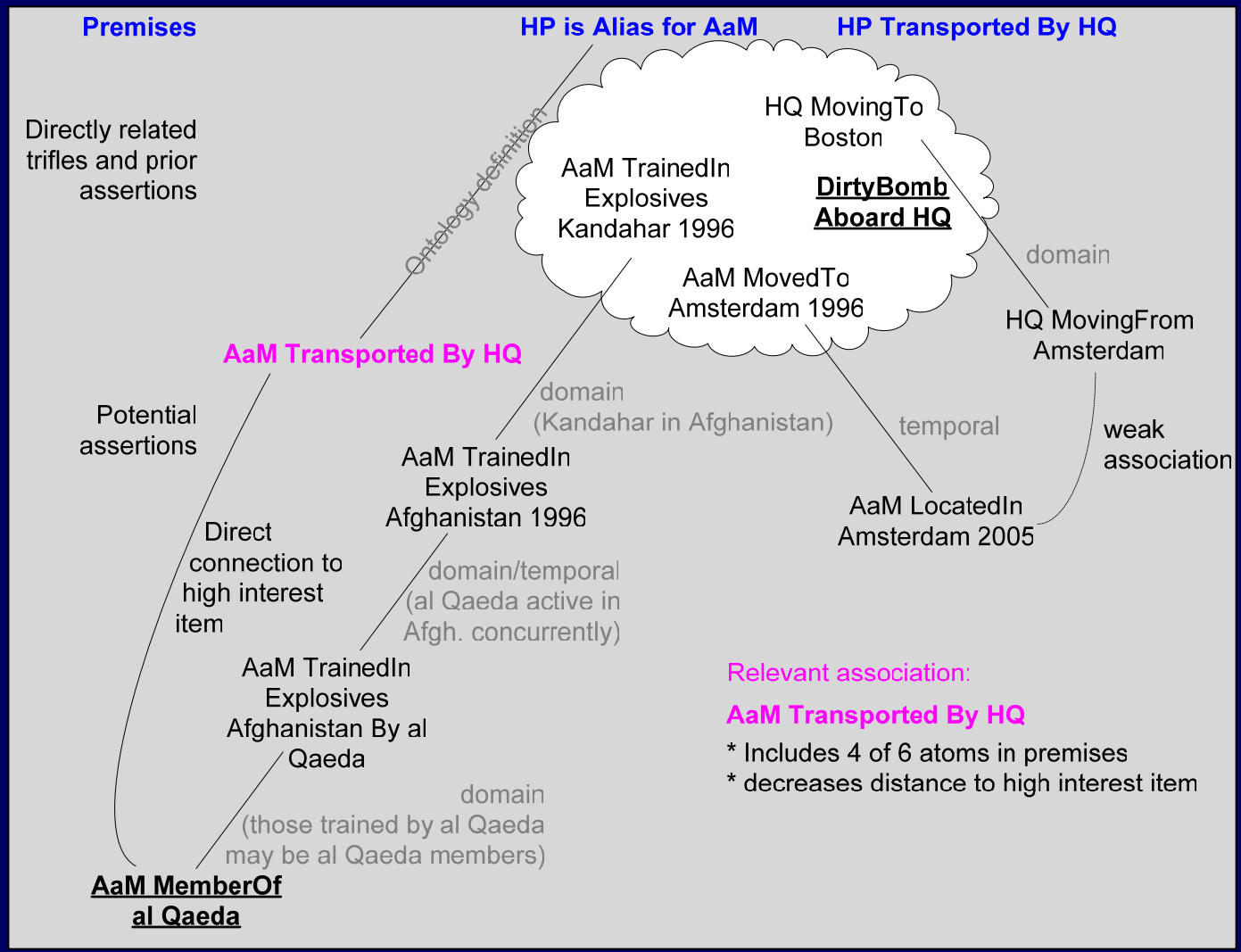


Approach: generate new assertions and determine if they enable new links & paths to high interest objects

Example Inference

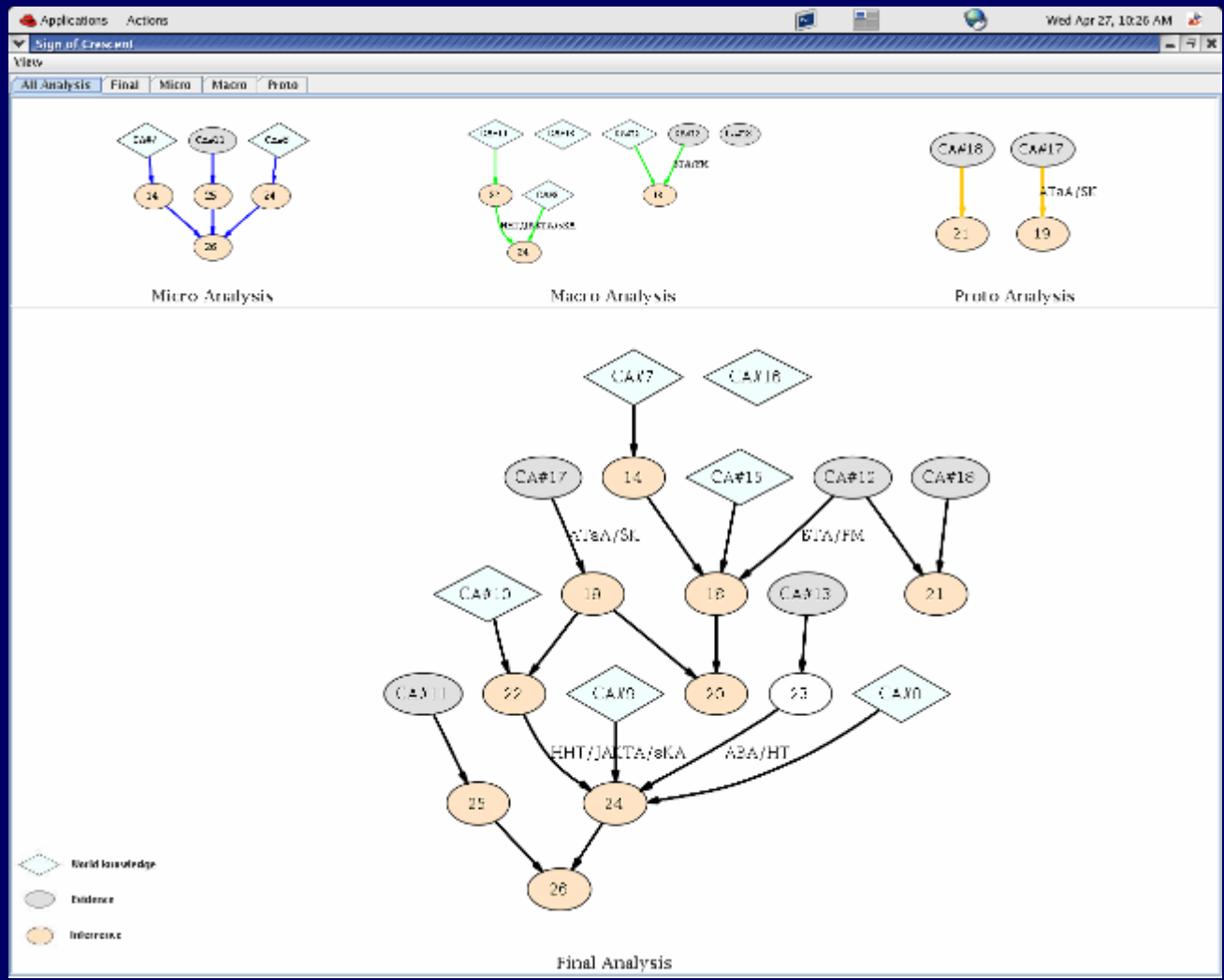
- Desired Inference: (X *rel* b) + (X = Y) => (Y *rel* b)
  - Alias replacing
- Example
  - 6 + 8 =>6'
    - 6. Hans Pakes is aboard the Holland Queen
    - 8. Hans Pakes is an alias for Abu al Masri
    - 6'. Abu al Masri is aboard Holland Queen
- Proto cognition
  - Creates clusters to group assertions such as 6 & 8
- Micro cognition
  - If no expertise with this inference, asks Macro cognition for help (think about potential connections)
  - Solution: Results in new knowledge at Micro level (comparable to Soar chunking across cognitions)

Example Soar Inference (Macro)



C3I1 Status

- Proof-of-concept developed for evidence marshalling task
- Integration & interaction across "cognitions"
  - Simple shared ontology
  - Message exchange



Conclusions & Future Work

- Exciting opportunity to investigate general architectural issues
- Overall approach reduces some of weaknesses of Soar (very large declarative memory)
- (Project also encouraging HW research to make individual cognitions more scalable)
- Future work
  - Control process
  - Problem decomposition (Generic Tasks)
  - UAV Mission Planning (demonstrate generality)
  - Explore adaptation & learning across cognitive levels

Nuggets & Coal (Soar PoV)

- Nuggets
  - Much previous Soar research & development applicable to architectural approach (cumulation driver)
  - Generalization of architectural ideas from Soar (caching experience in Micro-cognition)
  - New Soar tools significantly reduce integration and interoperability costs
- Coal
  - Lack mature methods for creating and using knowledge components dynamically (packaging research problem)
  - Overall approach not consistent with Soar theory (implementation or theory problem?)