

Retrospective Self-Adaptation of Domain Knowledge via Perceptually-Grounded Semantics

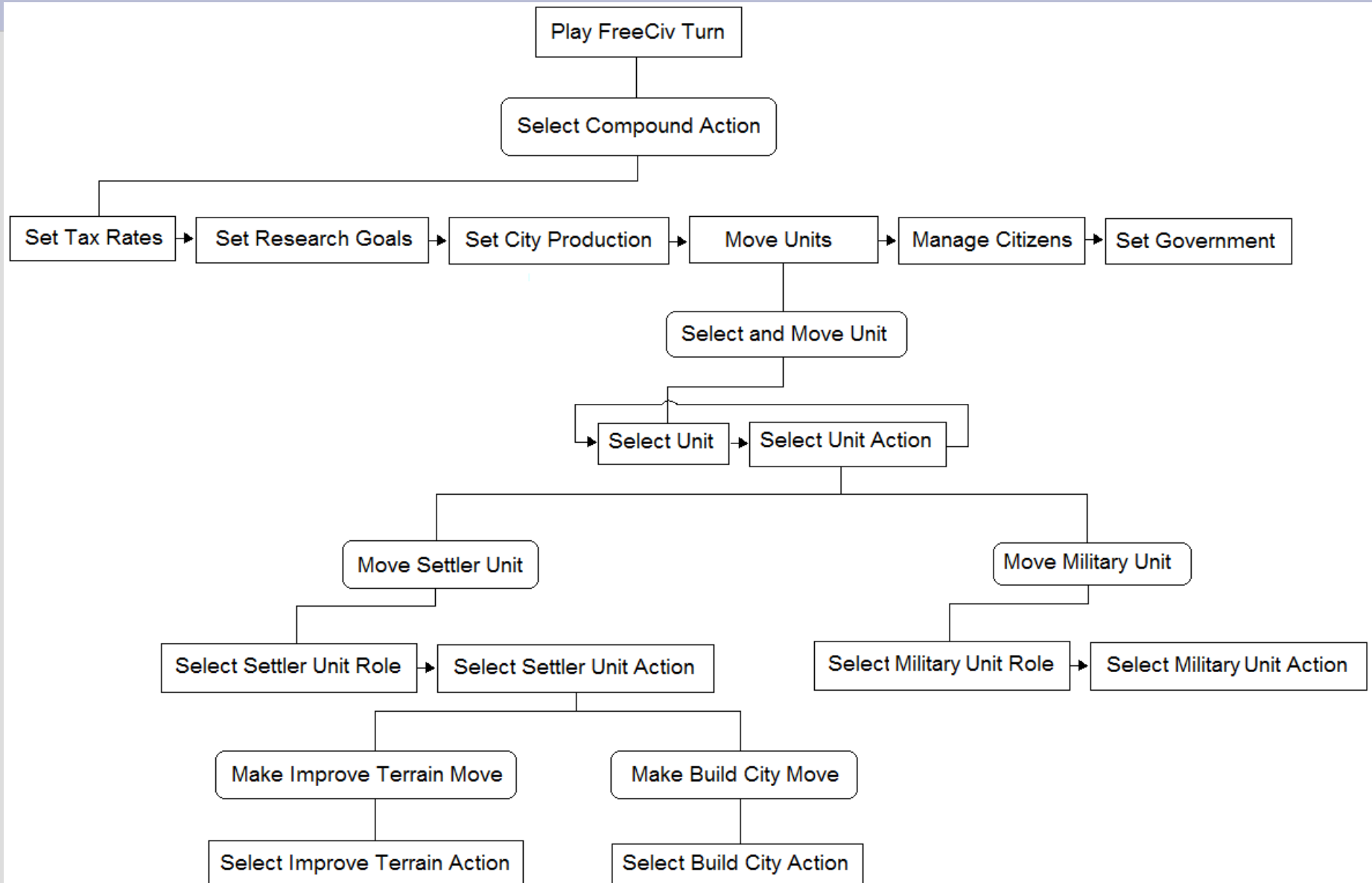
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FreeCiv



- Turn-based multiplayer strategy game
- Massive number of game states and many(compound) actions
- Interrelated subgoals (technology, population growth, military...)

Object-level Reasoning of a FreeCiv Playing Agent



Reflective Learning

- If the reflective layer detects that the agent has performed suboptimally, how to correct?
- *Our group's research theme:* View the agent as an abstract device, with a task-level design and a method-level teleology
- Endow the agent with a declarative self-model of its design/teleology
- Use the self-model for agent self-analysis (structural credit assignment) and self-adaptation.

Autognostic

- Retrospective adaptations only, for some classes of problems.
- Autognostic's reflective layer reasons over a process-oriented self model in conjunction with a trace of failed reasoning to localize and repair faults.
- *Stroulia, E. & Goel, A. K. AAAI-96, IJCAI-97*

Reflective Evolutionary Mind

- REM handles retrospective and proactive adaptations, again for certain classes of problems.
- Retrospective adaptation is similar to Autognostic.
- Proactive adaptation uses a description of a new problem plus background knowledge such as transformative operators.

Reflective Evolutionary Mind

- In some cases faults cannot be precisely identified, then an external technique (e.g. RL) is used to complete the adaptation.
- *Murdock, J. W., and Goel, A. K. ICAPS-2003, JETAI 2008.*

Reflection on object-level knowledge

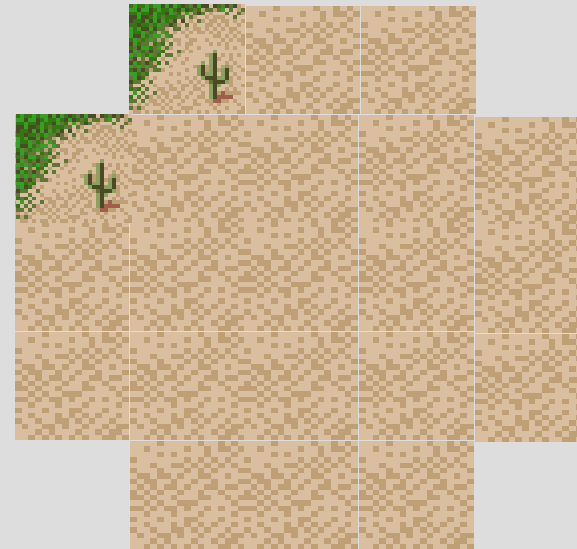
- What if a metareasoning process such as REM or Autognostic identifies a primitive task as the source of error?
- Primitive tasks are those that are directly implemented by object-level knowledge.
- Want reflective process to then descend into the task and reason about the knowledge.
- Take as an example the primitive 'select city build action' task.

City Location Quality Subproblem

- Predict shield (resource) production of a potential city over time



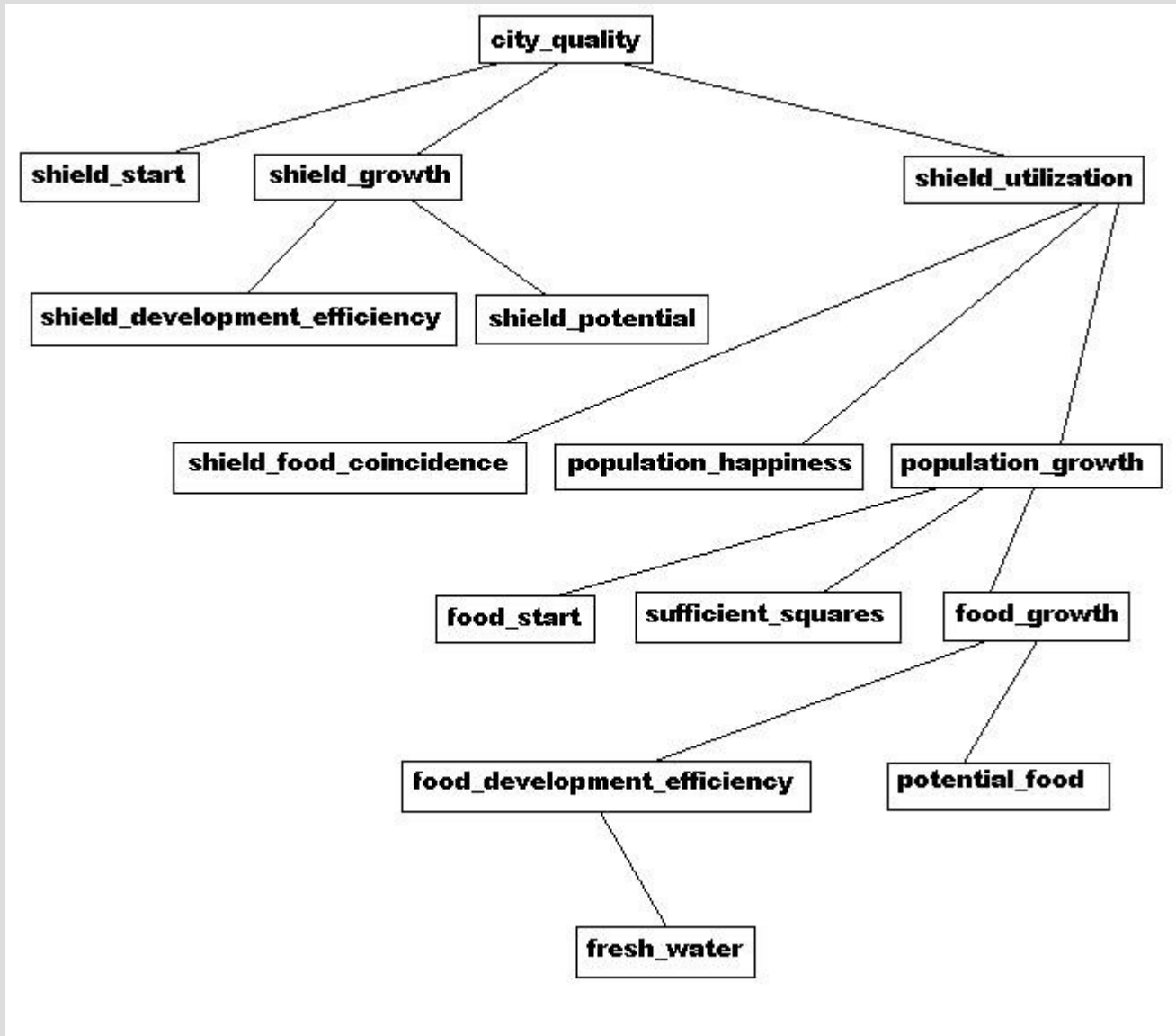
VS.



Object-level domain knowledge representation

- A commonly used pattern of hierarchical classification is “structured matching” (Bylander, et al., 1991)
- In structured matching, state features are progressively aggregated and abstracted
- Structured matching is efficient – linear in space and inference time with respect to input dimension

FreeCiv City Location Quality Knowledge Structure



Domain Characterization

- Task: Compositional Classification
- There is a set of “empirically determinable” features that share mutual information amongst themselves, and with the class label
- Assume a known independence structure
- Some features are only determinable after classification, and may have some cost

Empirical Verification Procedures

- REM and Autognostic provide theories of the kind of knowledge needed for metalevel reasoning over process – but what metaknowledge is needed for metareasoning over object-level knowledge?
- Use metaknowledge that grounds the semantics of object-level knowledge in *perception*.
- Can be exploited by the reflective layer to perform diagnosis over the object-level knowledge hierarchy

Learning

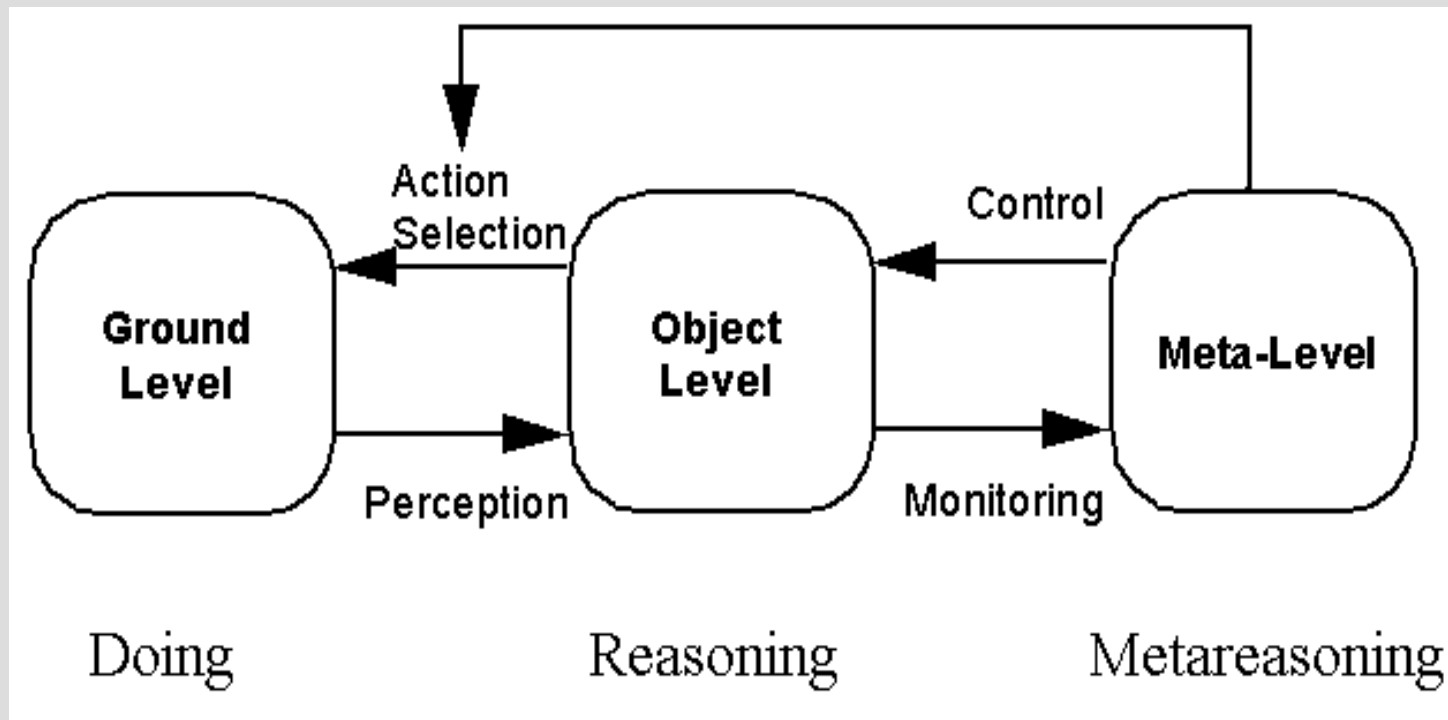
- Exploit the empirical determinability of the represented features
- Learning technique used within nodes is flexible, as is the internal knowledge representation
- Different learning progressions based upon other design choices and problem characteristics; in all cases the EVPs are key in assigning fault to specific nodes.

Experimentation

- Rote “table update” learners, neural networks and kNN learners have been placed within nodes in our knowledge structures.
- We have experimented in synthetic domains, as well as in the FreeCiv example described, financial prediction and sports prediction.
- Some positive results with several domain/learner configurations, please see papers for detail.

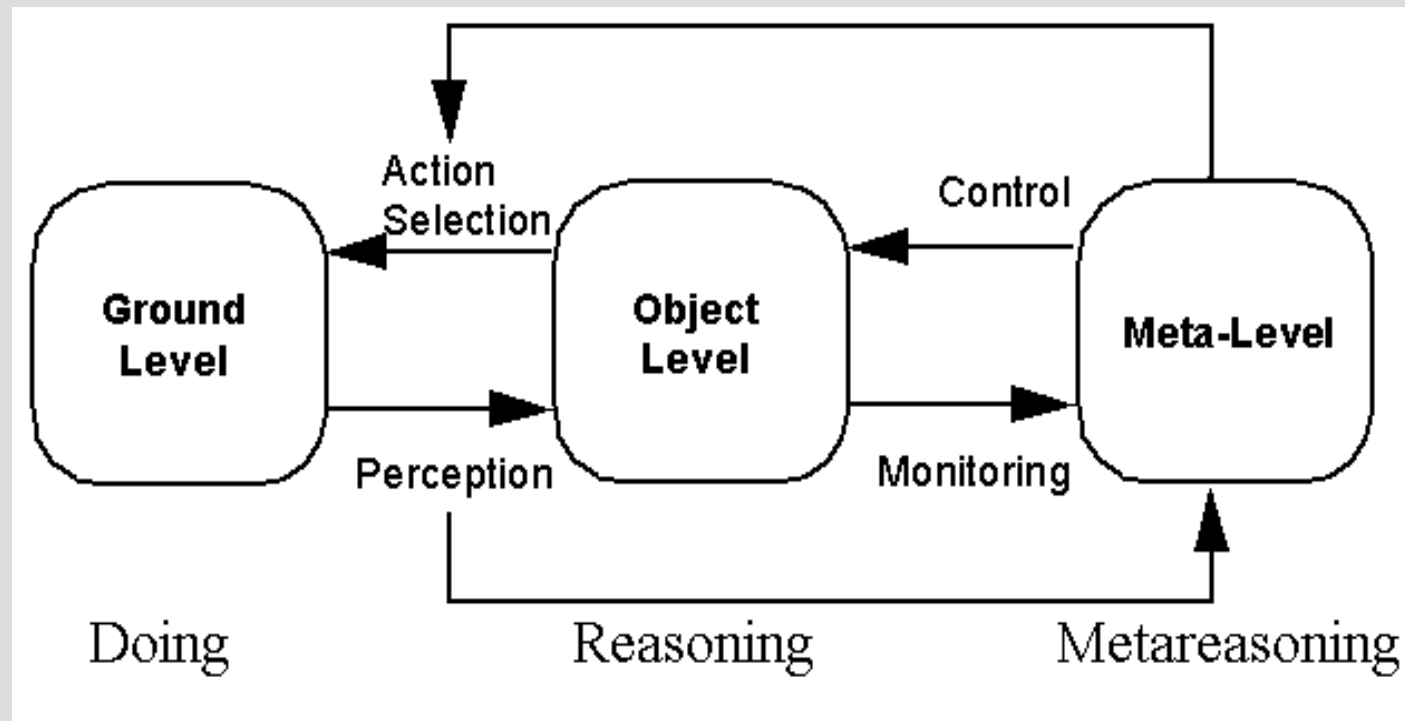
Metareasoning Architecture

- Ground-level actions may be in service of reflective layer diagnosis; thus the metareasoning level may in some cases drive action selection.



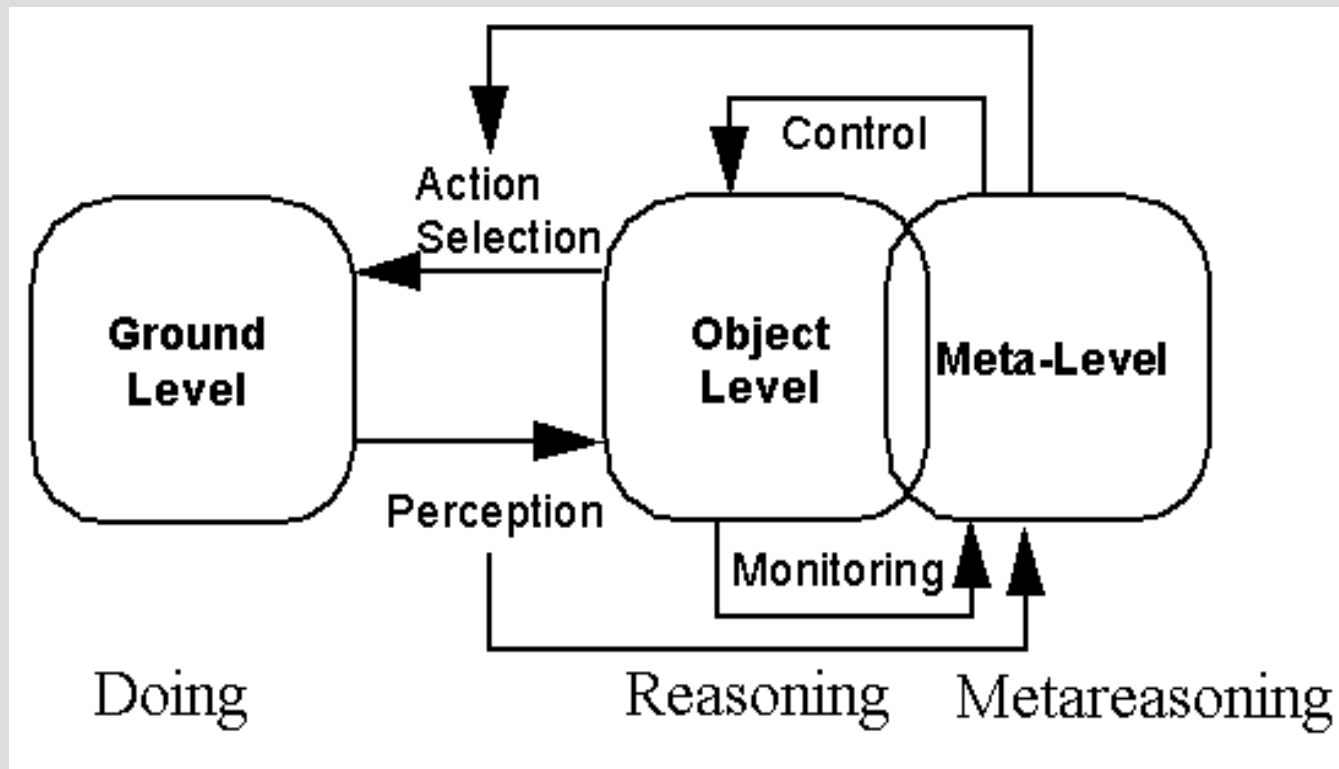
Metareasoning Architecture

- Meta-knowledge here takes the form of an explicit representation of object-level knowledge semantics via connection to ground level percepts.



Metareasoning Architecture

- Meta-knowledge is distributed over object-level knowledge structures, not confined to separate metareasoning level representations.



Conclusion

- As metaknowledge in the form of goals can be used by a metareasoner to reflect on an agent's object-level process, metaknowledge in the form of grounding of concept semantics in perception can be used to reflect effectively on an agent's object-level knowledge.
- This research is supported by an NSF SoD Grant (**#0613744**) “Teleological Reasoning in Adaptive Software Design.”