

**QUAIL:**  
**Question Asking to Inform Learning**

Melinda Gervasio  
Karen Myers

SRI International

*AAAI-08 Workshop on Metareasoning*

Chicago



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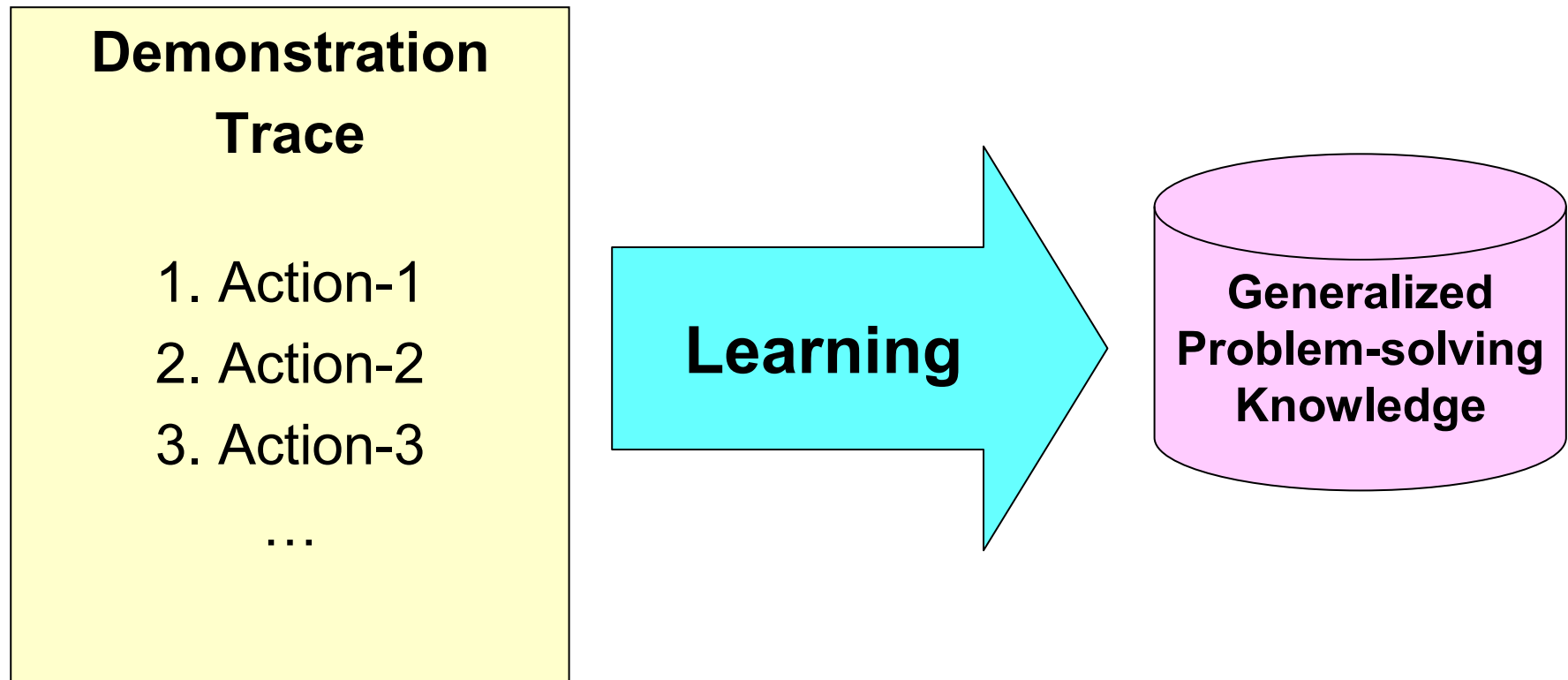


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# Learning by Demonstration





# Medical Logistics Domain

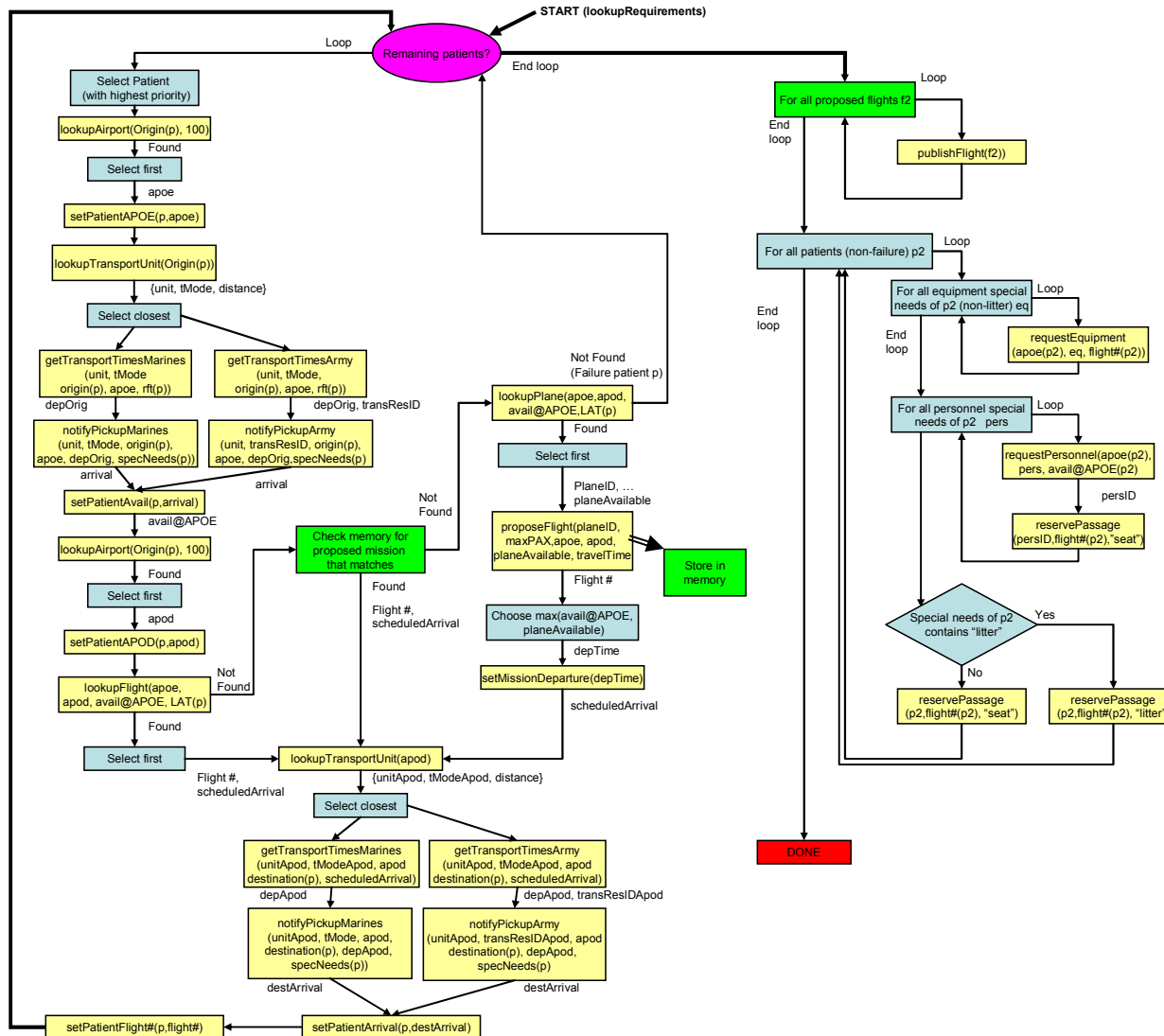


```
((lookupRequirements S42)
((lookupAirport PFAL 300m )((ORBI 90m BaghdadIntl)))
((setPatientAPOE P1 ORBI ))
((getArrivalTime P1 PFAL ORBI )(1h 3h ))
((setPatientAvailable P1 3h ))
((lookupHospitalLocation HKWC)((KuwaitCity)))
((lookupAirport KuwaitCity 300m 2)((OKBK 250m KuwaitIntl)))
((setPatientAPOD P1 OKBK ))
((lookupMission ORBI OKBK 24h 3h ))
((lookupAsset ORBI OKBK 24h 3h )((C9-001 15h 2h 10)))
((initializeTentativeMission c9-001 10 ORBI OKBK 15h 2h))
((getArrivalTime P1 OKBK HKWC 17h )( 18h 19h ))
((setPatientMission P1 M-006 ))
```

...



# Target Workflow



## Learned Knowledge

- Temporal Ordering
- Conditional branching
- Selection Criteria
- Iterations
- Method Generalization



# QUAIL Overview



*“Tell me and I forget, show me and I remember,  
involve me and I understand.”*

- Chinese Proverb

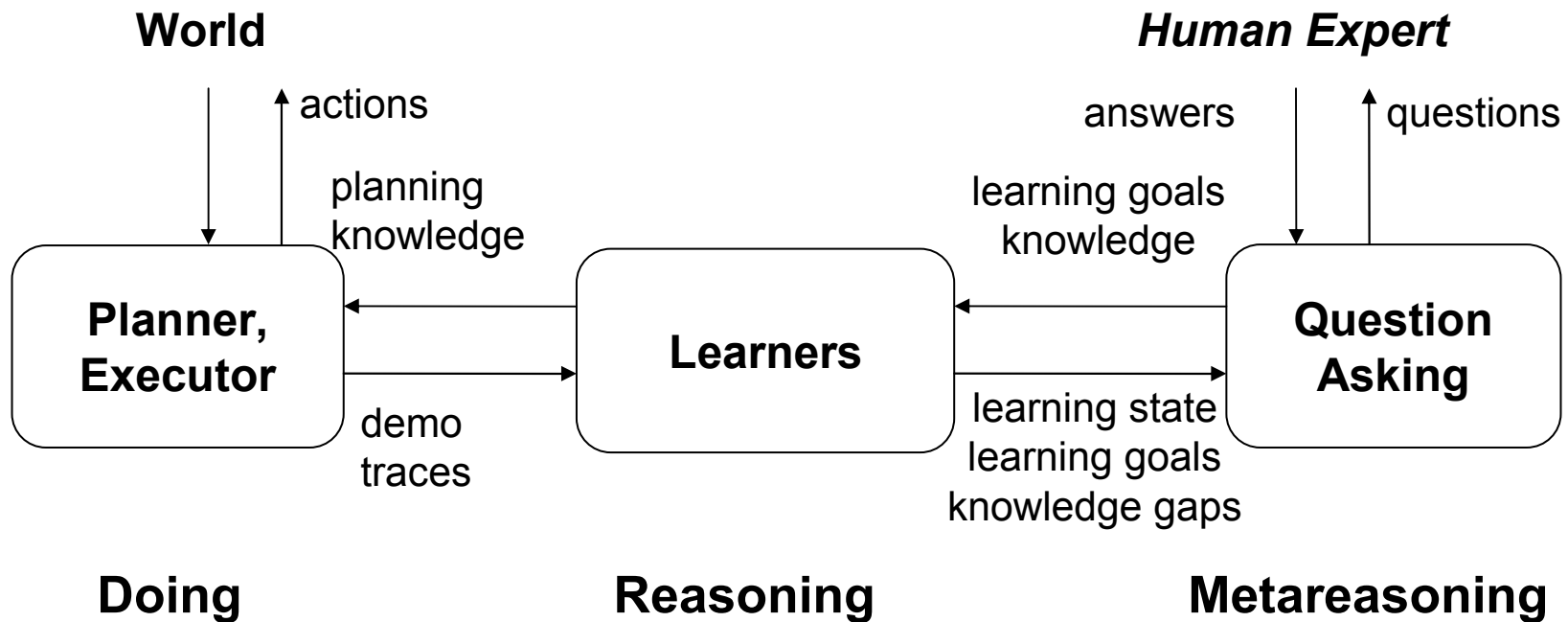
**Goal:** improve learning performance through system-initiated question asking

**Approach:**

1. define question catalog to inform learning by demo
2. develop question models and representations
3. explore question asking strategies



# Why Metareasoning?





# Question Asking Phases



## 1. Question Nomination

- Generation of questions to inform learning

## 2. Question Selection

- Choosing from among nominated questions

## 3. Question Posing

- Determine timing of question asking



# Question Catalog



## Question Categories

- workflow function and causality
  - decision alternatives and justifications
  - abstraction
  - limitations and failure
  - meta-questions
  - request for demonstration
- 
- Derived from consideration of task learning generally, supplemented by analysis of individual POIROT learning components



# Workflow Function and Causality



- Identify the function of trace elements and relations among them
  - Help understand the causal structure of the plan
  - *Which action(s) does  $A_i$  depend on?*
  - *Do  $P_j$  and  $P_k$  have to be the same value?*
  - *Does  $P_j$  determine  $P_k$ ?*
  - *Must  $A_i$  precede  $A_j$ ?*
  - *Is it desirable for  $A_i$  to precede  $A_j$ ?*



# Decision Alternatives



- Determine why certain decisions were made and what alternatives are possible.
  - Important for creating learned procedures that can adapt to execution in new contexts.
  - *Could  $A_i$  be used as an alternative to  $A_j$  ?*
  - *What factors affected the choice of  $A_j$  ?*
  - *Could  $P_i$  be used as an alternative to  $P_j$  in  $A_k$ ?*



# Abstraction



- Determine how to generalize the trace into higher-level constructs
  - iterations and methods
  - *Should  $\{A_i, \dots, A_j\}$  be generalized into a method?*
  - *What defines the domain of iteration for actions  $A_j$  through  $A_{j+k}$ ?*
  - *Is there a preferred order for processing elements in an iteration?*



# Limitations and Failures



- Understand limitations on the viability and desirability of the given trace
- Understands causes and possible solutions to failures that result when workflows are executed.
  - *Under what conditions would  $A_i$  fail?*
  - *Would this plan work if condition  $C$  did not hold?*
  - *Which conditions contributed to the failure of  $A_j$ ?*



# Meta-Questions



- Focus on *how to learn*, rather than the performance knowledge being learned
  - How to frame the learning problem (e.g., determining appropriate learning biases)
  - Priorities for the learning process.
- *Is there a preference function to determine the choice of  $P_i$ ?*
- *Given a set of conflicting hypotheses, what criteria should be used to analyze them?*



# Question Selection



## Considerations:

1. Expert user supports question answering.
2. Answering questions imposes a burden on the user.
3. Question asking should inform learning, not replace it.
4. Individual questions contribute different levels of value to the learning process, have different burden levels.
  - Is *<attr>* relevant when choosing *<param>* for *<action>*?
  - Is *<attr1>* more important than *<attr2>* when choosing *<param>* for *<action>*?
  - Which attributes in  $\{<attr1>, <attr2>, \dots\}$  are relevant when choosing the *<param>* for *<action>*?

⇒ Selection grounded in Cost and Utility models



# Question Cost



- Approximate the cognitive burden to the expert in answering the question
  - *FormatCost(q)*: measure of the complexity of the question structure
    - i.e., yes/no < single selection < multiple selection < demonstration
  - *GroundednessCost(q)*: questions grounded in trace will be easier to answer than hypotheticals

## Defn of Question Cost:

$$Cost(q) = w_F \times FormatCost(q) + w_G \times GroundednessCost(q)$$

$$w_F + w_G = 1$$



# Question Utility



- *BaseUtility* of a question determined by question nominators
- Overall utility computation needs to:
  - normalize across learners
  - consider relationship of questions to learning goals
  - account for multiple learners benefiting from the answer to a given question

## Defn of Question Utility:

$$Utility(q) = \sum_{l \in L} w_l \times Utility_l(q, l) \quad \text{where} \quad \sum w_l = 1$$

$$Utility_l(q) = w_B \times BaseUtility_l(q) + w_G \times GoalUtility_l(q)$$

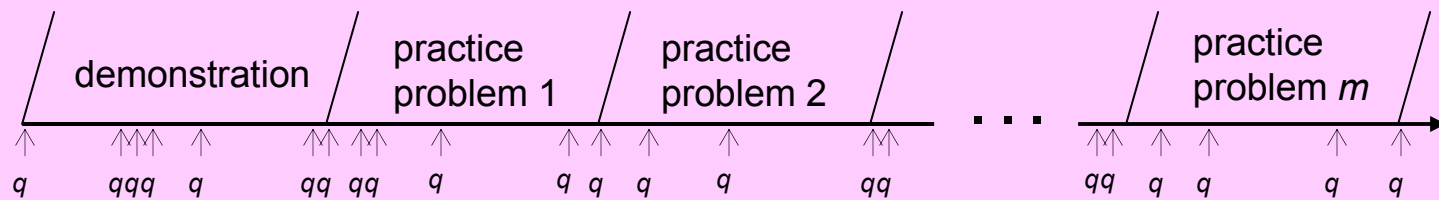
$$w_B + w_G = 1$$



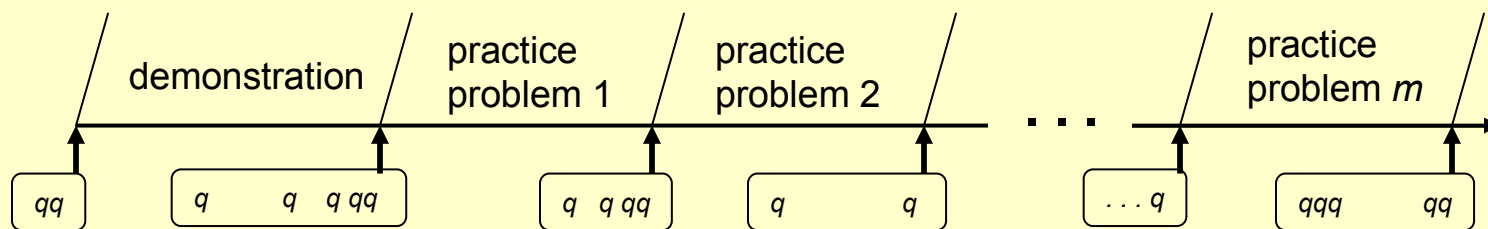
# Question Asking Strategies



**Objective:** Investigate impact of different question asking strategies on learning performance



**Asynchronous Selection:** evaluate questions as they are nominated



**Synchronous Selection:** consider questions at one or more set points



# Synchronous Question Selection



- Given:
  - questions  $Q = \{q_1 \dots q_n\}$  with costs and utilities
  - budget  $B$
- Problem: find  $Q' \subseteq Q$  with  $Cost(Q') \leq B$  with maximal utility
  - equivalent to 0/1 *knapsack problem* (no question dependencies)
  - efficient dynamic programming approaches –  $O(nB)$





# Related Work: Learning



- Active Learning:
  - Focus to date on classification, emphasizing selection of additional training data for a human to label
- Goal-driven Learning:
  - Ram and Hunter (1992): explicit knowledge goals to capture gaps in the system's knowledge, with utility measure
  - Gil et al (EXPECT): exploits explicit representations of factual and problem-solving knowledge and their interdependencies to identify potential gaps or problems



# Related Work: Question Catalogs



Focused on **human** (not system) understanding:

## *A. Electromechanical design (Gruber & Russell 1995)*

- Focused on background knowledge for the design task and validation of requirements
- Hypothetical reasoning, choice justification, causal dependencies

## *B. Task execution (McGuinness et al. 2007)*

- *Focus on state and problem-solving context – not general problem-solving knowledge*
- *Causal structure*



# Status and Future Work



## Current:

- Initial QUAIL Prototype
- Linked to POIROT learning environment

## Next Step:

- Experimental analysis of synchronous strategy:
  - Different nomination models, utility models, selection strategies

## Longer Term:

- Synchronous vs Asynchronous strategies