Soar Technology
Thinking *inside* the box.

Toward a Hybrid Cultural Cognitive Architecture

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Soar Workshop

Problem Statement

- Human Behavior Models tend to "mirror" their American developers, not taking into account (among other things) the particular background/motivations of the person or groups we're modeling

- One big behavioral motivator in humans is *culture*
  - surface features (dress, architecture, language)
  - cognitive features (norms, values)
  - interactional features (organizational behavior, language use)

- Overall Goal: a "Cultural Cognitive Agent Architecture" used to build HBMs that exhibit behavior consistent with cultural influences
  (and what would Soar have to say about it?)

Approach: (Cultural) Schema Theory

- D'Andrade (1992); Quinn & Strauss (2001); others
  - From a cognitive anthropology perspective: culture has rich *knowledge-based* representations within an individual's cognition,
  - Affects cognition in various ways:
    - perception – what is this situation I'm in?
    - appraisal/emotion – how should I feel in this situation?
    - expectation – what should happen next?
    - action selection – what should I do in this situation?
  - Culture is *epiphenomenal* – falls out of cognition, schema theory

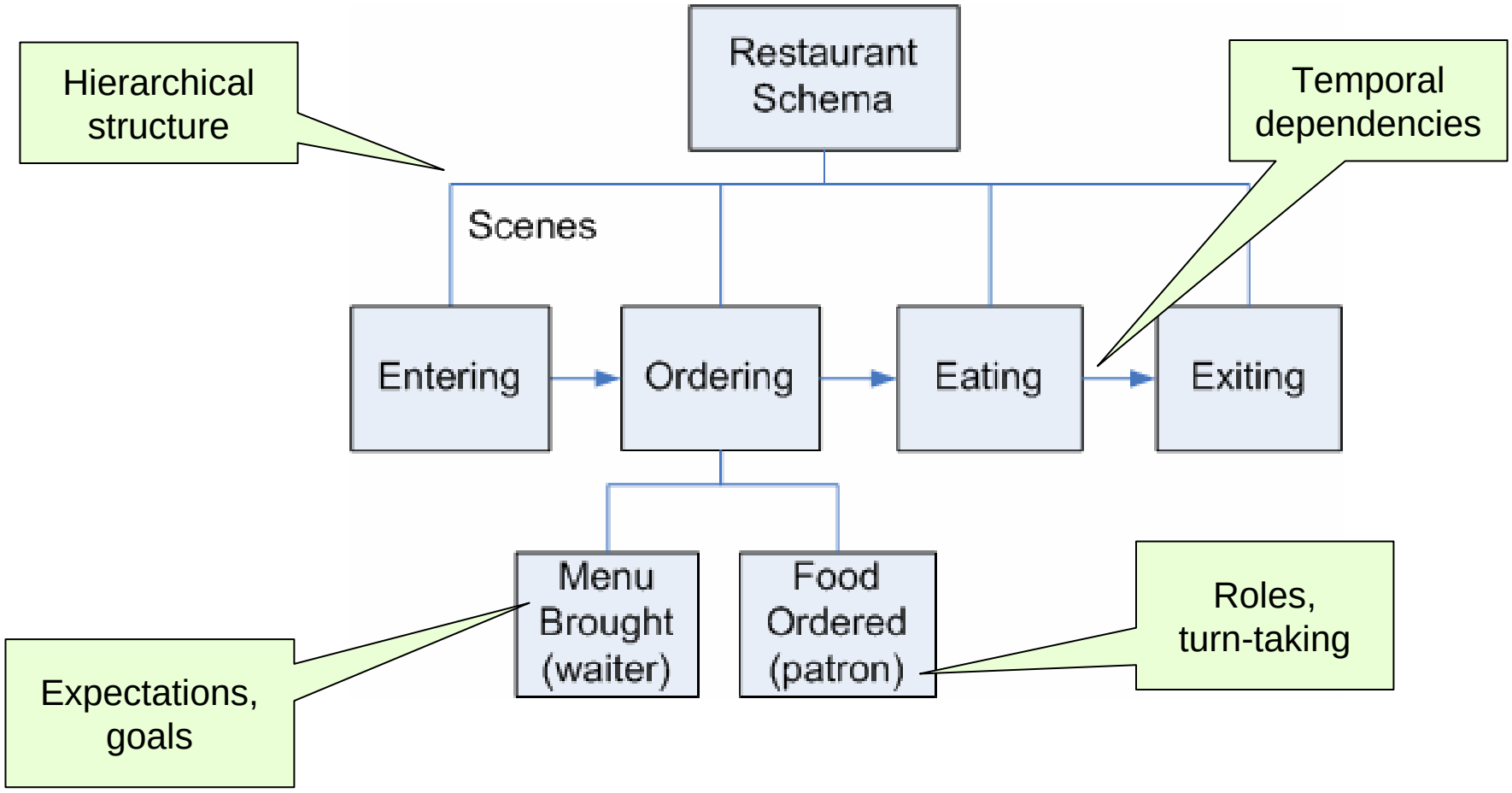
- Multitudes of cultural "stories" acquired over time that describe, for example,
  - everyday activities (going to a restaurant, personal interactions)
  - objects and their importance (monuments, sacred objects)
  - organizational structure (religious leader hierarchy)

(Cultural) Schema Theory

- Schema Properties (Bartlett; D'Andrade; Schank; Minsky; etc)
  - Serve as organized representations of knowledge about events, things, relationships, etc. (there are many kinds of schema)
  - Serve as processors of information, recognizing events or objects in the environment, and assigning meaning to those events or objects
  - Can be composed hierarchically – that is, the output interpretation of one schema is passed to another schema as input
  - Are learned through experience

- Cultural Schema
  - learned as part of the enculturation process deliberately (taught) or as a matter of experience
  - Patterns for recognition, understanding within cultural context
  - Patterns for appropriate/expected behavior ("norms")

Simple Example – Event Schema à la Schank



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Key Ideas

- Culture is about *knowledge*
  - inference, values, goals, motivations, beliefs, objects, meaning, perceptions
- Cultural “behaviors” are *epiphenomenal*
  - They “fall out” of normal cognition, where “content” of cognition is about norms, obligations, relationships, etc.
- Schema are
  - hierarchically organized
  - used for recognizing/understanding situation
  - used for driving behaviors and expectations

Background: Soar – Relevance

- Strengths of Soar w.r.t. Cultural Schema Theory
  - "Knowledge-Rich" BDI agent paradigm
    - goals, beliefs, etc.
  - Scalable Long-term Memory
    - lots of schema about lots of situations/things
  - Relevance-based memory activation
    - if rule matches situation, new knowledge is activated
  - Automatic and Deliberative Reasoning
    - mixed behavior – memory retrieval is automatic; choice/conflict requires deliberation
  - General Graph-based working memory
    - can be used to represent schema

Other bits: Activation and Appraisal Theory

- Schema Activation:
  - Key aspect of schema theory is “schema as processor”
  - Activation serves to:
    - determine relevance of events
    - manage competing situational assessments
    - manage conflict between goals/actions

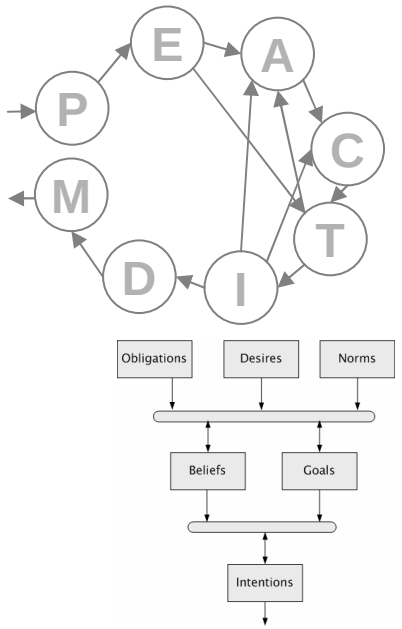
- Appraisal Theory:
  - observed events are appraised with respect to one’s goals and expectations
  - appraisals generate emotions
  - emotions moderate behavior (e.g., action selection for coping strategies)

  - **Included here as a way to generate variable behavior**

Knowledge-Based Cultural Cognitive Architecture

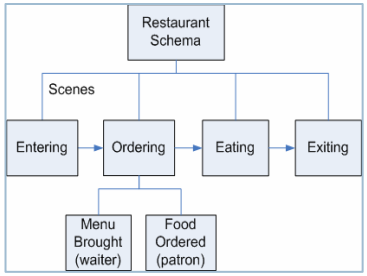
Soar Architecture

Information Processing
Deliberative Decision-Making
Short-Term Memory
Associative Long-Term Memory
PEACTIDM Theory
Beliefs-Desires-Intents Theory



Knowledge-Based Cultural Cognitive Architecture (with Appraisal/Emotion)

Event Schema



New Knowledge Representations:
- **Hierarchical Schema**
- **Events**

New Processes:
- **Activation & Decay**
- **Schema Recognition**
- **Goal Generation**
- **Event Appraisal**
- **Emotion Generation**
- **Emotion-based Coping**

Cultural Schema Theory (D'Andrade, et al.)
Universal Contingency Theory (Ellsworth, et al)
Appraisal Theory (Sherer, Ortony, etc…)

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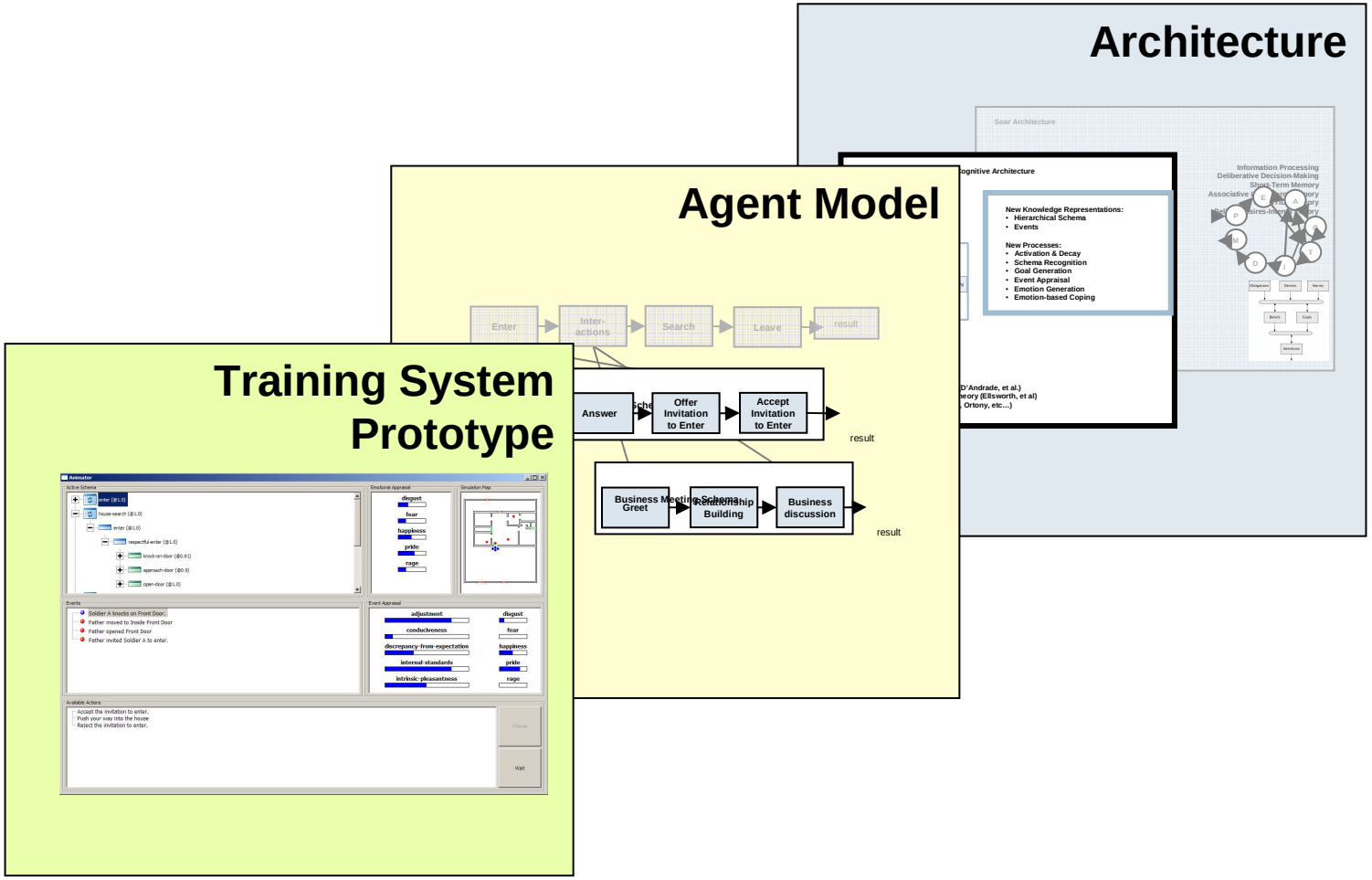
High-level Overview



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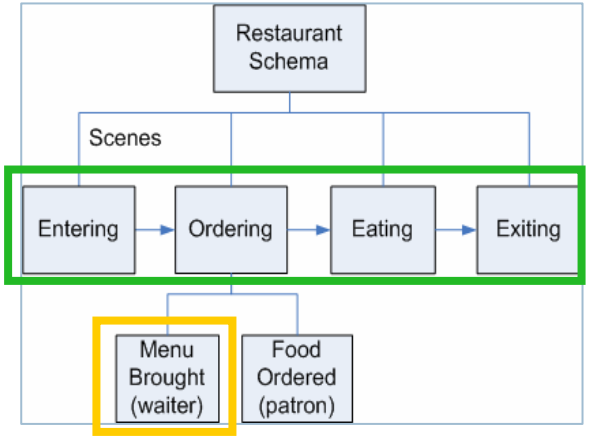
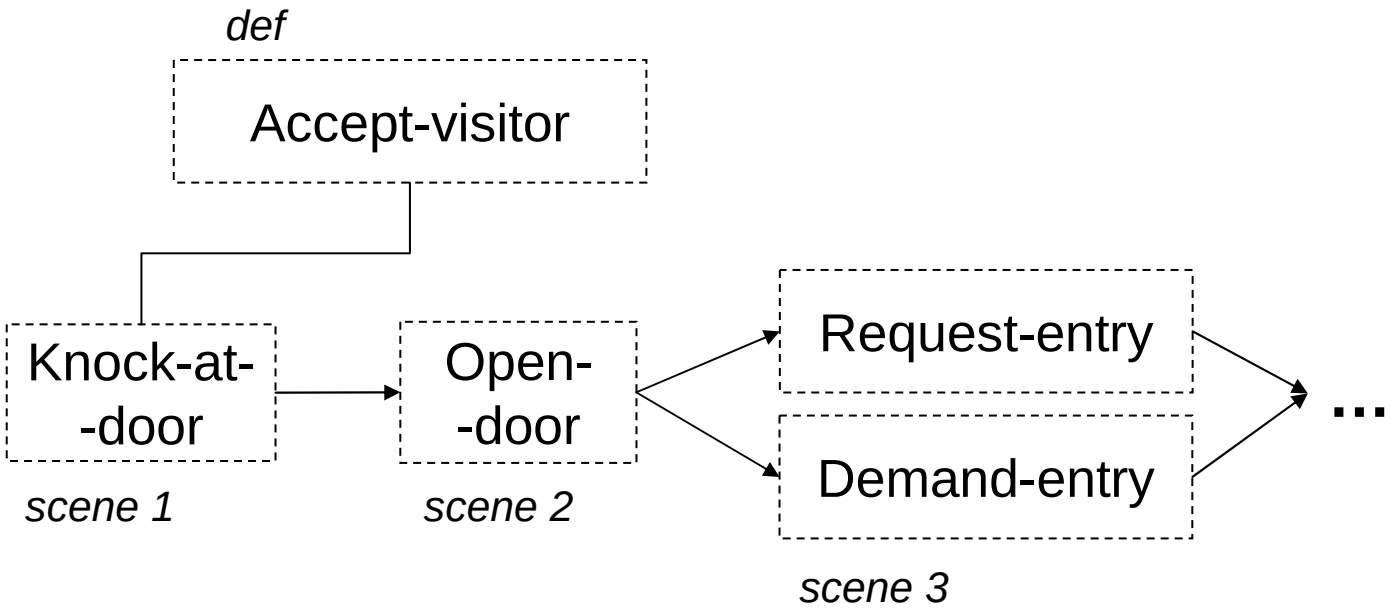
Schema Definitions



- "Schema Leaf Nodes"
  - Matches a single concrete event ("trigger")
  - Activation conditions determining how well concrete actions fit the schema in the current context
    - "A approaches B" ==> "A confronts B" if A looks angry
- "Schema"
  - A sequence of scenes
    - Each scene can have multiple realizations, or "expansions", in terms of lower-level schemas
    - Expansions have their own activation conditions
  - Scenes may be optional
- Defined in terms of abstract roles, which will be bound to concrete entities when a schema is activated

Schema



- Defined recursively in terms of lower-order schemas, which constitute “scenes”

Event Representation

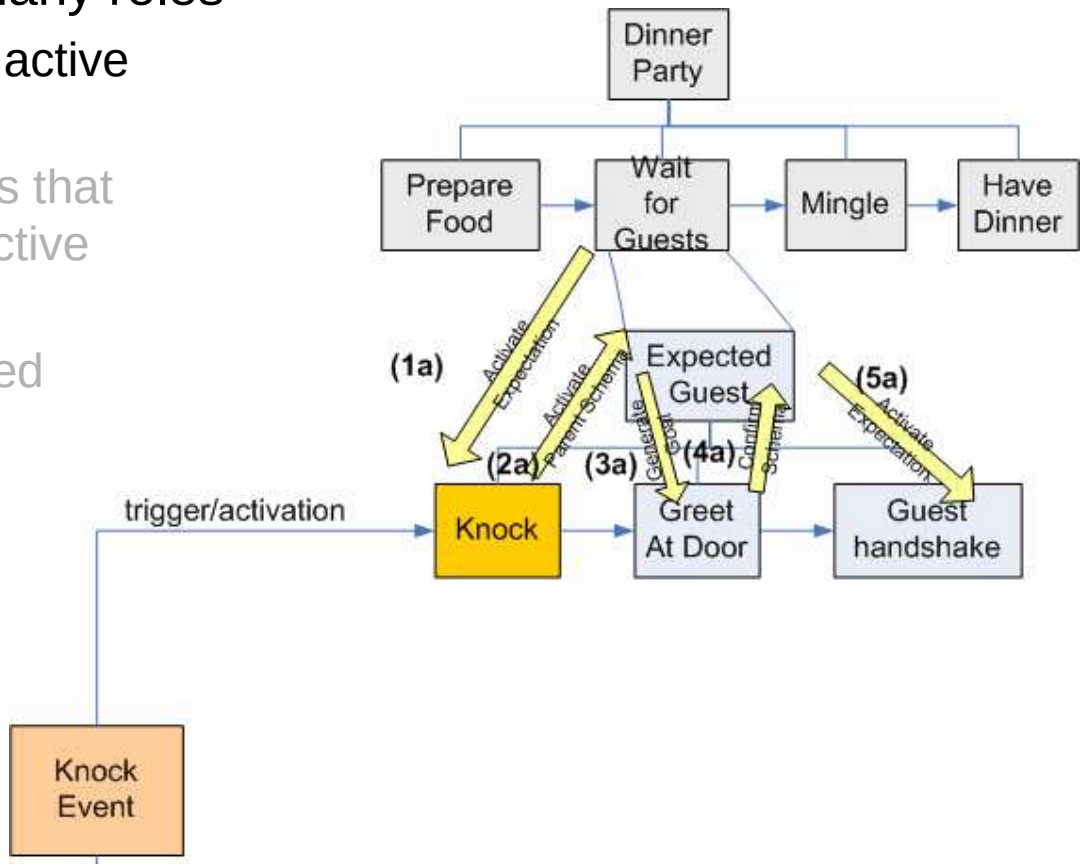
- Defined in terms of their thematic roles
  - Agent
  - Experiencer
  - Theme
  - Type
  - …
- Events are used to:
  - Activate new (event) schemas
  - Advance existing active (script) schemas
  - Generate appraisals that affect agents' emotions

Thematic Role	Definition
Agent	The volitional causer of an event
Experiencer	The experience of an event
Force	The non-volitional causer of the event
Theme	The participant most directly affected by an event
Result	The end product of an event
Content	The proposition or content of a propositional event
Instrument	An instrument used in an event
Beneficiary	The beneficiary of an event
Source	The origin of the object of a transfer event
Goal	The destination of an object of a transfer event

(Martin & Jurafsky, Speech & Language Processing, 2000)

Overall Flow

- Incoming events play many roles
  - Advancing/confirming active schemas
  - Creating new schemas that interrupt the current active schema
  - Reactivating suspended schemas



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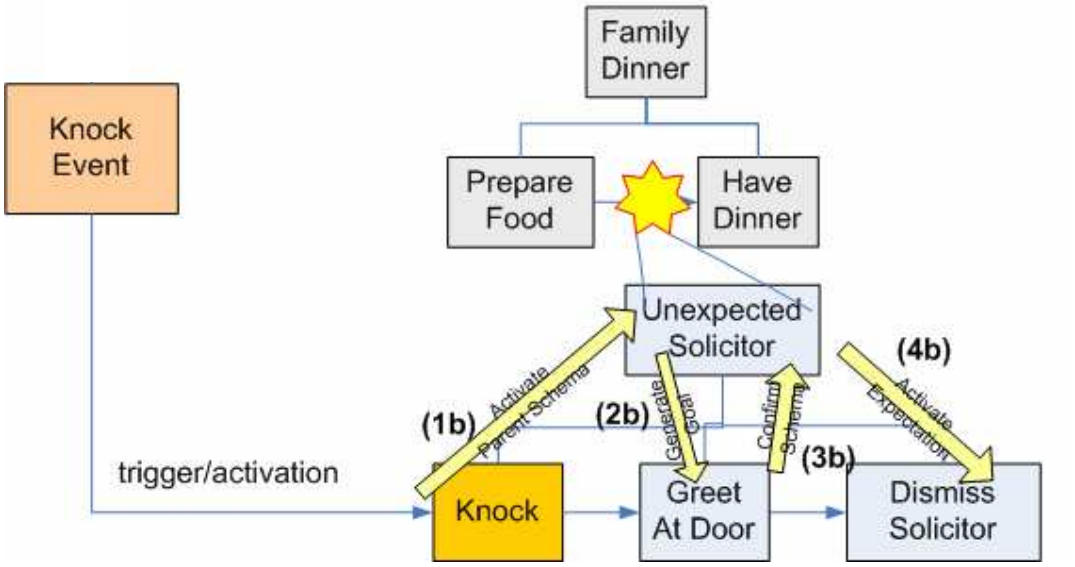

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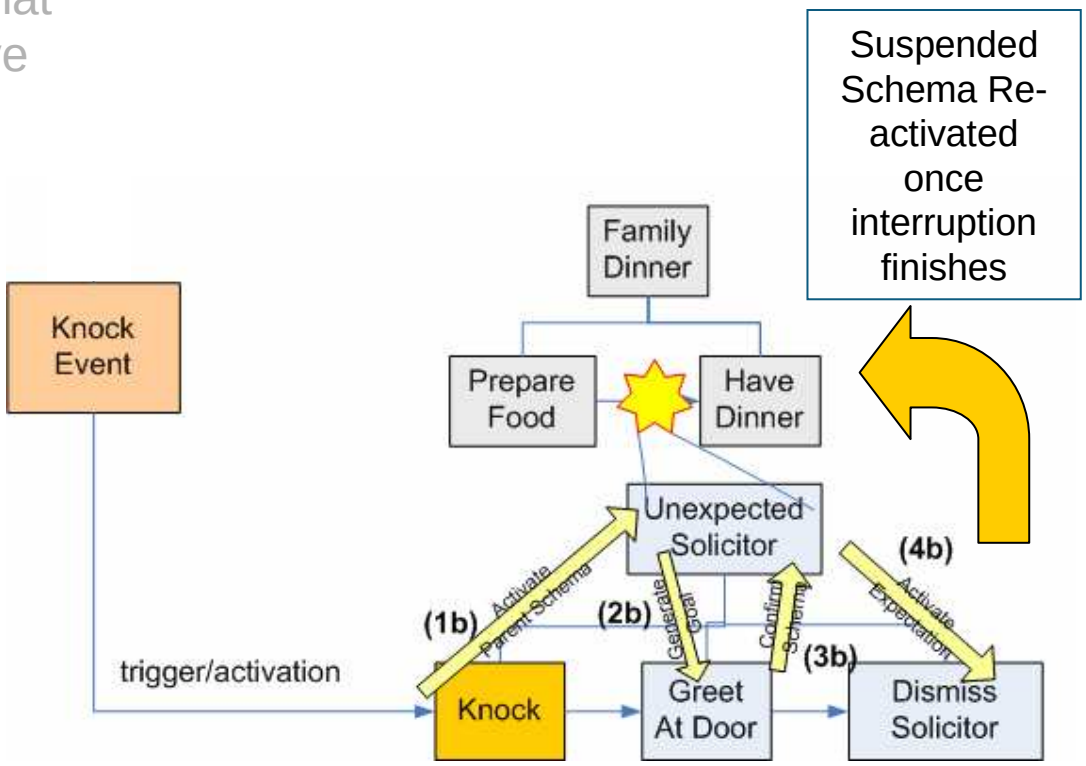

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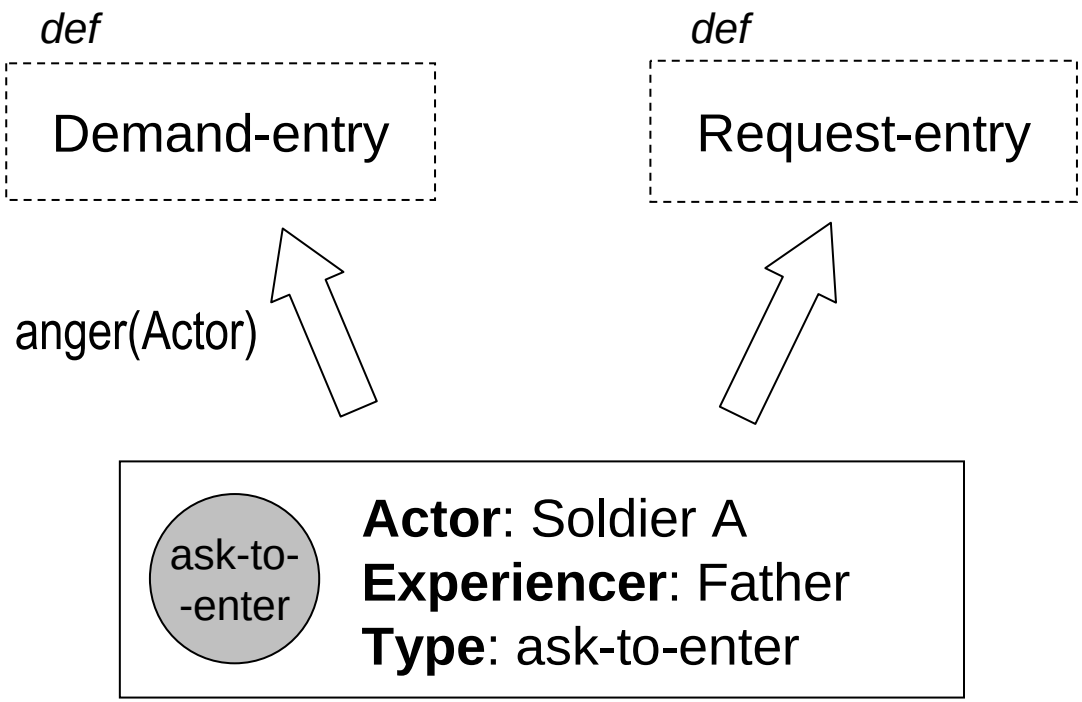
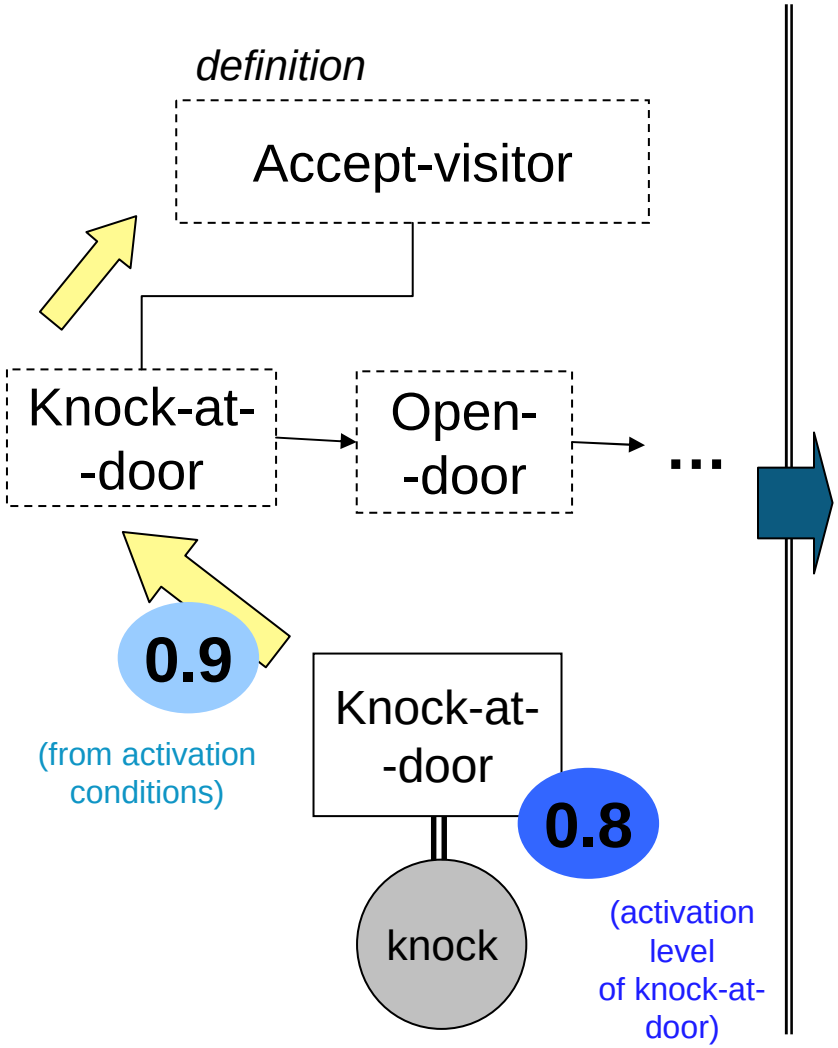
Schema Activation

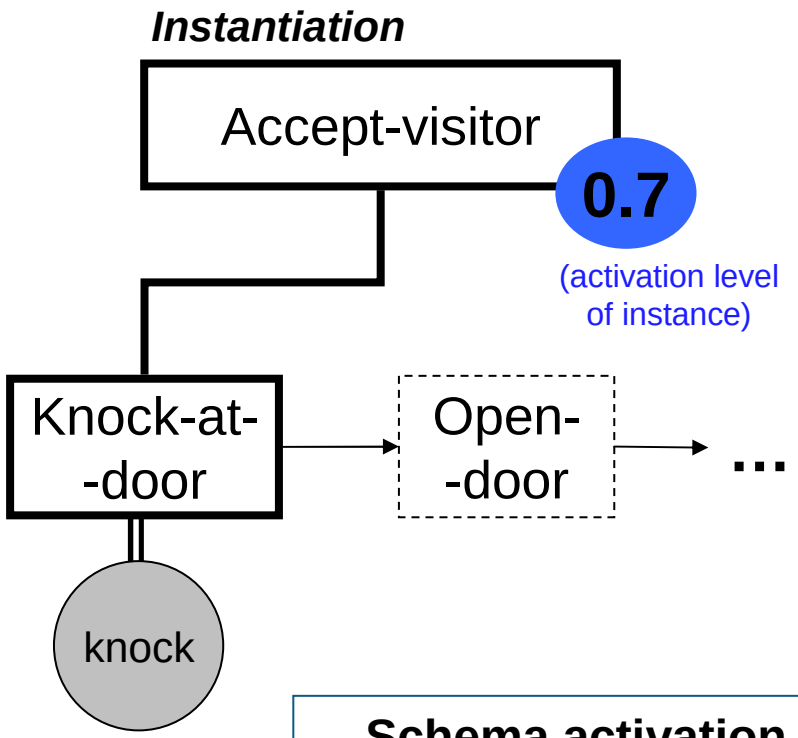
- Single event can create multiple active schemas
  - Activation levels may differ based on activation conditions
  - Role bindings may differ



Event Processing & Schema Activation



- Recursive activation terminates at the highest-level schema:

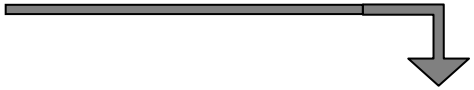


Schema activation is measure of likelihood that a schema represents the plan of other player

Schema Activation Conditions

- Activation is controlled by qualitative and quantitative tests of role entities' attributes
- Conditions are represented in XML
  - These are automatically translated into production rules

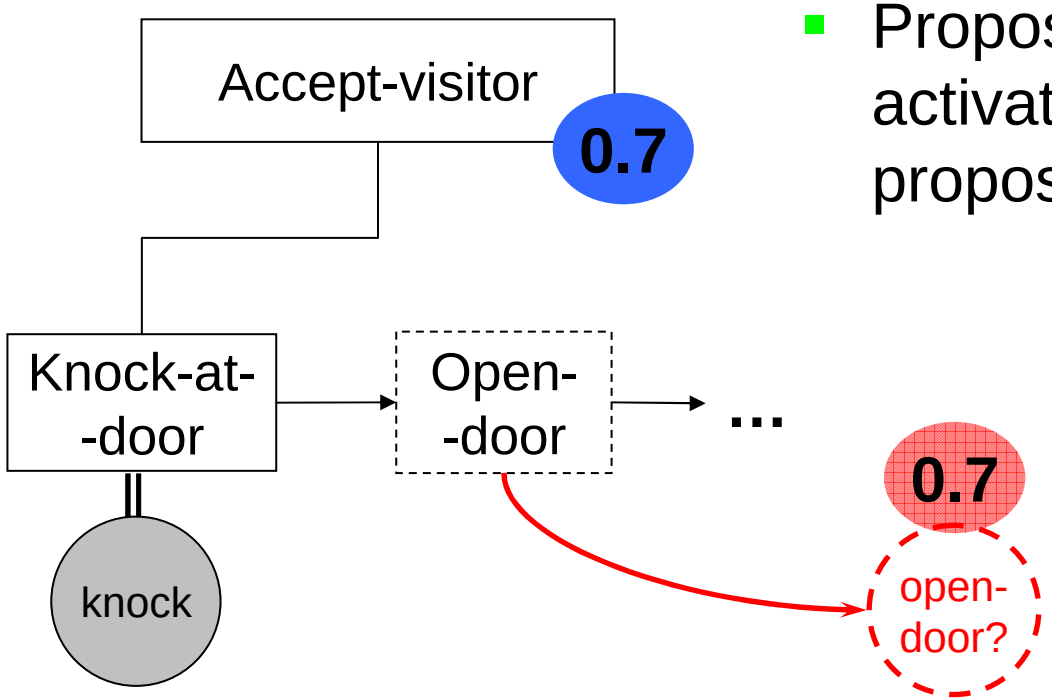
```
<activation-condition>
   <A>
      <isa>Person</isa>
   </A>
   <B>
      <isa>Person</isa>
      <rage>
         <greater-than>0.5</greater-than>
      </rage>
   </B>
</activation-condition>
<activation-condition>
   <relevance type='double'>0.5</relevance>
   <B>
      <knows>A</knows>
   </B>
</activation-condition>
```



```
sp "tst-TT
 (state <s> ^universe <universe>
            ^binding-sets.tst <bindings>)
 (<universe> ^<--A-name> <--A-entity>
             ^<--B-name> <--B-entity>)
 (<--A-entity> ^isa Person)
 (<--B-entity> ^rage > 0.5
               ^knows <--A-name>)
-->
 (<bindings> ^binding <new-binding>)
 (<new-binding> ^activation-level 1.5
                ^A <--A-name>
                ^B <--B-name>)
"
```

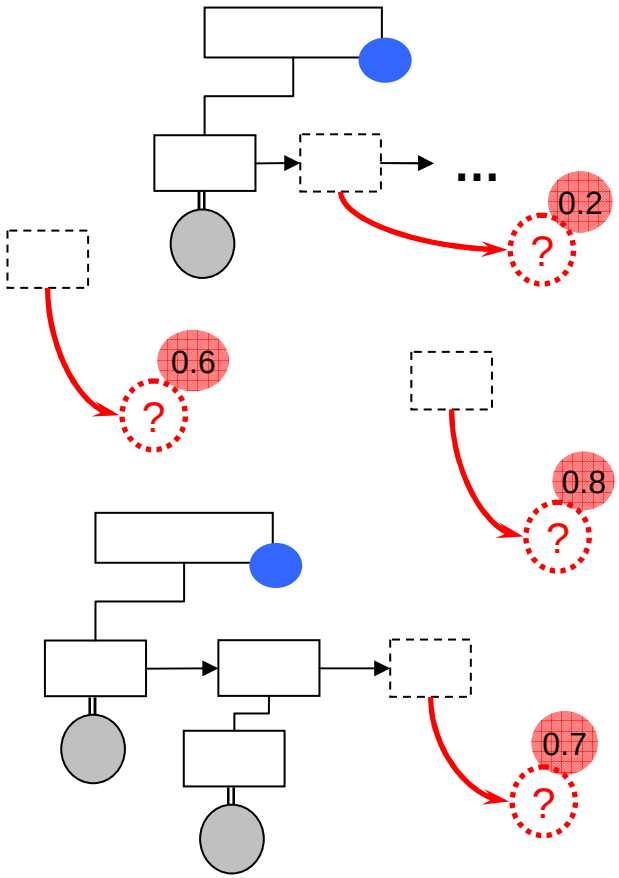
Agent Goal Creation

- When an active script's next scene begins with an event that the agent can cause to occur, the agent considers taking an appropriate action



- Proposal is weighted by activation level of proposing schema

Agent Goal Creation

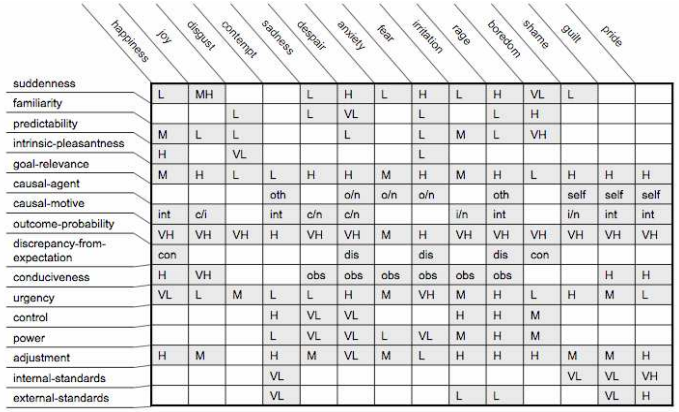


- Some schemas may also begin spontaneously, weighted only by their activation conditions
- Among the proposed actions, the agent currently prefers those with the highest calculated activation level… i.e., agent follows script that it *believes* is happening
- If scripts were annotated with results, agent could bias selection toward higher-level goals, i.e., follow the script that it *wants* to be happening

Event Appraisal

- Appraisal dimensions are mapped to emotional dimensions through a simple matrix multiplication

	happiness	disgust	fear	rage	pride
suddenness			H	MH	
intrinsic-pleasantness	H	VL	L		
discrepancy-from-expectation	L		MH	MH	
conduciveness	H	L	L	L	H
urgency	L	L	H	H	
adjustment	H		L		MH
internal-standards		VL		L	H



	happiness	joy	disgust	contempt	sadness	despair	anxiety	fear	irritation	rage	boredom	shame	guilt	pride
suddenness	L	MH			L	H	L	H	L	H	VL	L		
familiarity			L		L	VL		L		L	H			
predictability	M	L	L			L		L	M	L	VH			
intrinsic-pleasantness	H		VL					L						
goal-relevance	M	H	L	L	H	H	M	H	M	H	L	H	H	H
causal-agent				oth		o/n	o/n	o/n		oth		self	self	self
causal-motive	int	c/i		int	c/n	c/n			i/n	int		i/n	int	int
outcome-probability	VH	VH	VH	H	VH	VH	M	H	VH	VH	VH	VH	VH	VH
discrepancy-from-expectation	con					dis		dis		dis	con			
conduciveness	H	VH			obs	obs	obs	obs	obs	obs			H	H
urgency	VL	L	M	L	L	H	M	VH	M	H	L	H	M	L
control				H	VL	VL			H	H	M			
power				L	VL	VL	L	VL	M	H	M			
adjustment	H	M		H	M	VL	M	L	H	H	H	M	M	H
internal-standards				VL								VL	VL	VH
external-standards				VL					L	L			VL	H

Simplified from original appraisal matrix [Scherer]

```
VL = Very low =  -3
L  = Low      =  -1
M  = Medium   =   0
MH = Med high =  +1
H  = High     =  +3
```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Event Appraisal

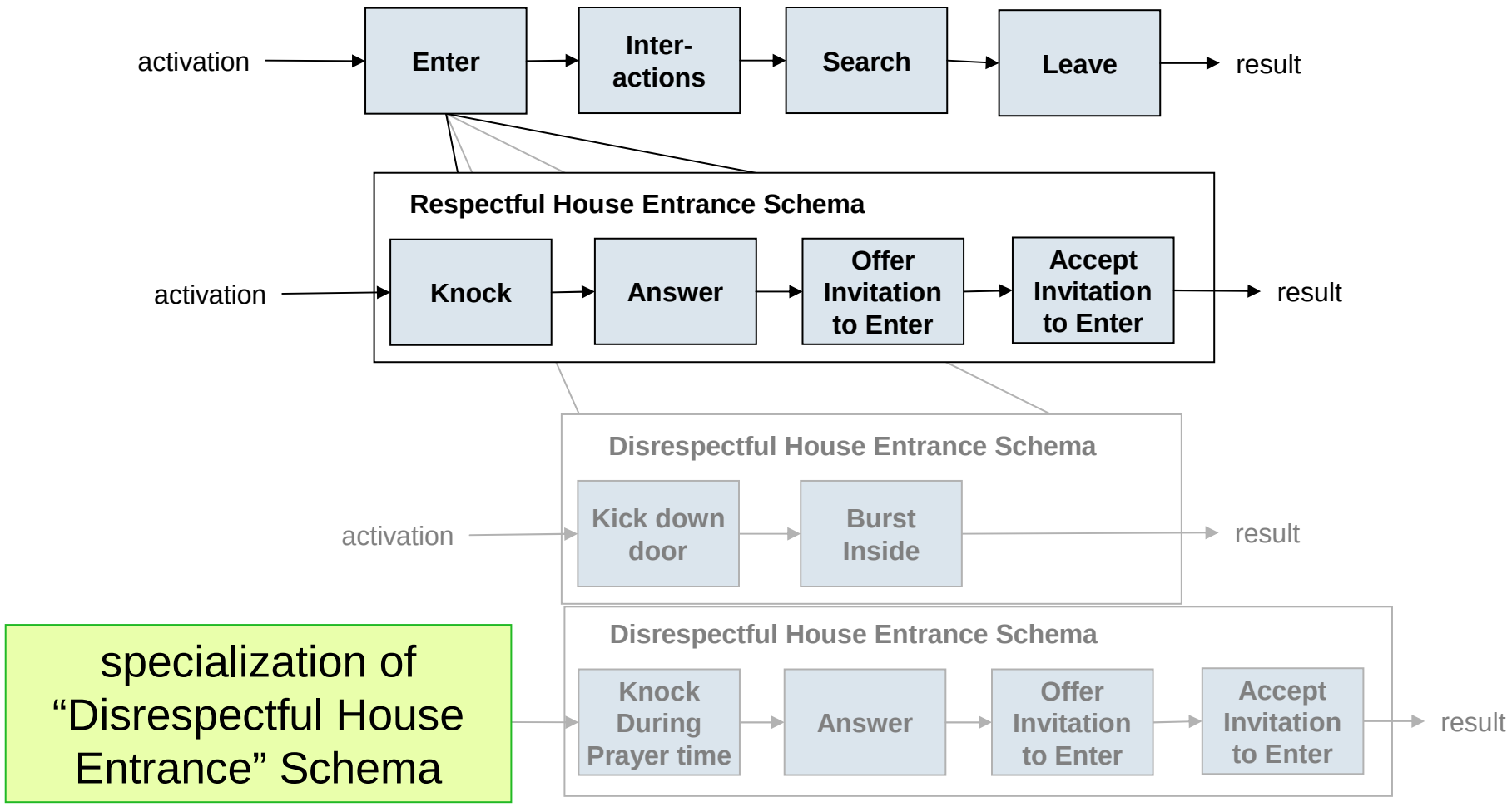
- Individual events are “appraised” (assigned values for appraisal dimensions) based on a lookup table

```
<kick-down-door>
   <suddenness> Very high </suddenness>
   <pleasantness> Very low </pleasantness>
   <discrepancy> High </discrepancy>
   <conduciveness> Low </conduciveness>
   <urgency> High </urgency>
   <adjustment> Low </adjustment>
   <internal-standards> Low </internal-
standards>
</kick-down-door>
```

Use Case: House to House Search

- Training context: training soldiers to do house-to-house searches
  - **Training Goal:** Understand how Iraqis might respond to different ways of doing search, interactions with Iraqis (kick in door, knock, talk to head of household, etc.)
  - **Modeling Goal:** “Culturally Representative” model of Head of Household in interactions/responses to Blue forces

Example: House Search Schema



specialization of "Disrespectful House Entrance" Schema

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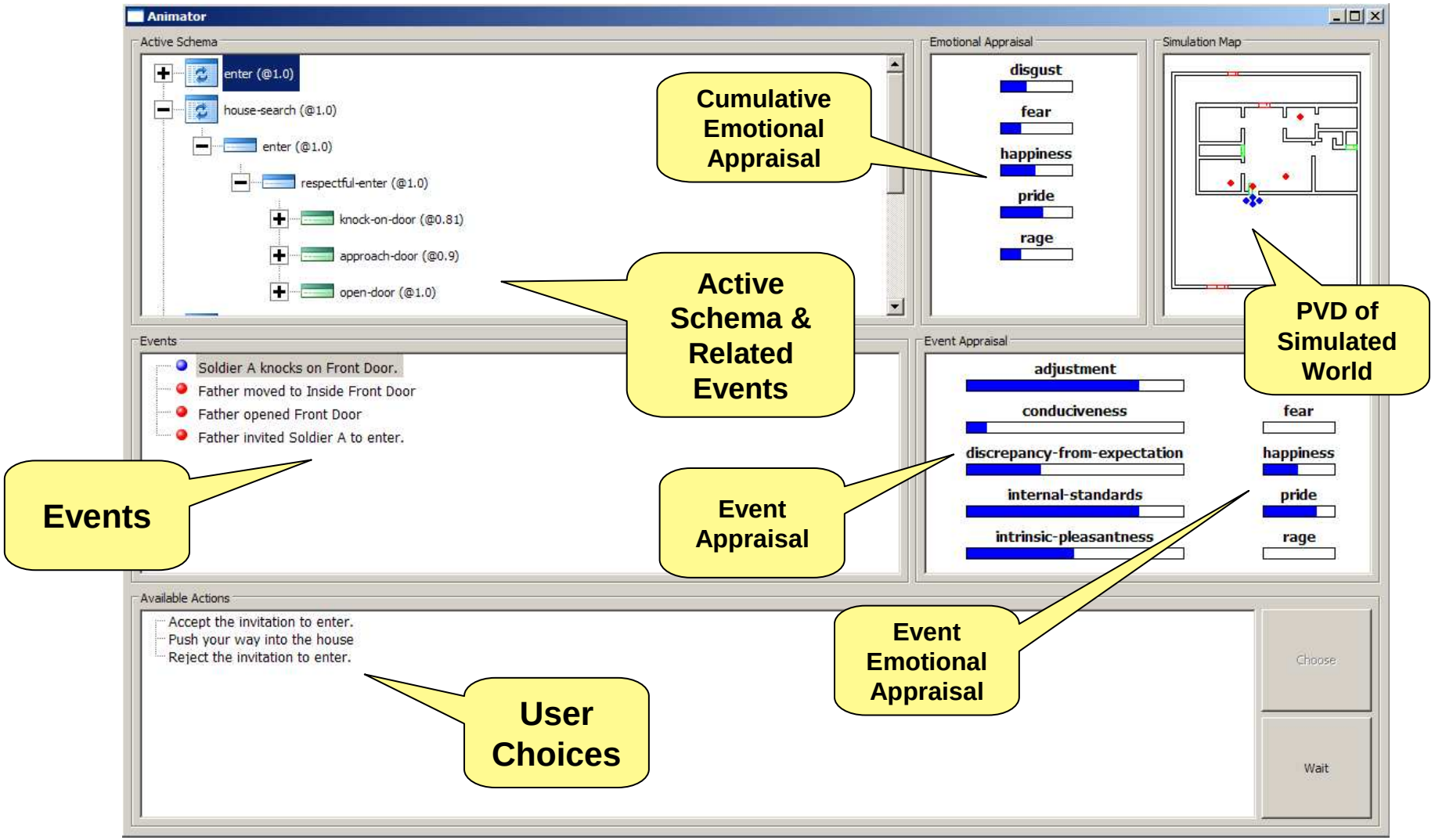
Demonstrator Screenshot



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Evaluation: Nuggets & Coal

- Nuggets:
  - Reasonable first pass at representing cultural behavior as schema
    - plays to the strengths of the Soar architecture
  - Essentially an implementation of symbolic plan recognition
  - Implemented “Choose your own adventure” training prototype
  - Interface to see what agent is “feeling”/”thinking” about

- Coal:
  - Very preliminary
    - only deal with Event Schema for now
    - little/no deliberation about action selection/conflict resolution
  - Activation process is ad hoc – could be more robust
    - Chong/Nuxoll work? Bayesian?
  - Appraisal/Emotion model very weak
    - Pull in Marinier work? Other emotion models?