Soar Technology
Thinking *inside* the box.

SOAR26:
SPatial And Temporal Reasoning (SPAT-R)

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What is Spatial/Temporal Reasoning?

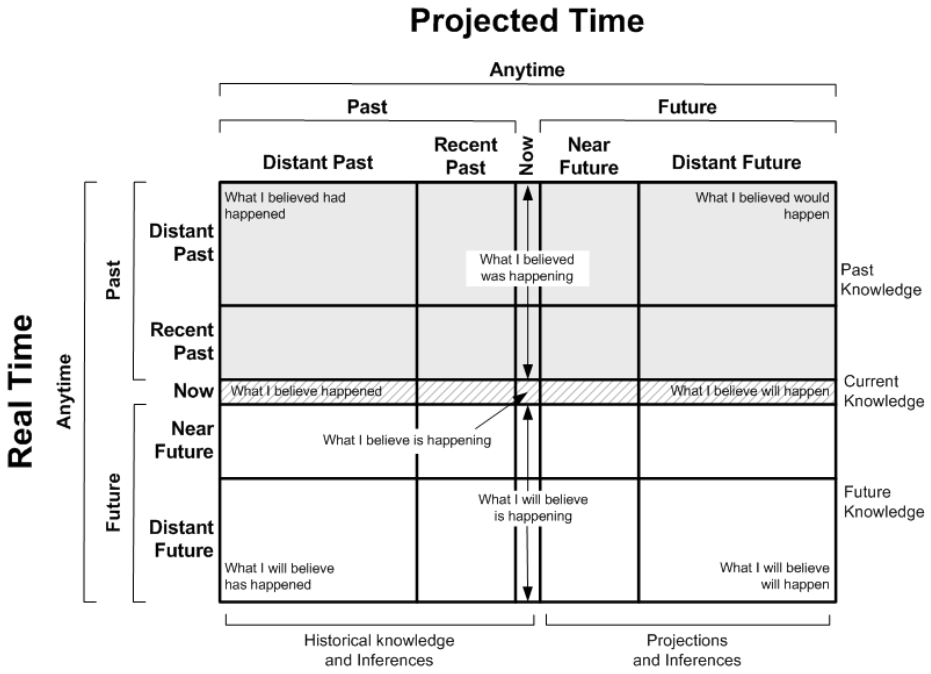
- Humans reason about space and time through both *quantitative* and *qualitative* assertions and relationships
  - qualitative
    - *"that object is closer to me than this object"*
    - *"I am inside this room"*
    - *"that event occurred a long time ago"*
  - quantitative
    - *"that event happened 6 minutes and 30 seconds ago"*
    - *"My current position is (23.2, 100.4)*
    - *"object B lies 6 meters closer to me than object C"*

What is Spatial/Temporal Reasoning? (cont'd)

- Humans use these assertions to make decisions in their environment
- Spatial and Temporal Reasoning are the **processes by which** these assertions (or beliefs, in some cases) are derived or calculated
- **To be effective in real-time environments, cognitive agents must also have the capability to generate and use assertions related to space and time**

What is the SPAT-R project?

- SPAT-R is the SPatial And Temporal Reasoning projec
- Created as a spinoff of the BINAH project
- Focused on developing re-usable spatial & temporal reasoning capability (as previously defined) for Soar (and other) agents



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How can SPAT-R help agents?

- Provides a general spatial, temporal, and spatio-temporal reasoning representation and inference capability
- Permits the leveraging of spatio-temporal reasoning knowledge from one domain application to another
- Forms a common metaphor for spatio-temporal reasoning, lowering the barrier for behavior-developer ramp-up

Why are we working on SPAT-R right now? (Scientific Motivations)

- Spatial and temporal reasoning are current, relevant, and useful
- Plenty of room for new scientific research in this area
- Plenty of opportunities for funded research efforts to extend the SPAT-R appliance

Why is SPAT-R better than the alternative?

- Cognitive rule-based systems are not generally efficient at mathematical calculation
- Majority of mathematical calculation in Soar agents often supports spatial and/or temporal reasoning
- Extensive mathematical calculations can make cognitive agents
  - **Difficult** to develop *(hard to do in Soar)*
  - **Brittle** in execution *(more opportunity for failure)*
  - **Expensive** in computation *(many steps required)*
- SPAT-R appliance moves most calculation out of the Soar agent but makes it easy for a Soar agent to use
  - **Easier** to develop *(it is a re-usable appliance)*
  - **Robust** in execution *(simple representation)*
  - **Efficient** in computation *(complex calculation offloaded)*

What can SPAT-R do for applications?

- Powerful tool for agent development
  - Agents frequently have to reason about space and time as preconditions to actions and decisions
  - The SPAT-R tool will provide developers with a tool to generate these preconditions, so that they can spend more time on domain-specific development
- Isolating spatial reasoning from the rest of the agent has several benefits
  - Supports rigorous engineering while avoiding the Soar kernel's data overhead
  - Enhances code reuse & portability
- We often confront the question of how to interface symbolic to non-symbolic reasoning & memory
- Our emerging customer base for C^3 agents and systems deals a lot with strategy and tactics

What is the current 2006 scope of SPAT-R?

- Spatial Reasoning (IN SCOPE)
  - General spatial reasoning capability not available
  - Almost every project needs, but rebuilds from scratch
  - A reusable general purpose
- Temporal Reasoning (**NOT** IN SCOPE)
  - Agent-based temporal reasoning module already investigated on BINAH project
- Spatio-Temporal Reasoning (**NOT** IN SCOPE)
  - Future Work

How does SPAT-R appliance work?

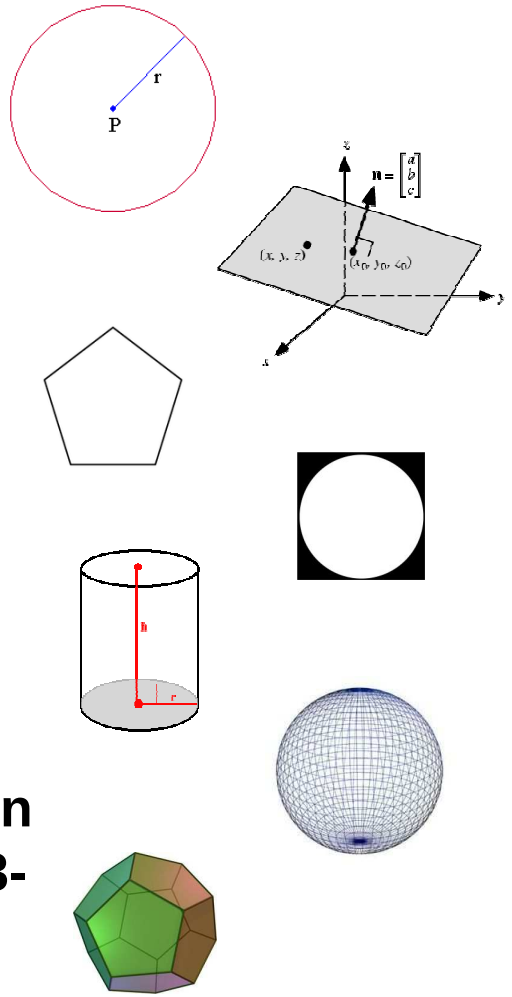
- Agent architecture agnostic spatial operation toolset
- Built on top of SoarTech's "information management system"
- Accessible to Soar agents as an ATE plugin
- Input/Output-link interface
  - Region definition, operator definition, queries
- Snapshot Query/Response and Persistent Query capabilities

SPAT-R Interface Elements

- Region Definition
  - qualitative spatial region definitions with frame-of-reference, dimensionality, and dimensional projection
- Comparison Operator Definition
  - most frequent operations on regions will be intersection testing “is region X enclosed by region Y?”
- Relationship queries
  - inside/outside, above/below

SPAT-R Region Definition

- **0-D/1-D 'Region' Types**
  - **Points, Route Segments, Routes**
- **2-D Region Types**
  - **Circular regions, polygonal regions, composite 2-D regions**
- **3-D Region Types**
  - **Spherical regions, cylindrical regions, N-gon regions, hyper-polygonal regions, generic 3-D regions, composite 3-D regions**



Comparison Operator Definition

- Comparison Operator Definition
  - most frequent operations on regions will be intersection testing “is region X enclosed by region Y?”
  - intersection tests include region transformation by dimensionality
    - i.e., asking a 2-D question from the reference of a plane whether a point is within a region which was originally defined as a 3-D sphere but is projected as a circle for the purposes of generating the result set

X in Y?	**X is 0-d**	**X is 1-d**	**X is 2-d**	**X is 3-d**
Y is 0-d	X == Y	N/A	N/A	N/A
Y is 1-d	X < Y	X < Y	N/A	N/A
Y is 2-d	X < Y	X < Y	X < Y	N/A
Y is 3-d	X < Y	X < Y	X < Y	X < Y

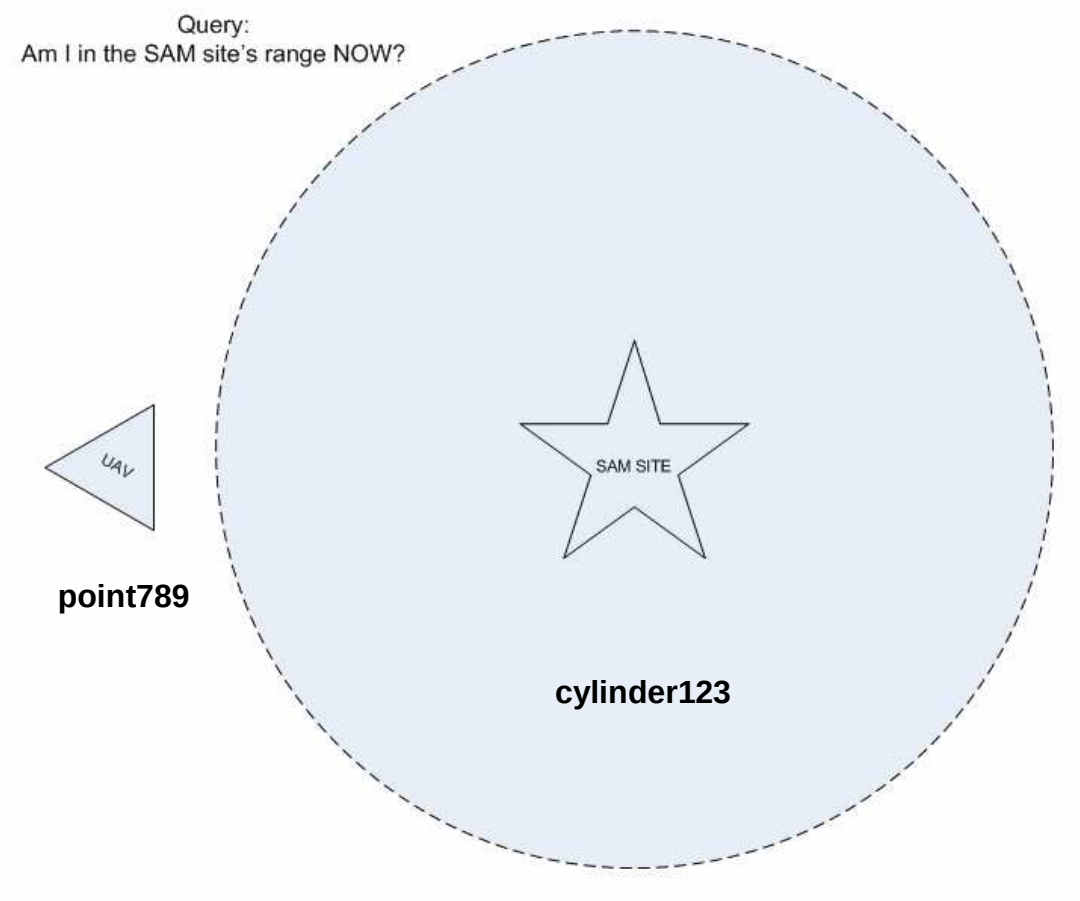
Relationship Queries

- Domain-specific
  - “is the **aircraft** in my **flight corridor**?”
  - “are any **enemies** on my **left flank**?”
- Composed from operator definitions
- Return those data elements which resolve as “true” (matching the query tests) in a result set

Example Use-Case: “Am I in danger?”

- Regions:
  - SAM site (type: 3-D cylinder)
    - ordered-triple center (x,y,z) scalar value radius
    - orientation unit vector (<x0,y0,z0>/|<x0,y0,z0>|)
    - scalar value height
  - aircraft (type: point)
    - ordered triple (x,y,z)
    - orientation unit vector (<x0,y0,z0>/|<x0,y0,z0>|)

^query
  ^comparison
    ^operator inside
    ^duration persistent-notify
    ^subject
      ^unique-id point789
    ^object
      ^unique-id cylinder123



What kinds of projects could benefit from SPAT-R?

- Airspace control:
  - dependent on spatial & temporal assertions
- Aviator behaviors:
  - Spatial understanding required in formation or route flying
- Intelligence analysis:
  - Spatial & temporal correlation of intelligence hypotheses
  - Spatial and temporal assertions made by the agent can be converted to graphical or textual notations displayed on the GUI
- C4ISR:
  - external planning & navigation systems require spatial/temporal assertions
- Pedagogic training systems:
  - Director needs real-time awareness of trainee's position and orientation relative to other objects and NPCs
  - Director is responsible for the proper timing of events in each training scenario

How could SPAT-R appliance help future work?

- Prevents re-invention of the wheel
  - Availability of a re-usable spatial & temporal reasoning capability (as previously defined) for Soar (and other) agents
- Additional feature at low cost
  - Permits the leveraging of spatio-temporal reasoning knowledge from one domain application to another
- Leverages well-considered representations and interfaces
  - Provides a general spatial, temporal, and spatio-temporal reasoning representation and inference capability
- Reduces resource mismatch risk
  - Forms a common metaphor for spatio-temporal reasoning, lowering the barrier for behavior-developer ramp-up

Nuggets & Coal

- NUGGETS:
  - We noted that an architectural change to Soar permitting direct access to arbitrary memory locations for designating input/output would be TREMENDOUSLY useful
  - We were able to leverage a number of existing Soar development tools (ATE, etc)
  - Many projects at SoarTech eager to use
  - First implementation to be finished in June
- COAL:
  - Known performance and scaling issues
- Coal for non-Soartech folks:
  - Requires ATE
  - Not currently available

Backup Slides

What have we accomplished?

- IR&D project initially approved - late November 2005
- Outreach requirement gathering from stakeholders - December 2005
- Project planning & “Internal 1st Stage Customer” (ISAT) defined –December 2005/January 2006
- Additional scientific & engineering resources brought on board - February 2006
- Created socialtext repository for team work products – February 2006
- Gathering results of initial scientific investigations - late February / early March 2006
- Appliance functionality & interface design – April/May 2006
- Initial Draft Implementation – May/June 2006