Multi-representational Architectures: Incorporating Visual Imagery

into a

Cognitive Architecture

Soar Visual Imagery (SVI)

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27th SOAR WORKSHOP

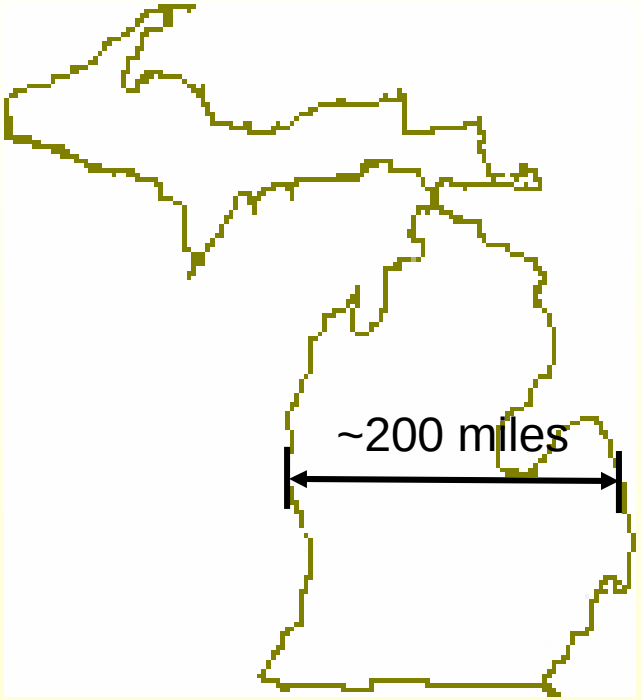
OUTLINE

- REVIEW
- CURRENT ARCHITECTURE (SVI)
- EXPERIMENTAL RESULTS
- FUTURE WORK

WHAT IS VISUAL IMAGERY?

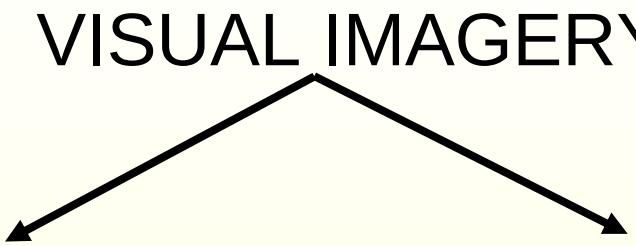
- What city is closer to Ann Arbor: South Bend, Indiana or Columbus, Ohio?

WHAT IS VISUAL IMAGERY



- **What is wider in the center: the lower peninsula of Michigan or Ohio?**

WHAT IS VISUAL IMAGERY?



VISUAL-SPATIAL

- Location, orientation
- Sentential, quantitative representations
- Linear algebra and computational geometry algorithms

VISUAL-DEPICTIVE

- Shape, color, topology, spatial properties
- Depictive, pixel-based representations
- Image algebra algorithms
  - ❑ Sentential/Algebraic algorithms
  - ❑ Depictive/Ordinal algorithms

MULTI-VISUAL REPRESENTATIONS

Representation	Processing	Uses	Example
Abstract symbols	Symbolic manipulation	Qualitative Visual & Spatial Reasoning	object(Mich) object(Ohio) south(Ohio,Mich) in(AA,Mich), sw(AA,Mich) center(Columbus, Ohio) etc.
Hybrid abstract and quantitative symbols	Sentential, algebraic manipulation	Quantitative Spatial Reasoning Intermediate Layer	Michigan shape: rectangle location: <10,20,0> AA shape: point location <20,2,0> Ohio shape: square location: <15,-5,0>
Iconic / Depictive symbols	Algebraic or Depictive manipulation	Visual Feature Recognition Quantitative Spatial Reasoning	

Abstract
Non-commital

Committal
Concrete

REVIEW SUMMARY

- Why research visual imagery?
  - "Best of both worlds" multi-representational approach
    - Abstract symbolic representations & computations
    - Perceptually-based quantitative and depictive representations
  - Add new capability
    - Visual-spatial reasoning
    - Visual-feature retrieval and reasoning
  - Gain computational advantage

- Previous architecture and experiments focused exclusively on quantitative representations and visual-spatial type tasks

- Open research questions as of last Soar workshop
  - What is a visual image's internal representation? Is there more than one format/data structure?
  - What is the relationship between high-level vision and visual imagery and how does that constrain the architecture?

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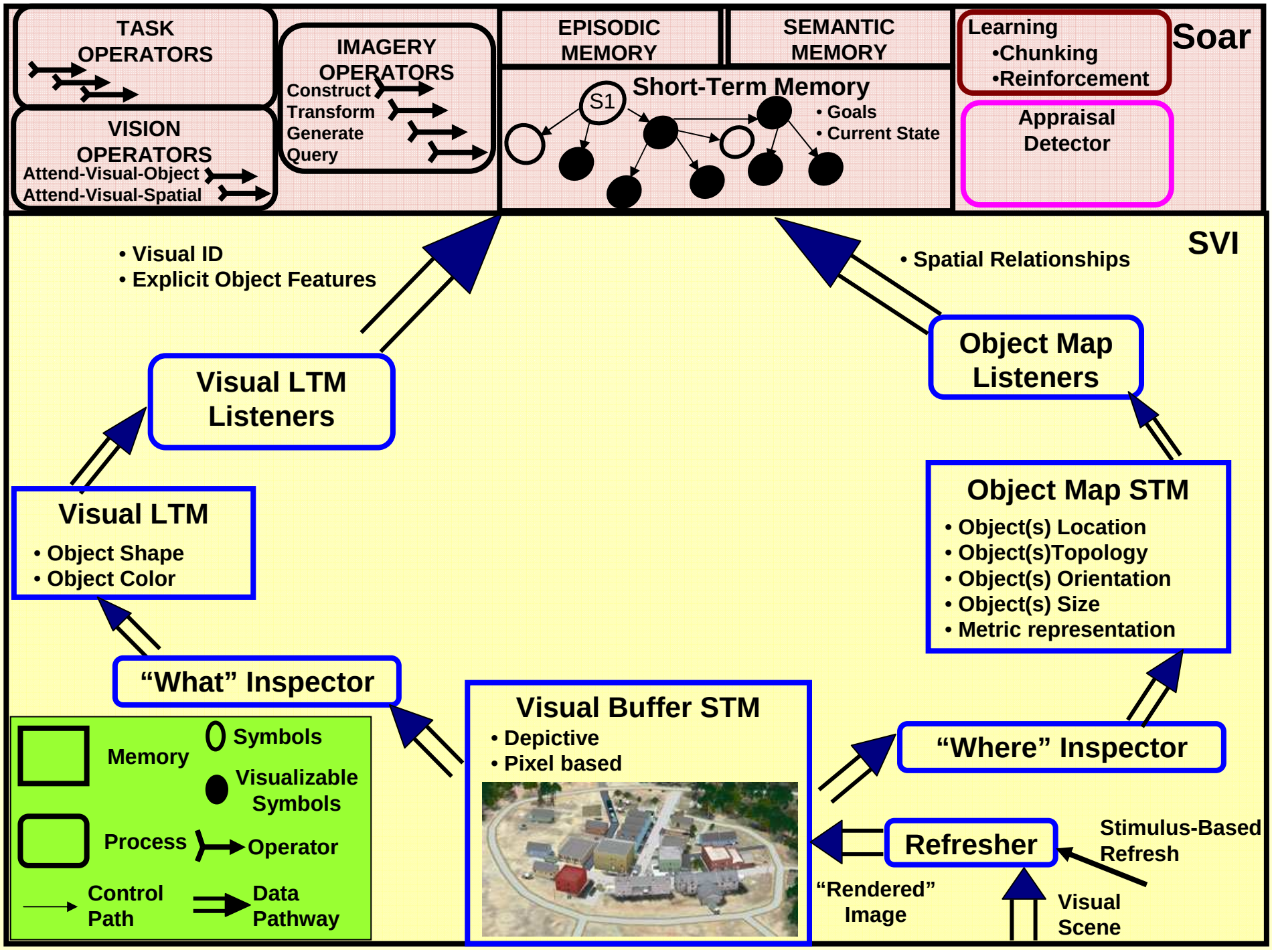
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VISION OPERATORS
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Attend-Visual-Spatial
IMAGERY OPERATORS
Construct
Transform
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Query
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SEMANTIC MEMORY
Short-Term Memory
S1
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• Current State
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•Reinforcement
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SVI
• Visual ID
• Explicit Object Features
• Spatial Relationships
Visual LTM Listeners
Object Map Listeners
Visual LTM
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Object Map STM
• Object(s) Location
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• Object(s) Size
• Metric representation
"What" Inspector
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• Depictive
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"Where" Inspector
Refresher
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Process
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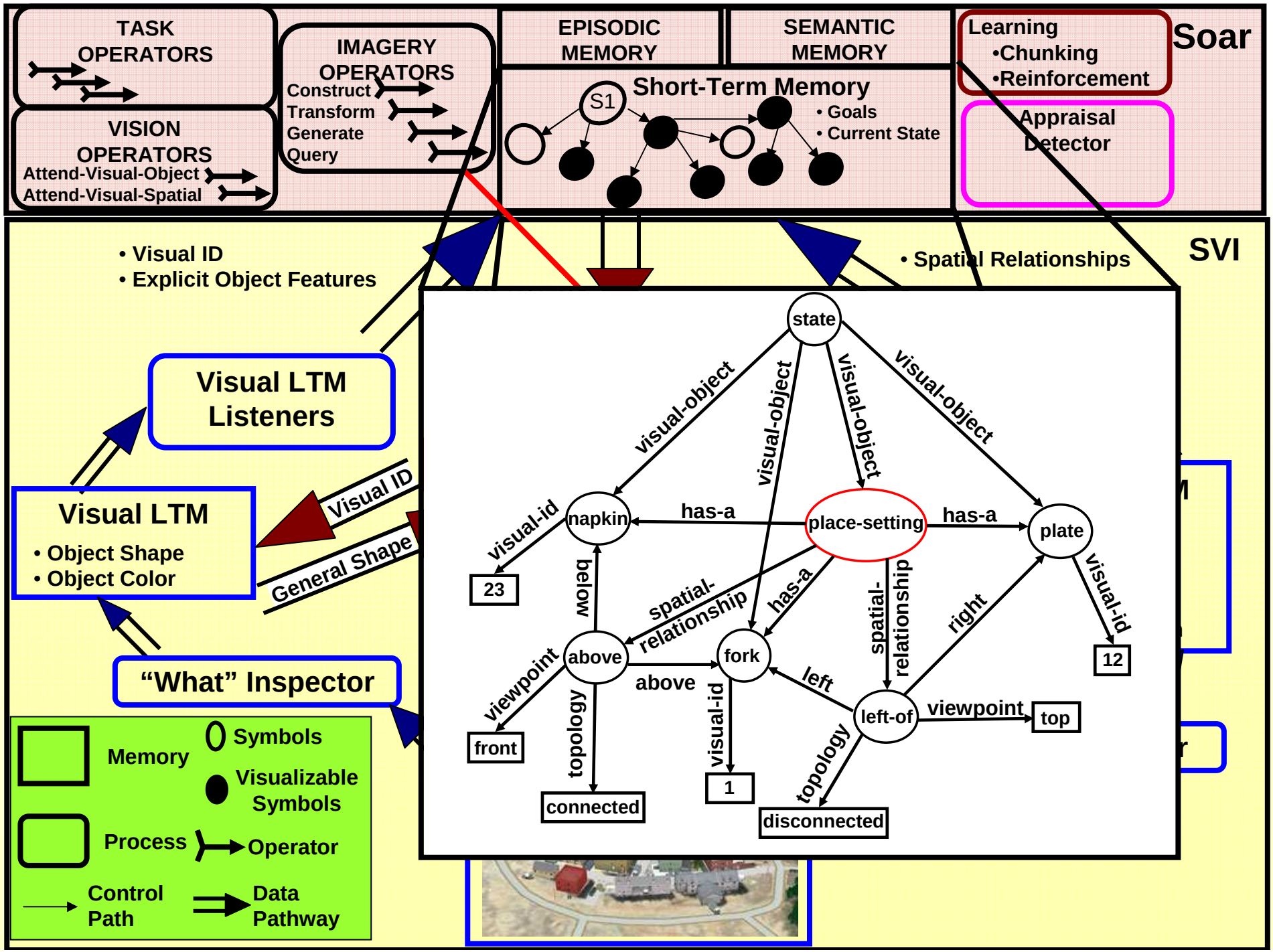
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napkin
place-setting
plate
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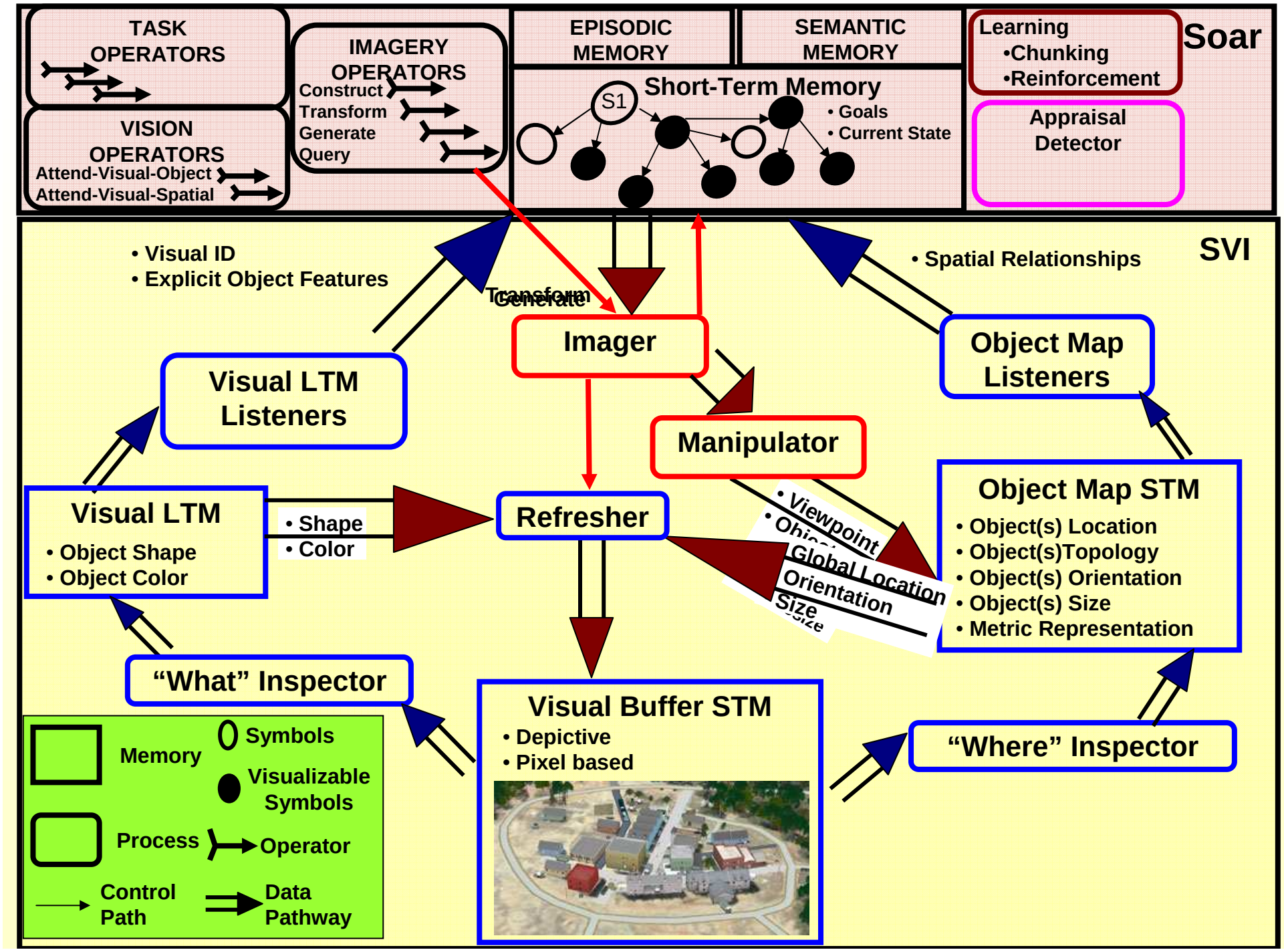
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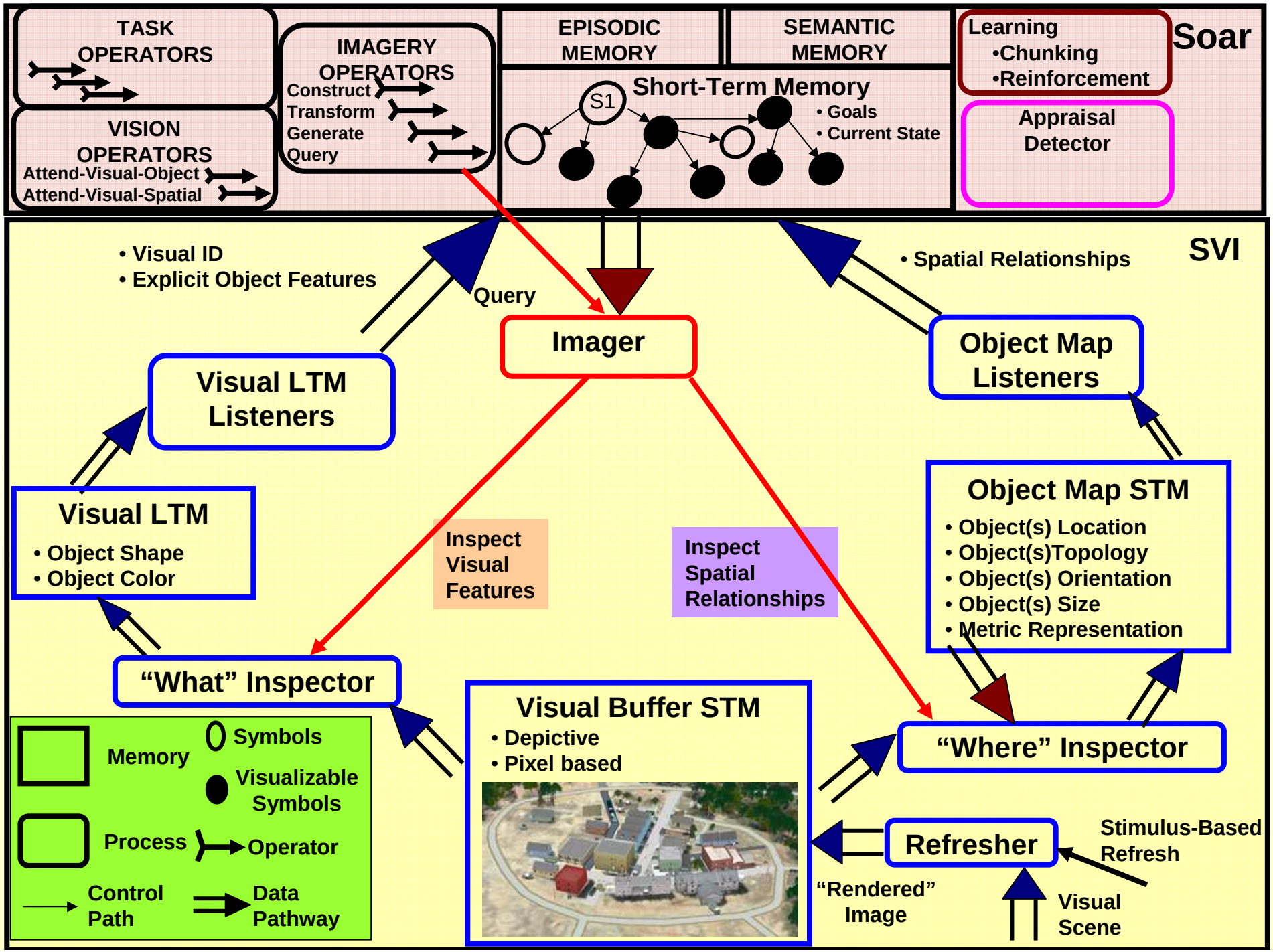
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KEY POINTS

- Central Cognition (Soar)
  - Abstract, symbolic visual representations
  - Domain knowledge (goals, states, task constraints)
  - Controls construction, transformation, generation, and inspection
- Vision / Visual Imagery (SVI)
  - Quantitative and depictive visual representations
  - Leverages mechanisms provided by visual perception.
  - Constructs and generates what it is "told"
  - Provides perceptions based on what it "sees"
  - Enables novel composition of previously perceived objects
  - Reacquires knowledge "abstracted away" during initial perception

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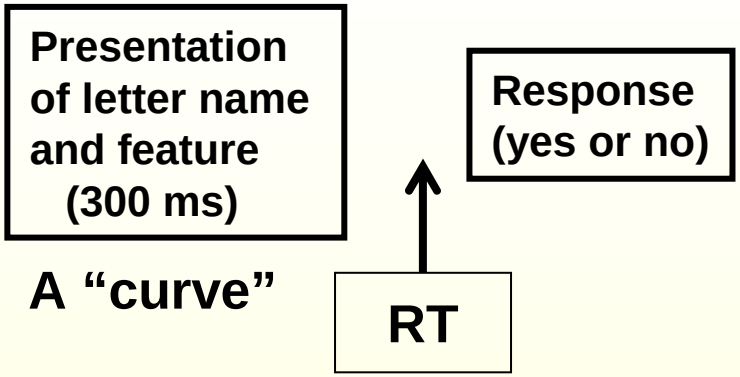
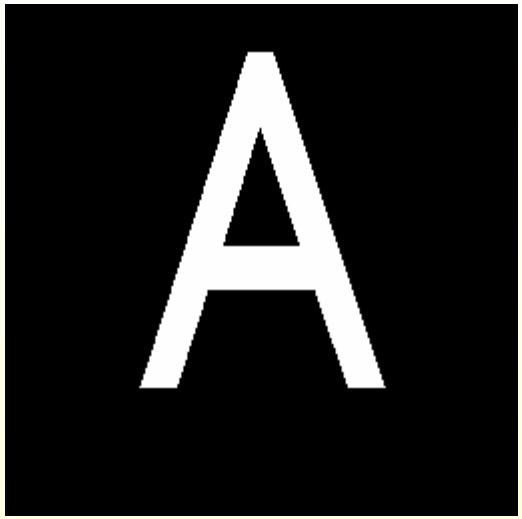
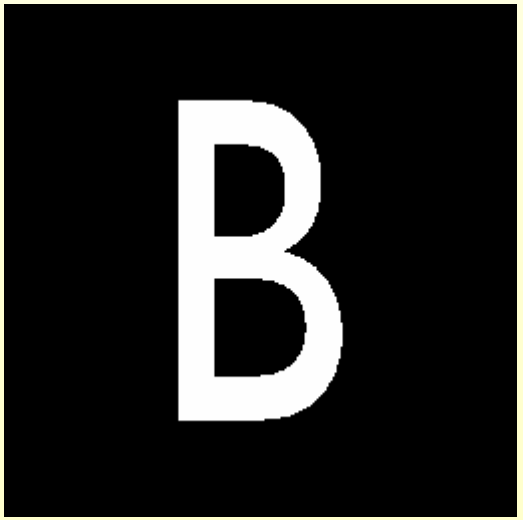
DEPICTIVE EXPERIMENT ALPHABET FEATURES



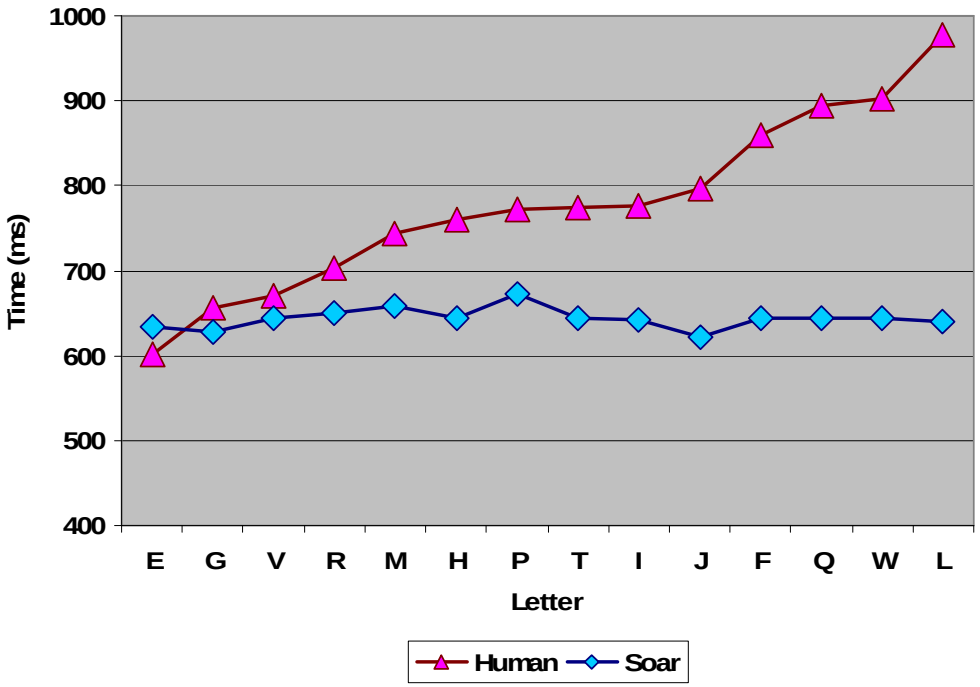


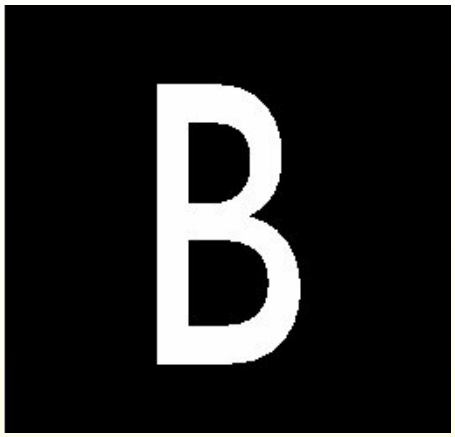


- Emphasized inspection of object features
  - curve
  - symmetry
  - enclosed space
- Depictive (pixel) representations
- Shape (vertices) stored in VisualLTM so had to "construct" visual representation
- External environment, non-visual interaction

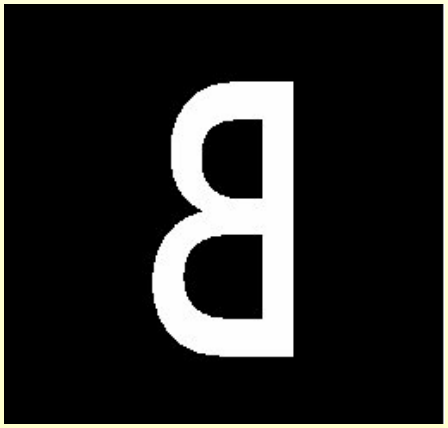
DEPICTIVE EXPERIMENT SYMMETRY

- Transform representation along axis of symmetry
- Make comparison by 'subtracting out" differences
- New capability (+)
- No correlation with human data (-)
  - Transformation in one "cycle".
  - No maintenance of visual representation





Transform



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EXPERIMENTAL DOMAIN CONSTRAINTS

- Interactive domain and not a “question and answer” task
- Emphasize the interaction with bottom-up visual perception and top-down visual imagery processing to evaluate the perceive-imagine-reperceive cycle
- Evaluate both visual-spatial and visual-depictive imagery
- Exercise major visual imagery functionalities (*construct, transformation, generation, inspection*)

“SCOUT” DOMAIN

- Agent imagines what it and teammate can see (field of view)
or teammate? (Decision)
buildings, bridges)
location and orientation
based on verbal report
verbal reports

LEGEND:
Scout Enemy

NUGGETS & COAL

- NUGGETS
  - Answered some of questions from last year
    - Types of representations
    - Intersection between high-level vision and visual imagery
  - Architectural components are relatively stable
  - Simulation is up and running

- COAL
  - Determination of when to use which representation without a big “switch”
  - Unclear as to details of specific algorithms
  - Processing with concurrent visual perception and visual imagery unknown (resource constraints)