Blackboard Architecture

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How do we solve complex problems?

- Using domain experts.
- Sharing the information between the experts.
- Controller for managing information and experts.
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Do we have experts in AI?

- Rule based systems.
- Inference Engines.
  - Forward Chaining
  - Backward Chaining
- Genetic Programming and so on..

Can we solve complex problems using these experts....?
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Can we solve complex problems using these experts....?
Blackboard Architecture

Knowledge Source - 1

Knowledge Source - 2

...

Knowledge Source - n
Blackboard Architecture

Blackboard

Knowledge Source - 1

Knowledge Source - 2

...

Knowledge Source - n
Blackboard Architecture

Blackboard

Controller

Knowledge Source - 1

Knowledge Source - 2

Knowledge Source - n
Blackboard Architecture

- Blackboard
- Controller
- Knowledge Source - 1
- Knowledge Source - 2
- Knowledge Source - n
Blackboard Architecture

Blackboard

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Knowledge Source - n

Controller
Blackboard: A New Perspective

- Advanced Multiprocessor Architectures
- Advanced Communication Systems
- Tools and Languages supporting Parallel paradigm
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Classification in Conceptual Paradigm

KS-1

Blackboard and Controller

KS-2

KS-3

KS-4
Classification in Conceptual Paradigm

KS 1
- LBB/WB

KS 2
- LBB/WB

KS 3
- LBB/WB

KS 4
- LBB/WB
Classification in Design Paradigm

- Shared Memory Based Blackboard Approach
- Distributed Blackboard Approach
- Blackboard Server Approach
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Shared Memory Based Blackboard Approach
Distributed Blackboard Architecture
Blackboard Server Approach
## Parallel BB Architecture Comparisons

<table>
<thead>
<tr>
<th></th>
<th>SMBB</th>
<th>DBB</th>
<th>BBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address space requirement</td>
<td>Shared heap</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>BB acess path</td>
<td>Multiple</td>
<td>Single</td>
<td>Single</td>
</tr>
<tr>
<td>Copies BB object</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>BB object reading</td>
<td>Direct</td>
<td>Direct</td>
<td>Often internode</td>
</tr>
<tr>
<td>BB object creation</td>
<td>Direct</td>
<td>Direct, followed by internode</td>
<td>Often internode</td>
</tr>
</tbody>
</table>
Blackboard Application Domains

- Speech Recognition
- Game Playing
- Image Understanding
- Planning
- Protein Structure Analysis
- Generic Blackboard Frameworks
Locate objects on the ground surface
Large size of pictures
No control over photographing conditions
Variations size and properties of objects
Difficult to create a generic model
BB based production system

- Multiple object detection subsystems
- Each designed to find specific objects
- Extraction of characteristic regions
- Focus on local areas
- Communication via Blackboard
- Controller solves conflicts
Hearsay-II

- Speech-Understanding System
- "Integrating knowledge to resolve Uncertainty"
- Find a complete interpretation
- Various sources of uncertainty as KS’s
- Many partial interpretations
- Large search space
Example

- Uncertainty at word/lexical level
  - difficulty in distinguishing the utterances
    till and tell
    rings and brings

- Uncertainty at phrase/semantic level
  - derived from the word level
    till Bob rings
    tell Bob rings
    till Bob brings
    tell Bob brings

- Goal is to reduce combined uncertainty at all levels
- Need to assess overall best interpretation
- Thus incremental approach of BBA is useful
Hearsay-II: Key Advantages

- Multiple sources of knowledge
- Multiple levels of abstraction
- Shared partial solutions
- Incremental formation of solutions
- Opportunistic problem-solving behavior
Distributed Vehicle Monitoring

- Network of vehicle monitoring sensors
- Each node is a problem solver
- Analyze sensed data to identify patterns
- Area-wise division of responsibility
- Integration into a single answer map
Crossword Puzzle Solver

- Multiple language knowledge sources
- Blackboard to store crossword state and clues
- Dictionary lookup, database search, search engine
- Synonym based approach
- Use of heuristics to reduce search space further
Crossword Initial State

Step 1: Solving Clue: utopian ID: 1
Opinions suggested by KS-1 are:
Crossword Solving Started ...

Step 1. Solving Clue: utopian ID: 1
Opinions suggested by KS-1 are: unrealistic, imaginative,
List of all opinions suggested by all KS's: unrealistic, imaginative
Chosen Solution: unrealistic > For Clue: utopian With ID: 1

Step 2. Solving Clue: unceremonious ID: 2
Opinions suggested by KS-1 are:
Crossword Solver Selects Constrained Clues...

Step 1: Solving Clue: 'utopian' ID: 1
Opinions suggested by KS-1 are: unrealistic, imaginative,
List of all opinions suggested by all KS's: unrealistic, imaginative
Chosen Solution: 'realistic' For Clue: utopian With ID: 1

Step 2: Solving Clue: 'unceremonious' ID: 2
Opinions suggested by KS-1 are: *
List of all opinions suggested by all KS's: *
BACK-TRACKING
Backtracked Chosen Solution: imaginative For clue With ID: 1

Step 3: Solving Clue: 'unceremonious' ID: 2
Opinions suggested by KS-1 are: informal,
List of all opinions suggested by all KS's: informal
Chosen Solution: 'informal' For Clue: unceremonious With ID: 2
Step 1. Solving Clue: utopian ID: 1
Opinions suggested by KS-1 are: unrealistic, imaginative,
List of all opinions suggested by all KS's: unrealistic, imaginative
Chosen Solution: unrealistic > For Clue: utopian With ID: 1

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List of all opinions suggested by all KS's: informal
Chosen Solution: informal > For Clue: unceremonious With ID: 2
Why use blackboard?

- Modularity
- Incremental Approach
- Efficiency
- Concurrency
What kinds of applications?

- Many specialized and distinct knowledge sources
- Integration of disparate information
- A natural domain hierarchy
- Continuous data problems
- Applications with sparse data
References