Implementing a General Purpose Framework Using Multi-Agents for CM Education

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Overview

- Motivation
  - CM Education
- Why Situational Simulation?
- Why do we need a General Purpose Framework (GPF)?
- The Multi-Agent Framework
- Experiments and Results
CM Education

De-contextualized knowledge

Separate Courses

Construction Management Domain

- Scheduling
- Estimating
- Project Mgmt.
- Safety

Unproblematically represented

Passively transmission of knowledge

Questions:

Results: Inability to apply “learning” to relevant situations.
Instead . . .

- Situated Contextualized Learning
  - Embedded in the environment
  - Physical Embodiment
- Adaptation
  - Student and environment:
    - coupled system
    - self-organizing
    - dynamically evolving
Simulations in Learning

- Explore “What-if” Scenarios
- Understand Inter-relationships
- Apprehend Feedback
- Take Risks
The Virtual Puget Sound
Challenge

- Real Life Construction Management Scenarios
- Artificial Environment
  - Interactive
  - Adaptive
  - Engaging
  - Situated

Model

- Descriptive
- Prescriptive
Challenge

• Extensible
  – Variety of operations/ processes / scenarios
  – Levels of granularity

• Re-usable
  – Reuse reasoning components

• Scalable (!)
The Framework

Systemic

Dynamic

Adaptive

Expressive

Inter-Relationships

Time Evolution Functions

Interface

Semantics: encoding context specific information

Dynamic

System Evolution

Relational Model

Perceptive

Interactivity

Autonomous Agent Reasoning

Framework
System Evolution: Relational Model  
(Rojas & Mukherjee, 2003)

Knowledge Base  
Rule Base

Deductive Reasoning

Autonomous Agent Reasoning  
(Mukherjee & Rojas, 2003)

Inductive Reasoning

Simulation Backend:  
Dynamic context sensitive scenario generation

User Interaction

Meta-Cognitive Knowledge Generation
Problem Classification in CM Domain

• Precedence Constraints
  – Finish to start, start to start, start to finish
• Resource Constraints
  – Requirement Availability
  – Specification checks
• Events: Constraint Violations
  – Rescheduling of activities
  – Reallocation of resources
- Plan evolution of system
- Act: Simulate events
- React to user interaction

Knowledge base

Agent

Systemic Behavior

Agent

- Capture disturbance in the system equilibrium
- Project sensitivity of environment

Situational Simulation Environment

Agent

- Take decisions
- Reallocate
- Allocate
Discrete Variables

\[ D = \{v_d\} \subseteq E \]
\[ v_d \subseteq \{s_1, s_2, \ldots, s_n\} \]

Continuous Variables

\[ C = \{v_c\} \subseteq E \]

Interface Variables

\[ I = \{v_i\} \subseteq E \]

Synchronized

Global Scope
Ex: weather

Activity
Specific
Ex: material availability

Situational Simulation Environment
The Framework

Simulation Environment ($S$)
$S = \{v_1, v_2, \ldots, v_n\}$
Entity ($E$) $\subset S$

$\forall i \in S$, $c: v_i(s,t)$

$\forall j \in S$, $c: v_j(s,t)$

$\forall k \in S$, $c': v_k(s,t')$

$\forall l \in S$, $c': v_l(s',t')$

Domain Specific Definitions of:
- Constraints
- Events

Systemic evolution
Constraint violation => Event

Grammar:
$F :: O1 \ O2 \ \ldots \ On$
$O :: A \ B \ o \ | \ A \ o$
$O(E1) :: E2$

$F$: Framework
$O$: Operation
$E$: Entity
$A$: Agent
$B$: Bases
$o$: Reasoning algorithm
The Framework

- Environment defined as a set of variables
- Operation defined on Environment
  - $O(E)$
- Agents implement Operations
  - $A\cdot O(E)$
The Virtual Coach

- **Database (DB)**
  - As-Planned Schedule
  - As-Planned Resource Allocation
  - Unit Resource Costs

- **Knowledge Base (KB)**
  - Event definitions `{Pre-Cond} → {Post-Cond}`
  - Event frequency
The Virtual Coach

- Three Agents and Operations
  - LA: Create, Infer
  - MA: Unite, Compute
  - VA: Visualize

- Utilities
  - Scheduling
The Virtual Coach

![Virtual Coach Simulation Interface]

- **Cost Track:** As-Planned vs. As-Built
- **Event Forecast:**
  - Event: Labor strike Probability: 21.0%
  - Event: Poor Quality Work Probability: 12.0%
  - Event: No Material Delivery Probability: 21.0%
  - Event: Cost hike Probability: 21.0%
  - Event: Bad weather: Snow Probability: 21.0%
  - Event: Bad weather: Rain Probability: 2.0%

- **Event Report:** Event: Poor Quality Work

- **Project Status:**
  - Project ahead of budget target
  - Project on schedule
  - Current State of material is F
  - Current State of delivery is F

- **Activity Variable Status:**
  - Activity: Activity 4
  - Current State of Productivity is 5
  - Activity: Activity 5
  - Current State of delivery is F
  - Activity: Activity 5
  - Current State of Productivity is F
The Virtual Coach
System Evolution: Relational Model (Rojas & Mukherjee, 2003)

Knowledge Base
Rule Base

Deductive Reasoning

Autonomous Agent Reasoning (Mukherjee & Rojas, 2003)

Inductive Reasoning

Simulation Backend: Dynamic context sensitive scenario generation

Situational Simulation

User Interaction

Meta-Cognitive Knowledge Generation
Testing

• Tested with 19 Senior level CM students: Pre-test/Post-test protocol
• Claim I: The environment is useful for training Construction Managers
• Claim II: Learning in the CM domain is based on an understanding of *Precedence and Resource Constraint Satisfaction*
Results

Temporal Constraint Satisfaction
Event Scheduling / Event Premonition
Discussion

• Learn interactively
• Understand constraints
• Apprehend problems
• Discover systemic relationships
Future Work

• Study the CM domain as a Human-Resource Coupled System
• Explore Mental Models of Experience
• Generate KB from Expert participation
• Develop an ontology for CM applications
Reinventing the Wheel?

- Not simulation of *The Operation*
  - Instead simulate processes *As it Happens*
- Planning and context-sensitive reasoning environment
- Web-based implementation
- Not an “Either-Or”
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Questions ?