Integrating BDI Reasoning into Agent Based Modelling and Simulation

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RMIT University, Melbourne, Australia
Outline

1 Motivation

2 Belief Desire Intention (BDI) Agents

3 Framework

4 Interaction and Synchronisation

5 Conclusion
Outline

1 Motivation

2 Belief Desire Intention (BDI) Agents

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Policy and Planning

Many policy and planning tasks benefit from exploration via simulation.
Modelling of Human Behaviour

Need to model the behaviour of different people/roles.
• Humans are reactive - but not entirely.

• They typically have goals and plans that extend over a period of time.

• They make and adjust decisions based on the unfolding situation.

• They know what they have been doing and why - this is part of what they do next.

• The BDI agent paradigm captures these aspects well.
Outline

1. Motivation
2. Belief Desire Intention (BDI) Agents
3. Framework
4. Interaction and Synchronisation
5. Conclusion
BDI (Belief Desire Intention) agents have been used in many successful applications in complex environments.
BDI Agent Oriented Programming

- BDI Agent-Oriented Programming provides abstraction at the level of mental attitudes to explain the operation of a system. Beliefs, Desires, Intentions.

- The modularity of plans makes it easy to develop complexity incrementally.

- The goal oriented approach makes it suitable for use in dynamic environments.

- Many efficient and powerful development environments available. JACK, Jadex, Jason, PRS, 2APL, ...

- BDI agent programs are fast to develop. A 2006 study showed:
  - Gain compared to Java programming 500%.
Belief-Desire-Intention (BDI) Agent Architecture

Percepts in, actions out. Internally, beliefs, goals and plans.
Example Plan Structure

- **goal**: RespondBushfire, Stay&Defend
- **plan**: EvacHouse, ObtainTransport, AssembleMembers, MoveSafeLoc
- **Action**: GetCar, ArrangeLift, NoTransport, HouseAssemble, DistAssemble, WalkToLoc, DriveToLoc, WaitPickUp
- **Messages**: M:msg, M:reqLift, M:toDoor, M:phoneInfo, M:toDoor
- **Actions**: GetFromRadio, LocalShelter, LeaveTown
- **Paths**: Walk(Car)Drive(Door), M:toDoor, Drive(L), Walk(L)
A plan is a sequence of steps
A step can be a **goal**, an **action**, a **message** to another agent, or some computation.
Example Plan Structure

A goal may have different plans, for achieving it in different situations.
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A goal may have **different plans**, for achieving it in **different situations**.
For a goal to succeed one of the plans must succeed. If one fails try another.
For a plan to succeed, all steps must succeed.
If things fail, recovery happens as locally as possible
Plan selection **responsive** to changing environment.
Advantages

- Intuitive representation

- Late selection: situation aware...

- Plan failure - retry new plan. Committed to choices, like humans.

- Agent is responsive to environmental changes.

- Huge number of options possible - over 2 million for modest tree.
  (Subgoal steps 4, Choices 2, Depth 3)
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**BDI System**

**ABM System**

T1
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### BDI System

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### ABM System

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**Motivation**  |  **BDI Agents**  |  **Framework**  |  **Interactions**  |  **Conclusion**
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**BDI System**

![BDI System Diagram]

**ABM System**

![ABM System Diagram]
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BDI System

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### Framework Overview

#### Agent | Action | Status
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A3 | act1 | dropped

#### Agent | Action | Status
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A2 | act7 | initiate
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BDI System

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The Interface

- **Actions:** `<id, parameters, status>`

- **Percepts:** `<type, value>` (value may be a complex object)

- **BDI sensing actions.**
  - While processing BDI can request information from ABM counterpart.
  - No effect on environment, but may include computation.
  - (E.g. get current location.)

- Anything that changes the environment must be a BDI action.
Generic Action Plan

- **goal**
  - **plan**
    - **Action**
      - M:msg
        - **ObtainTransport**
          - GetCar
            - Walk(Car)
          - ArrangeLift
          - NoTransport
          - HouseAssemble
          - M:ReqLift
          - M:toDoor
        - **AssembleMembers**
          - M:toDoor
          - DistAssemble
        - **MoveSafeLoc**
          - walkPickUp
          - Drive(L)
          - LocalShelter
          - GetFromRadio
        - **RespondBushfire**
          - EvacHouse
            - M:toDoor
          - Stay&Defend
          - DetermineLoc
          - DriveToLoc
          - WaitPickUp
          - Drive(L)
          - LocalShelter
          - GetFromRadio
          - LeaveTown
          - DetermineLoc
          - WalkToLoc
          - DriveToLoc
          - LocalShelter
          - GetFromRadio
          - LeaveTown
          - DetermineLoc
          - Walk(L)
Generic Action Plan

- GetCar
  - Walk(Car)
  - Drive(Door)

- ActivateAction(Walk(Car))
- ActionPlan
Generic Action Plan

1) **Write** action info for sending to ABM
2) Monitor action status
3) Respond to \textit{status}
3) Respond to status
Status = PASS, succeed plan which propagates up; Continue to next step.
3) Respond to **status**
Status = **PASS**, succeed plan which propagates up; Continue to next step.
Generic Action Plan

3) Respond to **status**

Status = **FAIL**, fail plan, propagates up; Plan fails.
3) Respond to status
Status = **FAIL**, fail plan, propagates up; Plan fails.
3) Respond to status
Status = Dropped, Same as fail, but BDI initiated.
3) Respond to **status**

Status = **Suspend** (also BDI initiated). No stepping on ABM side
Synchronisation Issues

• BDI and ABM take it in turn to run (BDI if needed)
  • System execution time should not affect conceptual model.
  • BDI runs only if action status change or percept generated.

• ABM systems generally use time-steps; BDI are generally event based, reacting to an external environment.
  • We use time-steps as basic model.
  • BDI system runs until each agent has finished its reasoning, possibly posting an action.
  • Depending on implementation platform, may require some care to detect end of BDI step.
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Efficiency Evaluation
Conclusion

- Successfully integrated existing BDI (JACK) and ABM (Repast) systems.
- Evaluation showed minimal efficiency cost.
- BDI representation supports easier specification of goal directed human behaviour over multiple time-steps.
- One next step is graphical interface for BDI specification.
- Also plan to work with social scientists to map SS models of human behavior to BDI style representations for richer simulation.
Questions