



Intelligent Systems Engineering 2023/24 Project

Literature survey:

Real-world applications of MAS and BDI agents

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Project goal

- Provide overview of real-world applications of MAS and BDI agents
- Answer research questions:
 1. Can MAS and BDI agents be applied to solve practical problems in the real world?
 2. In which domains are MAS and BDI agents a promising approach?
 3. How well do the MAS and BDI agent implementations perform?



Introduction to MAS

- **M**ulti **A**gent **S**ystems are decentralized distributed systems containing autonomous agents with individual goals
 - Agents can **cooperate** or **compete** to achieve higher level objective
- Agents can break down complex tasks into smaller tasks solvable by individual agents
- Agents have partial knowledge and communicate with other agents to acquire knowledge or update existing



Introduction to BDI

- The **B**elief **D**esire **I**ntention architecture is based on theoretical framework of human reasoning created by philosopher M. Bratman (1987)
 - Intentions are central for planning capabilities
 - Practical rationality to achieve goals
 - Self-governance (autonomy over actions)
- S. Rao later formalized this in computational terms using modal logic and introduced the BDI architecture to model agents (1991)



Introduction to BDI

- ***Beliefs***: agents' perceptions of the environment and information from other agents
- ***Desires***: goals the agent wants to achieve
- ***Intentions***: Actions to achieve a certain goal (possibly multiple at a time)



Selection criteria

1. Practical and real-world application of MAS and BDI agents to solve a problem
2. Preferable evaluated in a real-world scenario
3. Focus of publication lies on integrating MAS and BDI agents, instead of other technicalities
4. Years since publication (newer publications are preferred, and it is preferred that they are published within the last decade)

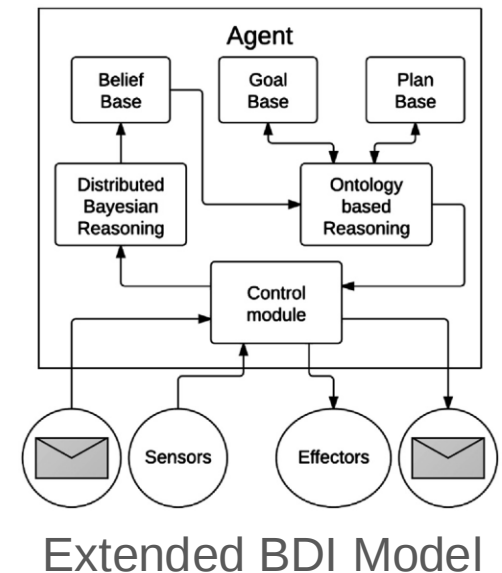


Quality Assessment

- Is the approach successful in achieving its high-level goal?
- How close is the evaluation scenario to the real world?
- Does the MAS and/or BDI architecture make a problem solvable or is just an alternative architecture to solve it?

Fault diagnosis for an ISP using MAS [1]

- MAS with the goal of finding fault to reduce diagnosis and repair times
- Agent divided into tasks for diagnosis:
 - Symptom detection
 - Hypothesis generation (confirm/reject)
 - Hypothesis confirmation (testing)
- Handle uncertain environment with Bayesian Network
- Deployed and evaluated in the real world over 1,5 years
- Diagnosis and repair times reduced by 45,32%





Restoration of smart grids using MAS [2]

- Find fault in electricity grid and it restore with Distributed Energy storage systems (DES)
- Switching agents and DES agents
- Switching agents divide grid into "teams"
 1. Detect fault
 2. Isolate fault with switch agents
 3. Activate DES, to restore load on the electricity field
- Implementation in a simulation provides a proof of concept

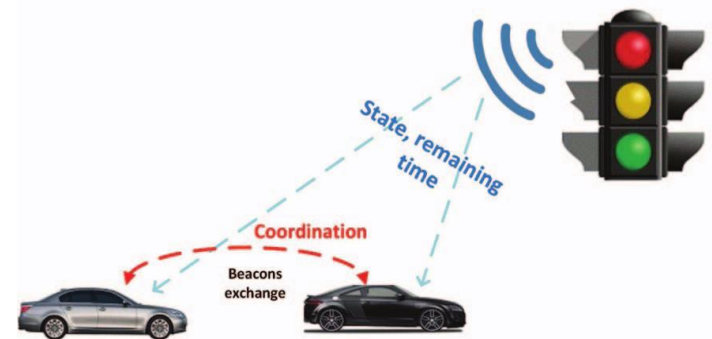


Partner selection in P2P video-streaming [3]

- Swap partners to provide a better user experience by improving bitrate, delay and hop count
- Goal orientated BDI approach with plans following priorities:
 - Ensure bitrate and buffer level are satisfactory
 - Lower delay and hop count
- Evaluated against a greedy approach selecting the partner with higher upload bandwidth
- Bitrate, delay and hop count significantly improved
 - Nodes with avg. Bitrate below 150kbps at 0%, compared to 20%

Reducing road traffic congestion [4]

- MAS with BDI agents that communicate with infrastructure (traffic lights) and other vehicle agents
- Cars adapt their speed at intersections to ensure optimal flow and coordinate lane changes
- In simulation environments on real roads (LA & NY) avg. travel time is significantly reduced up to 38%



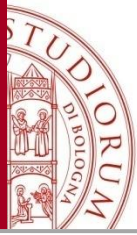
V2I and V2V
communication

Mail delivery robot [5]

- Combine Robot Operating System (ROS) and BDI agent
- Deliver mail on grid marked on the floor, use goals and plans to navigate grid and deliver mail
- Evaluate if reasoning loop can keep up with the frequency of ROS perceptions of the environment



Roomba robot



Answering research questions

- Can MAS and BDI agents be applied to solve practical problems in the real world?
 - Yes! The publications show MAS being applied to real world problems that can be formulated as distributed cooperation between agents
 - The BDI model needed to be expanded to cope with uncertainty in a real-world environment
 - But can be applied to give autonomous agents reasoning capabilities



Answering research questions

- In which domains are MAS and BDI agents a promising approach?
 - From the shown publications fault detection is prominent domain of application for MAS
 - Autonomous systems and robotics for BDI agents



Answering research questions

- How well do the MAS and BDI agent implementations perform?
 - Only one implementation was evaluated under real world conditions (ISP fault detection agent)
 - But provided significantly promising results
 - Simulated environments also provided promising results
 - But some simulation environments might be unrealistic (Congestions reduction agent & P2P partner selection)
 - Publications made groundwork to use MAS and BDI agents (Robot Operating System and BDI agents'integration)



Thank you for your attention!



References

- [1] Alvaro Carrera, Carlos A. Iglesias, Javier García-Algarra, and Dušan Kolařík. A real-life application of multi-agent systems for fault diagnosis in the provision of an internet business service. *Journal of Network and Computer Applications*, 37:146–154, 2014.
- [2] Cuong P. Nguyen and Alexander J. Flueck. Agent based restoration with distributed energy storage support in smart grids. *IEEE Transactions on Smart Grid*, 3(2):1029–1038, 2012.
- [3] Suleyman Yildirim, Muge Sayit, and Geylani Kardas. A belief-desire-intention agent architecture for partner selection in peer-to-peer live video streaming applications. *Expert Systems*, 32:32–343, 06 2015.
- [4] Soufiene Djahel, Nafaa Jabeur, Robert Barrett, and John Murphy. Toward v2i communication technology-based solution for reducing road traffic congestion in smart cities. In *2015 International Symposium on Networks, Computers and Communications (ISNCC)*, pages 1–6, 2015.
- [5] Chidiebere Onyedinma, Patrick Gavigan, and Babak Esfandiari. Toward campus mail delivery using bdi. *Journal of Sensor and Actuator Networks*, 9(4), 2020.