Agent-based Navigation and Multi-Agent System (MAS) for Optimal Path Finding in Unknown Environment

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Overview

What is navigation?

Navigation is the process of reasoning, utilizing every relevant piece of information available about the task and the environment, for the purpose of finding a sequence of steps leading to a goal [Chronis 2000].

Overview

Project Setting Description:

Multi-Agent system is located in an unknown environment (indoor, outdoor, or virtual) which may contain obstacles (either static or mobile).

Task:

Each agent has to avoid obstacles by finding an optimal path in shortest period of time to reach the target location.

What I would like to do?

Build a multi-agent system (MAS) so that agents can communicate and share information using appropriate synchronization methods.

Overview

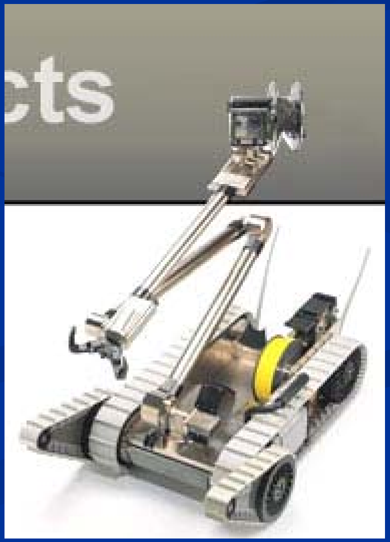
- Current Technology:

Roomba

1. Special Navigation system (Spinning Action)
2. Obstacle Avoidance
3. Stair Avoidance System

PackBot

1. Used in War in Iraq
2. Searches dangerous places and monitors movement of enemy
3. Autonomously adapts to environment



Overview

- However…

  Applications are still primitive and limited.

  Speed (perceiving environment and decision making) is VERY slow for practical usage.

- Therefore…

  Agent-based or MAS (Multi-Agent System) may help overcome issues in…

  1.Speed Problem (Fast decision making)

  2.Optimal Path Finding (Accurate and reliable decision)

Current Problems:

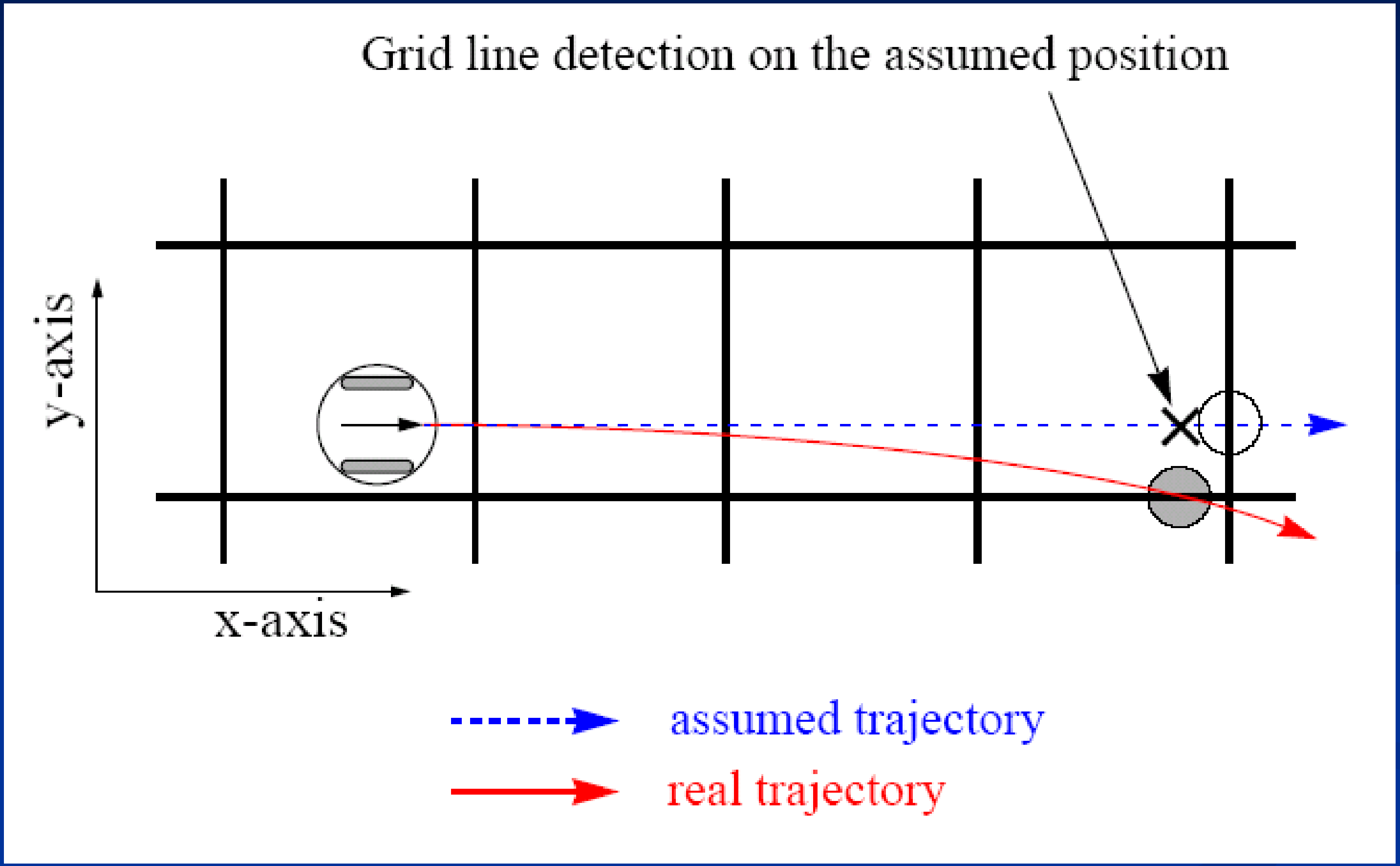
I. Perception System
II. Navigation Algorithm (Learning)
III. Collision Avoiding Mechanism
IV. Multi-Agent System (MAS) Environment
V. Synchronization Mechanisms

Perception System

- Odometry Approach [Fichtner 2003]

  measures the distance of ground and any obstacles surrounding the sensor by keeping track of the distance traveled
- Problem: method is not precise and may lead to many errors due to slipping of wheels or legs, which is quite common in outdoor environments

Perception System

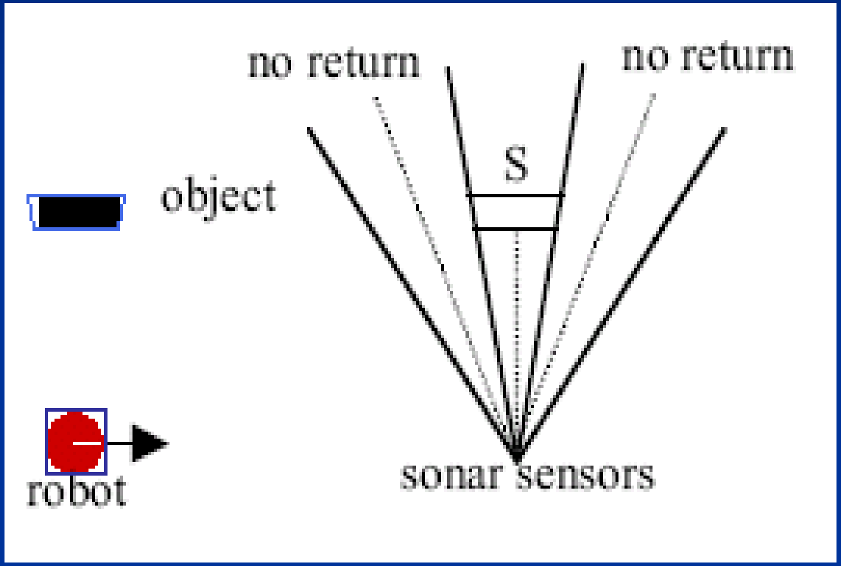


- Figure 1. Comparison of assumed and real trajectory after slipping

Perception System

- Spatial Relationship Finding with Sonar Sensor [Chronis 2000]
  - The sensor sends sonar signal and checks whether the signal is reflected back to the sensor
  - Measures distance

Perception System



- 16 Sonar Sensors are attached around the circumference of an agent.
- A single object is recognized from a single sonar reading.

Perception System-
Relative Measuring Method

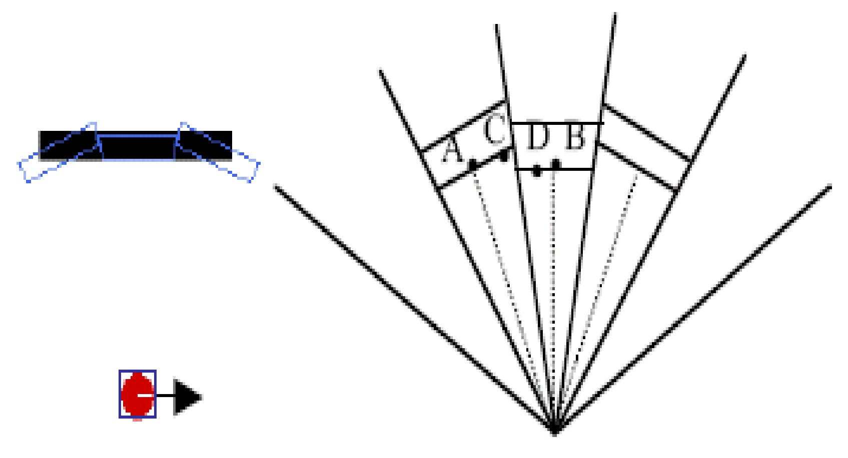


Figure 2. Object is relatively far from the agent

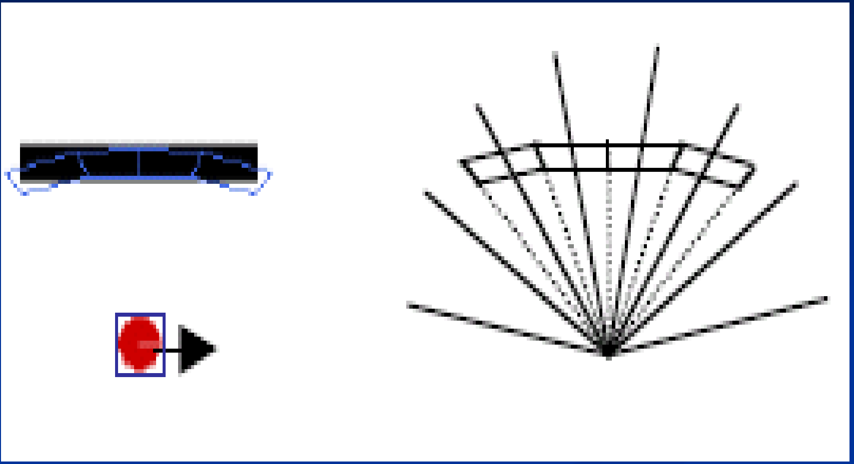


Figure 3. Object is closer to the agent

- When the obstacle is farther away, only 3 sensors return the signal – Agent may approach toward obstacle
- As the obstacle gets closer, 5 adjacent sonar reading – Agent turn away
- Problem - Measurement of distance is relational; Depth of obstacles cannot be measured.

Navigation Algorithm

- Beta-Coefficient Algorithm [Busquets et al. 2003]

  1. Three landmarks and a target have been detected already.

  Then, Agent moves…

  2. From another point of view, the agent is only possible to see the landmarks but not the target because of an obstacle.

  3. Agent can calculate the location of the target using Beta-coefficient system.

  $\beta = X^{-1} X_T$ Where $X=[X_A X_{\mathbf{B}} X_C]$

Navigation Algorithm

- Beta-Coefficient Algorithm

  object unit (e.g. A) and beta unit (e.g. ABC/D)

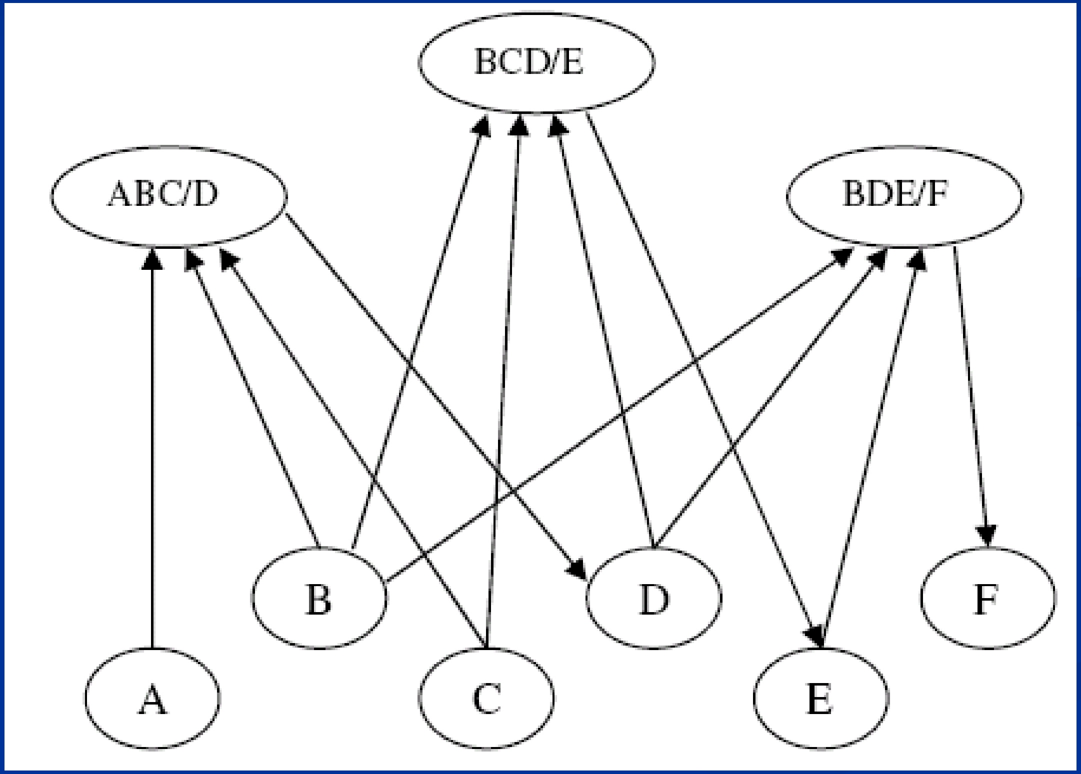


Figure 4. Associated Network of a Partial View

Learning Algorithm: Fuzzy-Genetic Approach

- Fuzzy logic is a type of logic that recognizes more than simple true and false values [Webb et al. 1994].
- A new rule is created every time it faces a new situation in the environment.
- System keeps track of certain rules in various situations and choose the most effective rule.
- Environment is represented using fuzzy rules *Figure 5*
- Adopted Genetic Science Theories – Each rule is represented as a chromosome *Figure 6*
- When identical or similar situation as stored chromosome occurs, that specific chromosome determines the action of the agent.
- Also adopted evolutionary science – Natural Selection and Mutation

Learning Algorithm: Fuzzy-Genetic Approach

- PROBLEMS:

1. Could create too many rules
2. Requires considerable time period to detect obstacles, create a new chromosome, select decision, and carry out the action.

Collision Avoiding Mechanism (Navigation with Mode Switching)

- The most important issue in Navigation system
- Comfort value: how comfortable is an agent in an environment.
- Comfort value is set to low-level in the beginning, and raised gradually as the agent gets more comfortable in the environment (Learning algorithm) [Aaron 2002].
- Aggressiveness(d_0): willingness of an agent to get close to obstacles and other agents
- Need to differentiate friendly and harmful objects (flower beds vs. trash can), also still and mobile objects (rock vs. dog).
- Different value of aggressiveness assigned to each obstacle (high d_0 = friendly; low d_0 = dangerous)

Collision Avoiding Mechanism (Navigation with Mode Switching)

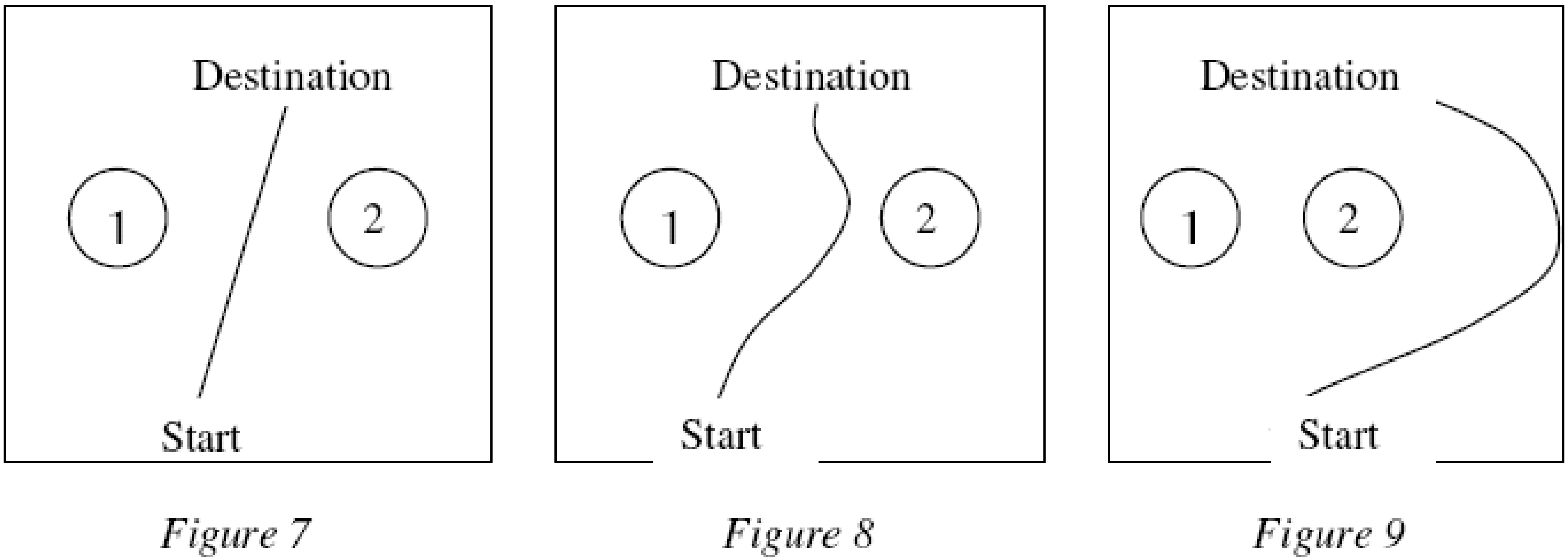


Figure 7. The agent moves in the middle of two objects (1 = rock; 2 = parked vehicle).

Figure 8. The agent moves toward object 2 (1 = rock; 2 = friendly object) as it passes two objects.

Figure 9. The agent goes around two objects by not passing through (1 = dynamite; 2 = friendly object).

Multi-Agent System Environment

- How is multi-agent based system can help the navigation task?

1. Enables agents to communicate
2. Path planning by sharing “learned path”
3. Provide enhanced reliability and speed

- Problems:

  How often synchronize?

  What extent of system should be synchronized?

Synchronization Timing Methods-

Synchronous Fixed Time Interval [Lee and Pritchett 2001]

- Updated at a fixed time interval
- Advantage:
- Provides accurate results that can be guaranteed not to miss any measurements or interactions.

- Disadvantage:
- Small time step results in a large number of update points

- Not appropriate for practical purpose because
- 1) they lead to unnecessary updates of agents
- 2) it is not easy to predetermine a single time step for the simulator as the smallest time interval among those associated with every agent under worst-case conditions

Synchronization Timing Methods-
Synchronous Variable Time Interval

- Updated at the same time between agents
- Select the most restrictive time step (demanded by any of the agents in the simulation)
- Time interval varies from one time to the next to meet the needs of the simulation
- Still forces some agents to update whether they need or not

Synchronization Timing Methods-
Asynchronous with Resynchronization Mechanism

- Theoretically, asynchronous timing mechanisms should be much more computationally efficient than synchronous timing methods [Lee and Pritchett 2001].
- Allows agents to update asynchronously following their own update times, and resynchronize only when update between agents are desired.

Synchronization Timing Methods-Complete Resynchronization

- Updates are done asynchronously until any agent requires a resynchronization. *Figure 10*
- The whole MAS has to be updated once the resynchronization is requested.

- Problem:

  If there is an agent (agent 3 in figure) that keeps requesting resynchronization often, the whole MAS has to unnecessarily update.

Synchronization Timing Methods-Partial Resynchronization

- Much better method than complete resynchronization.
- Each agent asynchronously update at their own update time until an agent selectively requires some of the agents to be resynchronized.

  Figure 11
- Appropriate method for my project – Agent only needs contact the ones with solutions

Synchronization Timing Methods- Resynchronize Intervals

- When interval is too large…
- When interval is too small…
- Cost of computation is proportional to number of agent executions performed (more executions, more expensive)

Conclusion

- Multi agent based Navigation will provide more reliable and faster analysis about the environment.
- MAS will solve storage limitation of the agents by communicating between agents instead of learning the whole environment by itself.
- Combining MAS with selective learning algorithm will produce the optimal path finding opportunity

Proposal Preview

- For my project, I would like to…
- 1. Set up a 3-dimensional virtual environment with indoor like (leveled ground and no water) terrains with stationary obstacles.
- 2-1. A single agent is placed in the environment, and it is required to reach the goal using mode switching and learning algorithm.
- 2-2. Place Multi-agent System in the environment, and repeat the experiment using asynchronous partial resynchronization mechanism (No learning algorithm)
- 2-3. Repeat the experiment with MAS and using learning algorithm.
- 3. The performance will be evaluated by measuring the distance (optimal path finding) and time (speed) that each agent traveled.

Research Title

Implementation of a Multi-agent system for Navigation in an unknown environment

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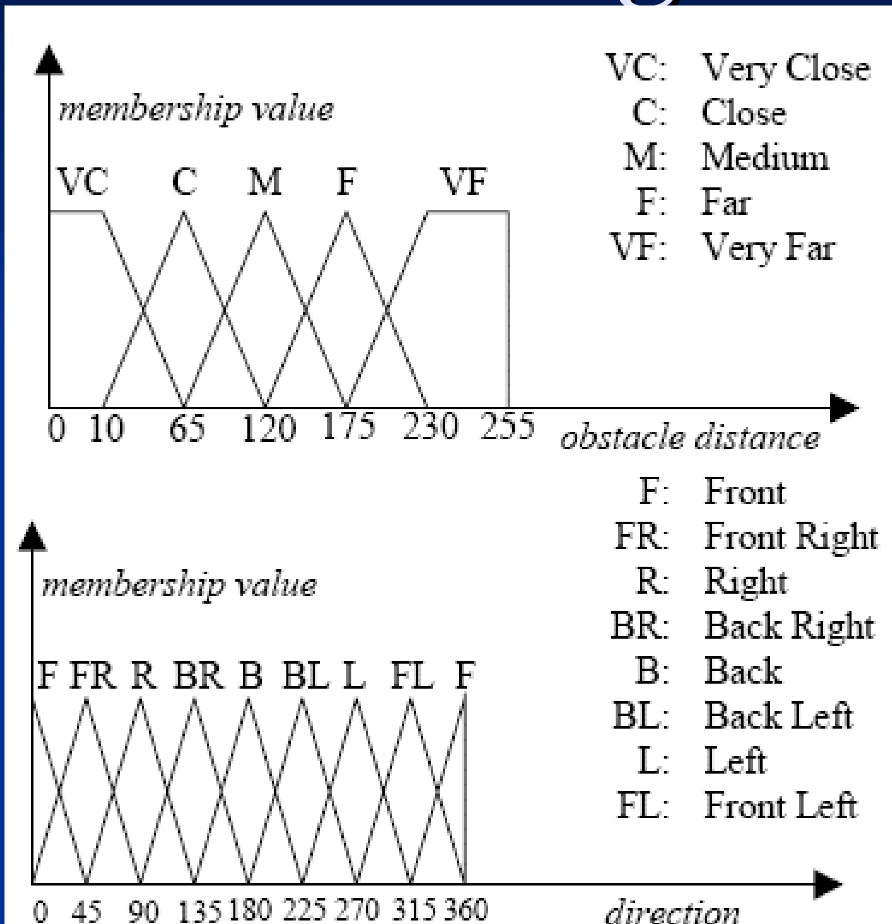
Fig. Fuzzy Rules



- Figure 5. Representation of environment using Fuzzy rules

obstacle distance	obstacle direction	target direction	robot direction
C	F	R	R

Figure 6. Chromosome representing a Fuzzy rule

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Fig. Asynchronous with Complete Resynchronization

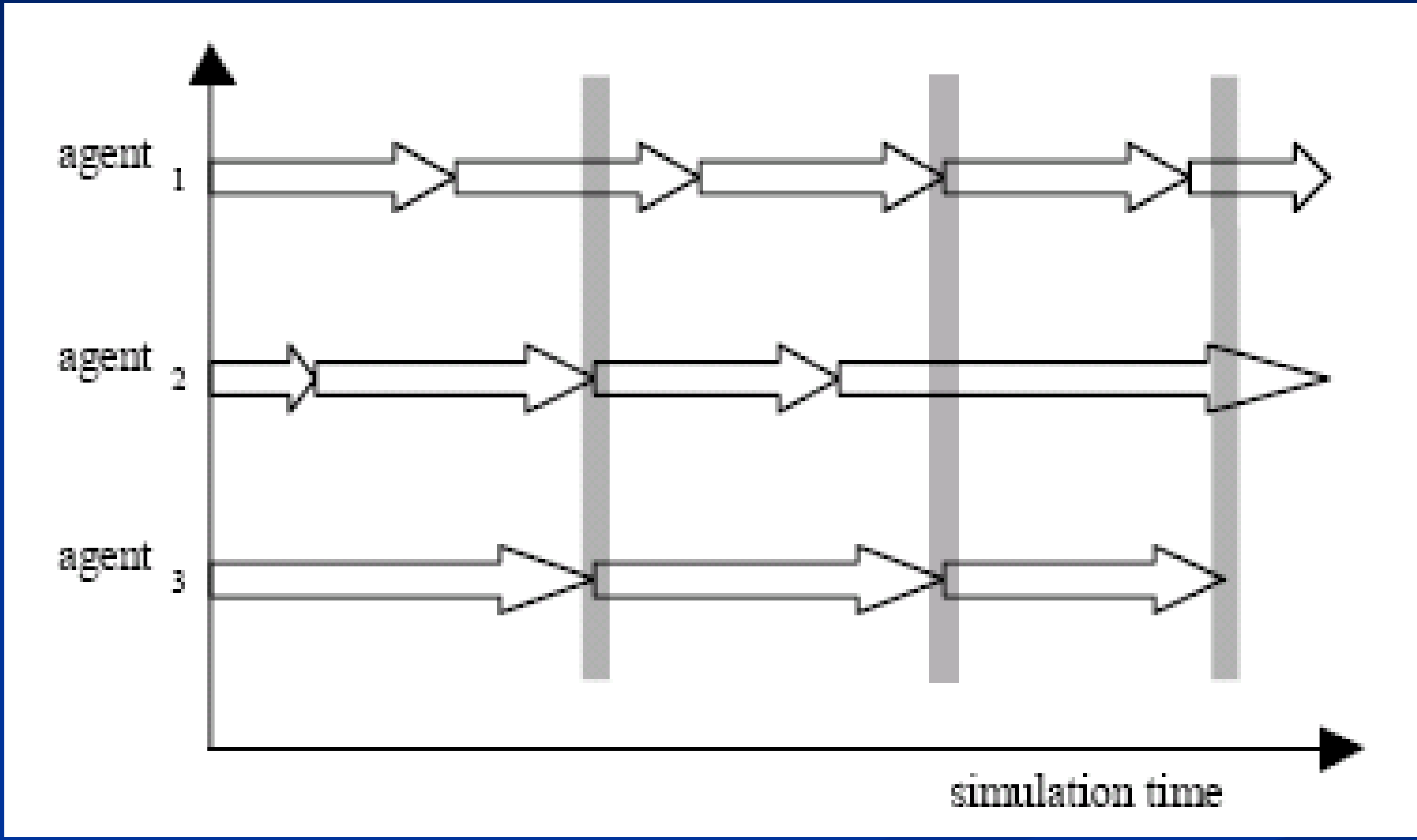

Figure 10. Asynchronous with Complete Resynchronization

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Fig. Asynchronous with Partial Resynchronization

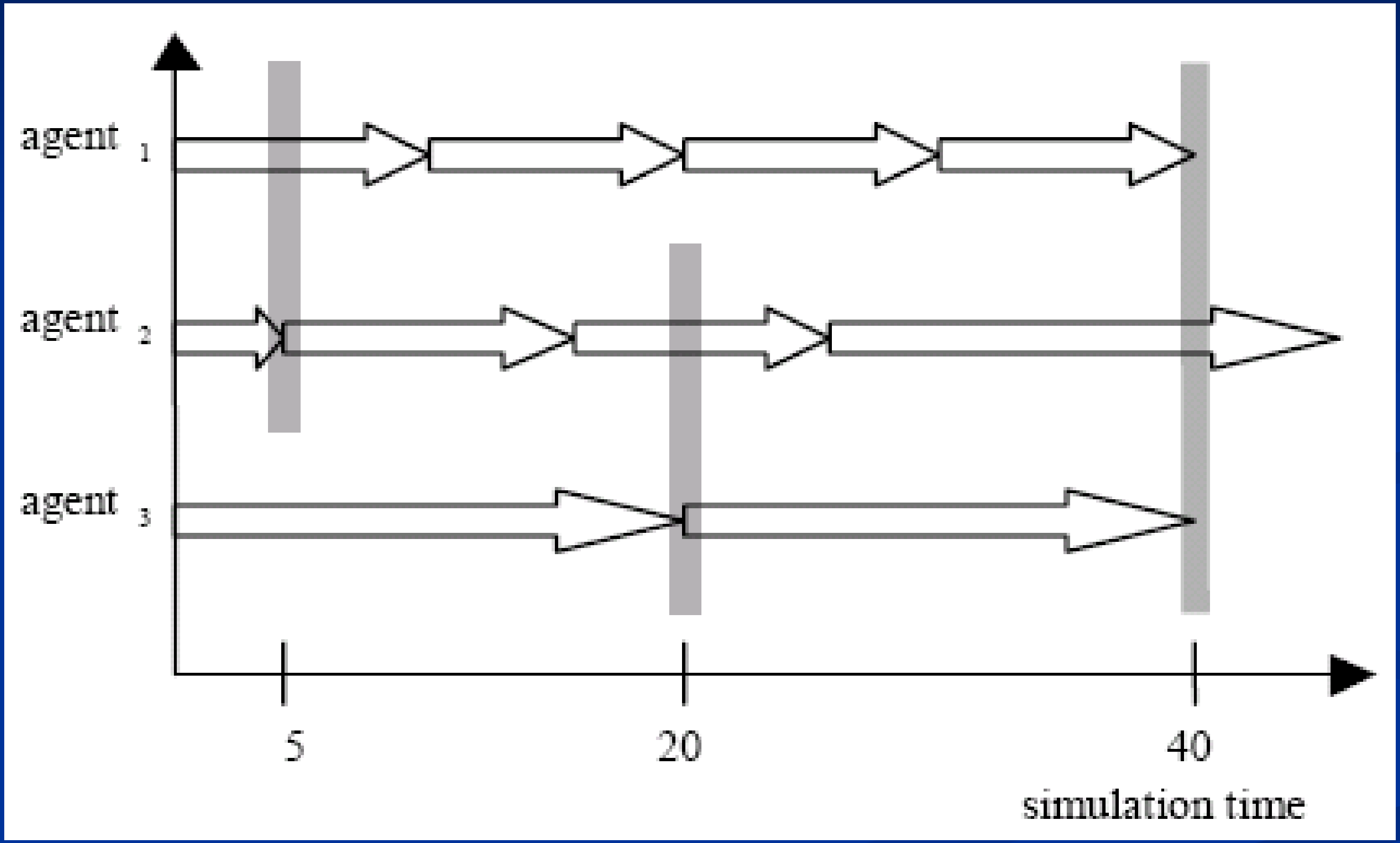

Figure 11. Asynchronous with Partial Resynchronization

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