Principles of Autonomy and Decision Making

Brian Williams
16.410/16.413
Session 1

Today's Assignment

- Read Chapters 1 and 2 of AIMA
  - "Artificial Intelligence: A Modern Approach" by Stuart Russell and Peter Norvig
- Begin reading "Java in a Nutshell"

Outline

- Objectives and Logistics
- Agents and Their Building Blocks

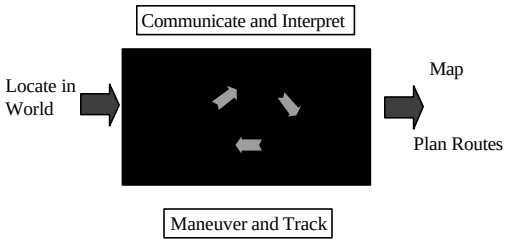
Course Objective 1: Agent Architectures

1. To appreciate the major types of agents, their major functions and the applications they support.
2. To understand the common architectures used to develop agents.
- Understanding exercised through case studies.

Types of Agents (Objective 1)

- Mission-oriented Agents
- Self-repairing Agents
- Mobile Agents
- Agile Agents
- Communicating Agents

Agent Architecture (Objective 1)



Course Objective 2: Principles of Agents

16.410/13: To learn the modeling and algorithmic building blocks for creating reasoning and learning agents:

1. To formulate reasoning problems in an appropriate formal representation.
2. To describe, analyze and demonstrate the application of reasoning algorithms to solve these problem formulations.

- Understanding demonstrated on paper and through implementation.

⇨ Introduction to modeling, algorithms and analysis the next two Wednesday.

⇨ Introduction to implementation the next two Mondays.

Agent Building Blocks

- Activity Planning
- Execution/Monitoring
- Diagnosis
- Repair
- Scheduling
- Resource Allocation
- Path Planning
- Localization
- Map Building
- Trajectory Design
- Policy Construction

Course Objective 3: Implementing Agents

16.413: To appreciate the challenges of building a state of the art autonomous explorer:

Fall 03:

- Mars Exploration Rover shadow mode demonstration.

Fall 04:

- Gnu Robot competition.

Fall 05:

- Model-based autonomy toolbox
- The virtual solar system
- Stay tuned for more.

Text and Language

- Text
  - "Artificial Intelligence: A Modern Approach" by Stuart Russell and Peter Norvig
  - 2nd Edition (not 1st Edition!!)
- Programming
  - All programming in Java
  - text "Java in a Nutshell"

Outline

- Objectives and Logistics
- Agents and Their Building Blocks

Types of Agents (objective 1)

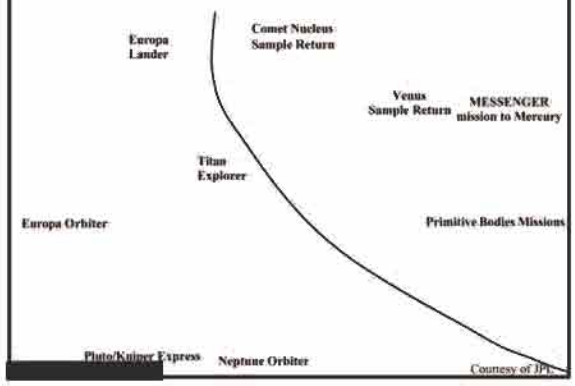
1. Mission-oriented Agents
2. Self-repairing Agents
3. Mobile Agents
4. Agile Agents
5. Communicating Agents

1. Mission-Oriented Agents

"Our vision in NASA is to open the Space Frontier . . . We must establish a virtual presence, in space, on planets, in aircraft and spacecraft." - Daniel S. Goldin, NASA Administrator, May 29, 1996

Courtesy of Kanna Rajan, NASA Ames. Used with permission.

Inner and Outer Planets Missions



2003 Twin Mars Exploration Rovers

- Will learn about the climate on Mars and scout for regions where mineralogical evidence of water has been found.
- The rover twins will determine the geologic record of the landing site, what the planet's conditions were like when the Martian rocks and soils were formed, and help us learn about ancient water reservoirs.

First microscopic view of Mars

Rover 1: Launch: May 30, 2003 Landing: January 4, 2004
Rover 2: Launch: June 07, 2003 Landing: January 25, 2004

Courtesy of Kanna Rajan, NASA Ames. Used with permission.

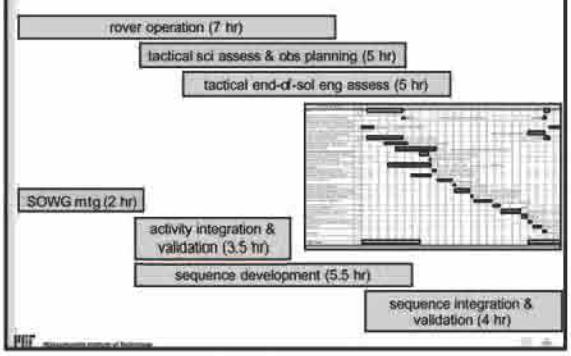
Mars Exploration Rovers – Jan. 2004

Mission Objective: Learn about ancient water and climate on Mars.

- For each rover, analyze a total of 6-12 targets
  - Targets = natural rocks, abraded rocks, and soil
- Drive 200-1000 meters per rover
- Take 1-3 panoramas both with Pancam and mini-TES
- Take 5-15 daytime and 1-3 nightime sky observations with mini-TES

Courtesy of Kanna Rajan, NASA Ames. Used with permission.

One day in the life of a Mars rover



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Agent Building Blocks (objective 2)

- Activity Planning
- Execution/Monitoring

Types of Agents (objective 1)

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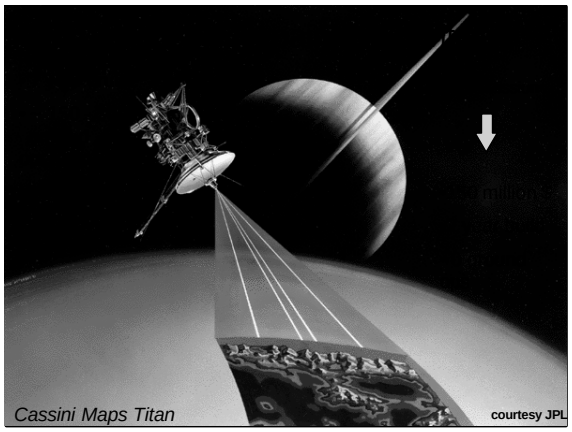
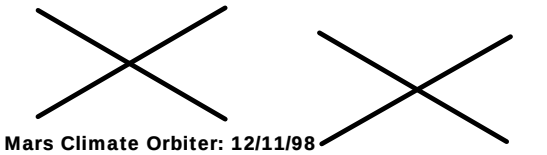


Four launches in 7 months



Mars Climate Orbiter: 12/11/98

Mars Polar Lander: 1/3/9

Stardust: 2/7/99

QuickSCAT: 6/19/98

courtesy of J

Mars Polar Lander

Spacecraft require a good physical commonsense…

Launch: 1/3/99

courtesy of JPL

Traditional spacecraft commanding

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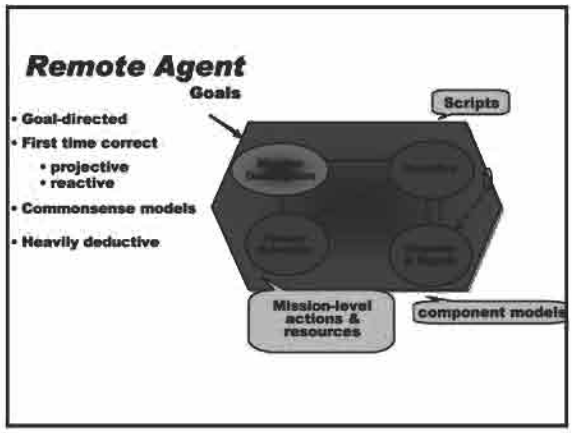
Whats a better paradigm?

Houston, we have a problem ...

- Quintuple fault occurs (three shorts, tank-line and pressure jacket burst, panel flies off)
  - Diagnosis.
- Mattingly works in ground simulator to identify new sequence handling severe power limitations.
  - Planning & Resource Allocation
- Mattingly identifies novel reconfiguration, exploiting LEM batteries for power.
  - Reconfiguration and Repair
- Swaggert & Lovell work on Apollo 13 emergency rig lithium hydroxide unit.
  - Execution

Courtesy of Kanna Rajan, NASA Ames. Used with permission.

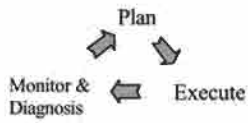


Remote Agent Experiment

May 17-18th experiment
- Generate plan for course correction and thrust
- Diagnose camera as stuck on
  - Power constraints violated, abort current plan and replan
- Perform optical navigation
- Perform ion propulsion thrust

May 21th experiment .
- Diagnose faulty device and
  - Repair by issuing reset.
- Diagnose switch sensor failure.
  - Determine harmless, and continue plan.
- Diagnose thruster stuck closed and
  - Repair by switching to alternate method of thrusting.
- Back to back planning

Agent Architecture (Objective 1)



Agent Building Blocks (Objective 2)

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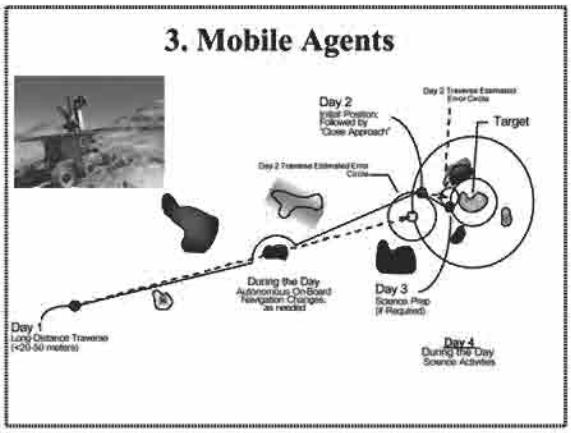

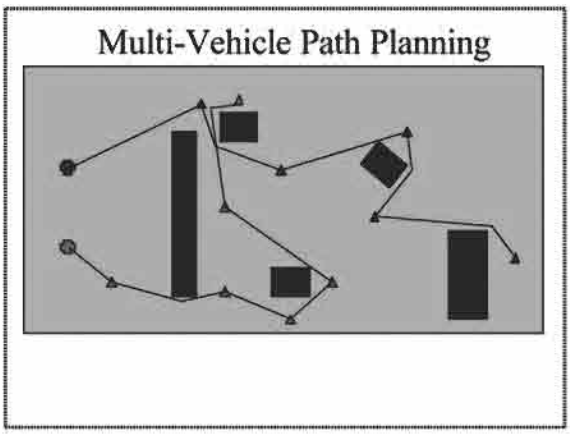

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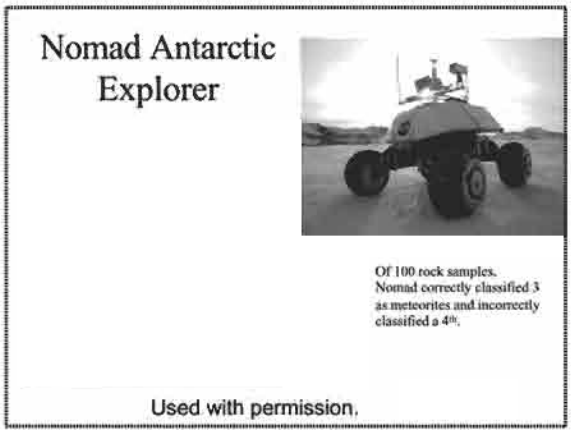

Used with permission.

Agent Building Blocks (Objective 2)

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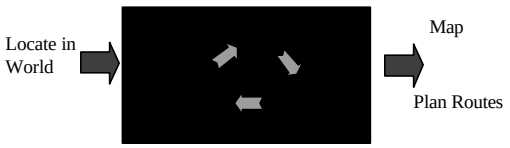

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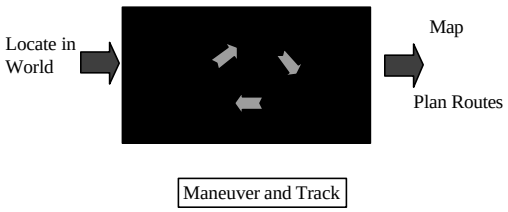

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- Map Building
- Trajectory Design
- Policy Construction
- Plan Adaptation
- Dialogue Management
- People Tracking

Agent Architecture (Objective 1)

NASA Exploration Initiative

- NASA has developed a bold vision focused on robotic and combined human-robotic exploration
  - Response to critical need to augment human presence in space missions with automated, closely cooperating robotic devices
  - Significant cost reduction and safety improvement

Courtesy of NASA.

Challenge

- Autonomous humanoid robots
  - Can execute tasks intended for humans

- Human-robot interaction
  - Understand human tasks

Courtesy of NASA.

Example: orbit assembly and repair

- Robonaut – Humanoid robot for EVA assistance

Courtesy of NASA.

Example: surface exploration

- ERA – EVA robotic assistant follows astronaut and helps with sample collection, instrument placement

Courtesy of NASA.

Example Mission Scenario: Task Execution

- Robot walks to its sample area
- Begins collecting samples
- Walks back to astronaut
  - Stumbles over unseen rock along the way, but recovers using appropriate limb motions

Outline

- Objectives
- Agents and Their Building Blocks
- Agent Paradigms