Strategic planning at NASA

Dra. Maria D. Rodríguez Moreno

Objectives

1. Know main NASA AI planners
2. Know how NASA uses AI Planning

Source

1. Special thanks to James Kurien's presentation
2. Yang Gao, and Steve Chien. Review on space robotics: Toward top-level science through space exploration. Science Robotics 28, Vol. 2, Issue 7, 2017.

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Legacy planners

- NONLIN+ (Tate y Whiter, 1984): general planning architecture, precursor of current planners
- SIPE (Wilkins 1988): independent domain planner and 1st in managing consumable and producible resources and managing conflicts. Used in air and military campaigns
- DEVISER (Vere 1983): based on NONLIN, was used in Voyager to photograph Jupiter, Saturn and its satellites in 1979, 1980 and 1981

New approaches

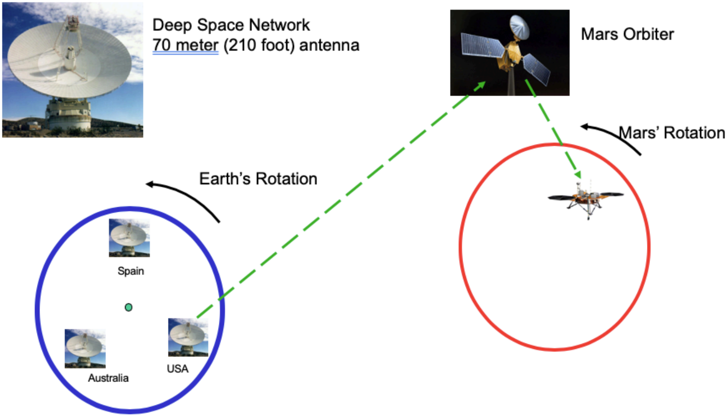
- HSTS (Muscettola 1994): integrates P& S, applied to the problem of planning observations in the Hubble Space Telescope
- O-PLAN2 (Tate et al., 1994): based on NONLIN and Blackboard techniques. Applications: rescue coordination, military operations, space missions
- NMRA (Muscettola and Smith, 1997): New Millennium Remote Agent was the first time that an AI agent controls a spacecraft for 6 days: the Deep Space One (DS-1)
- ASPEN (Rabideau et al. 1999): JPL-NASA P&S system
    - Earth Orbiting (EO-1): controllable by a small group
    - Citizen Explorer: small mission with teaching purposes
    - Antarctic Mapping Missions: Mars-01 Marie Curie rover
- EUROPA (Frank, Jónsson and Morris 2000): MSL or Phoenix

Summary

System	Mission	Year	Used	Techniques
DEVISER	Voyager	1977	On-ground	POP
PLANIT-II	Galileo Mars Pathfinder Spitzer Space Telescope	1995 1997 2003	On-ground On-ground On-ground	Used by AI experts who provide specific Scheduling algorithms
HSTS	DS-1	1998	On-board	HTN & SAT & Refinement CS
ASPEN	AMM-2	2000	On-ground	Repair CS
PROBA	Proba	2001	On-board	OR
ASPEN & CASPER	EO-1	2003	On-board	Repair CS
MPS	Smart-1	2003	On-ground	OR
EUROPA/ MAPGEN	MER	2003	On-ground	HSTS descendent
MEXAR-2	Mars Express	2005	On-ground	Refinement CS
EUROPA2/ ENSEMBLE	Phoenix MSL	2007 2009	On-ground On-ground	HSTS descendent

Introduction

How we communicate?

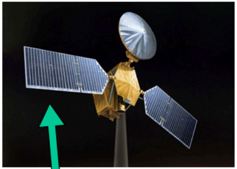


Introduction

Types of Data Exchanged

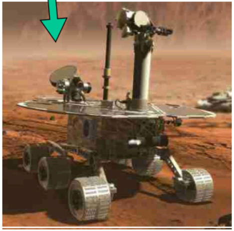
Data that is received from a rover

- Images
- Other scientific data
- Engineering data
  - Battery level
  - Temperatures onboard the lander
  - Amount of storage space available



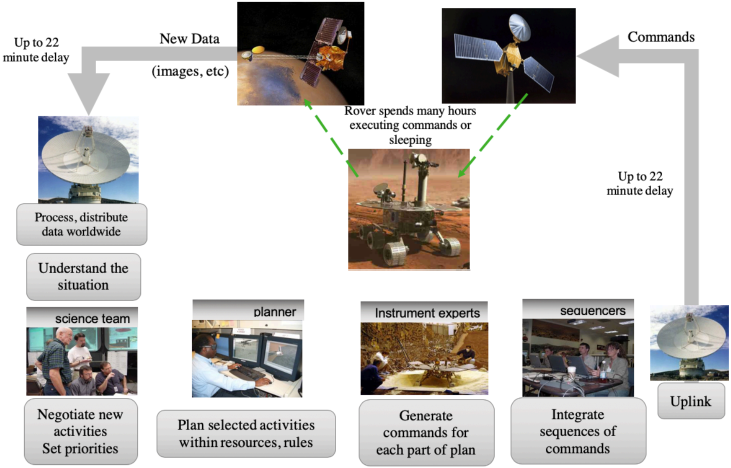
Data that is sent to a rover

- Sequences of commands to be executed
  Take a picture, point the camera, move the arm
- Complex behaviors to perform
  Drive to a target while avoiding rocks
- When to communicate with the orbiters
- Changes to heating or other parameters



Introduction

Daily Science Operations



Introduction

Controlling a rover

Communication is limited

- Commands take up to 22 minutes to reach Mars via radio
- Commands sent to the rover once per day (typically)
- Images and other data received once a day, sometimes at 4am

Resources are limited

- Runs on a battery supplied by solar panels or radio-thermal generator
- Some experiments can only be run a few times
- We don't have an unlimited ability to transmit data

Coordination

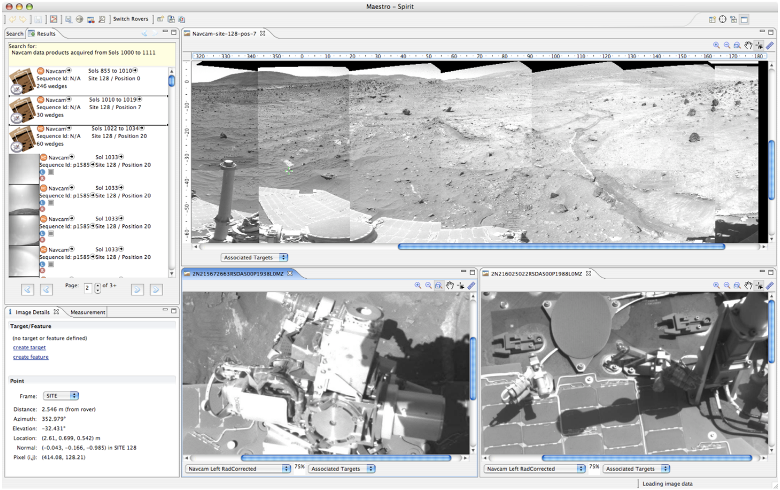
- Many scientists want to command the rover at once
- We want to respond to whatever the rover's last actions revealed
- We must come up with a plan quickly, in time to send it to the rover
- There are many safety constraints our commands must obey

Uncertainty

- The environment is complex (rocks, shadows, varying temperature)
- The rover may not succeed in performing the commands
- It takes time to understand what is going on around the rover

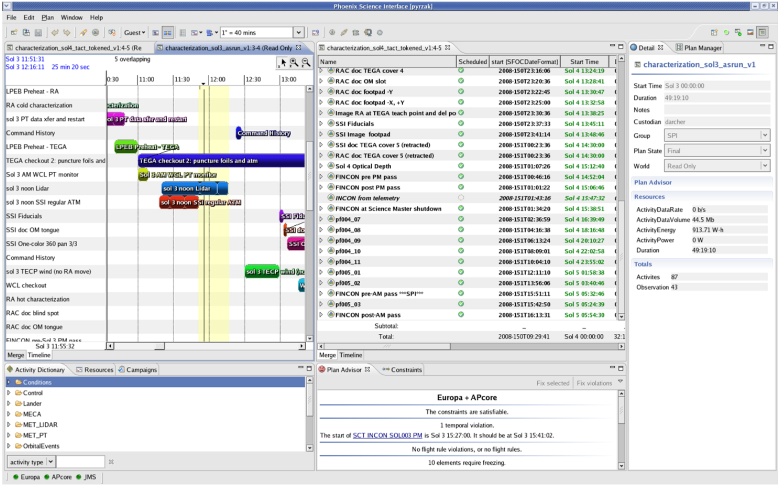
Introduction

Data Browsing, Image Analysis & Targeting



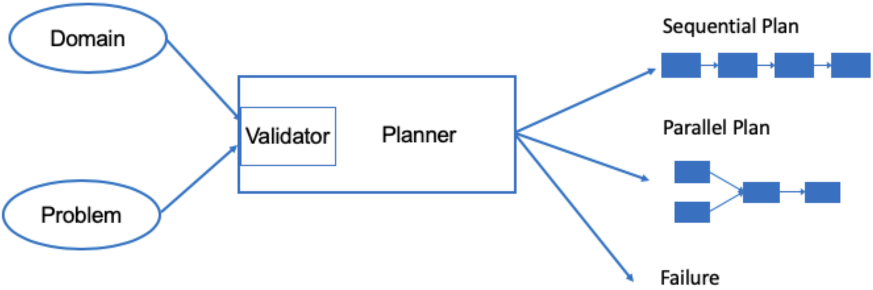
Introduction

Activity Planning & Analysis



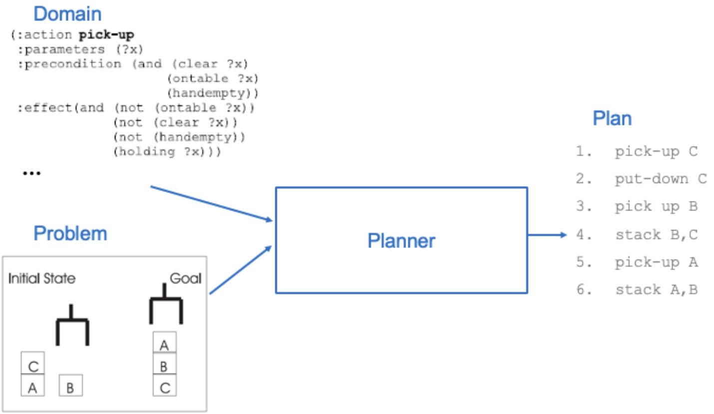
How we use AI planning?

Inputs & Outputs



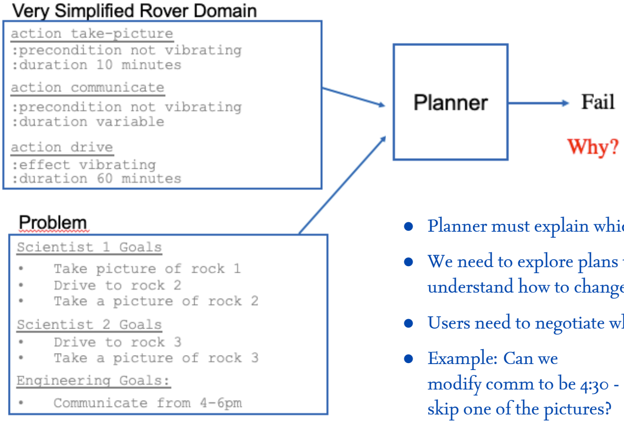
How we use AI planning?

Blocksworld



How we use AI planning?

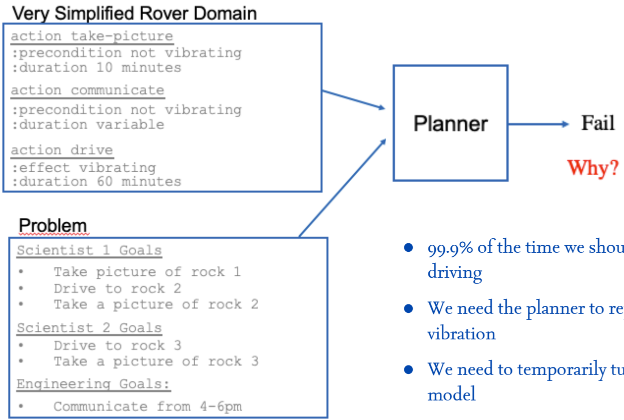
Problems?! (I)



- Planner must explain which goals are in conflict and why
- We need to explore plans that violate the domain to understand how to change them
- Users need to negotiate which goals to delete or modify
- Example: Can we
  modify comm to be 4:30 - 6?
  skip one of the pictures?

How we use AI planning?

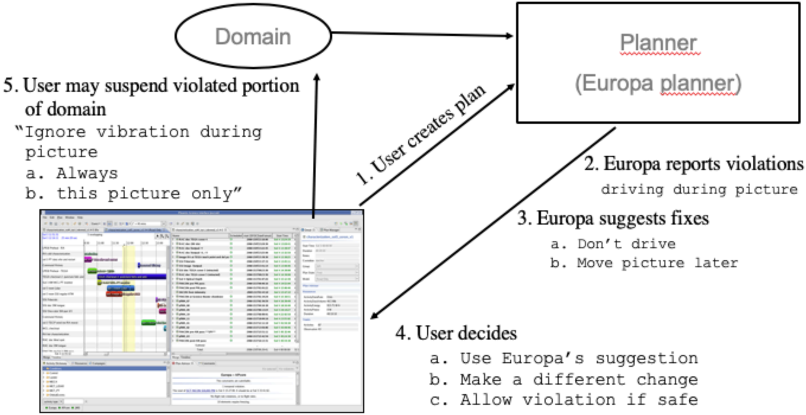
Problems?! (II)



- 99.9% of the time we should not take a picture while driving
- We need the planner to report the conflict involving vibration
- We need to temporarily turn it off without re-writing the model

How we use AI planning?

How it is done?



How we use AI planning?

How the planner appears to the user