Intelligent Rover Decision-Making in Response to Exogenous Events

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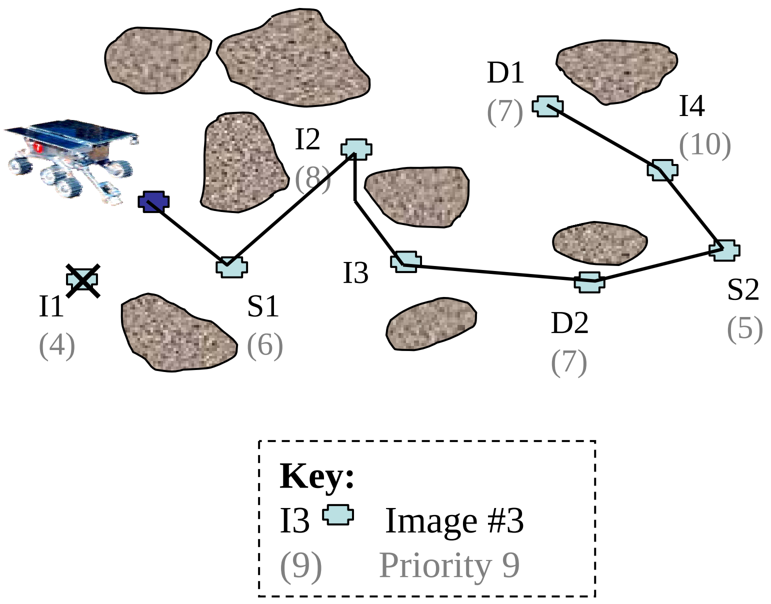
Outline

- Rover Planning and Execution Options
- Problem Description
- CLEAR Intro
  - DFBB (initial plan)
  - Re-planning for “events”
    - Oversubscriptions
    - Opportunistic Science
- Mars Yard demonstration
- Conclusions

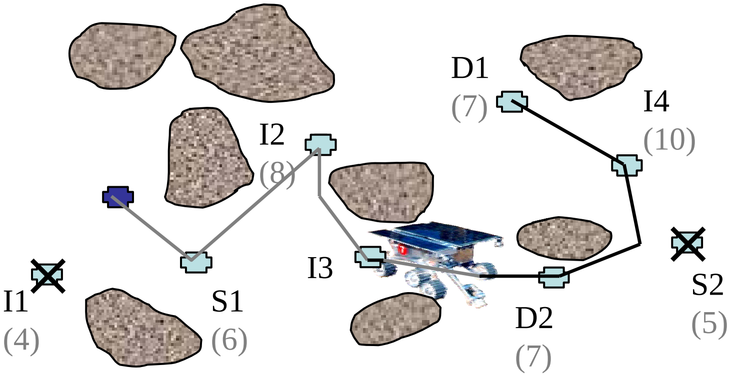
Rover Planning,…

- Number of activities per “scenario” or per “sol”
- Constraints
  - Resource (energy, RAM)
  - Temporal (time limitations, activity start-times)
- Manage activity priorities
  - Strict Priority
  - Sacrifice high priority for total gain



...Execution,…

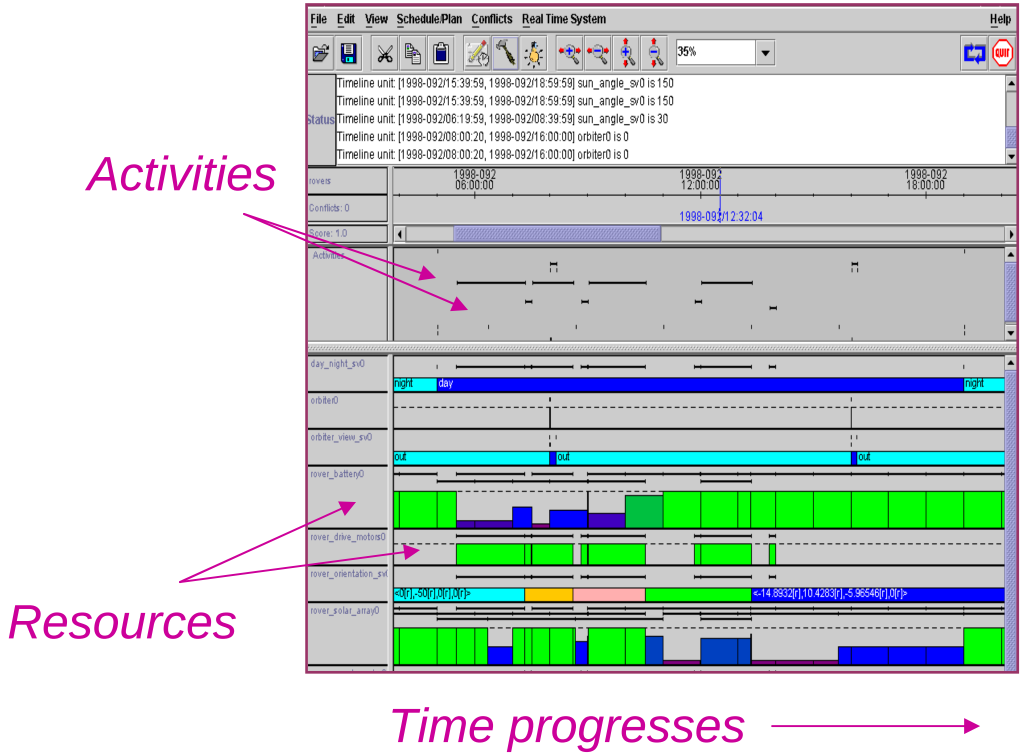
- Achieve the highest amount of science possible
- Make effective use of available resources
- Only an "estimation"
  - Over-subscriptions
  - Under-subscriptions



…and Re-planning

- Can the current plan be optimized?
- Do we need to re-order the plan based on obstacles?
- Can we add opportunistic science?

Activity and Resource Timeline



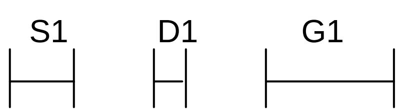
Pessimistic vs. Optimistic

Pessimistic

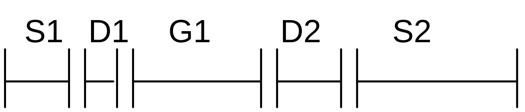
- If things **can** go wrong, they **will**
- Be safe, allow plenty of time for each activity
- Don't over-schedule the plan (not a lot of activities to start)
- Problems are "easily" solved

Optimistic

- Although things **could** go wrong, they probably **won't**
- Give activities a reasonable estimate of time, not a lot of buffer
- Initial plan is tightly-packed
- Problems may have "rippling" effect



30 minutes, 3 activities

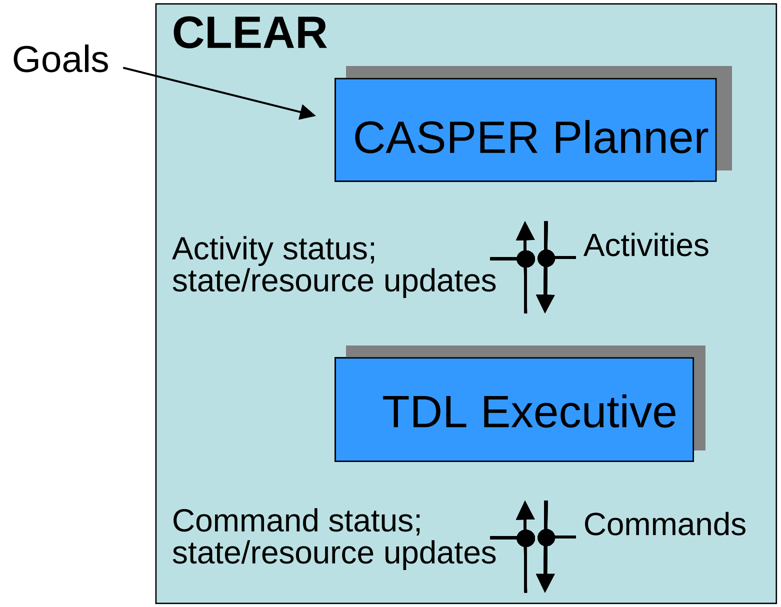


30 minutes, 5 activities

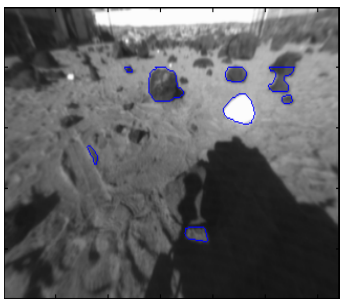
Problem Description and Solution

- Combine the options to best serve the rover
  - Protect against problems (over-subscriptions)
  - Maximize initial resource allowances
  - Exploit opportunities (under-subscriptions)
- Also continuously search for more science
- Solution:
  - First, generate the best possible initial plan based on reasonable estimates,
  - Then add real-time continuous optimization and re-planning throughout execution,
  - While using data analysis to search for new science and alert the system when found

CLEAR Architecture



Science "Alert" is received and the planner tries to fit in the new goal (an additional image). Not all "alerts" can be added.

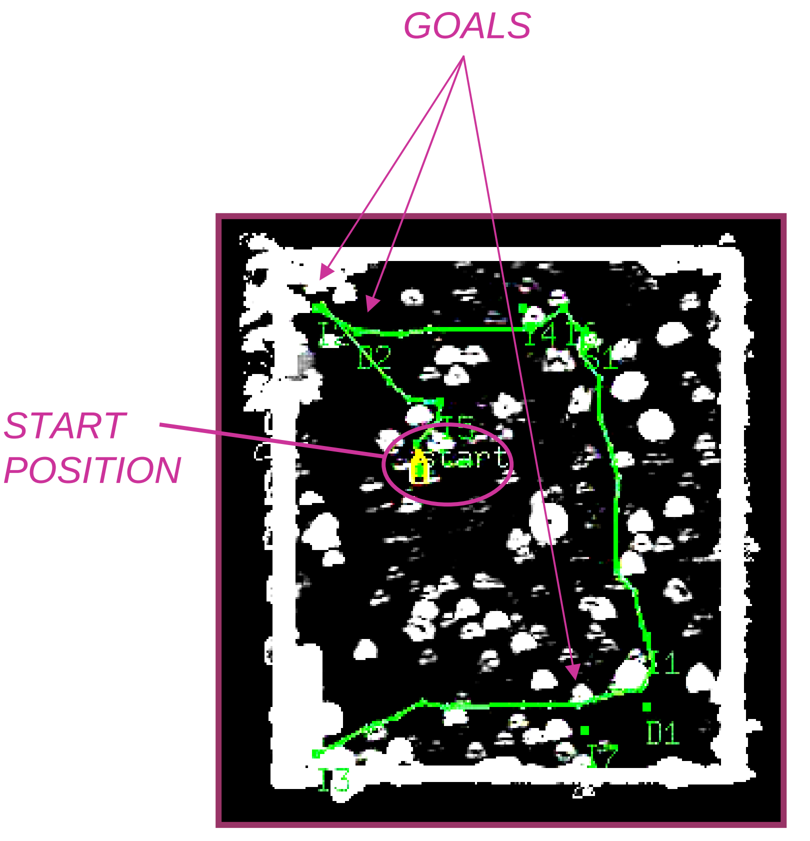


Data analysis tool detects "interesting" rock in hazcam images. Trigger science "alert"!

Real or Simulated Rover Control Software and Hardware

Initial Plan Generation

- Policy:
  - **Maximize priority score**, while maintaining “Strict Priority” rule: highest priority targets take precedence
  - **Minimize distance**
  - **Respect** time and resource **limitations**
- Depth First Branch and Bound
  - Quick for < 13 targets
  - Guarantees optimality
  - Easily adaptable



Laser scan of JPL Mars Yard used as backdrop for rover simulator GUI

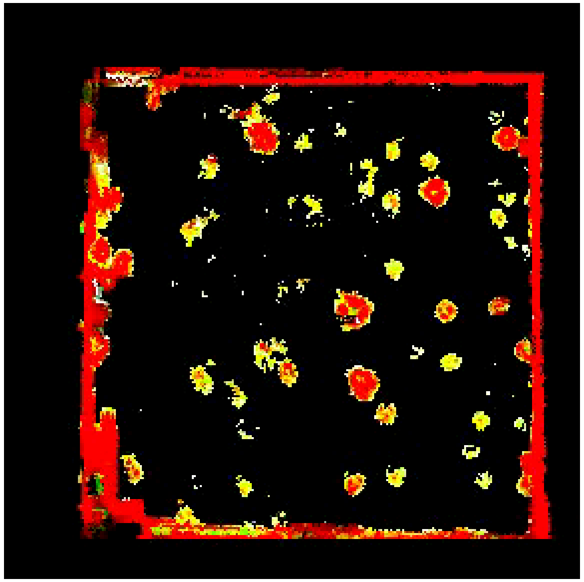
Re-planning for Events

- Opportunistic Science (“Alerts”)
  - Data Sample Request (DSR)
    - Expire, if not possible
    - Lower priority than science goals
  - Stop and Call Home
- Over-subscriptions
  - Can we move or add activities to solve the conflict?
  - Delete by priority
- Under-subscriptions
  - Add-back previously deleted goals
  - Add-in low priority goals
  - Retain resources for future dsrs

Mars Yard Demonstration

- Lowest priority (Image 1/I1) == will not be considered until higher is satisfied
- Position off planned path == high deviation == needs a lot of time
-Time accumulated throughout run allows add-back

- Simple planning due to time slot
- Initial plan is over-subscribed
- Re-planning for opportunistic science and run-time under-subscription



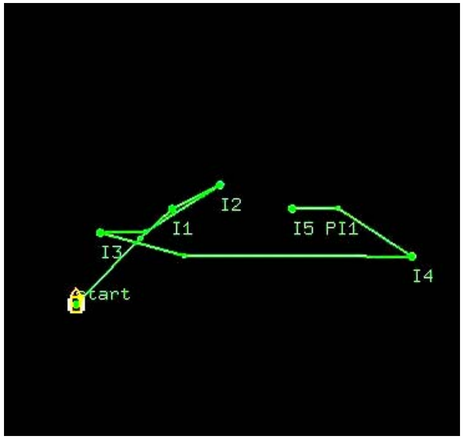
- Opportunistic Science (I4,I5,I6,and I7) occur during scenario: able to add-in without disruption to current state of plan

Related Work

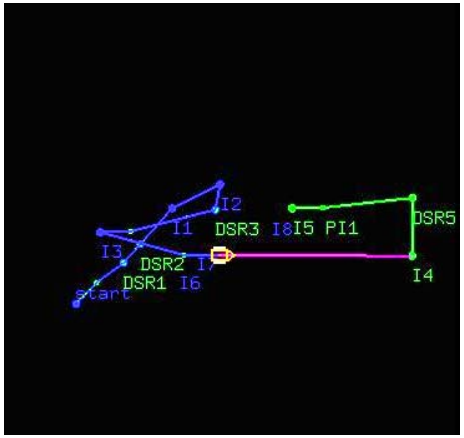
- OASIS (rock detection, criteria)
- MER planning (on ground), no re-sequencing, no opportunistic science
- AMES rover planning
- Autonomous Science Experiment (ASE)

Future Work

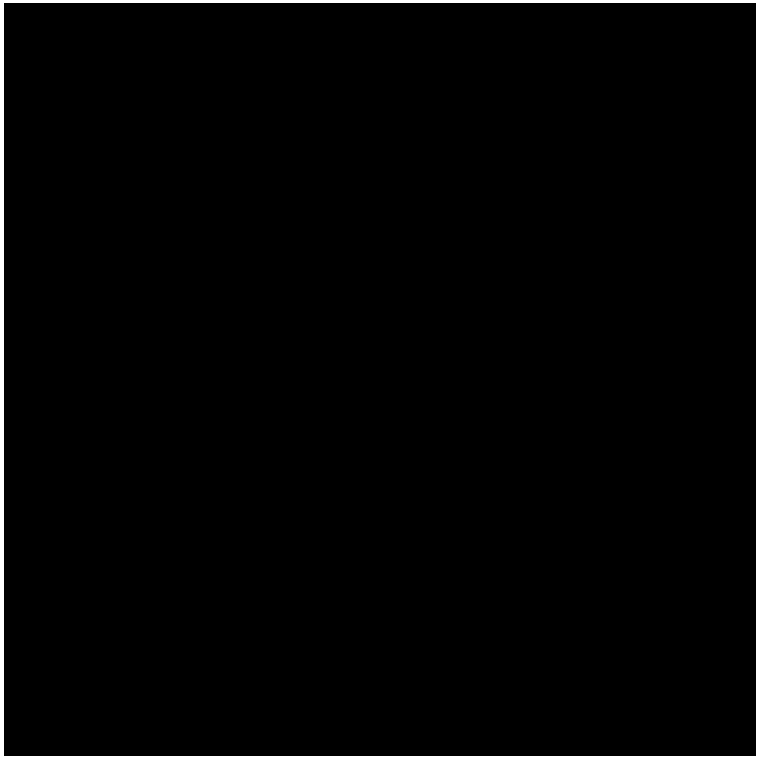
Sample Plan with Temporal Constraints



Initial placement respects start-time windows (I1 and I2 must occur early in the day)



*"Alerts" during execution are satisfied (mixed type: turn-to **and** drive-to)*



Temporal constraints and turn-to and drive-to alerts

Conclusions

- System takes advantage of pessimistic safety and optimistic return by appropriately reacting to over- and under-subscriptions
- Opportunistic science is achieved throughout plan without disruption to current state
- Temporal constraints have been easily added to the existing system (adaptable)

References

- OASIS webpage:
  http://www-aig.jpl.nasa.gov/public/mls/oasis
- CLARAty webpage:
  http://claraty.jpl.nasa.gov/
- TDL webpage:
  http://www.cs.cmu.edu/~tdl/
- Further CASPER References:
  http://www-aig.jpl.nasa.gov/public/planning/projects/current.html
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