On the Design of the Axel and DuAxel Rovers for Extreme Terrain Exploration

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Outline

• Steep terrains of interest
• Axel & DuAxel Rovers: A novel approach to steep terrain access
• Design features and advantages
• Field Testing
Extreme Areas of Extreme Interest

- Stratigraphic layers in polar caps, impact craters, and fluvial channels
- Lunar cold traps with temperatures of 40 K – 70 K may contain water ice in South polar Aiken basin region
- Lava Tubes & Pit craters under consideration for future human habitation
Science Dreams vs. Engineering Realities

Where scientists would ultimately like to go:

Where the state of the art allows us to go:

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Tethered Systems Concepts

**Axel**
- Fixed mother (lander)
- Mobile daughter (Axel)
**Pros:** simple deployment, minimal mass mobilized
**Cons:** Requires precision landing

**DuAxel**
- Mobile mother (untethered DuAxel)
- Mobile daughter (two Axels)
**Pros:** redundant capabilities, does not require precision landing
**Cons:** additional elements mobilized
Axel & DuAxel Concepts

- Each Axel rover has four primary degrees of freedom (two wheels, tether spool, & caster arm)
- Power & communication over tether with additional on-board energy storage
- Robust: can operate when flipped
- Simple: only a few rotatory joints to achieve mobility, camera pointing, and instrument placement
- Multiple science instruments tucked inside of wheels & deployed to the ground
- Instruments & body mounted stereo cameras can be pointed without descending/ascending slope
- Two Axels can dock to a central module to form a DuAxel rover which allows for long range mobility without consuming tether resource
Axel System Overview

- Commutation between spool and body
- Commutation between arm and body

- Rotating arm & drum in *same direction*, body rotates without reeling tether
- Rotating in *opposite directions*, applies twice the power for reeling the tether

Instruments deploy out and down towards the ground

Dimensions:
- 0.84m
- 1.52m
Axel Prototype Design Features

- Hemispherical wheels
- Tether
- Instrument module
- Stereo cameras
Instrument Module

- Each wheel can accommodate an instrument module.
- Instruments are mounted to the underside of a plate and are protected from the environment when the deployment mechanism retracted.
- Each quadrant of the module can support one deployment mechanism (simple four bar linkage).
Mechanical Design Elements

- Wheels, body structure, and instrument modules comprised mostly of riveted aluminum sheet
- Avionics packaged inside of a square tube that comprises the main chassis structure and are easily accessed
- Instruments modules are independent of mobility system structure and can be removed for servicing & calibration
Common Drive Modules

- Wheel and Tether drive actuators have similar mechanical output requirements (~30W to allow the 50kg Axel to drive/ascend at 10 cm/s)
- Tether requires more speed but less torque
- Wheel requires less speed but more torque
- Common design reduces unique part count and complexity

~Same output power
Tether Tension Sensing

- Based on automotive clutch plate concept
- Knowing spring constant, can encode relative angle between plates to determine line tension
- Absorbs some shock after sudden drop
DuAxel System

Mast with stereo cameras
Front Axel (A)
Deployable leg in stowed position
Central module
Rear Axel (B)
Passive roll joint
Axel Deployment

One Axel remains docked to central module

Axel descending cliff face

Central module

Passively deployed anchor leg

Tether
Traversing Nearly Vertical Terrain

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Black Point, AZ

March 2011
Canyon Country, CA

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Questions?

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  • Axel Principal Investigator: Issa Nesnas
  • Prof. Joel Burdick and his Caltech team
  • JPL Research & Technology Development Program
  • Dr. Daniel McCleese
  • Dr. Jonas Zmuidzinas

• Resources:
  • http://www-robotics.jpl.nasa.gov/systems/index.cfm
  • http://robotics.caltech.edu/~pablo/axel/home.html

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