State of the Art in Field Robotics 2004

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Outline

- What makes Field Robotics unique
- Industry Drivers
- Key Technologies
- Key Systems by Application Areas
  - Agriculture/Forestry
  - Mining/Construction
  - Field Service
  - Security/Surveillance
  - Exploration
- Unsolved Problems
- Issues in adoption of Field Robotics Technology
- References

Field Robotics

- Typically outside the factory/controlled infrastructure
- Operation in all weather conditions (precipitation, temperature range, smoke, dust)
- Conditions can not be controlled (lighting, vegetation)
- Terrain can be varied and dynamic with time and location
- Operating space may be in tens or hundred of kilometers
- BIG robots

Industry Drivers

- Governmental
  - Increased need and military funding of mobile robotics
  - Increased regulation of off-road machines
- Environmental
  - Environmental Cleanup: De-mining, UXO Removal, Operation in hazardous materials
- Social
  - Work Preference (4 “Ds”): Nothing Difficult, Dull, Dirty, Dangerous
  - Aging workforce (robots increase quality of novice operators)
  - Hard to recruit, train and sustain workforce.
- Efficiency
  - Increases in efficiency decreasing from traditional methods.

Key Technologies

- Environmental Perception
- Localization
- Task Planning
- Mechanisms
- Dynamical Models
- Systems Engineering
- Interfaces

Agriculture: Commercial Automation

- Commercial systems provide hands-free steering for straight-line operations (+/- 10cm accuracy) by retrofitting tractors
- Used in tillage, spraying, and seeding operations. Benefits:
  - Reduced use of fuel, spray material
  - Faster operation
  - Lower operator fatigue
- Operator needed to mark the extent of operation, assist in some stages (e.g. turn the vehicle at end of row) and for obstacle detection.
- Typical operation in vast open spaces
- Commercial systems: AutoTrac (John Deere), AgGPS AutoPilot (Trimble), AutoFarm (Integrinautics)
- Typical time to market starting with concept: 6 years

Agriculture: Fully Automated Systems

- Proof-of-concept machines have demonstrated autonomous operation over hundreds of acres mowed, harvested and sprayed
- Vehicles use GPS for precision. Inertial augmentation necessary when operating in undulating terrain and in presence of tall structures/canopy.
- Orchard Tractor has demonstrated vision-based collision avoidance in the presence of foliage.
- Mowers has demonstrated laser-based collision avoidance of small obstacles in undulating but smooth terrain.
- Automated vehicles achieve speeds comparable to human-driven versions.

Harvester: Case New Holland/CMU

Autonomous Orchard Tractor : John Deere/CMU

Agriculture: Concept Vehicles

- Commercial efforts developing slowly through internal development
- Focus on perceived future markets
- Autonomous versions to be commercialized by 2010

John Deere Orchard Tractor

John Deere Timber Jack Walking harvester

Mining: Commercial Systems

- Operator assist is common paradigm.
- Operator shown feedback (terrain map) as the vehicle moves and can determine areas above or below grade.
- In some cases, blade is actuated automatically while operator drives.

Landfill Compaction System: Caterpillar

Stakeless Grading System: Caterpillar

Grading with Military dozer, Caterpillar

Mining: Advanced Operator Assist

- Operator positions vehicle, Digging is automated (AutoDig)
- Available on Wheel Loaders (surface mining) and LHDs (underground mining)
- Excavator version in R & D
- Recent versions can adapt automatically to variety of soil types and conditions
- Operation rivals expert operator

AutoDig: Caterpillar

Mining: Research Systems

- Accomplishment: proof-of-concept, autonomous 75 ton, haul truck operating in a rock quarry for 8000 miles.
- Used GPS for positioning and radar for obstacle detection
- Early adoption first via displaying obstacles on road for operation in obscurants.

Fully Autonomous Haul Truck: Caterpillar/CMU

Visualization of obstacles in obscured conditions: Caterpillar

Mining: Research Systems

- Accomplishment: proof-of-concept excavator autonomously loading hundreds of trucks at rate comparable to expert human operator
- Unsolved problem/challenge: surface mines are complex with many types of machines and operational scenarios
- Goal: find the best way to marry autonomous control with human control in an integrated surface mine

Fully Autonomous Excavator Truck Loading: Caterpillar/CMU

Mining: Future Concept

Future concept: integrated autonomous systems for

- Dozing
- Loading
- Excavating
- Drilling
- Grading

Concept from Caterpillar

Exploration: Extreme Environments

- Robots developed to access extreme terrain for scientific investigation
- Volcanoes: Dante I & II rappelling robots for crater sampling (1994)
- Polar: Nomad Antarctic Meteorite Search (2001)
- Deserts: Hyperion long distance solar-powered survey (2003)
- Interpretation of science intent and data remains a significant challenge

Nomad: NASA/CMU

Dante: NASA/CMU

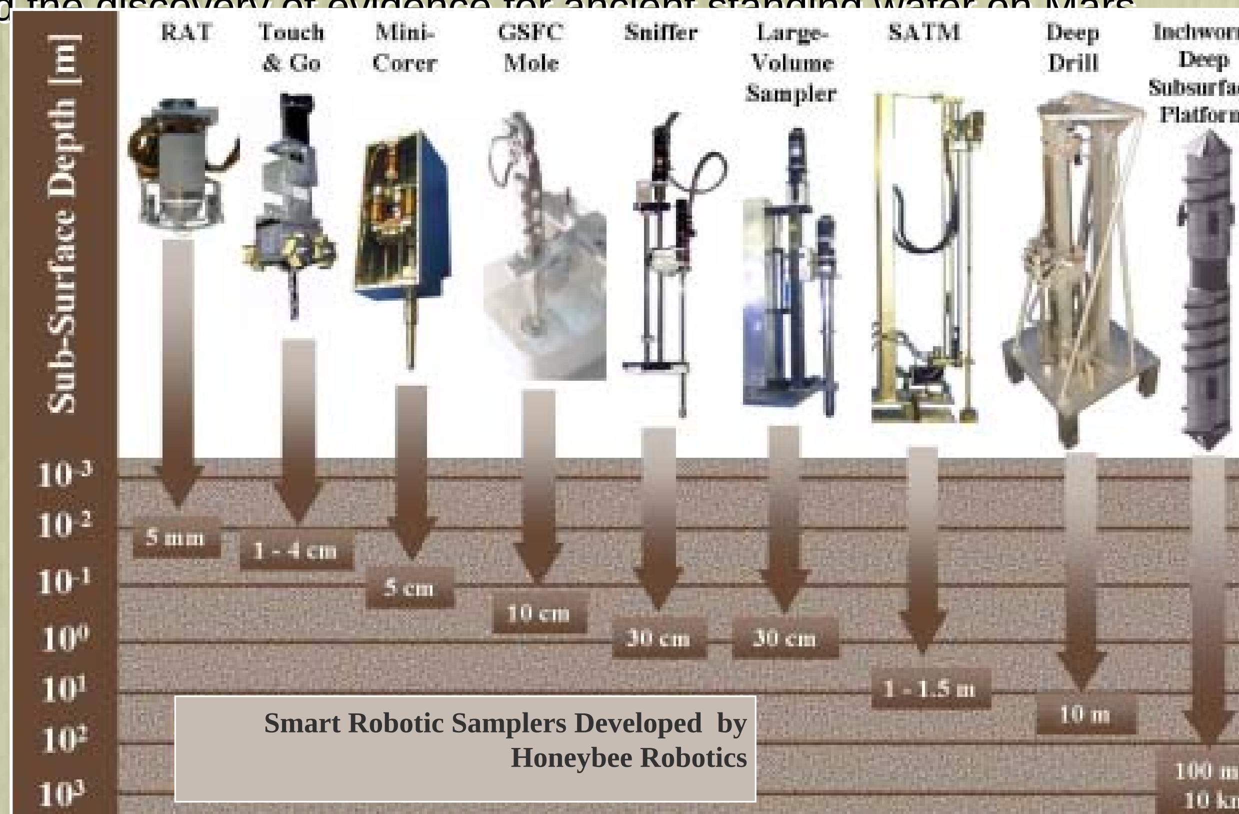
Hyoerion: NASA/CMU

Exploration: Drilling

- Rock Abrasion Tool for the Mars Exploration Rover mission continues to perform beyond expectations and in part enabled the discovery of evidence for ancient standing water on Mars

Subsurface exploration in rock/regolith environments that are unstructured and largely unknown.

Drilling deeper than 30 meters is a significant tall pole when considering systems must meet mission requirements of low mass, low (daily) power and long surface mission lifetime.



Rock Abrasion Tool [RAT] prepared rock at Meridiani Planum; led to evidence of ancient standing water on Mars. RAT telemetry has provided first measurements of Mars rock strength. *February 2004*

Robot Racing: DARPA Grand Challenge

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- Robot race to engage public, benchmark SOA, possibly spur research
- Navigate autonomously 140 miles through unimproved and paved roads using high-resolution prior map and on-board obstacle avoidance
- No teams completed the race to collect $1M, next race October 8, 2005 for $2M
- Emerging commercial spin-off in robot racing

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