Demining Robotics Case Study

METR 4202: Advanced Control & Robotics

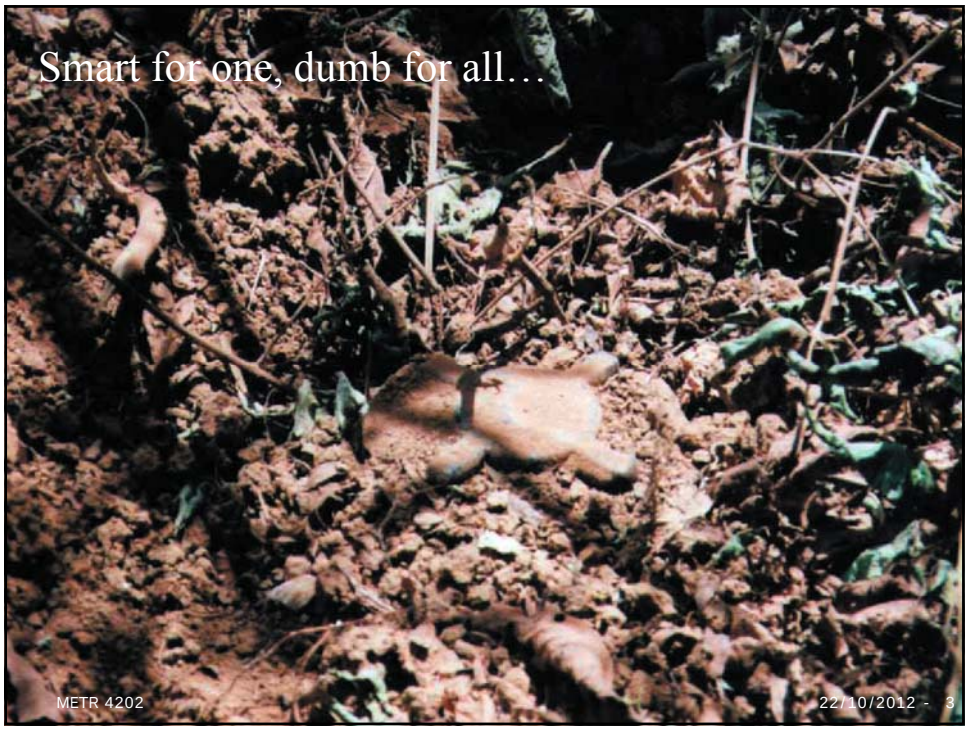
Drs Surya Singh, Paul Pounds, and Hanna Kurniawati

Lecture # 13 – Part 2 October 22, 2012

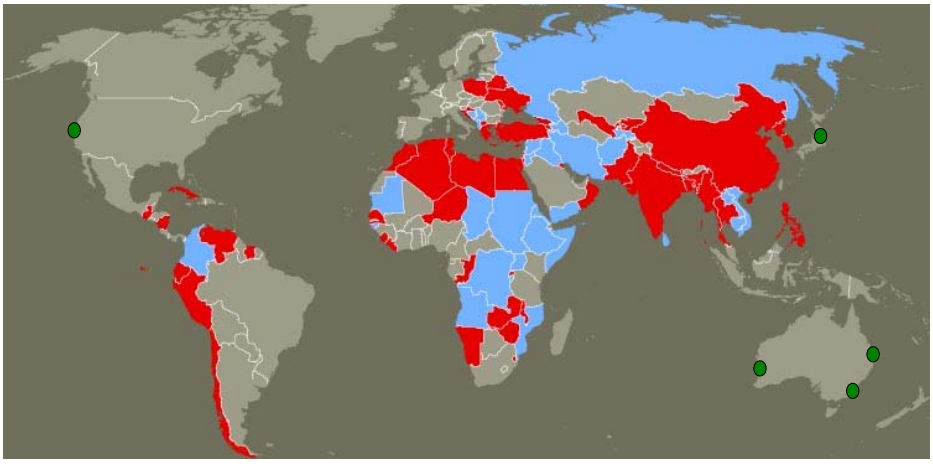
metr4202@itee.uq.edu.au

http://itee.uq.edu.au/~metr4202/

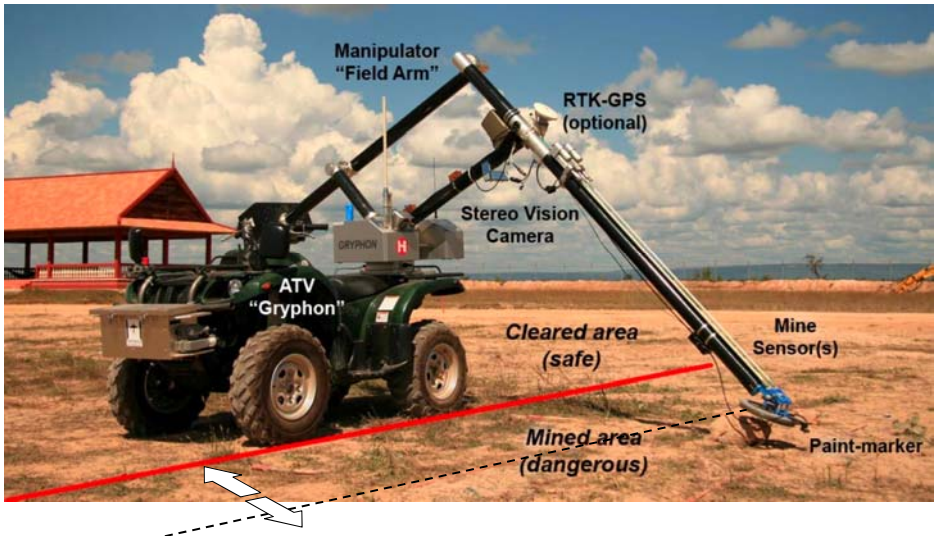
RoboticsCourseWare Contributor



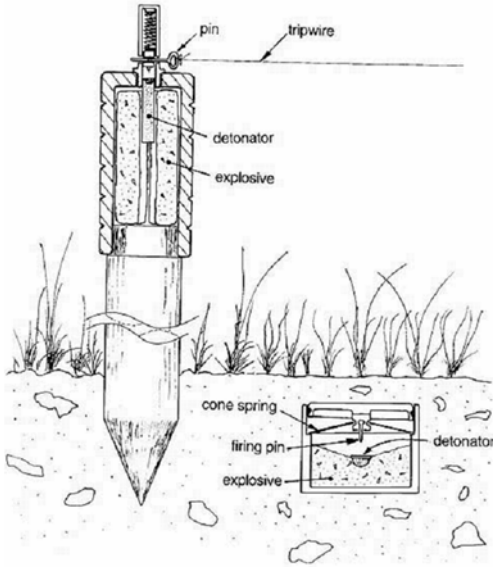
Landmines:Worldwide Problem



Gryphon: Mine Scanning Robot



Generalized Mine & Placement



(Antipersonnel) Landmines are Challenging

- Variable & Changing

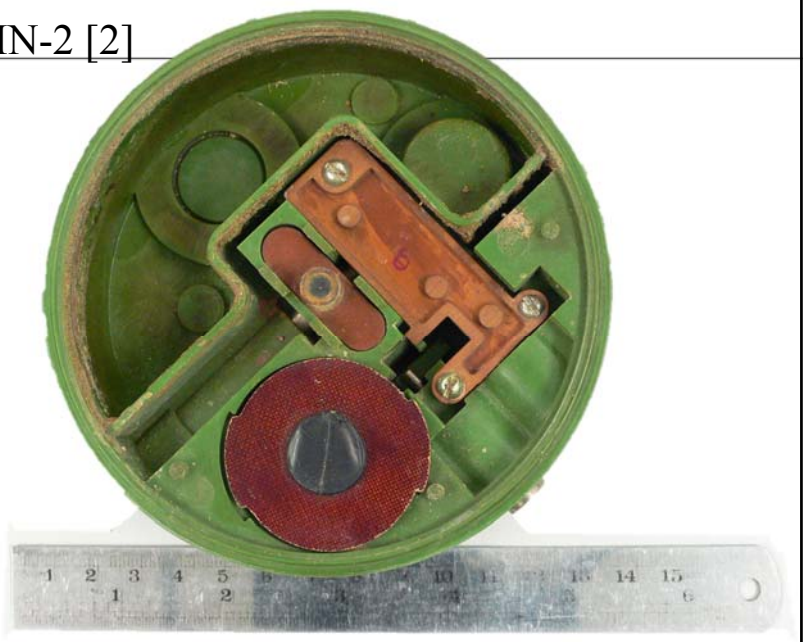
- Terrain Diversity

- Counter-thwart mechanisms

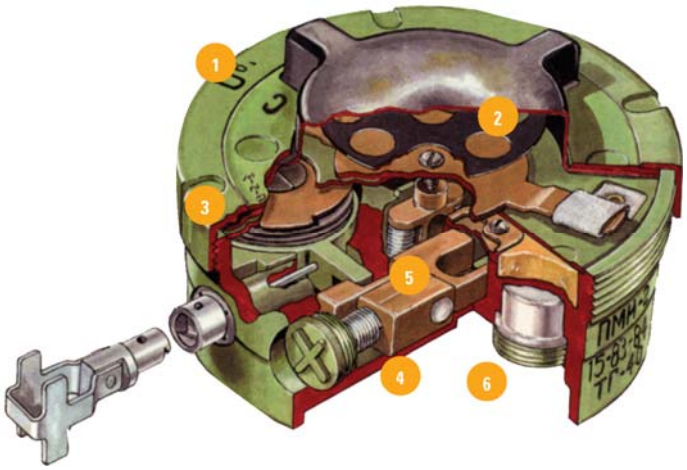
- False Positive Rate >100:1

Ex: PMN-2 [1]

Ex: PMN-2 [2]



Ex: PMN-2 [3]: Mechanically Intricate



Land Mines: **Highly Variable**

- Little metal
  ∴ "High-sensitivity" detectors / instruments
- **Highly Variable** (Example: PMN-2):
  - 3-stage detonation
  - Anti-thwart
  - All mechanical
  - Poor construction

  detectors / instruments

∴ Focus on **manipulating sensor** instead of complex sensing ???„„

Clearance & Breeching

	Humanitarian	**Military**
Detection	>98%	50-60%
Rate (m^2/day/person)	~ 200	~ 10,000
Conditions	Fair weather/daytime	All weather/24/7
Standards	Int. Mine Action Std.	Army Field Manuals
Funding (source)	Gov't, NGOs	Military

- Breeching: Line
- Demining: Area

  → International Mine Action Standards (IMAS)

Humanitarian Demining Process

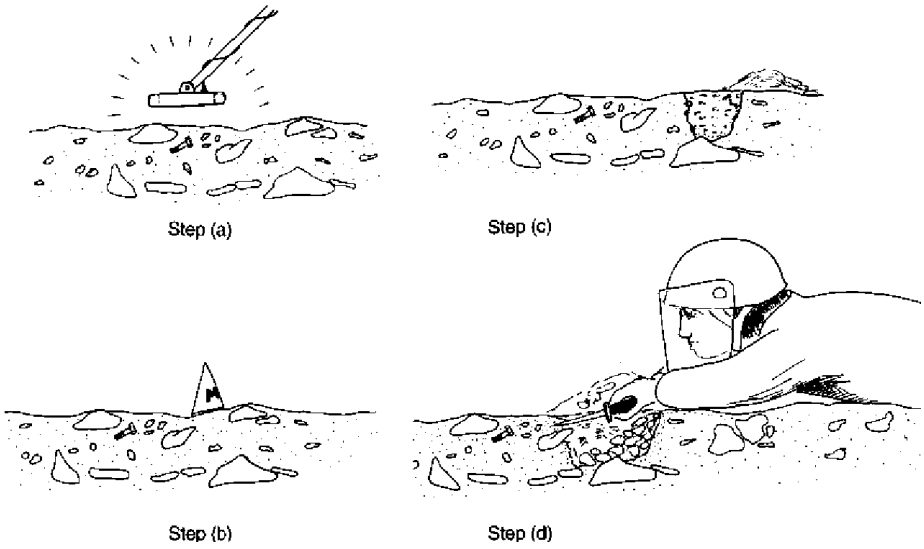
Humanitarian Demining Process

1. Level 1: Specification
   - Rough minefield location

2. Level 2: Clearing
   - Heavy machines
     (e.g., flails, grinders, rollers, ploughs, and sifters)
   - ~ 90% clearance

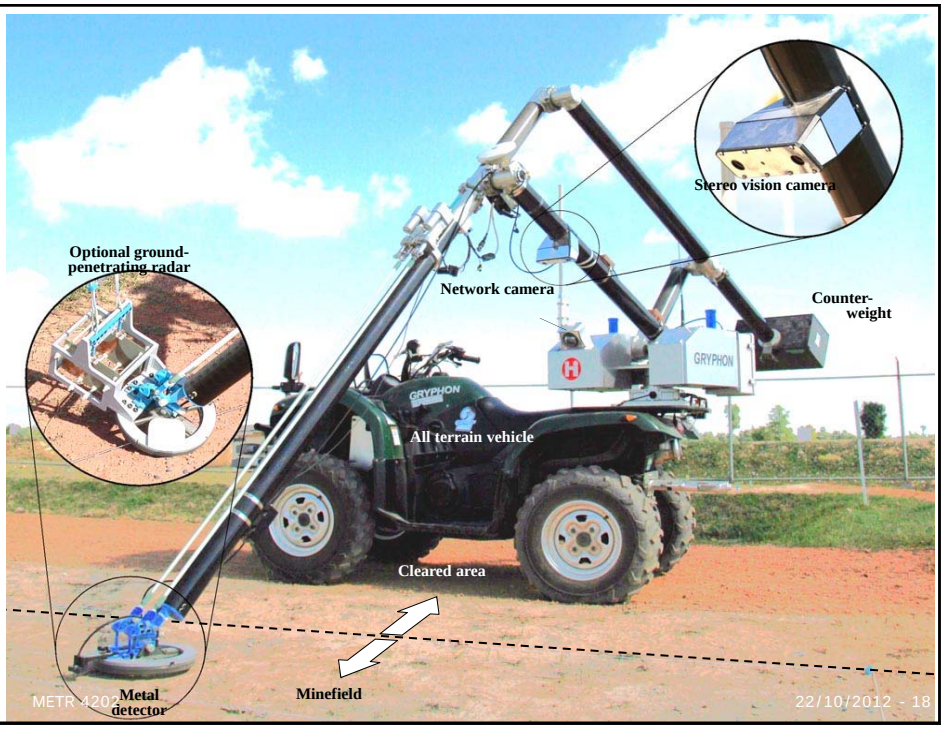
3. Level 3: Confirmation

Level-3: Confirmation

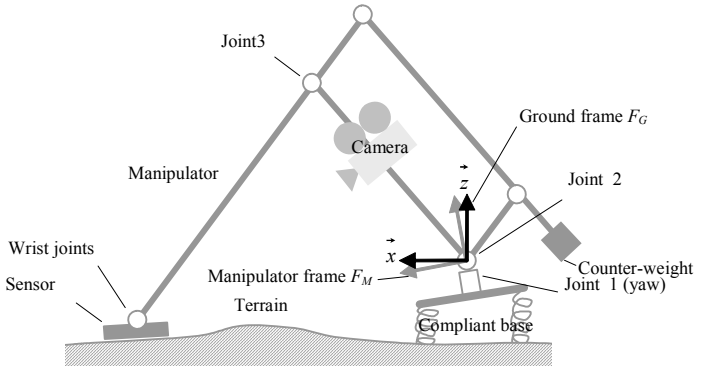


Sensor Mobility Is Critical

Back to Gyrphon …



Gryphon Schematic

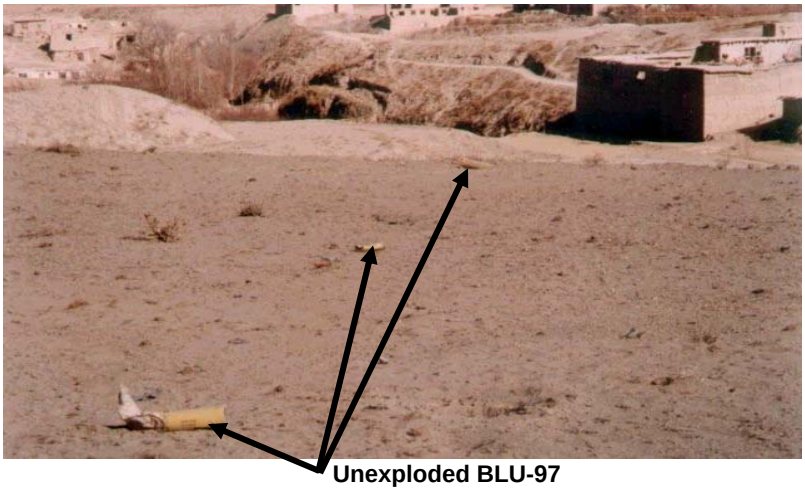


Gryphon: Comparison to other tracked robots

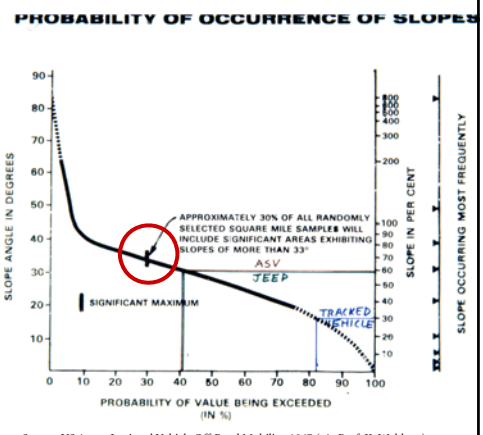
Control Robustness ("Autonomy")

Mechanical Robustness

Demining Terrain Not Always "Rough"



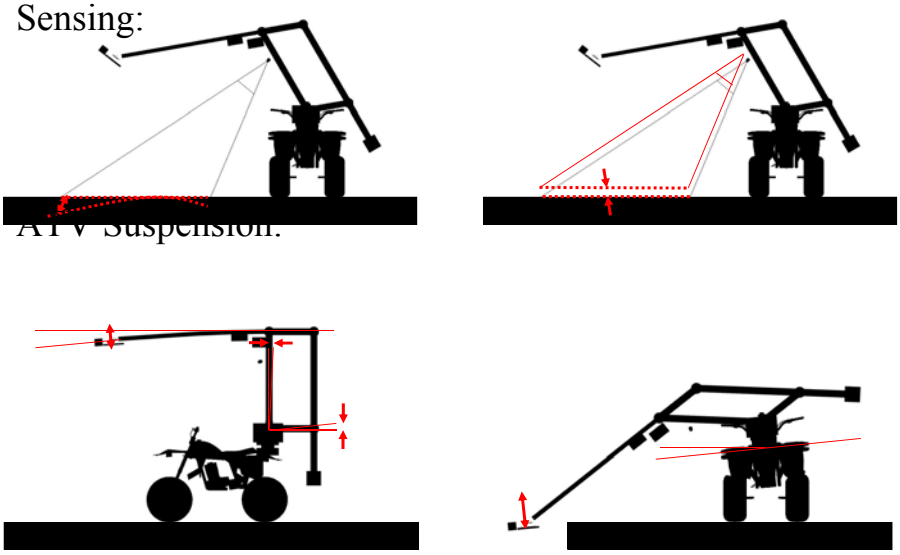
Remote Terrain: 30% > 30° Grade



Source: US Army, Logistcal Vehicle Off-Road Mobility, 1967 (c/o Prof. K. Waldron)

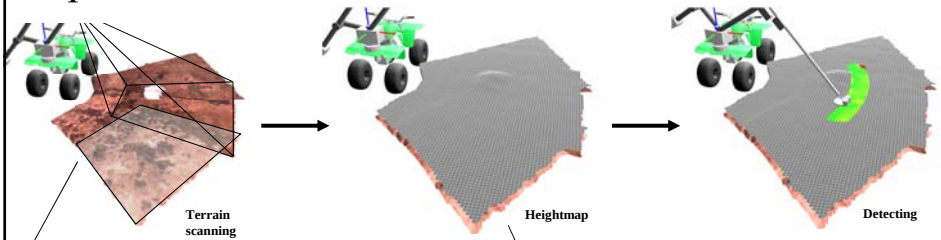
Multiple Inaccuracies

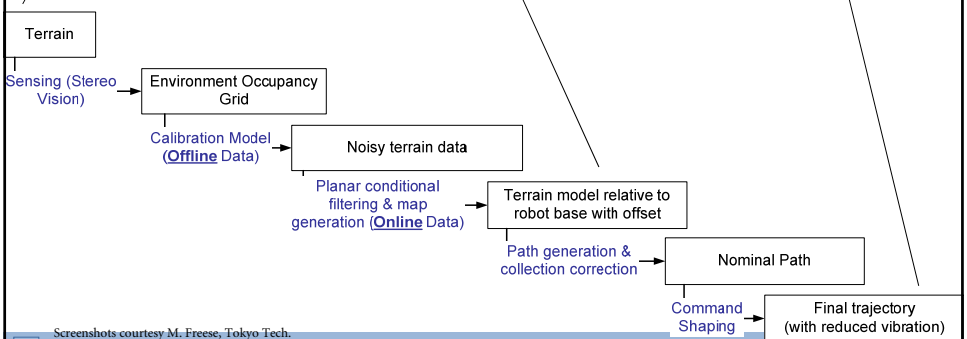
- Sensing:
- ATV Suspension:



Screenshots courtesy M. Freese, Tokyo Tech.

Operational Overview

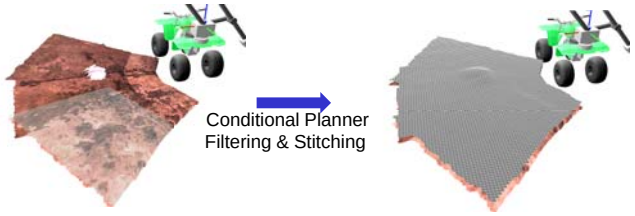




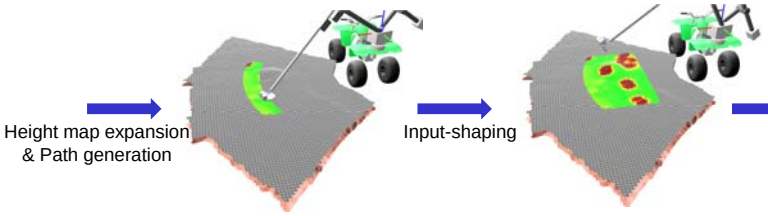
Screenshots courtesy M. Freese, Tokyo Tech.

Terrain Modeling & Following Overview

- I. Terrain Mapping
- II. Terrain Model

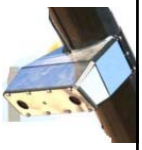


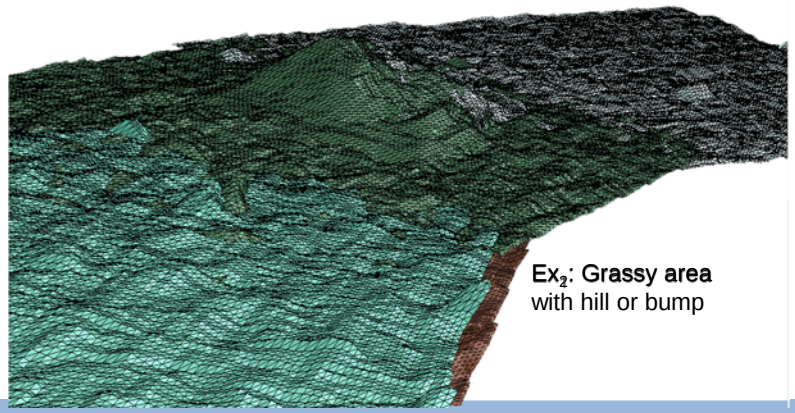
- III. Path Generation
- IV. Scanning



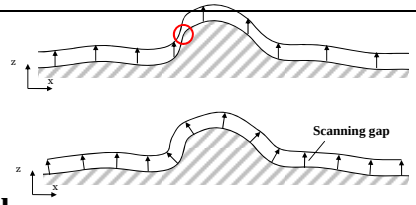
Terrain Mapping

- Stereo depth maps (Pont Gray Bumblebee)
- Kinematic calibration corrections

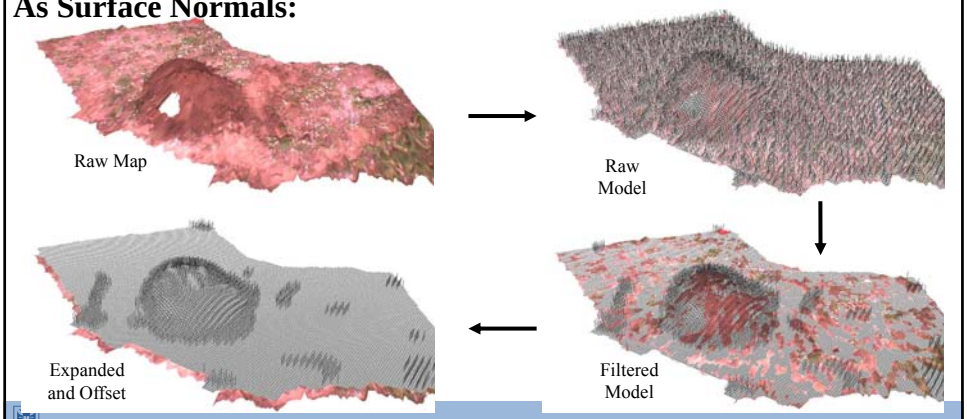




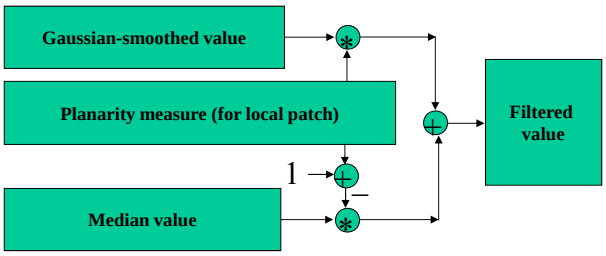
Terrain Geometry Model: Heightmap Expansion



As Surface Normals:

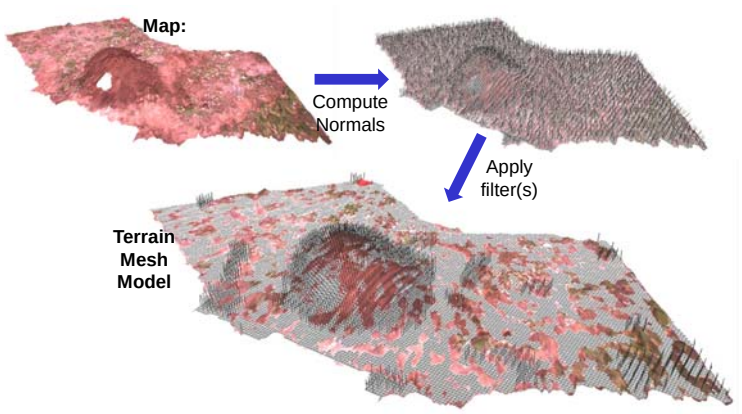


Terrain Geometry Model: Conditional Planar Filter



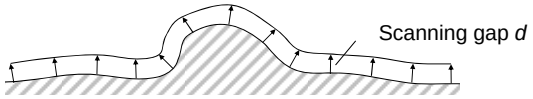
- Planarity: Found from plane eq. residuals for a surface patch
- Filter type and strength varied based on this
- Goal: Reduce noise without feature degradation

Terrain Map→Model: Conditional Planar Filter

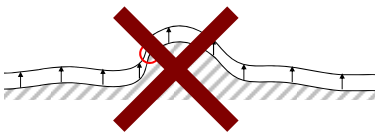


Map → Model (II): Height Map Expansion

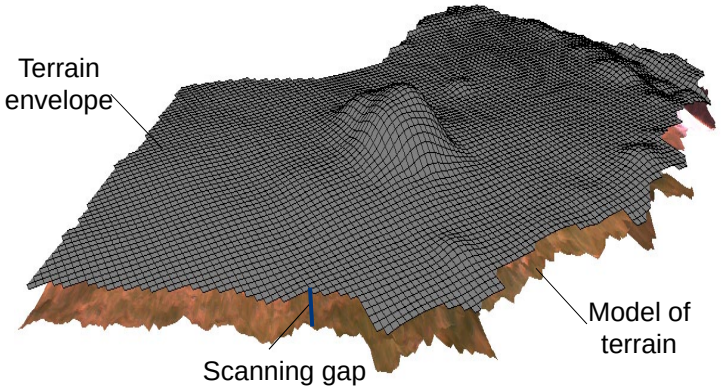
- Envelope expansion:
  - $F_{env} = F_{terr}$ + scanning gap …



  - Performed along the normals, more than vertical axis addition:

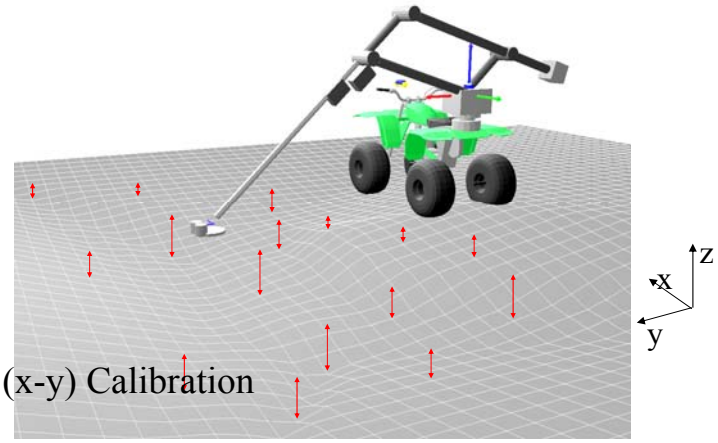


Map → Model (III): Height Map Expansion



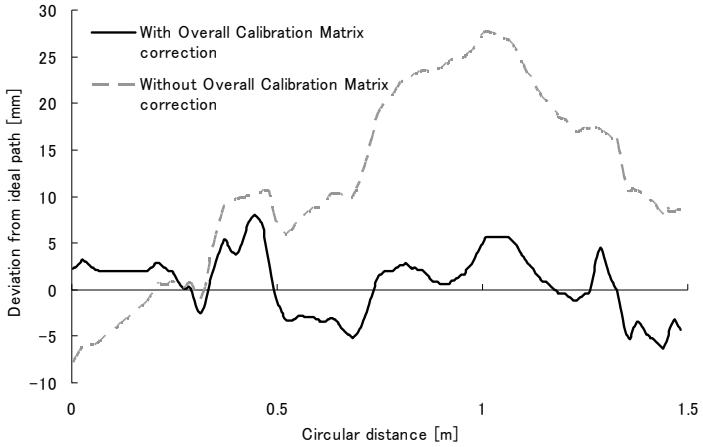
Calibration Model

- Height (z) Calibration:



- Plane (x-y) Calibration

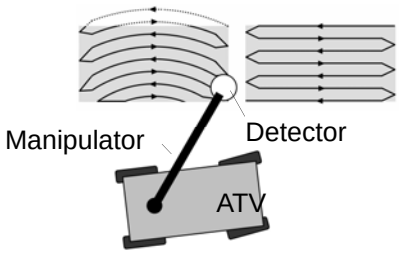
Effect of Overall Calibration Matrix



Scanning speed: 100 mm/s
Scanning gap: 100 mm

Path Generation

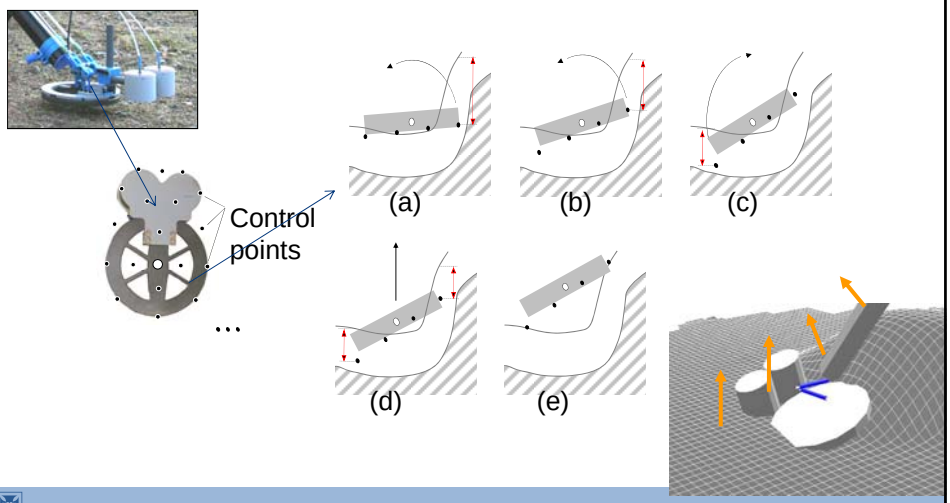
- x-y: Scanning Scheme
- Joint-space/Work-space?
- Reduce excess work …
- z: Terrain Sampling (z)
- Sample corresponding point based on the local patch & normals



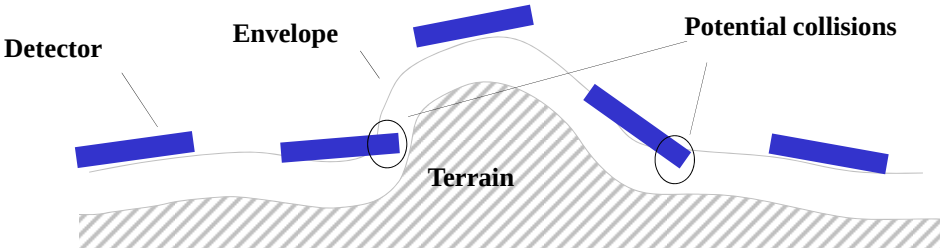
$$z_{path} \quad f_{env}(x_{path}, y_{path})$$

Path Generation (II)

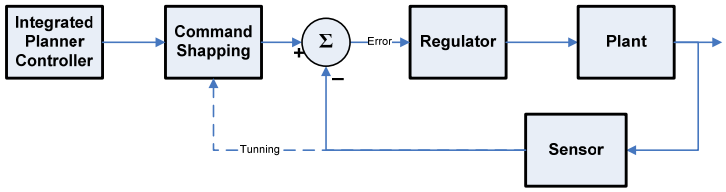
- Orientation: Advanced Terrain Following



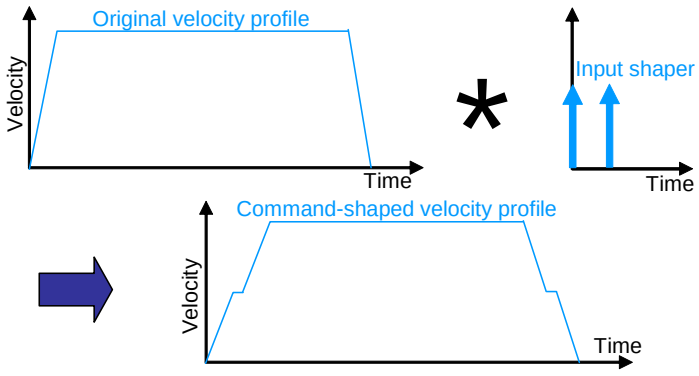
Contour Following



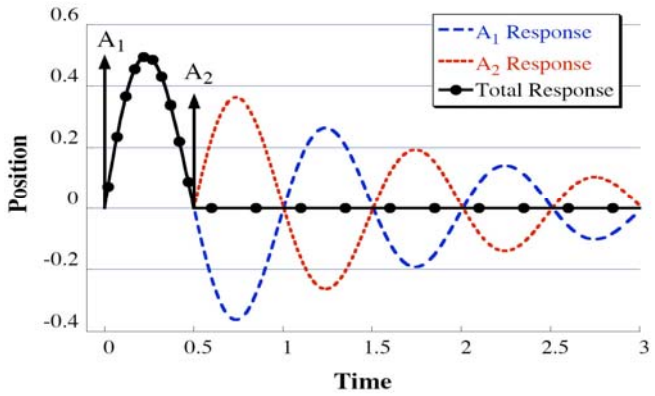
Robust Control:
Command Shaping for Vibration Reduction



Command Shaping



Command Shaping in Position Space



Command Shaping: Zero Vibration and Derivative

$$K = e^{\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right)} \qquad i = 1,2$$

$$\begin{bmatrix} A_i \\ t_i \end{bmatrix} = \begin{bmatrix} \frac{1}{(1+K)^2} & \frac{2K}{(1+K)^2} & \frac{K^2}{(1+K)^2} \\ 0 & \frac{T_d}{2} & T_d \end{bmatrix}$$

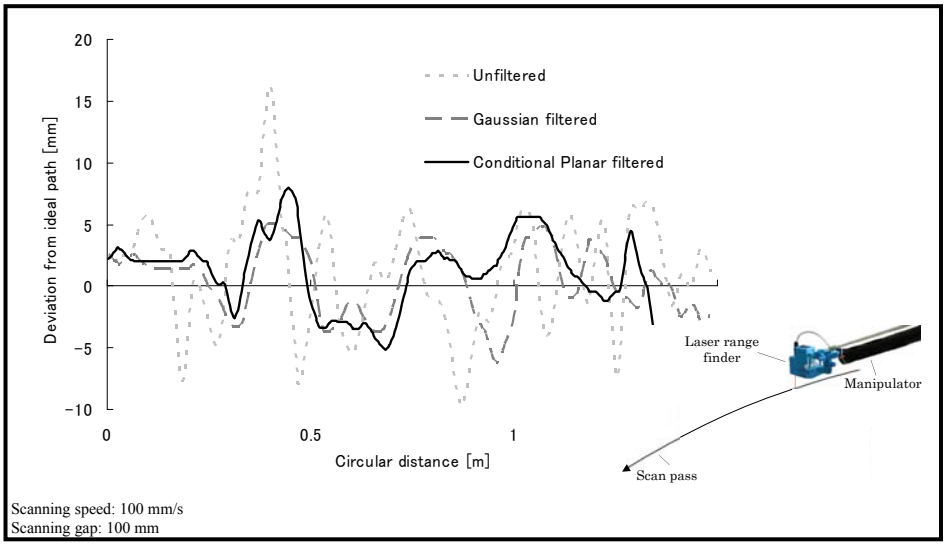
For Gryphon:

$$\begin{bmatrix} \omega \\ \zeta \end{bmatrix} = \begin{bmatrix} \omega_{\rho 0} \\ \zeta_{\rho 0} \end{bmatrix} \left(1 - \frac{\rho - \rho_0}{\rho_1 - \rho_0}\right) + \begin{bmatrix} \omega_{\rho 1} \\ \zeta_{\rho 1} \end{bmatrix} \left(\frac{\rho - \rho_0}{\rho_1 - \rho_0}\right)$$

		At ρ_0=1.5 [m]	At ρ_1=3.0 [m]
Axis 1	ω	2.32	1.81
	ζ	0	0
Axis 2 & 3	ω	3.3	3.0
	ζ	0	0

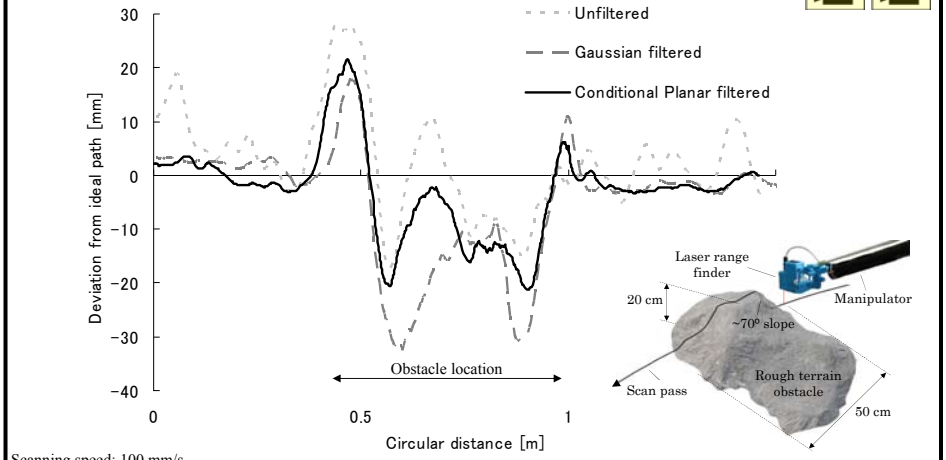
Terrain Modeling:
Find a good model to characterize

Scanning on ~ Level Terrain - Measurements



Scanning speed: 100 mm/s
Scanning gap: 100 mm

Scanning on Rough Terrain - Measurements

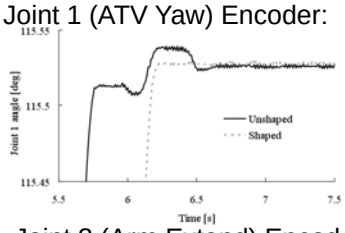


Scanning speed: 100 mm/s
Scanning gap: 100 mm

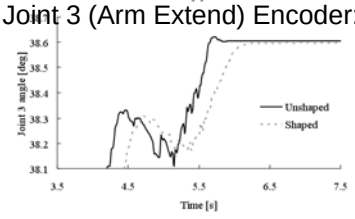
Command Shaping Tests: Step-Response

- Reduced Joint Encoder Vibration

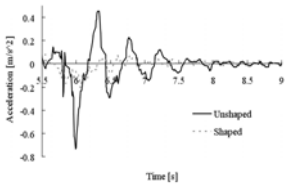
Joint 1 (ATV Yaw) Encoder:



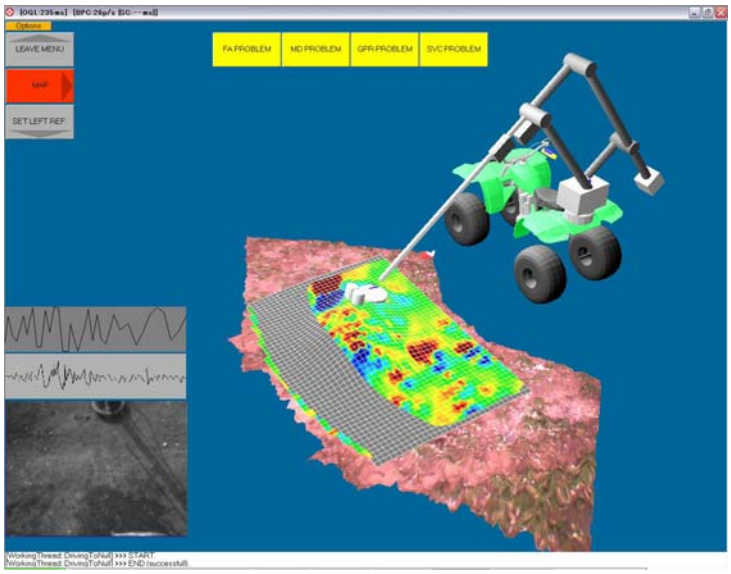
Joint 3 (Arm Extend) Encoder:



- Reduced Tip Acceleration



High-Level Control Software



Detector Imaging

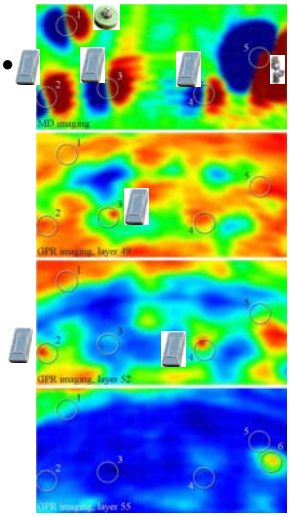
- Targets


PMA-1A


PMA-2


Fragment

Target#	Target type	Depth [cm]	MD	GPR
1	PMA-2	5	Yes	No
2	PMA-1A	12.5	Yes	Yes
3	PMA-1A	12.5	Yes	Yes
4	PMA-1A	12.5	Yes	Yes
5	Fragment	5	Yes	No
6	Stone	~10	No	Yes



Extensive Field Tests

2005: Kagawa, Japan

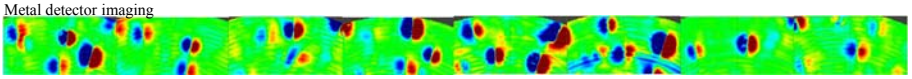
2006: Benkovac, Croatia

2007: Siem Reap, Cambodia

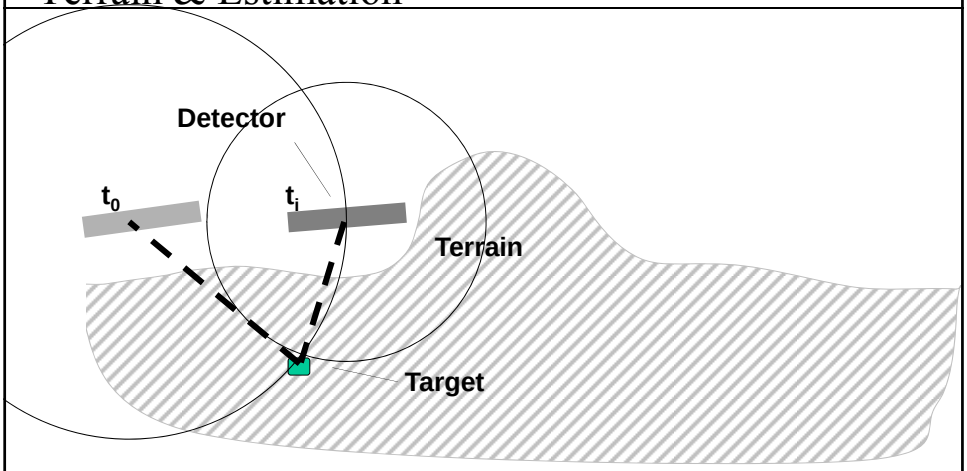
Gryphon: Field Tests in Croatia & Cambodia

February 2006: Tests in Croatia

Metal detector imaging



Terrain & Estimation



- IF we know terrain → Triangulation
- IF we know depth → SNR gives terrain "characteristic"
- → Estimate both simultaneously (→ solution up to scale)

End on a “Bang, Bang”…

A Better (Controlled) “Bang Bang”

Robotics, State-Space and The Meaning of Life

Seeing is forgetting the name of the thing one sees

What is it?

- "A Coca Cola Can"
- 1122q3134234232342
- (SIFT descriptor in HEX)
- (The PHOTID)
- (The Filename)
- …

Robotics & Uncertainty

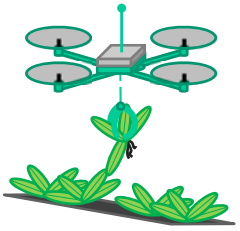
- University:
  - Critical questioning
  - Open exchange of ideas
  - Among equal participants.
- Corporatocracy:
  - Ruled by control freaks
  - Behavior modification
    - works best on dependent, powerless, infantilized, bored and institutionalized people
    (which is almost inimical to ↑)
  - Be careful of being overworked
- Et Tu?
- There are peddlers of uncertainty
  - They want you to be afraid
  - Thus, they "sell fear"
  - Yes, "They live for your schadenfreude"
- Insurance lets you risk and balance uncertainty

UQ Robotics: Dynamic Systems in Motion

Diverse international research group

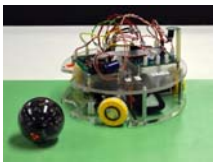
Hanna Kurniwati *(NUS/MIT)*
Paul Pounds *(ANU/Yale)*
Surya Singh *(Stanford/Syd)*

Aerial Systems



Bio-inspired Systems

Planning



Mechanics of motion