Modeling Terrain Traversal Cost for Hexapod Walking Robots

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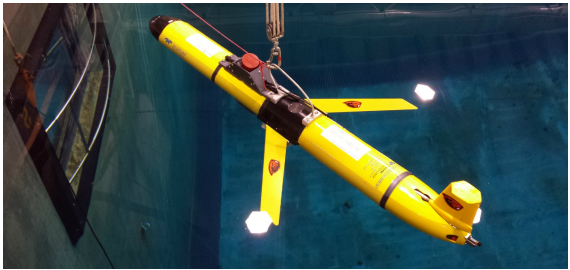
Outline

- Motivation: Multi-legged Walking Robots and Autonomy
- Learning Terrain Traversal Cost
- Jan Bayer: Robotic Exploration
- Exploring the Terrain Traversal Cost

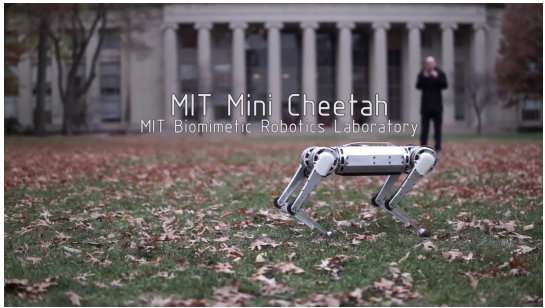


source: Oregon State University

P. Váňa and J. Faigl

- Model phenomena using measurements collected by mobile robots
- Autonomous mobile robots are commonly deployed in marine and aerial environments
- We aim to support long term deployment of ground robots in rough terrain

National Geographic



MIT

- Why should you deploy multi-legged robots?
  - Multi-legged robots are great platforms for rough terrains
  - The design is proven to work quite well in nature

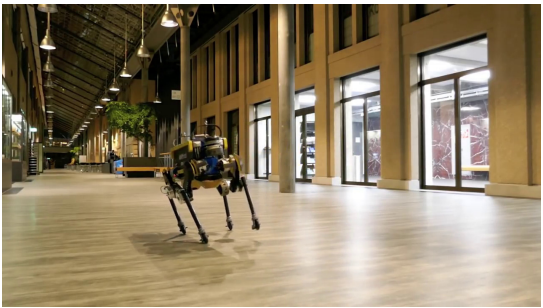
Rough Terrain Transportation

source: wikipedia.org

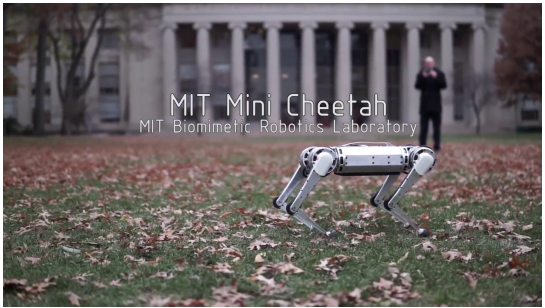
Boston Dynamics

KIOST Crabster CR200

Sellafield cleanup robot



ANYbotics / ETH Zürich: ANYmal



MIT Mini Cheetah

Unitree AlienGO

Boston Dynamics SpotMini (and friends)

Hexapod walkers in AIC

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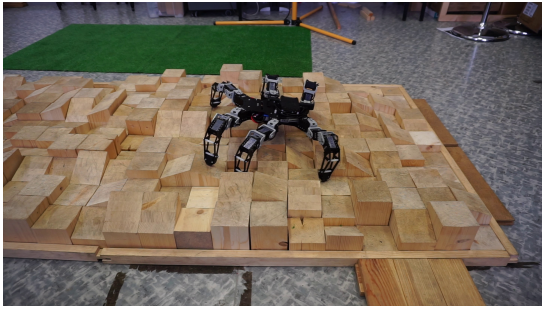
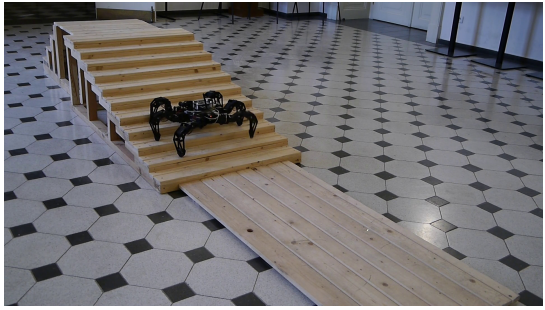
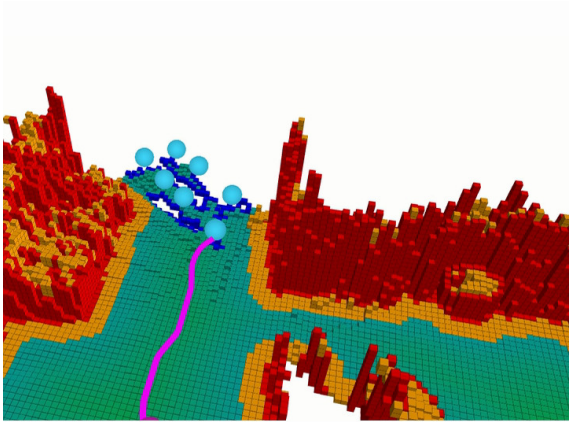
Why is Rough Terrain Hard?

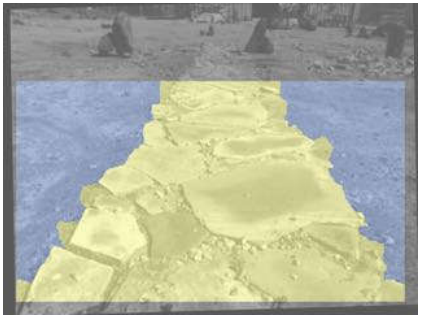


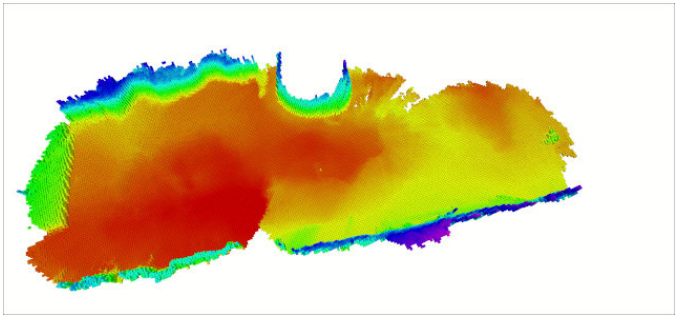


- Why is rough terrain hard to traverse?
  - It is dangerous - a robot cannot enter some areas, as it could be damaged, or simply stuck.
  - It is expensive - traversing rough terrain is not energy and time efficient.
- What are the challenges?
  - Identify the terrains that should not be entered at all.
  - Avoid terrains that can be traversed but are costly.
  - Do this in a priori unknown envrionment.



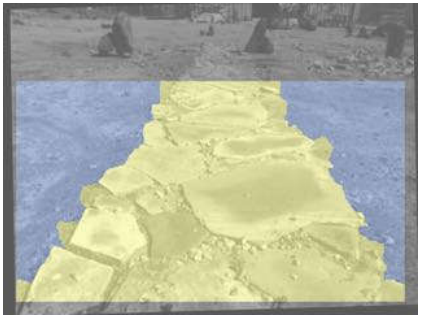
- Identify the terrains that should not be entered at all.
  - This is (relatively) easy.
  - Often it is enough to construct a geometric model of the environment and locate walls.

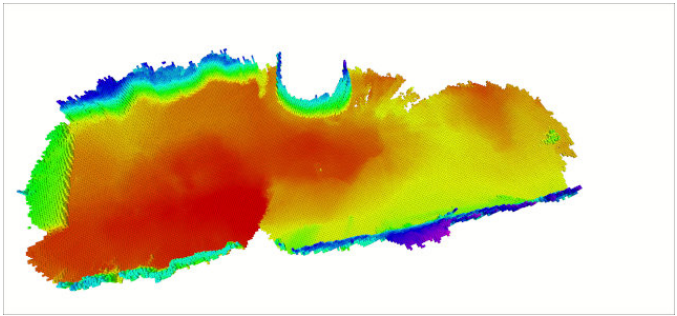




Otsu et al., 2016

- Avoid terrains that can be traversed but are costly.
  - Terrain classification.
  - Terrain traversal cost.





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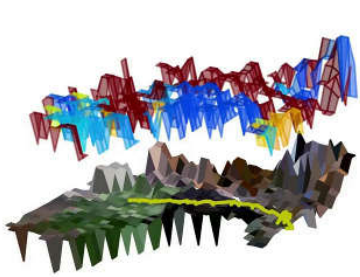
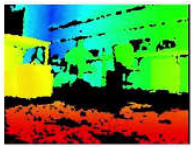
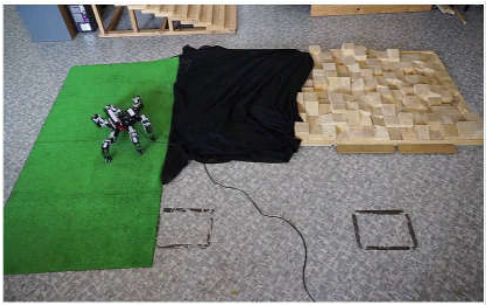




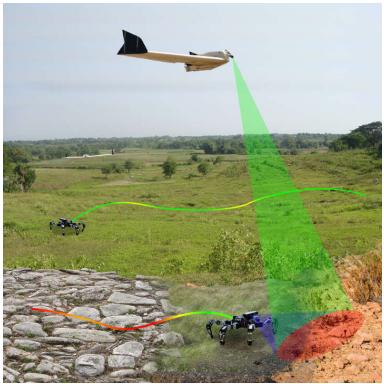


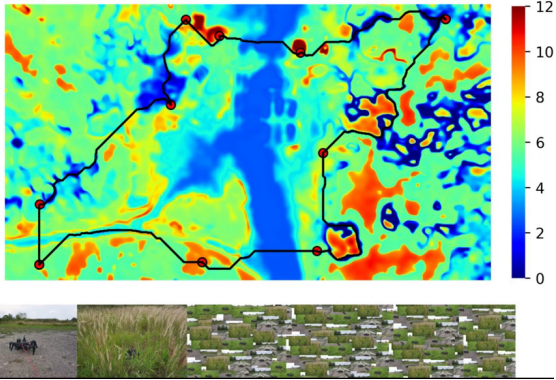
Cost of Transport Estimation for Legged Robot Based on Terrain Features Inference from Aerial Scan, **IROS 2018**

Incremental Learning of Traversability Cost for Aerial Reconnaissance Support to Ground Units, **MESAS 2018**

- Used terrain traversal costs

Cost of transport	Stability	Energy per distance traveled
$\frac{P_{in}}{mgv}$	$std(\phi_{roll})$	$\frac{E}{d}$





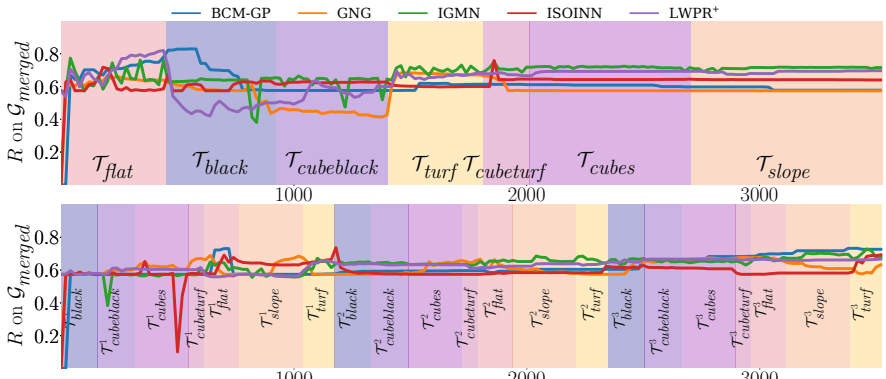
Aerial Reconnaissance and Ground Robot Terrain Learning in Traversal Cost Assessment, **MESAS 2019**

- **Online learning approaches** use training samples one by one, without knowing their number in advance, to optimise their internal cost function

  Incremental learning refers to online learning strategies which work with limited memory resources

  Gepperth and Hammer, *Incremental learning algorithms and applications*, **ESANN 2016**

- Learning incrementally on the robot brings a few challenges and limitations
  - Concept drift
  - Limited resources

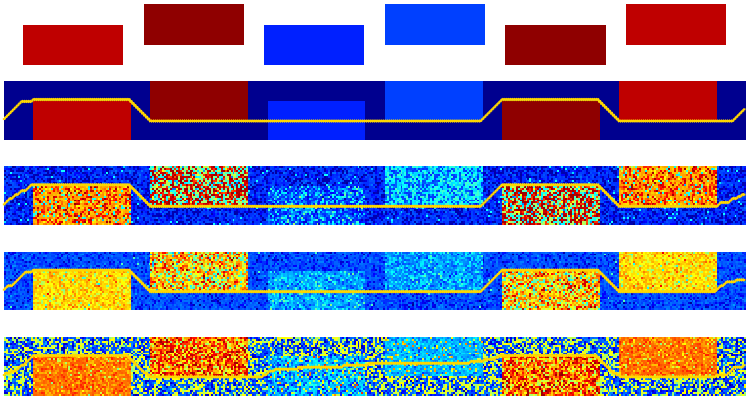


Incremental Traversability Assessment Learning using Growing Neural Gas Algorithm, **WSOM+ 2019**

Benchmarking Incremental Regressors in Traversal Cost Assessment, **ICANN 2019**

- Bechmarked regressors in terrain traversal cost prediction
  - Bayesian Committee Machine with GP Experts
  - Locally Weighted Projection Regression
  - Self-organizing Neural Networks
  - Incremental Gaussian Mixture

Evaluating Learned Traversal Cost



- Investigate the influence of the predicted cost on path planning.

On Unsupervised Learning of Traversal Cost and Terrain Types Identification using Self-Organizing Maps, **ICANN 2019**

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CTU
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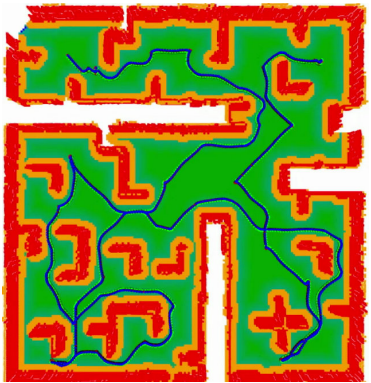

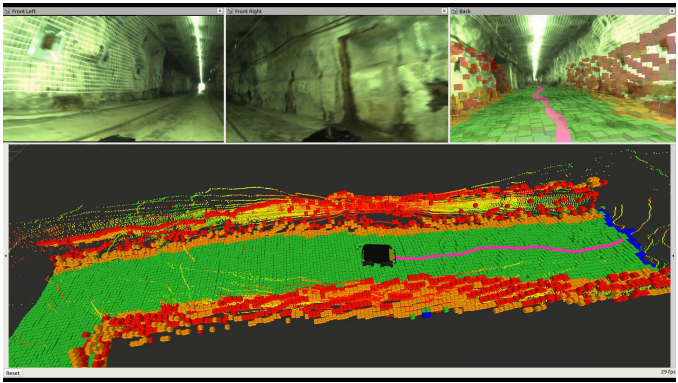

J. Bayer and J. Faigl, *Speeded Up Elevation Map for Exploration of Large-Scale Subterranean Environments*, **MESAS 2019**

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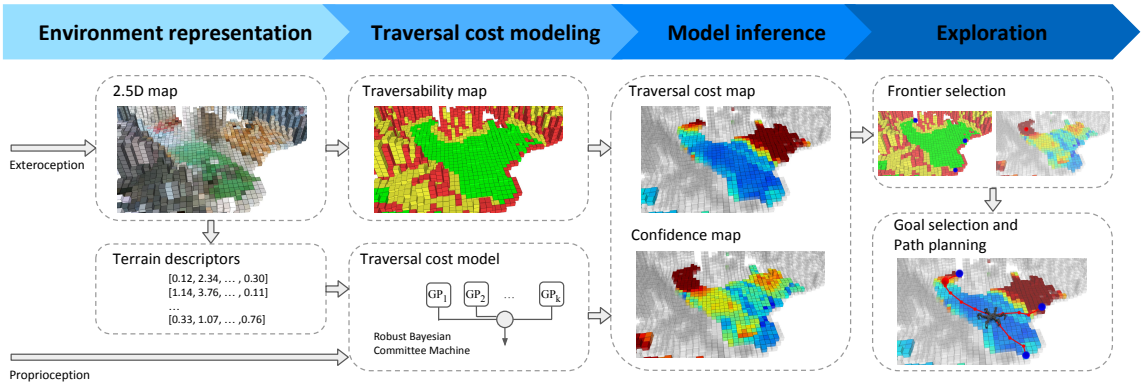
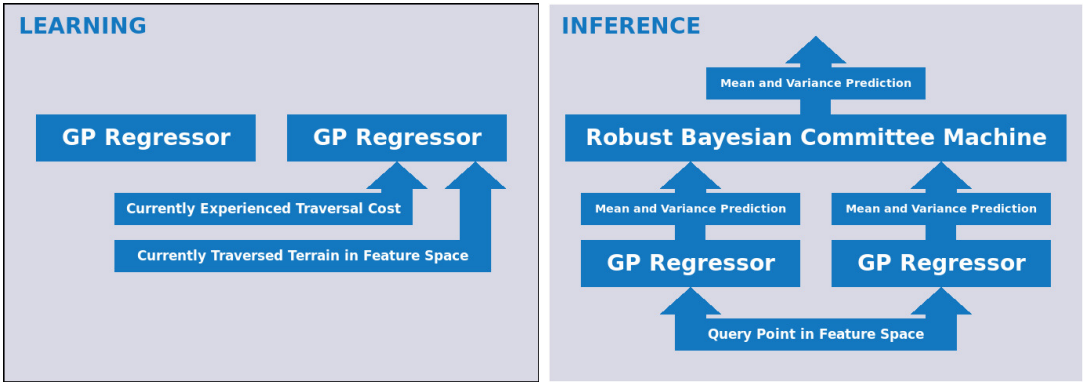
Exploring the Terrain Traversal Cost

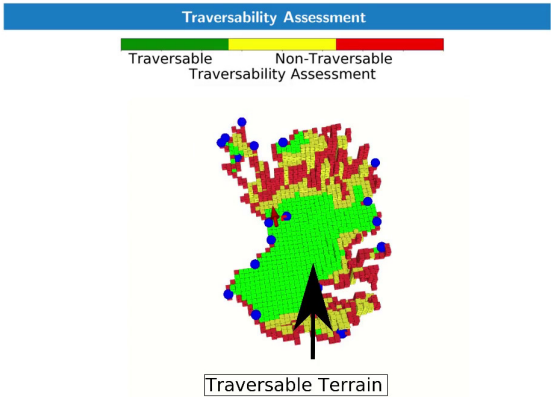


Online Incremental Learning of the Terrain Traversal Cost in Autonomous Exploration, **RSS 2019**

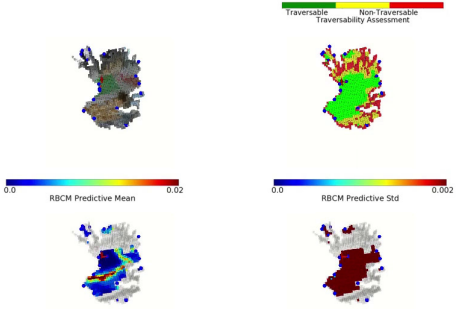


- Spatial exploration combined with **incremental traversal cost model learning**.
- Predictive variance of **Gaussian process regression** for cost model uncertainty.
- Online decision making using **Robust Bayesian committee machine**.

Exploring the Terrain Traversal Cost



The robot builds the spatial 2.5D map
and filters out non-traversable areas.



Thank you

List of External Image and Video Sources

- Oregon State University
  https://oregonstate.edu/
- National Geographic YouTube channel
  https://www.youtube.com/user/NationalGeographic
- MIT Biomimetics YouTube channel
  https://www.youtube.com/channel/UCvnLTIzyhH6oxazo7cpdH1A
- ANYbotics YouTube channel
  https://www.youtube.com/channel/UC1B-ML60I2hKTvygvMjubnw
- ETH Zürich Robotics Systems Lab Youtube channel
  https://www.youtube.com/channel/UCHjP785620I8LFjSxf_CJCw
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