NAVIGATING SOFT TERRAINS WITH QUADRUPED ROBOTS

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UNDERSTANDING THE NEED FOR SOFT TERRAIN NAVIGATION

Search and rescue, environmental monitoring, agriculture, exploration and mining or military operations.

https://www.flickr.com/photos/timconway/5604052127

https://www.ricefarming.com/departments/feature/rain-rain-go-away/

https://depositphotos.com/photo/withered-tree-swampy-river-bank-lake-dead-tree-stands-waterlogged-408093474.html

https://pixahive.com/photo/a-farmer-in-a-muddy-field/

https://www.cnet.com/science/watch-a-spot-robot-from-boston-dynamics-explore-an-old-mine/

https://newsus.cgtn.com/news/2021-04-09/Watch-French-military-using-robots-in-training-mission-ZiXaOPWZsA/index.html

MOBILE ROBOTS OVERVIEW

Wheeled, tracked, legged…

Starship robots

https://www.starship.xyz/wp-content/uploads/sb-instagram-feed-images/429449882_3122948257835161_7981061056595626525_nfull.jpg

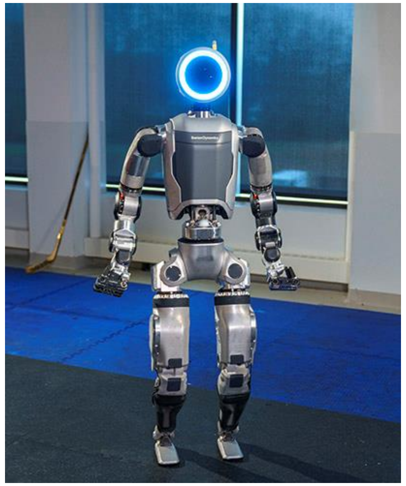
PackBot 510

https://www.army-technology.com/wp-content/uploads/sites/3/2017/09/1-image-45.jpg

Zee

https://i0.wp.com/research.csiro.au/robotics/wp-content/uploads/sites/96/2017/03/Zee-outdoor.jpg?resize=768%2C543&ssl=1

Boston Dynamics Atlas



https://cdn.sanity.io/images/7p2whiua/production/e9779086ee0438688bf288a4cdcc950fdc986af8-2048x1536.jpg?w=1400&auto=format

Unitree Go1

https://shop.unitree.com/cdn/shop/products/75.jpg?v=1668073774

ISSUES FACED

Key challenges:

X Sinking.

X Low traction.

X Balance and stability.

X Energy consumption.

The Superiority of legged Robots

✓ Versatility.

✓ Obstacle negotiation.

✓ Adaptability to various environments and terrains.

Joonho Lee et al., Learning quadrupedal locomotion over challenging terrain. Sci.Robot. 5, eabc5986 (2020). DOI: 10.1126/scirobotics.abc5986

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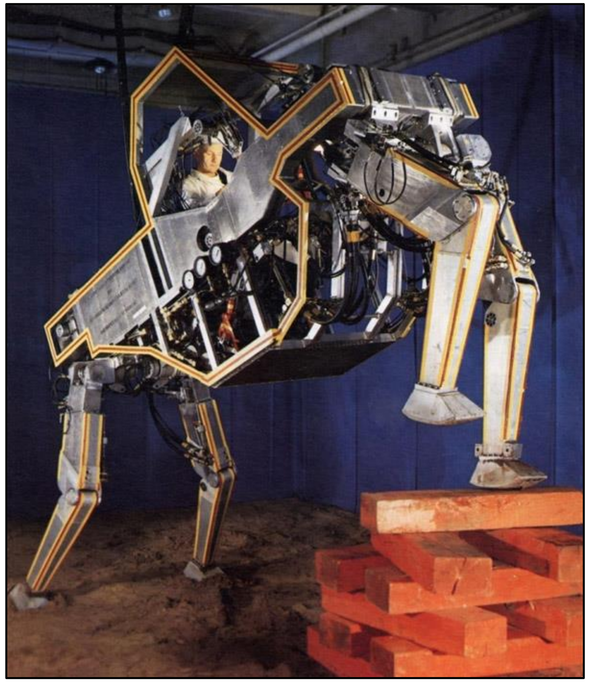
A HISTORICAL PERSPECTIVE ON QUADRUPED ROBOTS

Insect (1969)

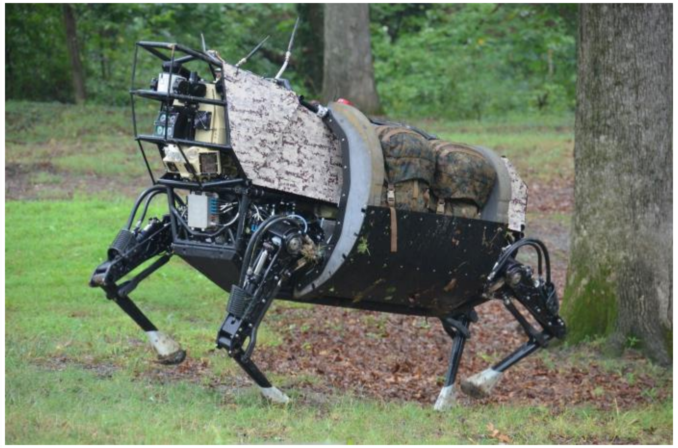


https://cyberneticzoo.com/walking-machines/1969-ge-walking-truck-ralph-mosher-american/

Sony AIBO (1999)

https://www.sony.com/en/SonyInfo/News/Press/199905/99-046/

BigDog (2004)



https://commons.wikimedia.org/wiki/File:Legged_Squad_Support_System_robot_prototype.jpg

Spot (2019)

https://bostondynamics.com/blog/an-ethical-approach-to-mobile-robots-in-our-communities/

GAITS OF QUADRUPED ROBOTS

The walking pattern of the robots.

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Kim, D., Di Carlo, J., Katz, B., Bledt, G., & Kim, S. Highly dynamic quadruped locomotion via whole-body impulse control and model predictive control. arXiv 2019. arXiv preprint arXiv:1909.06586.

FIELD TESTS AND LABORATORY EXPERIMENTS.

The commercially available dynamic gait is not adapted for these environments.

Simon Godon, Carlos Prados, Ahmed Chemori, et al. Walking in Mud: Modelling, Control and Experiments of Quadruped Locomotion. TechRxiv. July 08, 2024. DOI: 10.36227/techrxiv.172047167.78902329/v1

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BIOINSPIRED GAIT PATTERNS

Static gait and a specified leg sequence.

https://www.youtube.com/watch?v=ok7YFsNCtS4

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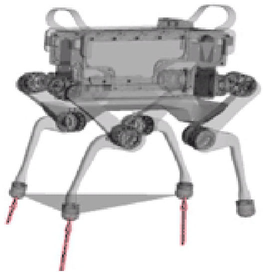
DEFINITIONS

Static stability:

The ability of a robot to remain balanced while standing still.

Support polygon (SP):



For static stability, the robot's Center of Mass (CoM) must stay within the support polygon.

CONTROLLER DESIGN

The controller is always calculating the optimal position of the Center of Mass (CoM) to maintain static stability.

How can we improve the performance?

Main idea:

Optimizing the leg movement.

1. Moving faster when the leg is not in contact with mud.
2. Estimating the mud resistance.

Simon Godon, Carlos Prados, Ahmed Chemori, et al. Walking in Mud: Modelling, Control and Experiments of Quadruped Locomotion. TechRxiv. July 08, 2024. DOI: 10.36227/techrxiv.172047167.78902329/v1

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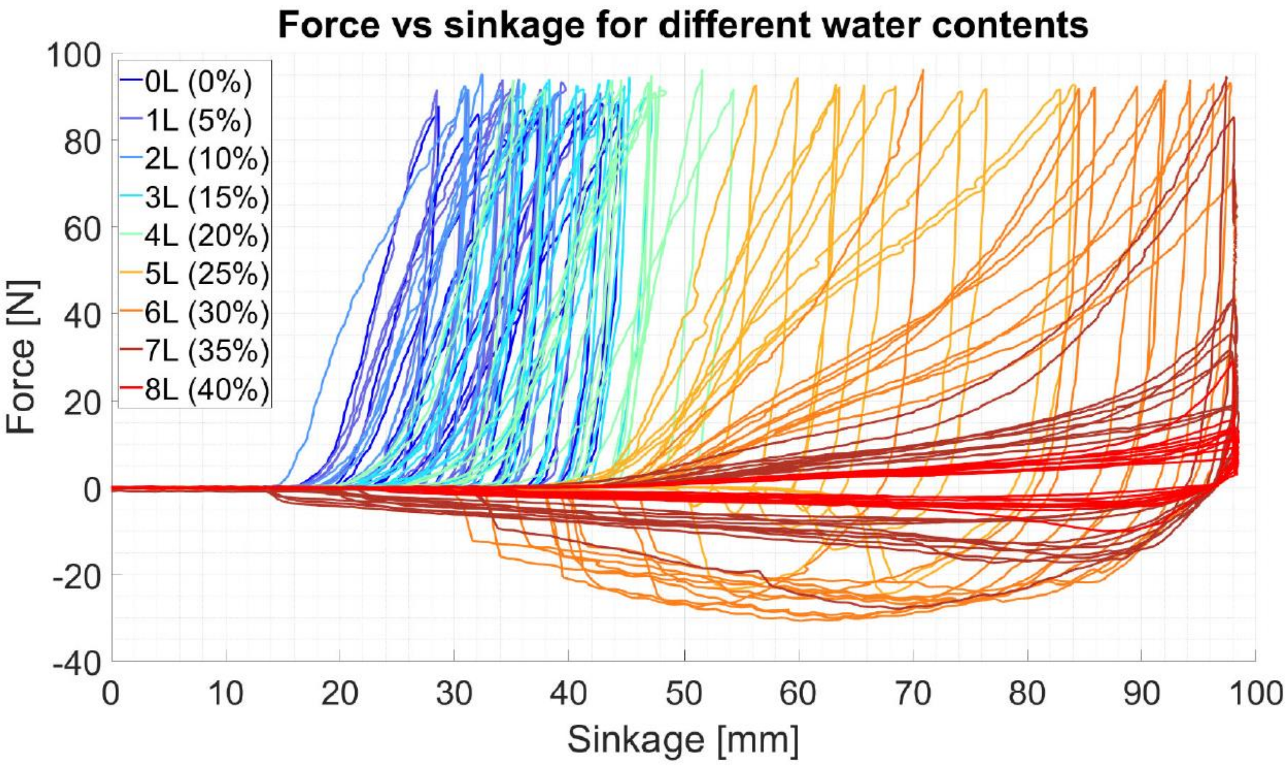
SUCTION FORCE ESTIMATION

Experiments with different water contents.



Godon, S., Ristolainen, A., and Kruusmaa, M. (2022). An insight on mud behavior upon stepping. *IEEE Robot. Autom. Lett.* 7, 11039–11046. doi:10.1109/lra.2022.3194667

RESULTS

The robot moves 3.14 times faster and consumes 12% less energy!

Tests on different natural environments:

- On the edge of a river
- On the shoreline
- On dry and wet sand
- On dry and wet forest ground

Simon Godon, Carlos Prados, Ahmed Chemori, et al. Walking in Mud: Modelling, Control and Experiments of Quadruped Locomotion. TechRxiv. July 08, 2024. DOI: 10.36227/techrxiv.172047167.78902329/v1

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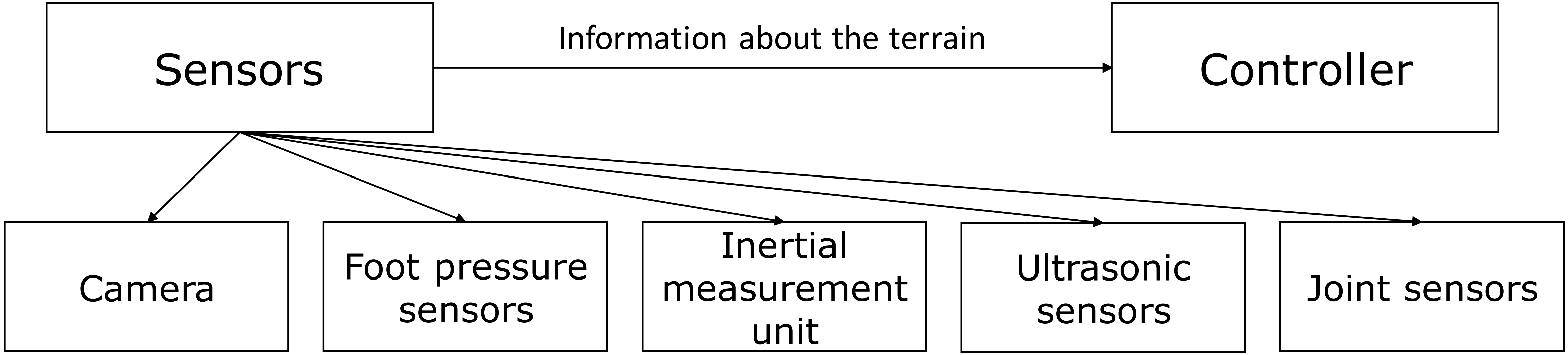
TERRAIN CLASSIFICATION



TERRAIN CLASSIFICATION

- Types of terrains:

1. Hard ground (dry mud).
2. Mud with 25% water.
3. Mud with 35% water.

- Classifier: Linear SVM.
- Statistical features: mean, median, std, var, skewness, kurtosis, min, max and range.

Accuracy of the model with 5-fold cross validation and 10% test data.

Step\Sensor	Joint position	Joint velocity	Joint torque	Estimated foot force
Half step	91.1%	92.0%	89.2%	85.0%
Whole step	97.5%	97.1%	97.5%	96.8%

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CONCLUSION

The results of our research allow the robot to:

- Effectively walk on mud.
- Classify terrains.

What's next?

- Terrain traversability analysis.
- SLAM for terrain types.
- Finding the optimal path.
- Adapting/transitioning between walking modes for different terrains.

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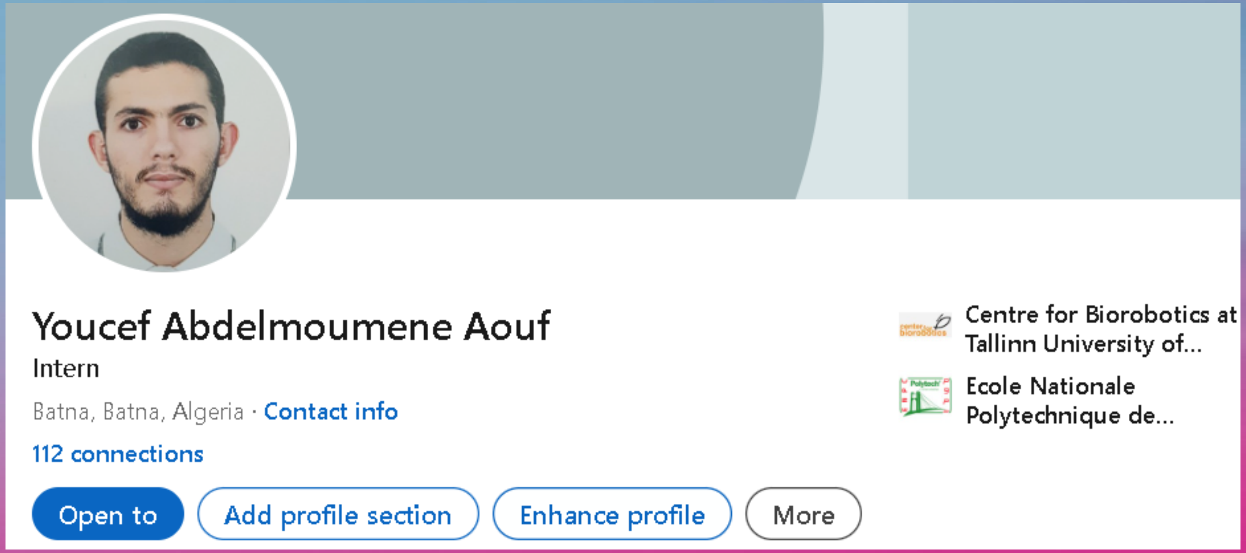

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THANK YOU FOR YOUR ATTENTION

SCAN ME

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ROBOT DEMONSTRATION + QUESTIONS & ANSWERS