MAARCO—Multi-terrain Amphibious ARCtic explOrer

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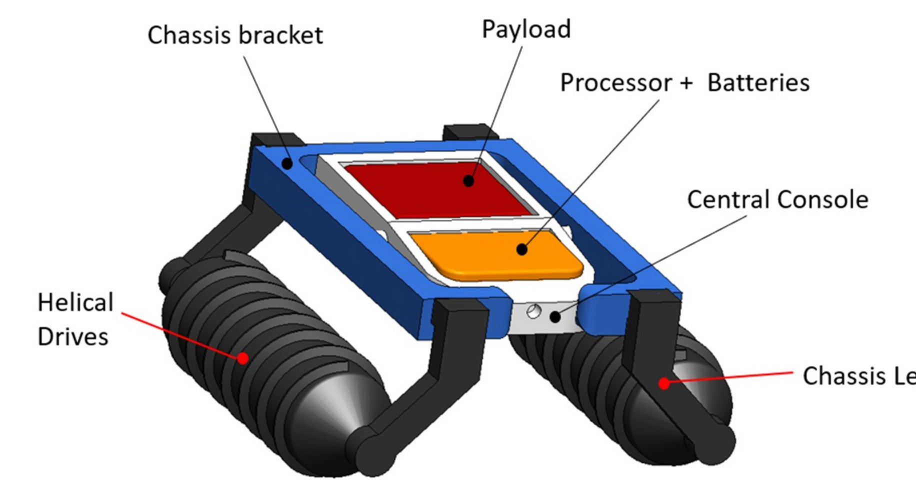
MAARCO—Multi-terrain Amphibious ARCtic explOrer

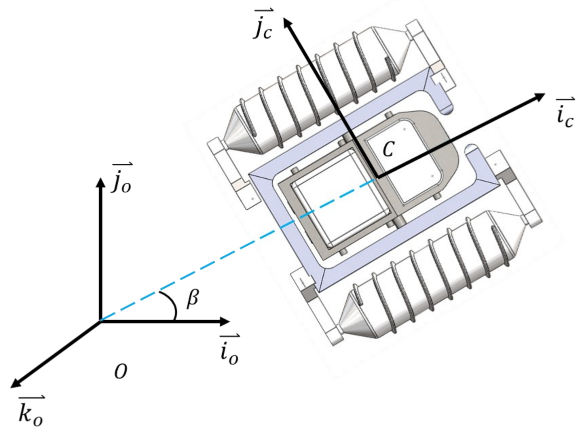
- The rapidly changing Arctic climate presents unique and heterogeneous combinations of terrains
- Snow, melting ice, partially-frozen lakes, wet/firm permafrost, sea ice, open ocean
- Rovers need to have multi-terrain and amphibious locomotion capabilities

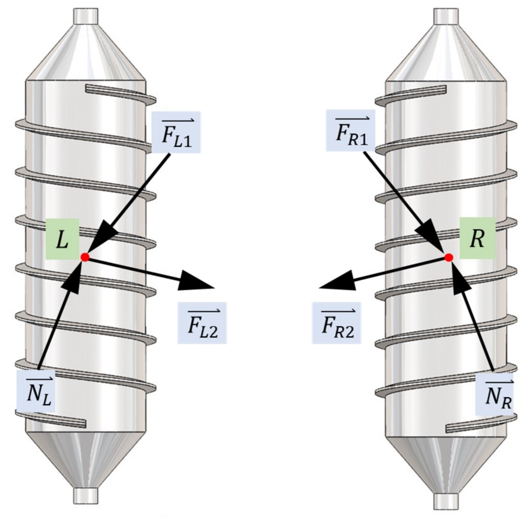


Terrestrial Locomotion Dynamics

- Planar or two-dimensional model
- All external forces on helical drives act through a single point on the surface of the helical drive
- Newton-Euler method is used to EOM
- External forces acting on helical drives:

1. Normal force due to weight of rover (Ng)
2. Reaction force exerted by surrounding surface on helical blades (NL, NR)
3. Friction forces due to normal force (FL1, FR1)
4. Friction force resisting blade motion (FL12 FR2)





- 3 Degrees of Freedom: X, Y , β
- 3 equations:

$$N_L cos\varphi + N_R cos\varphi - F_{L1} sin\phi_L - F_{R1} sin\phi_R - F_{L2} sin\varphi - F_{R2} sin\varphi = (m_{rover})(\ddot{x}_c \cos\beta + \ddot{y}_c \sin\beta)$$

$$N_R sin\varphi - N_L sin\varphi - F_{L1} cos\phi_L + F_{R1} cos\phi_R - F_{L2} cos\varphi + F_{R2} cos\varphi = (m_{rover})(-\ddot{x}_c \sin\beta + \ddot{y}_c \cos\beta)$$

$$w\left(N_L cos\varphi + N_R cos\varphi - 0.5 * \mu_{k1} N_g sin\phi_L - 0.5 * \mu_{k1} N_g sin\phi_R - \mu_{k2} N_L sin\varphi - \mu_{k2} N_R sin\varphi\right) = \tilde{I}_{C,sys,k} \cdot \ddot{\beta}$$

Terrestrial Locomotion Validation Setup

- A single brushed-DC motor drives the two helical drives in opposite directions using a pair of gears and belt drives
- The carriage is guided along a fixed axis by the rails mounted on the stock tank
- Sensors on-board the setup:

1. 6-DoF Load Cell
2. Linear Encoder for x-axis
3. Linear Encoder for y-axis
4. Rotary encoder for DC motor

- Weight off-loading mechanism is designed to reduce effective weight of carriage
- Different substrates such as dry or wet sand, clay, melting ice, and gravel will be tested

Motion along a Straight Line

- If $\tau_{ext} < \tau_o$ then $x = P \cdot \theta$
- If $\tau_{ext} > \tau_o$ then $x < P \cdot \theta$

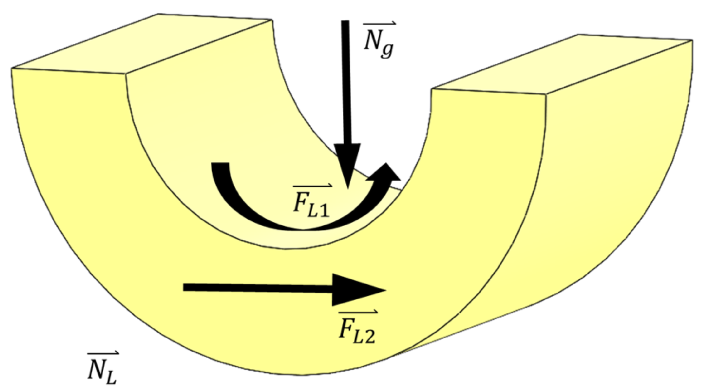
τ_{ext} - shear stress due external forces

τ_o - shear strength of the material

x - linear displacement of helical drive

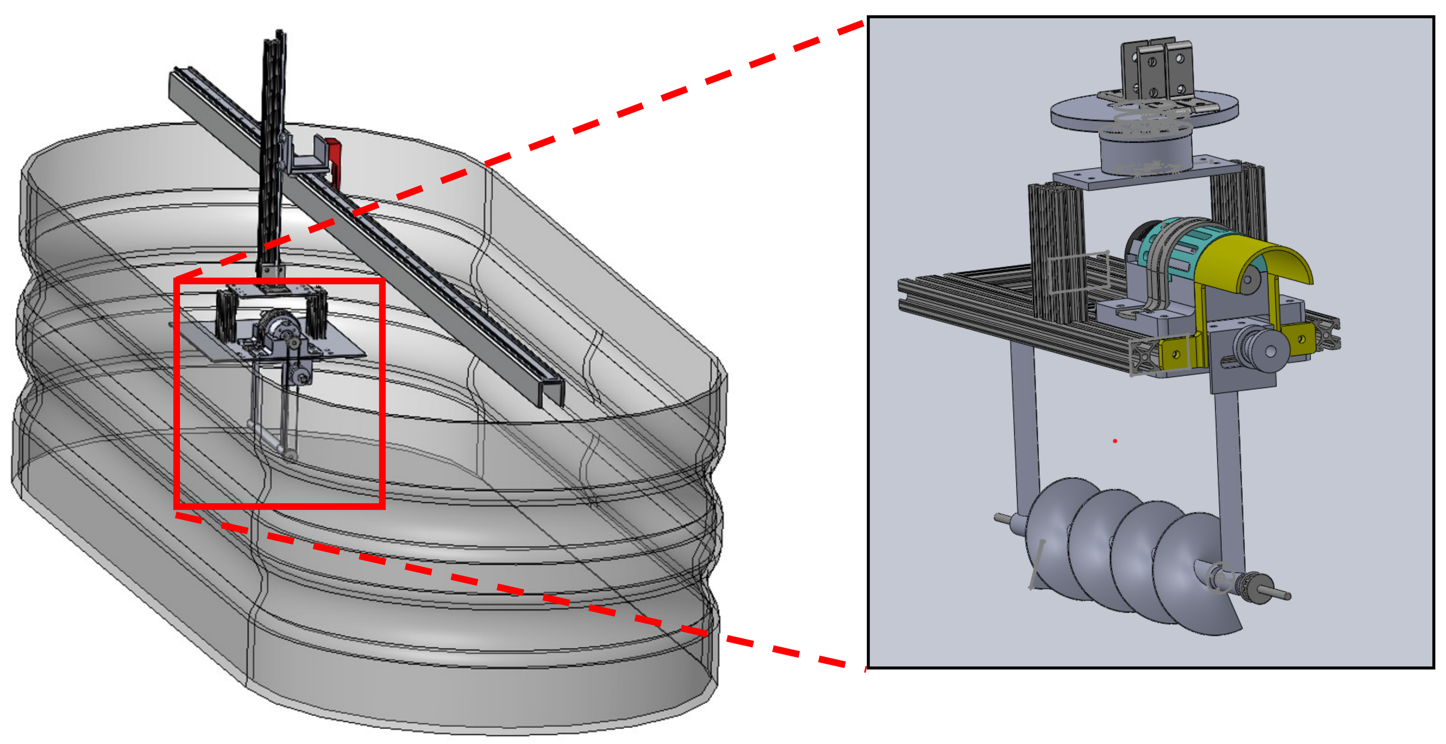
P - pitch length of the helical drive

θ - number of rotation of helical drive



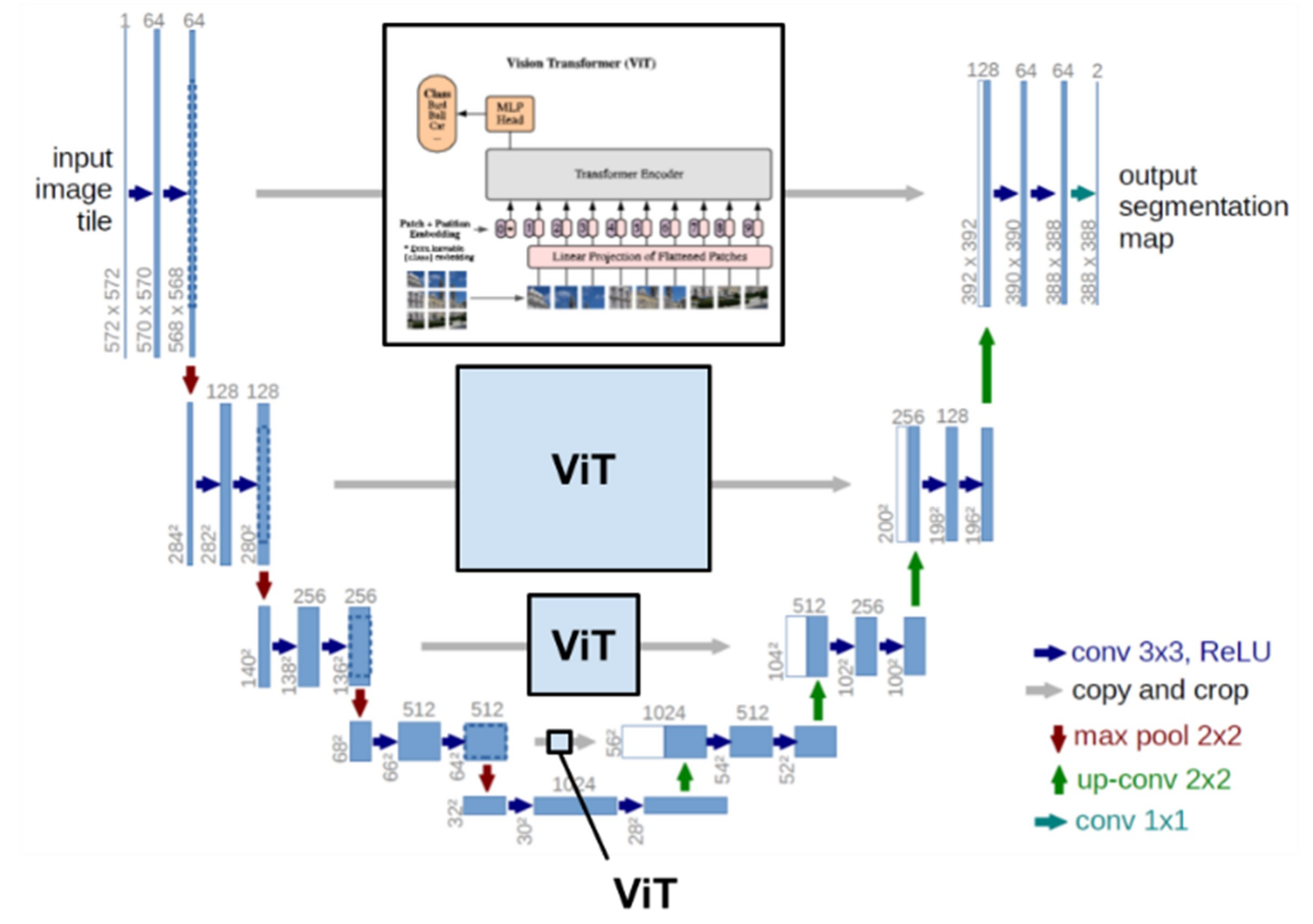
Underwater Propulsion Validation Setup

- A high RPM-low torque brushed-DC motor drives a single helical drive carriage through still water using a belt drive system
- Sensors on-board the setup: (1) 6-DoF Load Cell, (2) Linear Encoder for x-axis, (3) Rotary encoder for DC motor
- The net thrust is estimated using the load cell and the linear motion along the rails
- Different helical drive designs will be tested at different rotational speeds

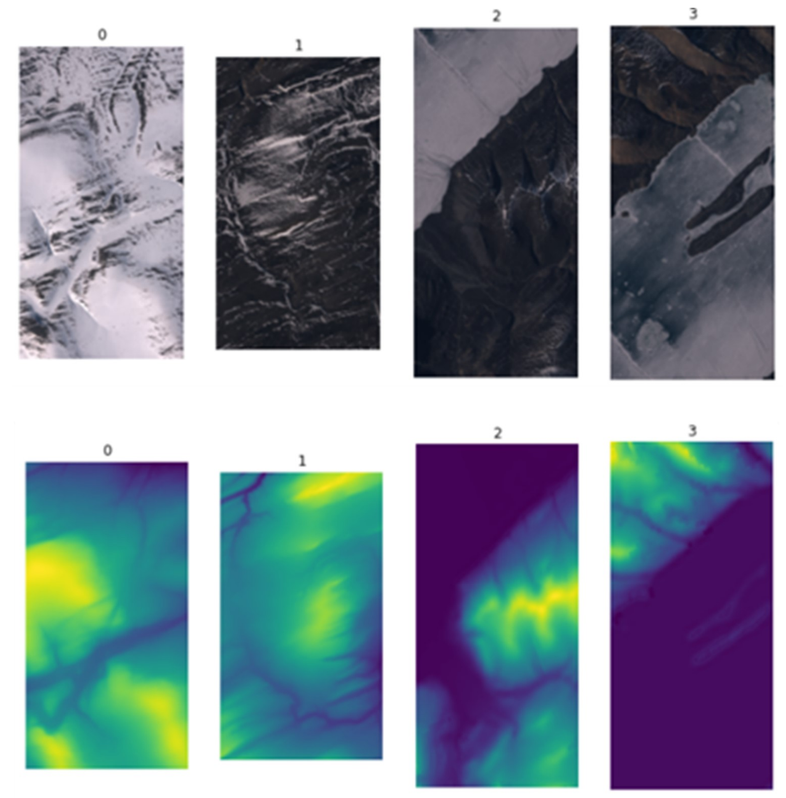


Satellite Images to Digital Elevation Map using NN

- This research explores the use of deep neural to generate digital elevation maps for exploratory autonomous rovers such as MAARCO
- Vision transformer neural networks (ViT) were implemented within the skip connections of a standard UNet model to create a new "TransUNet" model architecture.



- An area in the Arctic that is relevant to climate change research – Ellesmere Island, was selected for this project.
- Twenty-thousand satellite images and their matching digital elevation maps (DEMs) were then randomly sampled from a bounding box containing Ellesmere Island
- Top row: Satellite images of Ellesmere Island
- Bottom row: Corresponding digital elevation maps



Work-In-Progress & Future Work

- 1:5 scale prototype design and fabrication
- Terrestrial locomotion dynamics validation
- Underwater propulsion locomotion dynamics validation
- Development of an optimization framework to derive design, control strategy, and energy budgeting as a function of Artic mission requirements
- Formulation of Arctic survey missions