Thesis proposal:

Numerical simulations to evaluate the performance of a digging soft robotic probe in dry sand.

Background

In the last decade, grand challenges like the advancement of climate change, scarcity of resources, need of energy transition, ask for new, sustainable solutions for for soil characterisation, **deployment and maintenance** of sensors and utilities, **tunnelling** in areas inaccessible to conventional instruments.

As it often happens, smart strategies already exist in nature to answer similar needs, as animals have adapted over time to burrow effectively in different soil conditions. For example, earthworms have a soft body able to exploit **peristalsis locomotion** to excavate and move in soil. An earthworm can anchor in soft ground, penetrate in stiff underground layers or loose sand. Biological strategies provide a unique source of inspiration to design "innovative" technologies addressing modern challenges.

Aim

The primary objective of this cross-disciplinary project is to use numerical simulation with Finite Element Modeling (FEM) to explore the significance of the tip shape in the prototype for soil digging. Our investigation will concentrate on assessing the forces required for the soft robotic probe to rotate within the soil while controlling its advancement path.

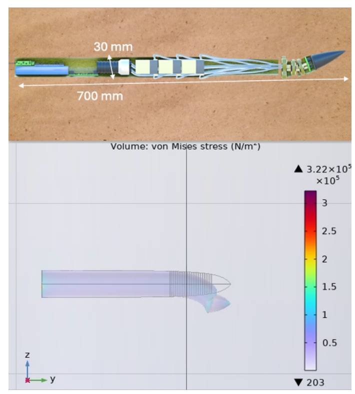

Figure 1: Top: Prototype of earthworm robot; Bottom: FEM model of the robot bending in the soil.

Key Phases:

1. Vertical and Horizontal Elongations: Initially, our focus will be on evaluating the forces involved in vertical and horizontal elongations.

2. Earthworm Mimicry: In a subsequent stage, the robot will emulate the shape of an earthworm, replicating the sequence of motions characteristic of peristaltic locomotion, which includes both elongation and radial expansion.

Research Objectives: The assigned student will delve into the following aspects:

- Identify optimal burrowing strategies to overcome soil penetration resistance via FEM simulation.
- Recognize and adapt to obstacles encountered during penetration tests.
- Establish a connection between soil properties, rotation and penetration forces at various depths.

This research aims to provide valuable insights into the dynamics of soil penetration and the potential applications of soft robotics in such contexts.

Method

Numerical research:

with the aid of a finite element software - COMSOL.

The student will be asked to develop a model that simulate dry sand at different initial bulk densities. The soft robotic probe will be added and the forces needed to impose the tip rotation extracted.

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