SNAKEBOT

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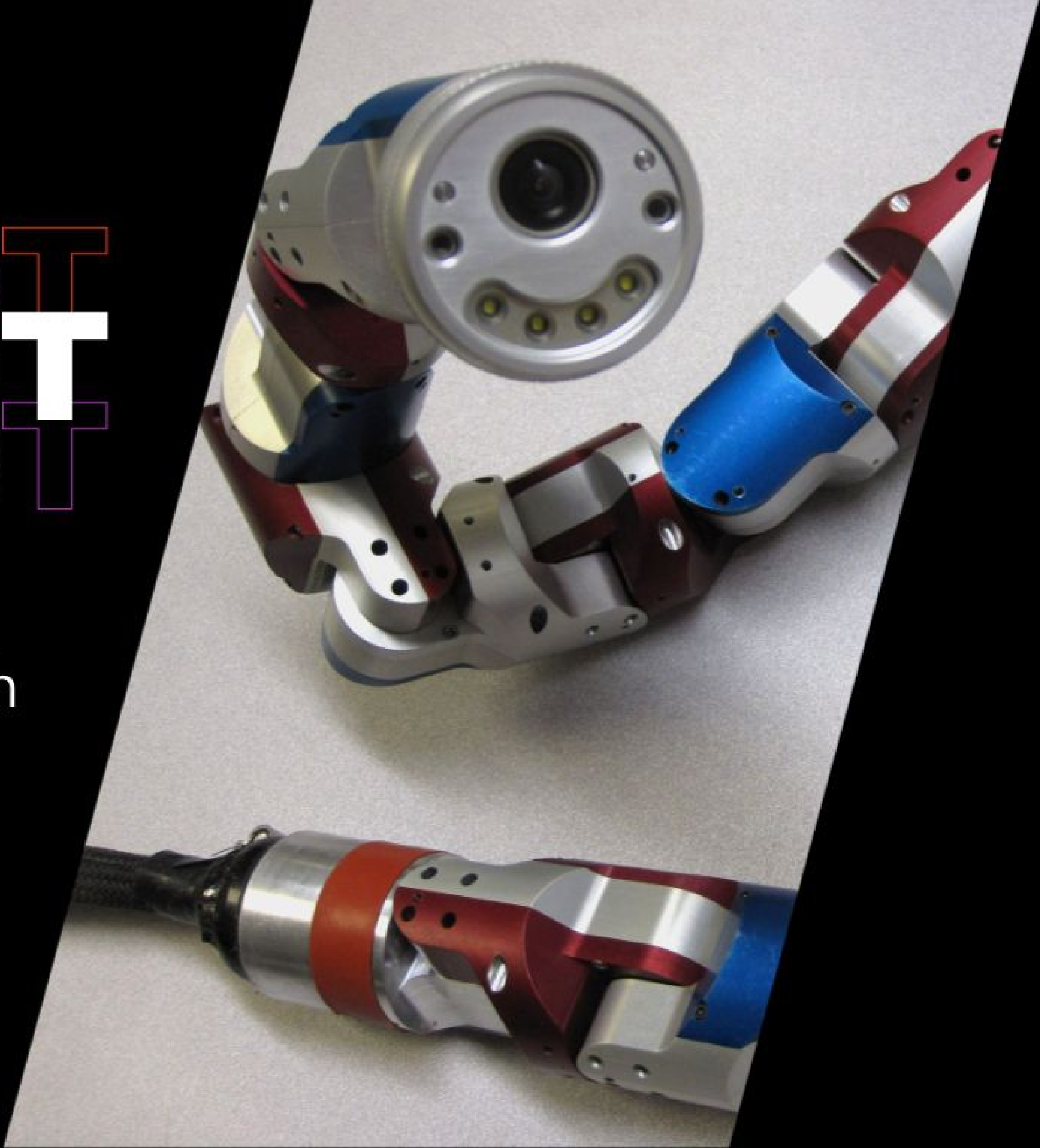
A 10 DoF robotic snake with teleoperation functionality



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MOTIVATION

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- Robot navigation through complex terrains is an attractive open research problem with various applications in space exploration, search and rescue, etc.
- Snake robots, due to their hyper redundancy and narrow cross section of their body, are versatile and can navigate within limited space through various hard to navigate environments
- In this project we want to explore the flexibility offered by a snake robot and the different types of gait motions that can be achieved with the robot.

ROBOT DESCRIPTION

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DoF

The robot is made up of 11 links joined by ten revolute joints. The joints each have one degree of freedom, making it a ten-degree-of-freedom robot.

Design

Each link will be in cubical shape to allow for easy movement. A tail link, different from the other links will be attached at the end of the robot

Actuation

The joint will have servo motors for actuation, which will respond to a control output. The joint angles will be measured using encoders which are included in the motors

CAD MODELING

CAD MODELING

- A CAD model for a cubical link, and a model for the tail was imported from available templates and the URDF was generated by combining the ".stl" files.
- The axis for the joints were defined according to the referenced research paper titled "ReBiS - Reconfigurable Bipedal Snake Robot"

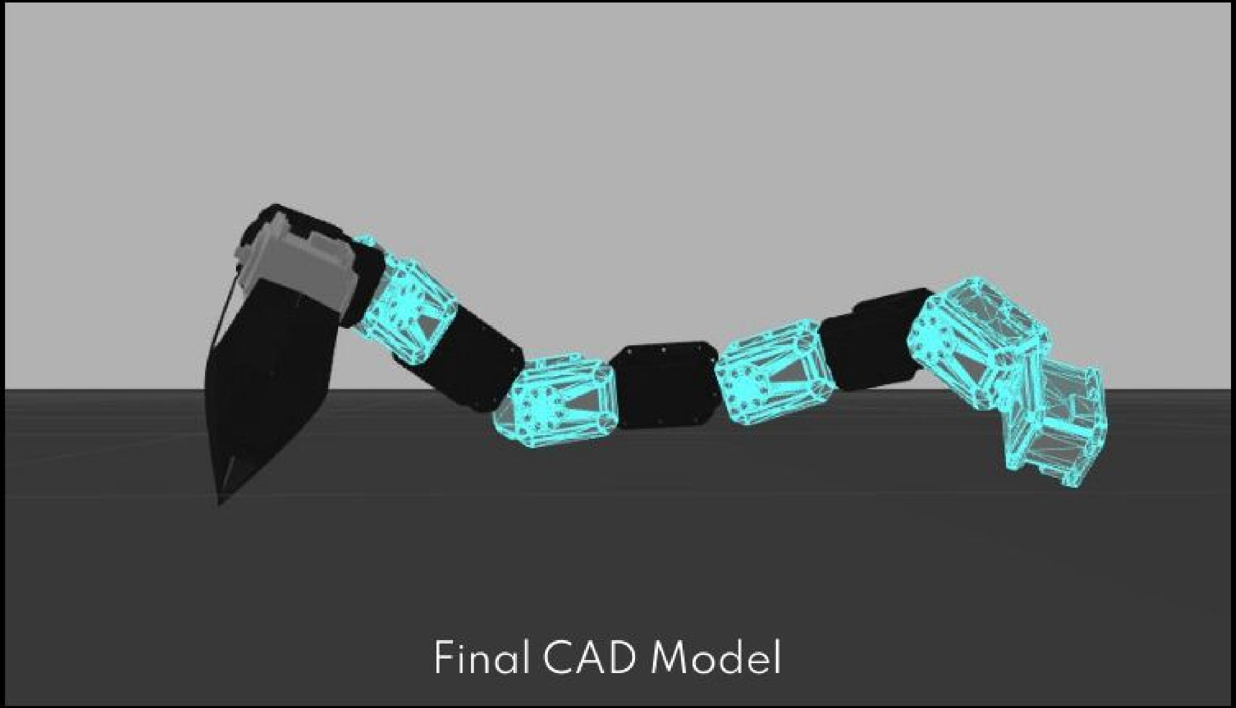
CAD MODELING

CAD MODELING

- Prebuilt parts files were initially used to assemble the robot and it waslater exported as a URDF file. The file had errors, such as high bends at some joints and axis misalignment.
- After multiple attempts, due to time restrictions, a CAD model for a cubical link, and a model for the head was imported from available templates and the URDF was generated by combining the ".stl" files.
- The axis for the joints were defined according to the referenced research paper titled "ReBiS – Reconfigurable Bipedal Snake Robot"

CAD MODEL

CAD MODEL



CONTROL

CONTROL

- To mimic snake motion, gaits were implemented based on sinusoidal curves, which was described in the previously mentioned research paper. The gaits consisted of two sinusoidal waves; one in each horizontal and vertical plane due to different axis or rotations in alternate joints

$$angle(n,t) = \begin{cases} A_x * \sin(\omega_x t + n * \delta_x), where\ n = even \\ A_y * \sin(\omega_y t + n * \delta_y + \emptyset), where\ n = odd \end{cases}$$

Where, n is the motor number when motor at each joint is numbered sequentially. A_x, A_y represent the amplitudes; δ_x, δ_y represents the spatial frequency; ω_x, ω_y represent the temporal frequency and ϕ represents the phase difference between the sine waves in horizontal and vertical plane.

CONTROL

CONTROL

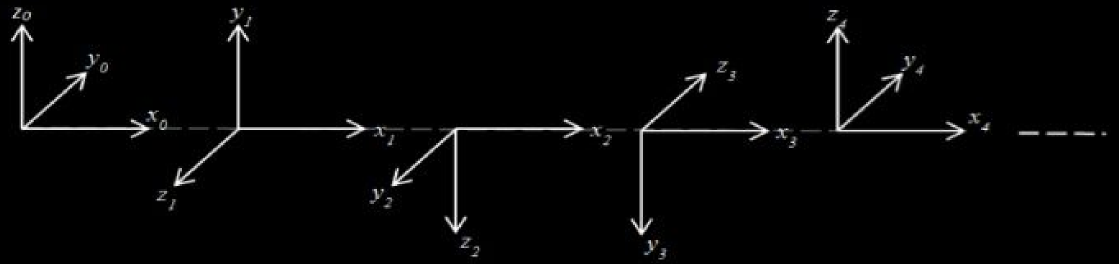
Based on the direction of motion that the robot should be moving, different gaits were generated, by changing the amplitude, frequency and phase difference as such

Gait	Parameters			
	Amplitude	***Frequency***	***Phase Difference***	ϕ
Lateral Undulation	$A_x = 60^0$ $A_y = 0^0$	$\omega_x = 5\pi/6$ $\omega_y = 5\pi/6$	$\delta_x = 2\pi/3$ $\delta_y = 0$	$\phi = 0$
Sidewinding	$A_x = 30^0$ $A_y = 30^0$	$\omega_x = 5\pi/6$ $\omega_y = 5\pi/6$	$\delta_x = 2\pi/3$ $\delta_y = 2\pi/3$	$\phi = 0$
Rolling	$A_x = 60^0$ $A_y = 60^0$	$\omega_x = 5\pi/6$ $\omega_y = 5\pi/6$	$\delta_x = \pi/2$ $\delta_y = \pi/2$	$\phi = \pi/6$
Linear Progression	$A_x = 0^0$ $A_y = 60^0$	$\omega_x = 5\pi/6$ $\omega_y = 5\pi/6$	$\delta_x = 0$ $\delta_y = 2\pi/3$	$\phi = 0$

KINEMATICS

KINEMATICS

DH parameters were calculated for the snakebot using the following coordinates



The DH parameters were

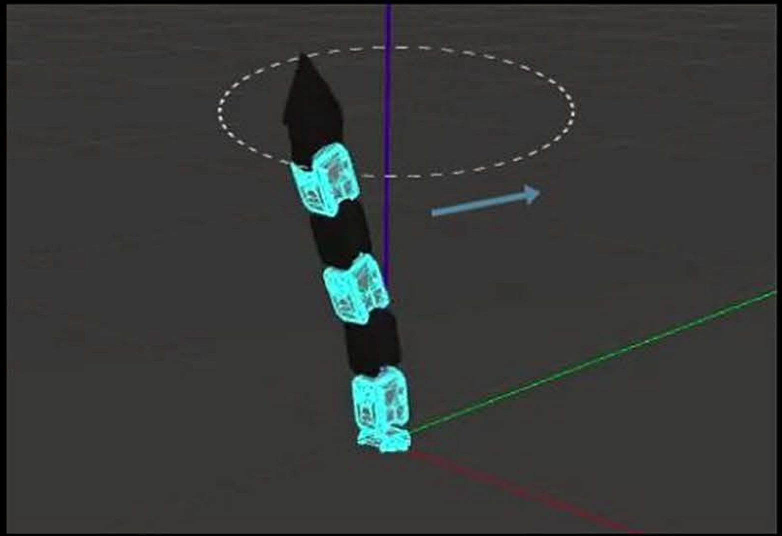
	ai	αi	di	θi
0→1	l	90	0	θ1
1→2	l	90	0	θ2
2→3	l	90	0	θ3
...	...	...	...	...

All the links of have the same DH Parameters as shown above

VALIDATION

VALIDATION

One end of the snakebot was attached to the ground frame and the other end was programmed to draw a circle to validate the kinematics of the robot.



Video Link

SIMULATION

SIMULATION

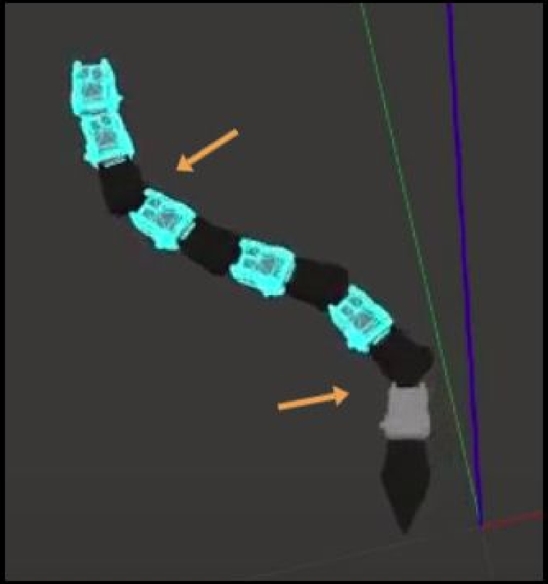
- ROS along with gazebo was used to simulate the movement of the robot which was controlled using keyboard input
- Based on the input received from the keyboard, the snakebot performed one of the five programmed gait movements

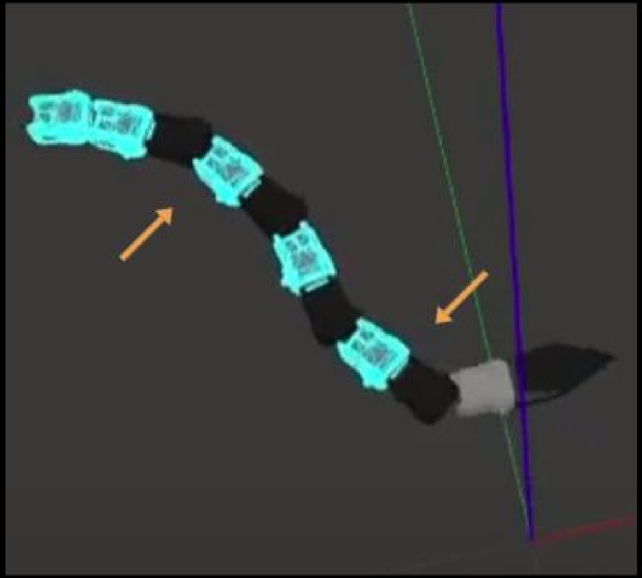
Input	Gait
s	Lateral Undulation
d	Rotate
w	Linear Progression
z	Rolling
q	Side Winding

LATERAL UNDULATION

LATERAL UNDULATION

In this gait the snakebot moves in a sideways slithering motion like a snake



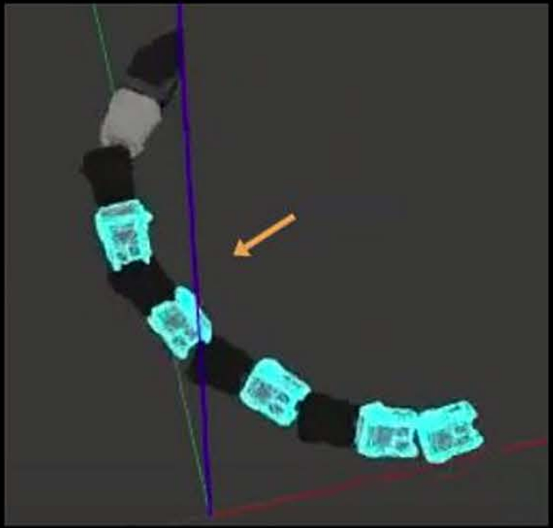


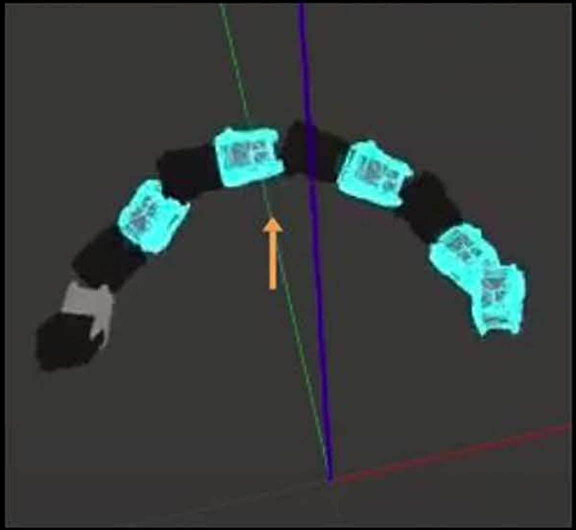
Video Link

ROTATE

ROTATE

In this gait the snakebot moves to rotate about the axis perpendicular to the ground. This gait can be used to change the direction of heading.



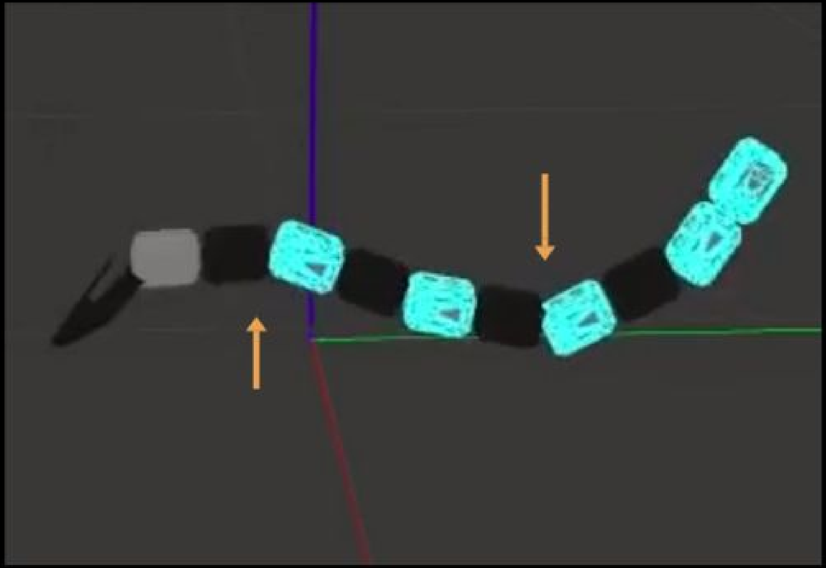


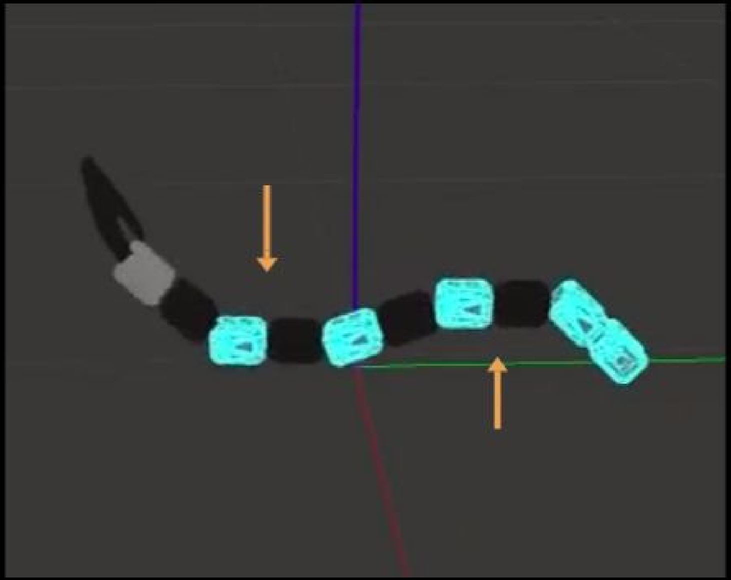
Video Link

LINEAR PROGRESSION

LINEAR PROGRESSION

In this gait the snakebot moves forward or backwards direction by performing sinusoidal wave like motion but in the plane perpendicular to the lateral undulation gait



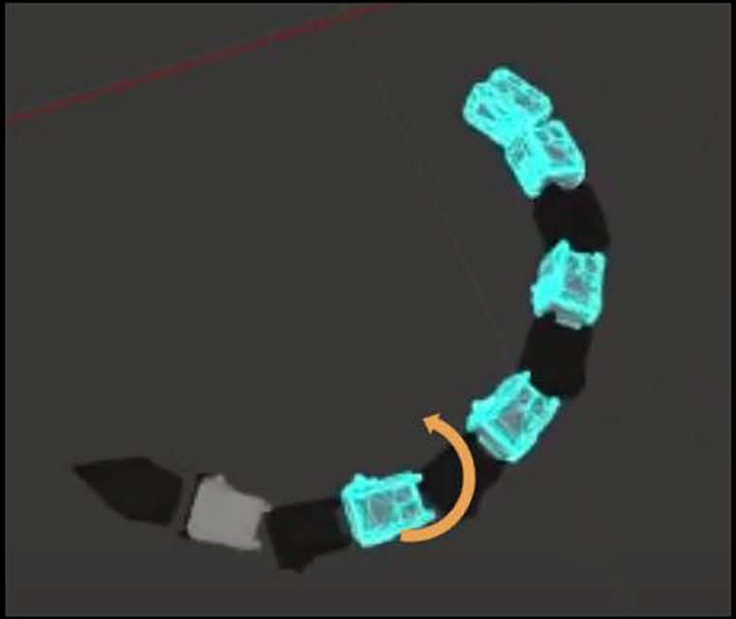


Video Link

ROLLING

ROLLING

In this gait the snakebot moves sideways by rolling along its length in either directions

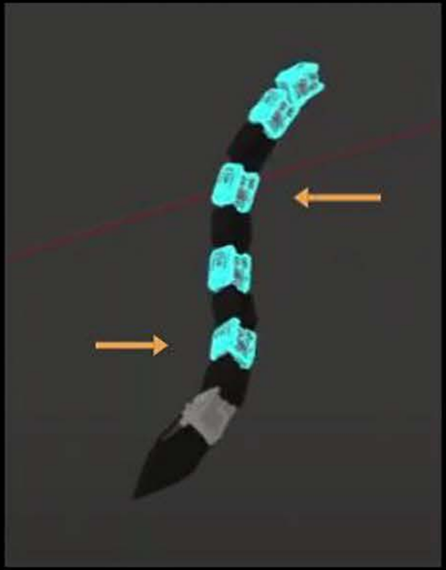


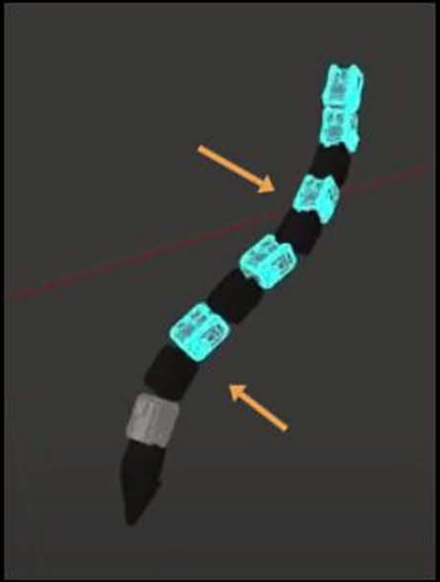
Video Link

SIDEWINDING

SIDEWINDING

In this gait the snakebot movessideways using sinusoidal wave like motion.





Video Link

CHALLENGES

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- Prebuilt parts files were initially used to assemble the robot and it was later exported as a URDF file. The file had errors, such as high bends at some joints and axis misalignment.
- The snakebot is not able to balance itself, to maintain linear progression for long stretches.
- Sidewinding gait starts as rolling which needs to be addressed

REFERENCES

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- Snake bot designs:
  - ARCSnake : https://www.sites.google.com/ucsd.edu/arcsnake/papers?authuser=0
  - Rebis : https://arxiv.org/pdf/2107.01197.pdf
  - Snake Robot : https://github.com/guzhaoyuan/snake_robot

- Gait Configurations and Navigation:
  - https://www.tandfonline.com/doi/abs/10.1163/156855309X452566
  - http://biorobotics.ri.cmu.edu/projects/modsnake/gaits/gaits.html

GitHub Link for our model

THANK YOU

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