Warsaw University of Technology
Faculty of Electronics and Information Technology
Institute of Control and Computation Engineering

MASTER THESIS

RESEARCHING SNAKE MOVEMENT STRATEGIES CREATED USING MACHINE LEARNING TECHNIQUES

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PLAN

- Introduction
- Snakes
- Realization
- Simulator module
- AI module
- Summary

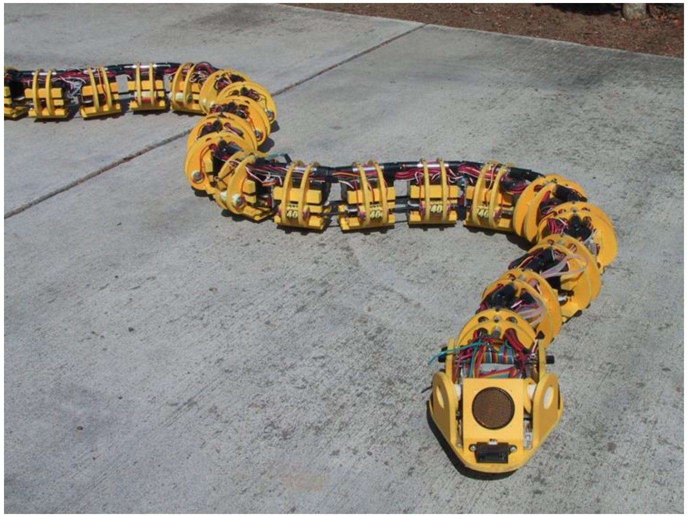
INTRODUCTION

„Snakes swim, dive, move rapidly through bushes or across rocks, crawl across featureless sand terrain, climb vertically up trees where they move swiftly through canopy, and, in some species, catapult from great heights and glide through the air to land without harm on the ground below.”

Harvey B. Lillywhite

INTRODUCTION

Dr. Gavin Miller



INTRODUCTION

SINTEF

Aiko

Anna Konda

Pneumosnake

INTRODUCTION

Black Mamba

- 19 km/h speed
- Lives on land and in the trees

Green Anaconda

- 30-70kg weight
- Lives mostly in the water

INTRODUCTION

Snakes are found on every continent (except Antarctica).

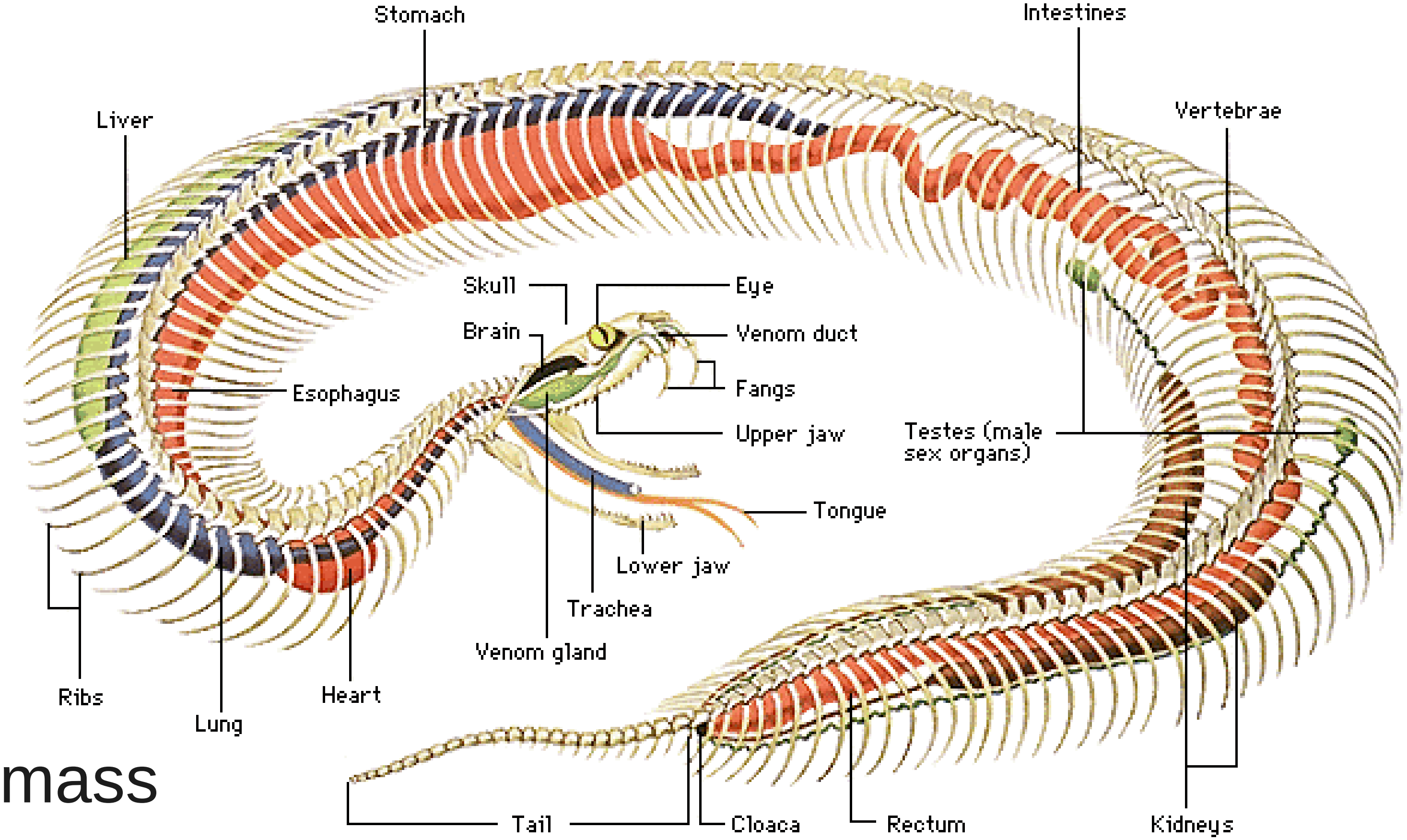
Known habitats:

- Water
- Forests
- Deserts
- Prairies

INTRODUCTION
Aim of the thesis

- Research snake locomotion
- Create simulation environment
- Create artificial intelligence module
- Conduct experiments
- Summarize learnt gaits and compare to natural ones

SNAKES



- No limbs
- Low center of mass
- Nicely distributed body mass
- Elongated body → reshaped organs and skeleton

SNAKES
Vertebrae

- „Dynamic” number of vertebrae with ribs (usually >100), whereas humans always have 12.
- Number of vertebrae depends on the body length, behaviour and environment.
- More vertebrae ≈ slower movement
- Lateral bending easier than dorsal-to-ventral bending (with exceptions)

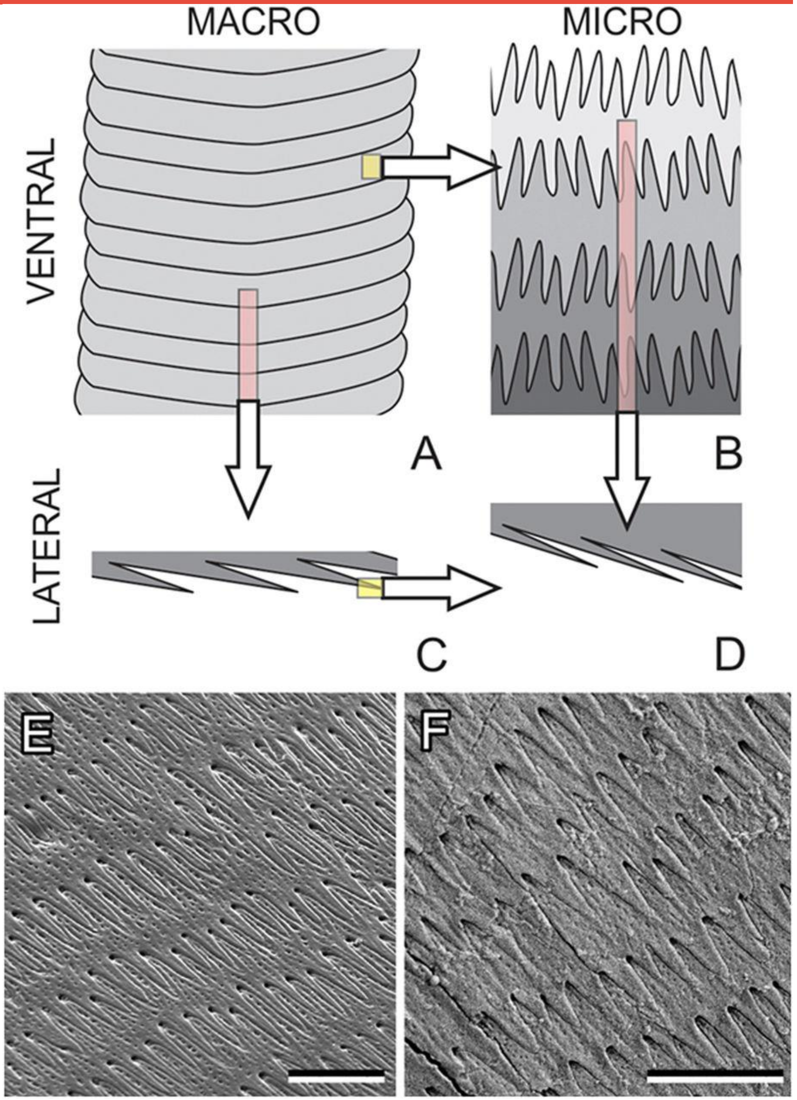
- Vertebral bending is used in various ways to generate propulsive forces

SNAKES
Musculature

- Extremely complex axial musculature
- Various muscle actions cause bending of the body and stabilize ribs against pulling
- Muscles form longitudinal columns, that span many ribs
- Longer the distance spanned ≈ faster movement
- Relatively short muscle units – stronger force of constriction

SNAKES
Ventral surface

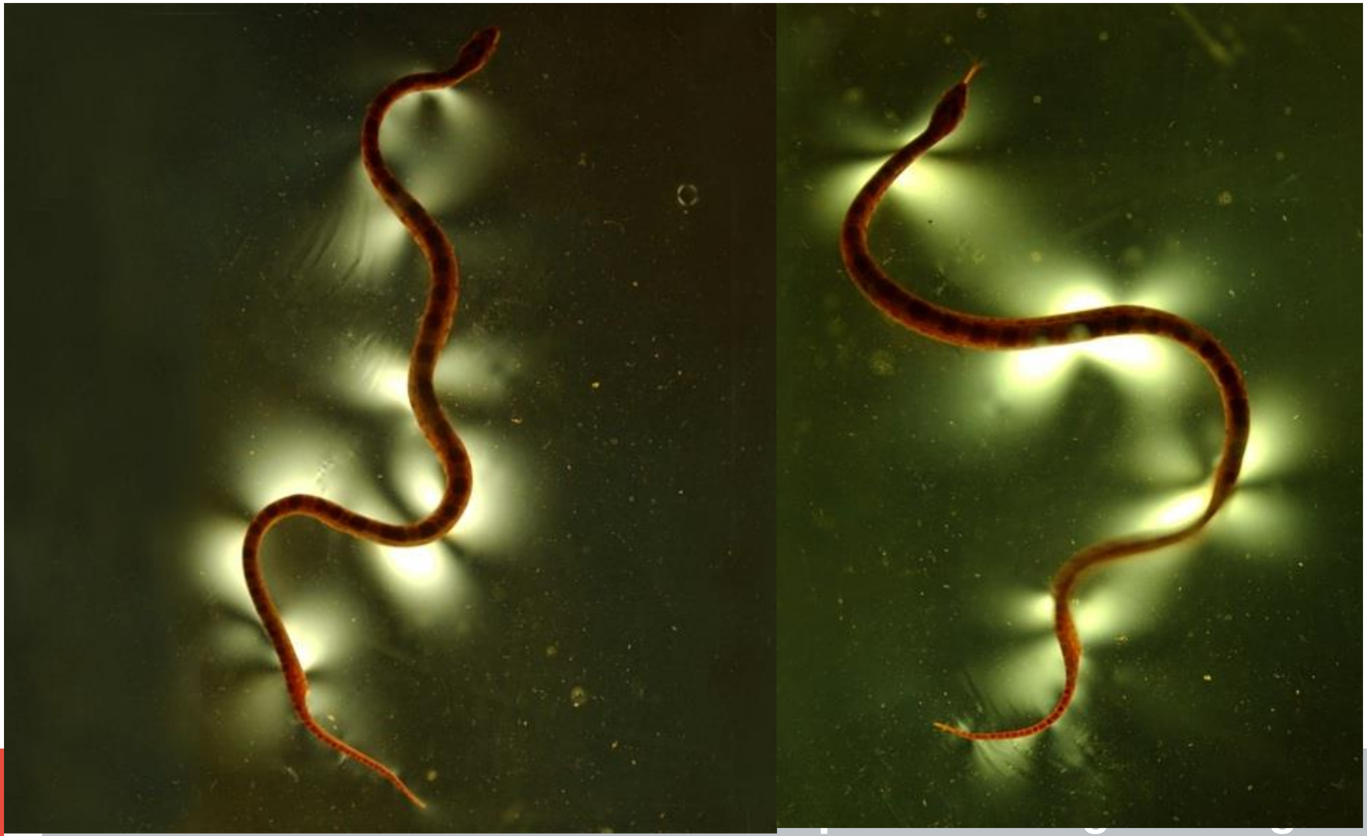
- Ventral scutes have anisotropic friction
- Costocutaneous muscles – they run between the ribs and the skin



Filippov, Gorb. 2016
Berthé, Westhoff, Bleckmann & Gorb. 2009, pp. 311-318

SNAKES
Locomotion

- Periodic undulations of the body
- Shifting body weight
- Maximizing friction in the contact zones

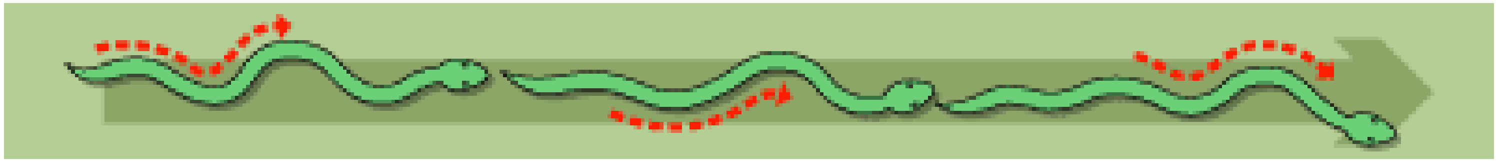


Dr. David Hu from Georgia Institute of Technology

SN
Loc

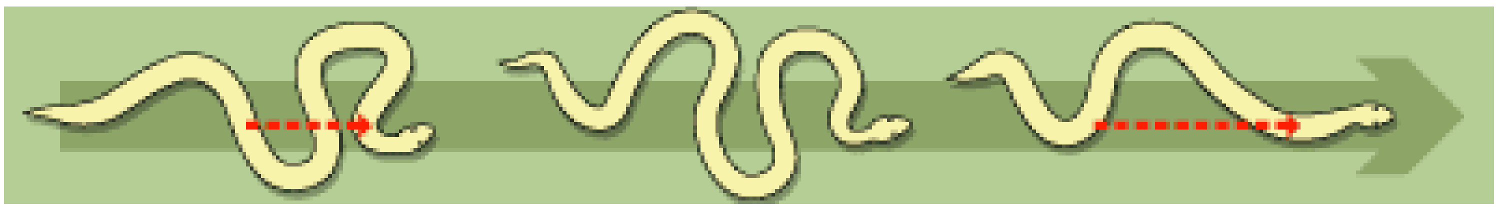
SNAKES
Gaits

- **Lateral undulation**



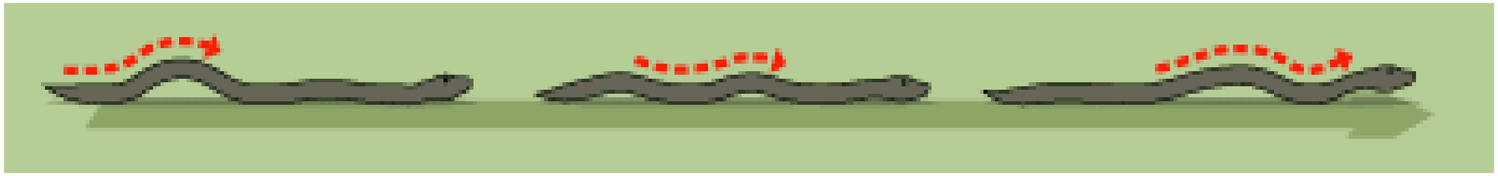
SNAKES
Gaits

- Lateral undulation
- **Concertina**



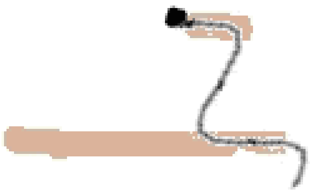
SNAKES
Gaits

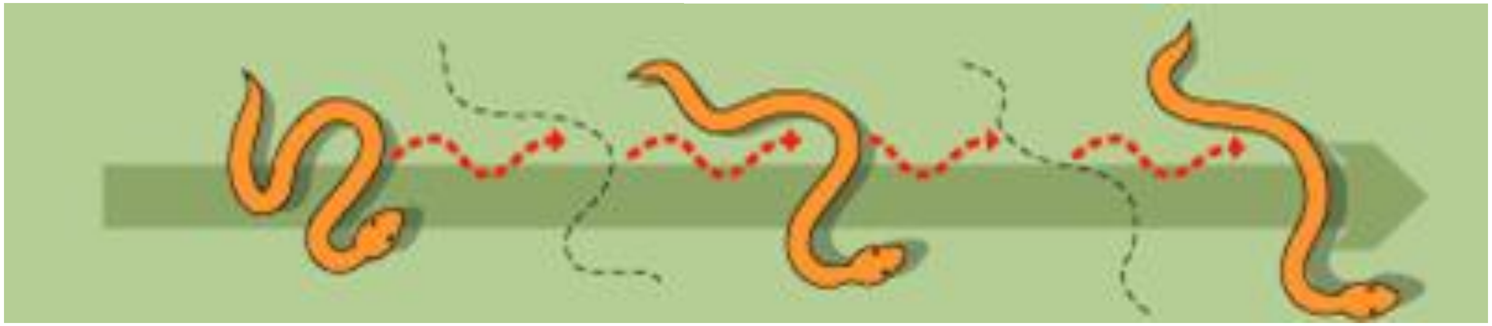
- Lateral undulation
- Concertina
- **Rectilinear**



SNAKES
Gaits

- Lateral undulation
- Concertina
- Rectilinear
- **Sidewinding**





REALIZATION

- Project consists of 2 modules:
  - Simulator
  - AI
- Simulator allows for visual preview
- Environment model is simplified. Mainly gravity & friction
- Snake model is simplified. Consists of linked cubes
- Results may be different from the natural gaits

SIMULATOR MODULE
Programming language

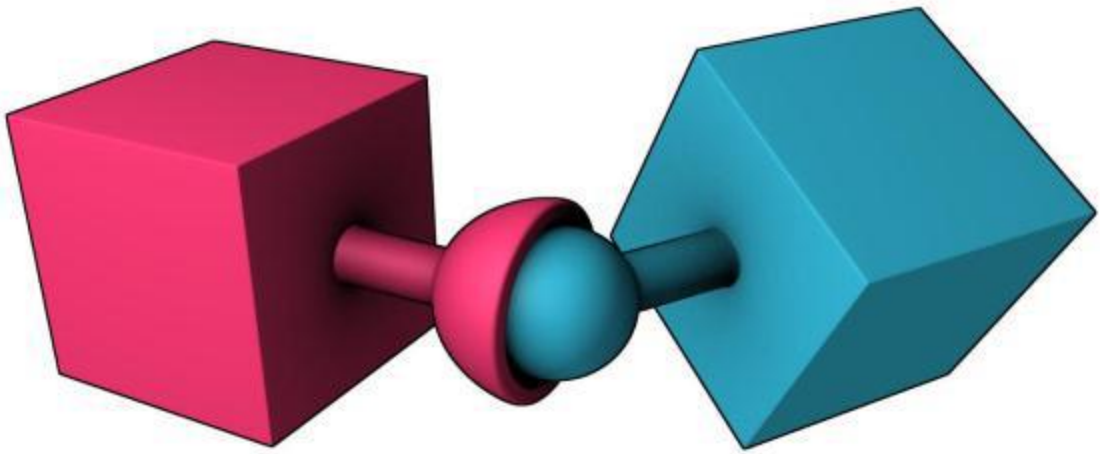
Simulator module is built with C++, using:

- Bullet Physics Library
- OpenGL
- GLFW
- Boost.Python

SIMULATOR MODULE

Snake is built from a given number of cubes, „linked” by cone-twist constraints.

Cubes have anisotropic friction.



SIMULATOR MODULE
API

Simulators API consists of several wrappers:

SnakeMoveStruct

- Segment no.
- Torque vector

SnakeSnapshotStruct

- Number of segments
- Each segments position and rotation vectors

SIMULATOR MODULE
API

Simulators API consists of several methods:

- GetMove
- SetMove
- GetSnake
- SetSnake
- IsMoveAvailable
- IsSnakeAvailable
- Step

AI MODULE
Programming language

AI module is built with Python, using:

- Numpy
- TensorFlow

AI MODULE
Requirements

Task – based on the current „shape” of the whole snake make a decision about the next move.

The right segment needs to be chosen and the right torque vector applied.

No previous knowledge.

Aim – moving away from the current point with maximum speed

AI MODULE
Requirements

Model – gravity, friction, maximum torque

Reward function:

- Cost based on the energy used (torque applied)
- Reward based on the speed
- Additional bigger rewards for „checkpoints”
- Time dependent reward for finishing

Reinforcement learning

- Learning based on the interaction with the environment
- Solution is not hinted in any way, only the aim
- Short and long term rewards

AI MODULE
Algorithm exploration

- Simple policy based algorithm
- Genetic algorithm
- DDPG
- ?

SUMMARY

- Snakes locomotion is very complex
- Model simplification - not enough or too much?
- Algorithm exploration

Current work available at: *https://github.com/mkulagowski/snAIk*

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