Unconventional gait exploration with salamander/snake robots

Semester Project-Midterm Presentation

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The side-winding motion - Visual Elements

Video source: https://www.youtube.com/watch?v=qLMriz8l0P8

Ground Contact Tracks (GCT)

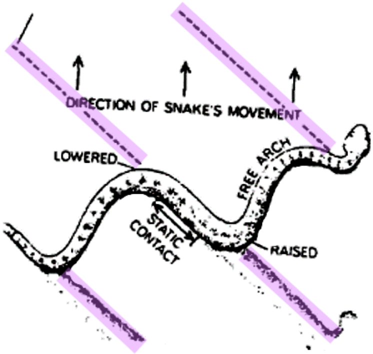

Figure 1: Ground Contact Tracks
Image source: Burdick et al, 1993

Gound Contact Segments (GCS)

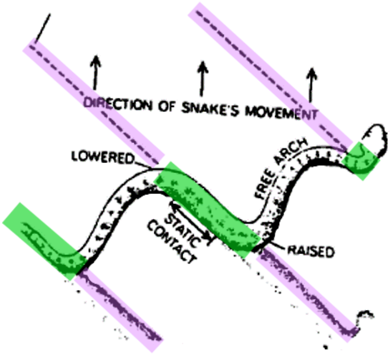

Figure 2: Gound Contact Segments
Image source: Burdick et al, 1993

Arch Segments (AS)

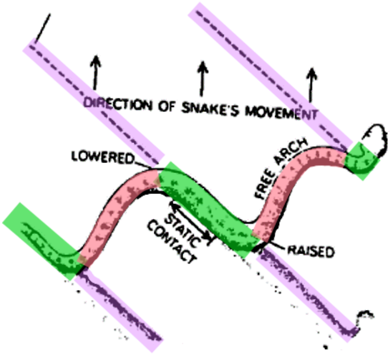

Figure 3: Arch Segments
Image source: Burdick et al, 1993

Description using two wave functions

$$\Theta(n,t) = \begin{cases} A_o Sin(\frac{n}{\lambda} + \omega t), n = odd \\ A_e Sin(\frac{n}{\lambda} + \omega t + \delta), n = even \end{cases} \quad (1)$$

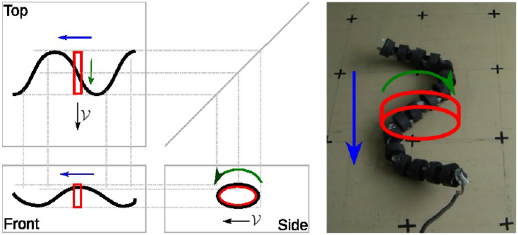

Figure 4: Top perspective-high amplitude wave , front perspective w.r.t the direction of dispalcement-low amplitude wave , and lateral perspective-ellypsoidal wheel . Image source: Melo, 2015.

(Play side) (Play top) (Play front) (Play all)

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Why side-winding is desirable

Side-winding is desirable because (Burdick et al, 1993 and Hatton et al, 2010)

- Terrain-wise
  - Big footprint of the snake on the ground $\Rightarrow$ improved stability
  - Static, not sliding friction $\Rightarrow$ minimal frictional resistance from its environment
  - Useful on granular terrain where the ground is not generating enough reaction forces needed for other motions
  - Contact reaction forces are distributed over several GCS $\Rightarrow$ improved stability (Burdick et al, 1993)
- Energetically-wise
  - Only static friction $\Rightarrow$ not wasting energy on resistant forces
  - Low energy used for the vertical motion, which is very small
- Performance-wise
  - Big speed
  - Reduced wear caused by friction

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The motion

$$\Theta(n,t) = \begin{cases} A_o Sin(\frac{n}{\lambda} + \omega t), n = odd \\ A_e Sin(\frac{n}{\lambda} + \omega t + \delta), n = even \end{cases}$$

- $\Theta(n, t)$ is the angle of module n
- A_o is the amplitude of the odd modules
- A_e is the amplitude of the even modules
- n is the number of each module
- λ is the wavelength of the two waves
- ω is the frequency of the waves
- t is the time
- δ is a phase shift

Key aspects in the motion(1)

Shortly after a module of the snake is lifted of a GCT, it also starts an horizontal motion in the direction of the displacement

$\Leftrightarrow$ The two waves are synchronized $(\frac{n}{\lambda} + \omega t)$, with a phase shift $\delta = \pi/4$, to make sure that the lifted portion has time to be propagated towards the direction of displacement

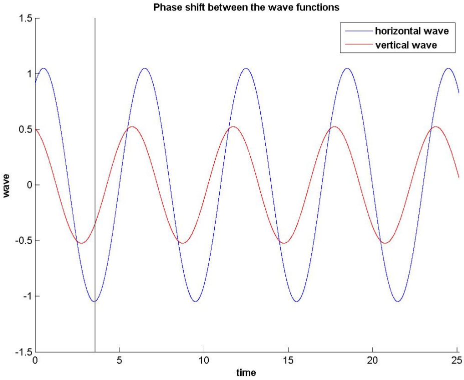

Figure 5: illustration of the synchronization of the wave functions

Key aspects in the motion(2)

The robot does a big displacement while making little lift from the ground $\Leftrightarrow A_o > A_e$ (small amplitude vertical wave and high amplitude vertical wave)

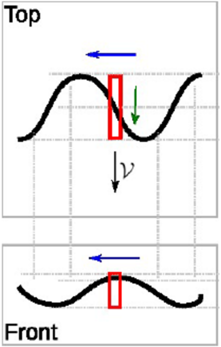

Figure 6: The two waves that produce the motion
Image source: Melo 2015

Key aspects in the motion(3)

(Play large amplitude horizontal wave)

(Play small amplitude horizontal wave)

There are a few modules on the ground; most of them are in the air "flying" (Melo 2015)
$\Leftrightarrow \lambda = \frac{n_{wave}}{2\pi}$, when n_{wave} is the number of modules in a complete wave.
For example for a $16DOF$ snake robot λ is $3/\pi$ or $6/\pi$ (Melo, 2015)

Key aspects in the motion(4)

(Burdick et al, 1993)
Straight and parallel GCT for **straight displacement**
$\Leftrightarrow$ A_o = *constant* and A_e = *constant*

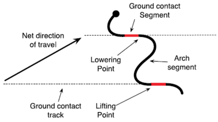

Figure 7: Ground Contact Tracks
Image source: Gong et al, 2012

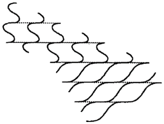

Figure 8: Head placement
Image source: Burdick et al, 1993

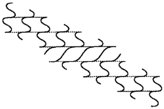

Figure 9: Skew GCTs
Image source: Burdick et al, 1993

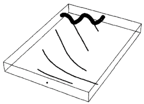

Figure 10: Curviliniaer GCTs
Image source: Burdick et al, 1993

Key aspects in the motion(5)

Turning can be done by curvilinear GCT
$\Leftrightarrow$ the spine forms a cone instead of a cylinder (Gong et al, 2012)

- the taper of the cone gives the turning rate
- the backbone's distribution on the cone's surface affects the lateral stability of the robot
- but this is not our concern

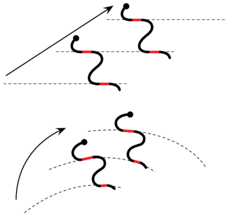

Figure 11: Conical side-winding
Images source: Gong et al, 2012

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Porting side-winding to Pleurobot

- Side-winding has lots of advantages, of which, reminding:
    - Functions on granular terrain
    - Big speed
    - Reduced ware
    - Little energy used for the vertical motion
- What can be done, to port the side-winding to Pleurobot?

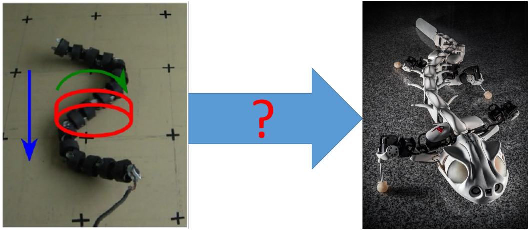

Figure 12: How can we implement the wave-wave-roll motion in Pleurobot?
Image sources: Melo 2015 and http://biorob.epfl.ch/pleurobot

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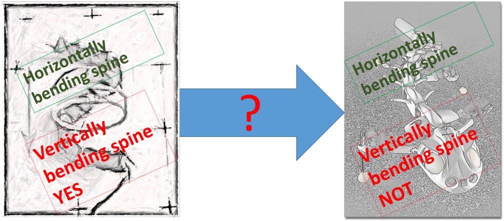

Figure 13: How can we implement the wave-wave-roll motion in Pleurobot?
Image sources: Melo 2015 and http://biorob.epfl.ch/pleurobot

What is available

Lola snake robot:

- For horizontal motion: the spine can be bent horizontally
- For vertical motion: the spine can be bent vertically

Pleurobot:

- For horizontal motion: the spine can be bent horizontally
- For vertical motion: the spine can NOT bent horizontally, BUT there are 4 DOF limbs capable of producing vertical motion

The question

How can the 4 DOF limbs be exploited, to produce the vertical wave effect present in the snake's spine?

Methodology

- How do we measure the success?
  $\Rightarrow$ define metrics
- Webots simulations
- (Maybe) Tests on the real platform
- Comparisons between the platforms

Methodology

- Workspaces of the salamander's limbs

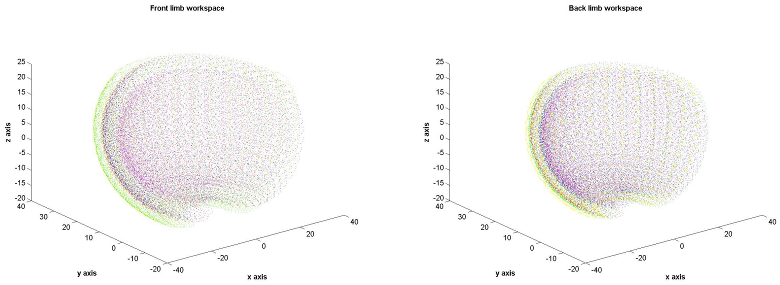

Figure 14: The Pleurobot's limbs workspace: to the left the front limb, and to the right the back limb

- For the snake, the contact points are known

  $\Rightarrow$ knowing the workspace, the limbs positions can be computed

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Bibliography

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Questions?