

 Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Praktikum: 12

### Snake-like robot realization

**Lecturers**

Houxiang Zhang  
Manfred Grove

TAMS, Department of Informatics  
University of Hamburg, Germany



@Tams/hzhang

---

 Ph.D. ZHANG, Houxiang  
Institute TAMS Technical Aspects of Multimodal Systems

hzhang@informatik.uni-hamburg.de  
http://tams-www.informatik.uni-hamburg.de/hzhang

1

 Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg



 Ph.D. ZHANG, Houxiang  
Institute TAMS Technical Aspects of Multimodal Systems

hzhang@informatik.uni-hamburg.de  
http://tams-www.informatik.uni-hamburg.de/hzhang

2

 Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Acknowledgments

- "Bioinspiration and Robotics: Walking and Climbing Robots "**  
Edited by: Maki K. Habib, Publisher: I-Tech Education and Publishing, Vienna, Austria, ISBN 978-3-902613-15-8.  
- <http://s.i-techonline.com/Book/>
- My colleague [Juan Gonzalez-Gomez](#) from the School of Engineering, Universidad Autonoma de Madrid in Spain.
- Other great work and related information on the internet  
- [http://en.wikipedia.org/wiki/Self-Reconfiguring\\_Modular\\_Robotics](http://en.wikipedia.org/wiki/Self-Reconfiguring_Modular_Robotics)





---

 Ph.D. ZHANG, Houxiang  
Institute TAMS Technical Aspects of Multimodal Systems

hzhang@informatik.uni-hamburg.de  
http://tams-www.informatik.uni-hamburg.de/hzhang

3

 Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Lecture material

- [Modular Self-Reconfigurable Robot Systems: Challenges and Opportunities for the Future](#), by Yim, Shen, Salemi, Rus, Moll, Lipson, Klavins & Chirikjian, published in IEEE Robotics & Automation Magazine March 2007.
- [Self-Reconfigurable Robot: Shape-Changing Cellular Robots Can Exceed Conventional Robot Flexibility](#), by Murata & Kurokawa, published in IEEE Robotics & Automation Magazine March 2007.
- [Locomotion Principles of 1D Topology Pitch and Pitch-Yaw-Connecting Modular Robots](#), by Juan Gonzalez-Gomez, Houxiang Zhang, Eduardo Boemo, One Chapter in Book of "Bioinspiration and Robotics: Walking and Climbing Robots", 2007, pp.403-428.
- [Locomotion Capabilities of a Modular Robot with Eight Pitch-Yaw-Connecting Modules](#), by Juan Gonzalez-Gomez, Houxiang Zhang, Eduardo Boemo, Jianwei Zhang: The 9th International Conference on Climbing and Walking Robots and their Supporting Technologies for Mobile Machines, CLAWAR 2006, Brussels, Belgium, September 12-14, pp.150-156, 2006.

---

 Ph.D. ZHANG, Houxiang  
Institute TAMS Technical Aspects of Multimodal Systems

hzhang@informatik.uni-hamburg.de  
http://tams-www.informatik.uni-hamburg.de/hzhang

4

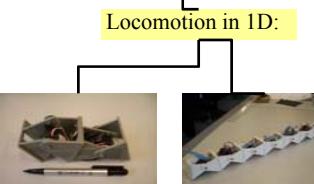


## Outline of today's lecture

- Build a snake-like modular robot
- Realization different locomotion gaits
  - Linear gait
  - Turning gait
  - Rolling gait
  - Lateral shift
  - Rotation



### 1D Topology:



Pitch-Pitch

### 2D Topology:



Star of 3 modules

### Locomotion in 1D:



8 pitch-connecting modules

### Locomotion in 2D:



Pitch-Yaw-Pitch



8 pitch-yaw-connecting modules

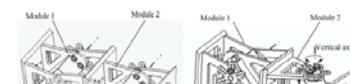


## Outline of today's lecture

- Build a snake-like modular robot
- Realization different locomotion gaits
  - Linear gait
  - Turning gait
  - Rolling gait
  - Lateral shift
  - Rotation



## GZ-I with four connecting faces



a. Pitch connecting



b. Pitch-Yaw connecting



c. Vertical connecting



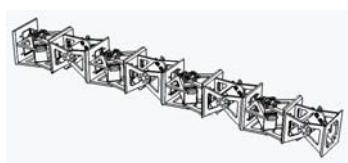
d. Lateral connecting



**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Your tasks

- Caterpillar-like movement
  - minimal configurations
  - Caterpillar with 4 to 8 modules
- Snake-like movement
  - minimal configurations ( new question)
  - Snake-like movement

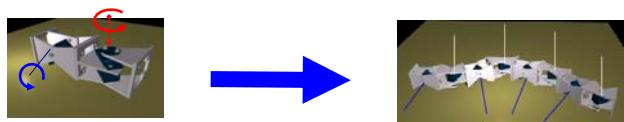



**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 9

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Your tasks

- Caterpillar-like movement
  - minimal configurations
  - Caterpillar with 4 to 8 modules
- Snake-like movement
  - minimal configurations ( new question)
  - Snake-like movement

**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 10

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Outline of today's lecture

- Build a snake-like modular robot
- Realization different locomotion gaits
  - Linear gait
  - Turning gait
  - Rolling gait
  - Lateral shift
  - Rotation



**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 11

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Locomotion controlling method

- The sinusoidal generators produce very smooth movements and have the advantage of making the controller much simpler. Our model is described by the following equation .

$$y_i = A_i \sin\left(\frac{2\pi}{T} t + \phi_i\right) + O_i$$

- Where  $y_i$  is the rotation angle of the corresponding module;  $A_i$  is the amplitude;  $T$  is the control period;  $t$  is time;  $\Phi_i$  is the phase;  $O_i$  is the initial offset.

**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 12

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Locomotion controlling method (cont')

The diagram illustrates a robot composed of four horizontal modules, labeled H<sub>1</sub> through H<sub>4</sub>, and four vertical modules, labeled V<sub>1</sub> through V<sub>4</sub>. Phase differences are indicated by arrows between adjacent modules: ΔΦ<sub>V</sub> between V<sub>1</sub> and V<sub>2</sub>, ΔΦ<sub>V</sub> between V<sub>2</sub> and V<sub>3</sub>, ΔΦ<sub>V</sub> between V<sub>3</sub> and V<sub>4</sub>, ΔΦ<sub>H</sub> between H<sub>1</sub> and H<sub>2</sub>, ΔΦ<sub>H</sub> between H<sub>2</sub> and H<sub>3</sub>, ΔΦ<sub>H</sub> between H<sub>3</sub> and H<sub>4</sub>, and ΔΦ<sub>HV</sub> between H<sub>1</sub> and V<sub>1</sub>.

- They are divided into horizontal and vertical groups, which are described as H<sub>i</sub> and V<sub>i</sub> respectively. Where i means the module number;
- ΔΦ<sub>V</sub> is the phase difference between two adjacent vertical modules;
- ΔΦ<sub>H</sub> is the phase difference between two adjacent horizontal modules;
- ΔΦ<sub>HV</sub> is the phase difference between two adjacent horizontal and vertical modules.

**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 13

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Locomotion capabilities

- Linear gait
  - Forward and backward movement
- Turning gait
  - Turn left and right; or the robot moves along an arc
- Rolling gait
  - The robot rolls around its body axis
- Lateral shift
  - The robot moves parallel
- Rotation
  - The robot rotates around its body axis

**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 14

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Locomotion capabilities-linear gait

- Parameters:

$A_V \neq 0$	$A_H = 0$
$O_V = 0$	$O_H = 0$
$\vec{x}_V = 120$	

The graph shows waveforms for vertical modules V<sub>1</sub>, V<sub>2</sub>, V<sub>3</sub>, and V<sub>4</sub> over time, with amplitudes A<sub>V</sub> and frequencies O<sub>V</sub>. Below the graph are two images of the robot in a linear gait configuration.

**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 15

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Locomotion capabilities-turning gait

- Parameters:

$A_V \neq 0$	$A_H = 0$
$O_V = 0$	$O_H \neq 0$
$\vec{x}_V = 120$	

The graph shows waveforms for vertical modules V<sub>1</sub>, V<sub>2</sub>, V<sub>3</sub>, and V<sub>4</sub> over time, with amplitudes A<sub>V</sub> and frequencies O<sub>H</sub>. Below the graph are two images of the robot in a turning gait configuration.

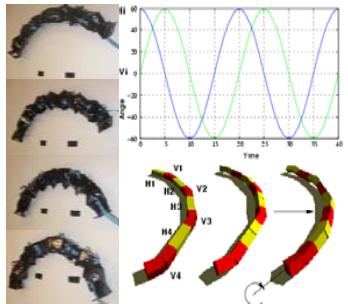
**TAMS** Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de Institute TAMS Technical Aspects of Multimodal Systems http://tams-www.informatik.uni-hamburg.de/hzhang 16



## Locomotion capabilities-rolling gait

- Parameters:

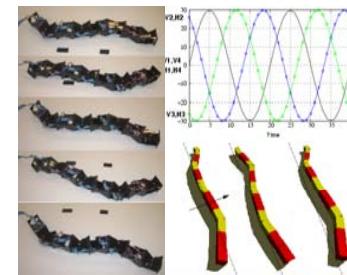
$$\begin{aligned} A_V &\neq 0 & A_H &\neq 0 \\ O_V = 0 & & O_H = 0 \\ \varphi_{V'} = 0 & & \varphi_{H'} = 0 \\ \varphi_{VH} = 90 & & \end{aligned}$$



## Locomotion capabilities-lateral shift

- Parameters:

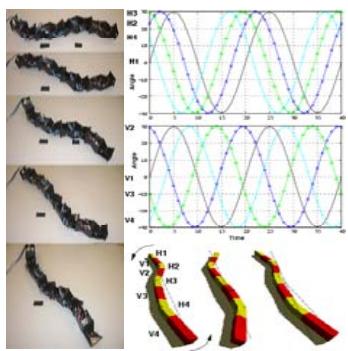
$$\begin{aligned} A_V &\neq 0 & A_H &\neq 0 \\ O_V = 0 & & O_H = 0 \\ \varphi_{V'} = 100 & & \varphi_{H'} = 100 \\ \varphi_{VH} = 0 & & \end{aligned}$$



## Locomotion capabilities-rotating gait

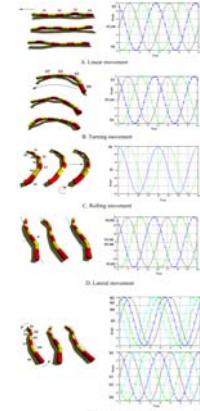
- Parameters:

$$\begin{aligned} A_V &\neq 0 & A_H &\neq 0 \\ O_V = 0 & & O_H = 0 \\ \varphi_{V'} = 120 & & \varphi_{H'} = 50 \\ \varphi_{VH} = 0 & & \end{aligned}$$



## Summary

Gate types	Parameters for sinusoidal generators
Linear movement	$A_H = 0; A_V = O_H = 0$
	$\Delta\Phi_V = 100 - 120, O_H = 0$
Turning movement	$\Delta\Phi_V = 100 - 120, O_H = 0$
	$A_H = 0; A_V = O_H = 0$
Rolling movement	$A_H = 0; A_V = O_H = 0$
	$\Delta\Phi_V = \Delta\Phi_H = 100, \Delta\Phi_{VH} = 90$
Lateral movement	$\Delta\Phi_V = \Delta\Phi_H = 100, \Delta\Phi_{VH} = 0$
	$A_H = 0; A_V = O_H = 0$
Rotation movement	$\Delta\Phi_V = 120, \Delta\Phi_H = 0, \Delta\Phi_{VH} = 50$
	$A_H = 0; A_V = O_H = 0$



**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Summary

**Sinusoidal**      **Turning**      **Lateral Shifting**      **Rotating**      **Rolling**

$A_V \neq 0$	$A_H = 0$	$O_V = 0$	$\Delta\Phi_V = 120$	$O_H \neq 0$
$O_H = 0$	$O_H \neq 0$			
$\Delta\Phi_{VH} = 0$	$\Delta\Phi_{VH} = 0$	$\Delta\Phi_{VH} = 0$	$\Delta\Phi_{VH} = 90$	$\Delta\Phi_{VH} = 0$
$\Delta\Phi_H = 100$	$\Delta\Phi_H = 50$	$\Delta\Phi_H = 0$	$\Delta\Phi_H = 0$	$\Delta\Phi_H = 0$
$\Delta\Phi_V = 100$	$\Delta\Phi_V = 120$	$\Delta\Phi_V = 0$	$\Delta\Phi_V = 0$	$\Delta\Phi_V = 0$

Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de http://tams-www.informatik.uni-hamburg.de/hzhang 21

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

It is time for you now...

Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de http://tams-www.informatik.uni-hamburg.de/hzhang 22

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

## Praktikum: 13

*Open possibilities using GZ-I*

**Lecturer**

**Houxiang Zhang  
Manfred Grove**

TAMS, Department of Informatics  
University of Hamburg, Germany

@Tams\_hzhang

Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de http://tams-www.informatik.uni-hamburg.de/hzhang 23

**UH** Technical Aspects of Multimodal System  
Dept. Informatics, Faculty of Mathematics, Informatics and Natural Sciences  
University of Hamburg

Thanks for your attention!

Any questions?

Ph.D. ZHANG, Houxiang hzhang@informatik.uni-hamburg.de http://tams-www.informatik.uni-hamburg.de/hzhang 24