Locomotion Capabilities of a Modular Robot with Eight Pitch-Yaw-Connecting Modules

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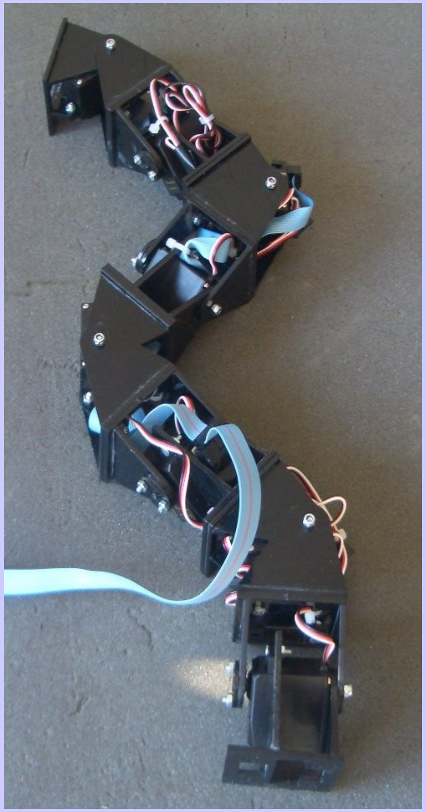

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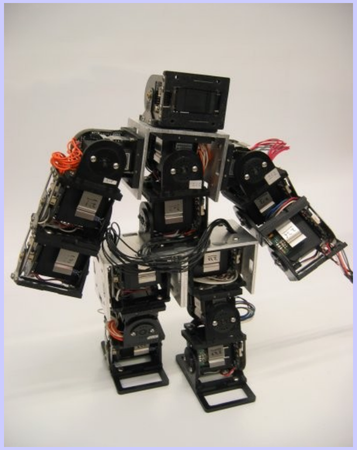
Outline

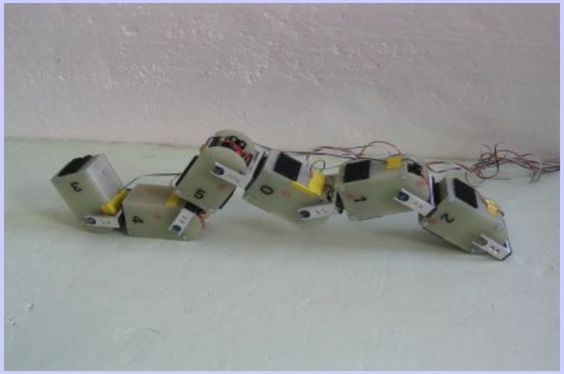
- Modular robotics
- Previous work
- Overview of the pitch-yaw-connecting robot
- Control approach
- Locomotion capabilities
- Videos
- Conclusion
- Future work

Modular Robotics (I)

- Main idea: Building robots composed of **modules**
- The design is focused in the module, not in a particular robot
- The different combinations of modules are called **configurations**
- **Some Advantages:**
  - Versatility
  - Fast prototyping
  - Testing new ideas

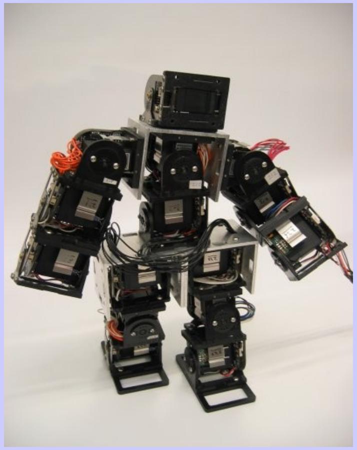


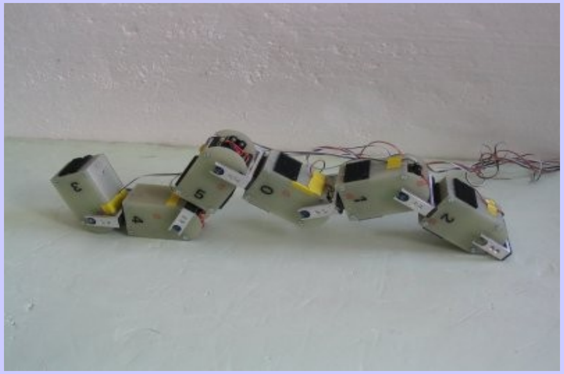
Very good platforms for researching in locomotion



Modular Robotics (II)

- The idea of modular robotics was introduced by **Mark Yim**, in 1994
- There are many groups working on this topic in the world.
- The most avanced robots are:
  - **POLYBOT** (USA). Palo Alto Research Center (**PARC**)
  - **M-TRAN** (JAPAN). Advance Industrial Science Technology (**AIST**)
  - **YAMOR** (Swiss). Ecole Polytechnique Federale de Lausanne (**EPFL**)





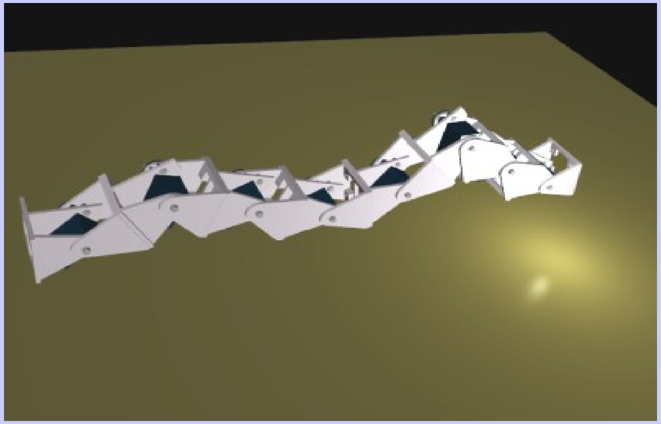
Modular Robotics: Topologies

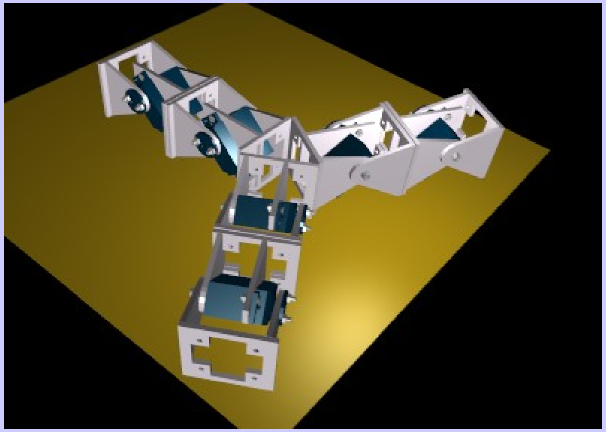
- There are an infinite number of configurations that can be built
- A general clasification is needed to study the properties of the subgroups
- We have proposed a classification based on the topology

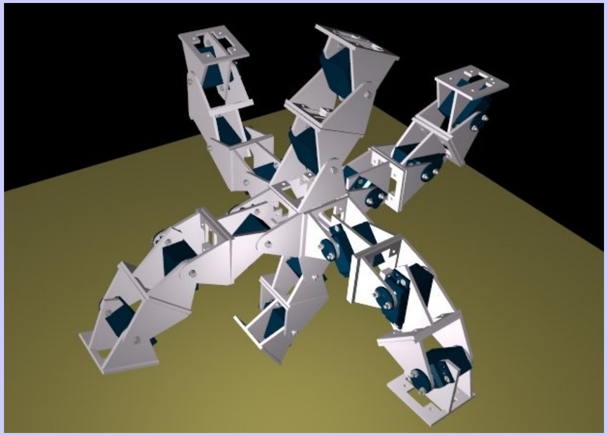
1D Topologies: one chain of modules (Worms, snakes, arms, legs...)

2D Topologies. Two or more chains connected along different axes

3D Topologies. Three or more chains connected along different axes

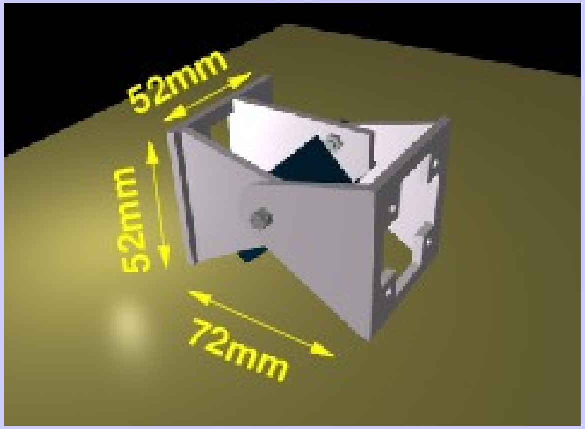


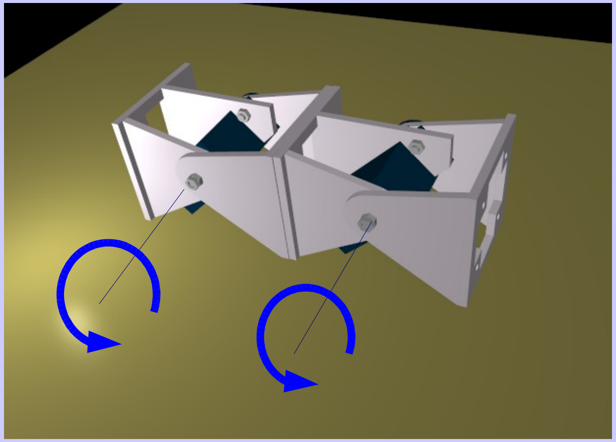


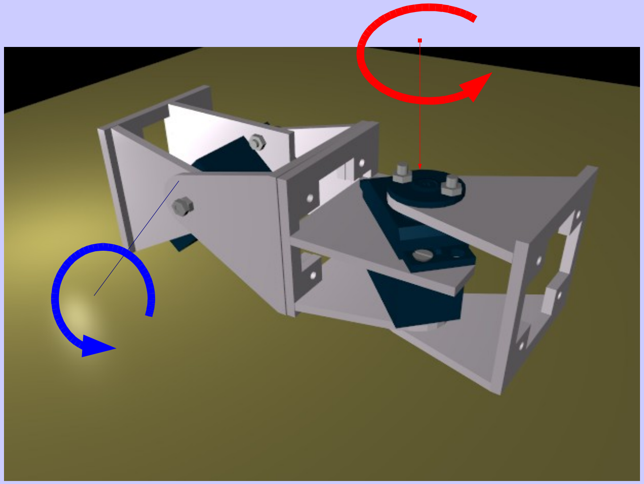


Previous work:
Y1 Module

- **DOF**: 1
- **Material**: 3mm Plastic
- **Servo:** Futaba 3003
- **Dimension**: 52x52x72mm
- **Range**: 180 degrees
- Cheap and easy to build
- Two types of **connection**:





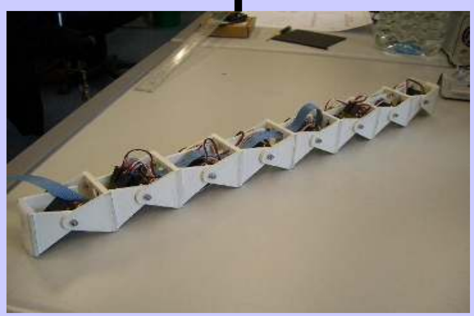


Previous work: Configurations

1D Topology:

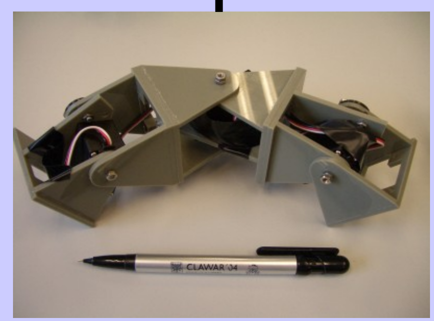
Locomotion in 1D:

Pitch-Pitch

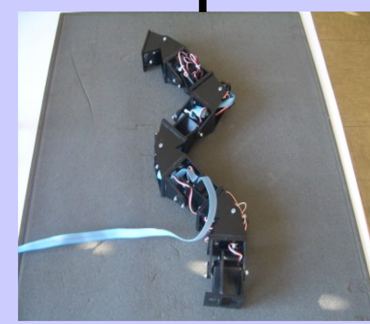


8 pitch-connecting modules

Locomotion in 2D:



Pitch-Yaw-Pitch

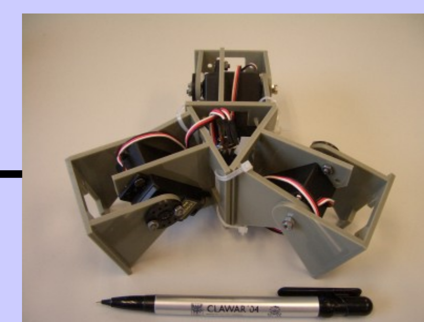


8 pitch-yaw-connecting modules

2D Topology:

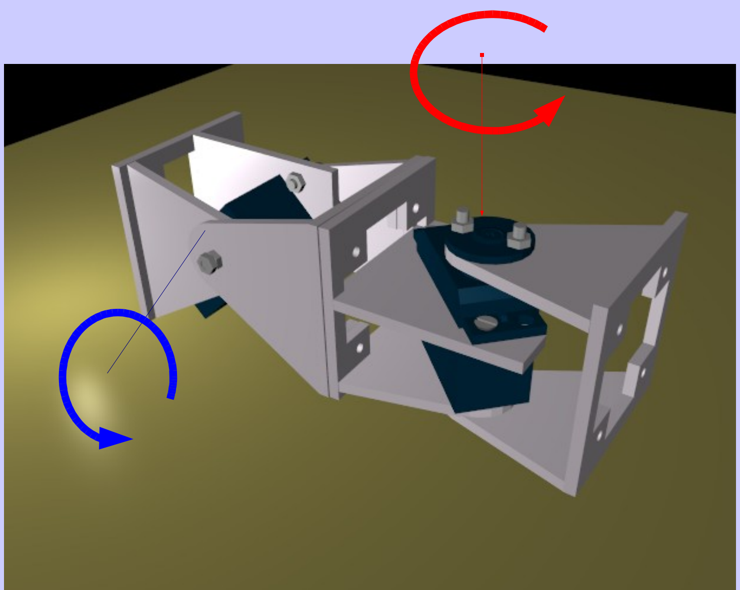
Locomotion in 2D:

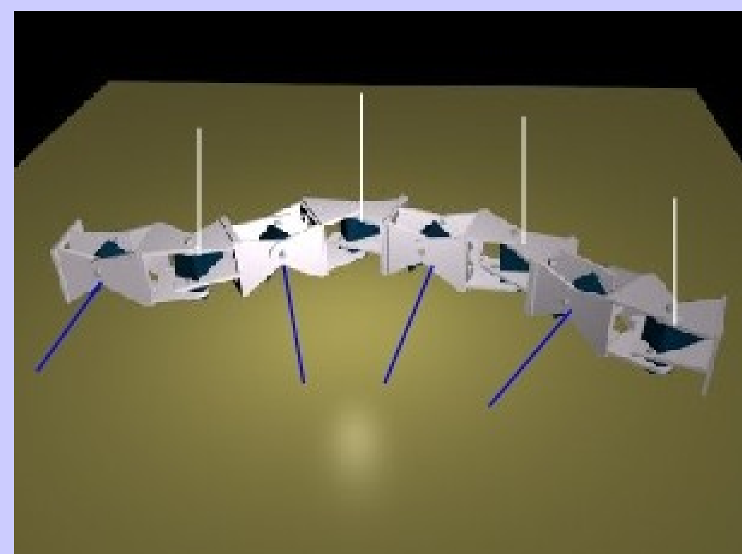
Star of 3 modules



Overview of the robot: Mechanics

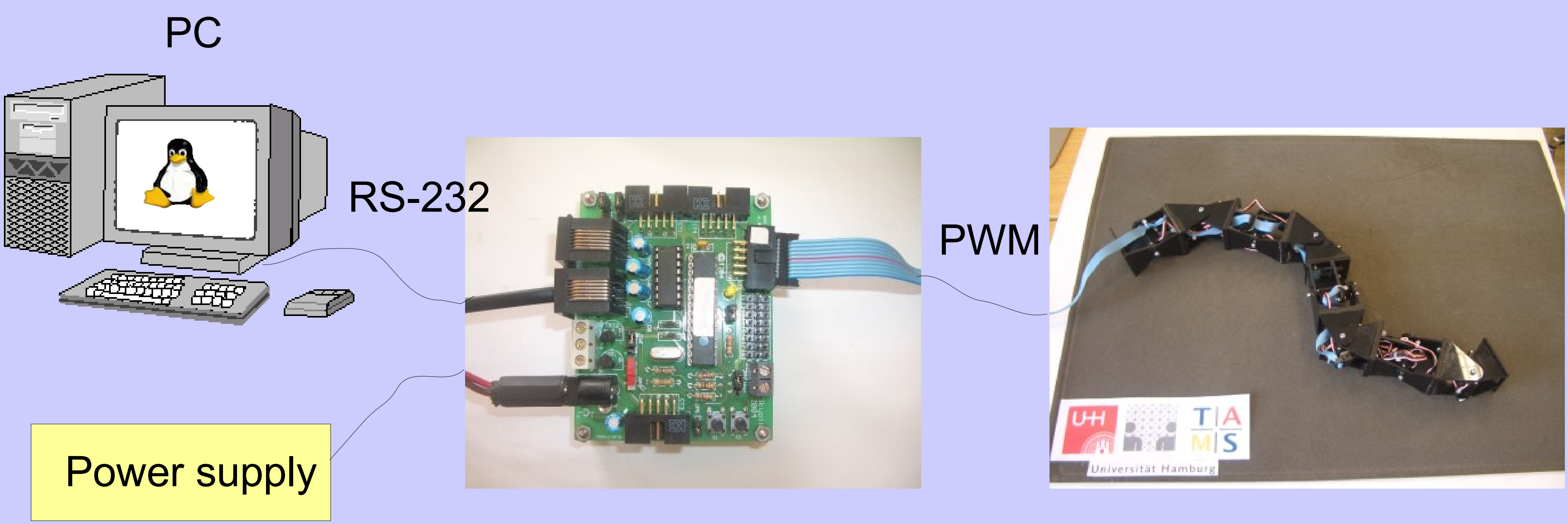
- 1D Topology
- 8 Pitch-yaw connecting modules
- 4 rotates around the pitch axes
- 4 rotates around the yaw axes
- Based on the Y1 modules





Overview of the robot: Control Hardware

- A small board based on the PIC16F876 (Skypic)
- Power supply and controller located off-board
- The locomotion algorithms are executed on a PC
- The PC is connected to the controller by RS-232

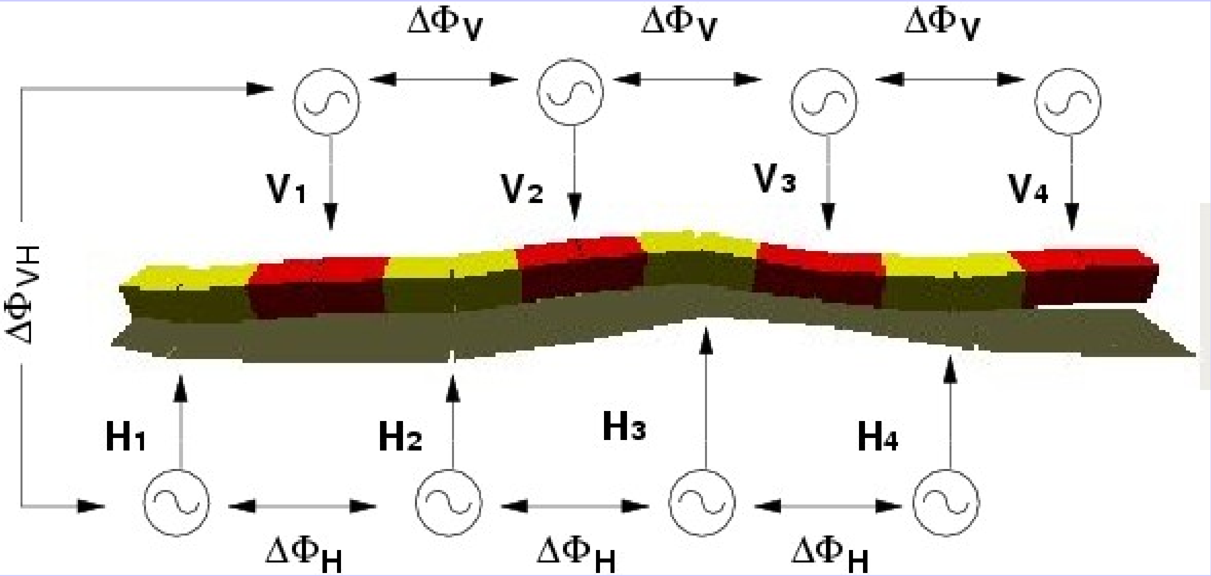


Control approach

- It is based on **Central Pattern Generators** (CPGs) to produce rhythmic motions.
- Our model of CPG is a generator of sinusoidal signals
- 4 CPGs controls the pitch modules and another 4 for the yaw ones.
- The **parameters** are:

- Amplitude: A_H , A_V
- Offset: O_H , O_V
- Phase differences:

  $\Delta\phi_H, \Delta\phi_V, \Delta\phi_{VH}$
- Period: T



Locomotion capabilities

- Using this control approach, 5 gaits have been achieved:

1D sinusoidal gait	Forward and backward movement
Turning gait	The robot move along an arc
Rolling gait	The robot rolls arount its body axis
Rotating gait	The robot rotates parallel to the ground
Lateral shift	The robot moves parallel to its body axis

- All these gaits have been simulated using the Open Dynamics Engine (ODE)
- They all have been implemented sucessfully on the robot

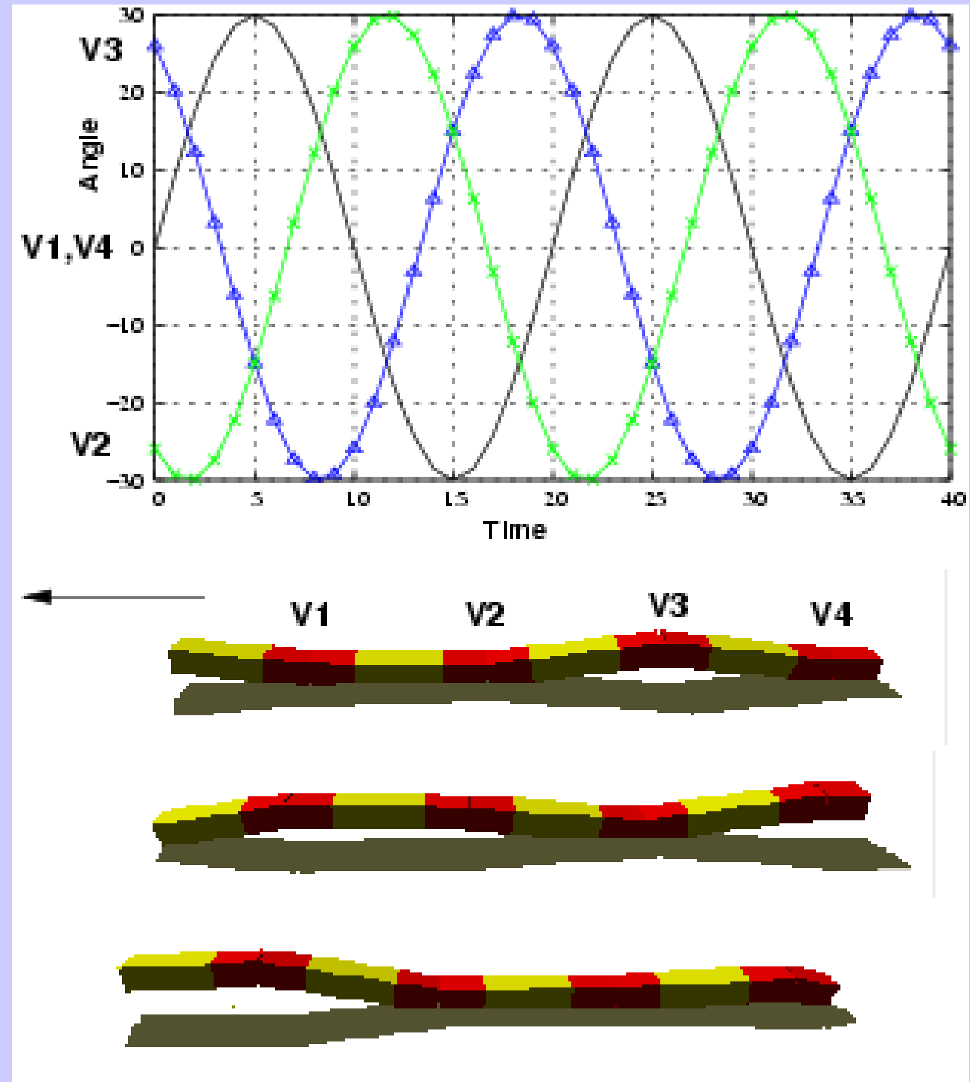
Locomotion capabilities: 1D sinusoidal gait

- Only the vertical joints are moving
- **Parameters**:

$A_V \neq 0$ $A_H = 0$

$O_V = 0$ $O_H = 0$

$\Delta\phi_V = 120$



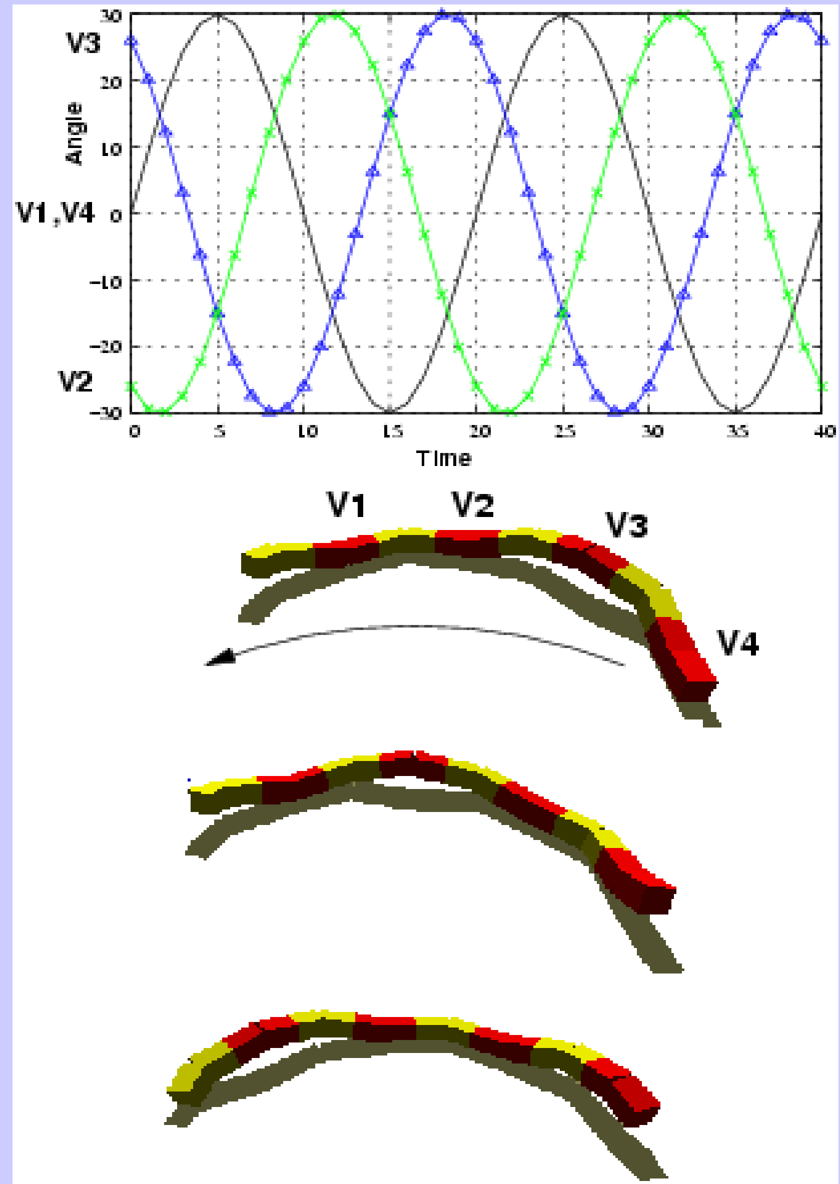
Locomotion capabilities: Turning gait

- Only the vertical joints are moving
- **Parameters**:

$A_V \neq 0$ $\quad A_H = 0$

$O_V = 0$ $\quad O_H \neq 0$

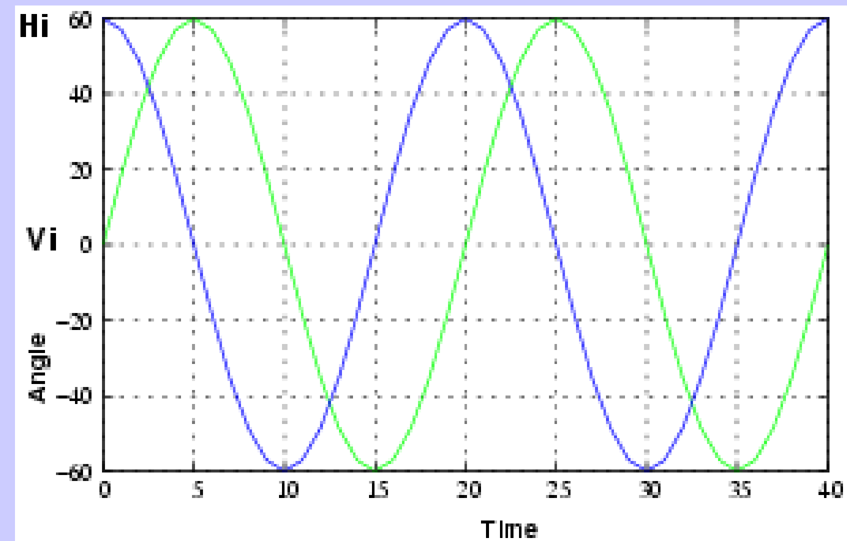
$\Delta\phi_V = 120$

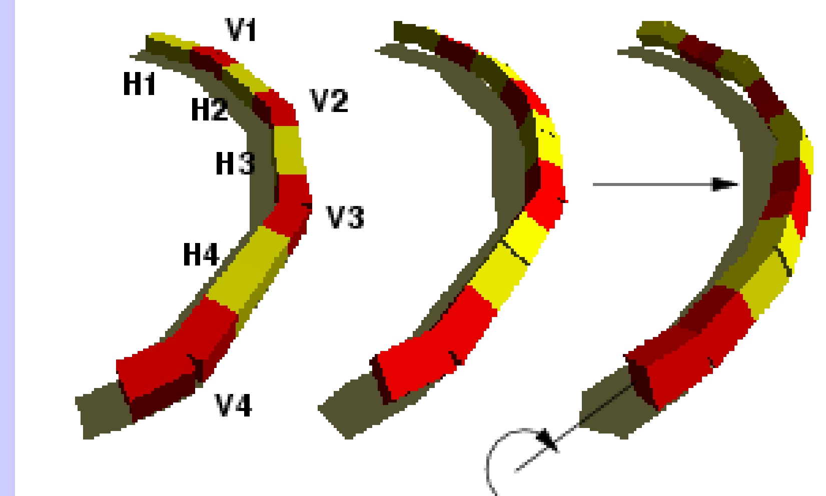


Locomotion capabilities: Rolling gait

- **Parameters**:

$A_V > 60$	$A_H > 60$	
$O_V = 0$	$O_H = 0$	
$\Delta\phi_V = 0$	$\Delta\phi_H = 0$	$\Delta\phi_{VH} = 90$





Locomotion capabilities: Rotating gait

- This is a **new gait** not previously mentioned by other researchers

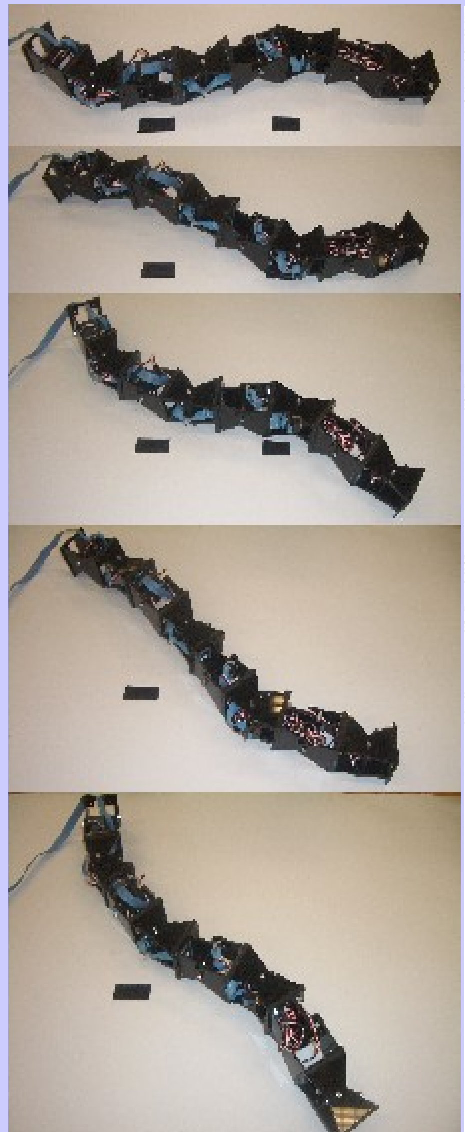
- **Parameters**:

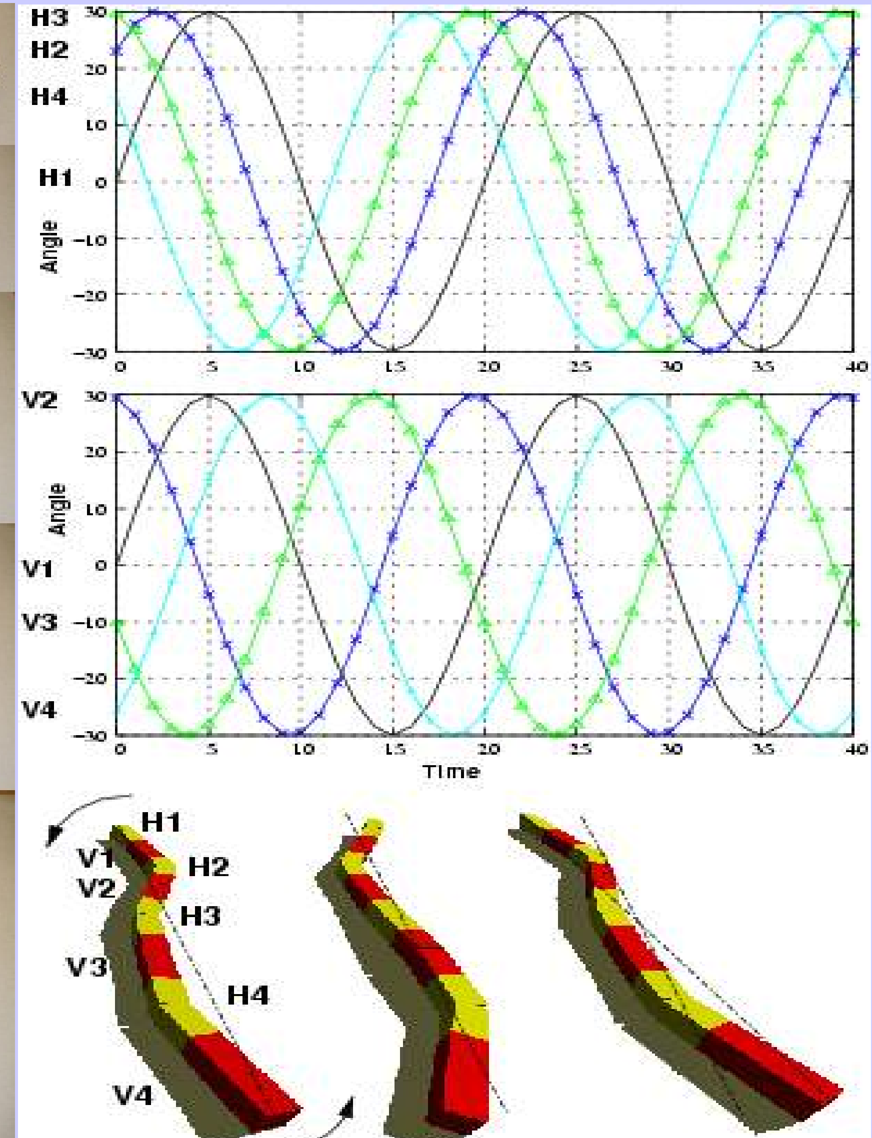
$A_V \neq 0$ $\quad A_H \neq 0$

$O_V = 0$ $\quad O_H = 0$

$\Delta\phi_V = 120$ $\quad \Delta\phi_H = 50$

$\Delta\phi_{VH} = 0$





Locomotion capabilities: Lateral shift

- **Parameters**:

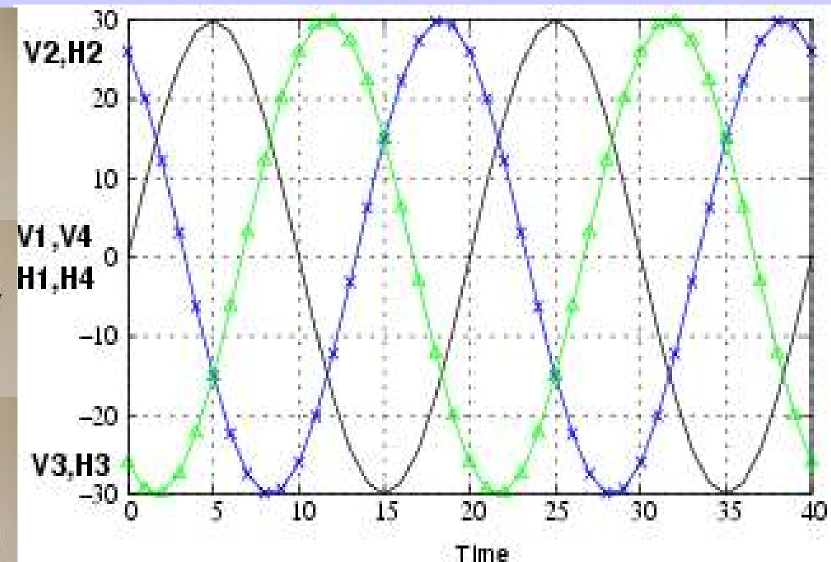
$A_V \neq 0$ $A_H \neq 0$

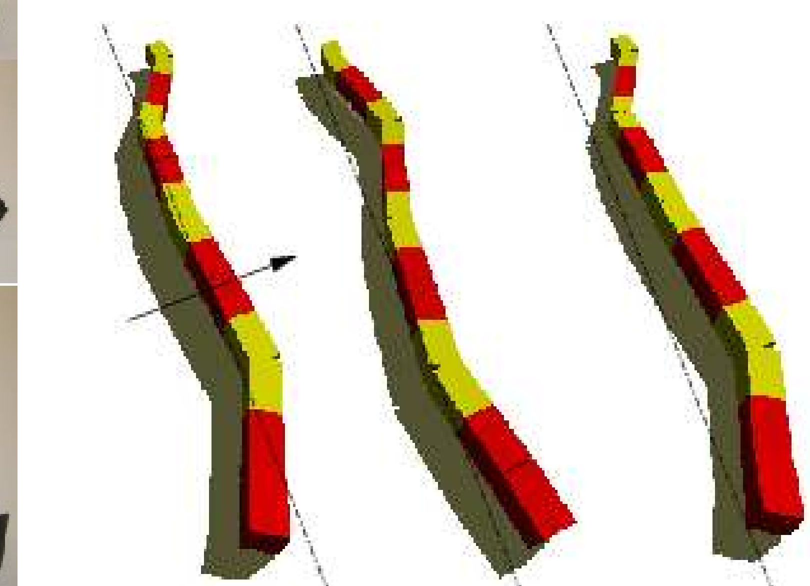
$O_V = 0$ $O_H = 0$

$\Delta\phi_V = 100$

$\Delta\phi_H = 100$

$\Delta\phi_{VH} = 0$

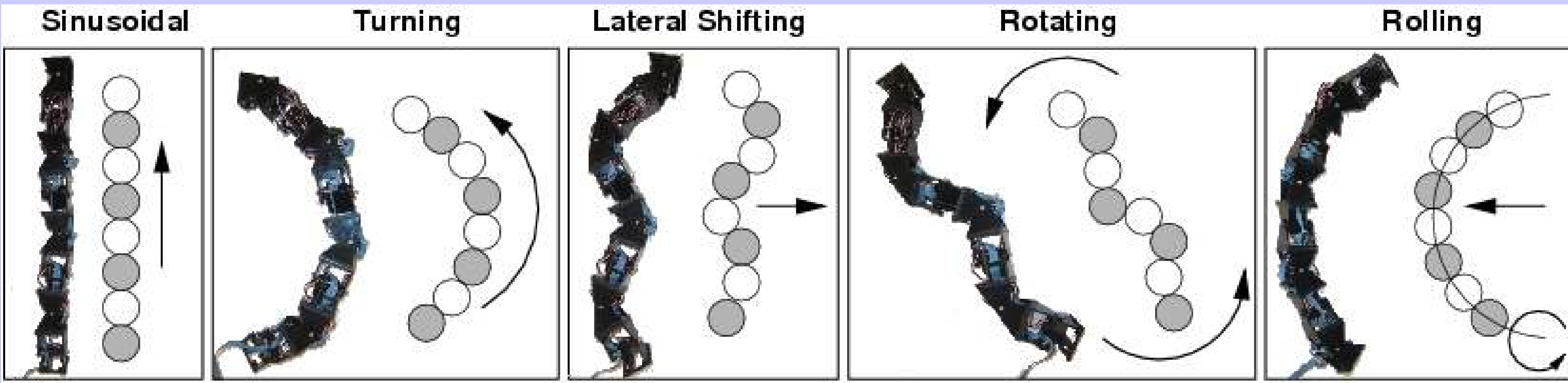




Let's see some videos...

Conclusions

- All the gais have been implemented using a sinusoidal CPG approach
- The parameters for achieving the gaits are summarized below:

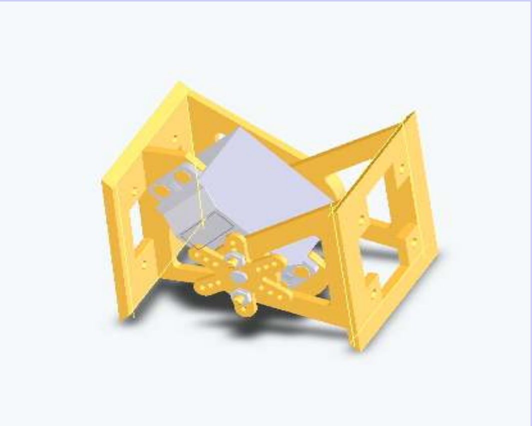


Sinusoidal	Turning	Lateral Shifting	Rotating	Rolling
$A_V \neq 0$ $A_H = 0$ $O_V = 0$ $\Delta\Phi_V = 120$		$A_V \neq 0$ $A_H \neq 0$ $O_H = 0$ $O_V = 0$		
$O_H = 0$	$O_H \neq 0$	$\Delta\Phi_{VH} = 0$ $\Delta\Phi_H = 100$ $\Delta\Phi_V = 100$	$\Delta\Phi_{VH} = 0$ $\Delta\Phi_H = 50$ $\Delta\Phi_V = 120$	$\Delta\Phi_{VH} = 90$ $\Delta\Phi_H = 0$ $\Delta\Phi_V = 0$

- The experiments confirm the principles of CPGs and the locomotion capabilities of the pitch-yaw connecting modular robots .

Future work

• A new generation of modules have been designed:



• Now it is possible to build more complex configurations like a 4 legged or a humanoid robot:

• We are studying the climbing properties to develop a climbing caterpillar

Thank you very much for your attention

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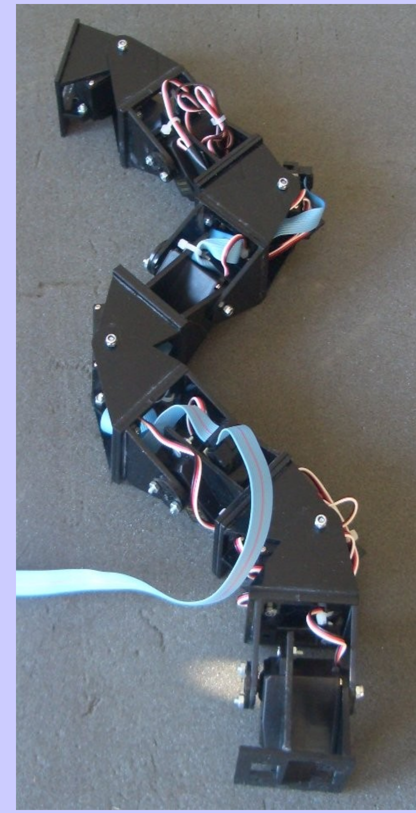

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