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

J. Gonzalez-Gomez, E. Boemo DSLab, School of Engineering,

Universidad Autonoma de Madrid, Spain

H. Zhang, J. Zhang TAMS, Department of Informatics, University of Hamburg, Germany





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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



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:



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

Locomotion capabilities: 1D sinusoidal gait

- Only the vertical joints are moving
- Parameters:

$$A_V \neq 0 \qquad A_H = 0$$
$$O_V = 0 \qquad O_H = 0$$
$$\Delta \phi_V = 120$$





Locomotion capabilities: Turning gait

- Only the vertical joints are moving
- Parameters:

$$A_{V} \neq 0 \qquad A_{H} = 0$$
$$O_{V} = 0 \qquad O_{H} \neq 0$$
$$\Delta \phi_{V} = 120$$





Locomotion capabilities: Rolling gait

Parameters:

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





Locomotion capabilities: Rotating gait

- This is a new gait not previously mentioned by other researchers
 - Parameters:
- $A_{V} \neq 0 \qquad A_{H} \neq 0$ $O_{V} = 0 \qquad O_{H} = 0$ $\Delta \phi_{V} = 120 \quad \Delta \phi_{H} = 50$ $\Delta \phi_{VH} = 0$



Locomotion capabilities: Lateral shift

• Parameters:

$$A_{V} \neq 0 \qquad A_{H} \neq 0$$
$$O_{V} = 0 \qquad O_{H} = 0$$
$$\Delta \phi_{V} = 100$$
$$\Delta \phi_{H} = 100$$
$$\Delta \phi_{VH} = 0$$



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:



• 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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