A New Principle for Climbing Wheeled Robots: Serpentine Climbing with the OpenWheel Platform

Jean-Christophe FAUROUX, Frédéric CHAPELLE, Chedli BOUZGARROU

Mechanical Engineering Research Group (LaMI)
Blaise Pascal University & French Institute for Advanced Mechanics (IFMA)

Clermont-Ferrand, France
1. Introduction

2. Paradigms
- mono-mode robots
- multi-modes robots
- slightly actuated
- Generic platform
- Explorating wheel
- Serpentine frontal climbing

3. Tridimensional Kinematic Validation
- Steps with motion continuity
- Joint angles laws

4. Conclusion
Mono-mode robots

1. Introduction
2. Paradigms
3. 3D validation
4. Conclusion

Robosoft
Pioneer
non suspended 4x4

LAAS Hilare
1 steering axle + casters

Only one mode of displacement: rolling

Robosoft
Robucar TT
suspended 4x4

LAAS Adam
suspended 6x6

JPL Robby
frame with pods

JPL Rocky 7
Rocker-Bogie suspension
Multi-modes robots

LAAS Lama
Pods with inter-axle DOF
Peristalsis capabilities

LRP Hylos 1 & 2
4 articulated leg/wheels

Univ SHERBROOKE Azimut 4 articulated legs/tracks

Two or several modes
• Rolling
• Peristalsis
• Crossing
• Balancing ......

EPFL Octopus
4 tentacles / 8 wheels
Slightly actuated robots

Passive mobilities for reactive configuration

- Flat / Concave / Convex / Step
- 4 actuated wheels

=> place for generic and modular mechanical architectures, possibly close to commercial vehicles, developed from new crossing strategies
Framework: generic platform OpenWHEEL

Modular assembly
Canonical components
slightly actuated
First study on a four-wheel version

• closer to the architecture of commercial vehicles,
• climbing abilities without the weight, size and energy consumption of six-wheel robots.

Model created in a generic way to assure the internal coherence during the analyze joint motions most independently of the kinematic architecture

Rotation of each axle on itself along \((G_i, z)\) without slip of the wheels
Reconfiguration for climbing

Exploring wheel paradigm

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Exploring Wheel Paradigm

- three wheels stability for a four-wheel vehicle
- put on for new support point

Mode 1: Rolling
- Support polygon with a rectangular shape

Mode 2: Climbing
- Exploring wheel going upward
- Support polygon becoming triangular

a) General four-wheel robot
b) Robot with two-pod architecture
### Stability property

<table>
<thead>
<tr>
<th>Wheel $W_{11}$ (front-right)</th>
<th>Wheel $W_{12}$ (front-left)</th>
<th>Wheel $W_{21}$ (rear-right)</th>
<th>Wheel $W_{22}$ (rear-left)</th>
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</thead>
<tbody>
<tr>
<td><strong>Front axle steering</strong></td>
<td></td>
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<tr>
<td>1)</td>
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<td>2)</td>
<td>3)</td>
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<td><strong>Stable</strong></td>
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<td><strong>Instable</strong></td>
<td><strong>Stable</strong></td>
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<tr>
<td><strong>Rear axle steering</strong></td>
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<td>5)</td>
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<td>6)</td>
<td>7)</td>
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<tr>
<td><strong>Stable</strong></td>
<td></td>
<td><strong>Instable</strong></td>
<td><strong>Stable</strong></td>
</tr>
</tbody>
</table>

**ex: when turning to the right**

Static stability during turns is ensured when the lifted wheel is inside the turn $\Rightarrow$ when a wheel is to be lifted, bring another wheel as close as possible to it.
Serpentine frontal climbing of a step obstacle

Wheel center motion
- Going up (Towards the eye of the reader)
- Going down (Away from the eye of the reader)

Support polygon
- For a very stable configuration (Centre of mass far from the edges)
- For a stable configuration (Centre of mass closer to the edges)
3D simulation

- 2 axles
- 4 wheels
- 2 intermediate bars
- 7 revolute joints
- Obstacles as high as the wheels

17 principal states with motion continuity ("functional motions")

Continuous series of poses:
- Ensuring permanent stability
- No add of any supplemental roller
- Only one central actuator

3D validation with Adams software ⇒ determination of angle variations from the functional motions
Wheel rolling angles

curves globally ascending when vehicle goes forward

reversing phases correspond to self rotation of axles
Large variation of R0 (central actuator) when wheels are lifted

Angle variation depends on obstacle height and axle length

Should not exceed 30 to 45 ° for keeping contact on the tire tread

Always lift to the maximum or possible parametrized control in function of the obstacle height
Conclusion

New climbing principle for a four-wheel robot
  • keep efficiency of wheels propulsion
  • ensure climbing capacities of high obstacle with one supplemental actuator

Enumeration of the poses continuously ensuring stability

Validation by a 3D model

Determination of the joint motion in a generic way independently of the kinematic architecture

Perspectives: methods for mechanical architecture synthesis of the inter-axle

Applications: new frames for quads and ATV