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Steerability Analysis on Slopes of a Mobile Robot with a Ground Contact Arm

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OUTLINE

1. THE LAZARO MOBILE ROBOT
2. NAVIGABILITY INDICES
3. TIP-OVER AVOIDANCE
4. EXPERIMENTAL RESULTS
5. CONCLUSIONS

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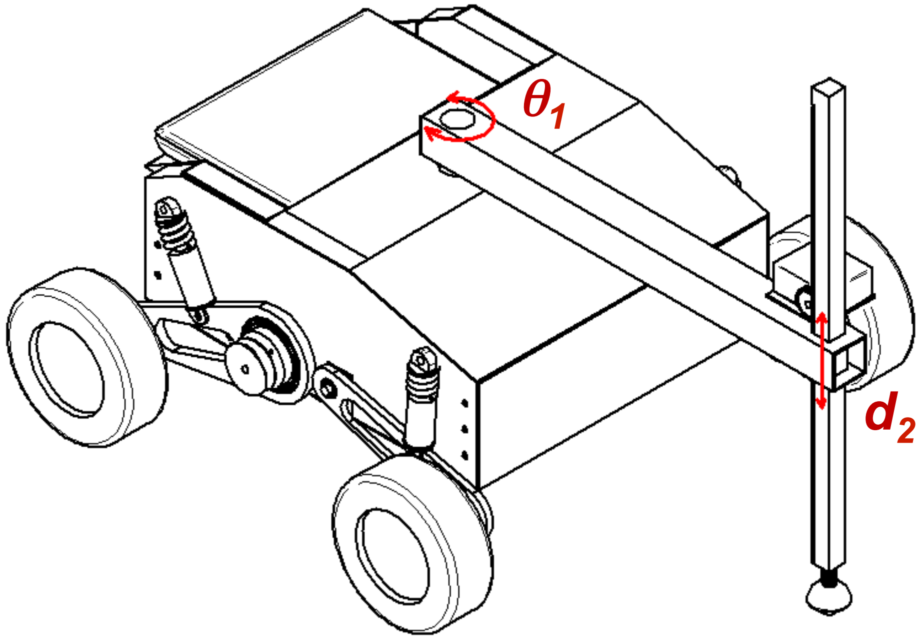
1. THE LAZARO MOBILE ROBOT

THE LAZARO MOBILE ROBOT

- **Specially designed to have an additional contact point with the ground**

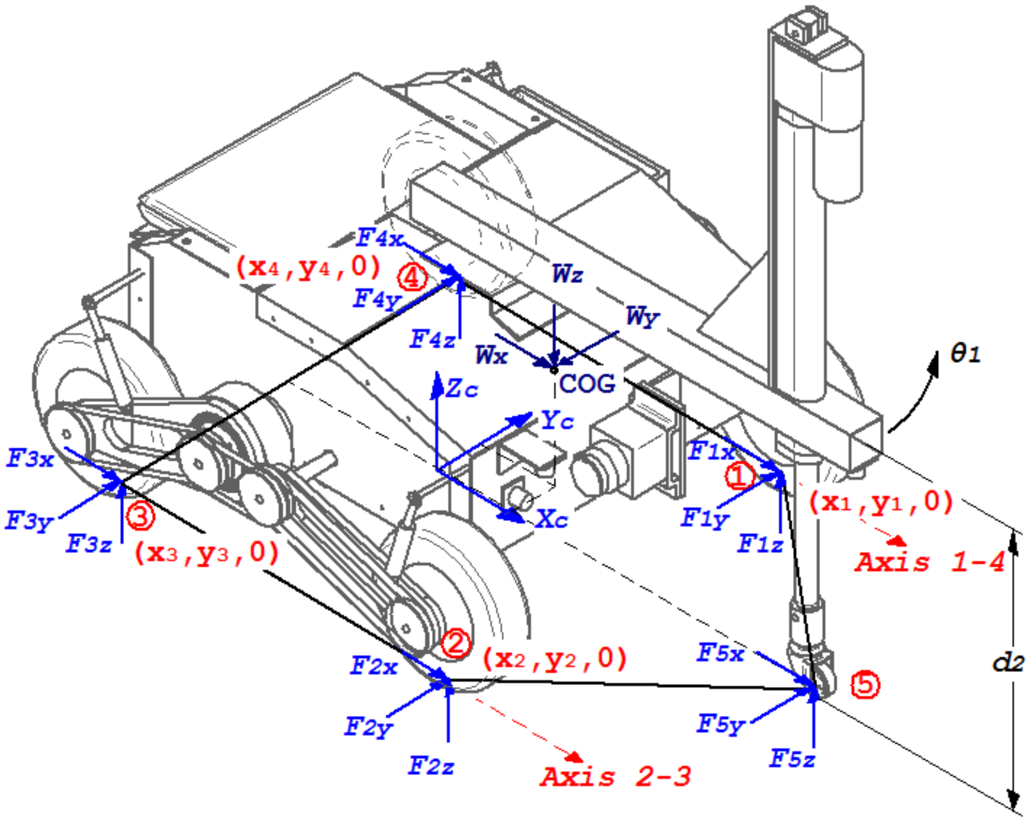
Four-wheeled skid-steered vehicle



Two degrees of freedom arm, whose end-effector is a caster wheel

THE LAZARO MOBILE ROBOT

- **Supporting forces of the wheels:** F_{1z}, F_{2z}, F_{3z}, F_{4z} can be estimated knowing the pitch and roll angles on the plane, angle θ_1, length d_2 and the force exerted by the caster wheel F_{5z}



Supporting forces of the wheels

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2.
NAVIGABILITY INDICES

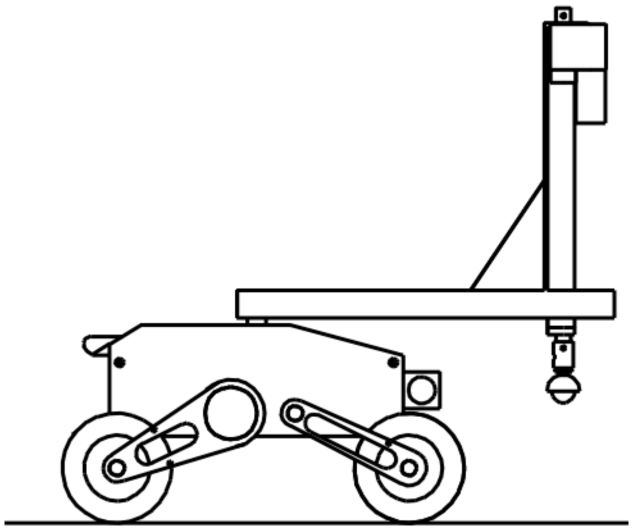
NAVIGABILITY INDICES

- **Tip-over stability index:** based on the minimum supporting force F_{min} that depends on the number of contact points with the ground

$$I_t = \frac{F_{min}}{|\overrightarrow{W}|/2}$$

Denominator normalize index between 0 and 1

- ***Four contact points***: F_{min} is calculated as the minimum supporting forces of the axes between adjacent traction wheels

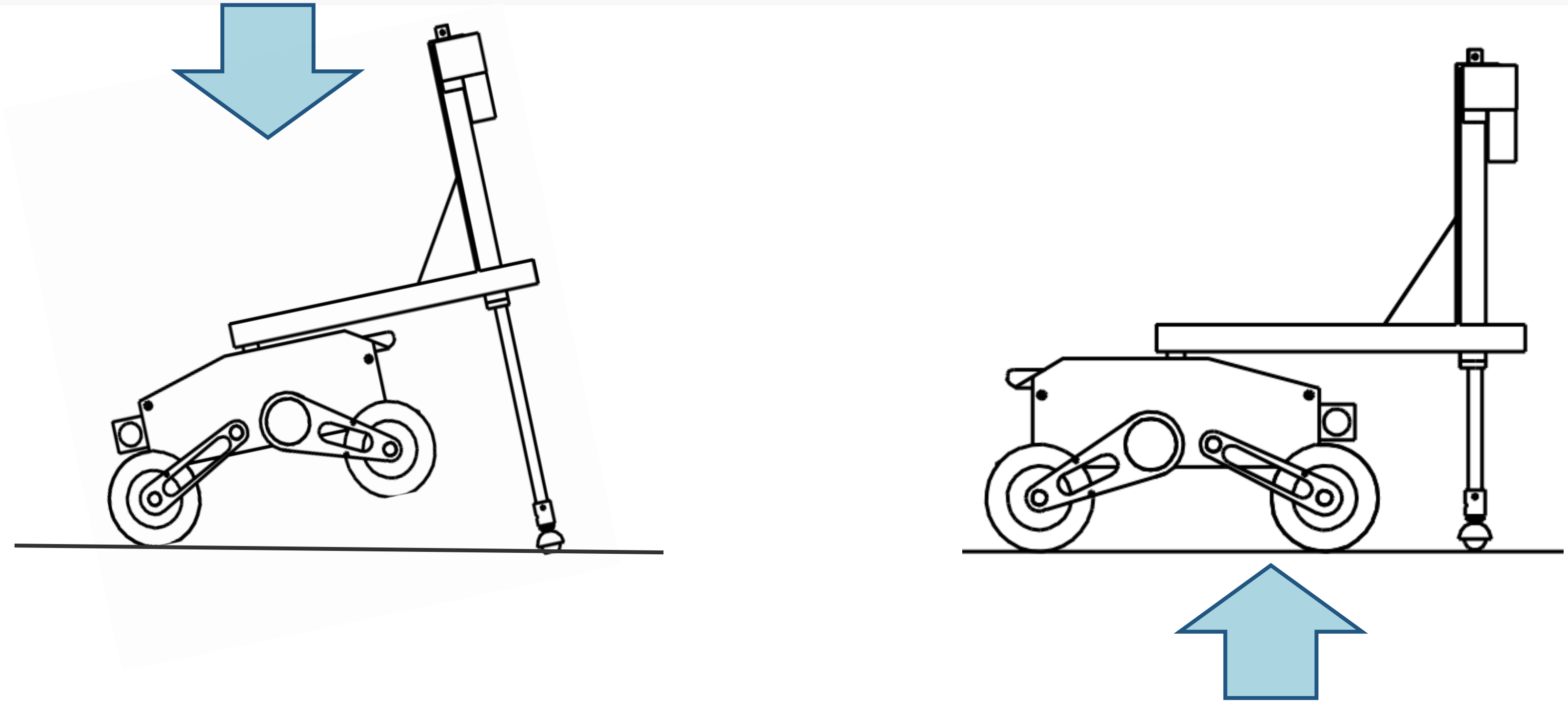


Supporting forces of the axis between adjacent wheels i and j:

$$F_{ij} = F_{iz} + F_{jz}$$

NAVIGABILITY INDICES

- **Three contact points:** F_{min} is calculated as the minimum supporting forces of the three wheels in contact with the ground

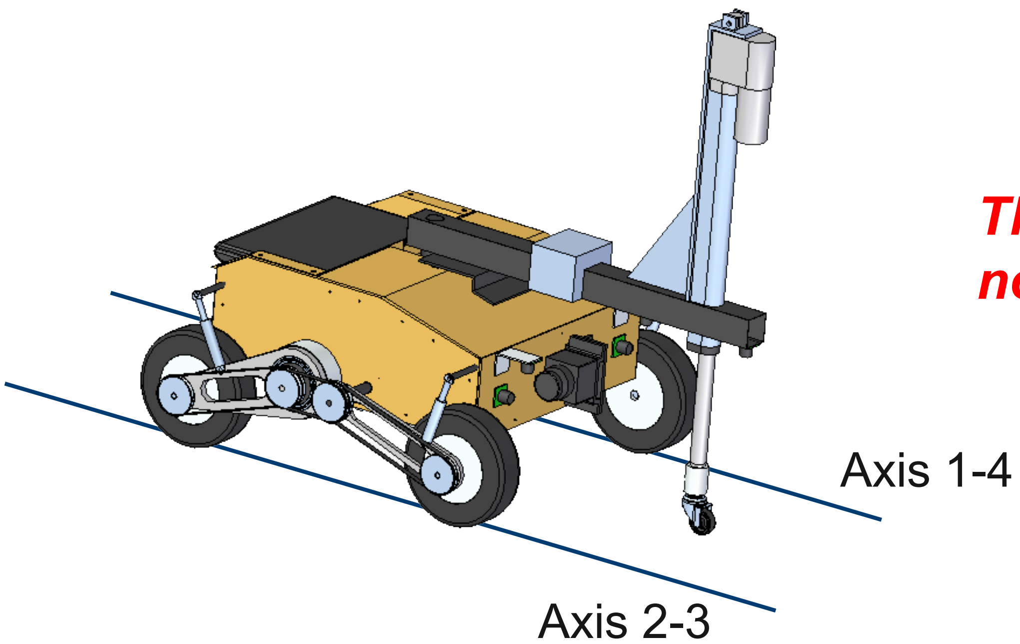


- ***Five contact points***: *It is an intermediate case between four and three contact points*

NAVIGABILITY INDICES

- **Steerability index:** calculated as the minimum supporting forces of the longitudinal axes of the vehicle

$$I_s = \frac{\min(F_{14}, F_{23})}{|\overrightarrow{W}|/2}$$



The caster wheel does not provide traction

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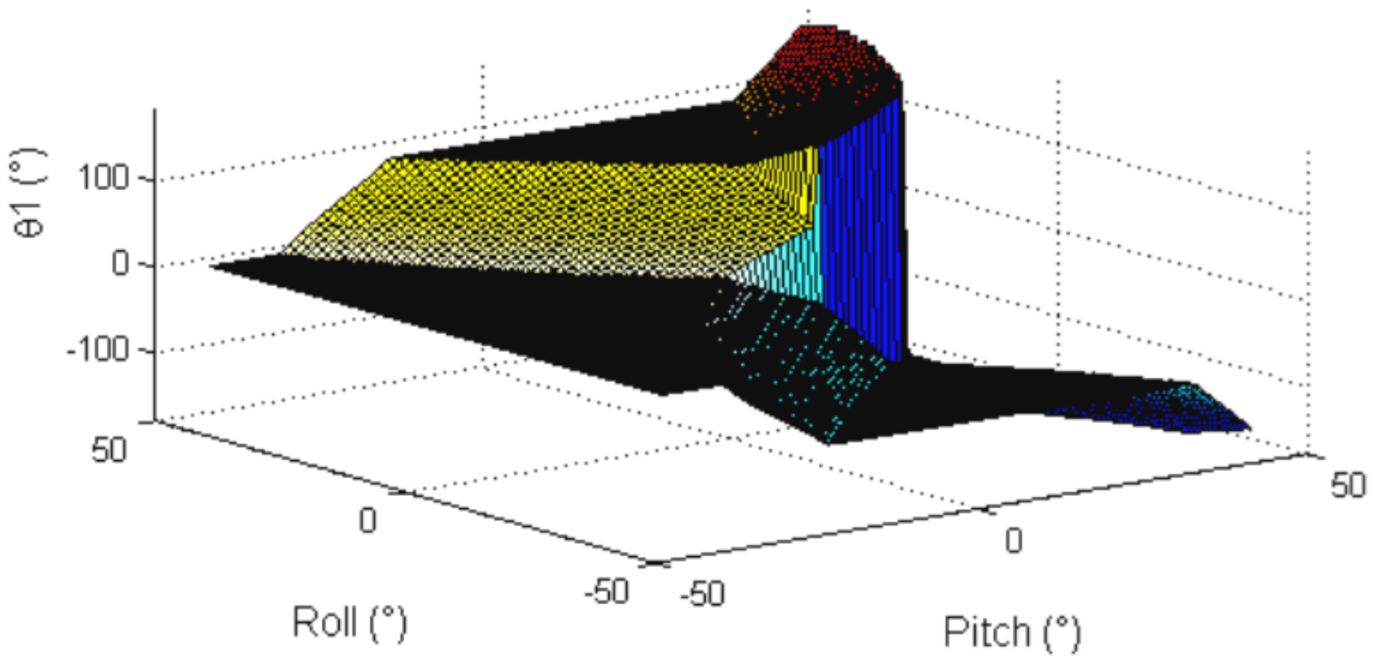
3.
TIP-OVER AVOIDANCE

TIP-OVER AVOIDANCE

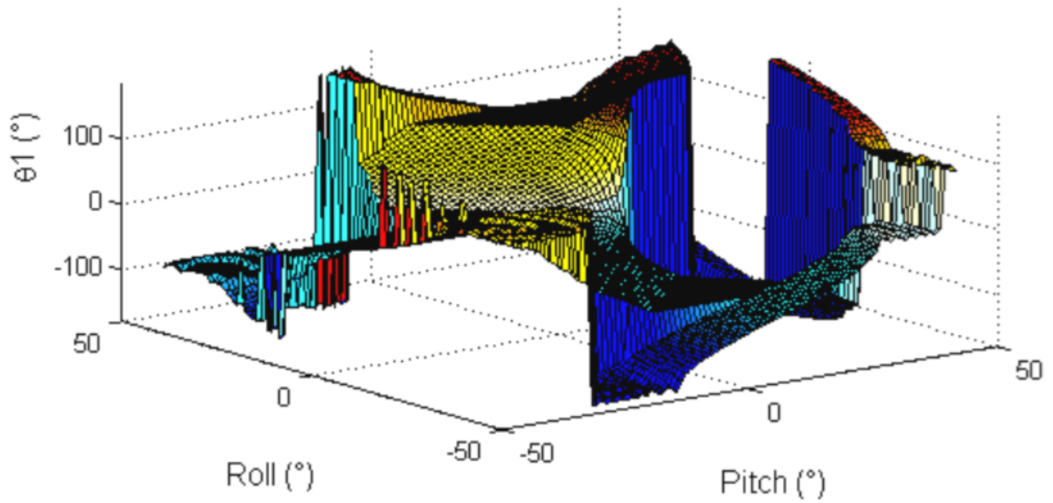
- **COG control strategy:** COG is modified by actuating on arm rotation θ_1 without additional contact with the ground (F_{5z}=0)



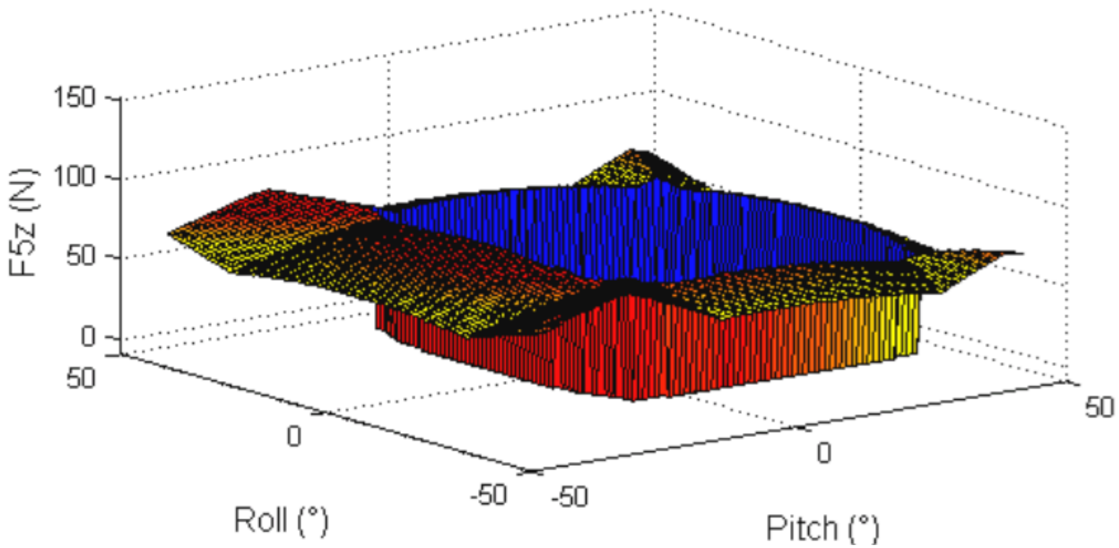
Optimal θ_1 for every combination of pitch and roll angles

TIP-OVER AVOIDANCE

- **Additional contact strategy**: by exerting a certain force F_{5z} against the ground with the caster wheel



Optimal θ_1 angles



Optimal F_{5z} forces

TIP-OVER AVOIDANCE

- **Static comparison**: Additional contact strategy obtains the best values for tip-over prevention. COG control achieves the best results for steerability

Strategy	Tip-over		Steering	
	mean	σ	mean	σ
Fixed COG	0.392	0.241	0.516	0.246
COG control	0.524	0.255	0.595	0.229
Additional contact	0.603	0.179	0.519	0.309

Mean and standard deviation of the navigation indices

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4.
EXPERIMENTAL RESULTS

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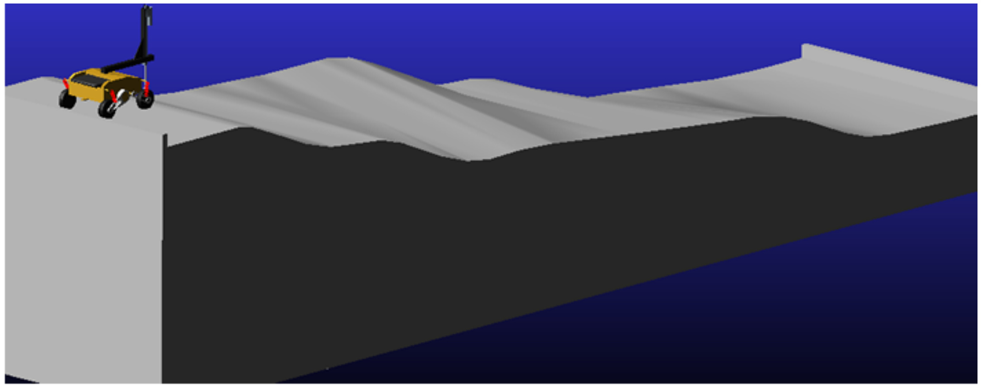
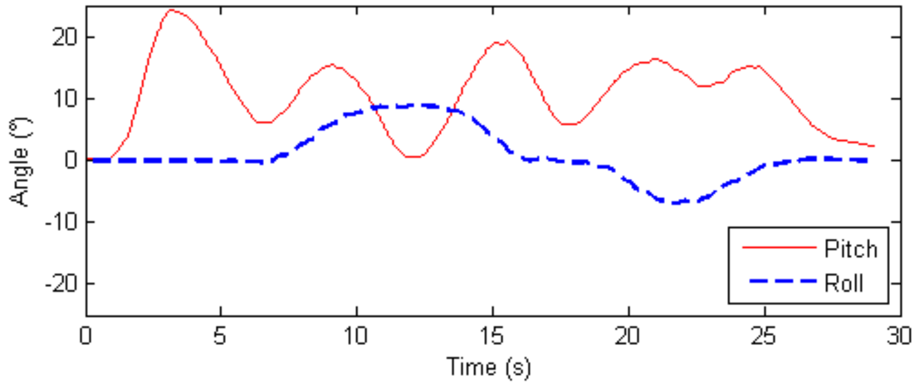
EXPERIMENTAL RESULTS

- **ADAMS simulations:** straight line motion along an undulating ramp

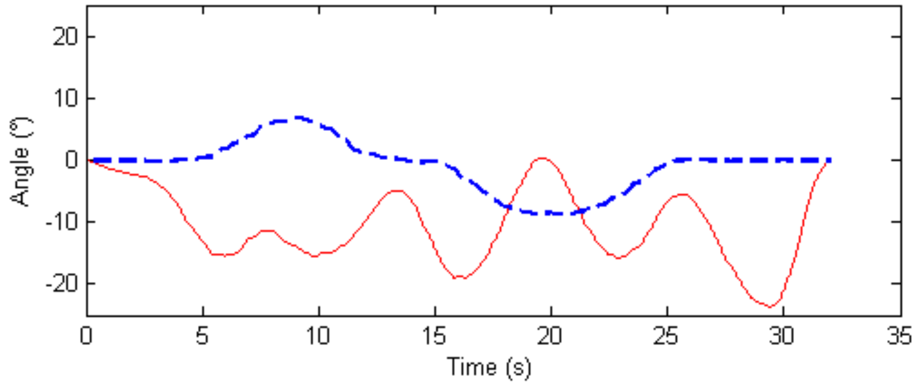


(a)



a)

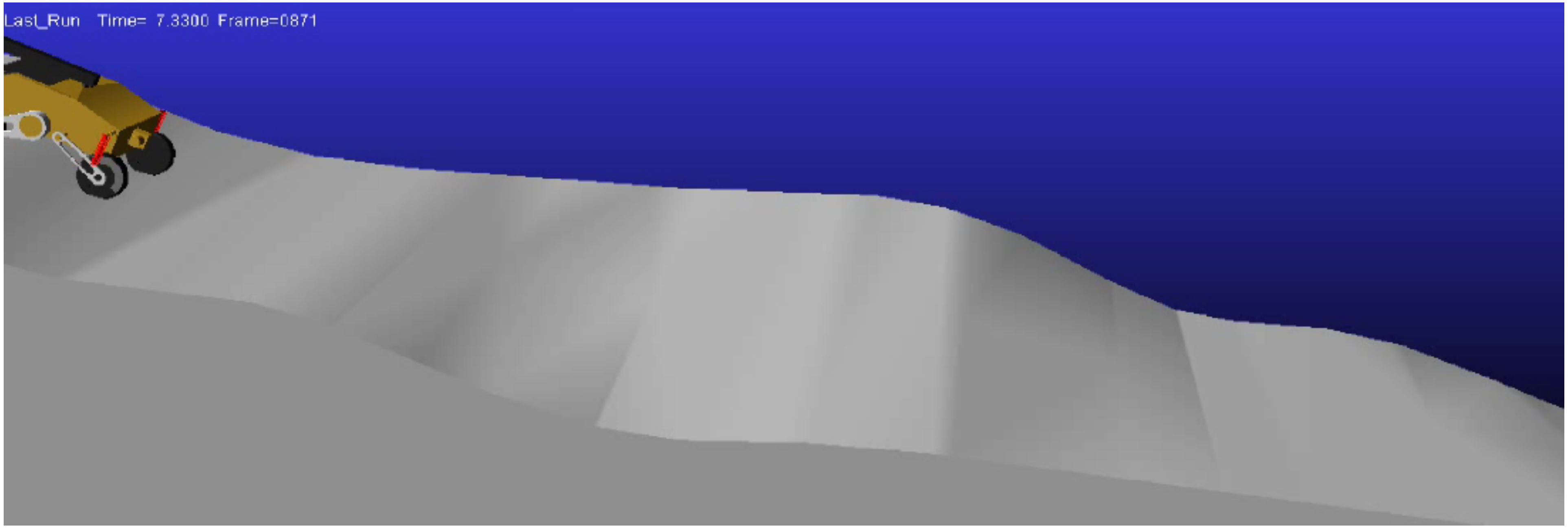
(b)



b)

EXPERIMENTAL RESULTS

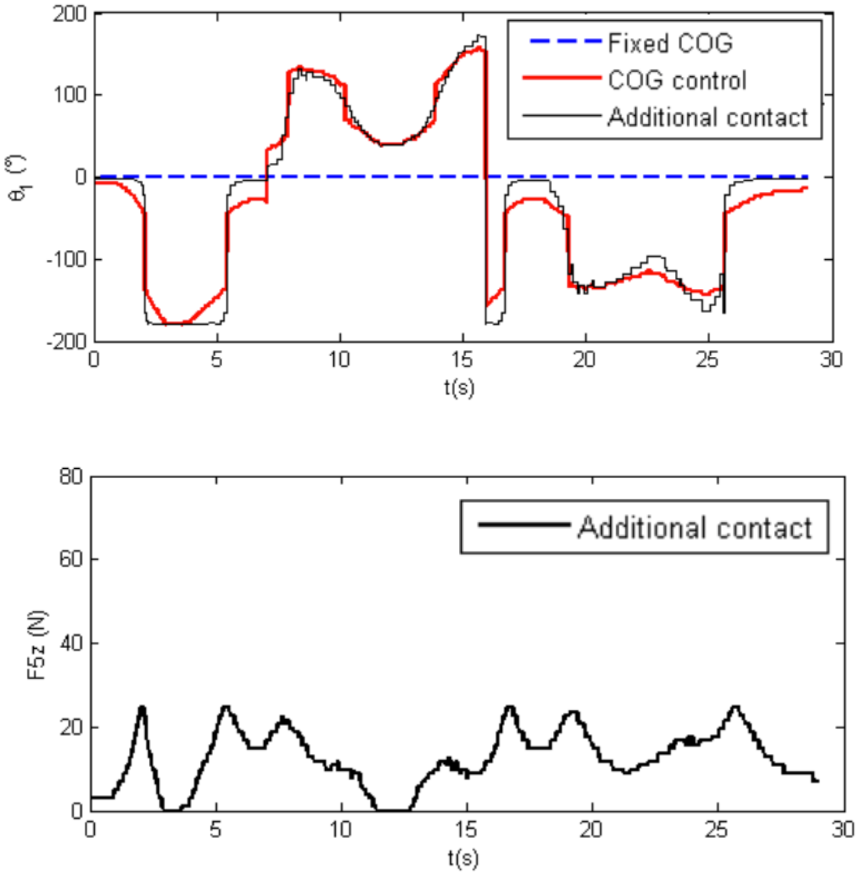
- **Downward motion**



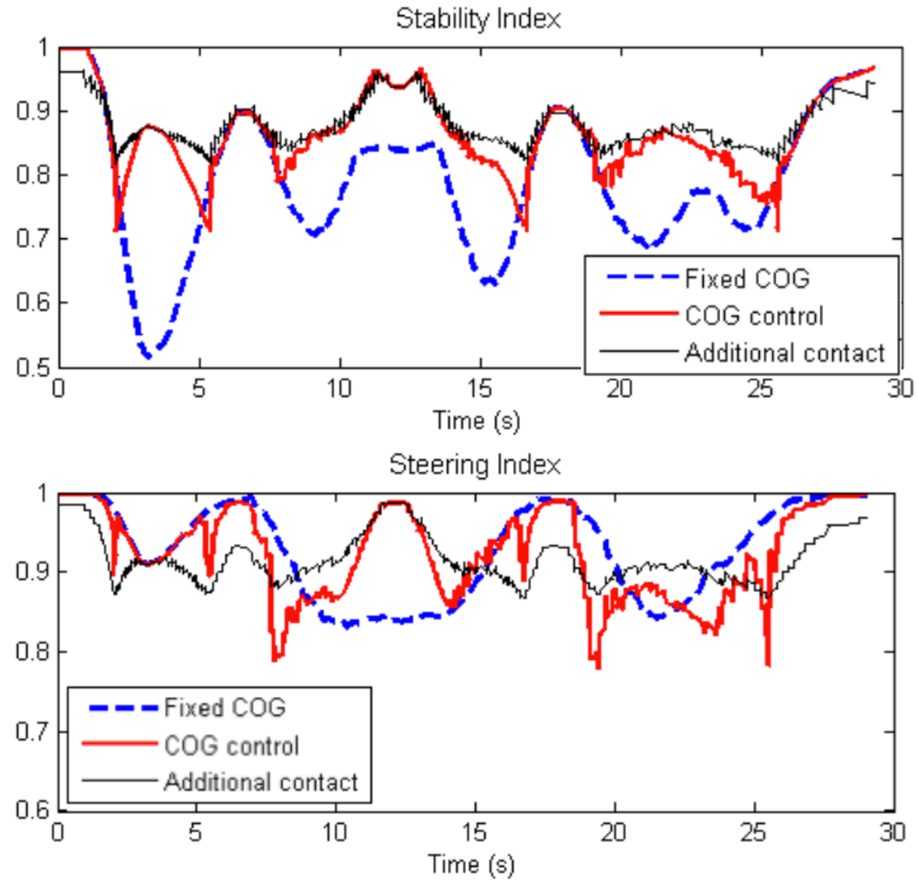
Navigation with an additional ground contact point

EXPERIMENTAL RESULTS

Downward motion



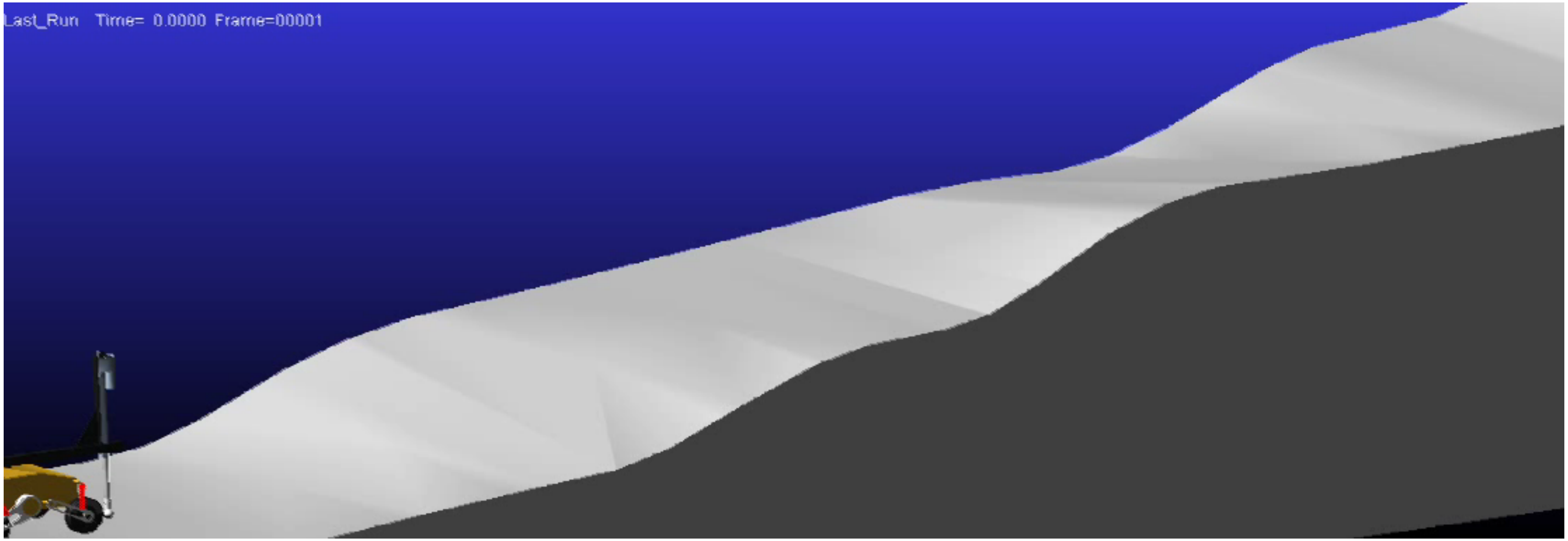
The θ_1 angle and the F_{5z} force



The tip-over and steering indices

EXPERIMENTAL RESULTS

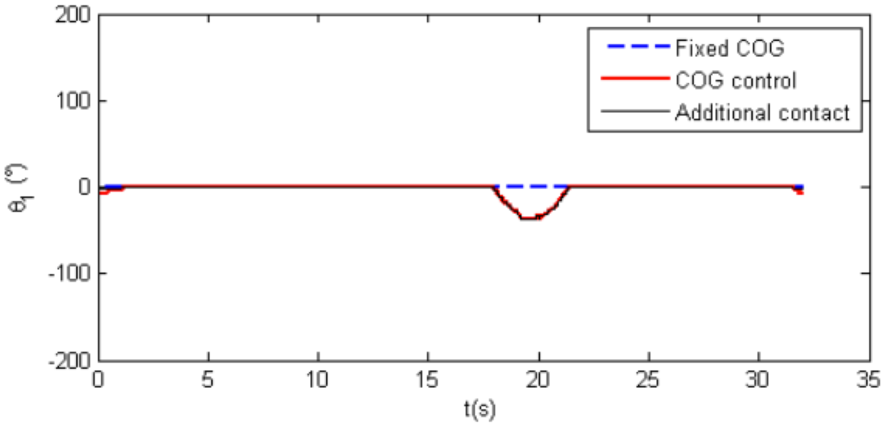
- **Upward motion**

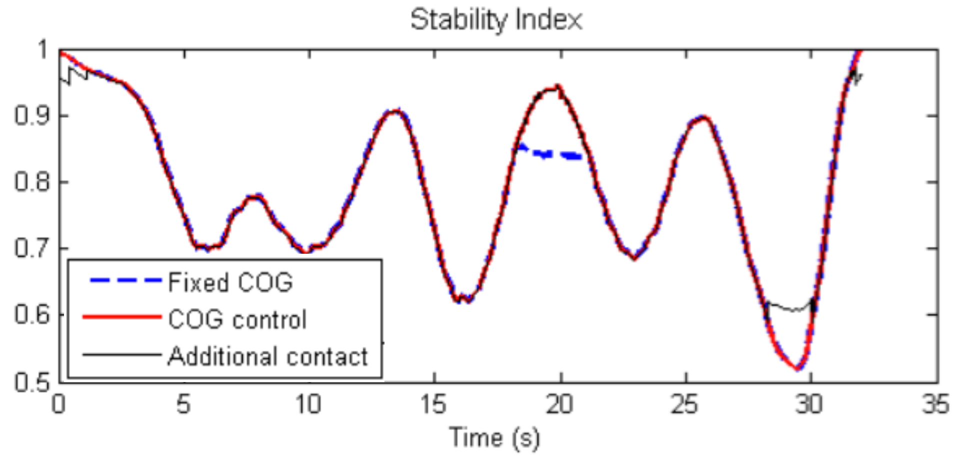


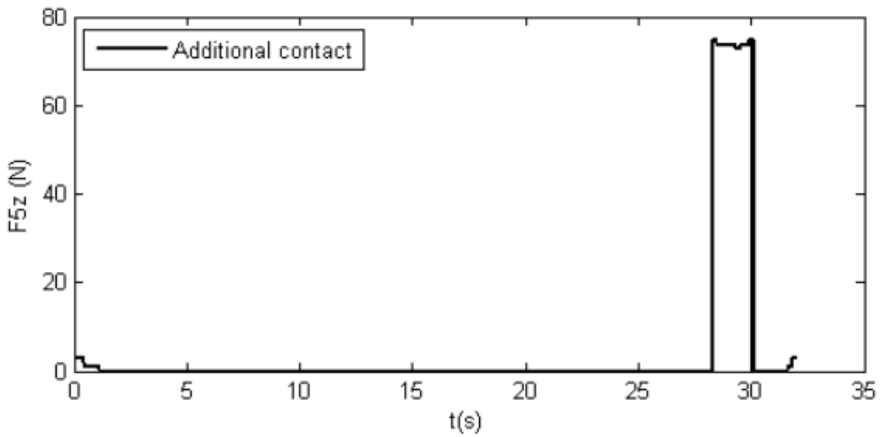
Navigation with an additional ground contact point

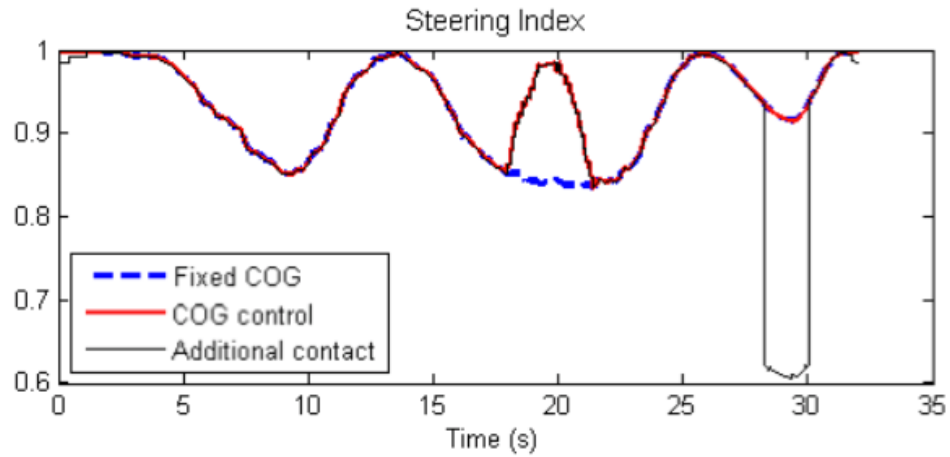
EXPERIMENTAL RESULTS

- **Upward motion**









The θ_1 angle and the F_{5z} force

The tip-over and steering indices

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5.
CONCLUSIONS

CONCLUSIONS

- **The effect on vehicle steerability of an arm ground contact have been analyzed**
- **The case study of the mobile robot Lazaro whose end-effector is a caster wheel have been presented**
  - *Simulation results with ADAMS show that tip-over can be improved with an additional ground contact but it can also provoke a loss in steerability*
  - *COG control of the on-board arm obtains goods results both in tip-over and steering indices*

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CONCLUSIONS

- **Future work**
  - *To complete navigability analysis with an sliding index*
  - *To obtain real data from experiments with Lazaro*

Thank you! **¡Gracias!**