



*Citation for published version:*

Bhatti, J, Iravani, P, Plummer, AR & Sahinkaya, MN 2012, Towards running robots for discontinuous terrain. in G Herrmann, M Studley, M Pearson, A Conn, C Melhuish, J-H Kim & P Vadakkepat (eds), *Advances in Autonomous Robotics: Joint Proceedings of the 13th Annual TAROS Conference and the 15th Annual FIRA RoboWorld Congress, Bristol, UK, August 20-23, 2012*. Lecture Notes in Computer Science, vol. 7429/2012, Springer, Berlin, Germany, pp. 461-462. [https://doi.org/10.1007/978-3-642-32527-4\\_59](https://doi.org/10.1007/978-3-642-32527-4_59)

*DOI:*

[10.1007/978-3-642-32527-4\\_59](https://doi.org/10.1007/978-3-642-32527-4_59)

*Publication date:*

2012

*Document Version*

Peer reviewed version

[Link to publication](#)

The original publication is available at [www.springerlink.com](http://www.springerlink.com)

## University of Bath

### Alternative formats

If you require this document in an alternative format, please contact:  
[openaccess@bath.ac.uk](mailto:openaccess@bath.ac.uk)

#### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

#### Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# Towards running robots for discontinuous terrain

## Extended abstract

Jawaad Bhatti, Pejman Irvani, Andrew R. Plummer, M. Necip Sahinkaya

Department of Mechanical Engineering,  
University of Bath,  
Bath, UK  
jb316@bath.ac.uk

### 1 Summary

Planar control is an important first step in the development of more complex running robots. This extended abstract describes a technique for control of a one-legged planar robot hopping over discontinuous surfaces. In simulations the robot is tasked with traversing across terrain which provides limited surface for foot placement. The robot has to hop between foot placement surfaces placed at varying distances and heights. The controller has to adjust leg landing angle and leg extension in order to produce the parabolic flight trajectory necessary to land at the next targeted foot placement spot.

### 2 Model

The simplified model of a running robot used for the development of the running controller is shown in Fig. 1. The model consists of a body and leg. The body is modelled as a simple point mass. The leg consists of a telescopic actuator and a spring-damper in series. The only control inputs to the system are displacement of the actuator  $y_{act}$  and the leg angle upon touch down  $\theta_{td}$ .

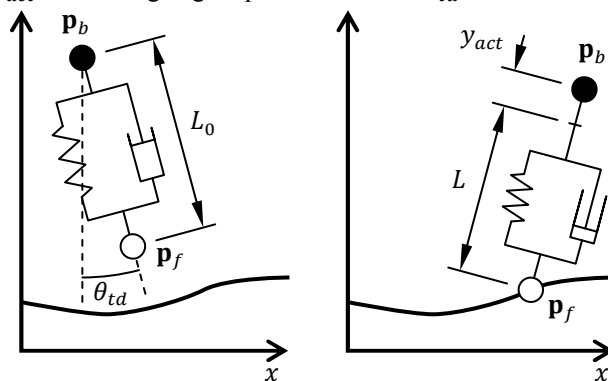


Fig. 1. Model of hopping robot in flight (left) and in ground contact (right).

### 3 Controller

Running speed is controlled by varying the leg touch-down angle  $\theta_{td}$ . A simple proportional controller which adjusts the leg angle in response to forward speed error can be used to achieve a steady running speed.

It was found that a demanded lift-off velocity  $v_d$  could be achieved by extending the actuator at a constant velocity  $v_{act}$  during the stance phase if the vertical touch-down speed  $v_{td}$  is known:

$$v_{act} = K_1 v_d + K_2 (v_d - v_{td}) \quad (1)$$

Because the trajectory of the robot in flight is parabolic, it is possible to target a given spot to land on if vertical lift-off speed is controlled accurately. There are many different parabolic flight trajectories which will land at the same point. One way to achieve a particular landing spot is to maintain a constant horizontal velocity while only varying the vertical lift-off velocity.

### 4 Results

Figure 2 shows hopping over a set of 0.1 m steps at a forward running speed of  $0.15 \text{ m s}^{-1}$ . The dotted line shows the trajectory of the point mass and solid lines are used to show the leg at touch-down and lift-off. It can be seen that the foot falls short of the target (centre of platform) when ascending stairs and overshoots when descending. This error may be reduced by taking into account the coupling between horizontal speed control and vertical hopping.

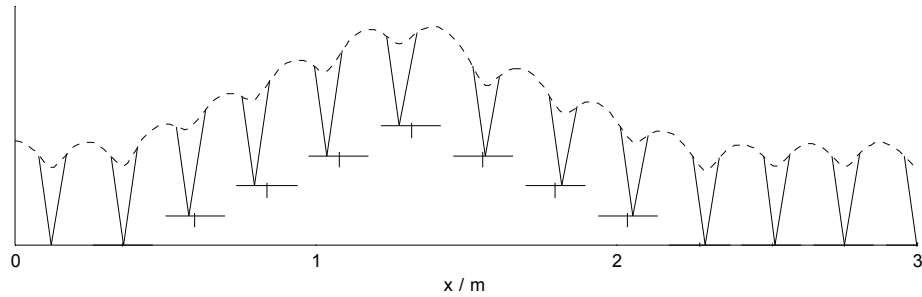


Fig. 2. Robot trajectory when ascending and descending platforms. Same scale on both axes.

### 5 Conclusion

Effective foot placement over rough terrain and over steps was achieved using a relatively simple control logic. Work is ongoing to experimentally validate and extend foot placement hopping into 3D.