# Receding Horizon Contact Planning for Advanced Motions in Hexapod Robots

**Document Version**
Final published version

**Citation for published version (APA):**
Johnson, D., Adorno, B. V., & Watson, S. (2023). Receding Horizon Contact Planning for Advanced Motions in Hexapod Robots. In F. Iida, P. Maiolino, A. Abdulali, & M. Wang (Eds.), Towards Autonomous Robotic Systems Extended Abstracts: 24th Annual Conference, TAROS 2023 Cambridge, UK, September 13–15, 2023 Proceedings (pp. 34-37).

**Published in:**
Towards Autonomous Robotic Systems Extended Abstracts

# Receding Horizon Contact Planning for Advanced Motions in Hexapod Robots[⋆]

Daniel Stephen Johnson[0000−0001−9002−4257], Bruno Vilhena Adorno[0000−0002−5080−8724], and Simon Watson[0000−0001−9783−0147]

Manchester Centre for Robotics and AI, University of Manchester, Oxford Rd, Manchester M13 9PL, UK
`daniel.johnson-2@manchester.ac.uk`,
`bruno.adorno@manchester.ac.uk`, `simon.watson@manchester.ac.uk`

**Abstract.** This work proposes a planning approach for advanced motions in hexapod robots. Contact sequences are explored until a user-defined planning horizon is reached. The contact change leading to the best position on the horizon is executed, and exploration resumes. In preliminary simulations, the algorithm consistently returned paths requiring at least 20% fewer contact changes than the state-of-the-art. Our algorithm generated 48.0% fewer nodes than the state-of-the-art in one terrain and 0.5% more in another, leading future work to examine the effects of specific environmental features on the number of nodes generated.

**Keywords:** Contact Planning · Legged Motion Planning · Hexapod Robots.

## 1 Introduction

Legged robots present unique challenges for motion planning, given their high degrees of freedom, under-actuation, and the need to maintain balance [5]. While gaited walking methods suffice in many cases [4], environments such as that shown in Fig. 1 require robots to plan and execute advanced forms of motion in order to navigate.

To plan such motions, legged robots must identify where they will make contact with the environment and the sequence in which contacts are made or broken. This work proposes a novel contact planning algorithm incorporating receding horizon methods to plan advanced hexapod motions. The planner is tested against state-of-the-art using a simulation of the Corin hexapod [1].

## 2 Planning Algorithm

Our Receding Horizon Contact Planning (RHCP) algorithm is based on the Contacts Very Best First Planning (CVBFP) approach of Escande *et al.* and shares several features in common with it, including the same potential field, guide path, and posture generator (PG) [3]. A flowchart summarising RHCP is shown in Fig. 2. The planner uses a tree search to explore possible stance sequences, where a "stance" refers to a set

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[⋆] This work was supported by a grant from the University of Manchester.

Fig. 1: An example of an environment requiring advanced motions to navigate. In this case, chimney walking (*left*) and wall walking (*right*) [2]

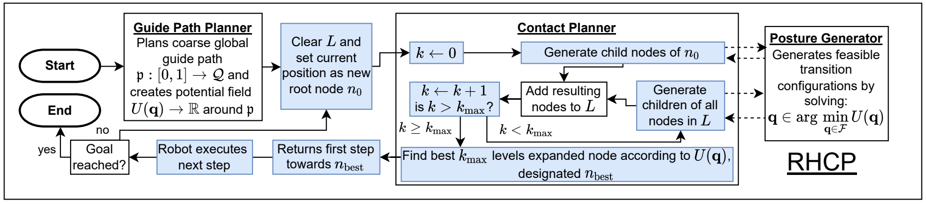

Fig. 2: Flowchart showing the operation of the RHCP algorithm. Elements present in RHCP but not in CVBFP are shown in *blue*.

of contacts made simultaneously, an example of which is shown in Fig. 3. Each node in the search is associated with a stance and a transition configuration that allows the robot to move into that stance from the previous stance. When these transition configurations exist, they are found by the PG, shown in Fig. 2.

RHCP explores possible stance sequences until a user-defined maximum sequence length $k_{\max}$ is reached. As these sequences always begin from the robot's current stance, the planning horizon effectively recedes each time the robot moves and its stance changes. The planning process starts with the root node $n_0$ being expanded, generating child nodes as follows:

- one child node is generated for each foot in contact in $n_0$ that could be lifted;
- for each foot not in contact in $n_0$, one child node is generated with that foot placed on each surface within reach at a point chosen by the PG.

Each child node of $n_0$ is then expanded, producing a 2nd generation of children. This process repeats until $k_{\max}$ generations have been produced. The $k_{\max}$ generation node with the lowest potential $U(\mathbf{q})$ is found, and the first contact change in the sequence leading to that node is executed. The planning process repeats with the robot's new position replacing $n_0$ as the root node. This continues until the goal is reached.

## 3 Preliminary Results

RHCP (with $k_{\max} = 2$) and CVBFP were each used five times to plan a path for the Corin hexapod across a section of rough terrain, as well as a more basic environment

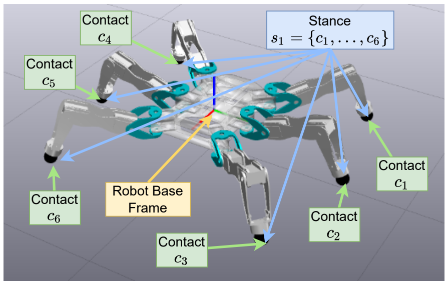

Fig. 3: Example of a stance with its constituent contacts labelled.

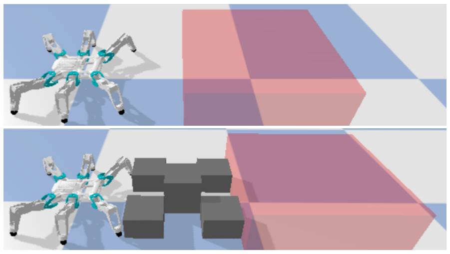

Fig. 4: Basic (*top*) and Rough (*bottom*) environments used for preliminary testing. Corin is shown in its starting configuration, and the goal region is shown in red.

without obstacles (shown in Fig 4). The testing results are summarised in Table 1. Two tests were cancelled (one of CVBFP in the basic environment one of RHCP in the rough environment) after they generated over 6000 PG calls without completion. These tests are excluded from Table 1 results.

Table 1: Planning data for CVBFP and RHCP in environments tested.

| Environment | Algorithm | Calls to PG | Nodes | Distance Covered (m) | Contact Changes |
|---|---|---|---|---|---|
| Basic (no obstacles) | CVBFP | 931 | 700 | 1.46 | 34 |
| | RHCP | 484 | 342 | 1.50 | 27 |
| Rough (with obstacles) | CVBFP | 2726 | 1392 | 2.25 | 55 |
| | RHCP | 2741 | 1350 | 2.16 | 30 |

As shown in Table 1, the average number of PG calls in the rough environment was just 0.5% higher for RHCP than for CVBFP. In the basic environment, however, RHCP made an average of 48.0% fewer calls to the PG than CVBFP.

Fig. 5 shows a plot of the potential of the nodes generated during the CVBFP tests in the basic environment. It can be seen on the graph that the average potential plateaus for several independent tests at a value of approximately 250. As this plateau is not observed in the RHCP tests on the basic environment, we believe that this is the principal reason RHCP made fewer PG calls than CVBFP. This is also believed to be why the two tests excluded from the results in Table 1 failed to conclude. We hypothesise that this plateau occurs because the robot has reached a state in which a foot that is critical for balance must be lifted to progress. An example of such a configuration is shown in Fig. 6. Future work will aim to confirm this hypothesis and understand what environmental features cause the algorithms to encounter this problem.

Table 1 also shows that the paths generated by RHCP required fewer contact changes than those generated by CVBFP, requiring 21.2% and 45.2% fewer in the basic and rough environments, respectively.

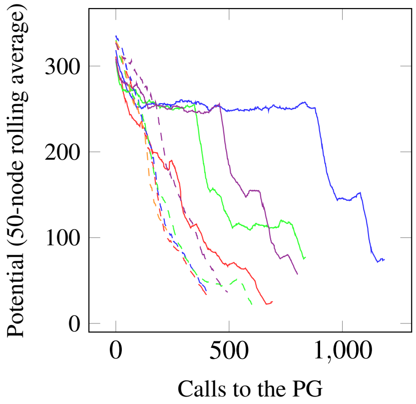

Fig. 5: Mean potential of nodes generated by the RHCP tests (*dashed lines*) and CVBFP tests (*solid lines*) in the basic environment.

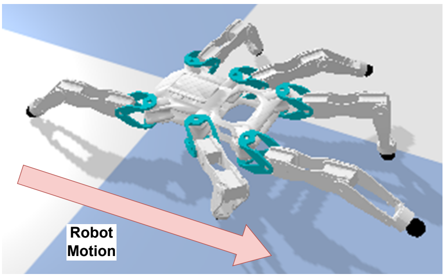

Fig. 6: Example configuration generated during planning plateau encountered by CVBFP in the basic environment. In the configuration shown, the robot must lift its right hind leg to progress, but doing so would cause it to tip backwards.

## 4 Conclusions

This work presented a novel receding horizon contact planner. In preliminary tests, the paths generated by RHCP required at least 20% fewer contact changes on average than those by CVBFP. Additionally, RHCP generated 48.0% fewer nodes than CVBFP in the basic environment while generating only 0.5% more nodes than CVBFP in the rough environment. Understanding which environmental features cause performance problems in the two algorithms is the subject of ongoing work.

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