Multi-plane Motion Planning for Multi-Legged Robots

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ABSTRACT

Hexapods are desirable due to its statically stable motions and redundant configuration. Studies on motion planning for these robots are in environments that are wide and contacts are typically made on the plane they are travelling on. Large obstacles or narrow pathway are avoided by planning another route. This limits areas that the robot is able to access such as in confined areas or discontinuous path. This paper presents the concept of multi-plane motion planning for multi-legged robots, specifically for hexapods to address limitations of their inherent design and on existing motion planners. A conceptual hexapod for multi-plane motion is also detailed.

I. INTRODUCTION

Mobile robots are increasingly used and researched to meet the demands in improving efficiency and carrying out operations dangerous for humans [1]. Legged robots have better capabilities in surpassing uneven environments compared to wheeled or tracked robots [2]. This is partly attributed to legged robots' capabilities in traversing on discontinuous path [3]. Among the different classes of legged robots (bipeds, quadrupeds, hexapods, octopods) [4], hexapods are well suited to applications that require statically stable motions and redundant configuration, such as in search and rescue or demining operations whereby in the event of an explosion results in a damaged leg, the robot will still be able to continue its mission [5]. Current research on hexapods has largely employed irregular terrains as their experimental environment such as rocks [6], snow [7], blocks [8] and steep terrains [9]. The commonalities in these motions are that the environment in wide areas and contacts are typically made on the plane they are travelling on. The motion planners employed plans route that avoids large obstacles or narrow pathways. This limits areas that the robot is able to access such as in confined areas or discontinuous path, as shown in Fig. 1. Such scenarios occur in urban environments following a disaster [10]. This paper presents the concept of multi-plane motion planning for multi-legged robots, specifically for hexapods to address limitations of their inherent design, and on existing motion planners. A conceptual hexapod for multi-plane motion is also detailed.

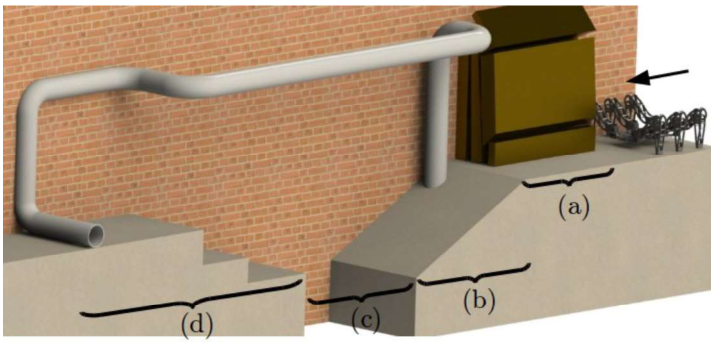

Fig. 1. Confined environment scenarios (a) narrow pathway (b) gradient slope (c) pit (d) steps and large obstacles

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II. MULTI-PLANE MOTION PLANNING

As mentioned earlier, most experiments for hexapods have been conducted on wide areas. For irregular terrains, this can often be approximated as a single plane and possibly with height data (2.5D map) [11]. The same is done on walls, gradient slopes and varying sizes of obstacles where they are flatten down onto a single plane [12]. This simplifies the motion planning involved where the robot's path and contacts are subsequently planned along this plane with no contact on walls and large obstacles. This constrains the robot's motion and contacts to the plane it is on. Thus for any type of motion or gait used, the footprint of the robot remains largely the same and the robot's weight is supported by the plane.

Using existing motion planners would not work for the scenario shown in Fig. 1 as contacts are constrained to the plane it is travelling on. Segment *a* and *c* are impassable as the large footprint of the robot prevents it from passing through *a* while the pit in *c* is too large and deep for the robot to step in or over. To pass through, motions that reduces the footprint and does not require its weight to be supported by the plane it is traversing on is required. Two examples of such motion is sideways (Fig. 2a) and chimney (Fig. 2b) walking. In the first instance, the robot starts by rearing up sideways and then walk along in this manner (Fig 2a). This reduces its footprint enabling it to pass through pathways even narrower than its body width. In the next instance, using the walls for contact would enable the robot to chimney walk across the pit.

There have only been few studies on such motions. For narrow pathway, different gaits have been proposed for reducing the robot's footprint but remains limited to the robot's body width [13]; the use of a semi- ellipsoid attached to the back of a RHeX type robot for running through flexible beams has been proposed but is only applicable to this particular type of robot [14]. The HyQ quadruped showed chimney walking in simulation (experiments were limited due to joint torque limitations) [15]. However, the robot started and ended within the chimney itself. The motion planner for executing the motions in Fig. 2 would need to plan the motion for moving into the respective stances (sideways, chimney) before moving forwards based on those stances. Recovery from those stances will also be needed on exit i.e. going from sideways to flat.

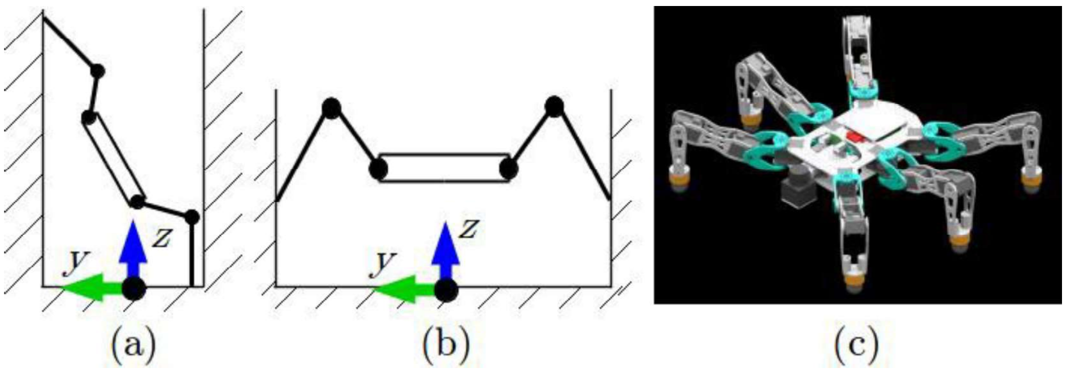

Fig. 2. (a) Sideways walking (b) Chimney walking (c) Conceptual hexapod

The requirements for a hexapod executing such motions are on their joint requirements. A number of methodology for designing legged robots have been reviewed in [16]. Current state-of-art hexapods employ the characteristic motion approach, subjecting the robot to motions such as the tripod gait [5], standing on two legs [17] or walking up stairs [18], to identify link and joint parameters. This approach will needs to be extended for the motions shown in Fig. 2. By designing the robot to be symmetrical about its body sagittal plane, there is no need for complex self-righting hardware or motions required on exit [19] or falling over [20]. Fig. 2c shows the CAD design based on these concepts for a hexapod that is adaptable to operate in confined environments, capable of the reach required for these motions. A simple self-righting technique is employed by mounting the sensors that are required on the top side of the body to be rotated about the body axis by an actuator.

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