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A Reactive Online Optimization Based Whole Body Contol for Quadruped Locomotion Over Challenging Terrain\*

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# INTRODUCTION

In the field of Civil Engineering, robots are being come up with as alternatives in restricted or hazardous environments. Especially in dangerous environments such as disaster, their priority is increasing. UAV, wheeled robots, and legged robots have been proposed to replace the workforce.

In the disaster environment, robots should make lots of interactions with its surroundings like activate valves, pull the lever, and go up and down the uneven platform. Wheeled robots, which have been widely used in the field(past), have limited approach to uneven terrain, large gaps, and obstacles made of debris due to their physical limitation. Although, UAVs have been adduced to solve these complication described above. However, they are easily affected by the climate like heavy fog and windy weather, and there are issues such as payload, and energy consumption. Legged robots are better fitted for the challenging terrains mentioned above. Furthermore, since they can interact surroundings directly through anthropomorphous manipulators, they have a potential to perform versatile tasks.

Compliance is the basic ability for robot in order to interact safely with complex environments. The robots controlled by a traditional ‘joint position control method’ generally uses a high gain to maintain the endpoint position accuracy, thus their joints has high stiffness. To maintain robot compliance without sacrificing position accuracy, inverse dynamic control method is widely used.

Nowadays, researches have been conducted to control legged robot through inverse dynamics control method. Various studies have extended the ‘operational space control framework’ proposed by Khatib(1987) and applied to floating based system, through Quadratic Programming (QP) method. In other words, using the convex optimization to calculate the reference control that finest follows the desired motion which given in the task space, while satisfying various constraints. Hutter et al. (2014) and Hearzog et al (2014), using hierarchical method, projected secondary tasks to null space of the high-priority tasks, thus implemented secondary tasks without interfering with the high-priority desired motions. However, there were disadvantages in that it is hard to implement desired motions with same priority, and in specific situation, there is no feasible solution. In contrast with hierarchical method with high constraints feature, Feng et al (2015) used soft constraints method that put weight at objective cost function.

Unlike the fixed base system, a contact force term exists in the equation of motion of the float base system, thus its sensing is needed. However, due to the characteristics of the force/torque sensor, the sensor noise is severe, if the low pass filter is used, the overall control bandwidth is decreased because of the phase delay. To compromised this issue, Sentis (2007), Aghili (2005) and Mistry et al. (2010) solved the QP problem using optimization variables consisting of joint accelerations and joint torque except contact force by mapping the equation of motion to a support-consistent manifold. However, using the reduced optimization variables has an issue that it is hard to handle the contact force constraint explicitly. Therefore, De Lasa et al. (2010), Bouyarmane et al. (2012) and Feng et al. (2015) considered to use full optimization variables, which consisting of joint acceleration, joint torque and contact force. Although using the full optimization variables can affect the computation time due to high dimensions of QP, according to Feng (2015), it is still solvable in real time(3ms).

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