The Rapid Rise of Quadruped Robots

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If we reflect on the past decade, we can see a clear picture of breakthrough progress in the field of quadruped robot locomotion. Boston Dynamics and its hydraulically actuated Big Dog were already YouTube sensations in 2011, but the practical use cases for quadruped robots were still up in the air, and only a handful of research labs had access to their own platforms due to prohibitive cost. Fast forward to 2021, and we have hundreds of quadrupeds in our labs and out in the field, servicing applications from security and patrolling of worksites to monitoring and inspection of chemical plants. In a world designed for legs, quadrupeds are ideal for these current uses, with an ability to step over pipes, climb stairs, and so on, and to do so while offering improved balance stability over bipedal solutions.

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Companies such as Boston Dynamics, Ghost Robotics, ANYbotics, and others have led the push into these high-value applications, with advances in sensing, actuation, control, and access underpinning the rapid rise. The previously prevailing vision of Big Dog carrying a 300-pound payload for our soldiers has shifted to quadrupeds carrying lightweight perception suites for capturing thermal, acoustic, and visual sensor streams. With this change, high-force hydraulics are less suited for current use cases, and electric actuation solutions have emerged that offer lower overhead and cost with improved actuation bandwidth. In addition, quadruped-specific locomotion control solutions have reached maturity for operation over moderate terrain, using careful modeling simplifications that ease computation challenges. The opportunity for academic labs to contribute to progress across these aspects has further accelerated through improved hardware access, with the cost of a small-scale quadruped now rivaling some of the sensors they are designed to carry.

Yet, if we look at the current applications of quadrupeds, we see many task simplifications that are key to their success. Whether in patrolling, mapping, or inspection, quadrupeds are providing a mobile sensing solution, and their jobs are “look, but don’t touch” by design. Most of these current applications further require little high-level decision making, with systems following a predetermined path through their worksite and avoiding a need for flexible autonomy to respond to unexpected situations. In a sense, these applications leverage the athletic intelligence of existing platforms without requiring broader cognitive capabilities that we typically associate with human intelligence.

As we look to transition these technologies into new applications for logistics, agriculture, or in our homes, quadrupeds need to migrate from pure mobility solutions to ones that do physical work. This need raises natural challenges to merge locomotion and manipulation, but more broadly raises questions of how to integrate high-dimensional sensor streams into loco-manipulation control architectures and high-level cognition. The added consideration of manipulation is likely to break many of the simplifications underlying current locomotion-specific solutions, requiring new approaches to whole-body control. Machine learning offers a powerful means to coordinate higher-level decisions, and it remains important research to merge these strategies with our existing model-based designs. As we begin sending quadrupeds to do physical work in spaces alongside humans, the relative merits of quadrupeds versus bipeds will further factor into deployment choices, and advancing safety and reliability will require more concerted efforts from the community. Overall, with the momentum of the field and a growing opportunity to impact real-world applications, it remains apparent that the next 10 years of legged locomotion research will be just as dynamic as the last.

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