# Quad-SDK Update: Estimation, Underbrush, and Other Improvements

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***Abstract*— This report presents extensions to Quad-SDK, a full-stack, open-source ROS based framework for control of quadrupedal locomotion. The modular software integrates motion planning, control, simulation, and estimation, while streamlining the development of novel robotics packages. With this update, Quad-SDK now incorporates an Extended Kalman Filter (EKF) for reliable onboard state estimation. Additionally, a specialized controller designed for walking through entanglements has been added, allowing the robot to disentangle itself from vine-like obstructions. Both serve to enable more reliable outdoor locomotion. Finally, several improvements have been made to the software architecture. The package is available online at `https://github.com/robomechanics/quad-sdk`.**

## I. Motivation

Recent advancements in legged robot locomotion have shown that quadrupedal robots are capable of navigating difficult outdoor environments. In order to realize the potential of legged robots for surveying, monitoring, or exploration tasks, they must be capable of traversing rough terrain reliably while negotiating entanglements and other obstructions. This requires reliable state estimation for control as well as effective strategies for disentangling the legs when moving. Much of the prior work in this area has focused on either solving each of these problems in isolation [1] or lack full-stack open-source implementation for how they would fit into a hierarchical control stack [2]. To address this gap, we propose multiple extensions to our existing Quad-SDK framework [3], a full-stack software framework for agile quadrupedal locomotion. In particular, we provide an Extended Kalman Filter (EKF) for state estimation [4], a specialized underbrush controller for walking through dense vegetation and entanglements, as well as other improvements to the framework.

## II. Results and Discussion

### A. State Estimation

Given that reliable control of a quadruped is often dependent on accurate knowledge of its body position and velocity, Quad-SDK now supports online state estimation, similar to [2] and [4]. EKF state estimation is integrated into Quad-SDK as an onboard alternative to existing estimation features. The filter fuses IMU sensor data in its process and leg kinematics in its measurement update to accurately estimate robot position, velocity and orientation.

### B. Underbrush Controller

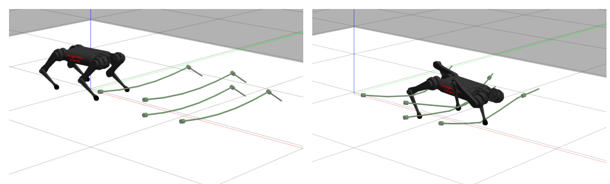

Fig. 1. Spirit 40 quadruped walking through bungee cords with underbrush controller in simulation. Bungees were used to approximate the stiffness of vines outdoors.

The underbrush controller is designed to enable the quadruped to walk through dense underbrush and entanglements. It is composed of a momentum based observer [1] that detects unexpected external forces from entanglements and a leg retraction strategy that modifies the swing leg motion to step over obstructions. A comprehensive summary of the method is described in [5].

### C. Other Software Updates

Quad-SDK has also been updated to support ROS Noetic and Ubuntu 20.04, ensuring its future compatibility with other systems given Melodic's EOL in 2023. Docker development support has been added to Quad-SDK, simplifying distribution and allowing users to easily encapsulate their dependencies into a container.

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