# Planning and Control with Attitude

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***Abstract*—Planning and controlling trajectories for floating-base robotic systems that experience large attitude changes is challenging due to the nontrivial group structure of 3D rotations. This paper introduces an accessible and unified approach for tracking control and optimization-based planning on the space of rotations. The methodology is used to derive an extension of the Linear-Quadratic Regulator (LQR) to systems with arbitrary attitudes, which we call Multiplicative LQR (MLQR). We compare MLQR to a specialized tracking controller designed for the SE(3) group, and derive an iterative variant of MLQR to optimize trajectories for a variety of robotic systems. We provide benchmark comparisons between several of the most common attitude representations used for motion planning and control and find that the combination of unit quaternion state variables with Rodrigues parameters to represent attitude errors provides an excellent combination of performance and algorithmic simplicity.**