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Geometric Methods for Modelling and Control in Robotics

Abstract

In this talk, we use as a mathematical framework the conformal geometric algebra for applications in computer vision, graphics engineering, learning, control and robotics. We will show that this mathematical system keeps our intuitions and insight of the geometry of the problem at hand and it helps us to reduce considerably the computational burden of the problems. Surprisingly, as opposite to the standard projective geometry, in conformal geometric algebra we can deal simultaneously with incidence operations (meet and join) and conformal transformations represented effectively using spinors (quaternions, dual quaternions, etcetera). In this regard, surprisingly this framework appears promising for dealing with kinematics, dynamics and projective geometry problems without the need to abandon the mathematical system (as current approaches). We present some real tasks of perception and action treated in a very elegant and efficient way: sensor-body calibration, 3D reconstruction and robot navigation and visually guided 3D object grasping making use of the directed distance, algebra of incidence and conformal transformations. For modeling and control problems, we reformulate Euler-Lagrange and Newton-Euler Dynamics and recursive Hamiltonians and design using screw theory controllers for robot manipulators. For a real time tracking of rigid motion $SE(3)$ we apply the Motor (dual quaternion) extended Kalman filter using line observation. We illustrate these methods in robot vision for robot manipulators and humanoids. For control of manipulators and artificial hands, we have developed the quaternion spike neural network which is used in a decentralized control fashion. We will briefly explain the Quantum Quaternion Neural Networks.

We believe that the framework of geometric algebra can be in general of great advantage for applications in image processing, stereo vision, range data, laser, omnidirectional and odometry based robotic systems, kinematics and dynamics of robot mechanisms, humanoids and advanced nonlinear control techniques.