Design and Optimization of Differentially Flat Robot Systems

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Abstract: Trajectory planning and control of autonomous machines and robots to traverse between given end points is an important engineering problem. A fully- actuated robot, which has as many actuators as the degrees-of-freedom, can execute any joint trajectory within its configuration space. However, under-actuated robots, which have fewer actuators than the degrees-of-freedom within the system, may be severely restricted in their ability to perform arbitrary motions between two end points. Examples of such systems include bipedal robots, car-like robots, satellite mounted manipulators, and others.

For certain classes of under-actuated robotic systems, it can be shown that the governing nonlinear systems are naturally diffeomorphic to linear systems. For some other classes, the inertia distribution within the system can be made so that this property can be achieved through careful design. Once this property of feedback linearizability or differential flatness is demonstrated for such a non-linear dynamic system, trajectory planning and tracking problems can be solved in a simplified manner. Additionally, the dynamic optimization can be alternatively posed such that the differential equations get explicitly embedded into the cost functional using the diffeomorphism admissible by the problem. The numerical approches to solve this problem may differ significantly from the 2-point boundary value problems typically posed for dynamic optimization problems. The above approaches apply to a variety of robot examples, including under-actuated arms, bipedal robots, mobile robots, and space robots. The talk will demonstrate both the underlying theory and experiment results from an under-actuated robot arm design.

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