HyRoDyn: A Modular Software Framework for Solving Analytical Kinematics and Dynamics of Series-Parallel Hybrid Robots

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***Abstract*— Parallel mechanisms (PM) are increasingly being used as modular subsystem units in various robotic systems for their superior stiffness, payload-to-weight ratio and dynamic properties. This leads to series-parallel hybrid robotic systems which are difficult to model and control due to the presence of various closed loops. Most model based kinematic and dynamic modeling tools resolve loop closure constraints numerically and hence suffer from inefficiency and accuracy issues. They also do not exploit the modularity in robot design. We present the concept of a modular software framework, called Hybrid Robot Dynamics (HyRoDyn), for solving the kinematics and dynamics of series-parallel hybrid robots analytically.**

I. MOTIVATION

PMs such as 2SPU+1U, variants of four bar linkage are repeatedly used in various hybrid robot designs such as Lola (TUM), MANTIS (DFKI), THOR (Virginia Tech.) etc. Solving their kinematics and dynamics is challenging because they are subjected to additional geometric loop closure constraints. Most multi-body dynamics libraries (like RBDL [1] and OpenSim [2]) adopt numerical resolution of these constraints for the sake of generality but may suffer from inaccuracy and performance issues. Further, such systems can have variable mobility, different assembly modes and can impose redundant constraints on the equations of motion. Hence, it is interesting for kinematics researchers, to study the analytical solutions to geometric problems associated with a specific type of PM and their importance over numerical solutions is irrefutable. But this domain specific knowledge is often underrepresented in the design of model based kinematics and dynamics software frameworks.

II. HYRODYN SOFTWARE FRAMEWORK

The main idea behind HyRoDyn is to store the analytically derived loop closure functions (LCF) [3] in a *configurable* mechanism library which is identified by its type (for e.g. 2SPRR+1U [4]). Based on submechanisms defined in a hybrid robot, HyRoDyn can modularly compose the LCF of the overall system in an automated way (see Fig. 1). The resulting loop closure jacobian has a block diagonal structure that can be exploited in the computation of various forward and inverse kinematics and dynamics algorithms. HyRoDyn is implemented in C++ and utilizes $O(n)$ multi-body dynamics algorithms for tree type systems from RBDL [1](based on [3]). The input to HyRoDyn is SMURF[1] file which can be generated using a Blender based visual editor called Phobos[2] (see Fig. 2a). HyRoDyn can be used both for simulation and real time control of the complex hybrid robots (see Fig. 2b and Fig. 2c). For example, inverse dynamics of RH5 (DFKI) humanoid (with $n = 71$, $m = 28$, 14 independent closed loops) can be solved in the order of a few microseconds.

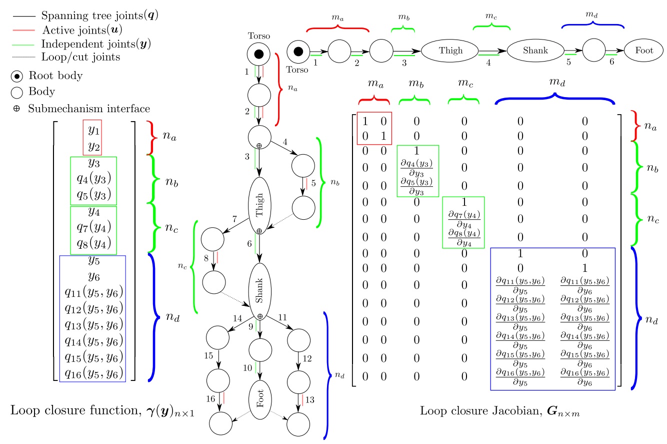
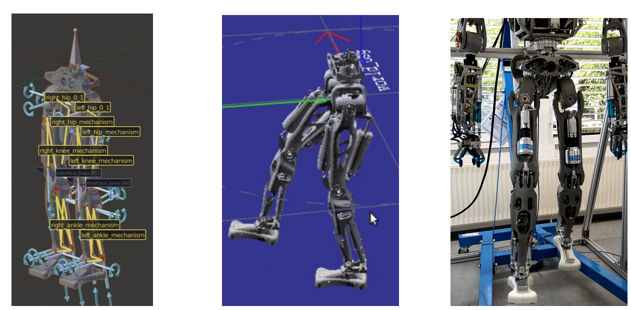


Fig. 1: Modular composition of loop closure function



(a) Modeling (b) Simulation (c) Control

Fig. 2: HyRoDyn: Modeling, Simulation and Control

References

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[1]https://github.com/rock-simulation/smurf_parser
[2]https://github.com/dfki-ric/phobos