Real-time control allocation using zonotopes[1]

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Control allocation is related to control of overactuated systems, and provides a method of distributing the total control demand among the individual actuators. The idea of control allocation allows to deal with control constraints and actuator faults separately from the design of the main regulator, which uses virtual control input. In many cases, this input consists of three moments or angular rates used to control a mechanical system [1, 2], while the number of physical actuators can be much higher. In case of fault in an actuator, instead of reconfiguring the main control law, we need to change only the distribution of the virtual input among other actuators that are still in use.

Using linearization, control allocation of virtual input v is equivalent to linear inverse problem with interval-constrained vector u, which we need to figure out: $v = Bu$, where B has more columns than rows. The problem can be solved by linear or quadratic programming [3], but this solution in some cases cannot be adopted due to the safety sertification issues or high complexity of optimization routines for on-board realization.

Note that if u constrained to a box, then v is constrained to its linear image, a zonotope. Zonotopes have been used previously for state and reachable sets estimation in linear discrete systems, also they are naturally considered in the affine arithmetics approach. We propose a method for calculating u, based on control box bisection and explicit description of its image in the form of a system of linear inequalities [4]. In our aproach, no over-approximation problem occurs - we immediately discard boxes that contain no given v in their image. If we divide control box into many parts in once, we can use convex function of u for choosing boxes with some additional optimization criteria.

References

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[1]This work has been partially supported within Program 1 ("Theoretical foundations of robotics and mechatronics") by the Russian Academy of Sciences (Brancn for Power Industry, Machine Building, Mechanics and Control Processes)