writeup

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1 15.083 Writeup

1.1 Introduction and overview of methods

1.1.1 Motivation

Spacecraft design tends to be a laborious and manual procedure, where engineers iterate on evaluating the perfomance while having a consistent design, i.e satisfying so-called budgets (a.k.a. constraints).

One interesting part of the problem is that although one could start from scratch to custom design all parts of a spacecraft(e.g. a satellite), companies generally try to save on development efforts by picking components from a database - either internal to the company, or from larger market availability.

Building a spacecraft based on commercially-off-the-shelf components is especially attractive within the new paradigm of CubeSats: a standard for cubesat component sizing and interfaces - turning the spacecraft problem into picking the right "LEGO" bricks, and reducing the engineering part to simple assembly and integration(saving a lot on development time).

Yet it still leaves the frustration of picking the right component to the engineer; normally the procedure will be quite manual and the engineer will iterate through both picking components, and making sure all constraints are satisfied. It can often be very much a whack-a-mole process, leading either to the engineers frustration, or indifference to looking for better solutions once the design converges on something that works - given the feel that any design changes will just be the same as starting from scratch and having to suffer through yet more frustrations.

1.1.2 The MINLP optimization approach

Here we present the optimization approach; the components selection process translate easily into a Mixed Integer formulation. The challenge is that most of the physical sizing constraints are highly non-linear, and oftentimes non-linear in more than one variable.

With further careful consideration, one can notice though, that many of the relationships are power laws: products of powers, or sum of products of powers. This is very promising, as this becomes a linear problem in log space, as long as any factors in front of the powers are positive.

Unfortunately there are still sometimes models that cannot be captured by this reformulation. These are oftentimes univariate expressions, and therefore the approach we take is to use PiecewiseLinear in JuMP to model them.

Finally, we might sometimes encounter disjoint constraints, where the choice is between two component with different physical models. This can also be introduced with a simple modelling technique.