Popular science summary of master's thesis in solid mechanics.

Accelerating topology optimization

by Vilmer Dahlberg

Topology optimization is a tool used for designing mechanical components, which can range in size from macro to micro-structures. The process is unfortunately very slow, but can be sped up by using reduced order models (approximations). As always, there is a trade-off between time savings and quality of the end design. Using Kirsch's Combined Approximation, we found that the amount of time can be reduced by 80% while producing very accurate results.

The eigenfrequencies of a structure are the frequencies at which the structure is prone to oscillate. Take for example the vibrations of a guitar string, or the hum of a bus driving on the highway. By optimizing the eigenfrequencies of a structure, resonance can be avoided. Imagine driving on the highway and not hearing any noise from the road, or sitting on a silent airplane.

These, and many other types of problems can be solved using topology optimization. This tool is very flexible, has many applications, and is easy to use. In fact, modern software applications used in the industry come with topology optimization packages. It is however very slow. Therefore, it is highly important to develop methods which use approximations to speed up the process. While this is not a new idea within mathematics, when applied to topology optimization the methods need special care. The reason is that we do not want the approximations to compromise the end results of the optimization.

One way of reducing the work is by approximating, for example the structure's eigenfrequencies, using a linear combination of so called basis vectors. These methods are especially efficient in topology optimization, since the basis vectors can be built by reusing information throughout the optimization. Although this method works very well for lower frequencies, it has the tendency of underestimating higher frequencies. A solution to this problem has been proposed, and is the subject of this work.

We found that while the solution produces more accurate approximations of the frequencies, it sacrifices some accuracy in other aspects. We suggest a simple fix which efficiently approximates both lower and higher frequencies, without compromising accuracy in other aspects. A test setup was developed to test and compare these methods, and to study how much work can be saved.

Results

Using these methods, we found that 80% of the work can be saved without compromising the resulting designs, shown in figures 1-2. The goal was to maximize the structure's fundamental (lowest) frequency in order to avoid resonance. From the tests we saw that there is practically no difference in the designs whether or not the approximation is used. Also, the structures' fundamental frequencies differ by only about half a percent. These differences are insignificant since topology optimization is often used to generate prototypes.

Figure 1: Final design when the problems are solved without the use of approximations.

Figure 2: Final design when the problems are solved with approximations.

Problem description

The task is to find how the material should be distributed in the so called design domain, shown in figure 3. The goal is to maximize the structure's fundamental frequency, while filling at most half the design domain's volume.

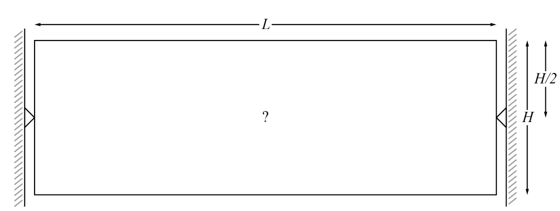

Figure 3: Beam with length L and height H with unknown material distribution. The beam is pinned to the walls at half its height by two supports.

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