Optimization of Natural Frequencies for Fabrication-Aware Shape Modeling

Christian Hafner

Introduction

Every solid has a characteristic pitch. We can analyze it with a microphone, or predict it computationally. The computation requires a mesh of the object and a finite element solver.

Problem Statement

We tackle the inverse problem—shape synthesis. From a target pitch, a target shape, and a target material, our algorithm computes a matching solid.

Shape Design Space

Our target shape is a manifold with boundary. We construct an inner offset surface, using the wall thickness as a parameter. The offset vectors target a skeleton.

Fabrication

1. Print a positive of our solid with an FDM printer
2. Create a negative with molding sand
3. Equip upper part with a feed opening and air holes
4. Pour melted tin into the mold
5. Remove the sand after cooling period
6. Saw off extensions for finished result

Finite Element Method

To predict the pitch, we construct a finite element mesh with thin-shell elements.

The pitch corresponds to the smallest non-zero eigenvalue \( \lambda \) of the undamped vibration system [1]:

\[
M\ddot{u} + KU = 0 \\
\Rightarrow Ku = -\lambda^2 Mu
\]

Optimization

Given a target pitch, we find the optimal wall thickness using an off-the-shelf non-linear optimization routine.

Results

We strike the bell with a hammer and record the sound. The Fourier Transform reveals a pitch of 1800 Hz. This deviates from our FEM prediction by 2.8%.

We use reference material parameters for tin. Our method requires no manual parameter tweaking.

References


Kontakt: chafner@cg.tuwien.ac.at

Masterstudium: Visual Computing

Technische Universität Wien
Institut für Computergraphik und Algorithmen
Arbeitsbereich: Computergraphik
Betreuer: Assoc Prof. Dipl.-Ing. Dipl.-Ing. Dr.techn. Michael Wimmer
Betreuender Assistent: Dr.techn. Dipl.-Mediensys.wiss. Przemyslaw Musialski