FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Diplomarbeitspräsentation

Optimization of Natural Frequencies for Fabrication-Aware Shape Modeling

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Masterstudium:
Visual Computing

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**.

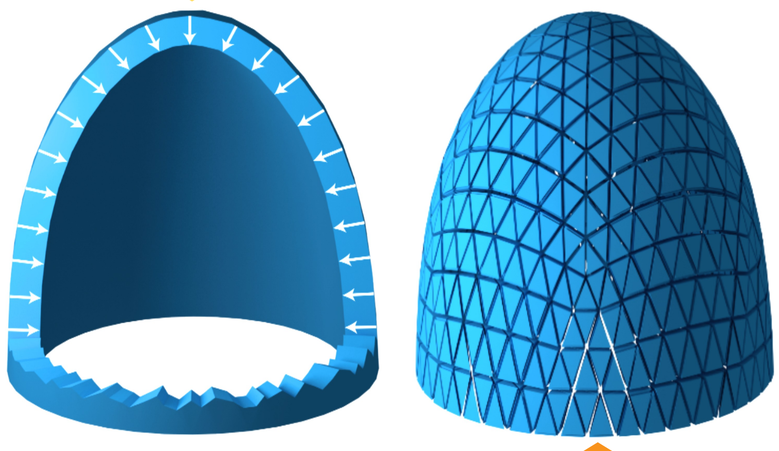
From a **target pitch**, a **target shape**, and a **target material**, our algorithm computes a matching solid.

Shape Design Space

Our target shape is a manifold with boundary.

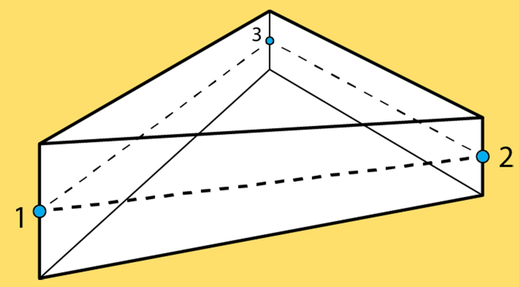
We construct an **inner offset surface**, using the **wall thickness** as a parameter.

The offset vectors target a **skeleton**.



Finite Element Method

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

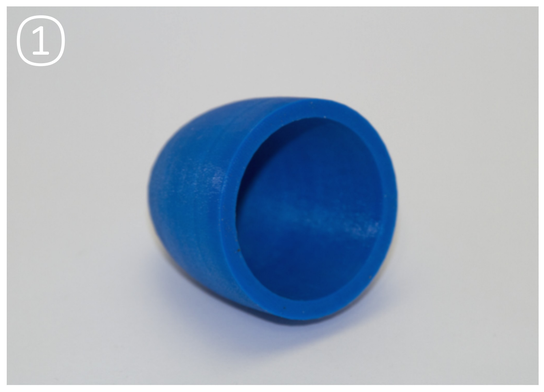


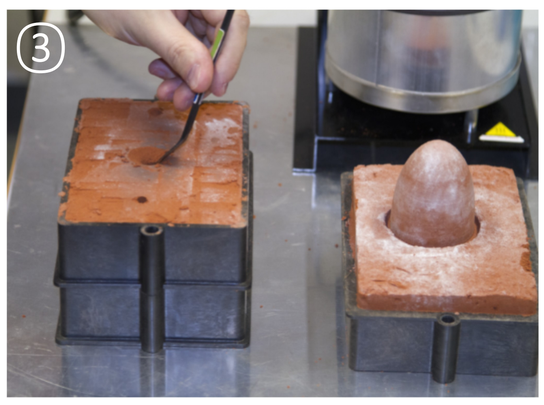
The pitch corresponds to the **smallest non-zero eigenvalue** λ of the undamped vibration system [1]:

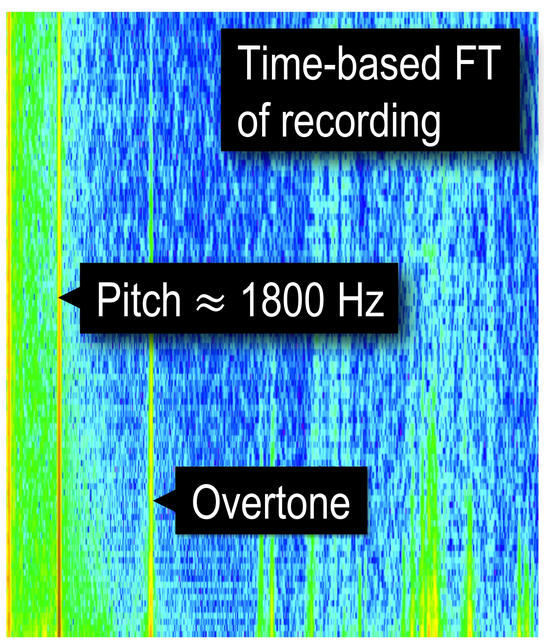
$$M\ddot{U} + KU = 0$$
$$\Rightarrow Kv = -\lambda^2 Mv$$

Optimization

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







Fabrication

① Print a **positive** of our solid with an **FDM printer**

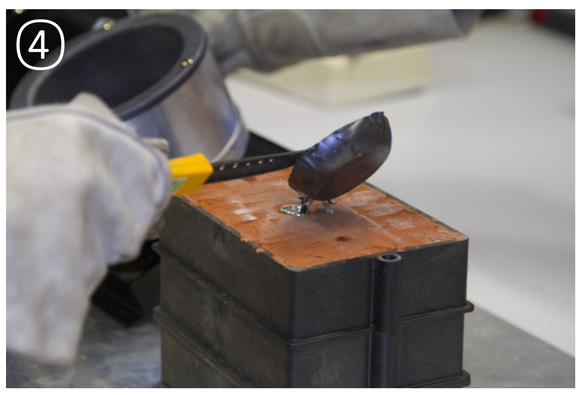
② Create a **negative** with **molding sand**

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



Results

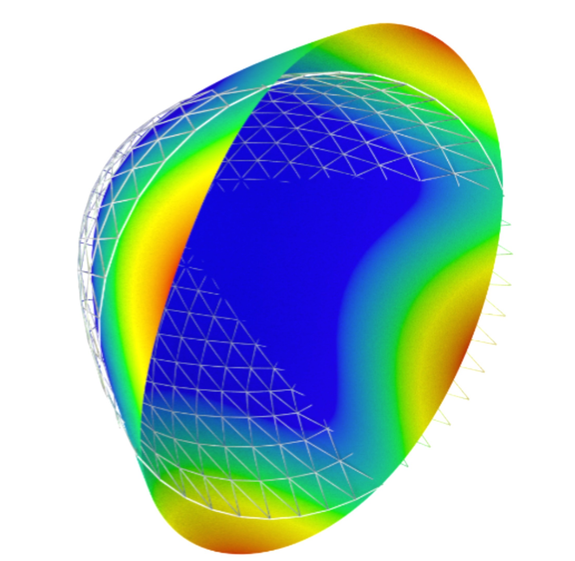
We strike the bell with a hammer and **record the sound**.

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**.



Mode shape found by FEM
Predicted pitch = 1760 Hz

[1] O'Brien, Book, Essl. 2001. Synthesizing sounds from physically based motion. In *Proceedings of ACM SIGGRAPH 2001*, ACM Press, 529-536.

[2] Umetani, Mitani, Igarashi. 2010. Desgining custom-made metallophones with concurrent eigenanalysis. In *Proceedings of the Conference on New Interfaces for Musical Expression (NIME)*.

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