Recitation 1

Template of a Structural Optimization Problem

ME260 Indian Institute of Science

Structural Optimization: Size, Shape, and Topology

G. K. Ananthasuresh

Professor, Mechanical Engineering, Indian Institute of Science, Bengaluru

suresh@iisc.ac.in

Structural optimization problem statement

Minimize Objective(optimization variables, state variables)

Optimization variables

Related to the geometrical features

Subject to

Displacements, temperature, electric field, etc.

Weight, cost, size, etc.

Constraints on state variables

Constraints on resources

Constraints on performance

Governing differential equations

Stiffness, strength, frequency, etc.

Limits on variables

Data

Material properties, loads, etc.

This is a typical structural optimization problem statement. Make it a habit to write in this format, including the data.

Can you think of another conflict in SO?

Sure, there is conflict in structural optimization.

- If you want to make a stiff structure for given loading, you need more material; more material increases the weight and cost.
- So, there is conflict if you want to design the stiffest structure with least amount of material.

What if we want to make a lightest structure with high natural frequency?

- Light structures have low inertia and low stiffness too, at least in general. This will mean that their frequencies will be low.
- So, there is conflict.

Suppose that you want to make a flexible structure that is very strong.

- Flexible structures deform and it may seem that they are weak when strains are large in them.
- So, there is conflict too.

Imagine a structure that is subject to multiple loading conditions.

- Making a structure stiff under one loading may cause it less stiff in another loading.
- So, there will be conflict.

Imagine more situations of designing structures. There will be enough conflict!

Conflict in SO

What else can be optimized for?

Optimizing a structure for

- Stiffness
- Strength
- Flexibility, desired motion
- Natural frequency, mode shapes, dynamic response
- Stability, preventing buckling
- Weight reduction
- Cost reduction
- Manufacturability
- Reliability
- Controllability
- Safety
- Aesthetics

What else can be optimized for?

Do you understand these in SO context?

Hierarchy
Modularity
Complementarity

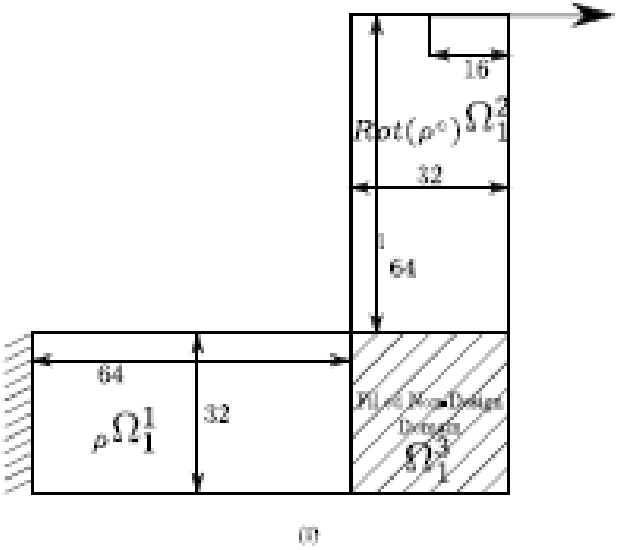
Hierarchy

Modularity

Most buildings and other civil structures are modular. Eiffel exploited modularity to a great extent.

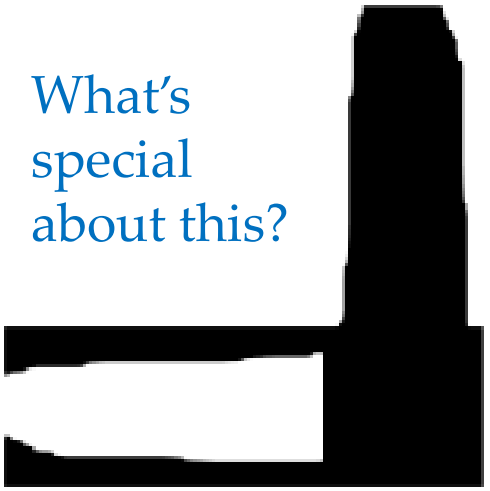
There is more to modularity… examine these ancient sculptures from a temple in Lepakshi, Andhra Pradesh.

Modularity (contd.)

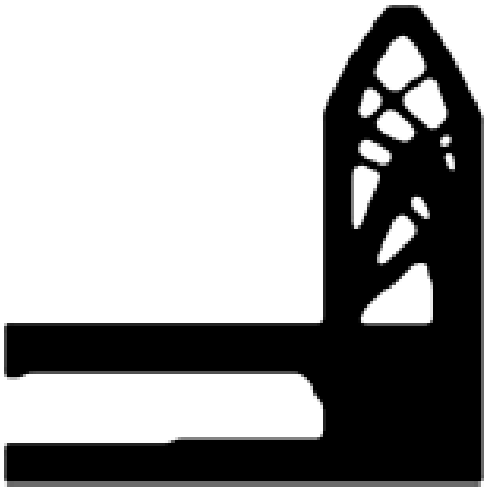


Modular topology-optimized design

What's special about this?



Usual topology-optimized design

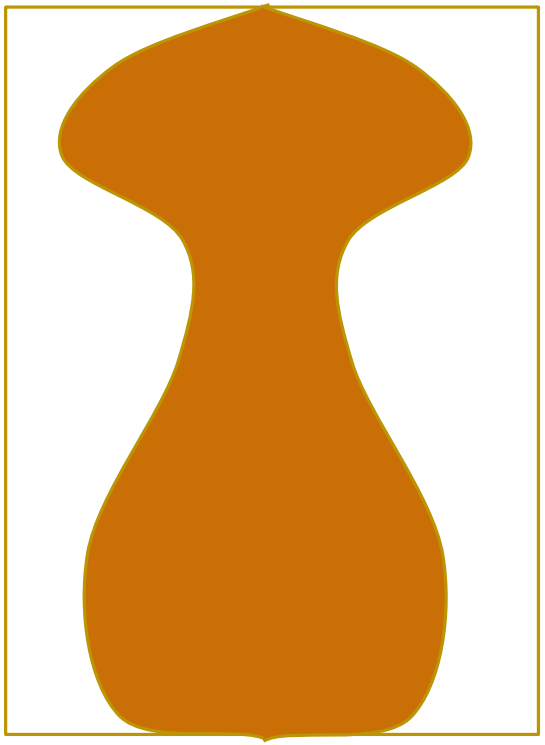


Sundaram, M., Limaye, P., and Ananathasuresh, G. K., "Design of Conjugate and Conjoined Shapes and Tilings using Topology Optimization," *Structural and Multidisciplinary Optimization*, Vol. 45(1), pp. 65-81, 2012.

Complementarity

Think of 3D printing. Can we reduce or even avoid support material?

No complementarity



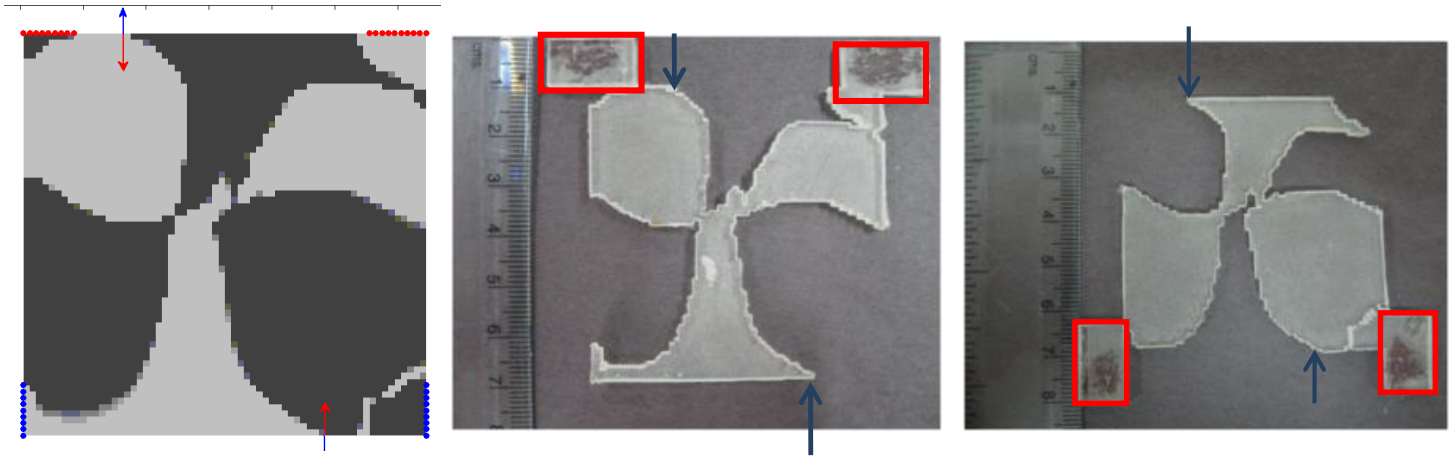
Simple complementarity

Non-trivial complementarity

Complementarity (contd.)

M. C. Escher's designs

Escher-like compliant mechanism topologies



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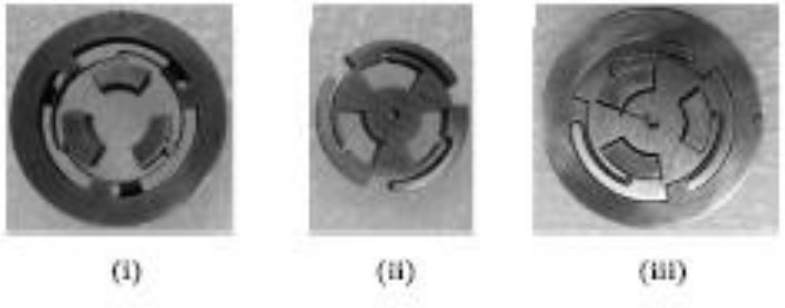

A "centrifugal clutch" and "circumferentially -actuated radial motion compliant mechanism" sharing a circular space.