

Interactive Topology Optimization

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Motivation: Topology Optimization is an engineering tool for optimizing material layout within a design space. To give students of the field an intuition of the topic an interactive application is created where the problem is solved in real-time and the users can see how the algorithm works.

1. Topology Optimization

Topology Optimization is a structural optimization tool, which optimizes the material distribution in a specified design domain in order to maximize stiffness or other objectives. The algorithm is finite element based and used by engineers, architects and industrial designers to find the optimal design given a number of input variables (design domain, boundary conditions, volume fraction, etc.).

This implementation deals with the minimum compliance problem in which the goal is to maximize the stiffness of a structure subject to a constraint on the available material.

2. Application requirements

The application needs to be both intuitive to use and be able to achieve a high frame rate even on devices with low CPU performance. The application should work on both desktop computers as a browser plugin and handheld devices such as touch based smart phones and tablets.

3. Challenges

Standard topology optimization solvers need to be modified to achieve a consistent high frame rate. Besides the solver needs to be able to start from any design and evolve to a new optimum (as can be seen in Figure 2).

These goals are accomplished using the multiresolution (MTOPT) design representation from (Nguyen et al., 2010). We use four design variables for each finite element. The element matrix contribution can be found as the sum of the element's four design variables. This allows us to work on a fine mesh, while the linear equation system is solved at a coarser level.

4. Implementation

The application is implemented using C# in the Unity game engine. The Unity engine abstracts away most platform differences and allows us to use the same codebase for web, Android and iOS devices. Even though modern handheld devices have a lot of computational power, they are still approximately around 10 times slower than a laptop computer. For this reason the resolution of the design domain is adjusted to these devices. The GUI is carefully designed so it works with both mouse and touch input.

The application is available on www.topopt.dtu.dk, Google Play (for Android devices) and AppStore (for iOS devices).

QR code links:



iOS



Android

5. Future work

- Educational game – Gamification of topology optimization
- Interface for 3D topology optimization
- Topology optimization as a 3D shape-modelling tool

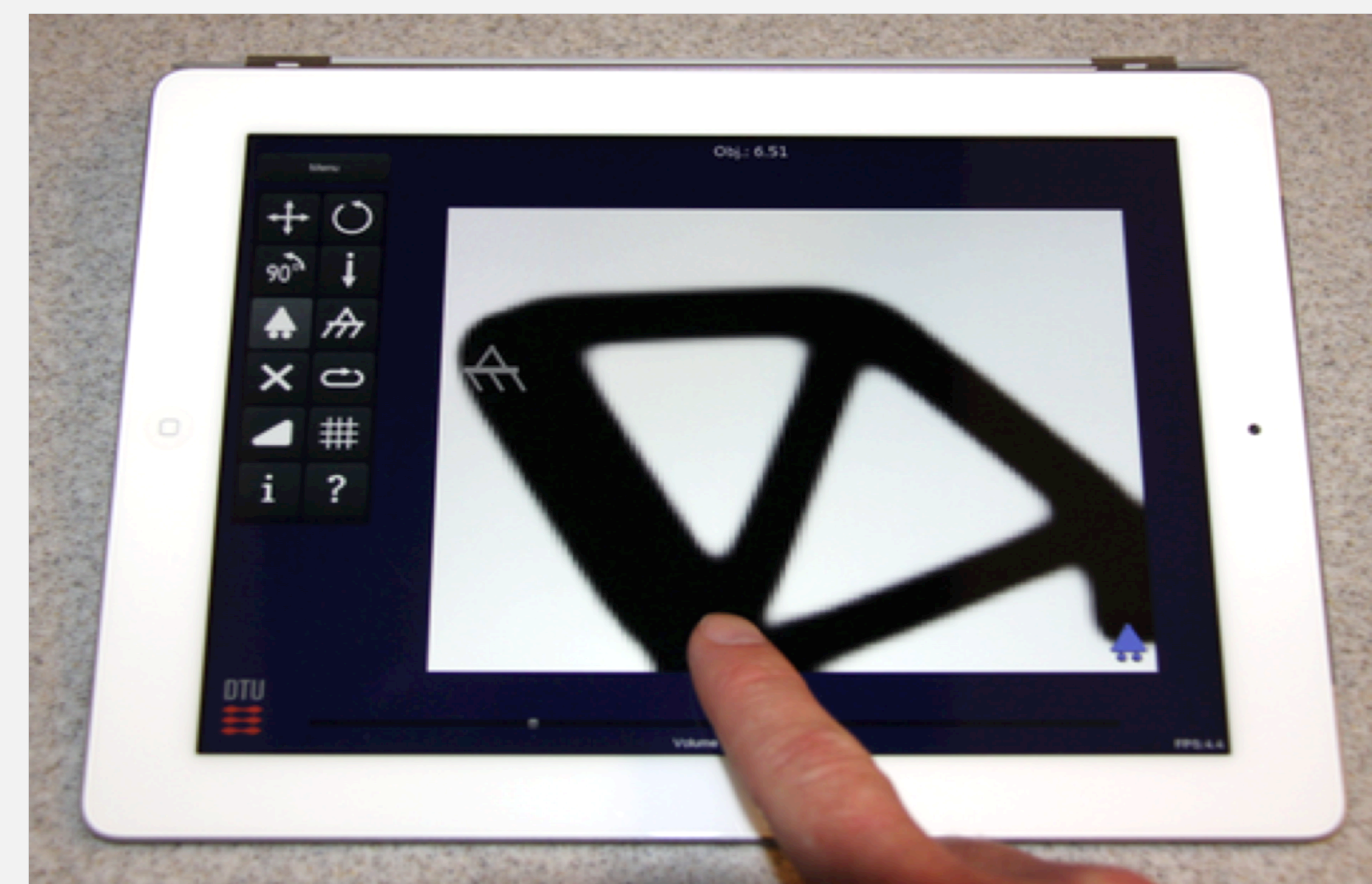


Fig. 1. TopOpt App running on an iPad. Black colour represents material.

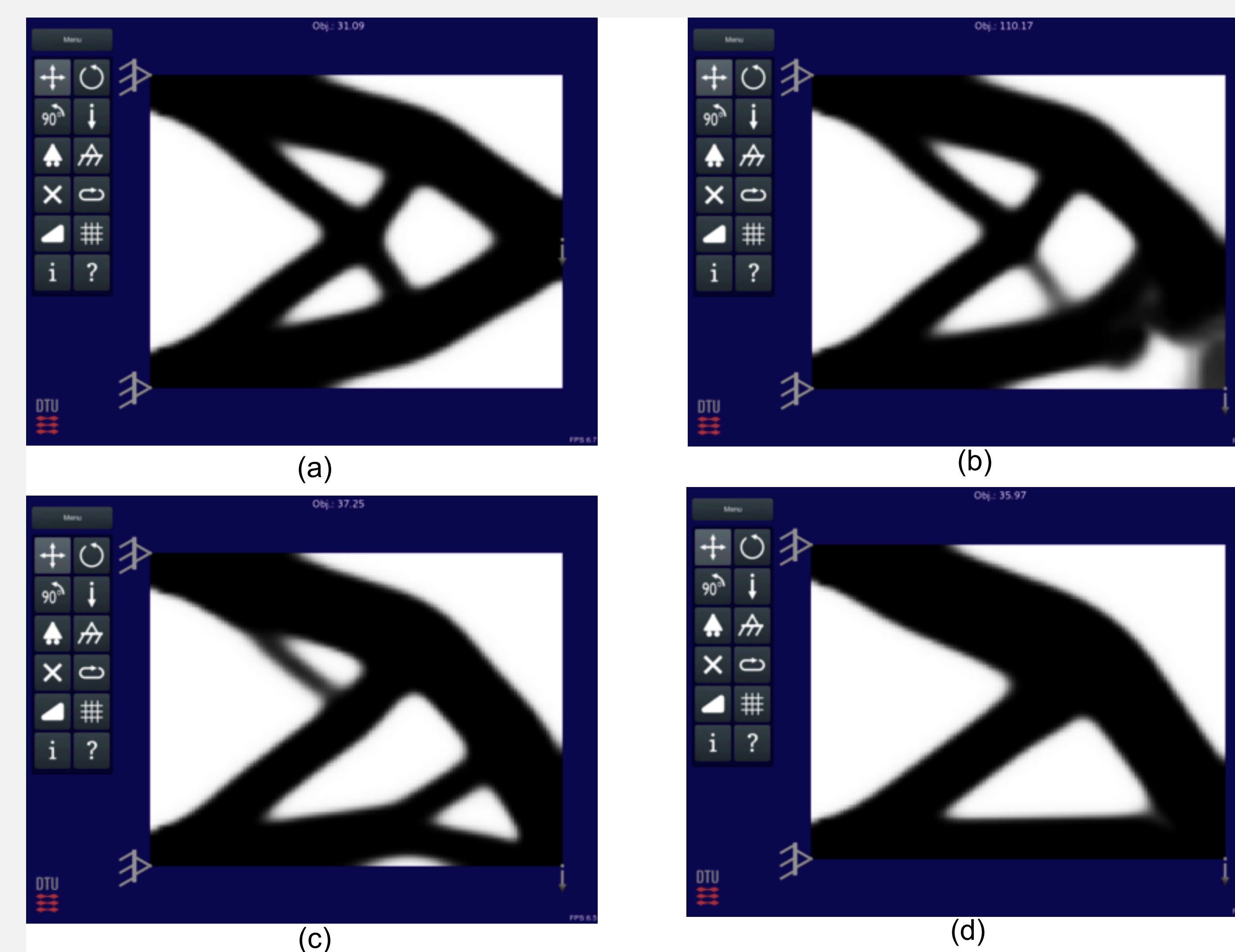


Fig. 2. Screenshots (a) through (d) show how the solution evolves from one optimum to another