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## **ForcePAD**

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*Published in:*

Proceedings of the Twenty Second Nordic Seminar on Computational Mechanics

*Publication date:*

2009

*Document Version*

Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*

Lindemann, J., & Damkilde, L. (2009). ForcePAD: a new User Interface Concept for Design and Optimisation. In L. Damkilde, L. Andersen, A. S. Kristensen, & E. Lund (Eds.), *Proceedings of the Twenty Second Nordic Seminar on Computational Mechanics* (pp. 225-227). Department of Civil Engineering, Aalborg University.

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## ForcePAD - A new user interface concept for design and optimisation

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**Summary** ForcePAD is a 2-dimensional finite element application that started as a concept application for finite element modeling. Over the course of 10 years the application has been evolved into an application that is used extensively in both an educational setting as well as a tool for design and engineering. In the latest version of ForcePAD an optimization module was added to enable to take advantage of topology optimization in the design process.

### Introduction

The traditional finite element modeling process is complex involving several steps and iterations. The complexity is often needed to support the precision needed in the modeling real objects. In a design or architectural setting the need for precision is replaced with the need for quick iterations and the ability to quickly change a design analyse the effects of the changes. ForcePAD [1, 2, 3] is designed to support this development process, reducing the number of steps in the modeling process.

### Analysis tools early in the design process

Early in the design process sketching is often used to iterate over several design concepts. Software supporting sketching is image-editing applications such as Adobe Photoshop [4], GIMP [5] or Paint.NET [6]. The design of ForcePAD is modelled after an image editing application, where color is replaced with stiffness, where black represent max stiffness and white no stiffness. To analyse the model the image is transferred to a finite element mesh, by sampling the image. The modelling workflow is shown in figure 1.

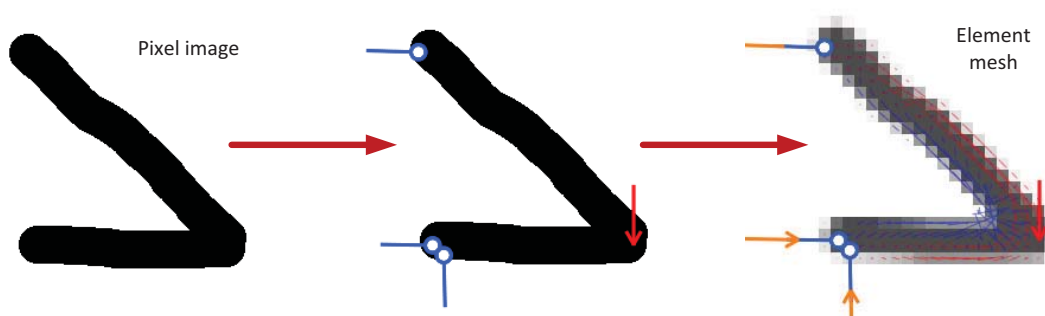


Figure 1: The sketch based modelling workflow of ForcePAD.

### Topology optimisation for finding shapes

In the earlier versions of ForcePAD the user could do some “manual” optimisation by looking at the stress fields and removing unnecessary material. In the latest version of the software a topology optimisation algorithm was added based on work by Bendsoe and Sigmund [7] and Pederson et al. [8]. Using this algorithm topology optimisation can be applied to existing sketches aiding the designer in finding an optimal design. Figure 2 shows the algorithm applied to a rectangular model.

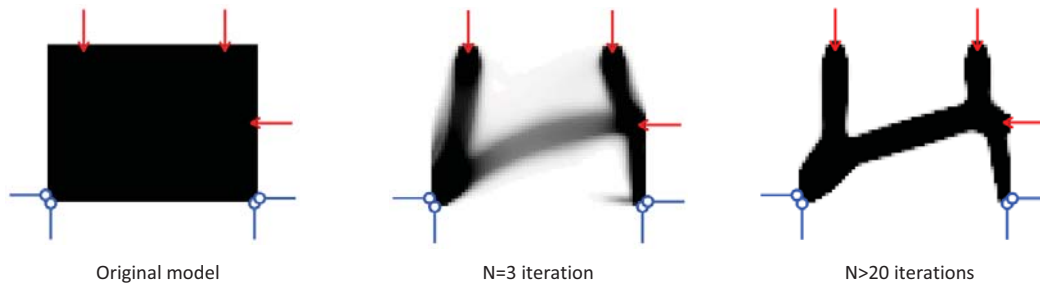


Figure 2: Topology optimisation in ForcePAD.

It is important to note that in this type of application the optimisation algorithm is used to provide the designer with ideas not the final solution. The user can stop the optimisation algorithm at any point and modify the model and restart the algorithm again.

### User interface

To reduce the complexity of the ForcePAD user interface a task-oriented approach is used. This means that if the user is sketching, only tools relevant to that task are visible in the user interface, see **Error! Unknown switch argument.**

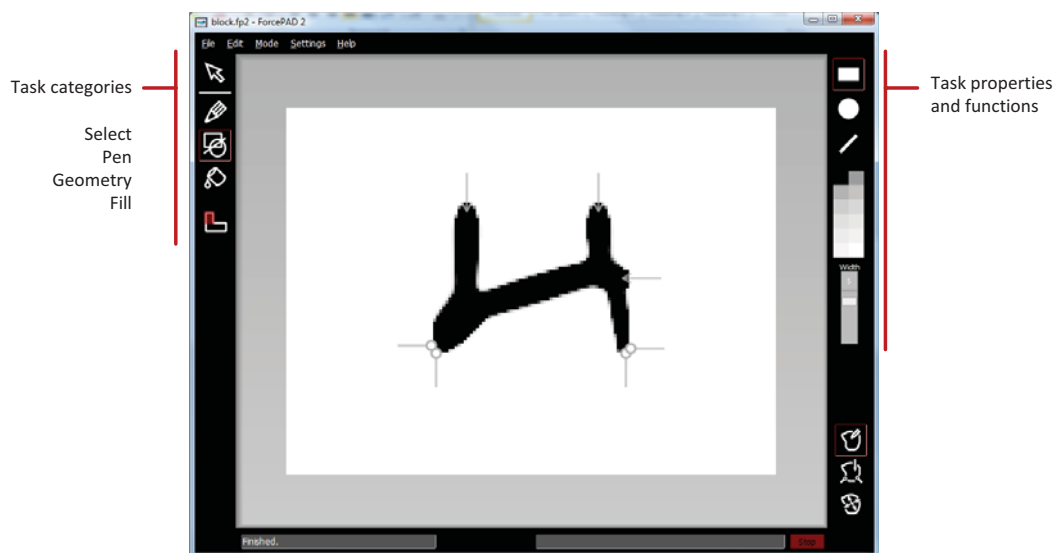


Figure 3: ForcePAD task oriented user interface.

There are 3 main modes in ForcePAD:

- Sketch mode – In this mode the model is created by painting with stiffness.
- Physics mode – In this mode the boundary conditions, such as loads and constraints are applied to the model.
- Action mode – In this mode analysis results can be viewed. It is also possible to modify loads and have the results updated in real-time.

### Implementation

ForcePAD is C++ application that runs on Windows, Mac OS X and Linux. To enable this platform independence the FLTK user interface library [9] is used. The finite element code is implemented using the Newmat11 matrix library [10].

ForcePAD is an open source application [11] that can be downloaded from SourceForge.

## Concluding remarks

ForcePAD provides a new user interface concept for modelling and optimisation that integrates well with the sketch based workflow of designers and architects. The user interfaces reduces the complexity of conventional finite element modelling, enabling easy updates of the model and quick feedback. The user interface is not limited to designers and architects; engineers can also use it as a tool for quickly illustrating design concept.

The reduced complexity also enables it to be effectively used in an educational setting, in which it also has been used for several years.

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