ForcePAD – A New User Interface Metaphore for 2D Finite Element Modeling

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Introduction

- First version developed in 2001
- Developed as a educational tool for understanding shape and force relationships
- Used continuously in courses for architect, design and engineering students
- ForcePAD targets
  - Designers, architects and people without knowledge of material, shape and force relationships.
  - Engineering graduate students as a tool for enhancing their understanding of basic mechanical concepts
A short history

- ForcePAD 1.0.5
  - Painting stiffness on element grid
- ForcePAD 2.0.x – 2.2.x
  - Introduced Image based modeling
- ForcePAD 2.3 –
  - Task oriented
  - New boundary conditions
  - Action mode with real-time updates
Why ForcePAD?

- There was a need for a tool, explaining the basic relationships in mechanics.
- Standard FE Software **too complicated**
  - Geometry modelling
  - Load cases
  - Must have knowledge to use
- ... **too many features**
  - Often designed to be general
  - Solve many types of problems
What is ForcePAD?

- 2D finite element model - Plane stress
- Image based geometry modeling
  - Uses the same user interface metaphores as in image editing software (Paintbrush, Photoshop etc...)
- Stiffness represented as a grayscale
  - White = no stiffness
  - Black = full stiffness
What is ForcePAD?

Pixel image

FE-grid
How do we create an easy to use user interface for 2D FE modeling?
Reducing user interface complexity

- Most evolving applications adds features
  - Users want features => more icons/menus
  - Application becomes complex
  - Donald Normal calls this “creeping featurism”
- Even simple FE user interfaces has to handle many features
- Solutions:
  - Avoidance and restrain (not always possible)
  - Organisation and modularisation
    - functions divided into modules with each a limited set of functions
ForcePAD 2.2 series

- Flipouts
- Many buttons
- Property panels
Solution?

- Task oriented user interface
  - Show only the tools needed for the task at hand
- To support this ForcePAD divided into 3 main modes
  - Sketch mode
  - Physics mode
  - Action mode
- Left toolbar - main tasks for the selected mode
- Right toolbar - task oriented commands
ForcePAD 2.3 series

Application modes
Sketch mode
Physics mode
Action mode

Main tasks
Task operations

Drawing area
Sketch mode

- Used to model the structure to be studied
- Modelling is done by ”Painting” with stiffness
- Available tasks
  - Select
  - Brush
  - Geometric tools
  - Flood fill
- All tasks are the same as in a conventional image editing application
Select

Selection marker
Cut
Copy
Paste
Paste from system clipboard
Brush

- Brush mode
- Erase mode
- Stiffness selection
- Brush size
Geometric tools

Rectangle tool
Circle tools
Line tool
Stiffness selector
Flood fill

Stiffness selector
Physics mode

- Defines the physical constraints of the problems
  - Forces
  - Constraints
  - Hinges (In the final 2.3.0 release)
  - Cuts (In the final 2.3.0 release)

- Tasks:
  - Forces
  - Constraints
Forces

Add forces

Erase forces

Enable self-weight
Constraints

- Add constraint
- Erase constraint
- Rotate constraint
Action mode

- Representation of the structure subjected to loads and constraints
- No "Start Calculation" button
  - Simulation is done when transitioning to action mode
  - Model must be consistent before entering action mode
- Visual representations of
  - Stress
  - Displacements
Action mode continued...

- Many parameters for the visualisation can be changed
  - Transparency, Arrow size, thickness, repeat etc.
  - Filters for compressive/tensile stress
  - Stress threshold

- Action mode provides 3 tasks
  - Principal stresses
  - Mises stresses (under development)
  - Displacements

- Applied forces can be modified in real-time.
  - This applies for all visualisation tasks
Principal stresses

- Arrow size control
- Stress arrow transparency
- Stress arrow skip control
- Stop autoscaling of result stress arrows
- Show compression and tension
- Show only tension
- Show only compression
Von Mises Stresses

“Jet” colorscale

“Hot” colorscale

Set threshold for max colorscale

Invert colorscale
Displacements
Real-time model modification
Real-time model modification
Interacting with other programs

- Most designers and architects use the sketch as the main design tool
- Software tools such as Adobe Illustrator, Photoshop are also common
- ForcePAD has the ability to import pictures from files or the clipboard
  - Scanned sketches can be used
  - Sketches in Photoshop can be imported directly
Interacting with other programs
Implementation goals

- Fast and responsive
  - Fast visualisations
  - Fast drawing
  - Fast solving
- Modern GUI
  - Hints
  - High-colored icons
  - Standard toolset
- Platform independent
  - Mac OS X, Linux and Windows
Implementation

- **Language**
  - C++

- **User interface**
  - Fast Light Toolkit (FLTK 1.1.x)
    - Available for Linux, Mac OS X and Windows
    - Very good performance on all platforms

- **Solver**
  - Implemeted using the NEWMAT11 library

- **Graphics**
  - OpenGL
    - Interface to hardware accelerated 3D and 2D
    - Fast rasterisation interface
    - Platform independent
Conclusions

- ForcePAD is an effective and easy to use educational software
- ForcePAD can be used in both engineering and design science education
- FE modeling without "geometry" definition for quick and easy modeling
- Visualisation and understanding of internal forces, part of the design process
- Task based user interface for reduced complexity
Future work

- More constraints types with intuitive user interface metaphors
- Eigenmodes
- Enable real-time constraint modification in action-mode
- Take advantage of multi-core for even more effective solvers
- Open the ForcePAD application, enabling custom application types and solvers
  - Current source available on sourceforge via subversion
Getting ForcePAD

www.byggmek.lth.se/resources/software