Engineering Optimization

• Most engineering design involves using optimization software
• Minimizes or maximizes a merit function
• Applies functional constraints
• Applies regional constraints
You Must…

• Select or define
  – the Merit Function (MF)
  – the Analysis Variables (AV)
  – and their sub-set of Design Variables (DV)
  – the Analysis Functions (AF)

• Define the constraints
  – Functional
  – Regional
Software Tools

• At least 4 software tools to solve optimization problems of different scope:
  – COSMOS finite element stress & thermal
  – ANSYS finite element multi-physics
  – OPTDESX user defined
  – TK Solver user defined
Problem Scopes

• Large FE system with a limited number of pre-defined MF, AV, DV, AF.

• **MF** is a user defined equation. Very general ability defined by application dependent subroutines in f90 or C.
OptdesX

• The X-Windows interface to the Optdes (Optimum design) system.
• Requires 3 user-written, compiled, and linked subroutines (for AV, AF, MF).
• Optionally, user can supply operating system commands to use a big “black box” code to form the MF.
• You supply consistent units.
OptdesX Interface

• Allows \textit{interactive selection} (mapping) of the DV from the AV.

• Allows \textit{interactive definition} of the problem constraints.

• Allows \textit{interactive definition} of multiple Merit Functions (MFs).

• \textbf{Graphical displays} of design history, etc.
OptdesX Algorithms

• Includes multiple algorithms for
  – **Continuous** optimization (smoothly changing variables)
  – **Discontinuous** optimization (tabular non-smooth items like pipe sizes or standard structural shapes)
3 OptdesX Subroutines

- **ANAPRE** (ANAlysis PRE-processor) is called only once. Open files, etc.
- **ANAFUN** (ANAlysis FUNctions) is called every iteration to define MF, etc.
- **ANAPOS** (ANAlysis POSt-processor) is called only if the user hits the post-process button.
Subroutine ANAPRE (model_name)

- Provides one time calculations, if any, before optimization.
- Can also be used to open files needed in ANAPOS or to initialize ANAPRE.
- Often it simply sets the model_Name (of 17 characters, max).
Subroutine ANAFUN, 1

• Provides **double precision** analysis function calculations of the trial vector

• **Three major segments:**
  
  – a) **gets** the scalar Analysis Variable (AV) values from the X-Window subprogram AVDSCA
  
  – b) you must use those AV names to **compute** needed constants and the Analysis Functions (AF) values
  
  – c) **returns** the scalar Analysis Function (AF) values to the X-Window subprogram AFDSCA
Subroutine ANAFUN, 2

• Step b) above could call any other analysis program, such as an FE code.
• Optdes provides a operating system level interface to aid with the calls
• Optdes can run in background
• These options are difficult to implement
X-Window Interfaces

• Two arguments to AVDSCA
  – local variable name used in ANAFUN
  – name (and units) used in the X-Window display, limited to 15 characters.

• Two arguments to AVFSCA
  – local variable name you created for the analysis function in step b.),
  – name (and units) used in the X-Window display, limited to 15 characters.
Subroutine ANAPOS

• Provides **optional** calculations, if any, after optimization

• Can be invoked by pushing the "Post process" button in the Design Variable Window

• Usually, if this function actually does any calculations they are written to a I/O unit you opened in ANAPRE
ANAPRE, ANAFUN, ANAPOS

• Fortran 90 source examples are on class web page, with compile, link, and run info.

• C and f77 source examples are in online manual.
ANAPRE, ANAFUN, ANAPOS

• Most common errors:
  – Integer division instead of double precision, $1 / 2 = 0$, not $0.5d0$ as do $1.d0 / 2$ or $1 / 2.d0$
  – Inconsistent engineering units in input and analysis functions
  – Omitting units in X-Window displays
OptdesX Documentation

• PDF Manual is on class web site
• Continuous optimization tutorial on p. 30
• Discrete optimization tutorial on p. 80
• Algorithm theories on p. 175
• Contents on p. 4, Index on p. 230
• Example source files are on class web site