A Tabu Search Environment for Engineering Design Optimisation

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Introduction

- Assumptions
- Background and History
- Introduction to Tabu Search
- Software Structure
- Applications
- Current Development Status
- Challenges
- Conclusions

Assumptions

- You know nothing about:
  - Me
  - SERL & AUT
  - Tabu Search
- Apologies if these assumptions are incorrect

Personal Background

- A mechanical engineer by education
- A software engineer by osmosis
- Ten years of academic and commercial experience in applying optimisation methods
- Previously focussed on practical application and “good” results
- At SERL the focus can be on the method and “elegance”

SERL and AUT

- The Software Engineering Research Lab is one of four research groups in Computer Science at AUT, the Auckland University of Technology
- SERL is a small, multidisciplinary team with research interests in:
  - Natural language processing
  - Numerical methods
  - Multi-agent systems
  - Software forensics

Project History

- Tabu Search first implemented whilst at the University of Bath for Fluid Power System design
- Further developed at the University of Cambridge and successfully applied to a wide range of problems
- Currently being refined and “repackaged” to enhance usability at AUT

Introduction to Tabu Search

- Tabu search is an optimisation method developed by Fred Glover in the late 80s
- It has been successfully applied to a wide range of both classical and practical real world problems
- Tabu search has always been the “poor cousin” to Genetic Algorithms and Simulated Annealing
  - A Google search returns 32,000 references for “Tabu Search”, 130,000 references for “Simulated Annealing” and 360,000 references for “Genetic Algorithms”

What Actually is Tabu Search?

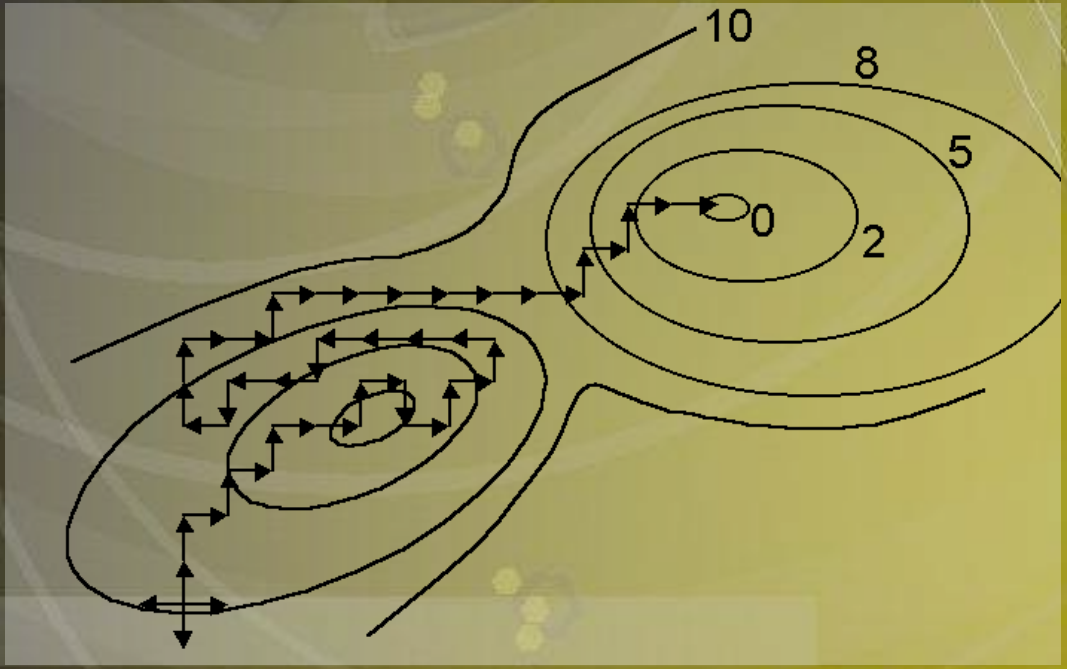
- Tabu search is a meta-heuristic that can be used to guide a search method to a global optima
- Rather than avoid local optima, the approach locates and “moves through” these optima
- The method utilises “cyclic memory” to retain information regarding the search and this information is used to guide the search into new areas of the solution space

Tabu Search Implementation

- The Tabu Search implementation presented here is based on a Hooke and Jeeves method
- Three different memory cycles are used
  - Short term memory is used to escape local optima
  - Intermediate term memory focuses the search
  - Long term memory expands the search
- Aspiration criteria are not implemented

Short Term Memory

- Short term memory is implemented as a list of recently visited solutions that are classed as “tabu”



Intermediate and Long Term Memory

- Intermediate memory is a similar list of previously visited “good” solutions
  - The search is focussed by examining and reinforcing characteristics that “good” solutions have in common
- Long term memory is a list of previously visited solutions stored at fixed intervals
  - The search is expanded by generating new solutions that are dissimilar to those in both the intermediate and long term memory

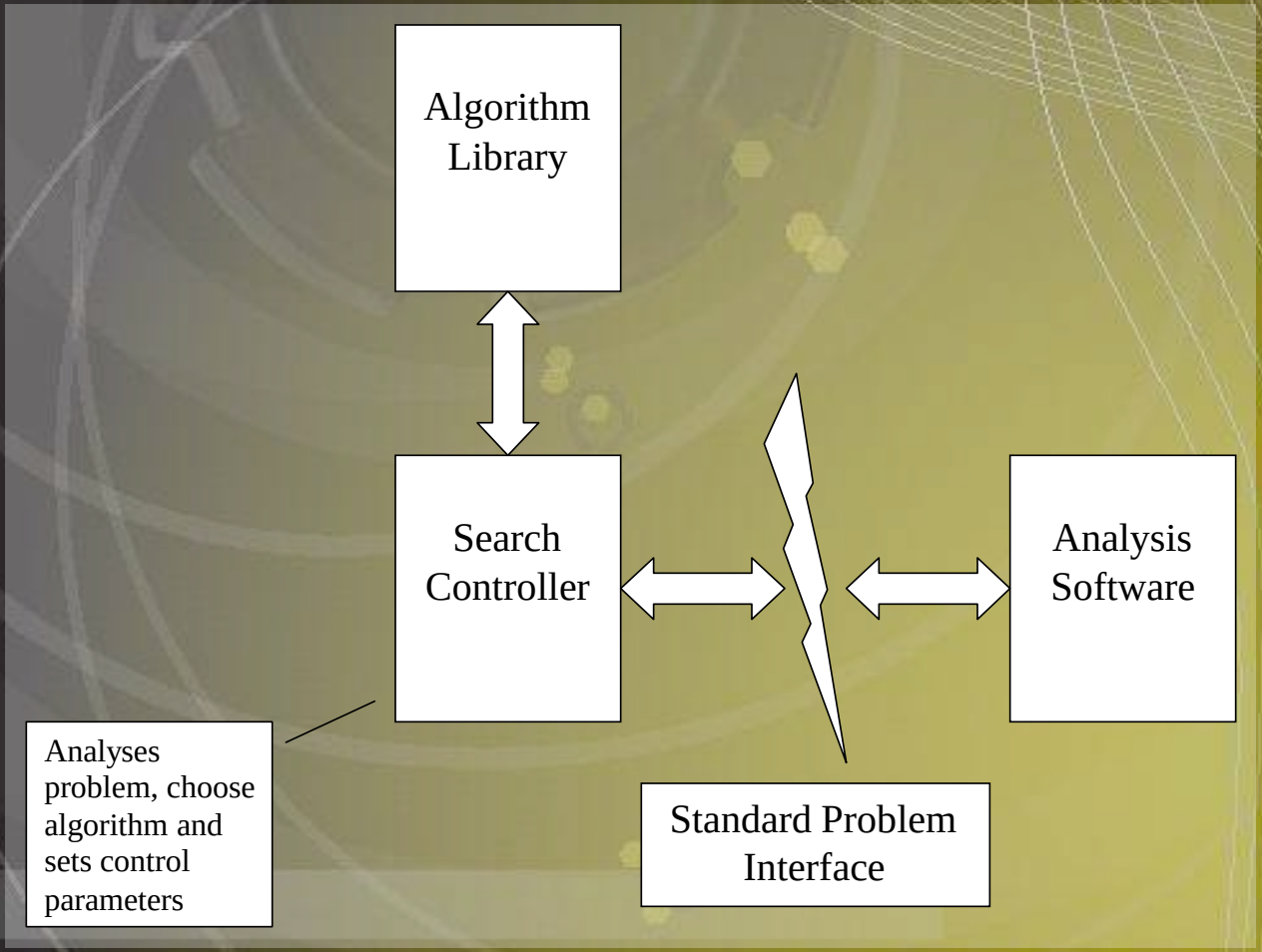
Search Control

- Progression through the solution space is monitored
- Search parameters are defined that determine at what point intensification (increasing focus) and diversification (expanding focus) occur
- Similarly, when progression has not resulted in improvement the step size is adjusted
  - Variable step size has been found to improve performance

Variations to the Algorithm

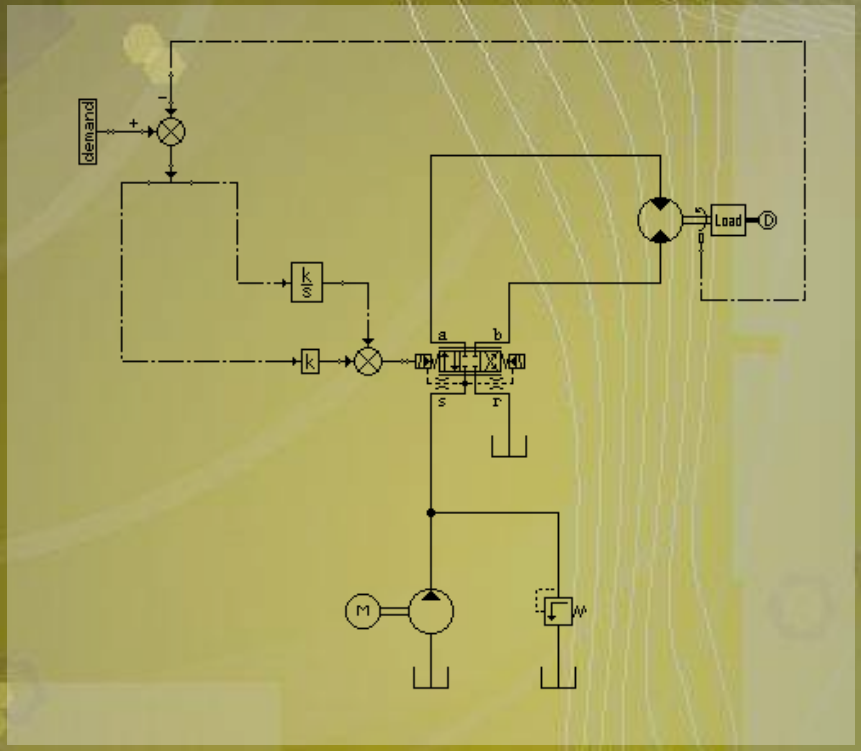
- The basic implementation is a single search thread for single objective problems
- Variations available in the algorithm include:
  - Multiple search threads that share information
  - Multi-objective search

Software Structure



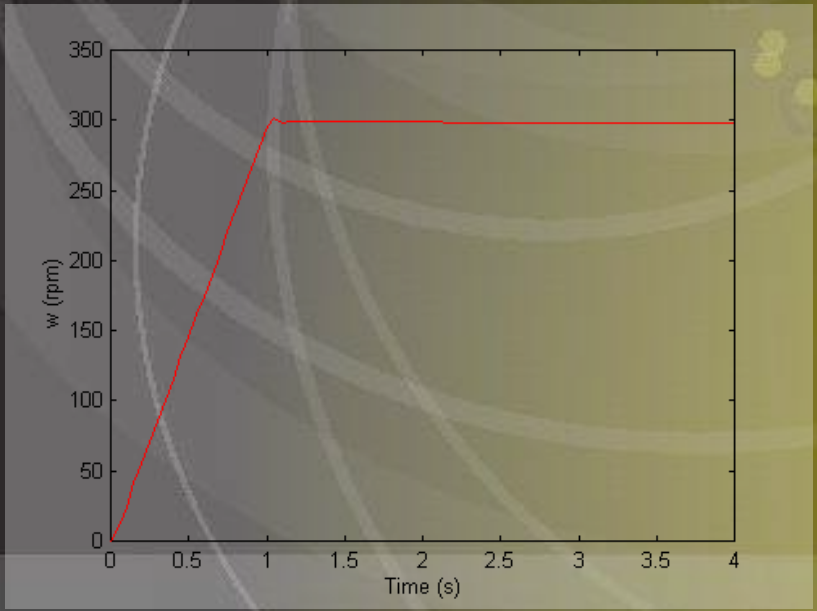
Application: Fluid Power Systems

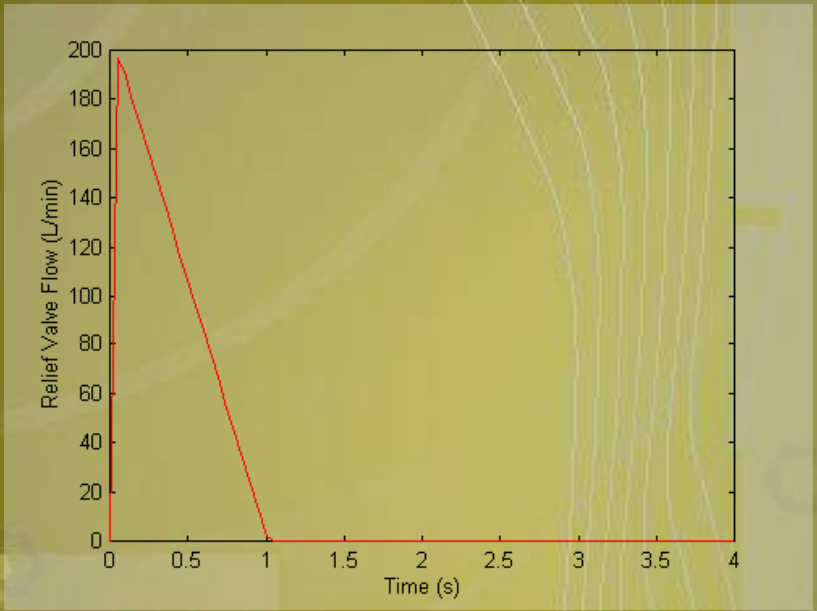
- An electrical proportional servo valve is use to modulate the flow from the pump so that the speed of the motor follows a desired profile
- The design parameters are the pump and motor displacements and the integral gain of the control system.



Application: Fluid Power Systems

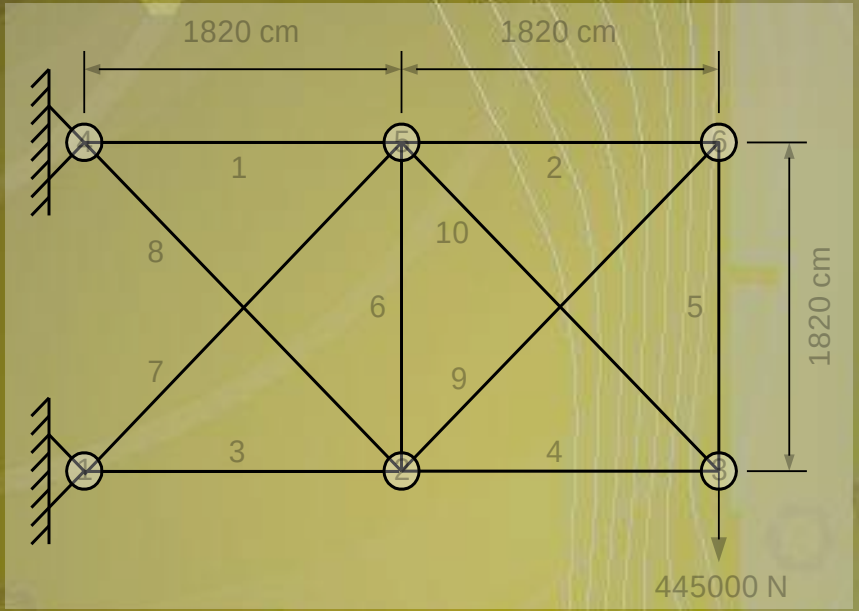
- The Tabu Search algorithm finds “reasonable” solutions in one quarter of the time than the previously used GA





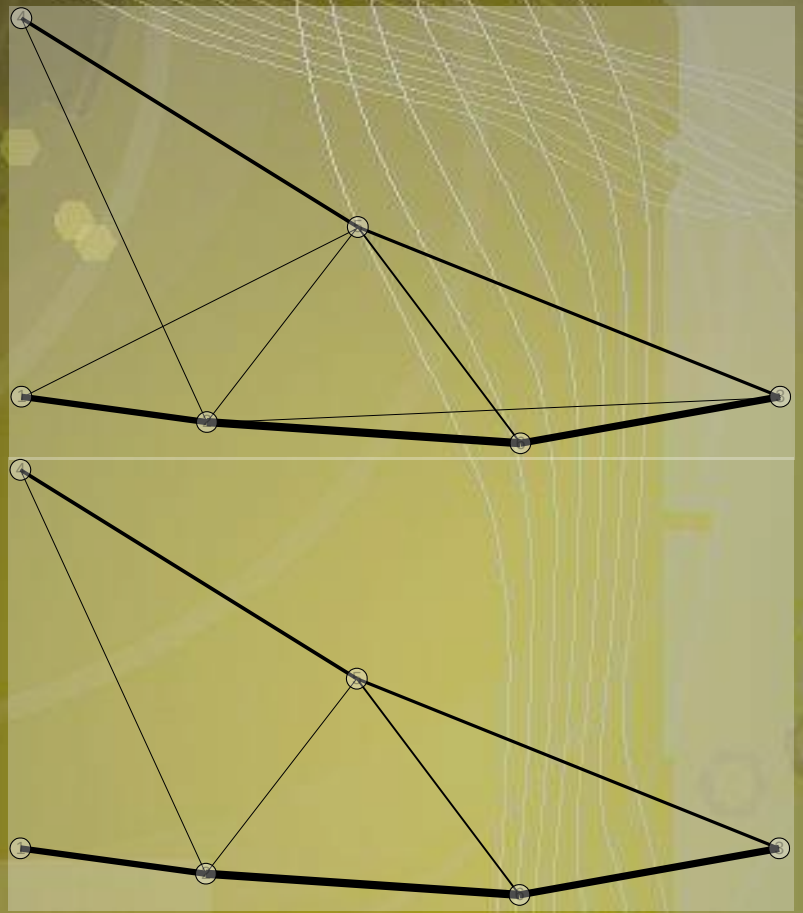
Application: Structural Design

- The ten bar truss is a classic structural design problem
- The design variables are the x-sectional area of the struts and the position of the unfixed nodes
- A comparison has been made to a mature Simulated Annealing algorithm



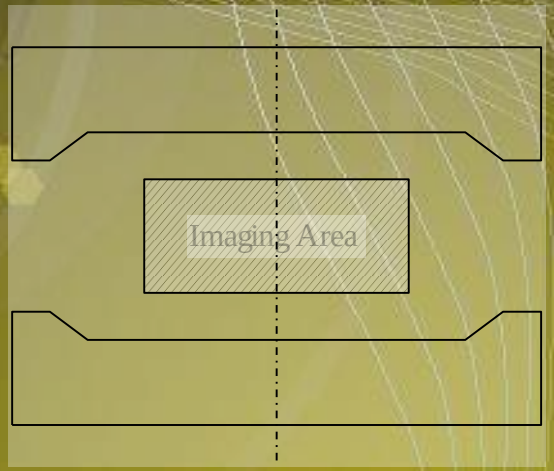
Application: Structural Design

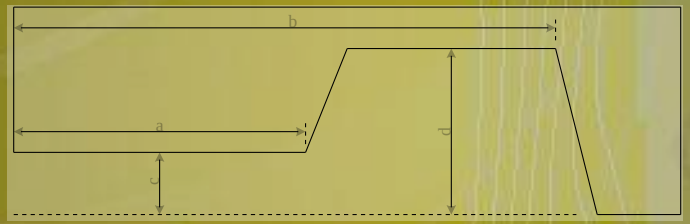
- The Tabu Search implementation finds elegant, low weight solutions
- These solutions do not violate the problem constraints
- The solution is different (but comparable to) that found by SA, but the search was more efficient



Application: MRI Pole Shape Design

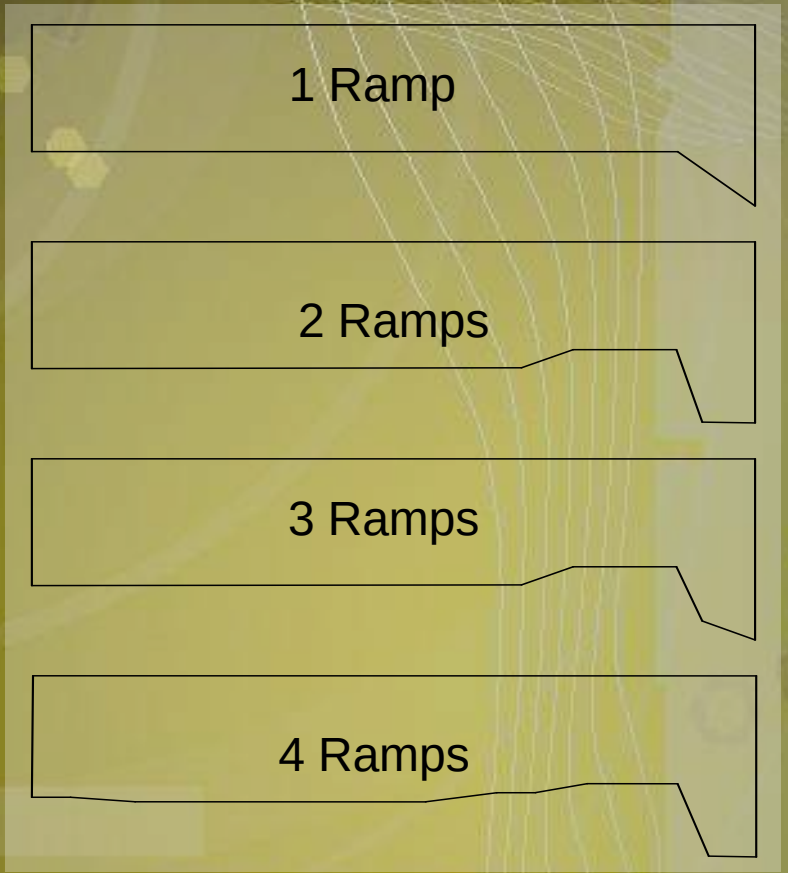
- MRI scanning requires a constant magnetic field in the imaging area
- The aim of this study was to investigate different parameterisations of the pole shape





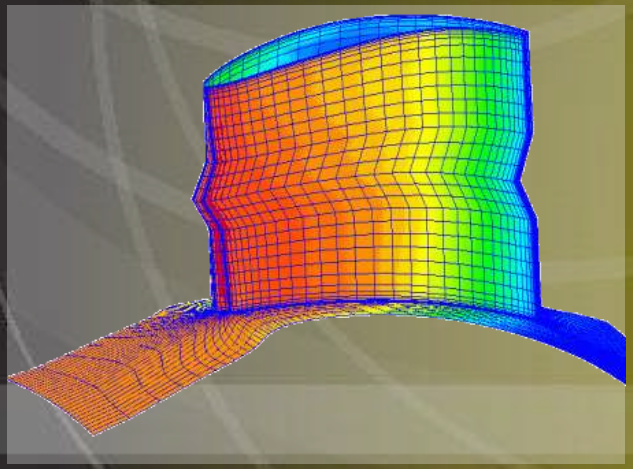
MRI Pole Shape Optimisation

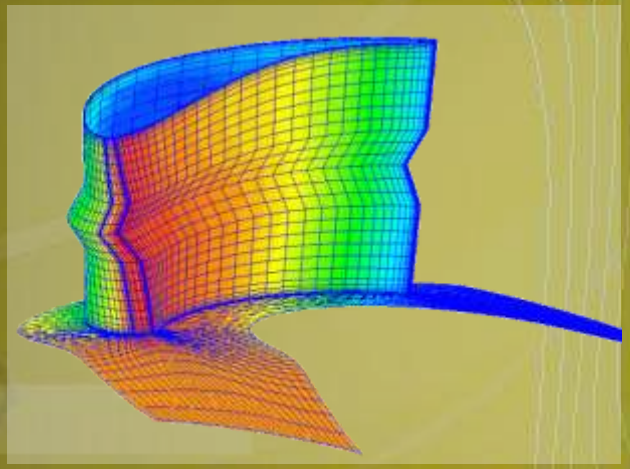
- By parameterising the pole shape, very efficient searches were enabled by allowing complex pole shapes to be described
- Search efficiency was an order of magnitude greater than allowing “free form” pole shapes



Application: Gas Turbines

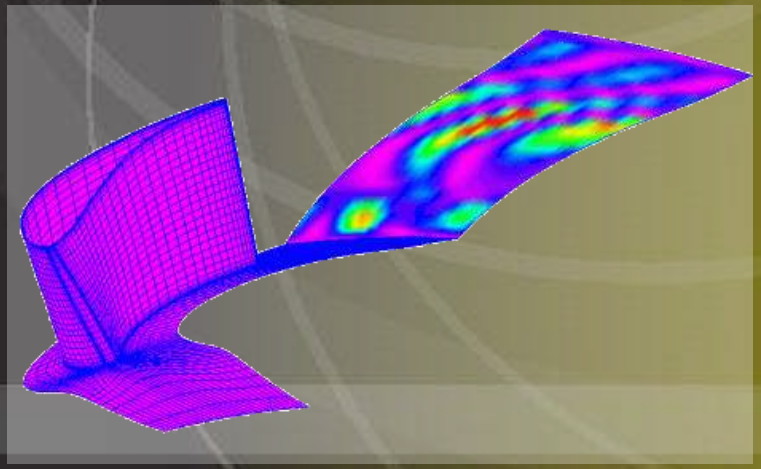
- The objective of the design effort is to minimize the secondary-flow kinetic energy (SKE) of a nozzle-guide vane (NGV)
- Results for two design categories namely lean (YCEN) and sweep (XCEN) are combined

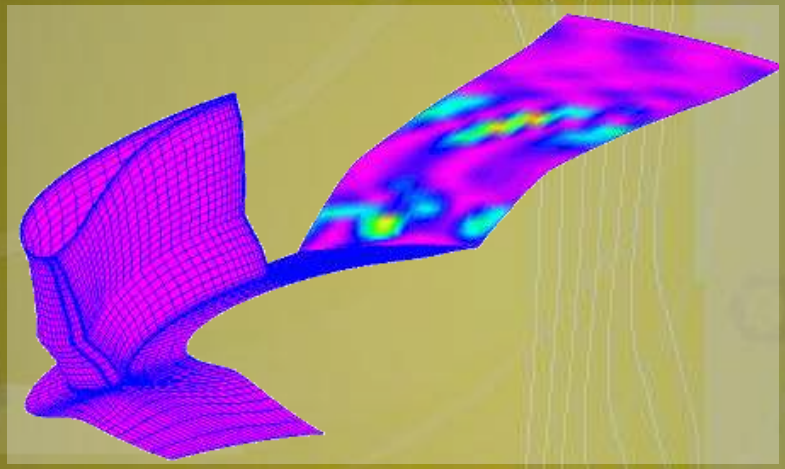




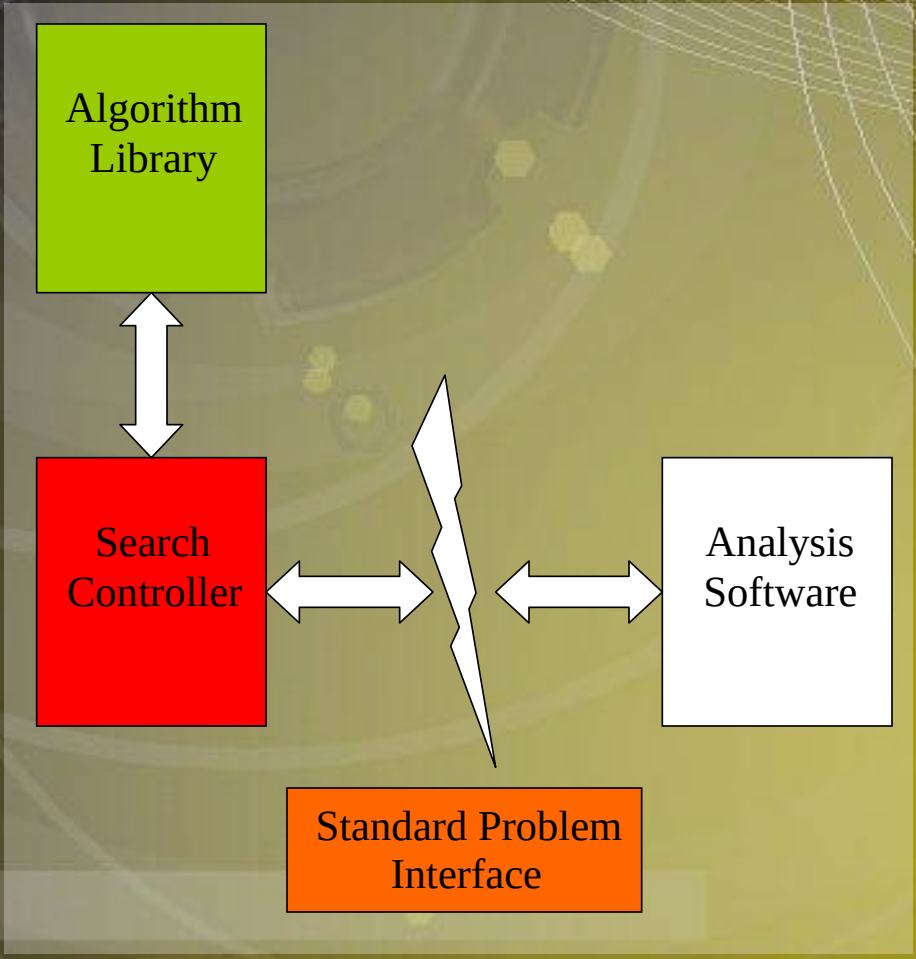
Application: Gas Turbines

- The contours of the SKE at the exit plane of the base and optimised geometry using 14 design parameters including lean and sweep design categories are plotted
- The optimised geometry shows a reduction in the secondary flow kinetic energy





Current Development Status



Challenges

- Capturing implicit knowledge regarding algorithm selection and setting control parameters and embedding this into the environment
- Defining a common interface to allow different analysis software to be easily accommodated
- Improving the user interface

Conclusions

- Tabu Search is a fun method
- Tabu Search works on a variety of different problem types
- Tabu Search can find good solutions more efficiently than other heuristic methods……

- ….. but there's still a lot to do!