

Teaching Optimization

Product Realization, Linköping University

Johan Persson

Product Realization

- Four groups
 - Design
 - Integrated Product and Production Development
 - Industrial Production
 - Design Automation Laboratory
- Educating engineers during years 1-5 in the programs
 - Mechanical Engineering
 - Design and Product Development

Design Automation Laboratory

Receive design suggestions automatically and minimize repetitive work

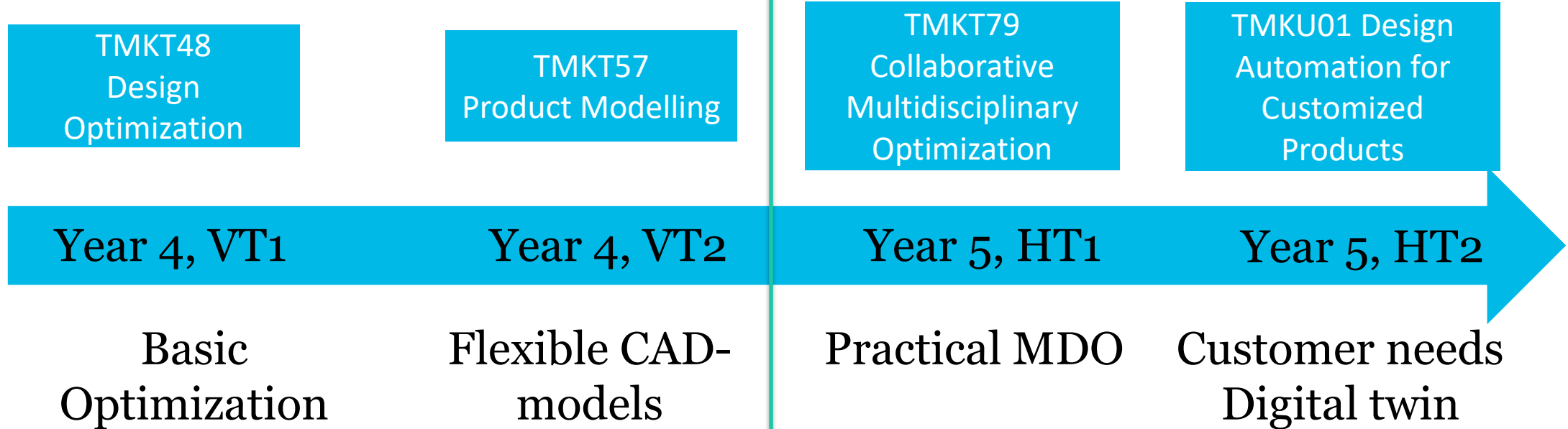
Methods

- Flexible CAD-models
- Modeling, Simulation and Optimization
- Machine Learning

Philosophy

- Combine optimization skills with engineering skills
- Tutorials to learn the basics / methods
- Projects to demonstrate that they can apply the methods
- We are trying to teach methods and tools that we think will be important in the future
 - Parametric CAD (TMKT57) started 2008
 - Multidisciplinary optimization (TMKT79) started 2014
- We constantly attempt to introduce knowledge and methods from our research in our courses to keep the course content relevant

Course Package



TMKT48 Design Optimization

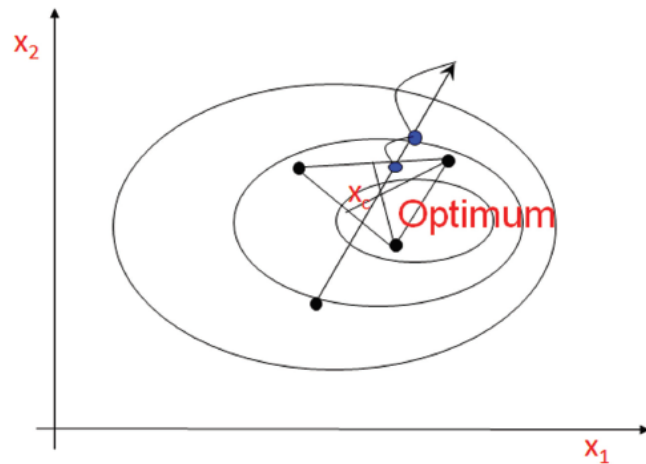
- Introduce
 - Modeling
 - Simulation
 - Optimization
- MATLAB
- Simulink

OPTIMIZATION ALGORITHMS

How they work
Advantages
Disadvantages

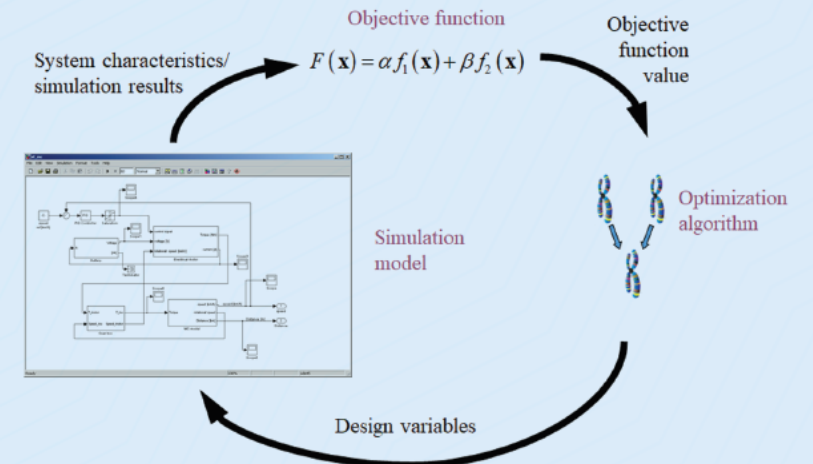
Algorithms
such as:

- Complex
- Genetic Algorithms
- Gradient-Based
- Particle Swarms



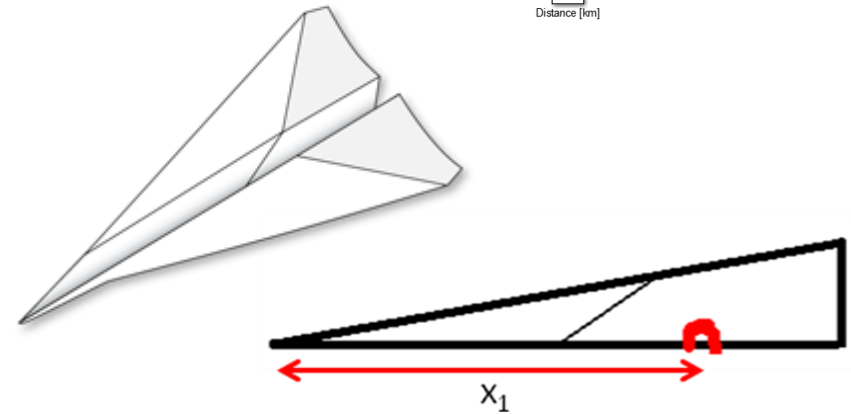
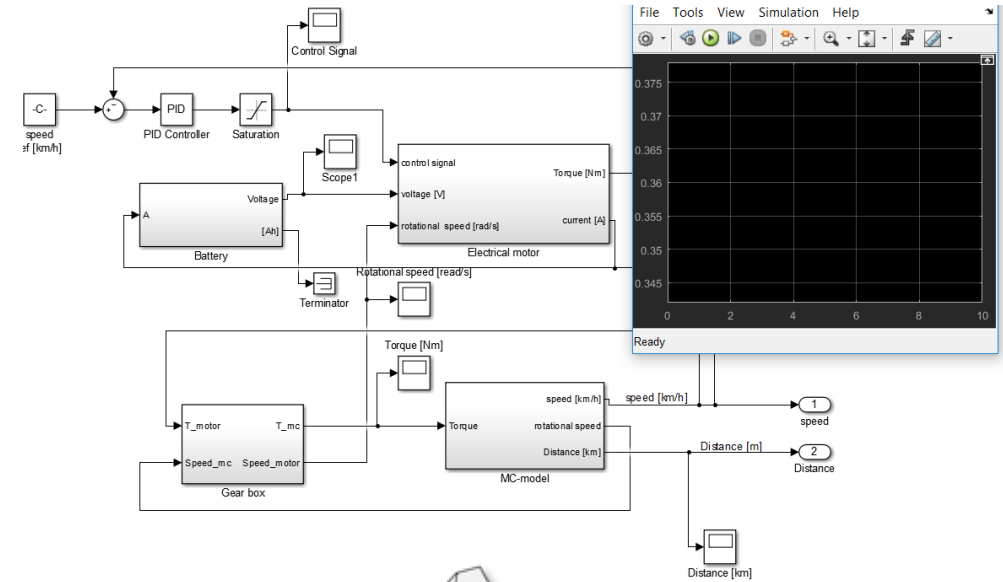
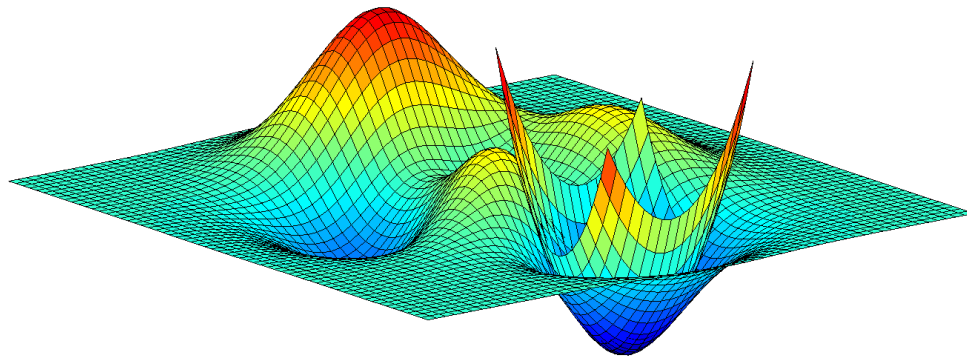
SIMULATION BASED OPTIMIZATION

Include simulation models
in the optimization



TMKT48 Design Optimization

- Optimization Algorithms
- Multi Objective Optimization
- Surrogate/Meta models
- Sensitivity Analysis
- Probabilistic Optimization
- Select Design



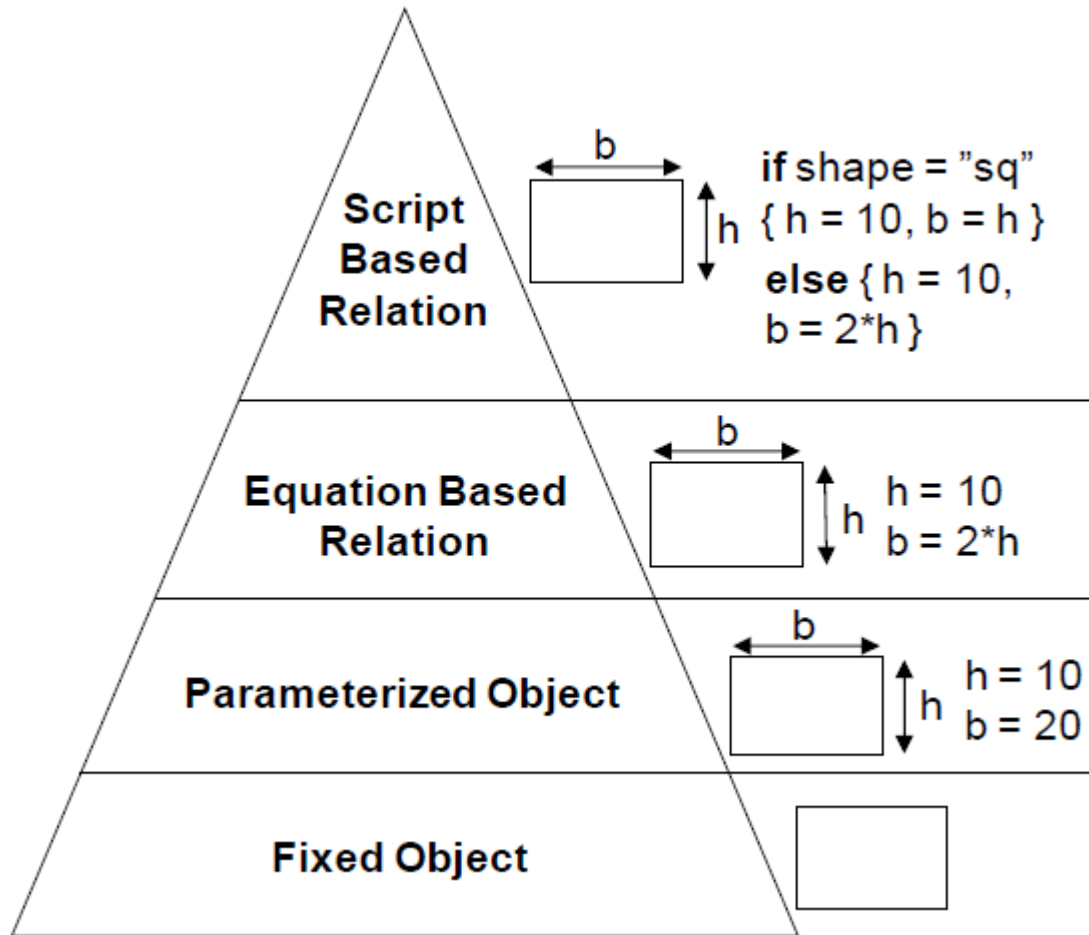
TMKT57 Product Modeling

- Flexible CAD-Models
 - Minimize repetitive work
 - Optimization

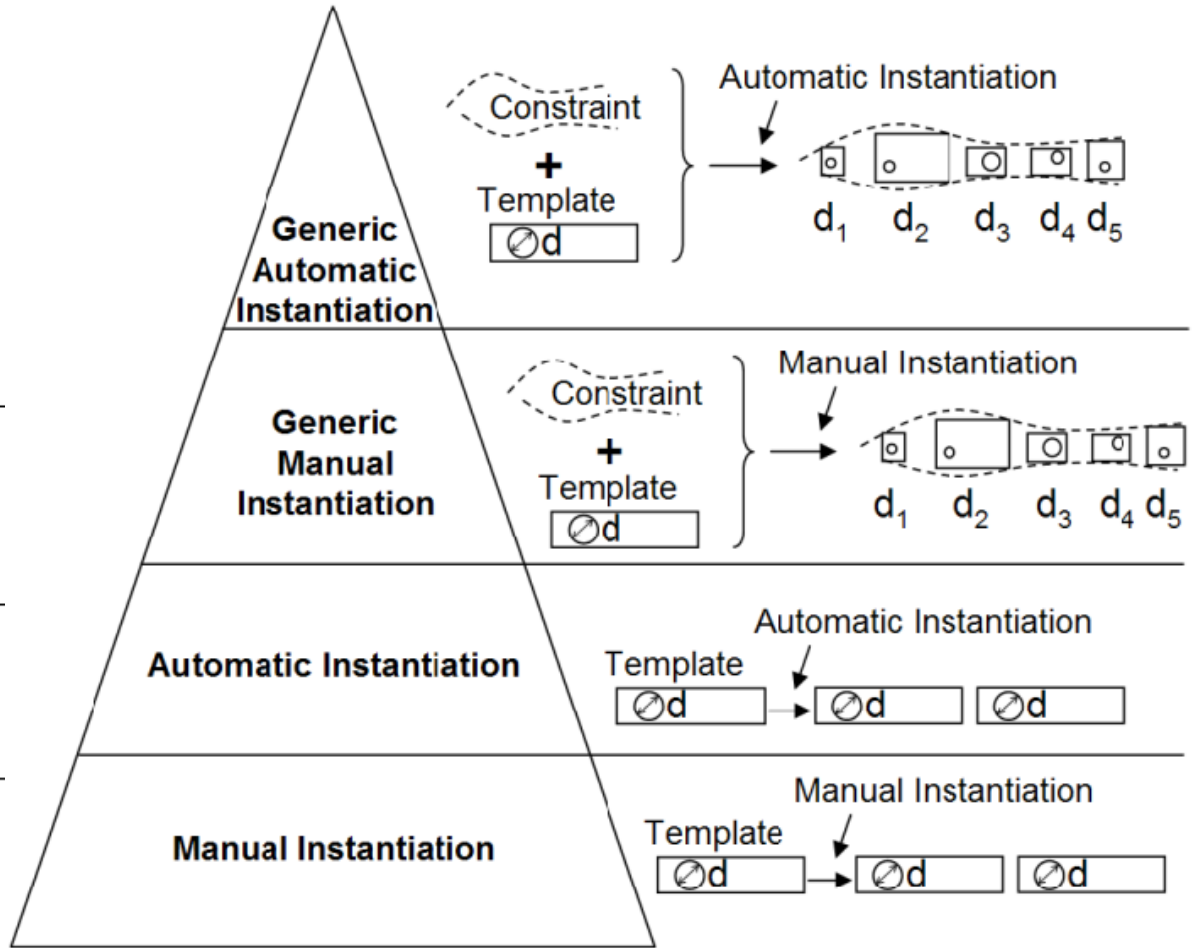
- CATIA
- VBA
- EXCEL



TMKT57 Product Modeling



Morphological Changes



Topological Changes

TMKT57 Product Modeling



How can a structure as complex as a helix bridge be built and rebuilt again and again by four people?
The answer lies in automation!

XLS CATIA VBA CODE



Three out of an infinite number of possibilities
Further instantiation

EXECUTION

To achieve our goals, we used different tools. We used CATIA V5 to model the island and create all the parts and surfaces. We used CATIA's own powercopy function to easily instantiate the houses, roof branches and pillars.

The model is generated automatically with VB script and the floors, roof surface and roof pattern are generated through code. For the final touch ups we used Autodesk Fusion 360 to render presentation pictures of the island.

NUMBER OF HOUSES



HEIGHT OF HOUSES



NUMBER OF BRANCHES



A project in TMKT57 at Linköping University by
Elin Mikaelsson, Julia Lindhagen, Ida Franzen and Raymond Xue



AUTOMATICALLY INSTANTIATED TENSILE STRUCTURES

LINKÖPING UNIVERSITY TMKT57 - PRODUCT MODELLING, V1 2018

MISSION
The goal was to create a tool to create and simulate the structure of a helix bridge. By allowing design submission multiple times can be generated in a computer instead of a designer of engineer. This enables the designer/engineer to have more time in improving the design.

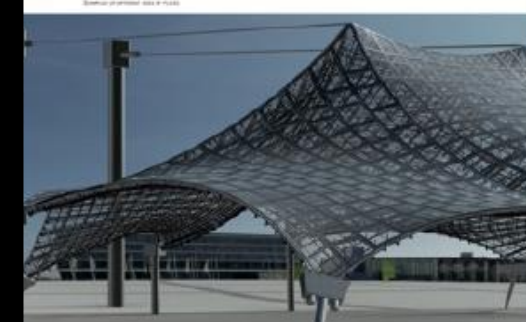
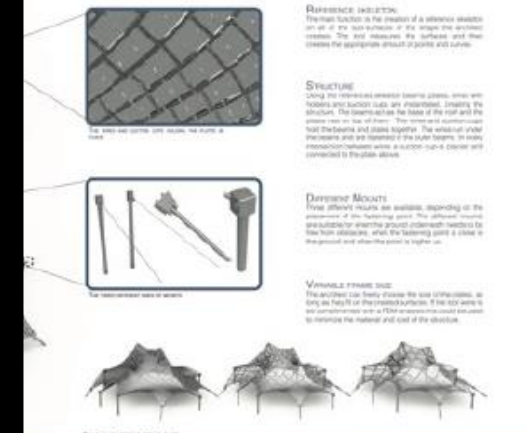
CREATING THE SHAPE
The model can be created any time, but needed for well-structured surfaces with few edges/faces the tool can be used. It is also necessary to have all the sub-surfaces, order and construction automatically. However, this is the only manual task.

REFERENCE INSTANTIATION
The main function is to instantiate a reference structure. The tool measures the surfaces and then creates the appropriate structure in points and curves.

STRUCTURE
Using the reference structure, the tool can create the structure. The tool can create the structure and then connect the beams and plates together. The structural analysis process and will determine the force factors, to make interaction/analysis with a custom script and then connected to the data sheets.

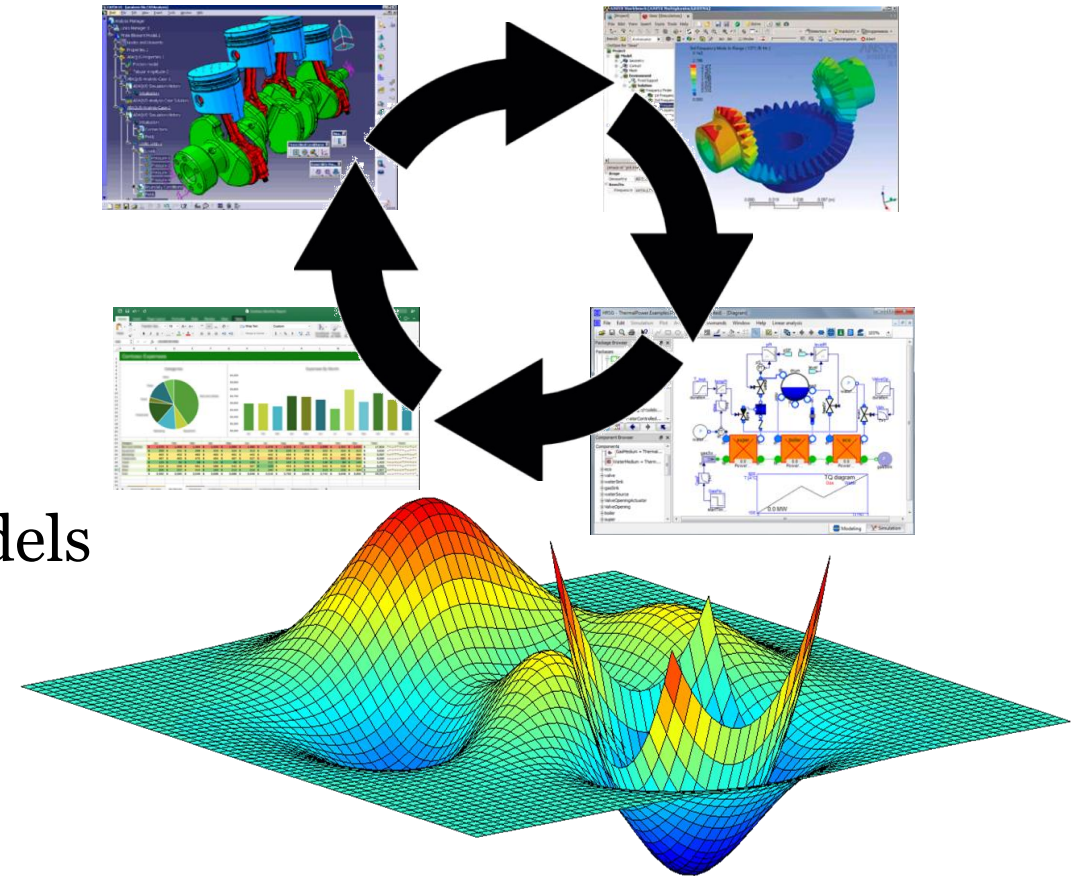
DIFFERENT MODELS
Five different models are available, depending on the environment of the building project. The different models are available to create the project information sheets to have full capabilities, what the building project is, the project and alternative point is right on.

VARIABLES FROM THE TOOL
The tool can be used to create the structure, as long as they fit or the structure surface. If the tool can't be used, the user can use the tool to create the structure to replace the material and cost of the structure.



TMKT79 Collaborative Multidisciplinary Optimization

- Practice MDO
- Integrate
 - CAD
 - FEM
 - Performance Models
- Speed up with Surrogate/Meta models
- modeFRONTIER



TMKT79 Collaborative Multidisciplinary Optimization

- Tutorials on a wind power plant– then own projects

LINKÖPING UNIVERSITY **Prajanya - Mjolnir** MULTIDISCIPLINARY DESIGN OPTIMIZATION Collaborative Multi-Disciplinary Design optimization - TMKT79 - 2022 Electric Aircraft Optimization

A Design Optimizer to provide the most efficient electric aircraft design for the criteria desired by the user.

Input Diversity:
Wide Ranges of input that the user can set or approximate

Range of Optimal Designs:
User can select optimal designs based on design parameters best suited for criteria

Visual Representation
The User also experiences visual representation of electric aircraft in it's optimal design point

Key Feature of Design Optimizer

Lift analysis

Stress & Deflection Analysis

Dimensional Analysis

Powerplant Calculation

Sample of variation

Pax: 40; Wingspan: 15 [m]

Pax: 80; Wingspan: 25 [m]

Pax: 120; Wingspan: 30 [m]

ELCARO SAAB 900

Introduction
Most electric cars have a modern and uniform look to them. This project aims to create an electric car with a classic look to it by modeling the car based on SAAB 900.

Design objectives

- Minimize difference in dimentions
- Minimize cost
- Maximize range
- Maximize speed

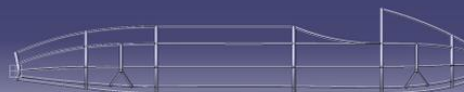
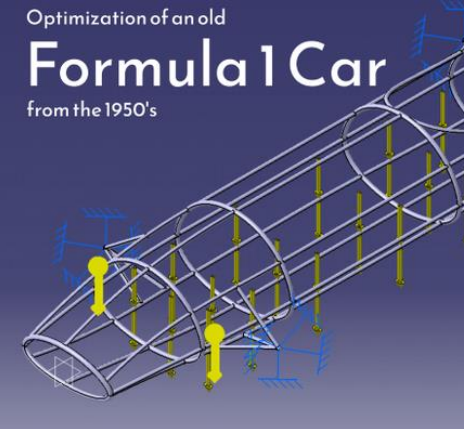
Results
The final design is a car with a 1.2% difference in dimentions and a similar max speed to the original SAAB 900. The cost and range is comparable to eelectric cars on the market today.



	Height [mm]	Length [mm]	Width [mm]	Clearance [mm]	Speed [km/h]	Range [km]
Original	1420	4650	1650	140.0	190-210	700
Model	1357	4693	1760	140.0	206	391

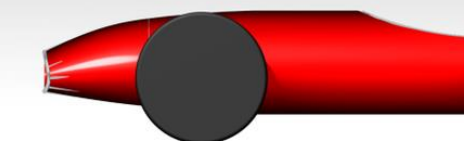


Optimization of an old Formula 1 Car from the 1950's



Optimizing for Range, TopSpeed, Acceleration and Cost by varying wheelbase, car width, motor power and battery size.

Optimization framework using modeFRONTIER to connect Excel and CATIA models.



SPOON : SOLAR POWER PANEL OPTIMIZATION

Motivation :
- To optimize the estimations from companies to customers & allow trade-offs between the customers requirements and constrains

Goals :
- Optimise a solar plant' power, cost and land usage
- Compare two locations with different latitude

-> We transform the problem into variables and objectives
-> We use and create models that we connect together to lunch an optimization

1 The models

Power and cost models (Excel)
Shading and wind force calculation, tilt efficiency (Matlab)
FEM model (Catia)

2 The optimization

NGSA - II Algorithm
200 initials designs x 30 generations
+ Surrogate models to save time

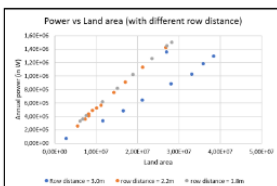
RESULTS !

• **Linköping vs Shanghai**
• High latitude area i.e. Linköping needs 10-20% more space compared to Lower latitude area i.e. Shanghai. Where sun can be directly above to avoid shading.

• Explanation on the variables

- > The number of panels and row distance have an important impact on all the objectives
- > Changing the cross section doesn't affect much the objectives
- > The power, especially during peak season, need an optimized tilt angle
- > Thickness of the support can have a slight impact

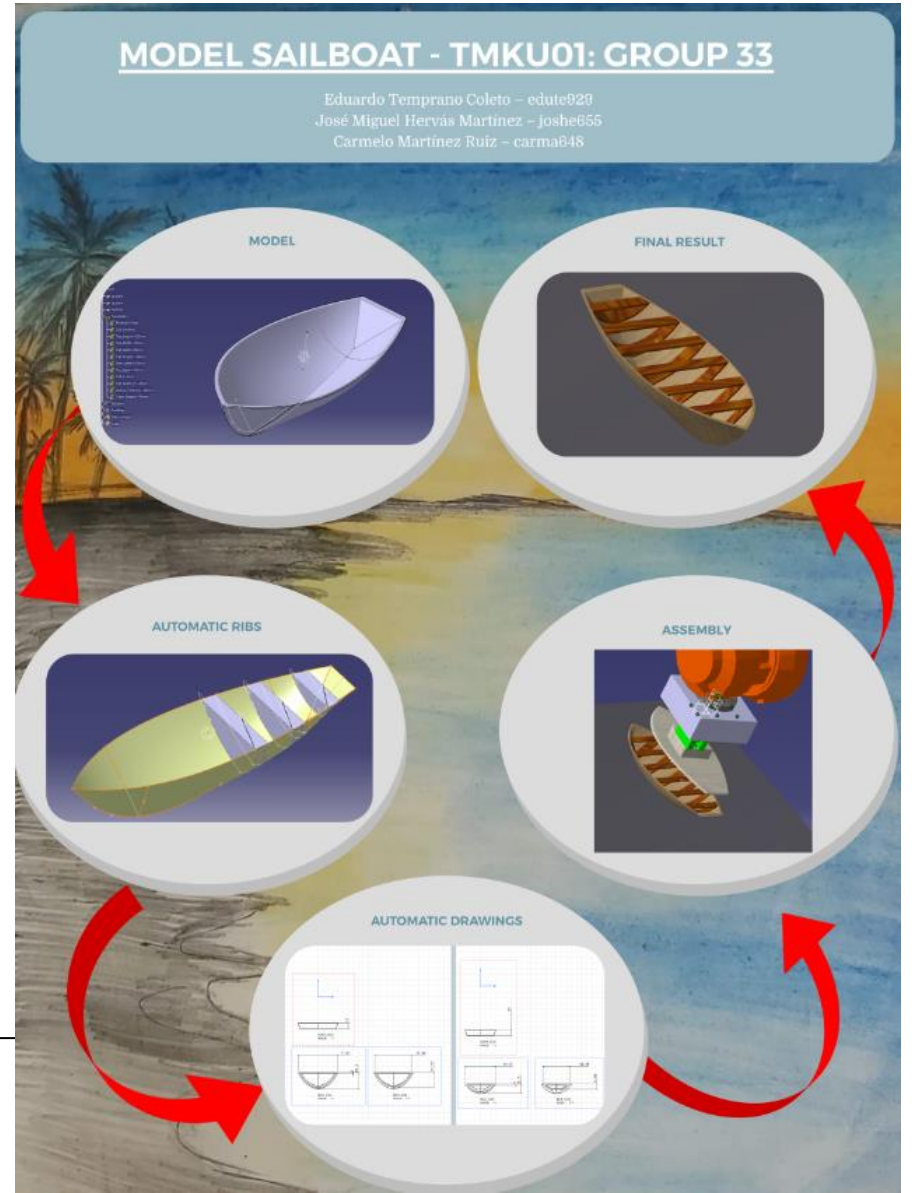
• Pareto front for the designs Objectives



THOMAS LE QUERE AND SHENGHAO HAN

TMKU01 Design Automation for Customized Products

- Customer adapted products
- Automatical frameworks
 - CAD-models
 - Drawings
 - Assembly instructions
- Digital twin
- Excel
- CATIA
- Visual Studio



TMKU01 Design Automation for Customized Products

Design Automation of Customized Crane

Linköping University - TMKU01 - HT2 2021

Automatic Instantiation of each Part through Excel Configurator

Automatic Drawing of all parts

P1.0	1000
P1.7	-800
P2.0	-1000
P2.7	300
P3.0	300
P3.7	300
P4.0	-300
P4.7	-800
EXTENSION 1	500
EXTENSION 2	-300

Automatic Production of a Section

auddu789 - sheha456 - kaur709

AUTOMATIC CEILING LIGHT GENERATOR

LINKÖPING UNIVERSITY | TMKU01 - Design Automation of Customized Products

Excel | CATIA | modeFRONTIER | mF

Width

Length

By eliminating repetitive work and instead emphasizing exploration and creativity, this generator allows you to create a custom ceiling light for your home in seconds.

The parts of the lamp are then laid out on a 2D surface by modeFrontier, optimizing the placement and reducing waste material. Measurements for the required sheet size are extracted to a drawing.

The optimized layout is finally imported into a DELMIA environment where a robot sequence is automatically generated. The robot uses a vacuum picker to place the components in a customized, product specific box.

Oskar Stedt
William Sundberg

Automated stairway to heaven

The stairway is customized through an Excel interface which is connected to VBA and CATIA. Through the same interface, drawings, and a simulation of the packing of the stairway with a robot can be created.

LINKÖPING UNIVERSITY | TMKU01 HT21

Linnéa Larsson
Moa Ståhlbrand

Challenges

- What will be important in the future?
- Programming
 - Included in all our courses
 - The students usually have low programming skills before our courses
- What software to teach?
 - Easy to use?
 - Open Source?
 - Used in the Industry?

- Repetitive Design – examples from the courses
 - <https://repetitivedesign.com/>
- Design Automation Laboratory – our research and results from our courses
 - <https://liu.se/forskning/design-automation-lab>
- Johan.persson@liu.se

www.liu.se