Code based constraints in structural optimization

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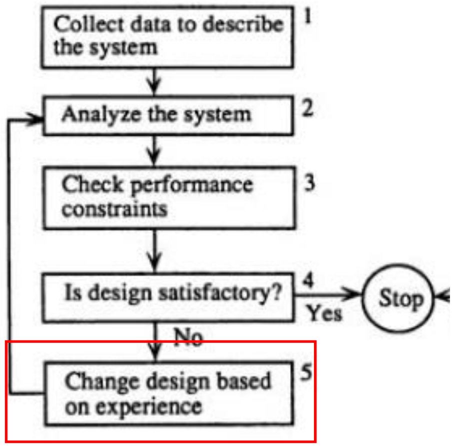
Optimization

Conventional design process

Design process with optimization

Design engineer



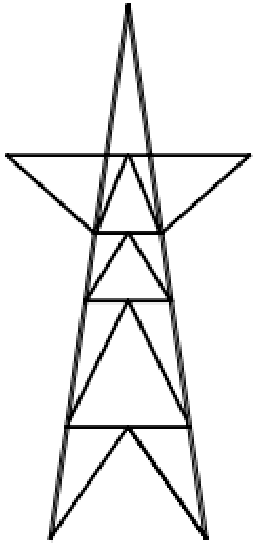
Conventional design process

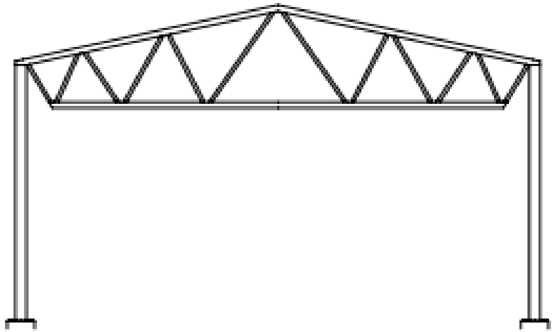
Computer (and design engineer)

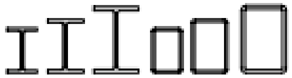
=> Systematic, fast and transparent design by utilizing optimization

Backround for code based structural optimization

- Stress and displacement constrained frame and truss optimization techniques are well-known
- Including joint and (member) stability constraints derived from design codes pose difficulties
- Moreover, the design variables in practical design optimization are discrete instead of continuous
- **In this presentation**: two approaches to enhance existing technicues are presented







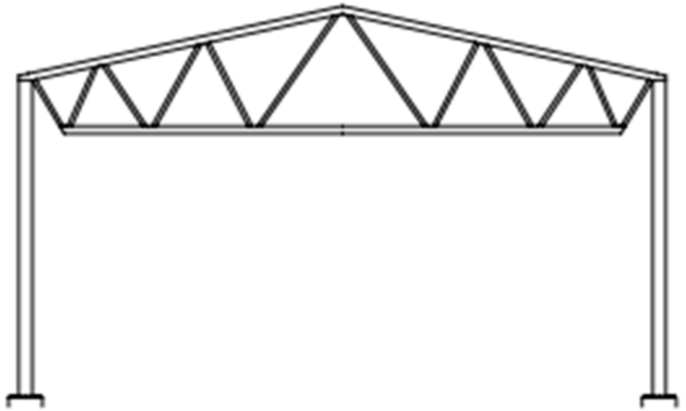
Features of code based design problems

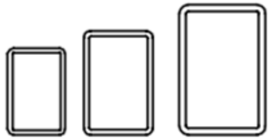
- **Objective function**: *cost* rather than structural weight
- **Design variables**: discrete profile selection variables (and in some formulations also continuous state variables)
- **Constraints**: member cross-section resistance, member stability, global stability, joint resistance
- **Special considerations**: manufacturability

= > The features control the usable methods and formulations

Example 1: Two-phase optimization of tubular truss

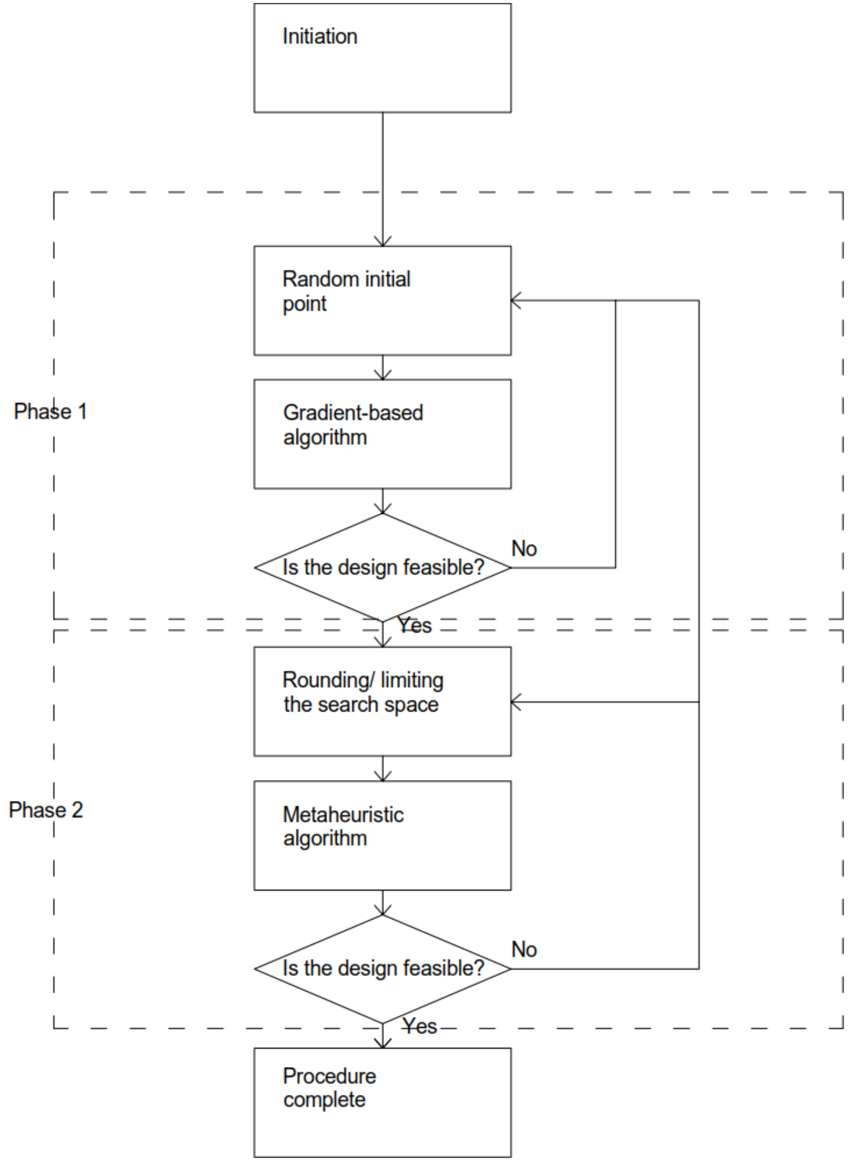
- Consider a tubular truss sizing problem with Eurocode 3 member and joint design rule based constraints
- With discrete design variables, the problem becomes highly non-linear and extremely difficult to solve
- When solved directly, only meta-heuristic methods can be applied (genetic algorithms, particle swarm optimization etc.)
- Very long computational time is needed for reliable results





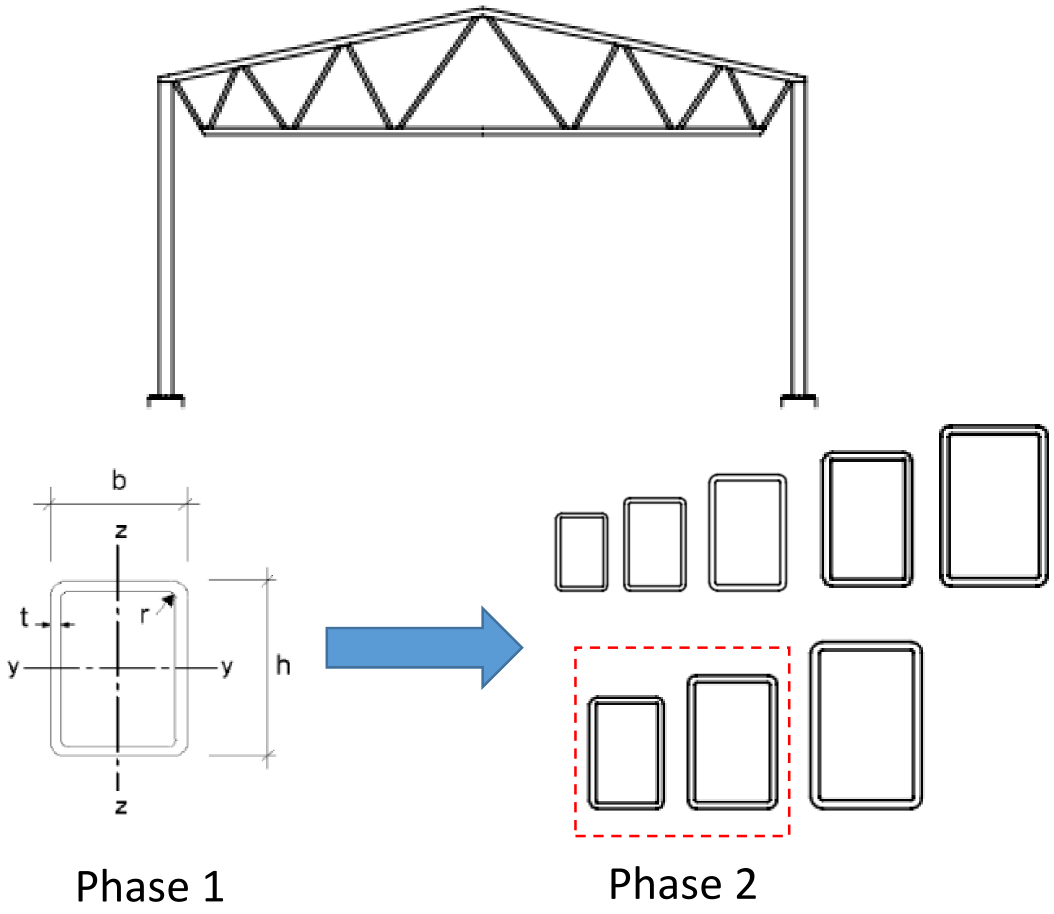
Two-phase optimization of tubular truss

- In phase 1 the problem is relaxed continuous and solved by efficient gradient based algorithm (hill-climb, SQP, etc.)
- In phase 2, the discrete space around the solution is searched by meta-heuristic algorithm
- Due to efficient phase 1 and very limited design space in phase 2, computational time is significantly reduced



Two-phase optimization of tubular truss

- In tubular trusses, the relaxation can be done by splitting the variable choosing profile as two continuous variables, outer dimension and wall thickness
- In phase two, proper metric should be used to identify the ”closest” discrete options
- Preliminary tests at TUT: in comparison with direct application of genetic algorithm and PSO, the two-phase approach finds good solution in minutes instead of hours and with less deviation
- The framework is general: if proper continuous relaxation and metrics to reduce the search space can be used, the approach can be used in frame problems etc.

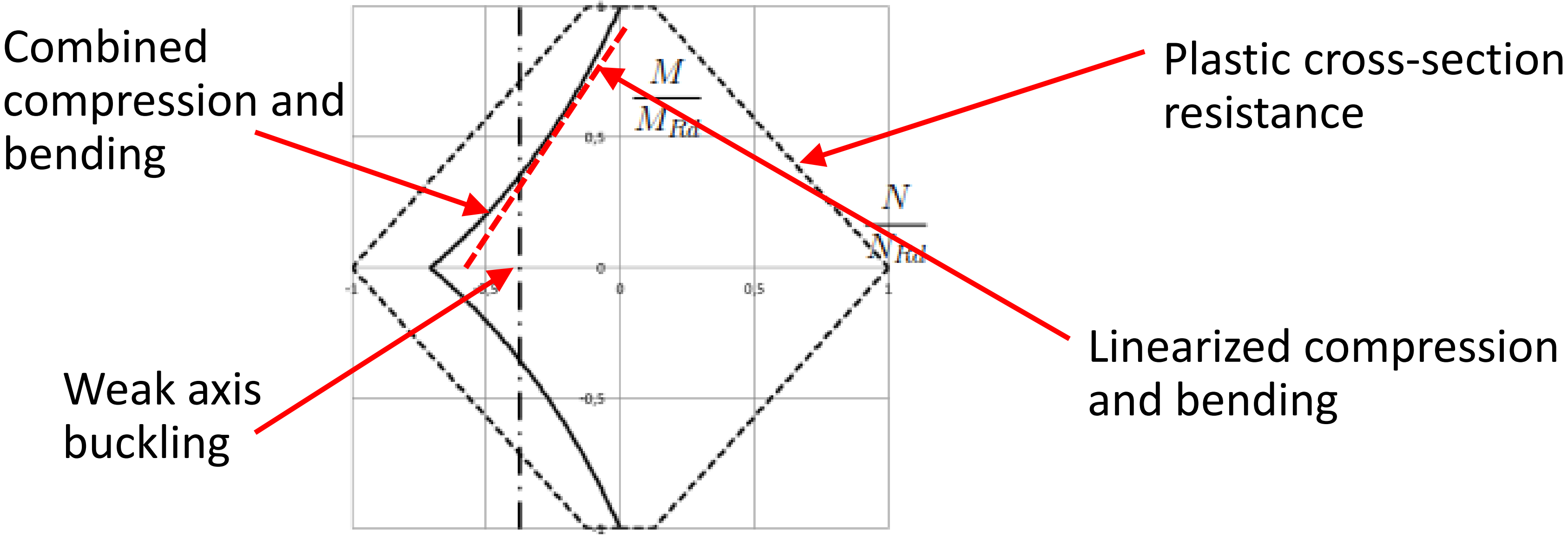


Example 2: Member stability constraints in global optimization of frames

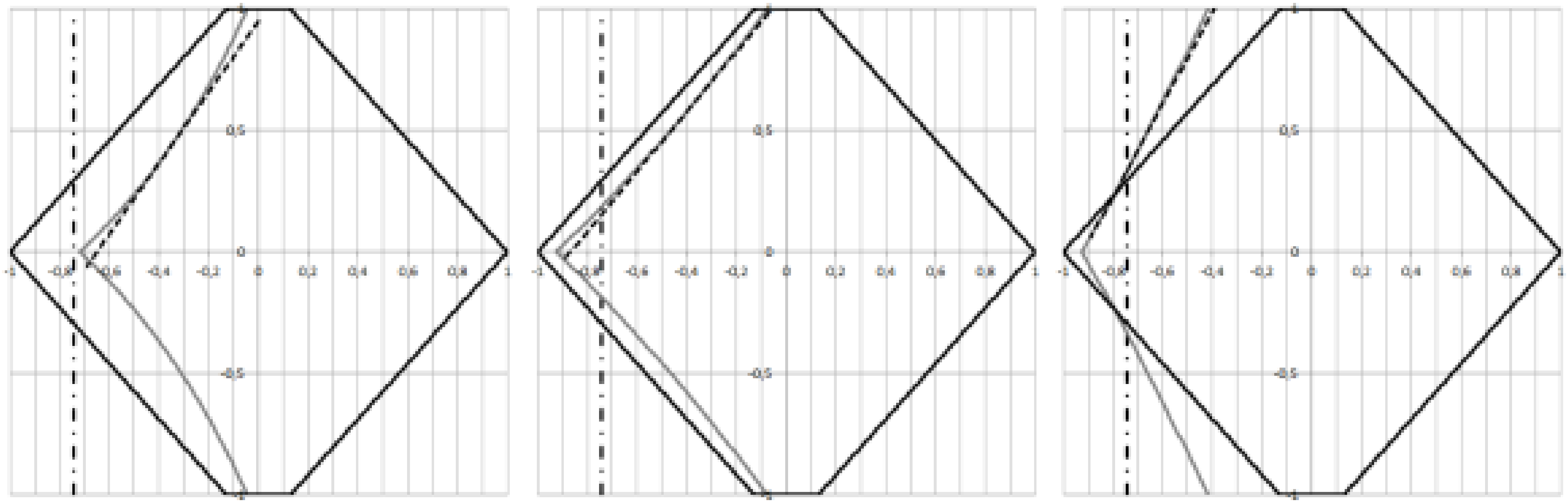
- Frame sizing (and topology) design problem can be formulated as mixed integer linear program (MILP) (shown also by the presentator in METNET previous year..)
- For this problem type, verified global optimum can be found with a well-known algorithm (no convergence issues like with meta-heuristic approaches)
- Only linear constraints can be used
- Combined compression and bending of Eurocode 3 is in this formulation non-linear thus requiring treatment

Member stability constraints in global optimization of frames

- Cross-section design and weak axis buckling constraints are linear already
- Only combined bending and compression constraint is non-linear
- With certain assumptions, linear approximation can be made



Member stability constraints in global optimization of frames



- Linearization of the stability constraint does not seem to produce large error
- If assumptions with the combination parameter values were incorrect, sequential approach can be adopted and updating the parameter values

Conclusions

- Code based constraints may cause difficulties in optimization
- The presented two-phase approach is a general framework aiming to reduce the high computational cost related to design code based structural optimization
- The linearization scheme for MILP allows including bending-compression interaction constraints