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FORCE DENSITY METHOD – BEYOND SIMPLE ITERATIONS

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Abstract

The idea of the PhD thesis is to propose an extension of iterative application of force density method, originally used for design and internal force evaluation of tensile structures. Improvements are aimed to be made in two directions i.e. to accelerate computation in order to successfully implement this method into interactive structural design tool, as well as to enable the user to influence the appearance of final solution in a more efficient manner. Reduction of number of iteration steps, and consequently execution time, can be achieved by optimizing accuracy for solving system of linear equations in each step. Further time reduction will be explored by incorporating new solver into the extended algorithm. Performance of new versions of the algorithm will be evaluated and processing time will be compared against Newton-Raphson method. Focus of the thesis is also on the ability to assign undeformed lengths of elements, in addition to force and length constraints from initial set up of the algorithm. Proposed extension is aimed to be used for form finding of spatial truss structures in either tension or compression.

Keywords: form finding, cable-net, force density method, unstrained length, time reduction

1. METHOD

Freeform geometry of spatial truss structure has high aesthetic appearance, but irregular shapes introduce great difficulties in structural design. For structural engineer the challenge is to generate forms with high structural efficiency subject to the architectural space constraints during the conceptual structural design process. The procedure is called constrained form-finding and it demands extension to nonlinear force density method (FDM). In order to avoid nonlinear system of equation (NSEQ), linear FDM can be iteratively used, and prescribed force and length values in elements can be achieved by changing the distribution of force density (FD) values. FD coefficients are calculated in each step by using their values from the previous one, and conjugate gradients are used to solve the system of linear equations [1]. The goal of this research is to reduce the number of iteration steps, and consequently the time, by optimizing in each iteration step, accuracy for solving the system of linear equations [2]. In that way, inspired by Inexact Newton method, procedure provides the balance between the accuracy of the solutions of linear systems and the amount of computations done in single step of the iteration. Extension of the method also enables assignment of unstrained lengths without introducing Lagrange multipliers, in addition to force and length constraints (as in [2] and [3]).

2. RESULTS AND FUTURE WORK

Extensive numerical experiments show that the proposed method is almost always efficient and robust, although there are cases in which the efficiency strongly depends on constants in the proposed termination rule. The proposed rule for relaxation of accuracy is not the only one possible, so there still exist areas for further research and development. The oncoming step is measurement of execution time for the extended version of the algorithm and comparison against initial version as well as Newton-Raphson method (most often used solver for NSEQ). Described research is part of the project [4] that proposes a new solver for systems of linear equations which will also be implemented in algorithm for investigation of further potential time reduction.

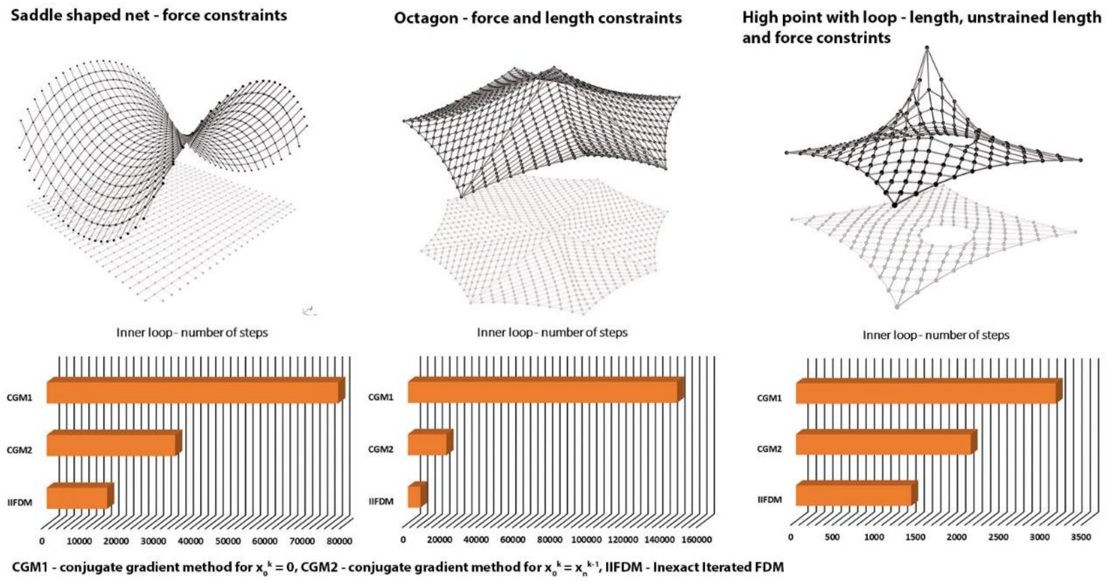

Figure 1: Reduction of steps in the inner loop for three types of examples with constraints

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