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On the practical usefulness of layout optimization theory

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Abstract

The theory of layout, whether considered from an analytical or numerical perspective, is often criticized for being of solely academic interest, with few if any obvious practical applications. Whilst it is true that practical applications have often been slow to materialize (Michell's seminal 1904 paper languished unappreciated for half a century, and subsequent numerical layout optimization techniques developed in the 1960s stretched available computational resources, limiting uptake). However, in this contribution a number of practical applications will be used to clearly demonstrate the practical usefulness of the theory.

Firstly, the forms identified using the Michell-Hemp optimality criteria frequently comprise a large number of short and/or thin elements which are difficult to fabricate using conventional techniques, or which would tend to buckle in practice. Consequently these forms have tended not to find favour in engineering practice. However, in this contribution it is on the one hand demonstrated that use of slightly modified optimality criteria leads to more 'practical' forms, and on the other that the emergence of new manufacturing techniques (e.g. 'additive manufacturing' / '3D printing') allows forms which have hitherto been considered 'impractical' to be fabricated.

Secondly, the recent (re)discovery of the analogy between the optimal layout of bars in trusses and the arrangement of slip-line discontinuities in plane plasticity problems has led to the development of an entirely new analysis method, 'discontinuity layout optimization', DLO. This method has been incorporated in software which is now widely used in the civil engineering industry. Various example problems will be considered, which illustrate the range of application of this method, and also its practical usefulness.

Finally, the feasibility of combining structural layout optimization with DLO is considered, so as to for example allow the presence of supporting material of finite strength to be taken into account when identifying an optimum structure. This potentially further increases the range of applicability of layout optimization techniques, and various 'arch bridge' examples will be used to demonstrate the efficacy of the approach. The latter also allow a recently voiced concern over the practical usefulness of studying Hemp-Chan arch structures to be specifically addressed.