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Review of “Efficient update of redundancy matrices for truss and frame structures”

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^E Editor

Review of version 1

Permalink: arXiv:2205.12264v1

Authors We thank the reviewer for his/her constructive and thorough review. In the following, we address each comment of the review in detail.

Reviewer 1 (Anonymous)

Reviewer The article presents an interesting calculation procedure of the so called “redundancy distribution” by assigning a significance rating to all members in frame or truss structures with respect to their significance for the structure stability. Moreover, an appropriate constitutive transformation renders the assessment of the redundancy distribution less computationally intensive. In the reviewer’s opinion this can be of advantage especially in the application of active adaptive structures reacting to abrupt extreme loading events (which is also related to the work of the authors in the funding research programs). It is overall well-structured and the methodology is demonstrated with adequate explanations and examples. The following comments should be taken into consideration prior to approval for publication, which are provided in good faith and with the hope to improve the manuscript.

Reviewer As currently formulated, the title may be misleading: it implies that other possible updating procedures are “inefficient”. This should be revised. The novelty of the study should also be demonstrated in a more specific manner.

Authors We agree with the reviewer that the novelty of the study should be presented more specifically. Therefore, we added a statement in Section 1 (second last paragraph and in the bullet point list). Concerning the title, however, we partly disagree with the reviewer’s opinion and argue that the current title is appropriate because there is no generic, efficient update procedure for the redundancy matrix at all; besides the work of Chen et al. (2010), where a formula is presented that only addresses the removing of single elements from truss structures and that does not provide a framework for multiple, interchangeable (with adding and exchanging) updates. Hence, the only “comparable” procedure is to compute the redundancy matrix from scratch (after updating the matrices A and C), resulting in an inefficient updating procedure.

Reviewer The limitations of the proposed methodology and analysis technique are not clarified. The examples claim that the analysis is done for a high-rise building (4.2), but essentially the examples presents 4-storey 2-dimensional frames. This is an oversimplification, since 3-D effects are

not accounted for, whereas the building typology is not one of a high-rise and the design situations do not account for transverse loads and second-order phenomena. These are distinctive characteristics of high-rise buildings and the example should be enriched accordingly or the example description should be rephrased (e.g. the authors may wish to use the definition “multi-storey frame structure” or similar).

Authors The redundancy matrix as defined by Bahndorf 1991, Ströbel 1997, and von Scheven et al. 2021 is independent of the loading situation and in this contribution only applied to linear problems. These limitations are stated in Section 2.2. Therefore, “transverse loads and second-order effects” are not relevant for this contribution.

We agree with the reviewer that the name of example 2 (see Section 4.2) is not appropriate. To be able to visualize the results, the “high-rise building” became smaller and smaller during discussions and ended up being only a multi-storey frame structure. We have adapted the heading and captions accordingly.

Reviewer Also, the connections of the members are modelled as idealised hinges or rigid connections, which is also rarely the case in reality. In any case, the limitations of applicability should be noted.

Authors The redundancy matrix and our proposed update procedures can also be applied to more complex connections including, e.g., spring elements. In our examples, we restricted ourselves to simple connections to enable a good comprehensibility. We have added a comment about this simplification in the introduction of example 2 (see Section 4.2).

Reviewer The model assumptions (matrix symmetry, regularity, Pellegrino criterion) should be justified further.

Authors We have further clarified the explanation of the symmetry of the stiffness matrix in Equation (2). The scope of this paper is limited to statically indeterminate and kinematically determinate structures. For kinematically indeterminate structures the the definition of the redundancy matrix in Equation (4) cannot be used directly due to the inverse of K . There exist contributions about the calculation of the redundancy matrix for kinematically indeterminate structures, and the application of our update procedures to those problems could be possible. We consider this as future work and have added a respective remark in the conclusions.

Reviewer In continuation of the above, the sensitivity of the model in changes e.g. in stiffness of the joints, defects or deterioration of the member materials should be discussed, as it may influence the redundancy distribution dramatically, e.g. even in terms of failure sequences.

Authors The scope of this paper is the efficient update procedure for the redundancy matrix. The mechanical interpretation and application of the redundancy matrix are beyond the scope and can be found in Linkwitz 1961, Bahndorf 1991, Ströbel 1997, von Scheven et al. 2021, and Gade et al. 2021. We have added a comment about this restriction in the introduction of the paper (see Section 1).

Reviewer Without having rerun the calculations independently, the results of the model are to some extend counter-intuitive, e.g. in Figure 5, top left segment: Failure of the horizontal element / beam would lead to immediate collapse of the vertical element / column due to their hinged connections; in fact failure of the outer left column does not lead to collapse, as the beam is a fixed cantilever – it would hence be expected that the redundancy index of the member would be different. Perhaps it is also necessary to elaborate further on the physical meaning and possible ranges of the redundancy indices.

Authors The at first sight strange redundancy distribution in Figure 5 appears due to the differences in the bending and elongation stiffness and the higher number of load-carrying mechanisms in the beam compared to the truss element. However, the mechanical interpretation of the redundancy matrix is beyond the scope of this paper.

Reviewer Previous studies on system redundancy and its association to codified robustness-based structural design are presented by Spyridis and Strauss (MDPI Buildings, 2020) and Strauss et al. (Beton Kalender 2022). These also describe probabilistic elaboration of redundancy calculations,

progressive collapse criteria and possible applicability on adaptive structures. They authors may wish to draw references from these documents with regard to the above issues.

Authors Thank you for pointing to these references. We have included the reference by Spyridis and Strauss (MDPI Buildings, 2020) in the introduction as it is more focused on the redundancy matrix compared to Strauss et al. (Beton Kalender 2022).

Review of version 2

Permalink: [arXiv:2205.12264v2](https://arxiv.org/abs/2205.12264v2)

Reviewer 1 (Anonymous)

Reviewer No further comment, the responses justify my recommendation for acceptance with the 2d submitted version.

Editor’s assessment (Alexander POPP)

Two independent reviews by expert referees had been requested and agreed upon for the given paper. The first review, as printed above, evaluated the contribution very positively besides a few minor comments. Unfortunately, the second reviewer did not provide a report as promised and the search for another second reviewer was not successful over a period of several months. Since the first review has been positive from the beginning, and since the authors had provided a convincing response on the few minor comments, the editor exceptionally moved on and reached an editorial decision with just one external review. To further support this decision, a few editorial comments are collected in the following, which are meant to complement the external review report.

With their focus on redundancy matrices for truss and frame structures, the authors address a fundamental, yet often overlooked topic in structural design and analysis, particularly with respect to a structure’s load carrying behavior. The characteristic feature of redundancy matrices is their ability to provide a meaningful description of the spatial distribution of the degree of state indeterminacy, and not just an aggregated global number. Seemingly forgotten for quite a while, the authors have successfully revisited the topic in recent years and have added valuable continuum-mechanical insights. If a structure is modified, as is typical for iterative design processes, the computational complexity associated with the (re)computation of the modified redundancy matrix can become prohibitive. The present paper proposes, outlines and quantitatively assesses a new strategy for efficiently updating redundancy matrices for the most typical structural design modifications. At its methodological core, new algebraic procedures are provided for the three exemplary scenarios of adding elements to a structural design, removing elements or exchanging elements. The work is limited to statically indeterminate but kinematically determinate structures, where the stiffness matrix K is invertible. All numerical examples are clearly presented and convincingly illustrate the applicability of the proposed methods to structures of practical interest. Numerical performance tests give first insights into the efficiency gains and simulation speedups that can possibly be achieved.

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