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Approximate Fuzzy Structural Analysis Applying Taylor Series and Intervening Variables

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One of the main challenges involved in the design, maintenance and operation of structural systems is the incomplete knowledge on variables that directly affect performance during the lifetime of a facility. Typical examples of such unknown variables refer to loads, material properties and behavior, deterioration processes, etc. Hence, there is a necessity for quantifying the effects of these uncertain parameters over the structural performance using an appropriate model. Among different approaches available, fuzzy set theory offers a suitable means for dealing with uncertainty. In this manner, uncertain variables are characterized as fuzzy values with associated membership functions. Then, using techniques of fuzzy structural analysis, it is possible to propagate the uncertainty from input variables of the model to output variables related with structural performance.

A particularly suitable approach for propagating uncertainty from input to output variables in fuzzy analysis is the application of the so-called α-discretization. This discretization implies solving a series of side constrained optimization problems. In these problems, the objective is determining the minimum and maximum of the structural response for various levels of the membership function. Undoubtedly, the solution of these optimization problems is a numerically demanding task. One possible approach to alleviate numerical costs is resorting to Taylor series expansions of the structural response. Usually, results obtained applying Taylor series are not extremely accurate, however they are most valuable as the numerical costs involved in its application are negligible while still providing valuable information on how uncertainty affects structural performance. Nonetheless, the applicability of Taylor series is limited due to the nonlinearity in the relation between input and output parameters and also the level of uncertainty associated with the input variables. In view of these issues, this contribution aims at enlarging the range of applicability of Taylor series and also improving the quality of the obtained approximations by employing the so-called intervening variables. These variables have been used customarily in the field of structural optimization, allowing the approximate representation of challenging and involved structural models by means of Taylor series. The key issue in the application of such an approach is selecting appropriate intervening variables which are a nonlinear function of the uncertain input variables of the model. In this contribution, two different criteria for selecting these intervening variables are investigated along with their implementation for performing approximate fuzzy structural analysis.

In order to demonstrate the accuracy and applicability of the proposed approach, numerical examples comparing the proposed approach with reference solutions are presented. Results obtained indicate the proposed approach can lead to improved results while keeping numerical costs similar to other approaches proposed in the literature.