A case where material interpolation fails ?

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Abstract

From the literature, it is seen that shape and topology approaches lead to similar sensitivities. An open question is if there exist a case where shape and density sensitivities differ and perhaps even have opposite signs. In this article we study an example problem that seems to posses this issue. That is, a design problem which is very difficult to solve using density approaches and thus is best treated as a binary (or shape optimization) problem.

To the authors knowledge so far only a few problems have this property, e.g. design of antennas (Aage, 2011), design of plasmonic resonators (Yamasaki et al, 2011) and probably the yet unsolved problem of topology optimization for turbulent flows.

We illustrate the failure by a simple 1D design problem concerning electromagnetic waves and the optimal distribution of a good conductor, e.g. copper, in order to obtain a strong field enhancement, e.g. resonators, antennas, waveguides (Aage et al, 2010). The problem is first and foremost, that the sensitivities in many situations have wrong signs, and thus leads the optimizer to artificial local minima. Secondly, to move a zero density variable towards one, a small, but non-zero, conductivity must be included in void regions, which then leads to non-physical losses and ultimately to artificial local minima. In fact, the drawback of the standard material interpolations described here does not only effect the density approach, but covers most fixed-mesh

level-set approaches. Excluded are methods with a true boundary representation, such as X-FEM, level-set methods with pure 0-1 designs and adaptive re-meshing, assuming that the sensitivities are computed based on shape gradients and not as effective density gradients.

Having described the design problem and shown its limitations with respect to density approaches, we then suggest a simple gradient based binary update algorithm. The method uses nodal shape gradients projected onto the density field in order to perform the design update. By numerical studies we show that the binary scheme can be used to obtain better designs than those of the density approach.

We further demonstrate the difference in density approaches and binary approaches using a 2D magnetic resonator example as given in (Aage et al, 2010) and (Nguyen et al, 2012) using topopt and isogeometric analysis, respectively. Currently, we have shown that we can beat the density approach, and it is expected that the design method will be able to match the results given in (Nguyen et al, 2012).

References

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