Preconditioning for Scattering by Multi-screens

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Problem background

We consider scattering at geometries arising from arbitrarily arranging of thin panels that meet in a junction line (see Figure 1 for an illustration). These structures are so-called *multi-screens* or *complex screens* in the literature. They appear naturally when considering for example the design of antennas, the modelling of cooling fins for electronics, and the design of hulls and wings in aerospace engineering.

Boundary element methods (BEM) offer a popular approach to simulate the scattering of waves at open surfaces. When using BEM for simple open surfaces (i.e. without junctions), the unknowns are jumps of traces of scattered fields. However, one of the difficulties when dealing with multi-screens is that this notion of *trace jump* is no longer meaningful at junctions. For this reason, many pieces of the standard BEM machinery break down.

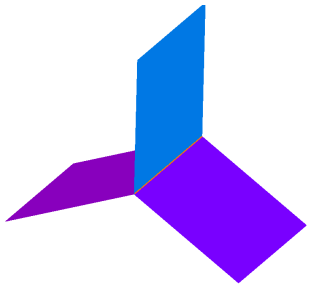

Figure 1: Example of Multi-screen.

In practice, people suppress some degrees of freedoms at junctions artificially, or by imposing that the sum of the quantities of interest on the different sides of the junction is zero. However, these strategies do not have a rigorous mathematical analysis, and this limits the applicability of numerical and computational tools to tackle this problem more efficiently. Many recent contributions have been made to overcome some of these difficulties [1, 2, 3, 4]. In particular, the BEM discretization based on discrete quotient spaces proposed in [4] promises to recover the usual BEM machinery and to be easily incorporated in existing BEM implementations. Yet, this still needs to be tested in practice.

Research description

The linear systems arising from low-order BEM discretization at open surfaces are typically ill-conditioned. This fact, combined with the use of iterative solvers, requires that one uses preconditioners to reduce the number of iterations it takes to find an approximate solution.

One of the most broadly used preconditioning techniques in BEM is the so-called *Calderón preconditioning*, which exploits relations between the boundary integral operators to achieve well-conditioned matrices. The goal of this master project is to build Calderón preconditioners for the discretization proposed in [4].

Within this master project the following tasks are foreseen:

1. Research literature on discretization and solution to multi-screen problems.
2. Analyse and implement Calderón preconditioning for Multi-screens.
3. Run numerical experiments.
4. Write Master thesis.

No previous knowledge on BIE or BEM is needed, but the student is expected to be willing to learn some key notions, and to have basis knowledge of numerical methods, discretization schemes, finite elements, and programming.

The student will have the freedom to choose to implement using existing code or to start their own code from scratch.

References

[1] K. Cools, and F.P. Andriulli, *Well-conditioned saddle point description for scattering by a metallic junction*, 2015 International Conference on Electromagnetics in Advanced Applications (ICEAA), Turin, 2015, pp. 1349-1352, doi: 10.1109/ICEAA.2015.7297337.

[2] K. Cools, and F.P. Andriulli, *Accuracy of the calderon preconditioned EFIE for the scattering by PEC junctions*, 2015 USNC-URSI Radio Science Meeting (Joint with AP-S Symposium), Vancouver, BC, 2015, pp. 144-144, doi: 10.1109/USNC-URSI.2015.7303428.

[3] K. Cools, and F.P. Andriulli, *A regularised electric field integral equation for scattering by perfectly conducting junctions*, 2015 9th European Conference on Antennas and Propagation (EuCAP), Lisbon, 2015, pp. 1-4.

[4] X. Claeys, L. Giacomel, R. Hiptmair, and C. Urzúa-Torres, *Boundary Element Methods for Complex Screens*, submitted (2020). Available as SAM-Research report 2020-11. `https://www.sam.math.ethz.ch/sam_reports/reports_final/reports2020/2020-11_fp.pdf`