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## FOV-equivalent block triangular preconditioners for generalized saddle-point problems

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### Abstract

We present sufficient conditions for field-of-values-equivalence between block triangular preconditioners and generalized saddle-point matrices arising from inf-sup stable finite element discretizations. We generalize a result by Loghin and Wathen [1] for matrices with a pure saddle-point structure to the case where the (2, 2) block is non-zero. Moreover, we extend the analysis to the case where the (2, 1) block is not the transpose of the (1, 2) block.

*Keywords:* Preconditioning, Field-of-values-equivalence, Finite Elements, Generalized Saddle-point Problems.

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In [1], Loghin and Wathen presented norm-equivalent and field-of-values-equivalent (or FOV-equivalent) block triangular preconditioners for a  $2 \times 2$  block matrix with a saddle-point structure. FOV-equivalent preconditioners are important in numerical analysis because when the GMRES algorithm is used to solve a linear system  $A\mathbf{x} = \mathbf{b}$  preconditioned with a matrix  $P$  that is FOV-equivalent to  $A$ , the convergence rate does not depend on the size of  $A$  ([2, 3, 4, 5]). For finite element applications, this means that the convergence rate is independent on the mesh size and therefore successive refinements of the mesh do not cause a deterioration of the convergence properties. We generalize the result of [1] on FOV-equivalent preconditioners to the case of a  $2 \times 2$  block matrix where the (2, 2) block is non-zero. Moreover, we extend the analysis to the case where the (2, 1) block is not the transpose of the (1, 2) block. For brevity we only consider the case of right preconditioning. We now introduce some definitions and identities that are used for the rest of the paper. As in [6],  $M_{m,n}(\mathbb{R})$  indicates the space of all  $m \times n$  matrices with real entries while  $M_n(\mathbb{R})$  represents the space of all square matrices of order  $n$  with real entries. If  $H_1 \in M_n(\mathbb{R})$ ,  $H_2 \in M_m(\mathbb{R})$  are two symmetric positive-definite (SPD) matrices

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