Multi-patch parameterization method for isogeometric analysis using singular structure of cross-field

Ye Ji[a], Yi Zhang[a], Chun-Gang Zhu[a]

[a]*School of Mathematical Sciences, Dalian University of Technology, Dalian 116024, China*

Keywords: Isogeometric analysis, Analysis-suitable parameterization, Multi-patch configuration, Cross field, Boundary element method, Domain partition

---

Abstract

The cutting-edge numerical methodology of isogeometric analysis [1] offers the potential to seamlessly integrate Computer-Aided Design and Computer-Aided Engineering, effectively bridging the gap between the two domains. Most Computer-Aided Design systems focus exclusively on the boundary representation of models during the design phase, whereas a spline-based mapping is essential in the analysis stage, commonly referred to as domain parameterization. However, generating analysis-suitable parameterizations from existing boundary representations continues to be a considerable challenge in the isogeometric design-through-analysis process, especially for computational domains featuring intricate geometries, such as high-genus cases.

To tackle this challenge, we propose a cross-field-based multi-patch parameterization method for computational domains. Initially, we employ the boundary element method to solve vector field functions across the computational domain. Subsequently, we create a one-to-one mapping between the vector field and the cross-field, thereby obtaining the cross-field. By analyzing the singular structure of the cross-field, we ascertain the position information and topological connection relations of singularities and streamlines. Furthermore, we introduce a simple and effective technique for computing streamlines.

We introduce a novel segmentation strategy for dividing the computational domain into several quadrilateral NURBS sub-patches. After establishing the multi-patch structure, we devise two techniques for generating analysis-suitable multi-patch parameterizations. The first technique expands upon the barrier function-based approach [2], while the second technique yields smoother parameterizations by including the control points at the interfaces of the sub-patches within the optimization model.

Numerical experiments showcase the effectiveness and robustness of the proposed method, highlighting its potential to enhance the isogeometric analysis process.

Email addresses: `jiye@mail.dlut.edu.cn` (Ye Ji), `cgzhu@dlut.edu.cn` (Chun-Gang Zhu)

Results

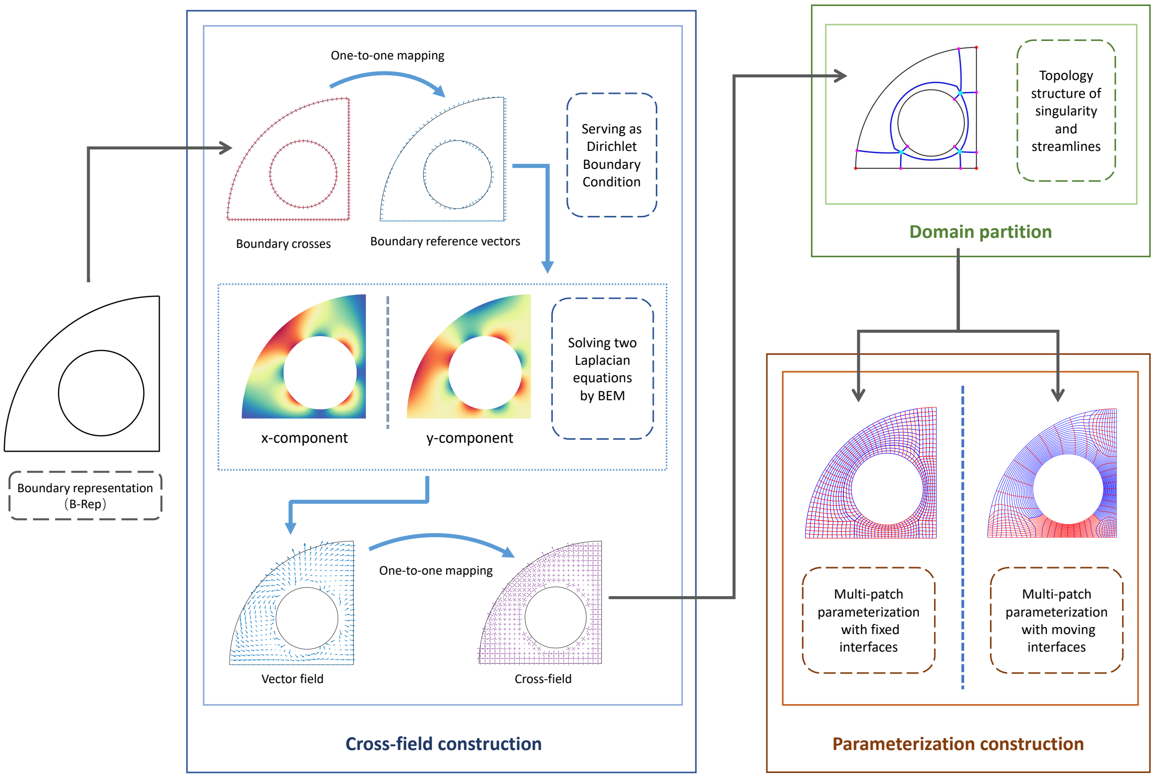

Figure 1: The overall workflow of our method

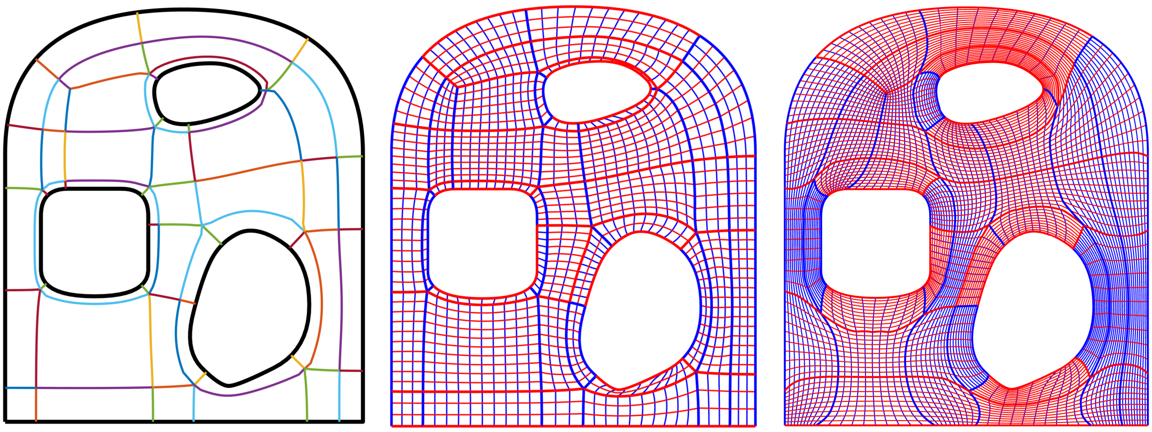

Figure 2: Left: Domain partition; Middle: Fixed-interface method; Right: Moving-interface method

References

[1] Hughes, T.J., Cottrell, J.A., Bazilevs, Y., 2005. Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement. Computer Methods in Applied Mechanics and Engineering 194, 4135–4195.

[2] Ji, Y., Yu, Y.Y., Wang, M.Y., Zhu, C.G., 2021. Constructing high-quality planar NURBS parameterization for isogeometric analysis by adjustment control points and weights. Journal of Computational and Applied Mathematics 396, 113615.