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Non-matching meshes data transfer using Kriging model and greedy algorithm

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ABSTRACT

The domain decomposition is a conventional approach to compute complex multidisciplinary simulations. The data transfer must be performed on their common interface due to the non-matching meshes for different domains. The adaptive Kriging interpolation method is proposed based on the greedy algorithm. By introducing a learning function, the Kriging interpolation model is constructed by the source grid values. In this way, part of the total source points are selected and the Kriging model is of high precision for the data transfer between the interface. Four examples are investigated to demonstrate the efficiency and accuracy of the proposed method.

1. Introduction

For decades, with the rapid development of computer technology, the simulation of complex multidisciplinary becomes feasible [1,2]. It is a common method to solve single subject by decoupling the physical qualities of multi-subjects for reducing computation difficulty [3]. In most cases, it needs data exchange between different disciplines due to the non-matching meshes [4,5] on the interface.

There are fruitful methods of data transfer between non-matching meshes. These methods can be divided into two categories, namely fitting methods and projection methods. The fitting methods transfer data by a fitting function, include polynomial function interpolation [6], radial basis function interpolation [7,8], Kriging method [9,10], etc. The projection methods are carried out by projecting the value on the source meshes to the target meshes and distributing the source value on the target nodes. The projection methods include nearest neighbor search method [11], inverse distance weight interpolation [12,13], isometric mapping method [14], virtual surface methods [15,16], etc. However, the fitting methods suffer from low precision on the massive meshes. The projection methods are complex and cost amount of computational time and memory.

For the calculation requirement, the data transfer methods between non-matching meshes are not only accuracy but also efficient. Further efforts have been made to achieve the purpose. Journeaux et al. [17] proposed a simply and efficient data transfer method by computing circulations along edges and fluxes through faces. Slattery [18] developed an efficient parallel algorithm for spline interpolation and moving least square reconstruction method for large scale multiphysics simulations. Huang et al. [19] adopted local nearest neighbor searching algorithm to deal with non-matching meshes between fluid and structure. Norbert et al. [20] described a spline based method of the fluid-structure interface, in which the isogeometric methods was used for structure analysis. Pont et al. [21] proposed a global interpolated method for two highly non-matching grids.

Kriging interpolation method [22] provides an exact prediction results at the sample points. As the best linear unbiased estimator, it is appealing for data transfer between multidisciplinary which demands high-fidelity approaches. However, the Kriging model can suffer from overfitting for the large amount of data transfer problems.

In this paper, an adaptive Kriging interpolation method is proposed to the data transfer between non-matching meshes. To improve the prediction precision, the optimal Kriging parameters are searched by genetic algorithm. In order to reduce the computational burden, the adaptive Kriging model is constructed by greedy algorithm, in which the source nodes can be partially selected from all the nodes. The interpolation results are compared with some other interpolation methods.

The rest of article is organized as follows. The methods of Kriging interpolation and greedy algorithm are proposed in Section 2. In Section 3, four examples are carried out to demonstrate the accuracy and efficiency of the method. We draw our conclusion in Section 4.

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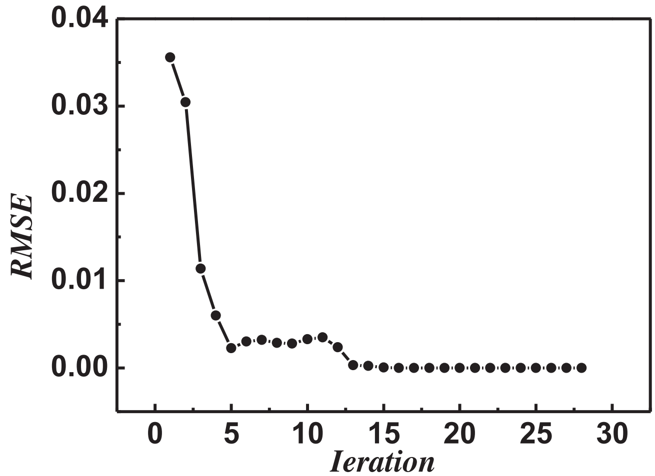

Fig. 1. The convergence history of training Kriging model.

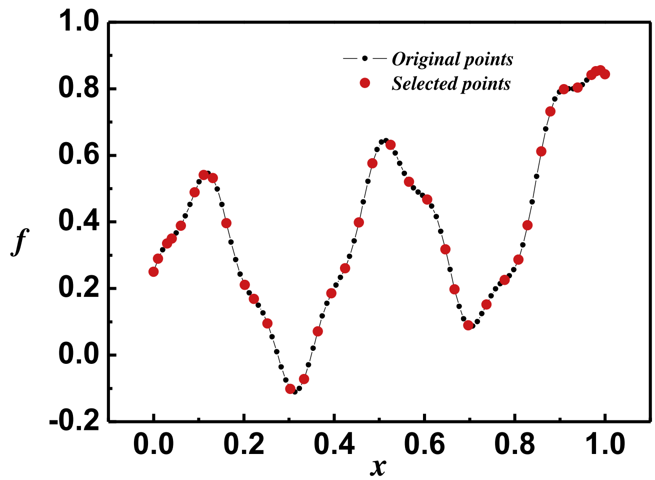

Fig. 2. The selected sample points.

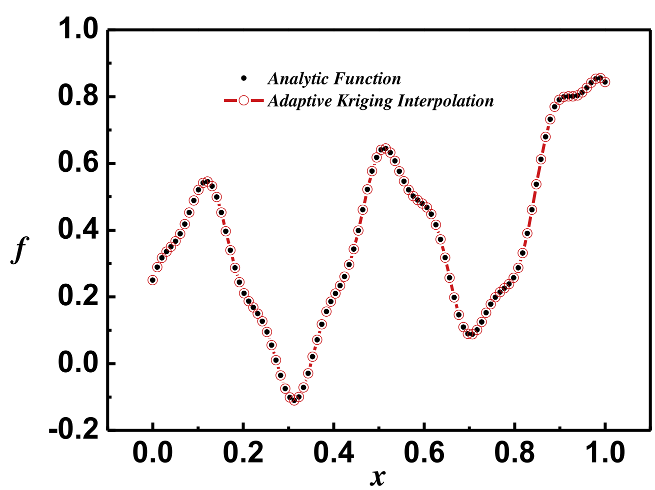

Fig. 3. Results comparison of the Kriging model and analytic function.

2. Kriging interpolation and greedy algorithm

2.1. Kriging interpolation

Proposed by Krige [23], the Kriging model has been successfully applied in geological exploration. Based on the theory of variation function, Kriging interpolation is an unbiased optimal estimator in a

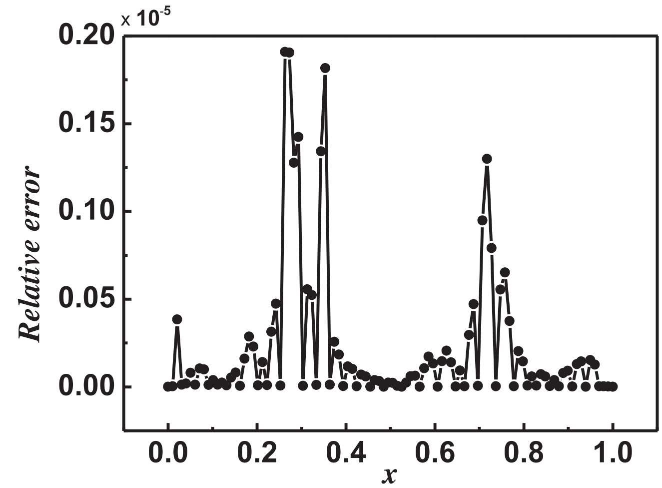

Fig. 4. Relative error between interpolating result and original function.

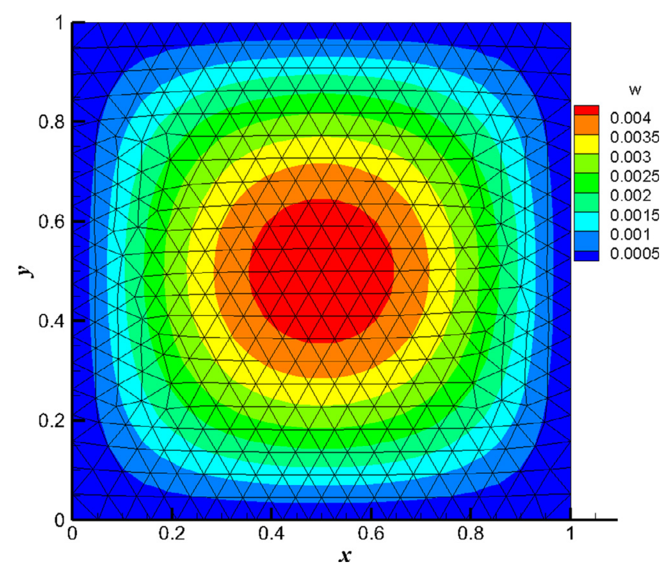

Fig. 5. The displacement contour on the source triangular grid.

finite domain. The basic principle of Kriging is governed by the condition of unbiased and minimal in statistics and estimation of probability. Compared with other interpolation methods, it holds the outstanding features, which can not only predict the mean value, but also estimate the variance at unknown points.

The Kriging algorithm is shown as followed. Suppose that a set of N_f known points $\boldsymbol{P}$ is given that each point P_i has the form ($\mathbf{x}$, Y), where, $\mathbf{x} = (x_1,x_2,x_3)$ denotes the coordinates of the known point and Y is the value. The relationship of value Y and the coordinates $\mathbf{x}$ in Kriging model can be expressed as the following form

$$y(\mathbf{x}) = f(\mathbf{x}, \beta) + z(\mathbf{x}) \tag{1}$$

where, $y(\mathbf{x})$ is the Kriging model, $f(\mathbf{x}, \beta)$ is the polynomial regression function with respect to $\mathbf{x}$ and β is the coefficients of regression function, it is a global approximation model in design space. $z(\mathbf{x})$ is a Gaussian process, whose mean and variance are defined as the written equation

$$\begin{cases} E[z(\mathbf{x})] = 0 \\ \mathrm{cov}[z(\mathbf{x}_i), z(\mathbf{x}_j)] = \sigma^2 R(\theta, \mathbf{x}_i, \mathbf{x}_j) \end{cases} \tag{2}$$

where, $R(\cdot)$ is correlation function with respect to parameter θ, which is related to the space distance between points $\mathbf{x}_i$ and $\mathbf{x}_j$. There is a variety of types of correlation functions, such as exponential function, Gaussian