Advances in Engineering Software 83 (2015) 19–30

Contents lists available at ScienceDirect

Advances in Engineering Software

journal homepage: www.elsevier.com/locate/advengsoft

An enhanced 3D data transfer method for fluid–structure interface by ISOMAP nonlinear space dimension reduction

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ARTICLE INFO

Article history:
Received 25 July 2014
Received in revised form 7 January 2015
Accepted 11 January 2015
Available online 2 February 2015

Keywords:
Data transfer
Non-matching meshes
Nonlinear dimensionality reduction
ISOMAP
Self-parallel
Turbine blade

ABSTRACT

With the accuracy limitation of some transfer methods in the self-parallel fluid–structure interfaces, a data transfer method is proposed by an ISOMAP (Isometric Mapping) nonlinear dimensionality reduction. Through this new method, the data transfer problem of the self-parallel interfaces is solved. Example of a 3D turbine blade shows that the proposed method can improve the transfer accuracy in the non-matching meshes.

1. Introduction

Many engineering applications involve fluid–structure interaction (FSI) problems, for example, designing of airplane wing or jet-engine. Partitioned method is the most important method for the simulation of FSI problem. It requires transferring coupling data(pressure or motion) over meshes of fluid–structure interfaces [1,2]. However, the meshes of the interfaces are commonly non-matching [3]. Transferring the coupling data over the meshes of the interfaces becomes a hard task [3].

In literature, a lot of methods are proposed to transfer data between non-matching meshes [1,3–16]. The first kind is function interpolation methods [3,6]. The function interpolation methods transfer data by approximating scattered data using functions, like, polynomial function or radial basis function (RBF). The second kind is projection methods [3,4,6–9]. The projection methods project the fluid mesh to the structure surface elements to extract the load vectors on the structure nodes.

These two kinds of methods provide good transfer results for fine meshes. But, when the meshes are non-matching, the transfer results of the methods are not always desirable [3,4,6,9]. More for that, the authors found that some of these methods may provide bad transfer results in the self-parallel interfaces (Fig. 1).

In order to achieve better transfer results, virtual surface methods [1,6,9,11–16] create additional meshes of the interfaces as the medium. Coupling data of the interfaces is transferred through the virtual surfaces in the method. As a development of the virtual surface methods, the authors proposed a method to transfer data through a planar projection space [17]. Similar methods are proposed by Refs. [18,19].

In this paper, the impact of self-parallel interfaces on the accuracy of the data transfer methods is investigated. A method is proposed to transfer data through the planar projection spaces. In the proposed method, a new technique is set up to project 3D interfaces into the planar space by ISOMAP [17], an isometric mapping method of nonlinear dimensionality reduction. The proposed method is compared with some methods in a pressure transfer of a turbine blade.

2. Transferring data of the self-parallel interfaces

2.1. Why to transfer data through planar space

Fig. 1 shows a self-parallel interface. Consider a structure point K at the topside of the interface. The value of the point K is calculated by the selected neighboring fluid points. The selected topside points are on the same side of the point K. The selected underside points are on the opposite side. However, these two sets of points are used equally by some data transfer methods. On this condition,

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http://dx.doi.org/10.1016/j.advengsoft.2015.01.009
0965-9978/

the transfer result of the point K may be influenced by the selected underside points. This may lead to wrong transfer result (see Section 2.2).

To solve this problem, this paper suggests unfolding the curved interfaces and transferring FSI data through the planar spaces. The reason can be found from Fig. 2. By unfolding the curved interface, only the nodes on the same side of the point K can be selected in data transfer.

There are also other benefits of unfolding the curved interfaces in transferring data.

Fig. 3 shows a data transfer problem of a 2D curve. This is an interpolation problem in the space of coordinate x and coordinate y. If the transferring is through the space of the parametric coordinate u of the curve, the interpolation will become easier.

Beside, If the data of the interface is transferred by a second-order polynomial function $F(x,y) = A + Bx + Cy + Dx^2 + Ey^2 + Fxy$ in the space of coordinate x and coordinate y, six points are needed

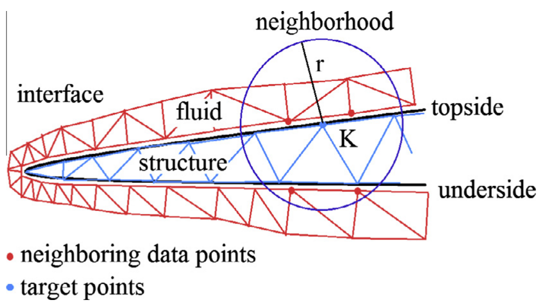

Fig. 1. Data transfer of self-parallel interface.

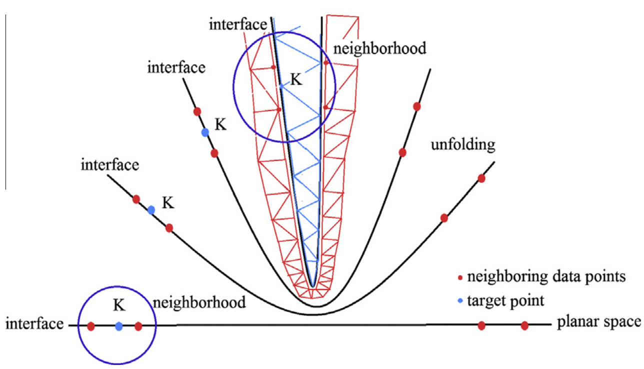

Fig. 2. Unfolding interface.

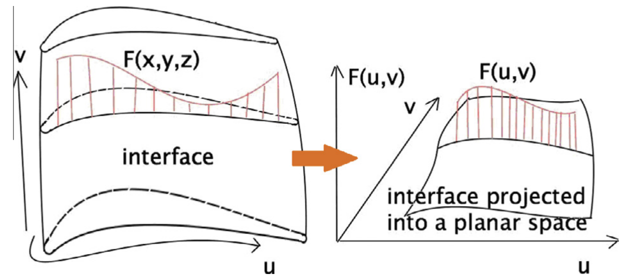

Fig. 4. Data transfer of 3D interface through planar space.

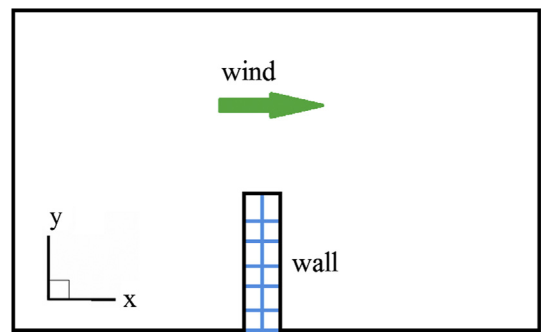

Fig. 5. Test case.

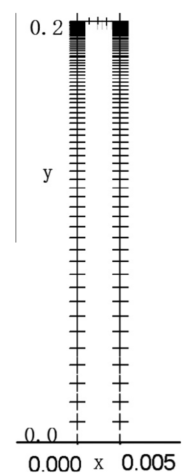

Fig. 6. Fluid meshes of the test case.

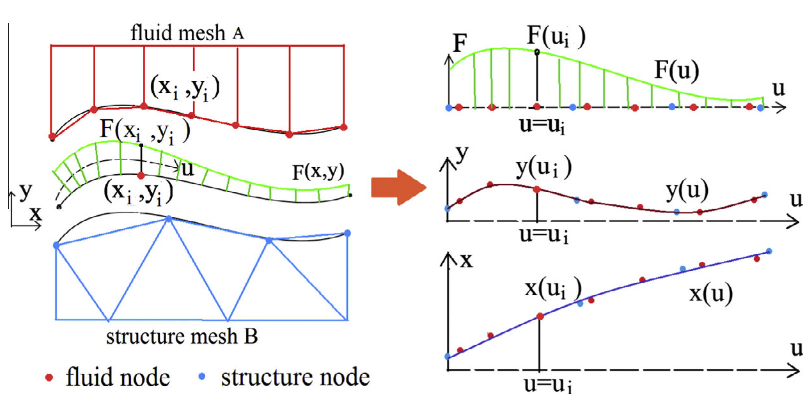

Fig. 3. Data transfer of 2D interface through parametric space.