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Adaptive Cloud Refinement (ACR) – Adaptation in Meshless Framework

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Abstract. In the present work adaptation in meshless framework is proposed. The grid adaptation or mesh adaptation is quite well developed area in case of conventional grid based solvers and is popularly known as Adaptive mesh refinement (AMR). In such cases the adaptation is done by subdividing the cells or elements into finer cells or elements. In case of meshless methods there are no cells or elements but only a cloud of points. In this work we propose to achieve the meshless adaptation by locally refining the point density in the regions demanding higher resolution. This results into an adaptive enriched cloud of points. We call this method as Adaptive Cloud Refinement (ACR). The meshless solvers need connectivity information, which is a set of neighboring nodes. It is crucial part of meshless solvers. Obviously because of refining point density, the connectivity of nodes in such regions gets modified and hence has to be updated. An efficient connectivity update must exploit the fact that the node distribution would be largely unaffected except the region of adaptation. Hence connectivity updating needs to be done locally, only in these regions. In this paper we also present an extremely fast algorithm to update connectivity over adapted cloud called as ACU (Automatic Connectivity Update).

AMS subject classifications: 76-04, 76M25, 65M50

Key words: KFVS, LSKUM, meshless methods, adaptation, ACR, ACU.

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1 Introduction

Mesh adaptation is a technique to reduce the errors in approximations used to solve the PDE's. This can be done by redistributing the grid (r-refinement), refining the grid (h-refinement) or increasing the order of approximation (p-refinement). In the conventional solvers i.e., FDM, FVM or FEM, h-adaptation is done by subdividing the cells or elements into finer ones. These techniques, called Adaptive Mesh Refinement (AMR) are fairly well developed [1,2]. The idea is to have finer discretization. The subdivision of cells or elements has to be done subject to quality constraints on resulting mesh. In particular the adapted mesh should avoid hanging nodes or edges and highly skewed cells. The subdivision and formation of new cells or elements has to reflect in the book keeping followed for the mesh and the solver. The data of cells, edges and nodes gets modified. In the AMR these challenges have to be faced to achieve adaptation for mesh based solvers.

The meshless methods have been very successful in solving several challenging CFD problems [3–5]. These solvers ease the process of grid generation which is often a bottleneck in CFD simulations. These methods in general require only a cloud of points and connectivity information at each of the nodes, where connectivity is defined as the set of nearest neighbouring nodes to a given node. Hence only node data is sufficient. Managing only node data offers considerable simplicity in book keeping. Further the quality constraints on the cloud of points are far less when compared to mesh based solvers. These observations are very encouraging to explore adaptation in meshless environment. The meshless methods do not contain any cells or elements, hence adaptation by subdividing the cells or elements on mesh based solvers is not relevant here. A new approach has to be followed for adaptation in meshless solvers. Keeping with the idea of finer discretisation we propose to refine the point density in regions demanding higher resolution. This results in an adapted and enriched cloud of points. We call this method as Adaptive cloud refinement (ACR). Connectivity which is defined as the set of neighbouring nodes is the crucial component of meshless solvers. When we refine the point distribution by increasing the local point density, the connectivity of the nodes in that region gets altered. The new nodes which are added do not have any connectivity. Hence the connectivity has to be updated for the nodes from initial cloud and has to be generated for new nodes. This should as well be carried out locally as the connectivity of nodes in unrefined regions is largely unaffected. In this work an efficient algorithm has been developed for this purpose and is called as Automatic Connectivity Update (ACU).

Adaptation through h-refinement essentially involves obtaining solutions on an initial discretized domain. Suitable sensors are used to mark the regions requiring refinement. Refinement in these regions obviously alters the domain discretization locally. The solver is run on the adapted domain to obtain a better solution. Several cycles of adaptation can be carried out to achieve good results i.e., accurate resolution of flow scales. We have chosen Least Squares Kinetic Upwind Method (LSKUM) [6] for computing flow solutions. It is a meshless solver requiring only a cloud of points and the connectivity information.