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ELECTROSTATIC LEVITATION OF LUNAR DUST: A NEW CHALLENGE FOR EFFICIENTLY SOLVING ELLIPTIC INTERFACE PDES ON STRUCTURED MESHES INSTEAD OF BODY-FITTING MESHES

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This presentation discusses a new finite element method to efficiently solve elliptic interface PDEs on structured meshes. One of our major motivations is the electrostatic levitation of lunar dust, which is one of the greatest inhibitors to a nominal operation on the moon. Recently it has become a very interesting and popular research topic for the coming lunar missions.

Particle-In-Cell (PIC) is a very famous and efficient way for plasma particle simulation. This method itself needs two meshes. One is to locate the simulation particles, collect the information from particles, and realize the effect of the electromagnetic field on the particles. The other one is for numerically solving a partial differential equation for the electric potential. Since we generally need millions of simulation particles and thousands of simulation steps to reach the stable status, the two meshes should be well structured and easily communicate with each other. Otherwise, the computational expense is formidable. However, the simulation usually has complicated interfaces between the space and different objects, such as lunar surfaces, spacecraft and astronauts. Therefore, when we use the standard finite element methods to solve the partial differential equation, we have to use body-fitting meshes, which are unstructured and not suitable for PIC. Meanwhile, when the spacecraft and astronauts are moving, the interfaces are moving. Hence the body-fitting meshes have to be reformed again and again, which will increase computational cost even further by significant amount.

There are numerous similar examples, in which a simulation domain is often formed by several materials separated from each other by curves or surfaces while a structured mesh instead of a body-fitting mesh is preferred. These problems are critical to many research areas, such as flow problems, electromagnetic problems, shape/topology optimization problems, mathematical biology problems and the modeling of nonlinear phenomena. The new finite elements we are developing for these problems are called immersed finite elements (IFE). IFEs allow structured mesh, such as Cartesian mesh, to be used for solving interface problems while keeping a similar structure to that of the standard finite elements. Another advantage of IFEs is that the algebraic system arising from this method is symmetric and positive definite.

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