Numerical methods for solving partial differential equations are commonplace in the engineering community and their popularity can be attributed to the rapid performance improvement of modern workstations and desktop computers. The ubiquity of computer technology has allowed all areas of engineering to have access to detailed thermal, stress, and fluid flow analysis packages capable of performing complex studies of current and future designs. The rapid pace of computer development, however, has begun to outstrip efforts to reduce analysis overhead. As such, most commercially available software packages are now limited by the human effort required to prepare, develop, and initialize the necessary computational models. Primarily due to the mesh-based analysis methods utilized in these software packages, the dependence on model preparation greatly limits the accessibility of these analysis tools. In response, the so-called meshless or mesh-free methods have seen considerable interest as they promise to greatly reduce the necessary human interaction during model setup. However, despite the success of these methods in areas demanding high degrees of model adaptability (such as crack growth, multi-phase flow, and solid friction), meshless methods have yet to gain Notoriety as a viable alternative to more traditional solution approaches in general solution domains. Although this may be due (at least in part) to the relative youth of the techniques, another potential cause is the lack of focus on developing robust methodologies. The failure to approach development from a practical perspective has prevented researchers from obtaining commercially relevant meshless methodologies which reach the full potential of the approach.

The primary goal of this research is to present a novel meshless approach called MIMS (Model Integrated Meshless Solver) which establishes the method as a generalized solution technique capable of competing with more traditional PDE methodologies (such as the finite element and finite volume methods). This was accomplished by developing a robust meshless technique as well as a comprehensive model generation procedure. By closely integrating the model generation process into the overall solution methodology, the presented techniques are able to fully exploit the strengths of the meshless approach to achieve levels of automation, stability, and accuracy currently unseen in the area of engineering analysis. Specifically, MIMS implements a blended meshless solution approach which utilizes a variety of shape functions to obtain a stable and accurate iteration process. This solution approach is then integrated with a newly developed, highly adaptive model generation process which employs a quaternary triangular surface discretization for the boundary, a binary-subdivision discretization for the interior, and a unique shadow layer discretization for near-boundary regions. Together, these discretization techniques are able to achieve directionally independent, automatic refinement of the underlying model, allowing the method to generate accurate solutions without need for intermediate human involvement. In addition, by coupling the model generation with the solution process, the presented method is able to address the issue of ill-constructed geometric input (small features, poorly formed faces, etc.) to provide an intuitive, yet powerful approach to solving modern engineering analysis problems.
Dr. Eduardo Divo, MMAE

Approved for distribution by Dr. Alain Kassab, Committee Chair, on June 22, 2010.

The public is welcome to attend.