Project Artie: An Artificial Student for Disciplines Informed by Partial Differential Equations

Anthony Patera, MIT

We present an Artificial Student, ""Artie,"" for engineering science disciplines in which the mathematical model is a partial differential equation (PDE); Artie considers here the particular case of steady heat conduction. Artie accepts problem statements posed in natural language. Artie provides a symbolic-numeric approximate solution: the PDE field; scalar Quantities of Interest (QoI), expressed as functionals of the field. The problem statement will typically not provide explicit guidance as to the equation or approximations which should be invoked. We also present Artie+, who provides the finite element solution to the PDE: the exact solution to within a prescribed tolerance controlled by an a posteriori error estimator.

Artie comprises four technical ingredients. Natural Language Processing: We proceed in two stages, domain-independent Google Natural Language syntax analyzer followed by frame-specific conduction parser. PDE Template: The PDE is exploited by the conduction parser to extract geometry, boundary conditions, and coefficients; subsequent approximations are deduced from this ground-truth description. Problem Classes and Geometry Classes, Components and Systems: A problem class places requirements on spatial domain, boundary conditions, properties, and QoI; associated to each problem class are several geometry classes. A component is an instantiation of the geometry class for prescribed geometric and PDE parameters; a system is represented as an assembly of connected components. Variational Formulation: We consider the weak statement and minimization principle to formulate the PDE and develop suitable approximations; implementation proceeds through static condensation and direct stiffness assembly over component ports.

We describe and illustrate a prototype implementation of Artie and Artie+.