Center for Environmental & Applied Fluid Mechanics

"The Hybrid Integral Transform Approach in Convection-Diffusion Problems"

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Abstract: Advanced The classical analytical methods for partial differential equations had their conception mostly within the 19th and first half of the 20th centuries, with very restrictive applicability bounds due to the unavoidable formulation simplifications and limited computational capabilities of that period. Though the idea behind discrete numerical methods was already introduced within this period, its dissemination had to wait for the advent of the digital computer and then an explosion of numerical techniques and schemes naturally followed, tearing the straitjacket of the problem formulations complexity level, along the second half of the 20th century. Simulation in engineering sciences then evolved to an unprecedent analysis power, leading to most of the material progress achieved till the present. With the inherent increase in formulation complexity needs and accuracy requirements, computational effort grew to a level, in different classes of problems, not closely followed by the concurrent continuous hardware improvement. In consequence, alternative hybrid numerical-analytical approaches were proposed along the way, with different degrees of generality and success, that attempted to reduce computing effort, improve accuracy, and warrant robustness. The Generalized Integral Transform Technique (or just GITT) is a well-established hybrid approach in the Transport Phenomena wide field, which derives from the classical integral transform method for linear diffusion problems. It combines controlled truncation of eigenfunction expansions with error controlled numerical solutions of ordinary differential equations to provide hybrid numerical-analytical solutions to different classes of problems such as nonlinear formulations, moving boundary problems, irregular domains, coupled problems, heterogenous media, boundary layer and Navier-Stokes equations. The relative merits of the hybrid methodology are discussed, especially in connection with highly intensive computational tasks that require numerous computations of the associated direct problem, such as optimization studies, inverse problem analysis, physics informed neural networks, and simulation under uncertainty. Recent progresses in this computational-analytical approach are here reviewed and a few selected applications from on-going projects are highlighted.

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