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Exponential integration and applications

In this talk we will discuss several ways in which the ideas of exponential integration can be used to construct accurate and efficient schemes for stiff systems of differential equations. We will present a new framework to develop and to analyze new class of schemes we call stiffness resilient methods. Previously proposed exponential integrators are typically derived using either classical or stiff order conditions. These order conditions are complex and difficult to solve to construct high order schemes. Classically derived methods can also suffer from the order reduction phenomenon. The new φ -order conditions we propose allow greatly simplified construction of exponential methods with favorable properties. The structure of the error of these methods is designed to prevent order reduction for many important stiff problems. At the same time stiffness resilient schemes are easy to derive using our proposed approach. In addition, we will discuss new exponential schemes for simulating particle dynamics in the presence of electromagnetic fields. We will show that these methods are highly competitive compared to the state-of-the-art integrators, such as Boris algorithm, which have been used extensively in particle-in-cell (PIC) plasma simulations.