Taylor-type 1-step-ahead numerical differentiation rule for first-order derivative approximation and ZNN discretization

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HIGHLIGHTS

- A formula is proposed to approximate the first-order derivative.
- An optimal step length rule for the proposed formula is investigated.
- A Taylor-type ZNN model is derived for time-varying matrix inversion.

ABSTRACT

In order to achieve higher computational precision in approximating the first-order derivative and discretize more effectively the continuous-time Zhang neural network (ZNN), a Taylor-type numerical differentiation rule is proposed and investigated in this paper. This rule not only greatly remedies some intrinsic weaknesses of the backward and central numerical differentiation rules, but also overcomes the limitation of the Lagrange-type numerical differentiation rules in ZNN discretization. In addition, a formula is proposed to obtain the optimal step-length of the Taylor-type numerical differentiation rule. Moreover, based on the proposed numerical differentiation rule, the stability, convergence and residual error of the Taylor-type discrete-time ZNN (DTZNN) are analyzed. Numerical experimental results further substantiate the efficacy and advantages of the proposed Taylor-type numerical differentiation rule for first-order derivative approximation and ZNN discretization.

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1. Introduction

Numerical differentiation, which describes methods/algorithms for estimating the derivative of a mathematical function, is widely used to solve ordinary differential equations (ODEs) and partial differential equations (PDEs) in numerical analysis and engineering applications [1–4]. Various methods/algorithms have been presented and employed for first-order derivative approximation, such as the polynomial interpolation method [5], the finite difference method [6], the regularization method [7], the method of undetermined coefficients [8] and the method of Lagrange-type 1-step-ahead numerical differentiation [9]. In [10], Mboup et al. derived a numerical differentiation explicit rule yielding a pointwise derivative estimation for each given order. Ramm et al. presented a new approach to the construction of finite-difference methods and they showed how the multi-point differentiators can generate regularizing algorithms with a stepsize being a regularization parameter in [11]. However, considering the following four situations: (1) that the backward differentiation rules may not adapt to the fast variational rate of the first-order derivative of target point, (2) that the central differentiation