Fixed-Time Stability and Noise Robustness of a Polynomial-Gain Gradient Neural Network for Absolute Value Equations

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Abstract

In this paper, we propose a Fixed-time Gradient Neural Network (FGNN) for solving the absolute value equation $Ax - |x| = b$. The FGNN employs a polynomial-gain architecture that combines sub-linear, super-linear, and reciprocal damping terms. We prove global fixed-time stability of the unperturbed system with an explicit settling-time bound and establish four robustness theorems: fixed-time stability and fixed-time boundedness under both bounded vanishing and bounded non-vanishing noise. Numerical experiments across nine models spanning three reformulation families validate FGNN's fixed-time convergence, dual noise robustness, and practical efficacy. A limitation analysis of the exponential predefined-time gain reveals catastrophic floating-point overflow at moderate initial residuals, further motivating the polynomial-gain design as a numerically reliable alternative with rigorous theoretical guarantees.

Keywords: Fixed-time stability; Gradient neural networks; Absolute value equations; Polynomial-gain architecture; Noise robustness; Non-vanishing perturbations; Lyapunov stability; Predefined-time limitations.