

A Method of Computing Complex Nonlinear Diffusion Equations by Cellular Neural Network

P. D. Long¹ and P. T. Cat²

Abstract: In this paper we propose a new parallel computing method for solving complex nonlinear diffusion equations by Cellular Neural Network (CNN). The Cellular Neural Network was invented by L.O Chua and L.Yang (University of California at Berkeley) in 1988 and then in 1992 the Cellular Neural Network Universal Machine (CNN-UM) is also invented by L.O Chua and Roska Tamas (MTA-SZTAKI Computer and Automation Institute of the Hungarian Academy of Sciences), that is powerful tool to solve Partial Differential Equations (PDE) in real-time.

The CNNs are lattices of cells those are locally connected analogical processors. CNNs are a lively expressing by hardware, they are perfect tools suitable for parallel processing flows huge data. By CNN one can to solve PDEs in real-time with difference method. Recently the heat diffusion, Burger, Sine Gordon, Fitz Hugh Nagumo PDEs have been solved by CNN by many authors. However, those equations are real PDEs. Studying the complex PDE have potential meaning in both theory and practice. In this paper firstly we deal with the complex diffusion process describing by the equation $\frac{\partial I}{\partial t} = C\Delta I$ where both C constant and function $I(x, y)$ are complex having real and imaginary parts, Δ is the Laplace operator. We use a two layers 2D CNN to solve this PDE. The first layer is used to compute real part and the other layer is used to compute the imaginary part. Between two layers there are interactions represented by locally interconnected nonlinear weights of neurons.

Secondly we deal with the problem of image denoising but preserving ramp type edge. We deal with the complex nonlinear diffusion PDE of type $\frac{\partial I}{\partial t} = \nabla \cdot (d(Im(I)) \nabla I$ where $\nabla \cdot$ and ∇ are divergence and gradient operator respectively. The components $I(x, y)$ and $d(Im(I))$ are the complex functions. This complex nonlinear PDE is useful in denoising and preserving ramp edge of image $I(x, y)$ in both x and y directions. We propose a two-layer 2D CNN model with nonlinear templates to simulate this complex nonlinear diffusion. The proposed model may be implemented in hardware CNN chip and due to parallel processing of CNN, the processing time is very fast in some micro seconds. So this is a way to solve complex nonlinear PDEs in real-time. We also give some simulation results on PC to demonstrate the performances of the proposed method in this paper.

¹ Faculty of Information Technology, Thai Nguyen University, Thai Nguyen City, Vietnam
dlong2na@hotmail.com

² Institute of Information Technology, Vietnamese Academy of Science and Technology
18 Hoang Quoc Viet Road, Hanoi, Vietnam
ptcat@ioit.vast.ac.vn