

# From the Editor



Chai Wah Wu

Editor-in-Chief, *IEEE Circuits and Systems Magazine*

It is my immense pleasure to introduce this special issue edited by Prof. Ronald Tetzlaff and Prof. Dalibor Bielek in honor of Prof. Leon Chua's 80th birthday.

Leon Chua was much more than just my Ph.D. dissertation supervisor. He was also my mentor, friend, colleague, advisor, and role model. He has a knack for finding beauty, elegance, and excitement in the sometimes mundane engineering topics. While his accomplishments in areas such as nonlinear circuit theory [1] advance the current state of the art and are found in textbooks and course curricula, many of his discoveries have continued to find important novel applications many years later. The discovery of memristors as the “missing” circuit element, described in his landmark 1971 IEEE TCAS paper [2], was an intellectual tour de force. The traditional circuit elements of resistors, capacitors and inductors were known for over a century, but Leon saw them as part of the systematic relationships between the fundamental properties of charge, voltage, time, and flux and deduce the missing part in these relationships. Only recently has it been practical to manufacture memristors at scale in novel memory architectures and this is now a thriving research effort. By the time I joined Leon's lab, Leon has changed his focus to study nonlinear dynamics, in particular chaotic dynamics of nonlinear circuits. This has been observed since Van der Pol [3] at the beginning of the last century, but only beginning to be understood in the last few decades. The introduction of Chua's circuit [4] provides a useful theoretical and practical device for studying such chaotic phenomena, especially in electronic circuits. The beautiful pictures of the myriad of strange attractors belie the immense complexity within.

He also introduced the world to Cellular Neural Networks [5], a powerful paradigm of analog computing that uses shift invariant templates to reduce the complexity of the network and leverage the shift invariant nature of many computer vision tasks such as edge detection. The feedback template allows computation to be iterated via the continuous-time dynamics and this has resulted in many nontrivial but useful dynamics [6], including chaos, whereas the feedforward template allows partial re-



With Diana and Leon Chua at IWCSN Shanghai, 2014.

sults to be propagated to the next layer. The technique of using shift invariance to reduce the number of free parameters was also found useful in feed forward Convolutional Neural Networks (same acronym!) to successfully tackle various difficult computer vision problems [7]. One of Cellular Neural Networks' strengths is that the use of feedback template allows the complex dynamics of the resulting ODE to play a role in the computation. Recently, Convolutional Neural Networks coupled with Residual Networks are analyzed as the Forward Euler discretization of an ODE that is of the same form as a Cellular Neural Network [8].

Leon also conducted fundamental research in piecewise-linear (PWL) functions [9]–[11] and introduced Canonical Piecewise-Linear representations of multidimensional PWL functions. PWL activation functions were used in the original formulation of Cellular Neural Networks and recently is becoming more important in deep learning as PWL activation functions such as rectified linear units (ReLU) were found to be easier to implement and improve training speed as they overcome the “vanishing gradient” problem when sigmoid functions are used in back propagation training. A recent paper on deep learning neural networks with ReLU

activation functions [12] leverages results [13] in the theory of PWL functions pioneered by Leon.

I was grateful to have an opportunity to be a small part of Leon's journey through science and technology and I am honored to be part of this special issue of excellent articles celebrating Leon's achievements. I wish Leon continued health and happiness and look forward to learning about his scientific innovations for many years to come.

Finally, I would like to welcome Prof. Ming Cao of the University of Groningen and Prof. Sule Ozev of Arizona State University to the Editorial Board.

### References

- [1] L. O. Chua, *Introduction to Nonlinear Network Theory*. New York: McGraw-Hill, 1969.
- [2] L. O. Chua, "Memristor: The missing circuit element," *IEEE Trans. Circuit Theory*, vol. 18, no. 5, pp. 507–519, Sept. 1971.
- [3] M. P. Kennedy and L. O. Chua, "Van der Pol and Chaos," *IEEE Trans. Circuits Syst.*, vol. 33, no. 10, pp. 974–980, Oct. 1986.
- [4] T. Matsumoto, "A chaotic attractor from Chua's circuit," *IEEE Trans. Circuits Syst.*, vol. 31, no. 12, pp. 1055–1058, Dec. 1984.
- [5] L. O. Chua, "Cellular neural networks: Theory," *IEEE Trans. Circuits Syst.*, vol. 35, no. 10, pp. 1257–1272, Oct. 1988.
- [6] T. Matsumoto, L. O. Chua, and H. Suzuki, "CNN cloning template: Connected component detector," *IEEE Trans. Circuits Syst.*, vol. 37, no. 5, pp. 633–635, Oct. 1990.
- [7] Y. LeCun et al., "Gradient-based learning applied to document recognition," *Proc. IEEE*, vol. 86, no. 11, pp. 2278–2324, Nov. 1998.
- [8] B. Chang et al., "Multi-level residual networks from dynamical systems view," in *Proc. Int. Conf. Learning Representations*, 2018.
- [9] L. O. Chua and A.-C. Deng, "Canonical piecewise-linear representation," *IEEE Trans. Circuits Syst.*, vol. 35, no. 1, pp. 101–111, Jan. 1988.
- [10] C. Kahlert and L. O. Chua, "A generalized canonical piecewise-linear representation," *IEEE Trans. Circuits Syst.*, vol. 37, no. 3, pp. 373–383, 1990.
- [11] C. Kahlert and L. O. Chua, "The complete canonical piecewise-linear representation: I. The geometry of the domain space," *IEEE Trans. Circuits Syst.*, vol. 39, no. 3, pp. 222–236, 1992.
- [12] R. Arora et al., "Understanding deep neural networks with rectified linear units," in *Proc. Int. Conf. Learning Representations*, 2018.
- [13] W. Sun, "Generalization of hinging hyperplanes," *IEEE Trans. Circuits Syst.*, vol. 51, no. 12, pp. 4425–4431, Dec. 2005.

## IEEE connects you to a universe of information!

As the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity, the IEEE and its Members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

Visit [www.ieee.org](http://www.ieee.org).

Publications / IEEE Xplore® / Standards / Membership / Conferences / Education



**IEEE**