



# A comprehensive review of Binary Neural Network

Chunyu Yuan<sup>1</sup> · Sos S. Aгаian<sup>1,2</sup>

Accepted: 9 March 2023 / Published online: 30 March 2023  
© The Author(s), under exclusive licence to Springer Nature B.V. 2023

## Abstract

Deep learning (DL) has recently changed the development of intelligent systems and is widely adopted in many real-life applications. Despite their various benefits and potentials, there is a high demand for DL processing in different computationally limited and energy-constrained devices. It is natural to study game-changing technologies such as Binary Neural Networks (BNN) to increase DL capabilities. Recently remarkable progress has been made in BNN since they can be implemented and embedded on tiny restricted devices and save a significant amount of storage, computation cost, and energy consumption. However, nearly all BNN acts trade with extra memory, computation cost, and higher performance. This article provides a complete overview of recent developments in BNN. This article focuses exclusively on 1-bit activations and weights 1-bit convolution networks, contrary to previous surveys in which low-bit works are mixed in. It conducted a complete investigation of BNN's development—from their predecessors to the latest BNN algorithms/techniques, presenting a broad design pipeline and discussing each module's variants. Along the way, it examines BNN (a) purpose: their early successes and challenges; (b) BNN optimization: selected representative works that contain essential optimization techniques; (c) deployment: open-source frameworks for BNN modeling and development; (d) terminal: efficient computing architectures and devices for BNN and (e) applications: diverse applications with BNN. Moreover, this paper discusses potential directions and future research opportunities in each section.

**Keywords** Binary Neural Network · Convolution Neural Network · Model compression and acceleration · Binarization · Quantization

---

✉ Chunyu Yuan  
cyuan1@gradcenter.cuny.edu

Sos S. Aгаian  
sos.agaian@csi.cuny.edu

<sup>1</sup> The Graduate Center, City University of New York, New York, USA

<sup>2</sup> College of Staten Island, City University of New York, New York, USA