

A Survey on the DeepJSCC for Wireless Communications

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Abstract

Deep Joint Source-Channel Coding (DeepJSCC) has emerged as a transformative approach in wireless communication, offering the promise of improved reliability, efficiency, and security. This paper presents a comprehensive survey of DeepJSCC, focusing on its techniques, applications, and comparative analysis with traditional methods. We delve into deep learning-based approaches for source coding and the integration with channel coding techniques, highlighting advancements in compressing structured data like images and text. Our survey covers diverse applications of DeepJSCC, from vehicular networks to Internet of Things (IoT) environments. Additionally, performance evaluation and comparison studies assess DeepJSCC's effectiveness across scenarios. This survey provides insights into the current state of DeepJSCC research and its potential in shaping future wireless communication systems.

I. Introduction

In the rapidly evolving field of wireless communication, the pursuit of effective and dependable data transmission is a constant challenge. However, this method encounters limitations when dealing with data of finite length and restrictions on the length of the encoding. An encouraging remedy to these constraints lies in incorporating deep learning methodologies into communication systems, notably through Deep Learning-based Joint Source-Channel Coding (DeepJSCC).

DeepJSCC has emerged as a transformative force in wireless communication, combining deep learning with traditional methods to present a robust departure from the traditional division between source and channel coding. Its application extends across various types of data, demonstrating improved error rates, reliability, security, and efficient bandwidth utilization. The flexibility of DeepJSCC, highlighted by its capacity to adapt to changing signal-to-noise ratios without performance decline, underscores its significance as a key technology for upcoming wireless communication systems.

II. Literature Review

A) Deep Learning-Based Approaches for Source Coding

Deep learning has transformed source coding by introducing novel methods to compress and encode data for transmission [1]. Unlike traditional techniques like Huffman or arithmetic coding, which aim to minimize code length on average, deep learning

approaches consider the semantic meaning of the data. On the other hand, deep learning-based approaches can be learned to preserve the semantic content of the data during compression, leading to more efficient and meaningful representations.

Deep learning plays a crucial role in source coding, particularly in compressing structured data like images or text. For example, Convolutional Neural Networks (CNNs) effectively capture spatial relationships in images, enabling efficient image compression techniques [2]. Similarly, Recurrent Neural Networks (RNNs) have been used for text compression, as they can handle sequential data and capture long-range dependencies in text. These deep learning-based approaches for source coding have shown promising results, outperforming traditional methods in terms of both compression efficiency and preservation of semantic content.

B) Integration of Deep Learning with Channel Coding Techniques

Deep Learning has been increasingly integrated with channel coding techniques to enhance the efficiency and reliability of wireless communications. A notable approach in this realm is Deep Learning-Based Adaptive Joint Source-Channel Coding (DJSCC) employing Hypernetworks [3]. DJSCC holds promise as a pivotal technique for upcoming wireless networks. However, the existing DJSCC schemes are encountered in adapting to varying channel conditions, often being trained under specific conditions. The integration of deep learning with these techniques allows for better adaptability to channel conditions and higher memory efficiency.

Another significant integration of deep learning with channel coding techniques is seen in the use of Low-Density Parity-Check (LDPC) codes. LDPC codes play a pivotal role in mitigating errors induced during data transmission [4]. The integration of machine learning with LDPC channel decoding techniques has been explored to enhance the reliability and efficiency of 5G networks. This integration facilitates the development of a more robust and efficient communication system, particularly in environments demanding high data transmission rates.

C) Applications of DeepJSCC in Different Wireless Communication Scenarios

Deep Joint Source-Channel Coding (DeepJSCC) has been widely applied across diverse wireless communication scenarios [5], especially in environments where conventional methods face challenges due to the unpredictable nature of the wireless channel. For example, in vehicular communication networks characterized by dynamic conditions, DeepJSCC has been employed to enhance communication reliability and efficiency. The deep learning models in DeepJSCC can learn the complex vehicular environment and optimize the source and channel coding jointly, thereby enhancing the overall communication performance.

D) Performance Evaluation and Comparison Studies

Performance evaluation and comparison studies play a critical role in assessing the effectiveness of Deep Joint Source-Channel Coding (DeepJSCC) across various scenarios. Researchers conducted simulations to compare various DeepJSCC schemes, including DeepJSCC-AF, DeepJSCC-DF, and DeepJSCC-PF, against traditional digital baselines [6]. The findings indicated that the proposed DeepJSCC schemes outperformed the digital baselines, demonstrating graceful performance degradation under deteriorating channel quality.

III. Conclusion

Deep Joint Source-Channel Coding (DeepJSCC) stands at the forefront of innovation in wireless communication, offering a paradigm shift in how data is transmitted, compressed, and secured. Through the integration of deep learning techniques with traditional communication methods, DeepJSCC enables more efficient and meaningful representations of data, leading to improved error rates, reliability, and bandwidth utilization. Our survey has highlighted the versatility of DeepJSCC across various applications, from vehicular networks to IoT environments, where its adaptive nature and robust performance have been

demonstrated. Additionally, comparative analysis studies have shown the superiority of DeepJSCC over traditional methods, reaffirming its potential as a key technology for future wireless communication systems. Moving forward, continued exploration, refinement, and widespread adoption of DeepJSCC will be essential to fully harness its capabilities and address the evolving demands of communication in the digital age.

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