

# A Survey on the DeepJSCC for Semantic Communications

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## Abstract

The integration of deep learning with communication systems has led to significant evolutions in the field, particularly through the development of Deep Learning-based Joint Source-Channel Coding (DeepJSCC). This innovative approach merges source and channel coding into a single, unified framework, significantly improving the efficiency and reliability of transmitting structured data such as text, images, and video over noisy channels. DeepJSCC transcends traditional methodologies by embedding data into a semantic space where similar meanings are closely aligned, thus preserving the integrity, and meaning of the transmitted information. This paper provides a comprehensive review of the applications and efficacy of DeepJSCC across diverse types of data transmission. It underscores the transformative influence of DeepJSCC on semantic communication, its resilience to common transmission errors, and its capacity to adapt to fluctuating channel conditions without the typical degradation observed in conventional systems.

## I. Introduction

In recent years, the integration of deep learning techniques into communication systems have brought about a paradigm shift, bringing in a new approach to improve information transmission and processing [1]. A significant breakthrough in this regard is the fusion of deep learning techniques with Semantic Communication, a domain that extends beyond the exchange of mere syntactic representations to the transmission of meaningful information. In this context, Deep learning-based Joint Source-Channel Coding (DeepJSCC) has emerged as a promising approach, leveraging the power of neural networks to optimize communication systems specifically for semantic content transmission [2].

## II. Literature Review

### A) Text Transmission

A key challenge in wireless communications is the joint source-channel coding of structured data, such as natural language, over noisy channels. The typical approach to tackling this issue involves a two-step process: initially, the text is compressed using source coding, after which channel coding is implemented to fortify its resilience during transmission across the channel. However, the conventional method encounters limitations when dealing with documents of finite length and restrictions on the length of the encoding. The optimality of JSCC is no longer guaranteed under these conditions, necessitating the exploration of alternative strategies.

To address these obstacles, Farsad, Rao, and Goldsmith introduced an innovative strategy in their research paper: a deep learning-based encoder and decoder aimed at achieving reduced word error rates in [3]. Their approach revolutionizes the way semantic information of sentences is preserved during transmission. Instead of treating source and channel coding as separate entities, they propose an end-to-end framework that embeds sentences in a semantic space. Within this space, sentences with similar meanings are positioned closer together. This inventive technique enables joint optimization of source and channel coding on these embeddings, enhancing the transmission of semantic content over noisy channels.

### B) Image Transmission

Image transmission over noisy channels presents unique challenges, particularly due to the high data rates required and the sensitivity of image data to transmission errors [4]. Efficient and reliable image transmission is crucial in a variety of applications, ranging from multimedia streaming to remote sensing and telemedicine. However, traditional methods that treat source and channel coding as separate entities encounter limitations when dealing with images of finite size and restrictions on the length of the encoding.

To tackle these obstacles, researchers have introduced a groundbreaking method called Deep Joint Source-Channel Coding (DeepJSCC) [3]. This innovation approach harnesses the power of deep learning to optimize both source coding (image compression) and channel coding simultaneously, thereby enhancing the reliability and efficiency of

image transmission. Notably, DeepJSCC exhibits a remarkable feature by avoiding the “cliff effect” and ensuring a smooth performance degradation as the signal-to-noise ratio (SNR) of the channel varies compared to the SNR value assumed during training. In scenarios involving a slow Rayleigh fading channel, DeepJSCC adeptly learns noise-resilient coded representations, surpassing the performance of separation-based digital communications across all SNR and channel bandwidth values.

### C) Video Transmission

Video transmission over wireless channels presents unique challenges due to the high data rates required and the sensitivity of video data to transmission errors [5]. Achieving efficient and dependable video transmission is vital for many applications, including multimedia streaming, video conferencing, and remote surveillance. However, traditional methods that treat source and channel coding as separate entities encounter limitations when dealing with videos of finite length and restrictions on the length of the encoding.

The innovative approach of DeepJSCC has emerged as a solution to these challenges. One notable example is DeepWiVe [6], the pioneering end-to-end JSCC scheme for video that utilizes deep neural networks (DNNs) to convert video signals directly into channel symbols. This method integrates video compression, channel coding, and modulation into a single neural operation. Additionally, the advent of DeepJSCEC marks the first DeepJSCC strategy designed for secure wireless video transmission, safeguarding against eavesdroppers. These advancements in DeepJSCC not only enhance video transmission quality over noisy channels but also tackle crucial issues like feedback use and security.

## III. Conclusion

Deep Learning-based Joint Source-Channel Coding (DeepJSCC) has emerged as a transformative force in the realm of data transmission across noisy communication channels. By fusing deep learning techniques with traditional communication systems, DeepJSCC offers a robust alternative to the conventional separation of source and channel coding, particularly in scenarios involving finite-length and bandwidth-restricted transmissions. Its application spans various types of data – text, image, and video – demonstrating not only improved error rates and reliability but also enhanced security and efficient bandwidth utilization.

The adaptability of DeepJSCC, especially its ability to adjust to varying signal-to-noise ratios without the abrupt performance degradation typical of traditional methods, underscores its potential as a pivotal technology in future communication systems. As we move forward, the continued exploration, refinement, and broad implementation of DeepJSCC will be crucial to fully harness its capabilities and

meet the evolving spectrum of communication needs. This survey serves as a testament to the revolutionary impact of DeepJSCC on semantic communication and its promising trajectory toward redefining the landscape of data transmission.

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