

Semantic Reference Matching and Diffusion Learning for Intelligent Super-Resolution in Visual Information Systems

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ABSTRACT

To enhance spatial detail in remote sensing images, super-resolution (SR) has become essential. Conventional single-image SR suffers from limited information, often producing overly smoothed results. Reference-based SR leverages high-resolution reference images to mitigate this issue, but real-world scenarios face cross-sensor discrepancies and temporal land-cover changes, causing concept omission and mismatch that hinder effective reference utilization. To address these challenges, the authors propose a diffusion-based SR framework with semantic reference matching, namely Semantic Reference Matching and Diffusion Learning for Intelligent Super-Resolution in Visual Information Systems (SRM-DL). It comprises two key modules: (a) Concept Activation, which uses diffusion priors to recover missing structures, and (b) Attribute Concentration, which used a local–global dual-branch alignment to robustly incorporate semantically consistent reference information while suppressing mismatches. Multiscale consistency constraints further align reference and target features across spatial and semantic domains. Extensive experiments validated its effectiveness and practical potential in multimedia visual information systems.

KEYWORDS

Remote Sensing Super-Resolution, Diffusion Models, Multiscale Concept Matching, Cross-Sensor Imagery

INTRODUCTION

High-resolution (HR) remote-sensing imagery is a critical information source for fine-grained Earth observation tasks, including urban structure analysis, land-cover mapping, and small-object monitoring (Han et al., 2025; Sun et al., 2025; Tang et al., 2023; Unnisa et al., 2025; N. Wang et al., 2022; Zhou et al., 2025). Promising studies have indicated that HR images not only provide clear visual information but also support higher level semantic understanding and knowledge extraction within intelligent information systems. However, practical satellite systems are constrained by an inherent trade-off among spatial resolution, temporal revisit frequency, and sensor coverage, resulting in an abundance of low-resolution (LR) imagery with limited spatial detail. Super-resolution (SR) aims to algorithmically recover HR representations from LR observations and have therefore become a fundamental tool for enhancing the utility of remote sensing data. In particular, effective SR methods

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enable the large-scale exploitation of frequently updated LR imagery while alleviating the dependence on costly and sparsely available HR acquisitions, making them highly valuable for real-world remote sensing applications.

From the perspective of visual information systems, effective SR should not only restore pixels but also preserve semantically meaningful structures that support downstream reasoning and decision-making. Early SR approaches in remote sensing primarily focused on *single-image super-resolution* (SISR), in which deep convolutional and attention-based networks (Dai et al., 2025; Guo et al., 2025; Liang et al., 2021; Wang & Sun, 2025) have achieved notable improvements in reconstruction accuracy. However, such pixel-driven reconstruction often lacks explicit semantic awareness and may fail to recover concept-level structures critical for scene interpretation. They often produce overly smoothed results or unreliable high-frequency details (Blau & Michaeli, 2018).

To address this issue, *reference-based SR* (RefSR) has emerged as an alternative paradigm that incorporates auxiliary HR images to supply missing spatial information. Although RefSR has shown promising results in controlled natural image settings, its extension to real remote sensing scenarios remains challenging. In practice, reference images are frequently acquired by different sensors or at different times, leading to cross-sensor discrepancies and land-cover changes that break semantic consistency between reference and target scenes.

In realistic remote sensing RefSR, reference unreliability manifests in two distinct but often conflated forms, which we term *concept omission* and *concept mismatch*, as shown in Figure 1. Concept omission refers to the absence or severe degradation of semantically meaningful structures in the LR target image because of resolution loss, sensor limitations, or atmospheric effects, even though such structures are present in the real scene. In an operational sense, this corresponds to target regions where the LR observation lacks sufficient evidence to support the reconstruction of a semantic entity, resulting in structurally incomplete or ambiguous representations. Concept mismatch, in contrast, arises when reference images contain semantically valid but scene-inconsistent content caused by temporal land-cover changes or cross-sensor variations. In this case, reference regions may be visually plausible yet semantically incorrect for the target scene, leading to erroneous texture transfer if used indiscriminately.

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