

Information Sciences

Special Topic: Microwave Vision and SAR 3D Imaging

Preface to the special topic on SAR microwave vision 3D imaging

Mengdao Xing*

*Academy of Advanced Interdisciplinary Research, Xidian University, Xi'an 710071, China**Corresponding author (email: xmd@xidian.edu.cn)

Received 1 August 2024; Accepted 1 August 2024; Published online 2 August 2024

Synthetic Aperture Radar (SAR) has significant applications in terrain mapping, environmental monitoring, disaster investigation and many other fields. Traditional SAR acquires two dimensional (2D) images of the observed scenarios, while interferometric SAR (InSAR) can acquire digital surface model (DSM, 2.5D images). However, in areas with steep terrain changes or complex infrastructures, there will be severe layover phenomenon, resulting in many targets being difficult to detect and interpret. SAR 3D imaging can solve this problem and significantly enhance the target recognition and 3D modeling capabilities. It has become an important trend in the current development of SAR technology. Currently, SAR 3D imaging techniques mainly utilize multi-incident-angle observations to construct a synthetic aperture in the third dimension, so as to obtain the third dimensional resolution ability. However, dozens of tomographic flights or multi-channel observations are required, leading to long data acquisition cycles or extremely sophisticated radar systems, which restrict its popularization.

In recent years, advancements in device technology have well satisfied the computational power demands by the massive data processing, injecting new vitality into the fields of computer vision, computational electromagnetics and so on. Catching sight of this development trend, Professors Chibiao Ding and Xiaolan Qiu proposed the concept of “SAR microwave vision 3D imaging”. The core of this concept is the combination of 3D imaging and image interpretation in an intelligent way. It proposes to extract 3D clues from 2D SAR images as prior information, thereby leveraging the reliance of SAR 3D imaging on multi-angle observations, achieving efficient and low-cost 3D imaging. Furthermore, it enhances our understanding of the scenario under consideration. SAR microwave vision 3D imaging pioneers a new direction in SAR 3D imaging, and it has also brought new inspiration to SAR imaging, SAR image interpretation and other aspects.

Here we are delighted to organize this special topic on Microwave vision and SAR 3D imaging in *National Science Open* (NSO). The selected papers highlight significant progress and novel methodologies in microwave vision and SAR 3D imaging, paving the way for enhanced imaging radar sensing capabilities. This special topic features four papers that exemplify the diversity and depth of current research in this field.

Phase unwrapping plays an important role in array 3D SAR imaging. Zhang *et al.* addresses the issue of

elevation ambiguity in low-altitude UAV (Unmanned Aerial Vehicle) platforms [1]. The authors propose a novel algorithm that integrates Markov Random Field (MRF) for image segmentation with optimal spatial phase unwrapping. Their results, based on real airborne array-InSAR data, show substantial improvements in resolving elevation ambiguities, thereby enhancing the coherence and resolution of 3D SAR imaging.

Non-line-of-sight (NLOS) imaging is a novel radar sensing technology that enables the reconstruction of hidden targets. In the second contribution, Liu *et al.* introduce a complex total variation (CTV) regularization-based sparse reconstruction method for NLOS 3D imaging radar [2]. The proposed RM-CSTV method significantly enhances imaging quality and speed by incorporating range migration and complex sparse joint total variation constraints. Through experiments with various NLOS targets, the authors demonstrate the effectiveness of their approach in providing high-resolution 3D imaging with detailed edge information. This research effectively demonstrates the significant role of scattering mechanisms in SAR 3D imaging.

As mentioned before, advancements in the field of computer vision have significantly enhanced SAR 3D imaging. In the third paper, Wang *et al.* explore a new paradigm in SAR 3D imaging by leveraging SAR visual semantics [3]. They investigate the extraction and utilization of scene conceptual structural information at different levels—low, middle and high. Through a case study on open-source TomoSAR datasets, they validate the effectiveness of SAR visual semantics in improving TomoSAR for 3D building modeling, offering insightful perspectives on the future of semantic-driven SAR imaging.

In the final paper, Qiu *et al.* review the evolution and current state of SAR microwave vision 3D imaging, emphasizing the role of artificial intelligence in recent advancements [4]. The authors propose a comprehensive theoretical framework for SAR microwave vision, encompassing representation models, computational models, processing paradigms, and evaluation systems. They also discuss their research progress and prospects, highlighting the effectiveness of microwave vision to powerfully promote SAR 3D imaging, which is leading the new development of SAR imaging technology.

Together, these papers provide a comprehensive overview of the state-of-the-art in SAR microwave vision 3D imaging technologies. They illustrate the innovative approaches being developed to overcome existing limitations. We hope this special topic will inspire further research and development in this exciting field, contributing to its continued growth and application across various domains.

We would like to thank all the authors for their valuable contributions and the reviewers for their critical insights. We are confident that the advancements presented in this special topic will significantly impact the field of SAR microwave vision 3D imaging and beyond.

References

- 1 Zhang X, Hu F, Xu F. Segmentation-aided phase unwrapping for 3D reconstruction with airborne array-InSAR images. *Natl Sci Open* 2024; **3**: 20230082.
- 2 Liu X, Wei S, Pu W, *et al.* RM-CSTV: An effective high-resolution method of non-line-of-sight millimeter-wave radar 3-D imaging. *Natl Sci Open* 2024; **3**: 20230085.
- 3 Wang W, Wang H, Yu L, *et al.* Exploiting SAR visual semantics in TomoSAR for 3D modeling of buildings. *Natl Sci Open* 2024; **3**: 20230067.
- 4 Qiu X, Jiao Z, Zhang Z, *et al.* Advances and prospects in SAR microwave vision three-dimensional imaging. *Natl Sci Open* 2024; **3**: 20240009.