Aerospace Technology in Social Applications

WELCOME to the concluding issue of IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS (TCSS) for the year 2023. We would like to seize this opportunity to extend our heartfelt appreciation and congratulations to all for your exceptional dedication and unwavering support. We eagerly anticipate further collaboration to enhance the publication quality and expedite the review process of TCSS in the upcoming year 2024.

In this issue, after the customary introduction of our 46 regular articles, we are pleased to present a special issue titled "Special Issue on Responsible AI in Social Computing," which comprises a collection of ten insightful articles. In addition, aerospace technology, a multidisciplinary field integrating geospatial information, remote sensing, and satellite technology for acquiring, processing, and applying airspace data, provides new perspectives on our world. Crucial to its development is aerospace data, encompassing various sources such as electronic signals and remote sensing images. Advancements in aerospace technology center around sensor technology, data processing, and visualization, with an increasing emphasis on accumulating well-labeled data to train artificial intelligence (AI) models, enhancing automation and robustness in applications. We are eager to share our perspectives on "Aerospace Technology in Social Applications."

I. SCANNING THE ISSUE

In [A1], Li et al. address a new task called conversational stance detection (CSD), which is to infer the stance toward a given target when given a data instance and its corresponding conversation thread. First, they propose a benchmarking CSD dataset with annotations of stances and the structures of conversation threads among the instances. Then, they propose a model called branch-bidirectional encoder representations from transformers (BERT) that incorporates contextual information in conversation threads. The study paves the way for future stance detection on social media platforms and sheds light on how to utilize contextual information in online conversations effectively.

In [A2], to explore the relationship between platform resource investment and value creation, this article constructs a three-party game model among the platform, supporters, and the initiator based on the evolutionary game theory. Then, it obtains the replicator dynamics function of the player and analyzes the evolution trend. Furthermore, this article analyzes the optimal pricing decision of the platform and the initiator under different crowdfunding modes and its optimal mode. This article also draws the management enlightenment that the crowdfunding platform should not blindly invest too many resources in the expansion of platform functions but should focus on refining the service function attributes of the platform itself.

In [A3], by adapting the concept of hypergraph to describe enterprise ecosystems, Yin et al. propose a novel multiview enterprise relation network (MERN) framework for enterprise competition analysis. Specifically, it first puts forward a hypertranslating embedding (HTransE) algorithm inspired by translation distance models for the hyperrelation embedding of ecosystems. Meanwhile, a relational graph convolutional network (RGCN) is designed for ordinary relation embedding. Afterward, this article proposes an industry trend embedding module to describe industry distribution and development trend factors for each enterprise. Finally, it applies the self-attention mechanism to integrate these three modules and adapt the bilinear model DistMult for competition link analysis.

In [A4], Feng et al. propose hybrid point–voxel RCNN (HPV-RCNN), a novel point cloud detection network that combines the merits of points and 2-D voxels. First, they propose a multiattentive voxel feature encoding module (MA VFE) to exploit multilevel attention of multiscale voxels. This article also presents a partial fusion pyramid network (PFPN) to effectively integrate multiresolution features and generate high-quality proposals. Then, a multiscale region of interest (RoI)-grid pooling (MSRGP) module is proposed to adaptively abstract proposal-specific features from sampled keypoints in multiple receptive fields. In addition, a cascade attentive module (CAM) is adopted to achieve incremental proposal refinement by subsequent multiple subnetworks.

In [A5], Ferguson et al. study the question of how a system operator can exploit system-level knowledge to derive incentives to influence societal behavior and improve system performance. Specifically, it addresses the question of what information can be most effectively exploited in the design of taxation mechanisms to improve the system performance. The main results characterize an optimal marginal-cost taxation mechanism and associated performance guarantee for varying levels of network and population information. In this work, this article seeks to bridge the gap between optimal taxation mechanisms that require detailed information and robust tolls that require less information but may fail to perfectly optimize routing.

In [A6], Alsmadi et al. provide a comprehensive review of the main approaches for adversarial attacks and defenses in the context of social media applications. They first provide a general overview of adversarial attack and defense techniques applicable to both text and image applications. They then review state-of-the-art techniques for attack and defense

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techniques. After that, they discuss the attack and defense studies. Finally, they highlight current research challenges in the context of security of machine learning for social media applications and state key lessons.

In [A7], Dewangan and Chandrakar propose a secure Internet of Medical Things (IoMT)-based data collection method for patients and storing the data on the blockchain in accordance with general data protection regulation (GDPR). In the proposed system, IoMT devices send data to the cloud via the patient's personal digital assistant (PDA), and the cloud server transacts data on the blockchain. They propose a miner selection algorithm to avoid bias in the blockchain. They simulate various attacks on open channels between IoMT devices and the cloud servers.

In [A8], Meng et al. proposed a novel multiview learning approach-based ClickBait detection (MCBD) model that considers useful signals from both titles and body contents. Combined with the information from the views of titles and body contents, the model can distinguish well-hidden clickbait news. Finally, extensive experiments were conducted on two real-world datasets to demonstrate that the MCBD model outperforms the state-of-the-art models.

In [A9], Zhang et al. propose a two-stage model that uses implicit link detection and link sign prediction. First, it uses the preference attachment closeness degree (PACD) to predict possible implicit links by adding a measure of relationship closeness to the traditional link prediction algorithm (PA). Next, this article proposes a negative link sign prediction (Ne-LP) method to predict relation types through multidimensional negative sign-related features. Finally, it evaluates PACD and Ne-LP through extensive experiments on three real-world social network datasets, whose results demonstrate that the method can effectively mine implicit relations and accurately predict negative links.

In [A10], Shi et al. review the application of social sensors in natural disaster emergency management. It summarizes the application functions of social sensors into three categories: natural disaster situation awareness and event detection, disaster information dissemination and communication, disaster sentiment analysis, and public opinion mining. Based on the above functions, this article analyzes the research status, data, technical methods, and application systems. Finally, it proposes a research trend of applying social sensors in natural disaster emergency management according to the requirements of real scenarios.

In [A11], Lu et al. propose an attentive time–frequency neural network (ATFNN) for SER, including a time–frequency neural network (TFNN) and time–frequency attention. Specifically, aiming at the first issue, it designs a TFNN with a frequency-domain encoder (F-Encoder) based on the Transformer encoder and a time-domain encoder (T-Encoder) based on the bidirectional long short-term memory (Bi-LSTM). Moreover, this article adopts the time–frequency attention with a frequency-attention (F-Attention) network and a time-attention (T-Attention) network to focus on the emotion-related long-range dependencies between frequency bands and across time frames, which can enhance the emotional discrimination of speech features.

In [A12], Wen et al. propose an autonomous privacy control and authentication sharing (APCAS) scheme based on quick response (QR) codes in social networks. By comparing advanced image sharing algorithms, the proposed APCAS can restore the secret images one by one according to users' wishes and can thus effectively mitigate the problem of autonomous privacy control in online sharing. Compared with related methods in recent years in terms of peak signal-to-noise ratio (PSNR), authentication operation, and authentication complexity, the proposed APCAS algorithm provides lossless decryption, lower authentication computation complexity, and no pixel scalability.

In [A13], in order to solve the problems of greedy boundary stateless routing (GPSR)'s neighbor node position acquisition lag and single routing criterion, a new routing method based on the fuzzy logic system [geographic routing method based on velocity, angle, and density (GRVAD)] is proposed. This method gets the relative velocity between the nodes and the angle between the current node, the neighbor node and the target node, and the node density of the neighbor node as the input of fuzzy logic, and the unscented Kalman filter is used to predict the location of the neighbor node to obtain more accurate location information of neighbor nodes.

In [A14], to improve clinical services and mitigate the risk of disruptions efficiently, this article conducts critical department analysis under three scenarios: one clinical improvement scenario [supply enhancement (SE)] and two clinical disruption scenarios (DS and SL). It accordingly proposes a simulation-based ranking method and implements a case study in a large-scale outpatient system (LSOS). The simulation results show that the criticality of the department highly depends on the time session. Surprisingly, SE may reduce patient satisfaction when the supply increases in several specific departments.

In [A15], Boahen et al. propose a new technology called optimized nonsymmetric deep autoencoder (OPT_NSDAE), which uses unsupervised learning methods for feature extraction, selection, and learning, reducing the level of human interaction required in feature selection and extraction. They discussed the various behaviors of online social network (OSN) users and the current methods for detecting OSN account damage, emphasizing their limitations and challenges. This article proposes a deep learning method that addresses the limitations faced by previous solutions. The experimental results show that this method is superior to most traditional OSN leak account detection schemes.

In [A16], in order to solve the prediction task of unlabeled data, this article proposes an effective unsupervised domain adaptation model, which can utilize knowledge learned from source cities with rich labeled data to achieve deep unsupervised domain adaptation methods. It is possible to predict the risk of cross city crime while addressing the issue of contextual inconsistency between cities. In order to verify the effectiveness of the method proposed in this article, the authors conduct a large number of experiments, and the experimental results show that the method proposed in this article is superior to various state-of-the-art comparative methods.

In [A17], two adaptive methods, feature analysis and semantic analysis, were used to investigate the influencing factors of user engagement in opinion leader blogs. In order to identify the correlation between user engagement and the actual accessible attributes of opinion leaders and their blogs, the authors used a state-of-the-art sentiment analysis model to process blog data and designed a saliency method to calculate the comprehensive gradient of sentences in blogs. The analysis in this article can provide valuable insights for advertisers on how to plan online celebrity marketing activities on these two platforms.

In [A18], Zhang et al. propose a method for generating adversarial perturbations based on retrieval tasks, called hashing fake. Specifically, it has recently been found that deep neural network (DNN) is susceptible to a specific set of attacks called adversarial perturbations. In addition, since existing adversarial perturbation generation methods are designed for supervised tasks, the hashing fake algorithm constructs a differential approximation to replace the perturbation generation of unsupervised retrieval tasks. Through extensive experiments on several deep retrieval benchmarks, this article demonstrates that using hashing fake can effectively generate interference signals that are invisible to humans to mislead strong retrieval models and make incorrect predictions.

In [A19], Wang et al. study the robust portfolio problem of investors who avoid losses under unclear distribution and average return. When the return distribution of risky assets is unknown, a distributed robust optimization model for avoiding losses is constructed. Then, assuming that the average return of risky assets belongs to an ellipsoidal uncertainty set, a joint fuzzy model of distribution and average return is constructed. This study solves these two robust models and derives their analytical solutions separately. Then, an empirical analysis is conducted on the effects of loss aversion and fuzziness aversion on the returns of robust optimal investment portfolios.

In [A20], Sivadas et al. propose a compartmental epidemiological model that combines the effectiveness of vaccines with dose dependence and analyzes the impact of vaccination schedules and social distance on total confirmed cases, active cases, deaths, and daily new cases. Sensitivity analysis of different model parameters indicates that the effectiveness of the second dose vaccine is the most sensitive parameter in the future evolution of the disease. The combination of vaccination and maintaining social distance is crucial in addressing the current situation and the coming months.

In [A21], Tian and She propose a visual–audio emotion recognition system. For the visual part, a rule-based emotion classification dimension classifier was proposed, and the root mean square of facial feature extraction was proposed. For the audio part, extract some emotional-related features and use deep convolutional neural networks (DCNNs) to extract 128-D global features. Finally, a combination of Bayesian and machine learning is used to integrate the information of audiovisual patterns. The experimental results show that the system has high recognition rate and good performance.

In [A22], Liu et al. propose a local self-attention (LSA) model to enhance the ability to capture n-gram features of self-attention. This model limits the range of original self-attention through a local window mechanism, thereby linearly expanding with the increase of sequence length. It captures the word-to-word relationship in the first layer and then captures the chunk-to-chunk. Finally, the model is evaluated on the dataset, and the experiments show that the model can capture multiscale phrase features, which is better than traditional self-attention.

In [A23], Zhang et al. propose a lightweight, efficient, and privacy-protected social network user profile matching protocol. This protocol not only provides privacy for user profiles and queries but also achieves privacy with different thresholds. Applying the Chinese remainder theorem (CRT), Bloom filter technique, and skyline computation idea, the matching users are efficiently returned with the help of any matching server without disclosing their identities. The experimental results show that this algorithm is more efficient than the existing two algorithms.

In [A24], Lu et al. develop a packet recommendation system based on graph neural networks—package graph attention network (PGAT). PGAT integrates users, items, and packages to create a unified heterogeneous graph and treat them as a whole. By performing graph attention and graph convolution operations on tripartite graphs, PGAT can learn node embedding more expressively, greatly solving the problem of data sparsity. A large number of experiments have verified its effectiveness on two real datasets.

In [A25], Yilmaz and Ulusoy solve the problem of error information dissemination in online social networks from a gaming perspective. First, they constructed a game based on the concept of cooperative games, where the nodes are players. Second, they create a game at the network level where players control a set of nodes. This article proposes a deep reinforcement learning technology based on multiagent deep deterministic strategy gradient algorithm. Finally, the proposed method is tested with known node selection algorithms and the satisfactory results are obtained on different social networks.

In [A26], Wang et al. introduced the framework model of crypto management, where blockchain is the underlying technology, decentralized autonomous organization (DAO) is the management structure, federated data are the decision basis, smart contract is the decision method, and nonfungible token (NFT) is the main decision incentive. Then, its collaboration mechanisms of on-blockchain DAO and off-blockchain organization as well as intra-organization and extra-organization nodes are discussed. Moreover, the potential applications of crypto management are addressed, and a case of task-oriented performance management is given to state how crypto management works to generate the real-time management decisions.

In [A27], by conducting a review on the literature covering the health certificate technology, its adoption in practice, and the exchange system technology published during the COVID-19 pandemic, this article learned about their usefulness and limitations in travel management in pandemic (TMiP). Then, this article analyzed the review outcomes to infer the six distinctive technical challenges of TMiP and the feasibility of referential solutions to these challenges and showed their applicability and limitations. Finally, this article offered perspectives on new TMiP solutions and concluded

that they rely on adapting existing solutions, creating new ones, and integrating all of them.

In [A28], Zhang et al. propose a novel heuristic method called the network dynamic graph convolutional neural network (GCN) influence maximization algorithm based on the leader fake labeling mechanism. They design a network dynamic GCN that owns adaptive layer numbers in terms of different network scales to obtain node representations, and a leader fake labeling mechanism to automatically generate node labels that are helpful to seed nodes selecting for model training and a heuristic method based on the Mahalanobis distance is developed to quickly select influential seed nodes. The experimental results demonstrate that their algorithm has a better performance for seed set identification under the premise of high efficiency.

In [A29], Xu et al. aim to explain how reciprocal social support forms by testing and integrating the social science hypotheses into the modeling of the outside social networks. A series of simulation experiments has been conducted to test their hypotheses and the proposed models. The results show that their proposed models can well capture the reciprocal properties observed in real-world social networks, and the hypotheses can collectively explain the formation of reciprocal social support.

In [A30], Rashid and Wang introduce CovidTrak, the concept of social intelligence-empowered contact tracing systems to monitor the COVID-19 spread and study its transmission dynamics. They highlight a few important challenges in CovidTrak applications, including privacy and security, data collection, reliability, location data scarcity, alerting and establishing awareness, and handling human reactions. By harnessing interdisciplinary techniques, CovidTrak can integrate the collective strengths of HI through social sensing alongside capable data-processing solutions to perform real-time analyses of the knowledge acquired from social data platforms.

In [A31], Razaghi et al. propose a multiobjective metaheuristic, based on the multiobjective gray wolf optimizer, to improve the fair propagation of information in influence maximization (IM) concerning various fairness metrics. The experimental results show that the proposed algorithm outperforms the previous work with respect to all introduced fairness metrics. They also carry out the detailed experimental analyses on real-world networks and report interesting relationships between fairness concepts and network characteristics, including the price of ensuring fairness in social networks, the effect of social groups' structure on fairness, and the dependence among fairness metrics.

In [A32], Wang et al. conducted a survey on workload and physical and mental health of surgeons in Gansu Province. Also, the mental health problems mainly included obsessive-compulsive, depression, interpersonal sensitivity, somatization, and anxiety. A study proved that the ten mental health literacy tips from the National Health Commission (NHC) emphasized that the incidence of mental diseases, such as depression and anxiety, was higher in patients with chronic diseases than in the general population. Their model successfully detected workload and disease as the influence factors on mental health of surgeons.

In [A33], Liu et al. present an experimental study on understanding the roles that research groups have in idea propagation within a community. Two facets of idea propagation were studied: 1) the ways in which different groups contribute to the impact research ideas make on other groups and 2) the function groups have in linking sets of groups with each other. The experiments used six metrics computed over group citation networks (GCNs). The authors think that the insight gained in this study can be useful in devising more productive research organization structures and management strategies, including funding policies.

In [A34], Yang et al. propose a user interest activation recommendation method that fuses multichannel information—MIAR, which contains two frameworks (interactive framework and distributed framework). In the interactive framework, they propose a user multichannel interest modeling framework MIF from the word embedding level of news headlines to capture more semantic cues related to user interests. In the distributed framework, they design a candidate-aware interest activation module target interest activation module (TAR) from the news embedding representation level obtained by attention aggregation. Finally, they effectively assign the weights of the two frame scores and demonstrate the effectiveness of the method by extensive experiments on the MIND news recommendation datasets.

In [A35], Qu et al. explore how group decision-making influences the evolution of cooperation, especially in a heterogeneous population. Group decision-making is ubiquitous in the real world. However, finding closely related and trustworthy partners is challenging since, like cooperation, competition is also typically seen in commercial, social, and financial contexts. When individuals try to find partners, they must consider all the relationships among the formed group. If the group is unstable, group decision-making will fail.

In [A36], Wei et al. consider the uncertainty of the opinions of decision-makers (DMs), noncooperators, and moderators separately. Thereafter, the robust optimization (RO) method is used to perturb the uncertain opinions within a given and concentrated range (i.e., the uncertainty sets); hence, the uncertainty set's uncertainty is described more accurately. In addition, they applied the constructed robust mixed-integer maximum expert consensus models (MECMs) to the passenger satisfaction evaluation of the Shanghai Metro. Owing to the strong conservativeness of the classical RO method, they further introduced an RO method based on data-driven methods. Finally, the comparative analysis leads to interesting conclusions.

In [A37], Cheng et al. introduce the current situation of crowdsensing and privacy protection technologies for crowdsensing in the digital city, emphatically analyze the privacy protection in crowdsensing under the background of digital city, and qualitatively evaluate the existing privacy protection technologies for crowdsensing. Finally, they present research challenges and future directions that should be addressed to improve the performance of privacy protection technologies for crowdsensing systems.

In [A38], Chen et al. take a leading home appliance manufacturing system in China as a case problem to study the

material delivery scheduling optimization problem. The problem can be divided into a number of subproblems, and they investigate one of its subproblems. They build a mixed-integer linear programming (MILP) model for the problem and use the optimizer to solve small-size problems. With the combinatorial nature, they design a grey wolf optimizer (GWO) algorithm to solve large-size problems.

In [A39], Wen et al. first propose a general phishing detection framework based on feature engineering and then propose a phishing hiding framework combining the greedy selection mechanism with four phishing hiding strategies to measure the robustness of the proposed general detection models. Extensive experiments evaluate the detective performance of the phishing detection model and its robustness against the hiding framework. The experimental results indicate that the detective model based on feature engineering is rather fragile under adversarial attacks.

In [A40], aiming at the shortcoming that the low-dimensional linear and the high-dimensional nonlinear relationships between users and services are seldom considered simultaneously, the authors propose a new quality of service (QoS) prediction model that fuses local and global location information of users and services in the interaction layer of the model. The proposed model uses a multilayer perceptron (MLP) to acquire high-dimensional nonlinear relationships of users and services, where the dot product is employed in complementing the learning of low-dimensional linear relationships.

In [A41], Qureshi et al. enhance the credibility of the academic ranking process, by performing fine-grained assessment of the academic data pertaining to the computing discipline. The proposed assessment approach explores the data at the sub-discipline level, analyzing several ranking dimensions, including the research productivity, research impact, and research contribution of influential research scholars affiliated with renowned HEIs in the computing discipline. This article, which focuses on the computing sub-discipline, is among the first few such efforts.

In [A42], a stereo vision odometry method in a dynamic environment is proposed, which can not only effectively overcome the influence of dynamic objects but also detect the position of dynamic objects. An optical flow filtering algorithm based on the quantitative histogram and the optical flow angle histogram of the feature points is proposed to obtain dynamic points. Furthermore, a multifeature fusion mechanism is used to perform binary segmentation and get the bounding box of dynamic object. The experiments show that the proposed method can improve the accuracy of pose estimation and detect moving objects in a dynamic environment.

In [A43], Joseph et al. propose a novel method for the pricing of electricity. In their approach, the electric demand of a household is predicted based on their past usage patterns. Users are then clustered into different bins based on their demands, and an evolutionary algorithm is used to generate the prices for the users present in different bins in a real-time manner to ensure the maximum attainable profit to a service provider. This approach makes sure that profit to electricity providers is maximized, and pricing is fair to the customers, i.e., customers who contribute more to the peak are only penalized.

In [A44], Ouyang et al. propose a novel privacy framework for FL based on blockchain and smart contracts, named artificial identification. It consists of two modules: private peer-to-peer identification and private FL, using two scalable smart contracts to manage the identification and learning process, respectively. Based on Ethereum and interplanetary file systems, the authors implement their framework and comprehensively analyze its performance. The experiments show that the proposed framework has acceptable collaboration costs and offers advantages in terms of privacy, security, and decentralization.

In [A45], Ni et al. employ blockchain technology for managing qualification certificates and delineate the format for valid certificates and the application process. The secure data-sharing protocol is divided into two stages. In the first stage, the authors ensure data authenticity before uploading it to the blockchain through a consensus process involving platforms, users, and merchants. In the second stage, they implement fine-grained access control based on the on-chain data from the previous stage, utilizing conditional proxy re-encryption and ultimately employing the data digest on the blockchain for verification.

In [A46], Dong et al. propose a novel surface-based morphometry analysis framework to reveal the association between plasma neurofilament light (NFL) levels and hippocampal subfields on a cognitively unimpaired (CU) cohort. The results show that the hippocampal multivariate morphometry statistics (MMS) encodes a great deal of information. This work has found significant hippocampal morphometry differences in the CU individuals with plasma NFL+/−. This proposed framework can be applied to verify the associations between other emerging periphery physiological biomarkers and neurodegeneration criterion.

II. Aerospace Technology in Social Applications

A. Concept of Aerospace Technology in the Era of Earth Observation Big Data

Aerospace technology is a multidisciplinary field of geospatial information technology, remote sensing technology, and satellite technology. It focuses on acquiring, processing, and applying information from the airspace, providing a new perspective on understanding our world. The key of aerospace technology development is aerospace data, including electronic signals, remote sensing images, digital maps, 3-D GIS vector data, gravity, and magnetic data. The development of aerospace technology mainly revolves around the following fields: sensor technology, data processing, and the visualization and application of aerospace technology. The development trend in the above fields is to accumulate a large amount of finely labeled sample data to build and train aerospace AI models with high generalizability for refinement, automation, and robustness.

B. Development of Aerospace Intelligence Technology

The development of aerospace intelligence technology includes data imaging processing, feature extraction analysis,

classification and recognition, as well as sharing and distribution applications. In comparison to big data technology, aerospace big data intelligent processing has longer acquisition chain, more extensive processing stages, and more complex key technologies.

1) Data Imaging Processing: Data imaging processing transforms the raw echoed signals from satellites into remote sensing images that can be interpreted by humans. The imaging processing can be divided into stages, including radar imaging, image correction, and preprocessing. The key to radar imaging, which reconstructs an image from the echo signal received by the radar, is to increase the resolution of the signal in all dimensions. For synthetic aperture radar (SAR), classical imaging algorithm range-Doppler (RD) [1] breaks down the imaging processing into two 1-D shift-invariant correlation processes through range migration correction and frequency-domain correlation. Image correction includes radiometric correction and geometric correction. Radiometric correction involves the correction of pixel values in the image to eliminate or rectify distortions caused by radiometric errors, including radiometric calibration, atmospheric correction, and terrain and solar elevation angle correction. Geometric correction involves the correction of pixel positions in the image to rectify geometric distortions and achieve georeferencing, including system geometric correction and precision correction through the integration of ground control points. Besides correction, image preprocessing includes image denoising, shadow and thin cloud removal, image mosaicking, and cropping.

2) Feature Extraction and Analysis: Feature characterization and extraction are prerequisites and foundations for object classification and recognition. Taking high-resolution remote sensing images as an example, due to constraints such as the imaging area, sensor conditions, and other factors, both object appearance and image backgrounds exhibit complex variations, containing significant redundant information. Therefore, in addition to existing artificial intelligence methods, the basic scientific problem lies in extracting distinctive and stable aerospace object features from the complex and variable information in different typical scenes and sensor outputs. Remote sensing images have unique and complex imaging mechanisms. In order to address technical challenges such as feature distortion under complex imaging conditions, invariant feature extraction analysis methods [2], [3] try to analyze the mapping rules between the external representation, structural composition, and image feature response for simulation and representation of object geometric stability characteristics under conditions of scale, rotation, and displacement.

3) Classification and Recognition: Image classification and recognition aim at identifying objects of interest within images based on the spectral features. Image classification and recognition involves determining discriminant functions and corresponding discriminant criteria to categorize the pixels or local image based on their properties. This process can be broadly categorized into supervised, unsupervised, semisupervised, and self-supervised classification methods. Supervised classification, the most typical approach in artificial intelligence, involves using machine learning methods to classify, label, or identify specific land features based on a labeled sample dataset. Classical supervised classification methods include convolutional neural networks (CNNs) [4], ensemble learning methods [5], support vector machine (SVM) [6], decision trees [7], [8], random forests [9], and Bayesian classifiers [10]. Recent supervised classification methods have also incorporated some new techniques from deep learning, such as transfer learning [11], attention mechanisms [12], and graph neural networks [13]. Unsupervised classification, also known as cluster analysis, involves statistical analysis of image without prior labeling. Typical algorithms for unsupervised classification methods include regression analysis, trend analysis, cluster analysis, and generative adversarial networks (GANs) [14]. Besides, semisupervised methods, such as MixMatch [15], and self-supervised methods, such as variational autoencoders (VAEs) [16], have achieved good results in recognition tasks.

4) Sharing and Distribution Applications: The advent of aerospace big data, along with its accompanying applications, has made previously impossible tasks feasible. Taking remote sensing images as an example, by incorporating the temporal and spatial attributes of aerospace big data and leveraging data mining techniques, valuable information and patterns are analyzed. Then, intelligent algorithms are able to obtain typical object information from sample data and automatically recommend appropriate tasks for specific data, thereby assisting decision-making in various industries and even making predictions for the future.

C. Key Directions of Aerospace Intelligent Technology Development

1) From Traditional Machine Learning Algorithms to Deep Neural Networks: Traditional statistical learning algorithms, such as Bayesian statistics and support vector machines (SVMs) [6], rely on manually designed approaches to construct models that approximate data features, which have limited generalization capabilities. In contrast, intelligent algorithms based on deep learning, such as convolutional neural networks (CNNs) [4], recurrent neural networks (RNNs) [17], and graph neural networks (GNNs) [13], leverage large-scale datasets and deep model architectures to excel in learning complex functions in high-dimensional spaces.

2) "Pretraining + Finetuning" Paradigm: In recent years, general artificial intelligence has been gradually moving toward large-scale data, massive computing power, and complex network models. Developing large-scale deep models incurs extremely high costs and is challenging to meet customized requirements. The new paradigm of "pretraining + finetuning" offers a viable solution. Pretraining foundation models [18], [19], [20] typically utilize the Transformer [21] architecture. The mechanism behind this approach involves training the model on a large-scale dataset through self-supervised learning tasks, enabling it to learn representations of text, language, knowledge, and various tasks.

The foundation model effectively captures knowledge from a vast amount of labeled and unlabeled data. By storing the knowledge in a multitude of parameters and fine-tuning the model for specific tasks, the model's generalization capability is significantly enhanced.

3) "Foundation Model + Remote Sensing" Explores New Horizons in Aerospace Technology: When applied to the field of aerospace remote sensing, there are still significant challenges due to the wide swath of remote sensing data and the complexity of scene content. These data exhibit substantial differences from natural scene data, resulting in limitations such as a lack of exploration of multimodal mechanism characteristics and difficulties in building and training base models. Therefore, it is worth considering incorporating domain knowledge from the aerospace field and leveraging the imaging mechanisms of different modalities in remote sensing to achieve stable extraction and representation of visual and electromagnetic features for multimodal remote sensing data [22], [23].

D. Applications of Aerospace Intelligence Technology

The continuous advancement of aerospace intelligence technology has provided a solid foundation for practical applications, spanning across various domains, including transportation, land resources, urban development, environmental protection, and weather forecasting. Typical application cases demonstrate how aerospace intelligence technology promotes the transition from a manual decision-making mode to a human–machine collaboration new mode.

1) Land and Natural Resources Monitoring: Aerospace technology provides the capability for informationization and data mining analysis in the field of land and natural resources management [24], [25], [26]. Through automated interpretation techniques aiding in breaking down information barriers, government and environmental agencies can access accurate land-use information, natural resource distribution, and environmental change trends, contributing to the formulation of land planning and resource management policies.

2) Urban Construction: The application of aerospace technology in urban planning and construction [27], [28], [29], [30], [31] assists urban planners in making real-time automated decisions regarding population movement, land use, and urban infrastructure need, which contributes to the efficient operation and development of urban planning.

3) Environment Protection: Aerospace technology enables the precise monitoring of atmospheric pollution, water quality, and forests, thereby achieving the analysis of large-scale geographic information data concerning atmosphere, water quality, and land surface [32], [33]. As a result, a quick understanding of the environmental conditions is beneficial for environmental agencies to formulate policies and measures.

4) Transportation: Aerospace intelligence technology provides innovative solutions for traffic management and safety protection [34]. Leveraging real-time traffic flow monitoring and prediction technology, intelligent transportation systems can optimize traffic signal control and effectively reduce traffic congestion. Based on aerospace big data analysis and autonomous navigation technology, autonomous vehicles can access real-time high-precision geographic information and opening up new modes of transportation.

5) Weather Forecasting: Weather forecasting is crucial for society and economy, including agriculture, aviation, marine navigation, and natural disaster management. Aerospace intelligence technology, based on satellite observations and sensor data, constructs specialized intelligent models [35], [36], [37] to assist in weather data analysis, which significantly enhances the accuracy and timeliness of weather forecasting and strengthens the ability to respond to climate change and extreme weather events.

E. Summary

Aerospace data provide descriptions at various levels of "spatial–temporal–spectral" characteristics for remote sensing objects. Combined with artificial intelligence technologies including aerospace object feature mining, cross-modal intelligent interpretation, and multitask learning, research has been conducted on imaging mechanisms, object characteristics, and knowledge cognition. Based on massive multimodal remote sensing data, the development of aerospace technology promotes the construction and optimization of multimodal remote sensing foundational models. Aerospace intelligence technology has disrupted the traditional predominantly manual interpretation mode and accelerated the transformation from manual interpretation mode to human–machine collaborative interpretation mode. Thus, the development of aerospace intelligence technology can not only enhance the timeliness and convenience of aerospace tasks but also promote the fields, including land and natural resources, urban development, environmental protection, transportation, and weather forecasting.

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APPENDIX: RELATED ARTICLES

[A1] Y. Li, H. He, S. Wang, F. C. M. Lau, and Y. Song, "Improved target-specific stance detection on social media platforms by delving into conversation threads," *IEEE Trans. Comput. Social Syst.*, vol. 10, no. 6, pp. 3031–3042, Dec. 2023.

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