Chapter-6

Conclusions and Future Scope

6.1. Conclusions

Numerous positive effects have resulted from the efficient application of the spatial upscaling-based approach for gas and odor detection. By successfully modifying sensor readings, enhancing feature extraction, ensuring data security, maximising the use of gas sensor arrays, utilising mirror mosaicking technology, and showcasing adaptability and scalability, this method has improved gas and odor detection accuracy. Businesses that depend on gas sensing technologies will be strongly impacted by these developments, which will lead to better safety procedures and environmental monitoring techniques. Furthermore, the implementation of a novel data-driven method for producing multi-sensor virtual responses in electronic noses with gas sensor arrays has fundamental effects on the classification of gases and odors. The method opens the door for more accurate and efficient gas classification systems and developments in gas sensing technology thanks to its versatility, increased number of virtual sensor responses, greater dynamic range, and higher performance compared to prior approaches. A comprehensive solution for quick and effective disaster response has also been made available by the successful implementation of the UAV Computing-Assisted Search and Rescue Mission Framework for Disaster and Harsh Environment Mitigation. The framework has enhanced search and rescue operations, situational awareness, and resource optimisation by merging intelligent gas sensor nodes, real-time detection tools, UAV computing paradigms, and network evaluation. These advancements help achieve the main goal of lessening the effects of disasters and preserving life in hazardous situations.

Accordingly, following are the conclusions which can be drawn:

- Success of Spatial Upscaling: The spatial upscaling-based technique was implemented and was successful in converting steady-state gas sensor data into a two-dimensional template. This method enabled accurate identification and estimate of dangerous gases and odors by applying Convolutional Neural Networks (CNNs) to key data points.
- Enhanced Feature Extraction: The approach produced a bigger set of input data vectors for CNNs by scaling the physically obtained gas sensor responses and incorporating virtual sensor responses. This made it possible for CNNs to extract features more effectively, utilising the strength of automated feature extraction approaches, and increasing the precision of gas and odor estimation.
- Information from the Raw Sensor Response Preserved: The information from the raw sensor response was preserved during the spatial upscaling procedure. By doing this, it was made sure that crucial information and traits of the gases and odors were preserved during the change. The information that was retained helped to accurately identify and estimate different kinds of harmful gases.
- Improved Gas Sensor Array Utilisation: The spatial upscaling approach allowed gas sensor arrays with few sensing elements to be used efficiently. The method extracted more valuable features by expanding a smaller virtual array into a larger virtual array. As a result, gas detection and estimation performed better overall and gas sensor systems' capabilities were boosted.

- Mirror Mosaicking approach: Using this approach helped the spatial upscaling process much more. The programme increased the size of the input vector by rearranging the data and expanding the elements of the gas sensor response vector. This expanded the possibility for precise gas and odor detection and enabled even more thorough feature extraction.
- Scalable and Versatile Approach: The spatial upscaling-based technique proved to be both scalable and flexible. It could be used to extract relevant features from sparse data in a variety of gas sensor systems with varied numbers of sensor elements. Mirror mosaic scaling of the technique also allows for more options for feature extraction.
- Accurate Gas and Odor Detection: The effective application of the spatial upscaling approach in conjunction with CNNs produced accurate gas and odor detection. The algorithm increased the dependability and effectiveness of gas sensor systems by making use of the saved information and improved feature extraction capabilities.
- Novel Virtual Sensor Response (VSR) Generation: A data-driven technique was successfully used to produce VSRs for gas sensor arrays. The number of VSRs was greatly boosted by utilising several data transformation methods, including a triple-input triple-output (TITO) technique. By enhancing the patterns of reactions and the dynamic range of responses, this unique technique increased the classification accuracy of gases and odors.
- VSRs for machine learning models were effectively multiplied by $6(n-1)(n-2)/3$ thanks to the method! where the gas sensor array's size, n, is shown. This growth

gave machine learning models a larger dataset to draw from, enabling more reliable and precise categorization methods.

- Complete Square Shape Formation: By including zero-value vector elements in the physical sensor array response, the method made it possible to form a complete square shape. The square's completion enabled a more thorough representation of the data from the gas sensor array, boosting the efficiency of following data-driven procedures.
- VSR Upscaling and Downscaling: The TITO technique created both upscaled and downscaled VSRs. The dynamic range of responses was expanded through the scaling process, allowing for the capture of a greater variety of gas and odor properties. The higher saliency and accuracy in the categorization of various gases and odors were made possible by the increased dynamic range.
- Comparative Performance with NDSRT Technique: The proposed method outperformed the well-publicized data-driven VSRs method known as "NDSRT" in terms of precision and effectiveness. Nine machine learning algorithms were used to test the effectiveness of the unique approach, which proved its superiority and potential for use in gas and odor classification systems.
- Versatile Application: Regardless of the size or design of different gas sensor arrays, the established data-driven approach can be used. The approach's versatility and scalability make it appropriate for various electronic noses and gas sensing applications, offering a useful tool for enhancing the precision of gas and odor classification.
- Framework for Advanced Disaster Mitigation: The Framework for UAV Computing-Assisted Search and Rescue Missions, which was established, offered

a sophisticated approach to disaster and harsh environment mitigation. The framework improved the efficiency and effectiveness of search and rescue missions, ultimately saving valuable lives, by using intelligent gas sensor nodes as payloads and enabling real-time identification of dangerous gases and VOCs.

- Real-time Detection and Response: The framework's integration of intelligent gas sensor nodes made it possible to identify dangerous gases and VOCs in real-time. The safety of search and rescue activities in catastrophe and severe situations was improved by the quick and targeted response methods made possible by this real-time information.
- The framework took into consideration the time-sensitive nature of search and rescue (SAR) missions during catastrophic occurrences. The framework accelerated problem-solving and provided specific missions, intelligent procedures, and functions by utilising UAV computing concepts. This allowed for quicker response times, shorter search times, and an overall increase in the effectiveness of SAR operations.
- Real-time situational awareness and high-resolution imaging were made possible by the use of UAV computing intelligence. This enabled data scientists to quickly assess important conditions. Real-time situational awareness provided SAR teams with insightful information that helped them organise resources and make wise judgements.
- Effective Search and guiding: The framework's integration of UAVs with smart devices shortened search times and offered efficient SAR mission guiding. UAV use improved search capabilities by enabling wider coverage and more effective identification of survivors or crucial regions. The framework used UAV

computing to enhance general search and guide procedures, increase search route optimisation, and more.

- Network Framework Evaluation: Various criteria, including delay, throughput, load, traffic sent and received, and path loss, were used to assess the proposed network framework, which included UAV computing, SAR, and disaster centres. The evaluation confirmed the framework's viability and effectiveness, ensuring that it can effectively facilitate communication and information exchange between SAR teams and UAVs over a variety of distances.
- Better Disaster Response and Mitigation: The UAV Computing-Assisted Search and Rescue Mission Framework's successful implementation resulted in substantial advancements in disaster response and mitigation. The framework improved the ability of SAR teams, reducing response times, optimising resource allocation, and ultimately saving more lives in disaster and severe situations. It did this by utilising UAV computing, intelligent gas sensor nodes, and real-time data processing.
- Potential for Gas Classification Technology developments: The successful application of the unique technique opens up opportunities for gas classification technology developments. The technique leads to the creation of more accurate and reliable gas sensing systems, enhancing safety precautions, environmental monitoring, and quality control in various industries by extending the dynamic range and enhancing response patterns.

6.2. Future Scope

Future research and development can be built on the accomplishments established in the use of the spatial upscaling-based method, the data-driven strategy, and the UAV Computing-Assisted Search and Rescue Mission Framework. The frameworks will continue to be improved in the future in order to increase their applicability, accuracy, and impact across a variety of industries and domains. This will include refinement, integration with advanced technologies, expansion to new gas and odor categories, validation in real-world scenarios, collaboration with stakeholders, and continuous improvement. The following may be the pin-pointed aspects which may be taken up in future:

- Refinement and Optimisation: The spatial upscaling-based technology for gas and odor detection can be improved and optimised by additional research and development. To improve the precision and effectiveness of the detection process, this involves optimising the parameters, researching various spatial upscaling strategies, and fine-tuning the algorithm.
- Integration with IoT and Smart Systems: Due to the data-driven approach's effectiveness in generating virtual replies, integration with Internet of Things (IoT) and smart systems is now a possibility. The integration of virtual replies with IoT systems can be explored in the future, providing real-time monitoring, remote control, and advanced data analytics for better gas classification and monitoring applications.
- Expansion to New Gas and Odor Categories: The mechanisms put into place have demonstrated potential in terms of identifying and valuing dangerous gases and odors. Expanding the scope to encompass the detection and odor categorization of new gas and odor types can be the main goal of future research. This would entail tuning the methods for certain gas and odor profiles and training the algorithms with a larger variety of datasets.

- Testing and Validation for Robustness: The created frameworks and algorithms can go through rigorous testing and Validation in hostile environments and real-world scenarios. To confirm the robustness, dependability, and generalizability of the methods, testing the spatial upscaling-based approach and the data-driven strategy on various gas sensor arrays and in a range of climatic circumstances is part of this.
- Integration of Advanced Sensing Technologies: In the future, it may be possible to investigate how to combine spectroscopic and hyperspectral imaging technologies with gas sensor arrays and UAV computing frameworks. The accuracy and capability of the detection and estimate procedures can be further enhanced by this integration, which can provide more thorough and detailed information regarding gases and odors.
- Collaboration with Industry Stakeholders: Working together with industry stakeholders, such as gas sensor producers, emergency management organisations, and environmental monitoring groups, can make it easier to put the proposed frameworks and methodologies into practise. Collaboration can be used to verify the efficacy of a given strategy, solve real-world problems, and promote wider use of the technology.
- Continuous Improvement of the Frameworks: By incorporating developments in UAV technology, data processing algorithms, and communication protocols, the UAV Computing-Assisted Search and Rescue Mission Framework can be continuously improved. The capabilities of the framework for autonomous operation, adaptive decision-making, and seamless interface with current disaster management systems can be improved in future development.