Abstract

In the management of urban and regional development, continuous environmental monitoring plays a relevant role because of its impacts on productivity, resilience, and sustainability. Among the tools for data-gathering and data-analysis, service robotics and machine learning are becoming widely adopted, allowing a deep understanding of the environment and its processes. Their use enables new methods for managing urban and regional development. Nevertheless, the state of the art of platforms, sensors, and automatic information extraction techniques highlights that technologies and methodologies for monitoring might be further enhanced. Thus, improvements are required concerning the acquisition and the rapid analysis of high spatial, temporal, and spectral resolution data.

In this scenario, the interdepartmental centre of Politecnico di Torino for Service Robotics (PIC4SeR[1]), within which the present research work develops, aims at integrating service robotics and artificial intelligence in several applications as precision agriculture, cultural heritage, and smart cities & search & rescue. In these application fields, the Centre's idea stresses the development of a multi-agent and multi-sensor uncrewed platforms collaborating among themselves and enabling various perspectives for monitoring and interacting with the environment. This thesis, funded by the Centre, focuses on the geomatics aspects and consists of platform definition, sensors calibration, and definition of quasi real-time machine learning algorithms for information extraction. Two complex case studies, aircraft inspection for de-icing operations and precision agriculture, were investigated to test technologies and methods.

The purpose of the research is to define quasi-real-time automated information extraction techniques applied to multi-scale, multitemporal and multi-sensor data

[1] https://pic4ser.polito.it/

for inspection and environmental monitoring. Real-time automated techniques can make data analysis time-effective and more efficient for different applications.

The research spans the whole process of remote sensing, from platform definition to information extraction. In detail, the present work focuses on Uncrewed Aerial Vehicle (UAV) platform configuration to integrate innovative sensors such as a hyperspectral camera. At the same time, the research tests methodologies for extracting information using machine learning techniques from data with different spectral and spatial resolution such as Red, Green, Blue (RGB), multispectral and hyperspectral images.

Among the obtained promising results, it is possible to underline the following main findings. A UAV platform was configurated and fully integrated with the hyperspectral sensor and the correlated hardware components, focusing in particular on the ice detection inspection. The hyperspectral sensor was characterized, and the data were corrected geometrically and radiometrically. A suitable dimensionality reduction procedure for hyperspectral data was performed, showing the advantages of data management. Reduced hyperspectral and multispectral data were compared to verify the goodness of their adoption. Moreover, the band reduction procedure provided helpful information for selecting a multispectral sensor with equivalent bands. The advantages that this outcome provides is great because the multispectral camera is cheaper and simpler than the hyperspectral camera. This prospects further developments for near- real-time application in which spectral information could be essential.

In the end, a near-real time detection task was accomplished using semantic segmentation and object detection techniques with different data types (RGB, multispectral and hyperspectral). The outcomes show a promising model generalization with high accuracy values (80%-95%) in both applications, i.e. precision agriculture and aircraft inspection for de-icing operations. The results of this work can be extended to several UAV application fields, offering improved methods in near real-time object detection.