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Integration of reflectances and thermography imagery for transport infrastructures diagnostics

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The integrated use of reflectances and thermography to study and diagnostic of transport infrastructures has been applied on the Musumeci Bridge (Potenza, Italy) test site as a fast and non-destructive tool in the framework of the Integrated System for Transport Infrastructures surveillance and Monitoring by Electromagnetic Sensing (ISTIMES) project, funded by the European Commission in the frame of a joint Call "ICT and Security" of the Seventh Framework Programme, in order to extract appropriate information and make useful decisions [1].

The applied hyperspectral imagery is primarily suited for the detection and characterization of alterations and defects in the structures' surface, whereas by means of thermography it is possible to attain near real-time information about the internal structure such as a bridge.

Hyperspectral data is able to discriminate materials on the basis of their different patterns of wavelength-specific absorption; in fact, they are successfully used for identifying minerals and rocks, as well as detecting surface materials properties [2]. For this study we used the HySpex VNIR-1600 and the SWIR-320 hyperspectral scanners (see details in Table 1) located beneath the Musmeci Bridge thus being able to acquire the structure. The hyperspectral data processing has allowed to derive indication/parameters related to the status of the structure surface, i.e. by means of the detection of the surface weathering status of the iron (i.e. iron oxides such as limonite/goethite) used to reinforce the cement structure and the occurring detachments of the cement covering the iron. This assessment can be used to foresee more severe damages of the armed concrete.

Concerning the rationale for using a high sensitivity Infrared camera in the MWIR range (3.5-5 micron; see Table 1) for the Musumeci test site is based on the fact that the high radiometric resolution of the thermal images time series allows analyzing the structure homogeneity and the cohesion of the cement structure layer with the substrate. As favorable environmental condition were satisfied: (a) the inner structure is thermally connected to the external surface of the bridge structure and (b) the thermal gradient at the surface does not depend on the atmospheric conditions (e.g., sun, rain, wind and so on), it was possible for the Musumeci Bridge to detect with a good accuracy the underlying structure. More specifically, the thermal series measuring sessions were executed during the night time in order to record and understand the diurnal/nocturnal thermal behavior of the structure according to the diurnal heating of the structure. Principal Components (PC) analysis and the assessment of the parameters describing the thermal decay were used. For this study the parameter that better describes the thermal decay of the bridge corresponded to the angular coefficient of the curve better interpolating the temperature decay ramp that for a limited interval of time could be approximated to a linear decay.

The jointly use of the two non-destructive techniques applied for this project is encouraged by the technical and operative characteristics of the observation systems at disposal that are able to observe the variables, physical and optical parameters in near real-time and connected to the transport infrastructures status. In particular, the hyperspectral imagery processing results show that such methodology is suitable to identify reliable parameters related to the structure surface by detecting anomalies and identifying the specific signature of the material of interest. The thermal long time series processing, i.e. both the PCA and decay coefficients images, has allowed to highlight the real inner structure of the bridge.

From the proposed non-destructive monitoring approach on the Musumeci test site experiences, we can conclude that the integrated use of the two sensing techniques is a valid support for a rapid and low cost evaluation of the bridge structure and also with respect to the rapidity of the sensing the output of this technology represents a powerful tool to build the first informative level in the framework of an operative decision-support system.

Table 1. Characteristics of sensors used for the study.

	Spectral Region	Spectral Resolution	Spectral Range	IFOV	Characteristics
Hyspex VNIR-1600	VIS-NIR	3.7 nm	0.4÷1.0μm	0.75 mrad	160 bands (1600 pixels)
HySpex SWIR-320m	SWIR	5.0 nm	1.3÷2.5μm	0.75 mrad	240 bands (320 pixels)
FLIR SC7000	MWIR	integrated	3.5÷5.0μm	1.20 mrad	640 × 512 (5÷300 ˚C)

1 References

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