A smart multi-sensor approach for dynamically guiding a solid-state X-band radar during intense weather systems approaching urban areas

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Densely populated urban areas are highly vulnerable to hydrogeological risks due to massive overbuilding, which sometimes has harnessed waterways or created artificial river canals. Recent statistics clearly indicate that economic and human damages caused by urban floods are rising. On one hand, the continuing urbanization process in combination with an overproportional growth of values in cities is responsible for this trend, while on the other hand extreme weather events are indeed increasing, in terms of frequency and intensity. To handle the flood risk in such areas, an efficient monitoring network is crucial for nowcasting the precipitation with high spatial and temporal resolution, so that supporting flood forecasting and issuing reliable alerts at the urban scales by the authorities in charge of such tasks.

SURFACE, a project of the FESR 2014-2020 program funded by regional administration of Tuscany (Italy), aims at developing a system for monitoring and classifying intense and extreme weather events on urban and small rural basin scales, based on a network of innovative X-band mini-radars that are solid-state, polarimetric and low-power output. These events are difficult to detect from traditional networks based on ground-based raingauges or long-range radar systems. Raingauges provide point measurements and often the network is not sufficiently dense to catch very local events, and in any case it is unable to feed the nowcasting of events approaching from the sea. Long-range radar systems are available from the national radar network, which is conceived to ensure the maximum coverage with the least number of radars and the Italian complex orography often limits radar observations, in any case not proper for urban applications.

The polarimetric radar system will be developed with a solid state technology and low power output to make it suitable to be used in densely populated urban environments, and will be equipped with a remote management system that allows remote interaction with the radar via a smart terminal. In the concept of Industry 4.0, which this project refers to, the radar operation is dynamically and automatically conditioned by the information arriving from other heterogeneous sensors, to improve the radar detection capability. More precisely the scan schedule of the radar system will be automatically configured to optimize the observation strategy of the more critical events approaching the area covered by the radar, with the aim of maximizing the information obtained through sampling different volumes and heights in the atmosphere, exactly where the main phenomena are foreseen to happen, according to the observations from the other sensors of the system. At the purpose this work is focused on the implementation of a detection scheme of convective initiation and development, under day and night time conditions, based on satellite and lightings data for guiding the optimised radar scans. It uses the IR (9.7, 10.8, 12.0, and 13.4 μm) and WV (6.2 μm) MSG SEVIRI channels, in a rapid scan mode (i.e. 5-minute). In our system lightning data are provided in real-time by the Blitzortung network, every minute. The criteria used in the scheme aim to detect rapidly moving convective cells in both early and mature stages, merging the information given by IR brightness temperature (absolute values, temporal and spatial gradients), with the occurrence of lightings.

Several case studies of different precipitation intensities and systems spatial organization have been chosen to test the reliability of the scheme and to qualitatively quantify its robustness. To this scope, the national radar and raingauge network have been used to validate the results. The characteristics of the solid-state X-band radar are part of the study, in order to build an effective system capable to exploit the information available from the selected external sources and smartly interact with the other sensors of the system.

Keywords: solid-state, X-band meteorological radar, Industry 4.0, intense weather events, satellite data, lightnings