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An integrated multiparametric system for infrastructure monitoring and earlywarning based on internet of things

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Our daily life strictly depends on distributed civil and industrial infrastructures in which Qatar and other heavily industrialized countries have large investments. Recently, fails in such infrastructures have incurred enormous economic losses and development disruptions as well as human lives. Infrastructures are strategic assets for a sustainable development requiring correct management. To this end, their health levels and serviceability should be continuously assessed. Geophysical and mechanical quantities that determine such serviceability are for instance tilt angles, vibration levels, applied forces, stress, and existence of previous structural defects. It follows that for a feasible serviceability assessment, appropriate sensing and data processing of those parameters have to be achieved. For example, bridges are monitored for structure movements and stress level while earthquake early warning systems detect primary seismic waves before arrival of strong waves. In case of riverbank conservation, water level must be monitored together with the associated mass flow for load estimation. In addition, precipitation rate and groundwater level are paramount indicators to anticipate slope fault. Finally, strain/temperature measurement can be used to sense the health of concrete gravity or arch dams. End-users, engineers and owners can take the most appropriate decisions based on the sensed parameters. The Structural Health Assessment (SHA) is not straightforward. The structural condition is generally complex in terms of architectural parameters like damage existence, distributed masses, damping factors, stiffness matrices, and/or applied distributed forces. The above factors make such SHA extremely difficult and/or exceptionally expensive. With the aim to alleviate this difficulty, possible approaches in SHA are based on vibration measurements. The analysis

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of such measurements reveals the structure dynamic behaviour, which in turn reflects the characteristics and distributed forces on structures. Also, structural soundness is obtained by the estimation of the inverse analyses of the dynamic performance. However, this dynamic behaviour that is inherently complex in both time and/or spatial scale, is more complicated by the fact that for example deterioration/damage/erosion is essentially a local phenomenon. Commonly, technicians with specific domain knowledge achieve SHAs manually. Obviously, this incurs high costs and inadequate monitoring frequency. Also, there is a high probability of making errors due to improper positioning of the instrumentation or to mere mistakes during data collection. Nevertheless, for commonly large buildings (e.g. towers, general buildings, bridges and tunnels), data from just few distributed sensors cannot accurately fulfil the SHA. Consequently, the use of dense distributed sensors working at a sufficiently high sampling frequency becomes a must. Physical wiring of the site under observation is impractical due to cost and architectural constraints. Thus, for Structural Health Monitoring (SHM), networks of dense distributed sensors, which are wirelessly connected, become imperative. When a copious number of transducers are adopted, wireless communication appears to be attractive. Also, the high cost needed for the installation of wired sensors can be strongly reduced by employing wireless sensors. The present research the authors implemented a WSN-based approach for widespread monitoring without forcing intolerable boundary conditions, i.e., requiring wiring the measuring nodes, triggering manual data collection or imposing strong modifications to the site before the deployment of the sensory hardware (less intrusive). In view of the above discussion, the investigators explored some key issues on the above challenges by referring to several SHM engineering paradigms. The author designed a novel multi-parametric system dedicated to stability monitoring and control of soils, engineering works (e.g. bridges, stadium, tunnels), underground rail tunnels, offshore platform in order to continuously evaluate danger levels of potentially instable areas. The proposed system can be assembled 'in situ' structuring an underground-instrumented column, where different modules are joined together on a digital bus (e.g. via RS485 or CANBUS communication). Each module contains up to ten different sensors (e.g. accelerometers, magnetometers, inclinometers, extensometers, temperature sensors, and piezometers) and an electronic board for data collection, conversion, filtering and data transmission. Special flexible joints that permit strong, continuous adaptability to bends and twists of the drilling hole, link the modules. A control unit, installed outside the ground provides the readings at regular time intervals and it is connected to other columns via wireless communication forming a wide network. In particular, the proposed approach allows both analysing the response of the infrastructure to vibrations on the fly, so an early warning signal can be triggered, and saving the corresponding measurements for further analysis. Authors believe that this proposal is original and unique in three aspects. First, as most of the earlier studies on SHM were carried out by adapting existing hardwired solution for snap shot measurements rather than representative long-term monitoring, our proposal presents the first initiative to develop green WSN technologies applied to sustainable SHM applications. Second, it will develop tailored sensor technology and new techniques for SHM taking into account metrological and physical parameters such as resolution, cost, accuracy, size, and power consumption. Third, the project will commission a novel multi-parametric SHM system, which can be customized to other areas (e.g. environmental monitoring, traffic monitoring, etc.). The research is to support innovations at system and component levels leading to out-of-the-box know-how. The proposed solution is based on novel/customized sensors and data processing, environmentally powered communication platform, and communication networks and algorithms embracing the visionary nature of the IoT with out-of-the-box solutions. Specific outcomes have been experimental proof-of-concept, through testing and prototyping, of a tailored SHM sensor technology and smart techniques that uniquely provide self-calibration and self-diagnostics of faults, a multi-sensor viable instrumented column for SHM with advanced techniques, and environmentally powered wireless platform with innovative MAC protocols (power-aware, context-aware, cognitive and polymorphic). This work employs tools and techniques of modern sensing, processing, and networking in order to generate novel SHM solutions that uniquely provide precision measurement, green IoT-based communication approach, viability, and cost-effectiveness.