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A real-time classification method for pipeline monitoring combining Distributed Acoustic Sensing and Distributed Temperature and Strain Sensing

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Distributed Fiber Optic Systems (DFOSs) refer to an ensemble of innovative technology that turns an optical fiber into a vast network of hundreds to thousands equally spaced sensors. According to the nature of the sensor, one can be sensitive to acoustic vibration (Distributed Acoustic Sensing, DAS) or to strain and temperature variation (Distributed Temperature and Strain Sensing, DTSS). DAS systems are well suited to detect short-term events in contrast to DTSS systems, which are intended to prevent long-term events. A combination of these two systems appears to be a good way to prevent against most possible events that can appear along an infrastructure. Furthermore, DFOS systems allow the interrogation of long profiles with very dense spatial and temporal sampling. Handling such amounts of data then appears as a challenge when trying to identify a threat along the structure. Machine learning solutions then proves their relevance for robust, fast and efficient acoustical event classification.

The goal of our study is to develop a method to handle, in real time, acquired data from these two DFOSs, classify them according to the nature of their origin and trigger an alarm if required. We mainly focus on major threats that jeopardize the integrity of pipelines. Our database contains leaks, landslides, and third-party intrusion (footsteps, excavations, drillings, etc.) simulated and measured at FEBUS Optics test bench in South-West France. Water and air leaks were simulated using electrovalves of several diameters (1mm, 3mm and 5mm), and landslides with a plate whose inclination was controlled by 4 cylinders. These data were acquired under controlled conditions in a small-scale model of pipeline (around 20m long) along different fiber optic cables installed along the structure.

Our method relies on several tools. A Machine Learning algorithm called Random Forest is used to pre-classify the DAS signal. Our implementation of this algorithm works in flow for a real time event identification. For DTSS signal, a simple threshold is used to detect if a strain or temperature variation occurs. Both results are then gathered and analyzed using a decisional table to return a classification result. According to the potential threat represented by its identified class, the event is considered as dangerous or not. Using this method, we obtain good results with a good classification rate (threat/non-threat) of 93%, compared to 87% if the DAS is used without the

DTSS. We have noticed that the combination of both devices enables a better classification, especially for landslides hard to detect with the DAS. This combination enables to dramatically reduce the part of undetected threats from 16% to 4%.