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Tracking of cracks in bridges using GPR: a 3D approach

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Corrosion associated with reinforcing bars is the most significant contributor to bridge deficiencies. The corrosion is usually caused by moisture and chloride ion exposure. In particular, corrosion products FeO, $Fe2O_3$, Fe3O4 and other oxides along reinforcement bars. The reinforcing bars are attacked by corrosion and yield expansive corrosion products. These oxidation products occupy a larger volume than the original intact steel and internal expansive stresses lead to cracking and debonding.
There are some conventional inspection methods for detection of reinforcing bar corrosion but they can be invasive and destructive, often laborious, lane closures is required and it is difficult or unreliable any quantification of corrosion. For these reasons, bridge engineers are always more preferring to use the Ground Penetrating Radar (GPR) technique.
In this work a novel numerical approach for three dimensional tracking and mapping of cracks in the bridge is proposed. The work starts from some interesting results based on the use of the 3D imaging technique in order to improve the potentiality of GPR to detect voids, cracks or buried object.
The numerical approach has been tested on data acquired on some bridges using a pulse GPR system specifically designed for bridge deck and pavement inspection that is called RIS Hi Bright. The equipment integrates two arrays of Ultra Wide Band ground coupled antennas, having a main working frequency of 2 GHz. The two arrays within the RIS Hi Bright are using antennas arranged with different polarization. One array includes sensors with parallel polarization with respect to the scanning direction (VV array), the other has sensors in orthogonal polarization (HH array). Overall the system collects 16 profiles within a single scan (8 HH + 8 VV).
The cracks, associated often to moisture increasing and higher values of the dielectric constant, produce a not negligible increasing of the signal amplitude. Following this, the algorithm processes the signal by comparing the value of the amplitude A(i,j,k) in the position of the 3D domain i,j,k all over the GPR scan with a threshold T(k), that depends on the depth k. The value of the threshold, that is variable in order to compensate attenuation effects, has been calibrated all over the depth of the scan comparing the real truth with the GPR prediction.
The algorithm analyzes the signal amplitude all over the domain of the radar scan for i=1,N (longitudinal length of the scan), for j==1,M (transversal length of the scan) and for k=1,L (depth of the scan), where N, M, L are the boundary domain limits. Starting from the generic position of the scan where the algorithm finds a signal amplitude greater than the threshold, A(i,j,k)>T(k), the 6 positions, left (j-1), right (j+1), up (k-1), down (k+1), forward (i+1) and backward (i-1), are checked in order to find the position where the amplitude reaches the maximum value Amax(i*,j*,k*). Of course this value must be over the threshold T(k*) to be accepted as belonging to the crack. At the next step the algorithm restarts the tracking procedure assuming Amax(i*,j*,k*) as the new generic value A(i,j,k). The procedure ends as the entire domain has been numerically scanned.