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Combined GPR and visible image databases of concrete structures

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1. GENERAL INFORMATION

The database has been performed in the frame of a research project named ADOUCIR (Aide au Diagnostic d'OUvrages par Couplage d'Images et Radar, or Aid to the Diagnosis of Structures by Image and Radar Coupling), founded by the FEREC (Fondation d'entreprise recherche collective pour la construction et les infrastructures) foundation. The general objective is to show the feasibility and the interest of artificial intelligence methods combining visible surface image and ground-penetrating radar (GPR) data for the inspection of civil engineering concrete structures.

In this database, images of concrete structure areas smaller than 1 m² are acquired in two ways: (i) images of the concrete surface acquired in the visible range, (ii) images of the concrete sub-surface obtained from GPR represented as B-scans. In relation to the observed surface, each area is also classified by an expert into two categories: healthy area and damaged area (with cracks).

1.1. EXPERIMENTAL SETUP

The visible and GPR images of concrete structures are acquired as follows. Each concrete area is delimited according to a 80 x 80 cm square, whose corners are drawn with chalk on the wall surface (see fig. 1.a). Two high-resolution visible colour images (usually 3000 x 4000 pixels) of the area are acquired, the first one is a front view of the square at a distance of about 2 meters and the second one is a view with an oblique angle of about 45°. A standard smartphone is used for the acquisitions.

On the same concrete area, two GPR profiles located at the center of each side of the 80 x 80 square are surveyed, one in the horizontal direction of the surface and the other in the vertical direction (see the blue dotted lines showing the profile directions in fig 1.a and the resulting B-scans in fig 1.c and 1.d).

The GPR sensor used for the experiments is a portable commercial radar (StructureScan model from GSSI manufacturer) whose central frequency is fixed at 2.6 GHz.

Note that the Radar signals (A-scan) are acquired at a rate of 1 acquisition every 1.25 mm. For a length of 80 cm, 641 A-scans lead to one B-scan (GPR time section). The time ranges during the acquisition have been fixed to 8 ns for the two concrete beams and 6 ns for a post-tensioned concrete bridge (structures presented in next section), in both cases sampling signals to 256 pixels. GPR processing consisted of several steps, an acquisition sampling limited to 5mm, a [520 MHz – 5200 MHz] pass-band filter and a time gain fixed at -15 dB. As results, leading to GPR B-scans of 161x256 pixels (Fig.1).

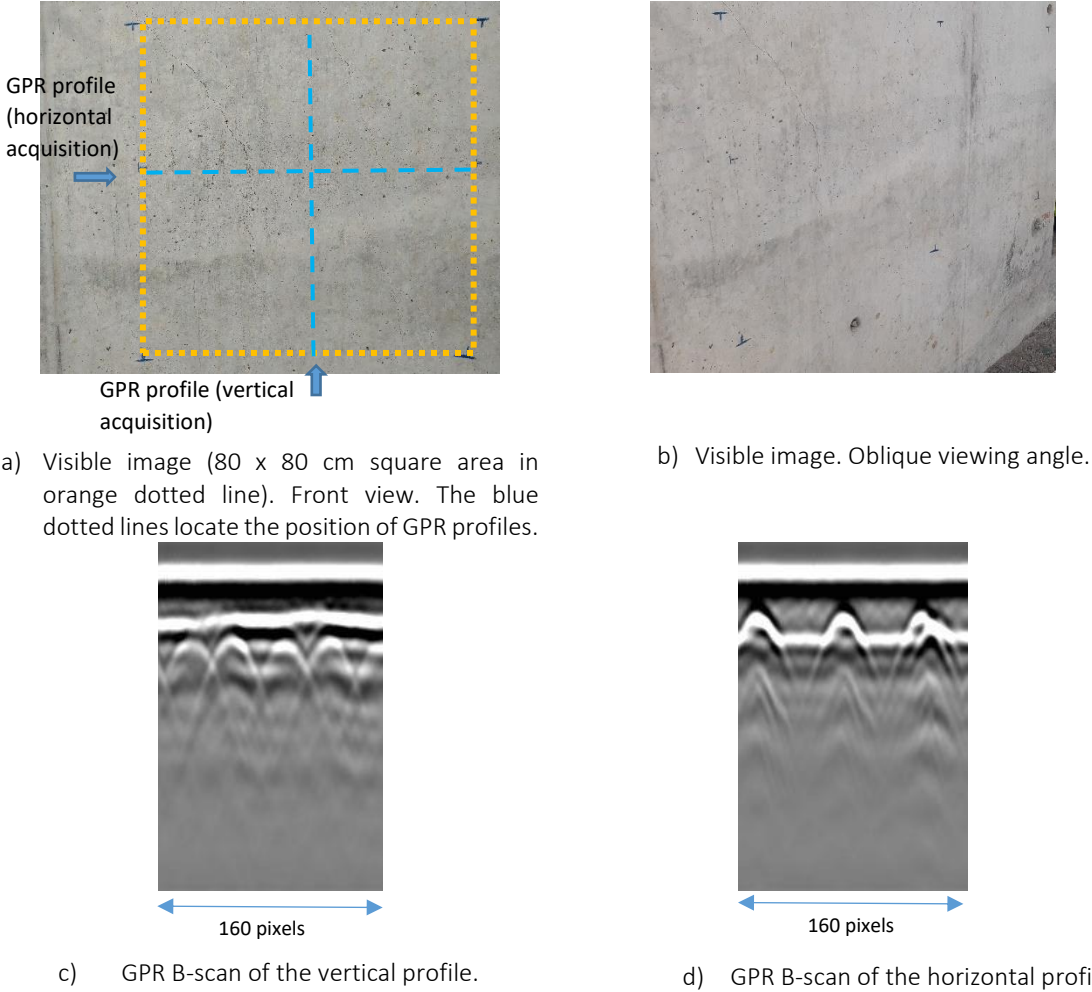


Figure 1: Examples of the 4 images acquired on an elementary area of a concrete wall.

Each zone of the structure is therefore associated with four images (see Figure 1). With the help of a specialist in engineering structures, we have visually classified these zones into two categories: healthy area or damaged area with cracks. The four images of the same area have the same label.

1.2. ACQUISITION CAMPAIGNS

Two experimental data acquisition campaigns were carried out in the summer of 2021. Two concrete structures were identified: The first series of acquisitions was carried out on two identical concrete beams with metallic reinforcements and used for tests at the Gustave Eiffel University, Nantes campus. One of the two beams presents strong degradations and in particular major cracks, and an area of 1 m² of spalling due to the impact of a 5 T block fall from 5 m. The other one is considered as healthy.

The second series of acquisitions took place on a post-tensioned concrete bridge in service. Its reinforced concrete piers, dating back some thirty years, show a certain number of degradations, mainly cracks, on their surfaces. These defects are due to the ageing of the structure and to the physicochemical internal reactions of the material. The importance of these defects varies according to the orientation of the pier faces, the sun and the weather (exposure to rain). Then 3 piers were investigated on their most exposed sides.

88 zones were identified, resulting in 176 visible images (front or oblique views) and 176 GPR images (horizontal or vertical profiles). 33 areas are considered as healthy and 55 as having a defect.

2. DATA FILES AND STRUCTURE OF DATA

The data files are structured as follows. There are 2 folders: *Beam* and *Bridge*. The folder named *Beam* comprises 24 sub-folders and the folder named *Bridge* comprises 64 sub-folders. Then, the structures gather a total of 88 elementary areas. A sub-folder is named using the following format:

- For the concrete beam, the first part of the folder name always begins with “Be”, followed by a number to locate the zone visualized on the beam. After the underscore, there is a label representing the state of the structure (S: health, CH: shock).
- For the bridge, the first part of the folder name is an acronym that indicates the orientations of the investigated faces of the structure pier. The number of the bridge pier is concatenated with the orientation acronym and a second number, separated by a dot, locates the area. After the underscore, there is a label representing the state of the structure (S: health, R: Reactive damage). For example, the folder “NE3.2_R” indicates North-Est (NE) face, pier 3, area 2, showing reactive damage.

Each sub-folder comprises four “jpeg” files: the two visible images and the two GPR images. The first part (up to the second underscore) of the name of each file matches exactly the name of the parent folder. The suffixes *IA* and *IB* correspond to frontal and oblique images respectively. The GPR files have either the suffix *H* (Horizontal acquisition) or *V* (vertical acquisition). two example of a sub-folder containing the 4 files, are shown in Figure 2-left for the beam, and Figure 2-right for the bridge.



Figure 2: On the left, the four images in the sub-folder (Be1.4_S) for the beam. On the right, the four images in the sub-folder (SO3.2_R) for the bridge.

CONCLUSION

The database is made available to the GPR community and can serve as a reference benchmark for both developing and testing the performance of various processing techniques. To our knowledge and to date, there are many databases for infrastructure inspection (Bianchi and Hebdon, 2022) in general, but none of them offer both surface and subsurface images.

This database including both visible and GPR images of real structures has been built to show the interest and feasibility of data fusion in automatic algorithms dedicated to the inspection of structures.

To this end, learning techniques can be applied in different ways. Classification algorithms can be used to classify areas of the concrete into healthy and damaged categories, including cracks. Other types of learning algorithms can be developed to extract features of interest or characteristics of the structure, either on the surface or sub-surface.

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