Boosting-based Visualization of Concrete Defects for Hammering Inspection

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In this paper, for automation of hammering test, a methodology of constructing the defect detector that can identify defective locations is proposed. Particularly, defectiveness of material is indicated as a score, and the condition of the material is visualized by associating the score and the inspected position.

1 Introduction

As a social issue, aged deterioration of social infrastructure is rapidly getting serious. For safety and security, automation of reliable inspection method such as *hammering test* is highly demanded. For automation of hammering test, a methodology to identify locations of defects is necessary. In this paper, a hammering based defect detector that can obtain the material defectiveness score and its location is proposed.

2 Method and Application

Basic algorithm of our defect detector is described in our previous work [1], which is based on a boosting framework. The algorithm integrates multiple weak learners which have, in each, a pair of frequency templates with regard to defect and clean (defect-free). The evaluation function of each weak learner $h(\boldsymbol{x})$ for new signal $\boldsymbol{x}$ is represented as follows:

$$h(\boldsymbol{x}) = \{{}^{D}S(\boldsymbol{x}) - {}^{C}S(\boldsymbol{x})\}/\theta\,, \tag{1}$$

where ${}^{D}S(\boldsymbol{x})$ is a similarity function between the signal $\boldsymbol{x}$ and the defective frequency template, and ${}^{C}S(\boldsymbol{x})$ is the clean one. The similarity is calculated by a weighted zero-mean normalized cross-correlation. Variable θ is the threshold for diagnosis. The frequency template pair and θ are peculiar parameters to be designed for each learner, which are automatically obtained during iterative refinements of the boosting algorithm.

The defective score $D(\boldsymbol{x})$, which is an index for defectiveness of a concrete material, is estimated from $\boldsymbol{x}$ as follows:

$$D(\boldsymbol{x}) = \sum\nolimits_{t=1}^{T} \alpha_t \,\mathrm{sign}\,[h_t(\boldsymbol{x}) - 1] \,/ \sum\nolimits_{t=1}^{T} \alpha_t\,, \tag{2}$$

where T denotes the count of weak learners. The score is a result of majority vote by learners $\{h_t\}$ with their confidences $\{\alpha_t\}$. In diagnosis, material condition can be visualized by associating the scores and the hammered points, for example by using colors which correspond with the condition.

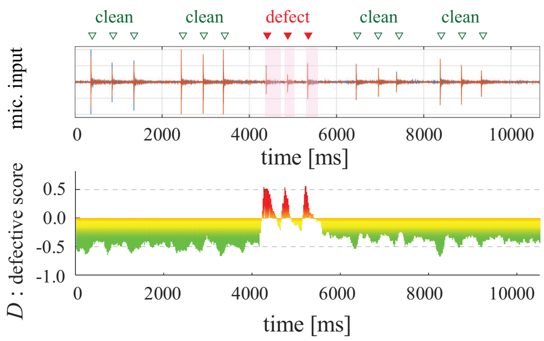
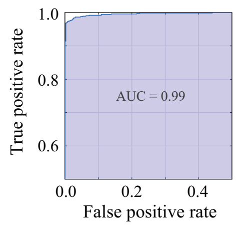
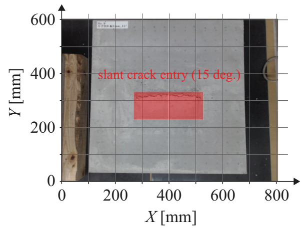


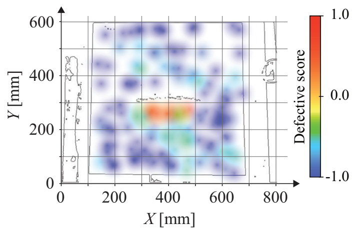
Fig. 1 The top chart shows hammering sound of time domain, and the bottom one shows the defective score D estimated by the proposed detector (eq. (2)).



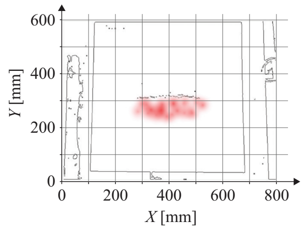
(a) ROC curve evaluated by 5-fold cross validation.



(b) Ground truth of defective area (half-toned in red).



(c) Defective score with location. The hammered points were detected by image processing.



(d) Binary classification result. The areas of $D > 0$ are shown with red color.

Fig. 2 Detection results of defective locations.

An acoustic signal of hammering is shown in Fig. 1, which contains the sounds of clean parts and defect parts. The time periods emphasized by a half-tone background on the top chart indicates the signals of $D > 0$. Hammering sounds of defect parts were detected correctly as high scored signals. The proposed method performed with high accuracy, whose area under the ROC curve was 0.99 (Fig. 2(a)). It was evaluated by using 5-fold cross validation of 6,320 samples which were obtained from various test-pieces such as one shown in Fig. 2(b). Experimental results are shown in Figs. 2(c) and 2(d). The defective regions were detected accurately.

3 Conclusion and Future Work

A methodology of constructing an accurate defect detector that can identify defective locations was proposed. This visualization method can be applied to inspections to find suspected areas of defect, such as screening works. Expansion of this method to detailed inspection is our next work.

Acknowledgements

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References

[1] Fujii, H., Yamashita, A. and Asama, H., "Improvement of Environmental Adaptivity of Defect Detector for Hammering Test Using Boosting Algorithm," Proceedings of the 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 6507–6514, 2015.