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Visual retrieval of concrete crack properties for automated post-earthquake structural safety evaluation

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ABSTRACT

The safety of post-earthquake structures is evaluated manually through inspecting the visible damage inflicted on structural elements. This process is time-consuming and costly. In order to automate this type of assessment, several crack detection methods have been created. However, they focus on locating crack points. The next step, retrieving useful properties (e.g. crack width, length, and orientation) from the crack points, has not yet been adequately investigated. This paper presents a novel method of retrieving crack properties. In the method, crack points are first located through state-of-the-art crack detection techniques. Then, the skeleton configurations of the points are identified using image thinning. The configurations are integrated into the distance field of crack points calculated through a distance transform. This way, crack width, length, and orientation can be automatically retrieved. The method was implemented using Microsoft Visual Studio and its effectiveness was tested on real crack images collected from Haiti.

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1. Introduction

After an earthquake occurs, entry into damaged buildings as soon as possible is necessary for a variety of reasons, including emergency search and rescue, building stabilization and repair, and salvage and retrieval of possessions [1]. There are always extensive risks associated with entering damaged buildings after an earthquake, and often, further structural collapse produces additional victims. Currently, the safety of entering damaged buildings is evaluated manually by structural specialists (e.g. structural engineers and/or certified inspectors). They follow the guidelines provided by the Federal Emergency Management Agency (FEMA) and/or the Applied Technology Council (ATC), and assess the impact of visual damage (e.g. cracks) on critical structural components to make sure that the damaged building remains stable and maintains a specific level of structural integrity.

Although civil engineers are the appropriate candidates to evaluate the safety of highly engineered environments [2], several limitations were found in the current evaluation process. First, it is time-consuming. In the October 15, 2006 Hawaii Earthquake and the December 22, 2003 San Simeon Earthquake, the whole building safety evaluation processes took several weeks to complete due to the large number of buildings requested for safety assessments [3,4]. Also, the subjective inspection nature may lead to erroneous judgments [5].

The aforementioned limitations can be overcome if the current manual evaluation practices are fully automated. This not only requires load-bearing members in a structure to be automatically recognized, but also the damage lying on these structural member surfaces to be detected and further assessed based on their properties. So far, many machine vision based methods have been created to locate the damage on structural member surfaces, and their effectiveness has been validated in inspecting structures such as bridges, pipes and tunnels. As a contrast, little work was found regarding load-bearing structural members detection, damage properties retrieval from detection and damage assessment based on the retrieved properties.

The authors recently proposed a research study that focuses on providing a crude but quick safety evaluation for post-earthquake concrete structures through the image/video analysis of these structures [6] (Fig. 1). In the study, concrete columns in images/videos are first recognized with the help of the column's visual characteristics. Then, the damage inflicted on these columns is detected and its attributes are calculated. The detected columns and damage are then correlated in the form of relative damage size, orientation and position. The correlation is used to query a case based reasoning knowledge base which contains apriori classified damage states of columns. The query estimates the damage state of the column for any given damage inflicted on it. If the damage state is severe, an imminent collapse is assumed and an immediate evacuation warning will be issued. So far, the first step, concrete column detection, has been completed [7].

As the step following concrete column detection, this paper presents a novel approach of retrieving the properties of the cracks

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