Eleventh U.S. National Conference on Earthquake Engineering
Integrating Science, Engineering & Policy
June 25-29, 2018
Los Angeles, California

AUTOMATING VISUAL DATA PROCESSING TO SUPPORT POST-EARTHQUAKE RECONNAISSANCE

C.M. Yeum[1], S. J. Dyke[2], B. Benes[3], T. Hacker[4], J. Ramirez[5], A. Lund[6], C. Sim[7], and S. Pujol[8]

ABSTRACT

Each extreme seismic event is an opportunity to assess the performance of our infrastructure under circumstances that cannot entirely be reproduced in the laboratory or through numerical simulation. When performing reconnaissance in the field, engineers record much of the information being gathered in the form of images. When large quantities of images are collected within a short time period and have such a wide variety of content, timely organization and documentation will be important. Clearly, manual sorting and analysis of all these images would be prohibitively tedious and expensive. Thus, to efficiently and thoroughly use these images, engineers need to exploit recent advances in computer vision and machine learning. Herein we introduce a series of automated capabilities we have developed, based on computer vision and machine learning, to classify, organize, and document the large volumes of visual data collected during a reconnaissance mission. We illustrate two specific techniques that can significantly enhance current data collection and organization procedures to support reconnaissance missions: automated (1) reconnaissance report generation, and (2) structural drawing reconstruction.

Automating Visual Data Processing to Support Post-Earthquake Reconnaissance

[1]Postdoctoral Researcher, Lyles School of Civil Eng., Purdue University, IN, 47906 (email: cyeum@purdue.edu)
[2,5,8]Professor, Lyles School of Civil Eng., Purdue University, IN, 47906
[3]Professor, Computer Graphics Technology, Purdue University, IN, 47906
[4]Professor, Computer and Information Technology, Purdue University, IN, 47906
[5]Graduate Student, Lyles School of Civil Eng., Purdue University, IN, 47906
[7]Professor, School of Civil Eng., University of Nebraska, IN, 47906

Yeum CM, Dyke SJ, Benes B, Hacker T, Ramirez J, Lund A, Sim C, Pujol S. Automating visual data processing to support post-earthquake reconnaissance. *Proceedings of the 11th National Conference in Earthquake Engineering*, Earthquake Engineering Research Institute, Los Angeles, CA. 2018.

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Each extreme seismic event is an opportunity to assess the performance of our infrastructure under circumstances that cannot entirely be reproduced in the laboratory or through numerical simulation. When performing reconnaissance in the field, engineers record much of the information being gathered in the form of images. When large quantities of images are collected within a short time period and have such a wide variety of content, timely organization and documentation will be important. Clearly, manual sorting and analysis of all these images would be prohibitively tedious and expensive. Thus, to efficiently and thoroughly use these images, engineers need to exploit recent advances in computer vision and machine learning. Herein we introduce a series of automated capabilities we have developed, based on computer vision and machine learning, to classify, organize, and document the large volumes of visual data collected during a reconnaissance mission. We illustrate two specific techniques that can significantly enhance current data collection and organization procedures to support reconnaissance missions: automated (1) reconnaissance report generation, and (2) structural drawing reconstruction.

Introduction

Our built environment is the most realistic laboratory that exists, and perishable data collected after seismic events is one of the more important sources of information for evaluating the performance of our infrastructure. For such evaluations, vast amounts of visual data are formally gathered by reconnaissance teams after an earthquake. Each team visits several buildings each day, collecting images at each building site and taking measurements from each building. Well-established procedures are followed, as documented in several existing guidelines for rapid structural evaluations [1]. A typical mission could continue for several days to collect much visual data from representative buildings before these informative data are destroyed. In the field, timely analysis of these visual data is critical. In a span of just a few hours, decisions must be made on how to allocate teams and resources. Manual handling of these images is time- and labor-intensive. Thus, automation of these tasks will save these teams tremendous time and effort.

In this paper, we introduce two promising automated techniques we have developed to support post-event reconnaissance: (1) reconnaissance report generation and (2) structural drawing reconstruction. Both methods provide automated capabilities to directly support rapid and robust visual data analysis in the field. First, we illustrate deep learning using convolutional neural network (CNNs), which enables automatic extraction and analysis of the metadata and visual contents according to a set of appropriate classes [2,3,4]. The extracted information is

[1]Postdoctoral Researcher, Lyles School of Civil Eng., Purdue University, IN, 47906 (email: cyeum@purdue.edu)
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[3]Professor, Computer Graphics Technology, Purdue University, IN, 47906
[4]Professor, Computer and Information Technology, Purdue University, IN, 47906
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systematically organized to enable rapid generation of reports in a digital format of use to engineers in the field. Second, we introduce an automated method for reconstructing high-resolution full drawing images by stitching together segmented photographs of drawings [5].

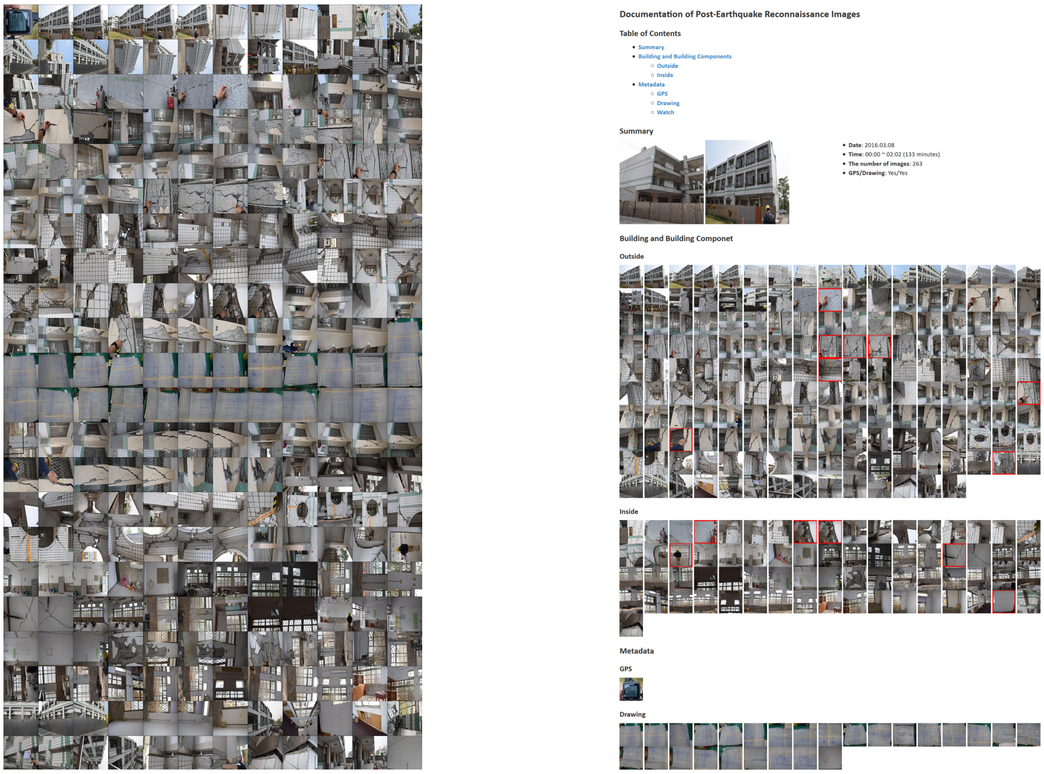
Two Techniques for Supporting Post-Event Reconnaissance

Reconnaissance Report Generation: When visiting a building to collect perishable data, post-event building reconnaissance teams will take many photographs of both the exterior and interior of that building. They also document certain observations by collecting images containing associated metadata, such as structural drawings, GPS devices, watches, and measurements [2,4]. Thus, these large quantities of images have a wide variety of content. Engineers will need to provide accurate and rich descriptions of such images before the details are forgotten. However, the window of opportunity to do so is short. Automation will thus support the rapid organization of these data, enabling their efficient documentation and use.

We have developed an automated approach to organize and document such rich scientific information in an efficient and rapid manner. A schema is first designed to organize the data based on the real needs of the teams in the field. CNNs are implemented to extract robust key visual contents in the images. A significant number of images collected after past earthquakes are used to train robust classifiers in advance of the event to automatically classify the images. The classifiers and associated schema are then used to automatically generate individual building reports. Classification requires about less than 1 seconds per image, and thus report can be generated in a few minutes for each building, depending on the number of images collected.

To demonstrate the technique, we first build a large-scale, ground-truth image database to train classifiers for each of the classes used in the schema selected [2,4]. Thousands of images collected from many events must be used to train classifiers that are robust. Using these trained classifiers, a report is created from a set of images collected in the field from a building severely damaged due to Taiwan earthquake in 2016 [6]. The original 264 images collected from the building and the report generated are shown in Figures 1(a) and (b), respectively. A red box is used to indicate which images were captured for recording a measurement. Rather than looking at a sequence of mixed and unstructured individual images in Figure 1(a), the team can efficiently and rapidly explore the images using this report in Figure 1(b). Note that the report is automatically generated with the web-based tool we have developed. No manual process is used, although users can freely add comments to the images or the report. Because space here is limited, results from only one sample building can be provided, but the report generation tool has been applied to image collections from dozens of buildings.

Structural Drawing Reconstruction: Among the various class of images collected during a mission, structural drawing images provide critical information that allows the engineer to better understand the cause of the damage observed in the field. In Figure 1, drawings often are captured as multiple photographs, which we call partial drawing images (PDI). The small print and fine details that are characteristic of such drawings mean that many images may need to be collected (e.g. 20 ~ 40 images for each drawing) at a close distance to legibly capture the details. Because they are manually-captured, these images also often have inconsistent perspective distortion and level of details between the images when they are captured with different angles or from different distances. Each user would need to expend great effort to understand the proper arrangement of such PDIs to view the real contents of these drawings.



(a) (b)

Figure 1. Reconnaissance report automatically generated using our technique: (a) original images collected in Taiwan, 2016, and (b) report generated from original images shown in (a).

To overcome these barriers, we have developed a solution to automatically recover full structural drawing images. First, PDIs are classified from images collected using an image classification, based on the methods described in the previous section. Then, using the well-known structure-from-motion algorithm, the geometric relationship between each of the PDIs and a corresponding physical drawing are computed to identify their arrangement. Then, images of high-quality full drawings may be reconstructed in which all visual contents are clearly visible. This tool can produce a high-resolution image less than 10 minutes per drawing.

We demonstrate the capability of the technique from a typical set of PDIs. For data preparation, a drawing is printed on Arch E1 paper. Each drawing has fine text and thin lines, for which the details cannot be captured in one photograph. Thirty PDIs in Figure 2(a) are collected from the drawing. The images are captured by a human photographer with no photographic aids. A reconstructed full drawing image is shown in Figure 2(b). The performance of the technique is quite successful. The necessary small text, digits, and thin lines are also clearly legible. Note that the full drawing image is fully automatically constructed from PDIs [5].

(a) (b)

Figure 2. Sample reconstructed full drawing image: (a) partial drawing images and (b) full drawing image automatically output from the method.

Acknowledgments

Partial support was provided by the National Science Foundation under Grant No. NSF 1608762 and DGE-1333468. Data sources include: CrEEDD at Purdue University (datacenterhub.org), the EUCentre (Italy), UNAM (Mexico), FEMA (USA), and the EERI collections (USA).

Conclusions

Two automated techniques based on computer vision methods are illustrated. These methods are intended to directly support field data collection and documentation efforts. First, automated report generation is introduced to organize the images from a building, and facilitates readily finding images-of-special-interest to add proper descriptive information. Second, we demonstrate a technique to reconstruct high-resolution full structural drawing images from PDIs. We expect that these capabilities and tools will be invaluable for future reconnaissance missions.

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