



**11th National
Conference on
Earthquake Engineering**
integrating science, engineering, & policy

Automating Visual Data Processing to Support Post-Earthquake Reconnaissance

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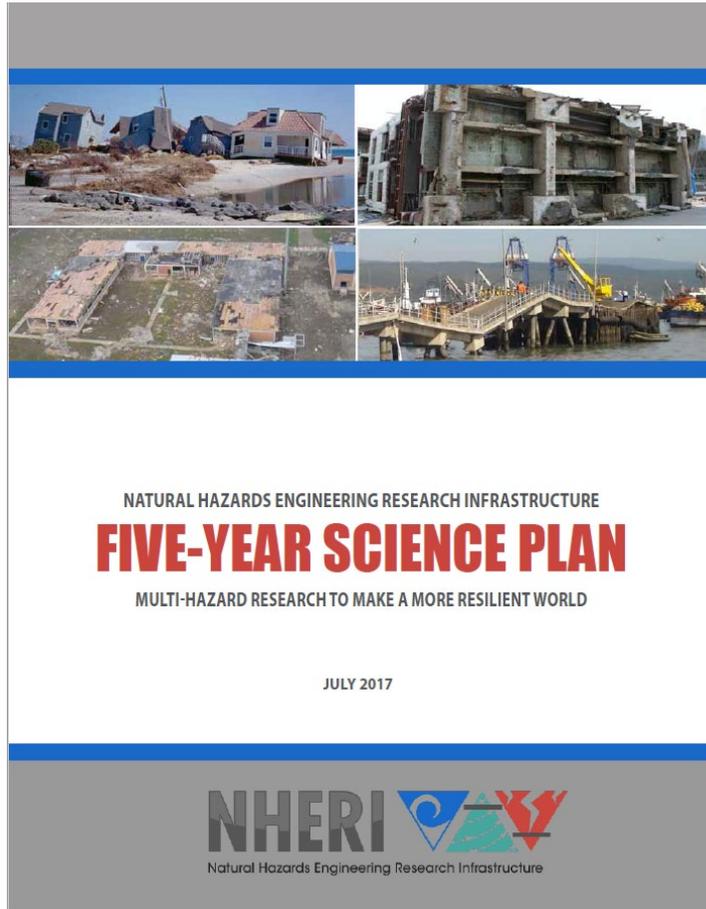
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Motivation: NHERI Five-Year Science Plan



NHERI is the next generation of National Science Foundation (NSF) support for a natural hazards engineering research large facility.

KEY RESEARCH QUESTION # 5 in this plan

How can the scientific community **collect and share data and information** to enable transformative research and outcomes?

Develop regional systems to collect and analyze sensor and **image information** for use in planning, mitigation, response, and recovery.

Key Idea: Automated Processing of Big Visual Data



A large collection of images after disaster



Various types, size, contents

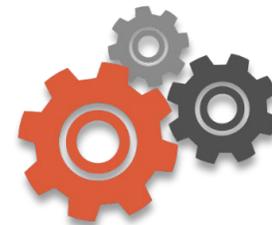
Current visual data classification



Various image collection platform

Processing

Autonomous image recognition



Computer vision



Collapse



Spalling

New visual data classification

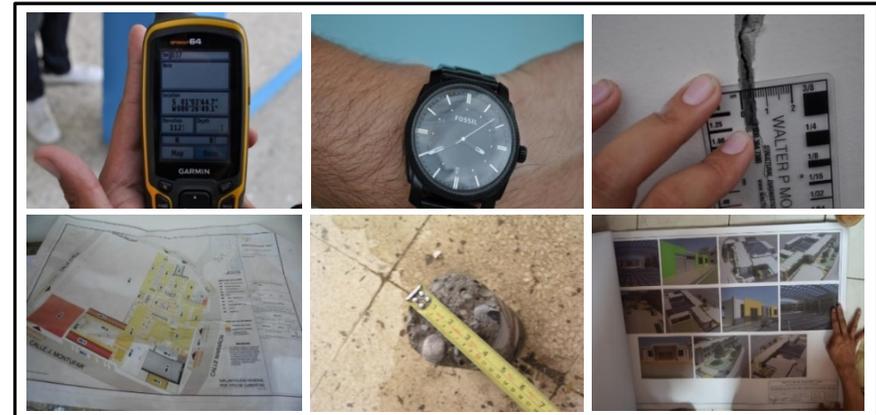
Post-Disaster Reconnaissance Mission



Reconnaissance mission (Taiwan, 2016)

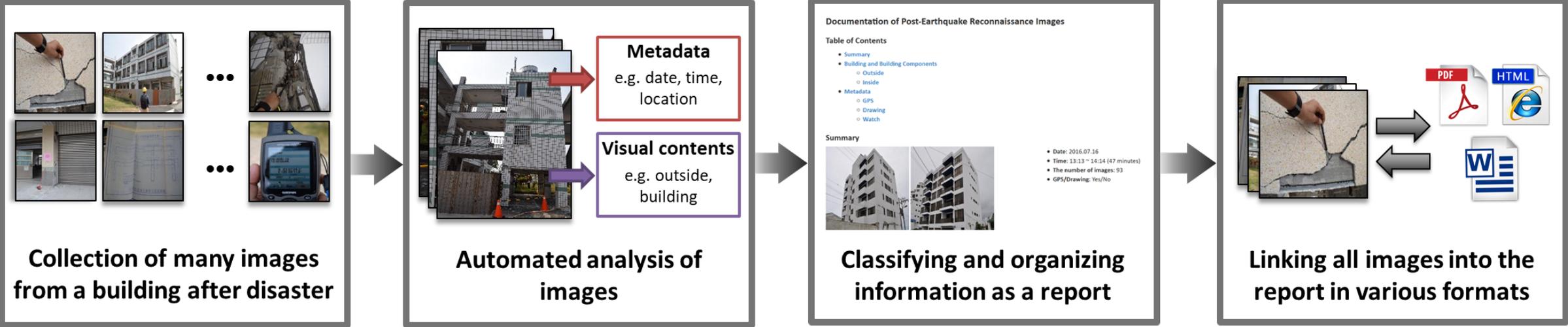


Building and building components



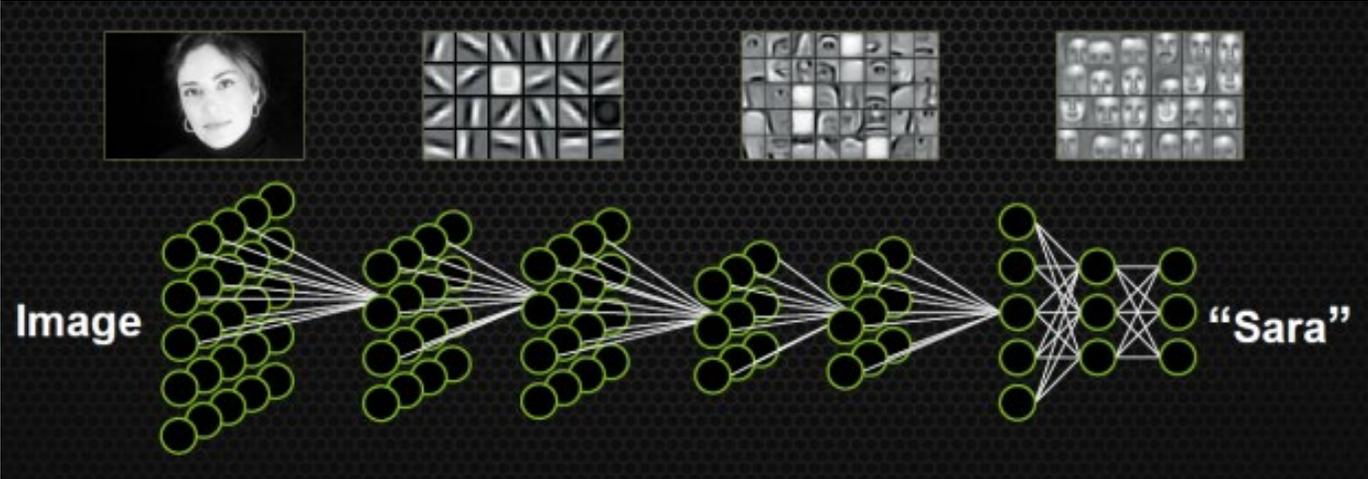
Metadata (recording information using images)

Automated Post-Event Reconnaissance Image Documentation

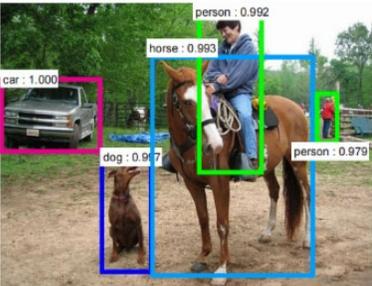


How to support field engineers to readily find and analyze images

Deep Convolutional Neural Network (CNN)



Convolutional neural network



Object detection

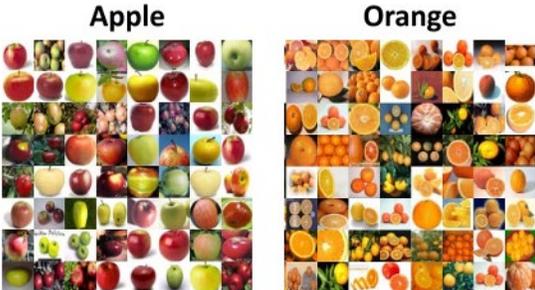
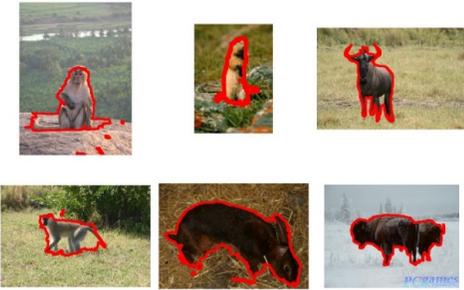


Image classification



Drone navigation



Object segmentation

Construction of Big Disaster Image Database



Taiwan earthquake in 2016 (14,102 images)



Nepal earthquake in 2015 (16,201 images)



Hurricane Katrina in 2011 (445 images)



Ecuador earthquake in 2016 (7,327 images)



L'Aquila (Italy) earthquake in 2009 (414 images)



Florida hurricanes in 2004 (1,178 images)

- # of curated images: **85,000**
- # of un-curated images: **490,000**
- Total hours of reconnaissance videos: **10.5 hours**
- # of event: **59 (EQ: 46, HR: 4, TN: 9)**
- Image sources: **datacenterhub, EERI, FEMA, CEISMIC, etc**
- Current labeled classes: **spalling, collapse, drawing, overview, etc**

Designing Image Categories



Building overview



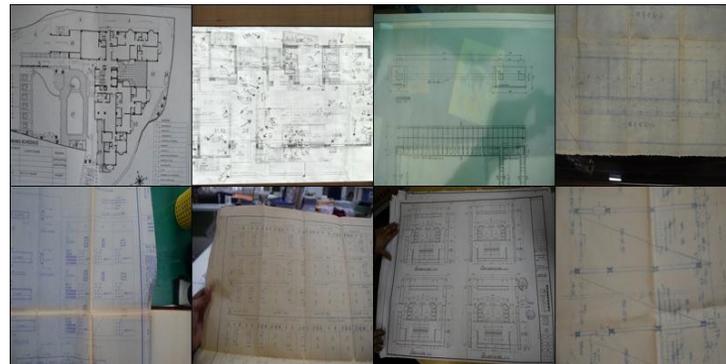
Measurement



Building exterior



Building interior



Drawing



GPS navigator

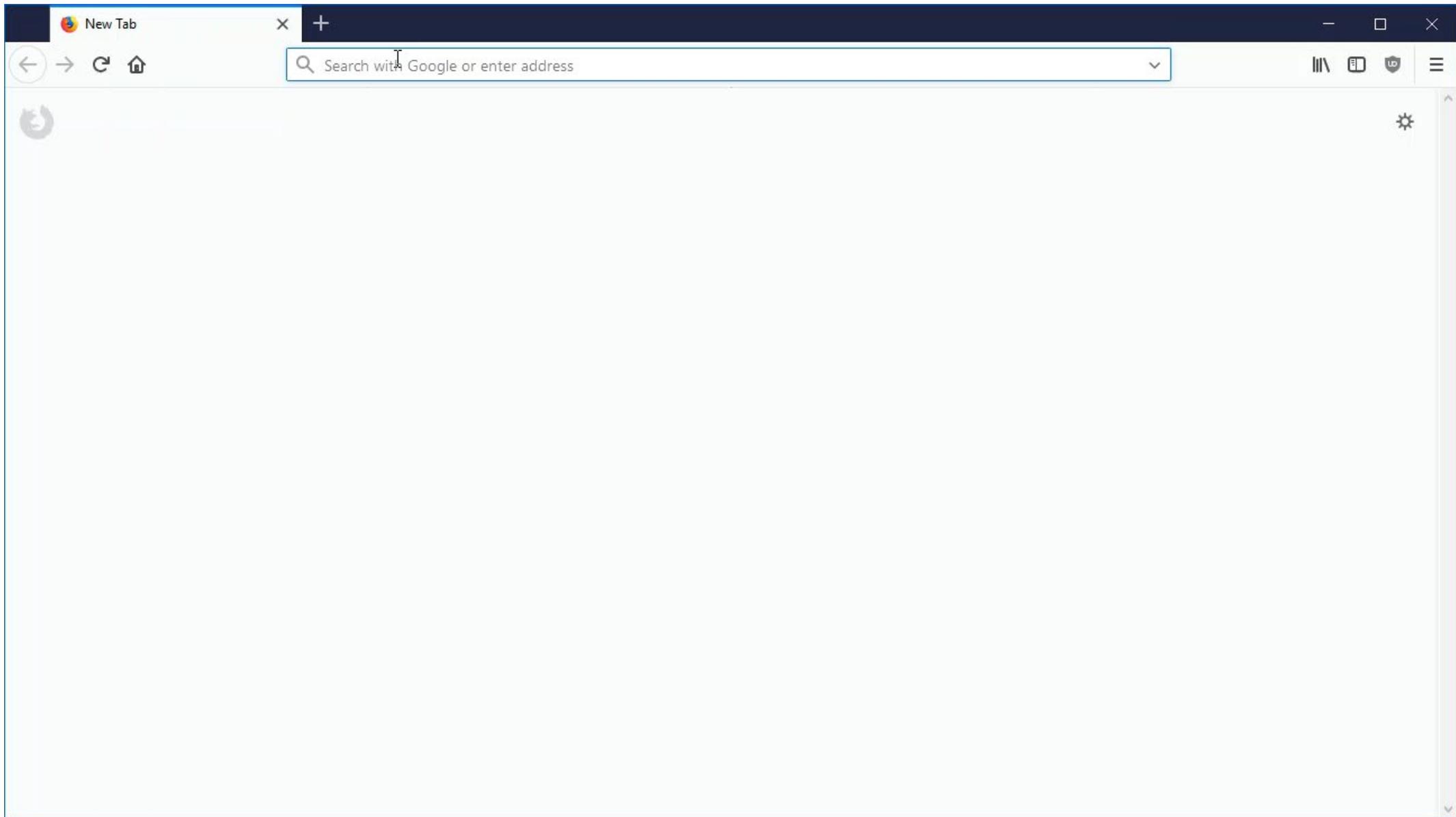
Sample Report Generation (Ecuador, 2016)

A sequence of the images collected from a single building



Building information

Event	Date	# of images	Structural damage	Masonry wall damage
Ecuador earthquake	July 16, 2016	93	Moderate	Severe



Automated Reconnaissance Image Organizer (ARIO)

The screenshot shows a web browser window with the URL `ario.mgaillard.fr/home`. The page title is "Automated Reconnaissance Im...". The navigation menu on the left includes "Home", "Reports", and "Categories". The main content area features a paragraph describing the tool's capabilities, followed by sections for "Team", "Sample Data", and "Acknowledgment".

Automated Reconnaissance Im...

- Home
- Reports
- Categories

these image to support reconnaissance teams. In just a few minutes, this tool can organize **a few hundred images collected from a building into a structured report**, linked to the images. The views taken from both the exterior and interior of the buildings are categorized. Associated metadata that is collected in the form of images, such as structural drawings, GPS devices, and measurements can also be organized automatically. GPS coordinates embedded in the image can be extracted and linked to a map. The tool will automatically generate an individual report for each building. Using a sequence of such reports, a team can efficiently review the image sets, rather than looking through a massive collection of mixed and unstructured individual images.

Team

- [Shirley J. Dyke](#), Purdue University
- [Bedrich Benes](#), Purdue University
- [Thomas Hacker](#), Purdue University
- [Chul Min Yeum](#), Purdue University
- [Mathieu Gaillard](#), Purdue University

Sample Data

- Bldg1: Ecuador earthquake in 2016 ([link](#))
- Bldg2: Ecuador earthquake in 2016 ([link](#))
- Bldg3: Taiwan earthquake in 2016 ([link](#))
- Bldg4: Taiwan earthquake in 2016 ([link](#))
- Bldg5: Nepal earthquake in 2015 ([link](#))
- Bldg6: Nepal earthquake in 2015 ([link](#))

Acknowledgment

- [NSF 1608762](#): CDS&E Enabling Time-critical Decision-support for Disaster Response and Structural Engineering through Automated Visual Data Analytics
- [CrEEDD](#): Center for Earthquake Engineering and Disaster Data at Purdue University
- [EUCentre](#) at Pavia, Italy
- [The Instituto de Ingenieria of UNAM](#) at Mexico
- [EERI clearinghouse](#)

ario.mgaillard.fr/reports

Create a reconnaissance report

ARI0 - Automated Reconnaiss... x +

ario.mgaillard.fr/report/30

Building Reconnaissance Report: Ecuador 2016

Automated Reconnaissance Image Or...

- Home
- Reports
- Categories

Building information

Report information

Report name: Ecuador 2016

Report generation date: June 21, 2018 9:36 AM

Data collection: ~ (about a few seconds)

Number of images: 0

GPS: No

Drawing: No

Choose files... **93 files selected** Upload

Export in a ZIP file

Categories



Review the report

ARI0 - Automated Reconnaissance Image Or...
ano.mgaillard.fr/report/30

Building Reconnaissance Report: Ecuador 2016

Automated Reconnaissance Image Or...

- Home
- Reports
- Categories

Building information



Report information

Report name: Ecuador 2016

Report generation date: June 21, 2018 9:41 AM

Data collection: July 16, 2016 9:21 AM ~ July 16, 2016 10:08 AM (about an hour)

Number of images: 93

GPS: Yes

Drawing: No

Choose files... 93 files selected Upload

Export in a ZIP file

Categories

- External
- Outside
- Inside



Export the report

Potential Function 1: Earthquake Damage Recognition

Collapse Classification and Spalling Detection

Collapse



Image showing that the buildings or building components:

- lost their original shapes
- produce a large amount of debris

Spalling



Image including

- exposed masonry areas in a wall due to cracking
- exposed rebar in a columns
- small section lose due to large cracking

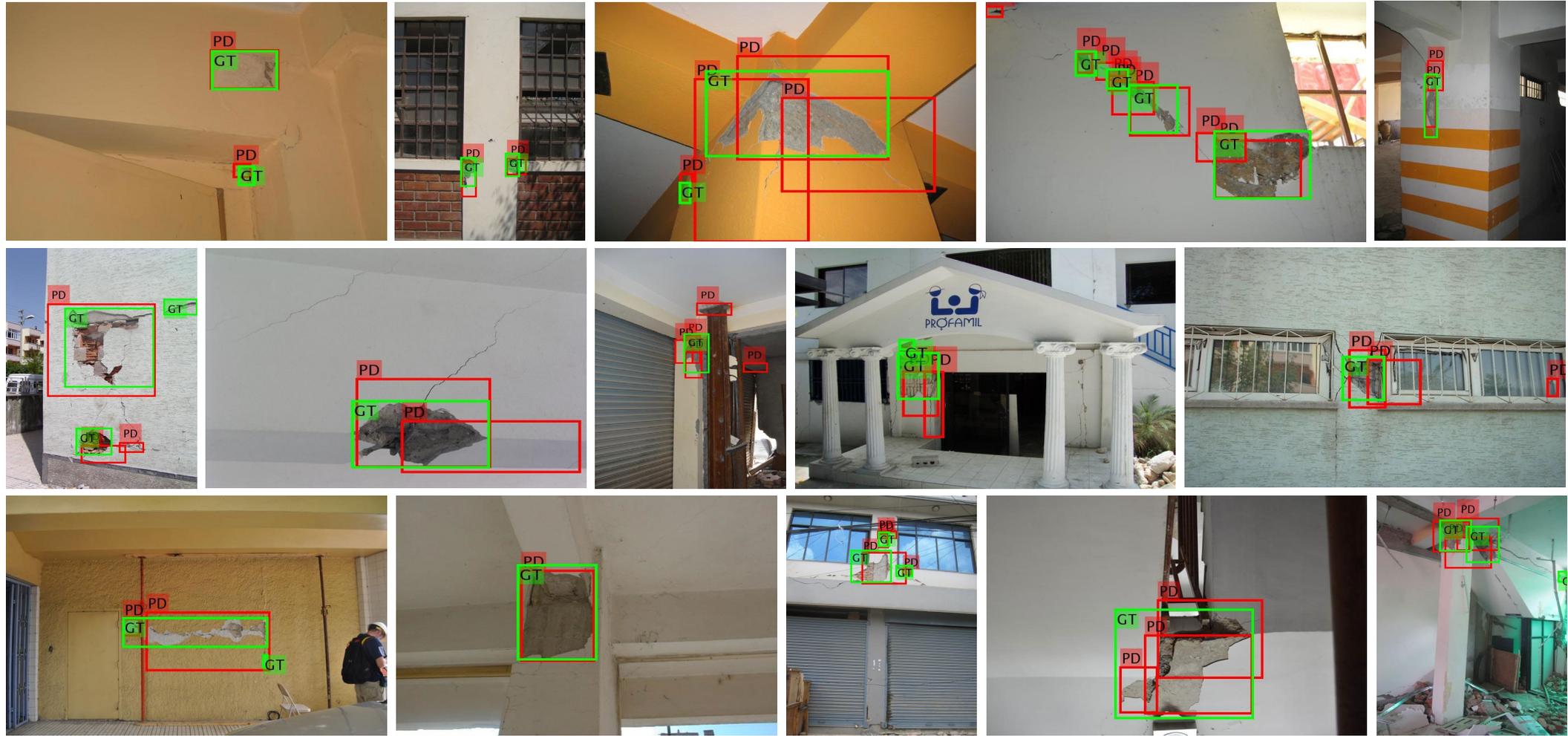
Potential Function 1: Earthquake Damage Recognition

Sample of Collapse Classification



Potential Function 1: Earthquake Damage Recognition

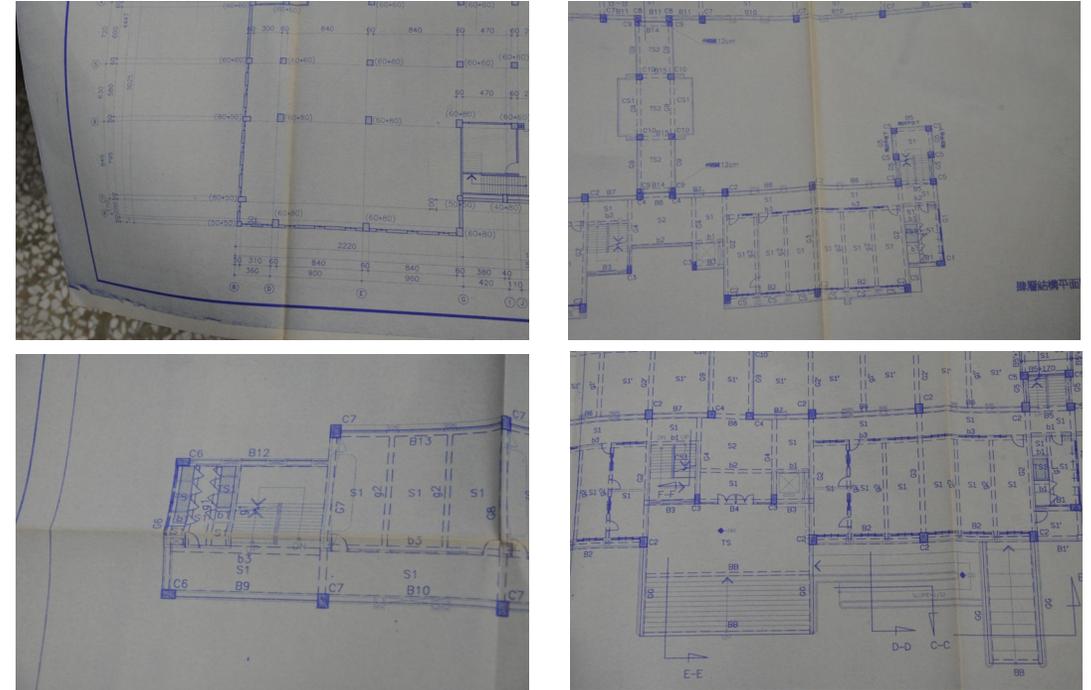
Sample of Spalling Detection



Potential Function 2: Automated Recovery of Structural Drawing Collecting Partial Drawing Images during Recon. Missions



Images collected from a single building after
2016 Taiwan earthquake



Sample partial drawing images
captured from a drawing

Potential Function 2: Automated Recovery of Structural Drawing

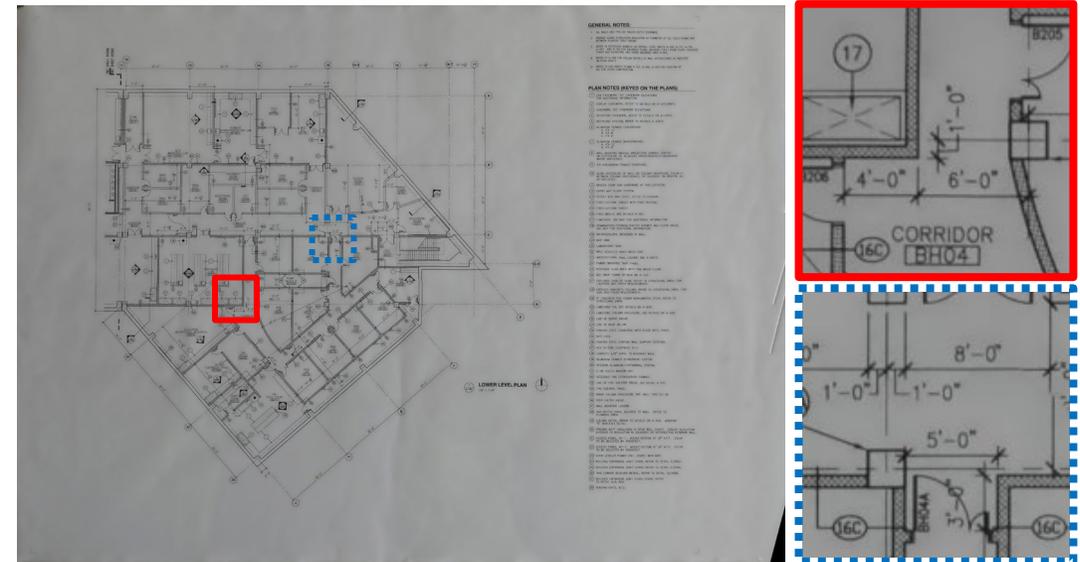
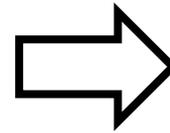
Demonstration of the Developed Technique



Structural drawing printed on a large engineering paper



Partial drawing image captured from the original drawing



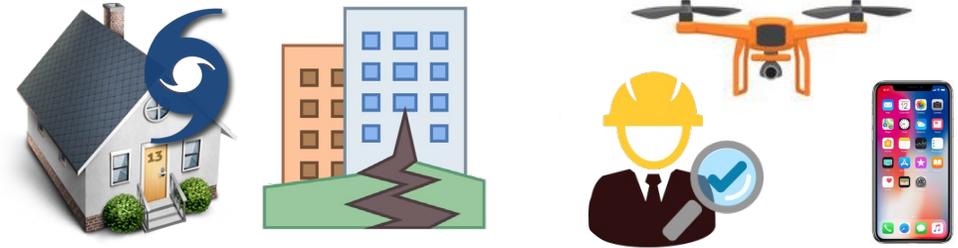
High resolution full drawing image

Conclusion

We developed a novel approach for rapidly and autonomously classifying and organizing post-event reconnaissance building images

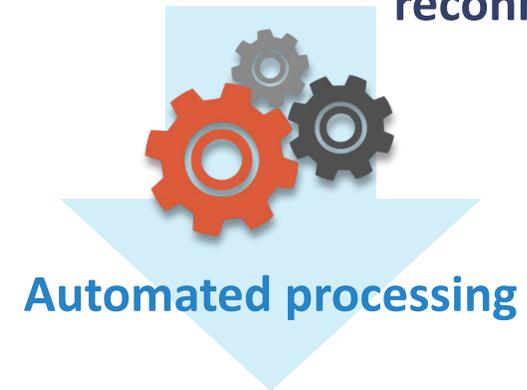
As the use of drones and other data collection system increases, and more images are collected in future missions, automation will be essential to organize and understand the data.

We envision that our tool will support real-world natural hazard reconnaissance missions leading to safer infrastructure and more resilient communities.



Natural disasters

Data collection in reconnaissance



- **Collect more valuable data in the field**
- **Understand gaps in structural design codes**
- **Mitigate potential loss in future events**

Acknowledgements

Funding Agency

- CDS&E: Enabling time-critical decision-support for disaster response and structural engineering through automated visual data analytics, *supported by NSF under Grant No. NSF-1608762*

Data Contributors

- CrEEDD: Center for Earthquake Engineering and Disaster Data at Purdue
- EUCentre (Pavia, Italy)
- The Instituto de Ingenieria of UNAM (Mexico)
- FEMA and EERI



Publications

- Chul Min Yeum, Alana Lund, Shirley J. Dyke, Julio A. Ramirez, “Automated Recovery of Drawings from Earthquake Reconnaissance Images,” accepted to Journal of Computing in Civil Engineering (2018).
- Chul Min Yeum, Shirley J. Dyke, Bedrich Benes, Thomas Hacker, Julio A. Ramirez, Alana Lund and Santiago Pujol, “Post-Event Reconnaissance Image Documentation using Automated Classification,” submitted to J. of Performance of Constructed Facilities (2018).
- Chul Min Yeum, Shirley J. Dyke, and Julio A. Ramirez, “Visual Data Classification in Post-Event Building Reconnaissance,” Engineering Structures 155 (2018): 16-24.
- Chul Min Yeum, Ali Ienjani, Shirley J. Dyke and Ilias Bilonis, “ Automated Detection of Pre-Disaster Building Images from Google Street View,” submitted to the 7th World Conference on Structural Control and Monitoring, China, July 22-25, 2018.
- Chul Min Yeum, Shirley J. Dyke, Bedrich Benes, Thomas Hacker, Julio A. Ramirez, Alana Lund, and Santiago Pujol, “Rapid, Automated Image Classification for Documentation,” Proceedings of the 7th Conference on Advances in Experimental Structural Engineering, Pavia, Italy, September 6-8, 2017.
- Chul Min Yeum, Shirley J. Dyke, Julio A. Ramirez, Tomas Hacker, Santiago Pujol and Chungwook Sim, “Annotation of Image Data from Disaster Reconnaissance,” Proceedings of the 16th World Conference on Earthquake Engineering, Chile, 2017.
- Chul Min Yeum, Shirley J. Dyke, Julio A. Ramirez, and Bedrich Benes, “Big Visual Data Analysis for Damage Evaluation in Civil Engineering,” Proceedings of International Conference on Smart Infrastructure and Construction, Cambridge, U.K., 2016.



Questions and Answers
