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

PHOTO TAGGING TOOL FOR RAPID AND DETAILED POST-EARTHQUAKE STRUCTURAL DAMAGE IDENTIFICATION

A. Behrouzi[1] and M. Pantoja[2]

ABSTRACT

A significant task in earthquake reconnaissance is to conduct rapid and accurate assessments of damage to built infrastructure. This can be accomplished, in part, by analyzing the large volumes of high-resolution image data collected after a seismic event. However, detailed image tagging remains a task for trained human volunteers, which is both time-intensive and error prone. The authors developed a software tool to simplify and standardize the process of assigning damage and structure pairs to sub-regions of images. The goal of the tool is to facilitate the tagging of thousands of images from historic and recent earthquakes to train a deep learning (DL) algorithm to automatically identify damage observed in civil infrastructure. DL is a subset of machine learning that can be used for image classification problems. This process requires thousands of expertly tagged images for robust and automatic visual recognition capabilities. In detecting specific structural damage after an earthquake, images must have explicit tags for the building material, damage and location, as well as the impacted structural members. To obtain such a descriptive set of images, there is a need for a task-specific tool that facilitated tagging of the most common post-earthquake structural damage types. The resulting software solution consists of a simple user interface that displays the most frequently used damage and structural member tags as pre-loaded radio buttons and includes the flexibility for users to customize tags when necessary. The program generates marked-up images that show location-specific damage and structural member labels, as well as output files in the PASCAL Visual Object Classes (VOC) format that are compatible with TensorFlow and most DL frameworks, such that tagged images are ready to be used for training a DL algorithm.

---

[1]Assistant Professor, Dept. of Architectural Engineering, California Polytechnic State University – San Luis Obispo, San Luis Obispo, CA 93407 (email: behrouzi@calpoly.edu)
[2]Assistant Professor, Dept. of Computer Science & Software Engineering, California Polytechnic State University – San Luis Obispo, San Luis Obispo, CA 93407 (email: mpanto01@calpoly.edu)

Behrouzi A, Pantoja M. "Photo Tagging Tool for Rapid and Detailed Post-Earthquake Structural Damage Identification." *Proceedings of the 11[th] National Conference in Earthquake Engineering*, Earthquake Engineering Research Institute, Los Angeles, CA. 2018.

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

Photo Tagging Tool for Rapid and Detailed Post-Earthquake Structural Damage Identification

A. Behrouzi[12] and M. Pantoja[2]

ABSTRACT

A significant task in earthquake reconnaissance is to conduct rapid and accurate assessments of damage to built infrastructure. This can be accomplished, in part, by analyzing the large volumes of high-resolution image data collected after a seismic event. However, detailed image tagging remains a task for trained human volunteers, which is both time-intensive and error prone. The authors developed a software tool to simplify and standardize the process of assigning damage and structure pairs to sub-regions of images. The goal of the tool is to facilitate the tagging of thousands of images from historic and recent earthquakes to train a deep learning (DL) algorithm to automatically identify damage observed in civil infrastructure. DL is a subset of machine learning that can be used for image classification problems. This process requires thousands of expertly tagged images for robust and automatic visual recognition capabilities. In detecting specific structural damage after an earthquake, images must have explicit tags for the building material, damage and location, as well as the impacted structural members. To obtain such a descriptive set of images, there is a need for a task-specific tool that facilitated tagging of the most common post-earthquake structural damage types. The resulting software solution consists of a simple user interface that displays the most frequently used damage and structural member tags as pre-loaded radio buttons and includes the flexibility for users to customize tags when necessary. The program generates marked-up images that show location-specific damage and structural member labels, as well as output files in the PASCAL Visual Object Classes (VOC) format that are compatible with TensorFlow and most DL frameworks, such that tagged images are ready to be used for training a DL algorithm.

Introduction

The existence of the Internet of Things (IoT), where smart devices and sensors are enabled with network connectivity, is changing the existing methods of post-hazard reconnaissance and recovery. Just in the last few years, the Earthquake Engineering Research Institute (EERI) has adapted to the growth of IoT by establishing virtual response teams. EERI can now activate volunteers shortly after a significant seismic event to begin online data mining for text, image, and

[1]Assistant Professor, Dept. of Architectural Engineering, California Polytechnic State University – San Luis Obispo, San Luis Obispo, CA 93407 (email: behrouzi@calpoly.edu)
[2]Assistant Professor, Dept. of Computer Science & Software Engineering, California Polytechnic State University – San Luis Obispo, San Luis Obispo, CA 93407 (email: mpanto01@calpoly.edu)

Behrouzi A, Pantoja M. "Photo Tagging Tool for Rapid and Detailed Post-Earthquake Structural Damage Identification." *Proceedings of the 11th National Conference in Earthquake Engineering*, Earthquake Engineering Research Institute, Los Angeles, CA. 2018.

video information related to earthquake damage. These teams are able to immediately begin compiling updates for dissemination to the engineering community and to inform reconnaissance teams that will be dispatched to the effected region. The source data for virtual reconnaissance is largely provided by local engineers, journalists, amateur photographers, and general citizens who capture and upload photographs/video-recordings to technical repositories as well as formal and social media platforms. With the present-day IoT environment, the amount of data generated by a single major seismic event can be staggering and the responsibility for a few human data-gatherers to locate, identify, organize, and summarize the damage information in a meaningful and efficient manner is challenging and very time consuming.

This paper presents the implementation of a software tool, Civil Infrastructure Tagging Tool (C.I.T.T.), that expedites the image tagging process and facilitates the standardization of damage/structural member labels. Both speed and consistency of tagging are critical to add detailed metadata to the thousands of images necessary to train deep learning (DL) algorithms for automatic tagging [1] and improve the accuracy of online database/repository search queries. Aside from benefits to DL algorithms and search queries, the direct output of the software tool includes storage of detailed image metadata which allows users to instantaneously execute a search on the entire tagged image set to find only images associated with a given damage type for a particular structural member, or to identify the precise location of that damage in each resulting image. The metadata storage approach also makes it straightforward to conduct a statistical analysis to determine the most common tags as well as the distribution of tags for an image set. The various capabilities of the image tagging tool supports immediate post-hazard reconnaissance and recovery efforts as well as the research efforts necessary for the long-term refinement of codified and performance-based seismic design methodologies.

Previous Work in Post-Hazard Image Tagging

Barrington *et al.* [2] and Deogawanka [3] provide a summary of a variety of effective crowdsourcing image tagging efforts that were enacted immediately after the 2008 Wenchuan, 2010 Haiti, 2011 Christchurch, and Nepal 2015 earthquakes, including the tomnod app as well as the international GEO-CAN and CrisisMappers networks. Using a combination of satellite/aerial and geo-tagged social media images, volunteers were able assess impact to roads and buildings. The structural damage is identified a global level; for example, tomnod damage classifications for buildings are: substantial damage, very heavy damage, and complete destruction. There does not appear to be location-specific tags for damage of a structural member in a given building.

Zhai *et al.* [4] presents an online crowdsourcing tool which provides for greater specificity in structural damage tagging of images from the 2010 Haiti earthquake. The tagging tool asks users which primary structural elements are visible (beam, column, slab, wall); damaged (yes, no), damage pattern (flexure, shear, concrete loss; or for walls: sliding shear, diagonal shear, out-of-plane); and level of severity (yellow, red). Limitations to this image tagging tool include: (i) inability to mark the location of damage, (ii) restrictive list of pre-loaded damage/structural member labels to select from, (iii) no method to create user-defined labels, and (iv) incompatible output for training of DL frameworks.

Yeum *et al.* [5] describes progress in extracting robust features of key visual contents in post-earthquake structural damage images via a trained neural network capable of image binning for building/building components (building overview, inside, outside, or component measurement) or metadata (GPS receiver, watch/timepiece, document). Further work has been conducted by Yeum [6] in the automated tagging post-disaster images of structures which includes binning for a collapse-no collapse scenario and location-based of spalling in concrete building components. It appears that this research group has created an image annotation tool where a user can assign a structural member, location in building, damage level, orientation, material type, shape. Additionally, there is an interface to query assignments made to images that have already been tagged. However, at the time of the writing of this paper the image tagging tool could not be located in the public domain for use by other earthquake engineers engaged in reconnaissance and data analysis.

Image Tagging Software Tool Description

The Civil Infrastructure Tagging Tool (C.I.T.T.) developed by the authors attempts to overcome some of the shortcomings identified in the previous crowdsource image tagging approaches by focusing on the following basic principles during software design:

1. Simplicity of Graphical User Interface.

The software was designed so a novice user could review either a five minute tutorial video and/or short instruction manual on the project's GitHub repository [7] to familiarize themselves with all the program functionalities. The initialization window, shown in Fig. 1, provides an easy-to-navigate root menu to various capabilities: (i) tagging damage in concrete buildings, (ii) tagging damage for user-defined structural/material types, (iii) reviewing or editing images that have already been tagged using (i) and (ii), and (iv) resizing images.

The window for tagging damage in reinforced concrete buildings, shown in Fig. 2, has an organized layout where the image appears on the far left adjacent to columns containing radio buttons for damage and structure type. On the upper right, there are text boxes to create new damage and/or structural member tags and save these for future use in an accessible scroll-down menu. In the center right, there are editing options so a user can resolve errors made in the selection of a damage-structure pair or the location of a bounding box. At the bottom right, a history window is populated by the image name as well as the bounding box location and damage-structure pair for each tag created by the user. The items shown in the history window are also saved to the PASCAL VOC file that is later utilized to train the DL algorithm. The window for tagging user-defined damage follows the same organizational structure.

2. Flexibility of Programming Language.

The software tool was implemented using Python [8] as the basic programming language since it contains several libraries that allow for the desired image processing capabilities (including the selection of sub-regions of an image as demonstrated in a generic tagging tool developed by Lin [9]) and it is easy to deploy on different the major operating systems most users would have access to – Windows, MacOS and Linux. Python also allows developers a relatively straightforward approach to build a graphical user interface (as described previously in Principle #1) so users do not need to run any command-line instructions.

3. Standardization of Damage and Structure Label Names.

A challenge that the earthquake reconnaissance community faces in assigning consistent and searchable metadata to images is that experts utilize varying naming conventions. To increase consistency, the built-in module shown in Fig. 2 contains a comprehensive, yet finite, list of common damage and structural member labels for reinforced concrete buildings based on past EERI reconnaissance reports available in the Learning from Earthquakes database [10]. While it is possible to use the tagging software to create new tags for damage-structure pairs not available in the pre-loaded list, users are advised to be judicious in doing so to limit variability. To encourage selections from pre-loaded lists rather than new user inputs, the tagging module contains constant radio buttons so all options are permanently visible for users to rapidly review and make informed selections, rather than drop-down or branching menus that mask the options and may lead to abuse of the ability to create new labels.

4. Compatibility of Output with Deep Learning Frameworks.

The motivation for developing the software tool was to facilitate rapid tagging of thousands of post-earthquake structural damage images for training a deep learning algorithm. Therefore, it was necessary that the standard output from the tagging software be compatible with most machine learning frameworks. An output file in PASCAL VOC [11] met this requirement and the authors was successfully able to use the files to train a DL algorithm implemented in TensorFlow [12]. An example of this PASCAL VOC file and the associated tagged image are shown in Fig. 3.

5. Extendibility of Tagging Modules based on User Needs.

Although it is critical to standardize the labels used for damage tagging (as discussed previously in Principle #3), there is a need to allow earthquake reconnaissance experts to establish new sets of damage and structural member labels, re-use, and submit/share them with others via the project's GitHub repository [7]. At present, there is only an established module for reinforced concrete building damage, yet there are many more potential applications of the software tool. Creating a flexible interface that a user can adapt to their own needs was one of the design objectives when developing the tool. For example, one of the research team members was interested in tagging earthquake damage to civil infrastructure such as roadways/railways, and was able to leverage the user-defined tagging module to do so.

6. Review of Previously Tagged Images.

The software tool was originally intended to aid earthquake engineering experts in tagging images of damage to built infrastructure. However, it can also be used by volunteers (students and citizen engineers) in processing the vast number of damage images produced after a seismic event. There is greater uncertainty associated with tags assigned by novices, which necessitates final review and revision by an expert. There also may be discrepancies or differences of opinion between experts. For both of these reasons, the software tool has an interface "Review/Edit Previously Tagged Images" that allows a user to delete and relabel tags previously assigned to an image. As shown in Fig. 4, the review window has a distinct blue background to differentiate it from the tagging modules.

7. Ease of Querying Output and Extracting Knowledge from an Image Dataset.

The output files are organized in such a way that a user can write simple scripts to query the data. For example, a user might be interested in the frequency of a certain damage-structure pair tag for the images from a single, or multiple, earthquake events and could generate histograms with this information. A sample script to create histograms, in the form of a Jupyter Notebook, is available on the project's GitHub repository [7]. There are many other, more complex data analysis tasks conceivable using the output files from the software tool and these are only limited by the imagination of a data scientist or engineer.

Image Tagging Software Tool Usage

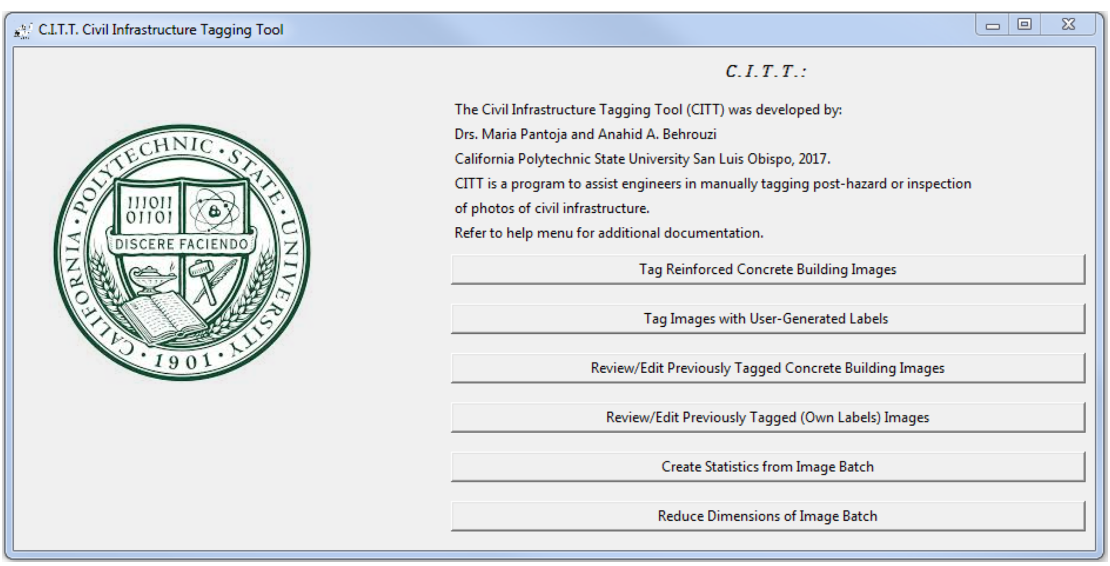

Figure 1. Initialization window contains root menu.

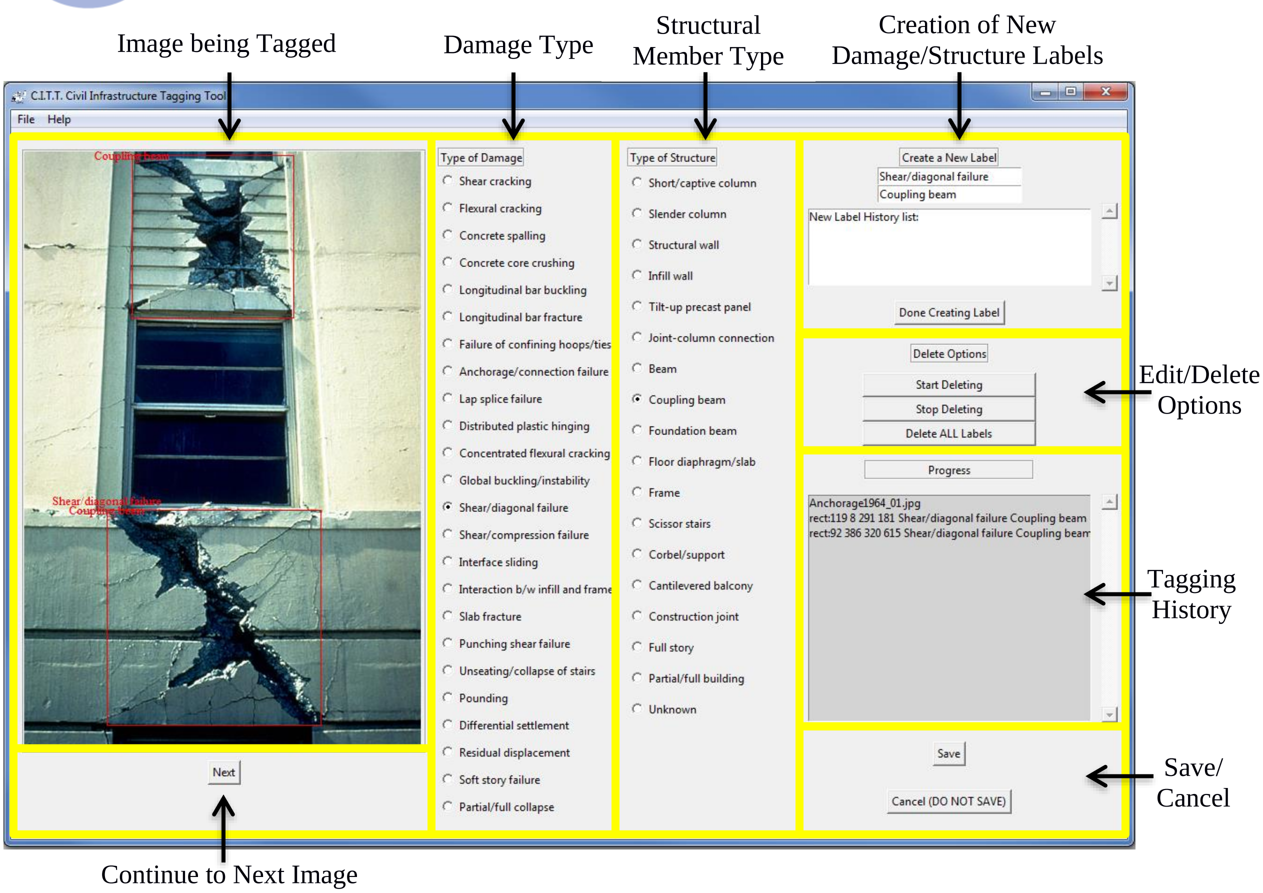

Figure 2. Reinforced concrete building image tagging module (yellow boxes and labels added).


```
<?xml version="1.0"?>
- <annotation verified="yes">
    <folder>images</folder>
    <filename>Anchorage1964_01.jpg</filename>
  - <size>
      <width>427</width>
      <height>640</height>
      <depth>3</depth>
    </size>
    <segmented>0</segmented>
  - <object>
      <name>Shear/diagonal failure Coupling beam</name>
    - <bndbox>
        <xmin>119</xmin>
        <ymin>8</ymin>
        <xmax>291</xmax>
        <ymax>181</ymax>
      </bndbox>
    </object>
  - <object>
      <name>Shear/diagonal failure Coupling beam</name>
    - <bndbox>
        <xmin>92</xmin>
        <ymin>386</ymin>
        <xmax>320</xmax>
        <ymax>615</ymax>
      </bndbox>
    </object>
</annotation>
```


Figure 3. Sample output: (left) tagged image and (right) associated PASCAL VOC file.

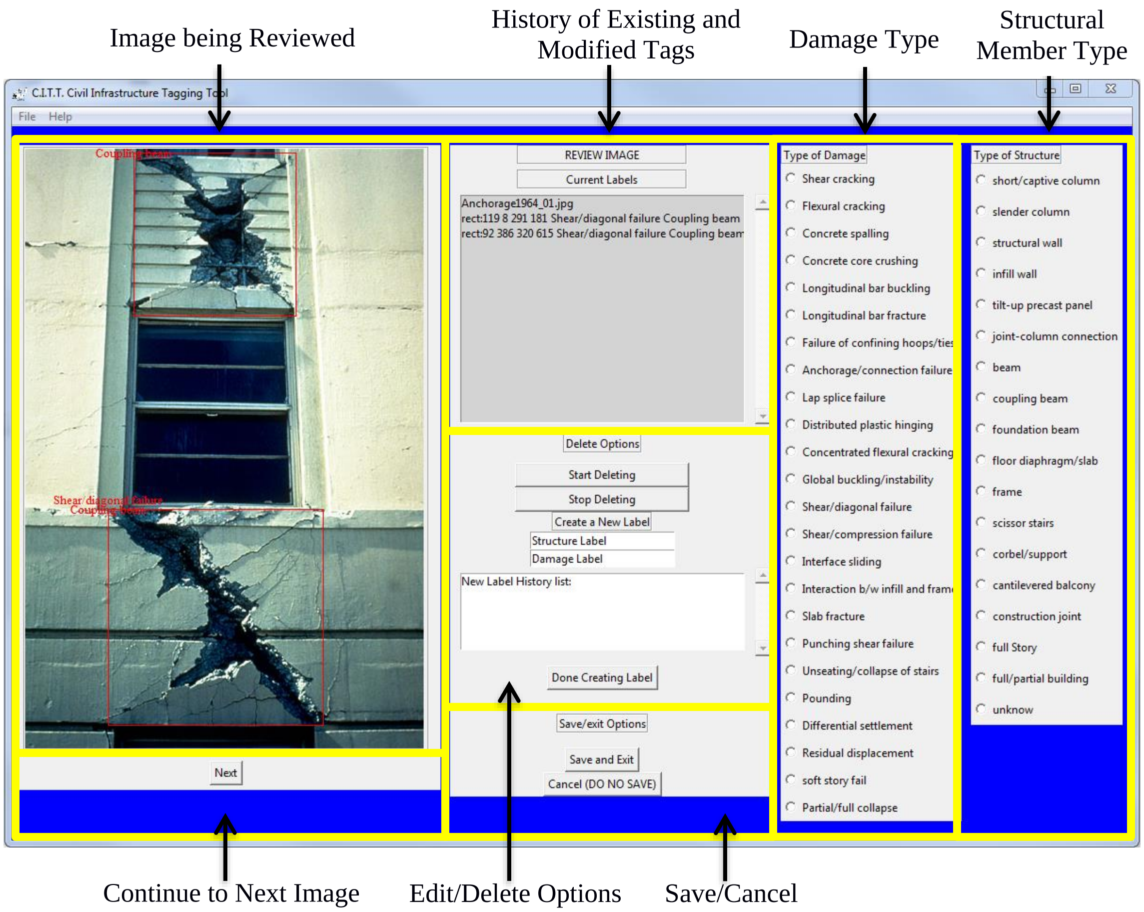

Figure 4. Review module (yellow boxes and labels added).

Conclusions

The software tool discussed in this paper enables structural engineers to rapidly and accurately tag multiple damage occurrences in a single post-earthquake image. Specifically, the tool: (i) facilitates standardization of damage and structural member name assignments among experts, (ii) permits the creation of new tagging modules beyond the pre-loaded building/material types, (iii) allows users to create location-specific tags that are added to image metadata, and (iv) generates an output file that is compatible with most DL frameworks.

The most significant outcome of this image tagging tool is that it produces a consistent set of tagged images that allows a faster development of the field of computer vision for post-hazard damage to civil infrastructure. The authors have been able to use to the tool to process around 40-50 images per hour when tagging multiple damage-structure types, and upwards of 120 images per hour when tagging a single damage-structure type. PASCAL VOC file outputs from prior image tagging efforts of reinforced concrete buildings have already been used to successfully train a DL algorithm that detects shear-diagonal damage to short/captive columns [13]. Moving forward the research team intends to continue tagging efforts to build a database of around 2500-5000 images of reinforced concrete building damage which will be released as an open source database for other experts to verify and build upon. These images will also be utilized to expand the abilities of the DL algorithm to automatically detect other damage types.

Deep learning has gained popularity in recent years for solving object recognition and image classification problems, in some cases even outperforming human beings. Many participants in the earthquake reconnaissance community are beginning to recognize the potential for this type of machine learning: to add detailed, location-specific damage metadata to photographs as well as enabling more robust statistical analysis of structural damage based on large image datasets. The image tagging tool presented in this paper serves as one step forward in this new direction.

Acknowledgments

The authors would like to acknowledge the support of California Polytechnic State University – San Luis Obispo via the CPConnect and Research, Scholarly, and Creative Activities (RCSA) Grant Programs.

References

1. Goodfellow I, Bengio Y, Courville A. Deep learning**.** *MIT Press* 2016. www.deeplearningbook.org.
2. Barrington L, Ghosh S, Greene M, Har-Noy, S, Berger J, Gill S, Yu-Min Lin A, Huyck C. Crowdsourcing earthquake damage assessment using remote sensing imagery. *Annals of Geophysics* 2011, **54** (6): 680-687.
3. Deogawanka S. How crowdsourced mapping is supporting relief efforts in Nepal. *GIS Lounge* 2015, www.gislounge.com.
4. Zhai Z, Kijewski-Correa T, Hachen D, Madey G. Haiti earthquake photo tagging: Lessons on crowdsourcing in-depth image classifications". *IEEE Int'l Conference on Digital Information Management* 2012: 357- 364.
5. Yeum CM, Dyke S, Benes B, Hacker T, Ramirez J, Lund A, Pujol S. Rapid, automated post-event image classification and documentation. *7th Int'l Conference on Advances in Experimental Structural Engineering*.
6. Yeum, CM. Computer vision-based structural assessment exploiting large volumes of images. PhD Thesis, *Purdue University* 2016.
7. Pantoja M, Behrouzi A. ImageTagVER Repository. *Github*. https://github.com/mpantoja314/ImageTagVER.
8. Rossum G. Python Library Reference. Technical Report, *Centre for Mathematics and Computer Science Amsterdam, The Netherlands* 1995.
9. Lin T. labelImg Repository. *Github*. https://github.com/tzutalin/labelImg.
10. EERI. Learning from Earthquakes Reconnaissance Archive. https://www.eeri.org/projects/learning-from-earthquakes-lfe/lfe-reconnaissance-archive/.
11. Everingham M, Eslami SMA, Van Gool L, Williams CKI, Winn J, Zisserman A. **"**The PASCAL Visual Object Classes Challenge: a Retrospective" *Int'l Journal of Computer Vision* 2015, **111**(1), 98-136.

12. Abadi M, Barham P, Chen J, Chen Z, Davis A, Dean J, Devin M, Ghemawat S, Irving G, Isard M, Kudlur M, Levenberg J, Monga R, Moore S, Murray DG, Steiner B, Tucker P, Vasudevan V, Warden P, Wicke M, Yu Y, Zheng X. TensorFlow: a system for large-scale machine learning. *12th USENIX Conference on Operating Systems Design and Implementation* 2016: 265-283.

13. Patterson B, Leone G, Pantoja M, Behrouzi A. "Deep learning for automated image classification of seismic damage to built infrastructure " *Proceedings of the 11th National Conference in Earthquake Engineering* 2018.