Architecture and Planning Journal (APJ)

Volume 28 | Issue 1
ISSN: 2789-8547

Article 9

March 2022

ASSESSING PHOTOGRAMMETRY ARTIFICIAL INTELLIGENCE IN MONUMENTAL BUILDINGS' CRACK DIGITAL DETECTION

Said Maroun
PhD Candidate, Faculty of Architecture - Design & Built Environment, Beirut Arab University, Lebanon, saidjmarounleb@gmail.com

Mostafa Khalifa
Assistant Professor, Faculty of Architecture - Design & Built Environment, Beirut Arab University, Lebanon, m.khalifa@bau.edu.lb

Nabil Mohareb
Associate Professor, Department of Architecture, School of Sciences and Engineering, The American University in Cairo, Egypt, nabilmohareb@gmail.com

DOI: https://doi.org/10.54729/OPTG2546

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Abstract

Natural and human-made disasters have significant impacts on monumental buildings, threatening them from being deteriorated. If no rapid consolidations took into consideration traumatic accidents would endanger the existence of precious sites. In this context, Beirut's enormous 4th of August 2020 explosion damaged an estimated 640 historical monuments, many volunteers assess damages for more than a year to prevent the more crucial risk of demolitions. This research aims to assist the collaboration ability among photogrammetry science, Artificial Intelligence Model (AIM) and Architectural Coding to optimize the process for better coverage and scientific approach of data specific to the crack disorders to build a comprehensive model consolidation technique. Despite the current technological improvement, the restoration of the existing monument is a challenging and lengthy process where the actual site situation's re-ignitions consume enormous time, from assessing the damages to establishing the restoration relying on human resource developments and manual drawings.

Keywords

Digital Documentation, Photogrammetry, Artificial intelligence, Algorithm

1. INTRODUCTION

This research reviewed the existing technologies, programs, and data related to the topic, considering both modern restoration techniques and AI, as it implies, neural network recognition, photogrammetry, 3D modeling database, and computerized graphics, recently established in the field, were included explicitly in advertising, movies, video games, and photo documentation. Besides, AI's involvement in visual effects put this technology in many sectors, such as architecture, urban planning, military simulation, and every used item of our everyday living day.

1.1 Generative Technical Drawings in Historical Sites

The methodologies followed for generating good technical drawings are so essential. The restorer has to visit the site many times to collect as much as possible of data. The data collection process is time-consuming, from detailed images, hand measurements, sketches classifying them to implement them on the existing computerized tools. Even with the development of some modern technics using photogrammetry (a method of capturing, analyzing, and understanding digital photographs and electromagnetic radiant imagery patterns), and laser scanning, all the data are studied manually and visually responsible knowledge. In order to achieve an as-built of the existing on-site, the restorer has to draw each detail manually and recognize the deficiencies, cracks, and pathologies where each time when the results are not satisfied with a small missing detail or measurement, a site visit is recommended. Highlighting and dimensioning the defects is never accurate when done manually, where a small crack is defined with infinite points, and it is almost impossible to take all of its dimensions. The now-day used technics are limited to the tools and human knowledge, which is time-consuming, implicating multiple site visits inducing critical fallibility and mistakes.

1.2 The Importance of AI and Definition

Colloquially, AI defines machinery and computers that imitate the cognitive roles humans equate with human brains, such as problem-solving and learning from their own experiences (Javadi, 2017). By definition, AI is the science of making computers do things that require intelligence to be done initially and recognized by people or even imitating animals (Poole, 2020). Leading AI textbooks describe the discipline as the analysis of intelligent agents where any system perceives its world and takes action that maximizes its chances of achieving its objectives successfully (Thomaz, 2016). Its reasons, accompanied by the accumulated knowledge of some specialist subject and logarithmic equations of the expert developed computer programs designed to solve problems or give advice.

The domain of modern Machine Learning, specifically in the area of multi-layer, deep neural networks, generative adversarial networks, differentiated programming, and related novelties defined as AI, shows many difficulties in the social sciences to take its rich and varied phenomena as subjects of research (Spears, 2017). Machine learning (**ML)** is a subset of AI where all counted as part of AI, but not all of the last ones are ML. The only aspect of ML is its ability to self-modifying when exposed to additional data.

There are no questions that architectural and engineer practitioners are already regularly utilizing computing and Information Technology (**IT)** resources for several activities. Although this condition may suggest that the industry is keeping track of technical advances, a fast contrast with other industries such as automobile and aerospace shows that computing applications in construction have been intermittent and unevenly spread throughout the industry, the substantial effect only on a few tasks and sectors. (Salman, 2011)

It is challenging to provide computer assistance for engineering, design activities, and data recognition. Projects can be complicated, time-consuming, lengthy, and expensive (Puri, 2014). Companies contributing to planning, building, and repair are always worth less than their programs' valuation. Contextual variables have a significant effect that renders generalization challenging, where the restoration life span can extend years, and the operating specifications can vary throughout the service period. It is also no surprise why specialists in this field have been too hesitant to embrace modern computer systems. Educational attempts and initiatives have become ad hoc reporting of a modern e-learning tool (Engeström, 2015). However, to date, there is no existence of the same analytical rig as the study's findings in other areas aim to draw an overview study on learning theory into a scientific blueprint.

1.2 Reinforced and deep learning

The Machine Learning field is basing on deep neural networks. Deep learning currently offers the best alternatives to several well-known computer scientific knowledge issues, such as 2D image recognition, speech recognition as sound, and text processing in natural languages. However, there are just a few deep learning trials for 3D processing (Mohsen, 2018).

Enhanced learning algorithms supervised learning algorithms that have built-in self-improvement mechanisms. Usually, improved ML strengthens the algorithm model by modifying training knowledge with new data. These usually chosen data using a score or preset value that estimates how well the data set is classified, then either apply it to the training set for optimal growth and development or discard it.

Deep learning has a potential contribution, where the visible and tangible parts are related to the existing monument, processes, and materials; meanwhile, the hidden embedded sections are all about the AI contributed to the advanced 3D modeling, the significant data formation, processing, connection of the pixels, generation of the algorithm behind them. It is the relationship between the digital and the physical world.

As a subdivision of the digital world, there are two major streams. One focuses on the development of sophisticated software with a new user interface. In reality, advances in designer artist-oriented design applications, combined with Computer-aided Design, Computer-aided Engineering (**CAD**), Computer-aided Manufacturing (**CAM)**, and Computer-aided testing (**CAT**), are very hot domains. These trials refer to Computational Design and Algorithmic Design.

The other is the so-called Big Data strategy. The development of the 3D search engine would be the best example to explain this approach. The 3D-Search engine projects base on a massive dataset of 3D (Mostly, STL) files. Original 3D-Search-Service connects to collecting human-made files with a crawling algorithm from the Internet, which has created an extensive database with an original indexing algorithm that allows users to retrieve interfaces, search keywords, and browse in 3D space. (Tanaka, 2019)

Simultaneously, the data collection for in-depth learning analysis as back-end processing transforms all STL data to the 3D Voxel Index file is similar to a 3D bitmap file. Voxel Data is simpler to add to deep learning libraries since deep learning libraries practically implement image processing based on a vector-based, photo file format.

Pattern recognition offered a strategy for reproducing any human classification that might result in a limited set of photographs or other categorical results. Insofar as designation was a synecdoche of meaning, the recognition of value became an issue of engineering. Finding the characteristics of the picture associated with every human being working in the same classification was a problem that could be partly automated. This ambition to create a technique capable of dealing with any or all decision-making challenges led to a disciplinary identification crisis for pattern recognition close to that faced by statistics in the twentieth century and computer science today, which expresses itself in the uncertainty and confusion of the terms machine learning and artificial intelligence. (Katz, 2017)

Traditional data is inherently deductive. In several cases, the solution is to choose a design from a range of general design principles and, at the most, to change it marginally. No unclear or new design creation with many assumptions and concepts; thus, no abduction takes place. These architecture paradigms refer to selection and adjustment. (Wahyuni, 2012)

1.3 The status of the Survey Modeling

Image-based 3D models and rendering have been a central branch of computer vision for the past decade, initiated in robotic. A developed camera device installed on a robot gives automation an actual depth of perception of its surroundings and encourages interaction. Efforts in this direction, which are still underway, have also given rise to a new area in which the key considerations were no longer relevant to physical interaction but rather to the precise capture of the scene's geometry. This area is generally known as the X form. There is a wide range of approaches related to various fields behind this general denomination, from medical imaging to the outdoors. (Snavely, 2007)

Many moves and developments in imagery models are related to 3D projective geometry theory in general, including various aspects such as Epipolar Geometry (Hartley, 2004), self-calibration techniques, and bundle adaptation (Triggs, 2000). More efficient approaches were then suggested, such as a sparse package modification or a swift path (Lourakis, 2010). The general trend for fully automatic systems emerged from this entire coding (Snavely(a), 2006). The range of correspondences further filtered to exclude outliers by considering geometric Epipolar constraints. A non-linear equation scheme involving both camera parameters and 3D positions resolves the monitored points based on this stage's performance. This method contributes to calculating the camera's intrinsic and extrinsic parameters along with a sparse 3D point cloud. The technique also refers to a sparse structure and motion, where the structure corresponds to the cloud point and motion to the cameras' location (Pollefeys, 1999). A complementary process is required to achieve the optimal visual representation density. In what follows, this step will be referred to as the Dense Motion Structure since, considering the minimal data constraints, it attempts to make the representation of the scene denser. Therefore, the final output is a denser point layer. (Hartley, 2004)

The 3D reconstruction literature is rich and ever-changing. Existing approaches vary in several crucial ways. It is also complicated to draw up a detailed description of this significant branch of Computer Vision. Nevertheless, few such attempts have been sufficiently successful in being noted. They aimed to establish a multi-view reconstruction taxonomy and propose a benchmark for assessing reconstruction approaches. (Seitz, 2006)

While the rare functional benefit in emancipating quantitative distinctions between state-of-the-art methodologies, Seitz offered a straightforward and systematic summary of current methods, which are still important today in this domain. The distinction between the works considered is dependent on a variety of parameters, such as photo-consistency measurement, visibility considerations, prior form, reconstruction algorithm, and even representation of the scene.

1.4 The Status of Crack Detection Using Image Processing

Non-Destructive Evaluation methods are effective for concrete surface evaluation, and thus several studies have been performed due to their flexible use and effectiveness. Framework for assessing the dimensional and surface content of precast concrete components based on BIM and 3D laser scanning. (Kim, 2015) . In the SHRP 2 report, as part of the Strategic Highway Research Program, Infrared Thermography was identified as one of the leading technologies used to detect surface irregularities and delamination in concrete bridge decks. Ham described micro-crack damage to concrete by creating a contactless ultrasonic wave propagation system (Ham, 2013). Under Shah et al., the micro and macro levels investigating concrete defects by calculating linear and quasi ultrasonic pulse vectors (Shah, 2013).

Digital image pre-processing refers to improving the image's accuracy by eliminating noise within the image frame. Proper pre-processing is a significant step in preparing images for various applications, such as computer learning and data mining, using spatial filters to increase image clarity by blocking some image frequencies while allowing others to move through. For each pixel defining filter functions to determine a new value depending on the adjacent pixels' values. The method performance depends on the kind of and the size kernel used in the filter.

In the research about crack detection using image processing, S.Mohan and S. Poobal cited growing interest in image-based crack detection for non-destructive inspection. Some image-based identification problems are due to the random shape and varying size of cracks and different noises, such as irregularly colored environments, shadows, and blemishes (Mohan, 2017). Due to its ease of processing, there are several approaches for identifying image processing, dividing these approaches into four groups, including an applied algorithm, a morphological solution, a percolation-based procedure, and a functional methodology. (Wang, 2010)

The most significant benefit of the image-based crack detection analysis is that it produces reliable results using the image recognition methodology relative to traditional manual approaches (Anwar, 2014). The processing complexity of crack detection depends entirely on the size of the signal. The latest digital cameras have an image resolution of more than 10 megapixels. This increased resolution allows the acquisition of accurate photographs of concrete surfaces using a single shot, acquiring modern commercial cameras, a wide variety for concrete surfaces where besides a wide variety of images may be used for accurate crack detection (Rodriguez-Martina, 2016).

The optical image processing technology used to assess the surface bug-holes of concrete involves image acquisition, image graying, image processing, screen sizes segmentation, non-bug-hole filtering, an inspection of the image obtained by sampling equipment carried out to find bug-holes mostly on specimen structure.

Pixel is the standard encoding of the color variable, which the gray level, and is the basic unit for digital images. The image's resolution is represented as pixels per inch, rendering the image detection by the relationship between the single pixel in the image and the actual region gives the single pixel in the image a simple unit of measurement. The actual region of the single-pixel is the complete precision of the surface bug holes. The higher the pixel size of the image at the same firing rate, the higher the detector's precision. When the pixel value in the image is constant, the distance of firing is further, the larger the area corresponding to the single pixel, and the lower the detection precision. (Gonzalez, 2009)

DOI: 10.54729/OPTG2546

The Macro studies in the Computer Sciences are encoded in patterns and rules that specify the mapping of a particular input, understand the algorithm behind it, and develop the specific replacement output. It transforms the existing physical into algorithmic inputs and outputs followed by sequences of characters, lexical tokens, and syntax tree, supported in software applications. (Holbrook, 2020)

1.5 Deduction of the Literature

About the mentioned literature, AI is a new extent in supporting accuracy, time consumption, and limited knowledge related to human intelligence. Despite solid evidence of volumetric depictions' reliability, they suffer from certain significant shortcomings in the scenes. The essential explanations are that they need prior knowledge of the bounding box of the area and the concept of discretion. Consequently, their use should remain restricted to individual objects. The modeling technique usage is minor in the restoration field or data collection from the captions. It only interferes in modeling the shape and gathering syntax correlated to the imagery using a system of based identification, statistical pattern methods sensing the one-dimensional vibration. The analysis of features common examples of damages found in practice include cracks, voids, delamination, and ablation. Besides, to diagnose these various forms of damage, the imaging instrument must also be calibrated to capture the physical damage features; thus, the resulting equipment can be costly. Most of the data collected are from photos and manually studied withing basic algorithm related based on their types, pixilation, and hue changing contrasts. To date, approximation methods are the only ones used in determining the cracks shapes, quantification, and dimensions, where no drawings, nor specification, neither consolidation technical drawings can be generated from the files. Furthermore, AI is a vast space that should be implemented to accomplish a better understanding and coverage for the disorders.

1.6 The Uncovered Gaps in the Domain and Challenges

Artificial intelligence is a new evolving field and the most challenging step that needed a consistent decision. Up to date, generating a model is related to the usage of relatively simple photogrammetry techniques and volumes corresponding to the main facades, details, and deriving models from inputs along with photographs recovering specific structural features such as materials, specifications, and facade fixtures. More importantly, many services and development have emerged in the field, reserving an ideal context, significantly improving the data collection with advanced methods. The obstacles must be resolved for the disorder’s detection, to take off, separate, and to come up with sound outputs in historical sites. Looking at the existing end-to-end open-source platforms and brain generation systems, each one of them enables ideally to generate building dataflow structures and graphs, but at the same time focuses on one side of the specific minor side of work. In this case, establishing a combination of these utils to create a bonding must develop a valuable and efficient final product. Many additional services propose advanced interaction with the evolvement of the models from the photos.

The most challenging is transforming the images from 2d to 3d; pattern recognition offered a strategy for reproducing any human classification that might result in a limited set of photographs or other categorical results. Insofar as designation was a synecdoche of meaning, the recognition of value became an issue of engineering. Only contextual dimensions of representations are criticized in terms of completeness and consistency. The most serious of this is the lack of relation between the restored points. As a result, the model is not an accurate surface and suffers from some of the same disadvantages resulting from a sparse. Finding the characteristics of the picture associated with every human being working in the same classification was a problem that could be partly automated. In several cases, the solution is to choose a design from a range of general design principles and, at the most, to change it marginally. No unclear or new design creation with many assumptions and concepts; thus, no abduction takes place. These architecture paradigms refer to selection and adjustment.

Crack detection and classification activities achieve high efficiency in three areas. The most critical criterion for the solution is the detection rate, which ensures that the crack detection and classification approach must ensure that the vast majority of crack duration found in the initial picture in the final performance data. Detection accuracy, under the assumption of a high crack detection rate, the accuracy must be sufficient, ensuring the elimination of misidentified artifacts to the greatest extent possible to achieve high productivity.

2. THE PROCESS OF WORK – FROM IMAGE TO CRACK DETECTION

The proposed integration of crack classification, detections and classification methodology of work from the input to the outcome:

Fig. 1: The methodology of the working process (by author, 2021)

Image scanning is used to spot cracks using the following stages in the image processing technique; first, capture an image of the structure subjected to the crack detection process. After the image capture, the captured images are pre-processed, where performing segmentation to make the image operation more effective. Using the product of the initial image, crack detection will be detected on the structure. Crack attribute extraction is the process of separating observed cracks based on their distance, depth, and direction of propagation. As shown in Figure 1, the whole process begins with the data collection, development of the model, recognition of the data, training the model, testing and analyzing the outputs for the final application.

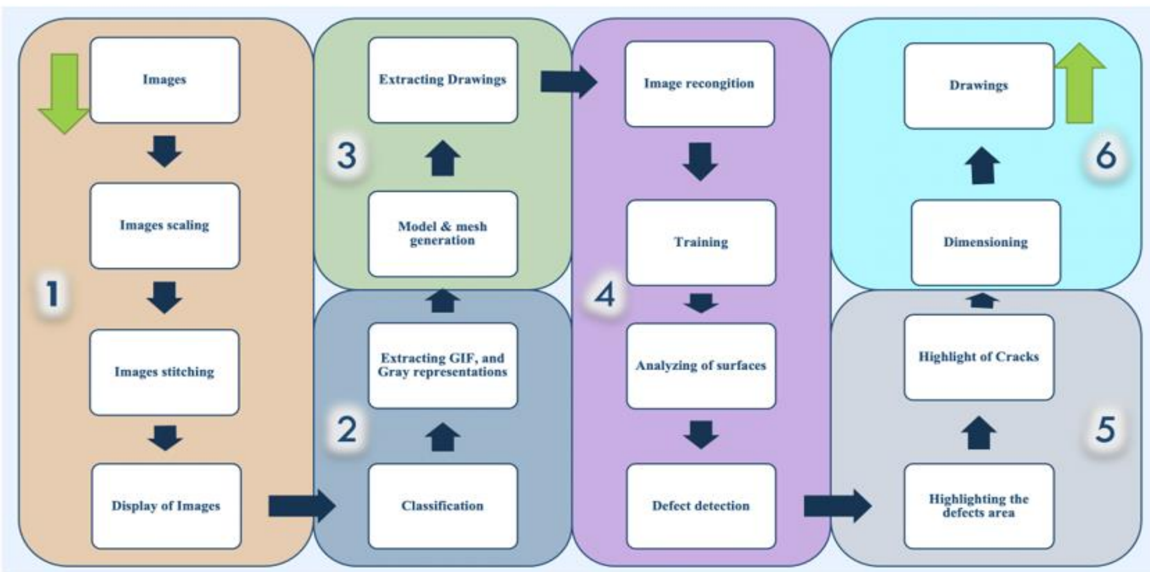

Fig.2: Images processing from input to the final output (by author, 2022)

As shown in Figure 2 highlighted in orange (stage 1), the process begins with collecting images and variables derived from the collected data; then, the images undergone under scaling and stitching to create a display of images without repetitions. Afterward, as highlighted in dark blue (stage 2), the data is trained and verified with all the relationships and split into classification sets, designated for the cracks and defining its parameters, and for non-cracks as typical walls. In this stage, the extraction of GIF and gray representations transformed the RGB colors into gray, defining the input variables connected with the pixels' intensities and inverting them to establish the first output extracting drawings. As highlighted in green (stage 3), from image outputs, a 3D model is generated with depths creating a mesh from triangles and exported as (.STL) files. As highlighted in purple (stage 4), defining the input attributes for the image's recognition creating training and testing classification, highlighting the areas, encoding them with the specific attributes and types (as cracks, splitting, bursting), and running the first training based on the previous outputs and developed meshes, the output will be able to recognize the areas with highlighting the percentages of cracks detection and separating them in batches related to their classifications. Testing the model against serval criteria and new images to identify its efficacy and accuracy. Furthermore, as highlighted in Gray (stage 5), creating a connection between the GIF-generated images and the highlighted drawings in all their classes to generate a detailed highlighted output of the crack's border and shapes, the dimensions are added with the final output defined with drawings and tables of the studied area highlighted in light blue (stage 6).

2.1 Display and Recognition of the Images

Fig.3: Displaying of the images for detection (by author, 2022)

This section describes the fundamental framework for crack detection using image recognition. The primary benefit of image-based crack detection analysis is that it produces more precise results than traditional manual approaches. The processing complexity of crack detection is entirely dependent on the image scale. A wide range of pictures can be used for accurate crack detection in low-cost applications. The basic foundation of this stage is to scale the input images and stitch the related ones together to generate a comprehensive full image recognition. The method of merging several digital photographs with overlapping views to create a segmented panorama or high-resolution image is known as image stitching or picture stitching to find correspondences between images automatically; feature identification is needed. Robust correspondences are used to approximate the transition used to match an image with the image on which it is being composited. Implementing many photos of the same area without stitching them together in one single shot will generate unneeded and repeated drawings that will recommend additional classifications.

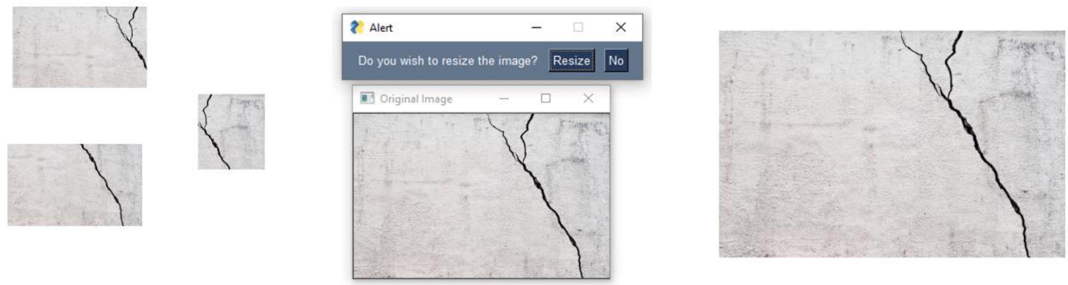

Fig.4: Stitching and rescaling a number of images into one final output (by author, 2021)

2.2 Classification of Images

Fig.5: Image classification process for detection (by author, 2021)

There are numerous classification methods, each with its own set of approaches and assumptions. Supervised classifiers are a type of classifier that performs the classification process in two steps. The first step entails identifying each class, its training area in the image, which serves as a descriptor of the spectral characteristics of the groups; the findings obtained in the first step are used to allocate to each spatial unit of the image. A class, usually a pixel or an object, or multiple classes if soft classifiers are used. Following classification, the findings must be validated. This is typically accomplished by comparing the classification to a reference data set, referred to as ground reality.

The technique used is summarized in the flowchart and consists of several stages, beginning with image acquisition and ending with output class generation. Prior to classification, a visual inspection of the image is performed to identify the groups to be used, defects, and materials to be classified, changing the names of the images to numbers to simplify the process.

	Filepath	Label
0	archive\crack\03842.jpg	CRACK
1	archive\crack\12899_1.jpg	CRACK
2	archive\crack\15033_1.jpg	CRACK
3	archive\no_crack\16782.jpg	NOCRACK
4	archive\crack\09202.jpg	CRACK
...	...	...
39995	archive\crack\07814.jpg	CRACK
39996	archive\no_crack\12512.jpg	NOCRACK
39997	archive\crack\05193.jpg	CRACK
39998	archive\crack\12173_1.jpg	CRACK
39999	archive\no_crack\13004.jpg	NOCRACK

40000 rows × 2 columns

Fig.6: Classification and labeling of the images in two, Crack and NoCrack (by author, 2022)

DOI: 10.54729/OPTG2546

The next step is to create a stratified series of locations, one for each class, with the pixel as the sample unit. This decision is made with the aim of collecting both the training data set, which is used to train both the classified and the tested data set, which is used to analyze the classifier's actions at the same time.

The dataset included 40000 images with a total resolution of 756 pixels. These images were taken from different online specimens. The key concept was to gather photographs with varying surface appearances in order to expand the diversity of the dataset and, as a result, of the AI system that learns from it. To supplement the dataset without sacrificing precision, the images were scaled into 250-pixel images, yielding a final dataset of 40000 samples, which were then manually divided into two categories: surfaces with Cracks and No cracks.

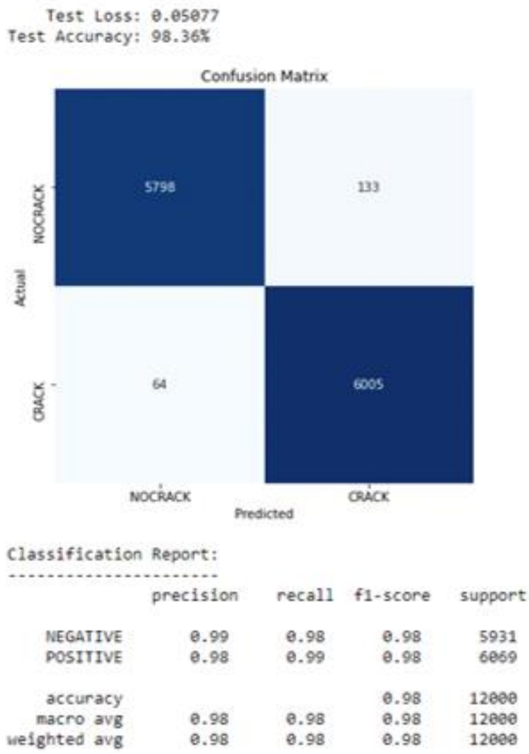

Fig.7: Accuracy test for loss and the actual matrix of the images (by author, 2022)

The details from the training data collection were also used to investigate and test separately the spectral of the groups at the pixel level. If the outcomes are unsatisfactory, the training data set can be redefined. The pictures are then subjected to supervised classification at the pixel level. Two classifiers were used, and their performance was assessed by comparing their classification scores. The consistency of the thematic map obtained with the classifier that demonstrated the best behavior was then evaluated. A graph is generated from the classification showing that the error is less than 0.06, and the results are satisfactory to be used in the crack detection training.

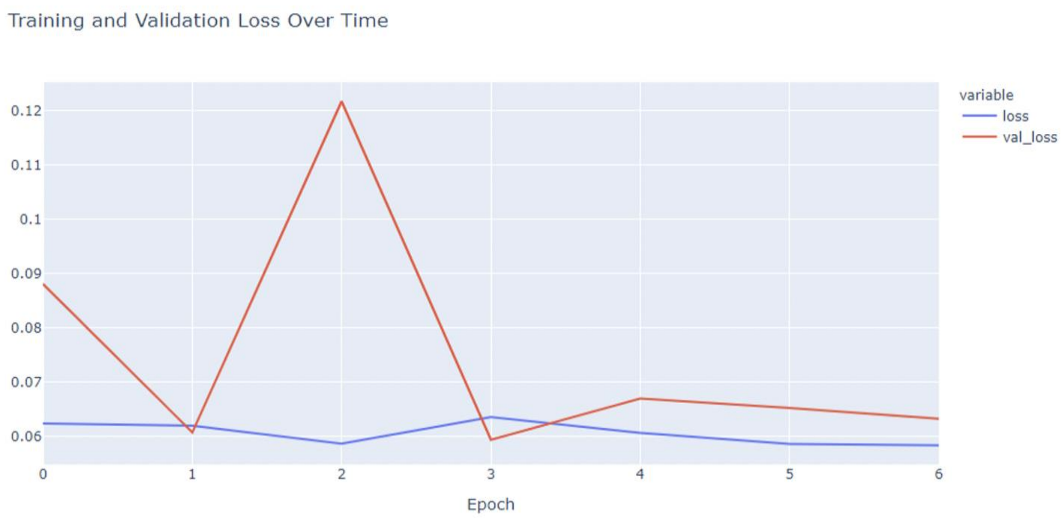

Fig. 8: Graph showing the training and validation loss over time with the test accuracy matrix and the images classification number (by author, 2021)

These matrices allow for the estimation of many accuracy metrics, such as Global Accuracy, which defines thematic error as a single value dependent on the degree of agreement between the classified sample units and a reference, considered to be the ground truth. This sample collection must satisfy such requirements in order to be representative, and the evaluation results must be generalizable to the whole map.

2.3 Drawing Generating

Generating drawings is a necessary process, and it will be contributed to all of the stages where numbers and graphs are not easily readable by everyone and cannot point the issue. In restoration documenting the existing is a must to keep records. The foundation of image digitization is to convert a natural type of image into a digital form suitable for computer processing; the image is interpreted in the computer as a digital matrix, with each part of the matrix containing different image characteristic information.

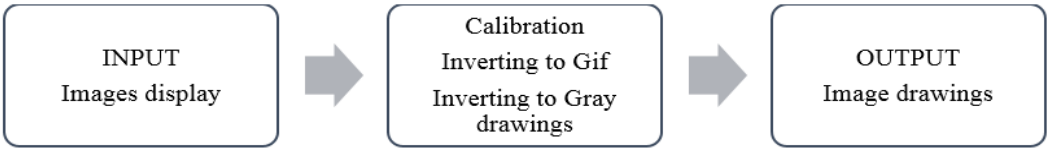

Fig.9: Generating of drawing Process (by author, 2021

A pixel is a standard unit in digital images that is the basic encoding of the color variable and gray level. Picture size is measured in pixels per inch. At this stage, the image display is calibrated and inverted to gray and generated to GIF drawings used as shop drawings for the existing site condition.

As shown in Figure 10, inverting the input of the image with converting the GBR to RBG and inverting them into gray-scale generates GIF images used in developing shop drawings. These outputs are accurate and well defined.

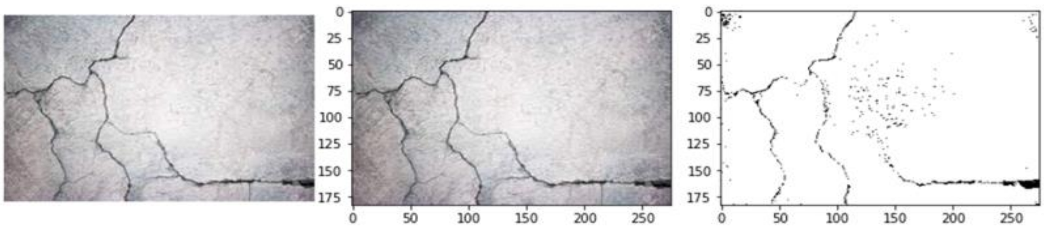

Fig.10: Generating of image drawing from the original image (by author, 2022)

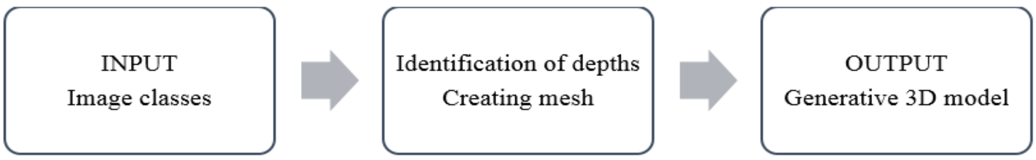

Fig.11: Generating of 3D mesh process (by author, 2022)

2.4 Mesh & 3D Model Development

The image-based mesh generation technique is numerical simulation. In general, these methods break the method into two significant steps, pre-processing and mesh generation. The pre-processing phase filters and segments the image to detect regions of interest, which are meshed in the mesh creation step, and binarizes the original image to extract well-defined contours from which a mesh is created.

The mesh is created by defining an implicit function from the binary image that guides a space partitioning strategy. They also have a post-processing phase to boost the mesh element consistency.

Generating the mesh used in the research is straight from the image aiming to represent it by a set of triangulations. These methods, also known as mesh modeling, aim to build a mesh that minimizes the approximation error between the original images and the depicted ones by the triangular mesh.

Converting the image of the cracks to 3d mesh as .stl files allows identifying the depths of these defects; these generated drawings are used in understanding the texture and for the training of the model for more accurate and precise crack detection. (as shown in Figure 12)

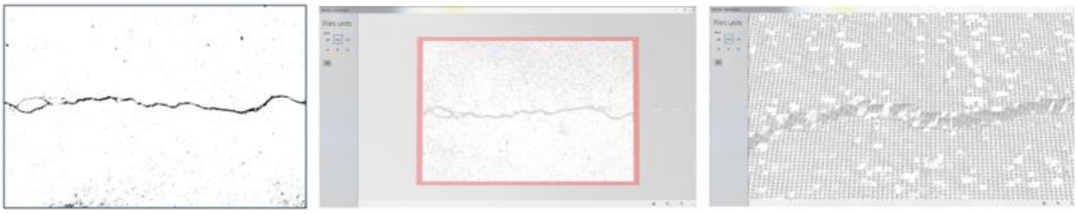

Fig.12: Converting the image into 3d mesh with triangulation (by author, 2022)

2.5 Defects and Cracks Detection

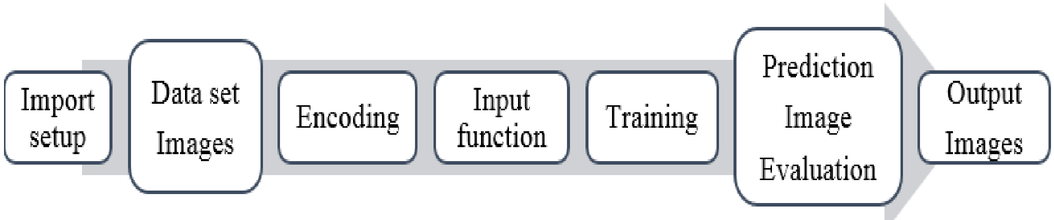

Fig.13: The defects and crack detection process (by author, 2021)

In this stage, all of the generated outputs from the previous are used for training and testing. As a start without any background, we had to go through the process of manually labeling and creating different classes for test and training (as shown in Figure 14). Using Labeling, a set of images with cracks were highlighted, giving each type a name. The algorithm behind this leaves will turn the pixels and the data of the images into annotation numbers and vertices where the coding can track them, read them, and understand their characteristics.

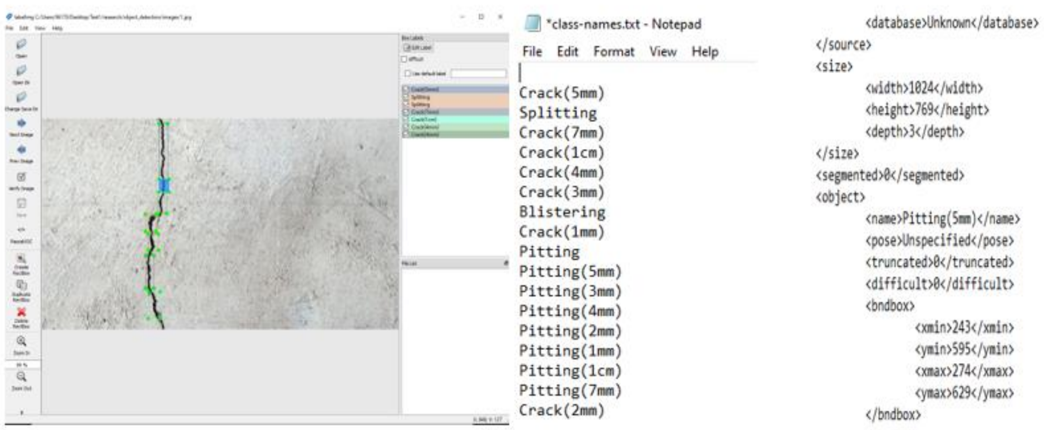

Fig.14: Labeling the cracks using Labelimg (by author, 2021)

The identified classes, images, and annotations are transformed into arrays, set for training with a high number of epochs to reduce the errors. Input the function, training, and testing until the best results with fewer errors are established. Testing the retrieved values on a number of images. The cracks are highlighted in a rectangular square showing the percentage and the classes to which they belong. Using the 3d mesh and the GIF photos, the ML shows more than 70% efficiency are the results are acceptable.

The most critical criterion is to ensure that the crack detection and classification technique must cover the vast majority of crack lengths in the initial picture is found in the final output with high-performance data.

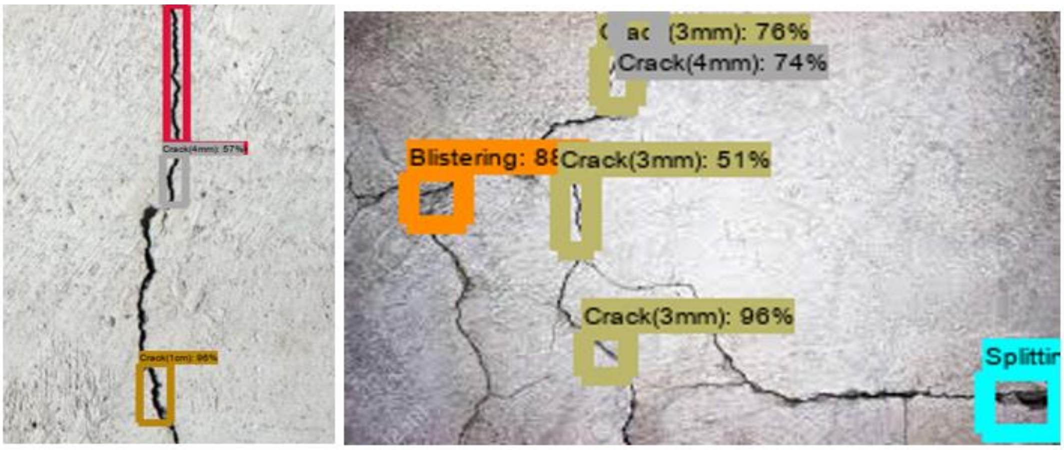

Fig.15: Output of crack, Blistering and splitting on the images (by author, 2022)

2.6 Highlight of Cracks

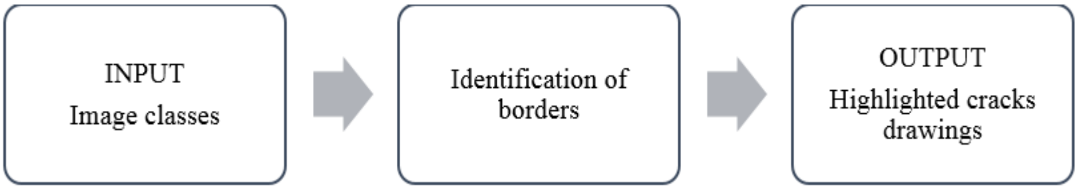

Fig. 16: Image classification process for detection (by author, 2022)

The obtained gray-scale sub-graph representation contains potential cracks and many other objects with local minimum gray levels after being filtered by the top-hat transformation. The dark cracks and other dim regions can be regarded as the intended, while other patterns of higher luminance pixels can be regarded as the backdrop. As a result, a thresholding operation is used to separate the cracks from the resulting image collection. The detected cracks are highlighted in red after identifying the borders, and the output is retrieved with drawings, with an additional green box to the condensed area.

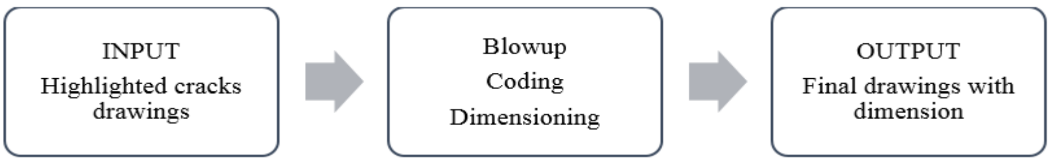

Fig.17: Image classification process for detection (by author, 2022)

DOI: 10.54729/OPTG2546

2.7 Dimensioning and Final Output

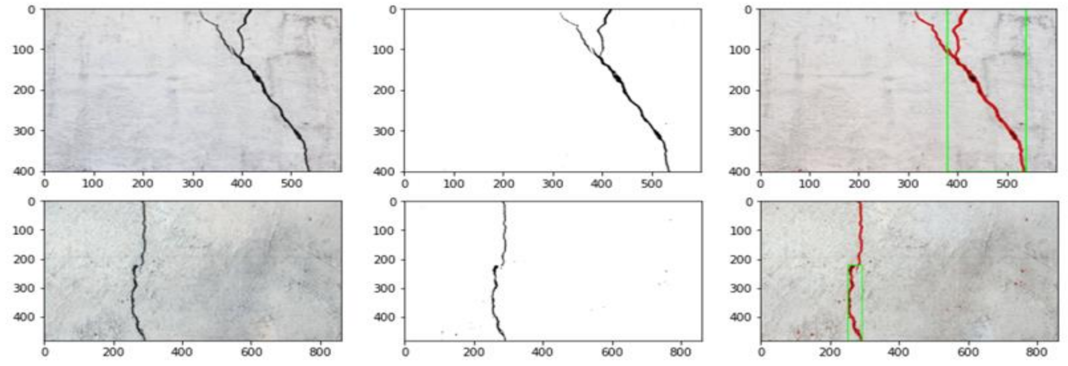

Fig.18: Crack detection output results (by author, 2022)

Crack length and crack width are critical metrics for determining the severity of cracks. The segmented objects in the final binary image will measure the crack length. The initial gray-scale image can be used to calculate crack distance, and the final binary image can be used to calculate crack positions.

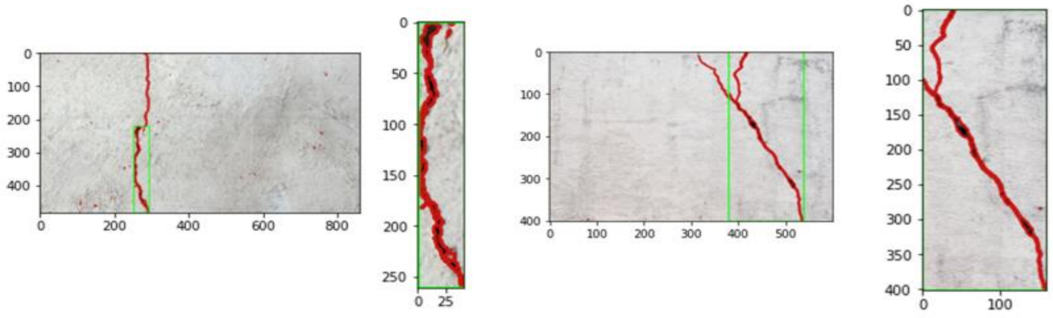

Fig.19: Crack detail and dimensioning (by author, 2022)

CONCLUSION

This paper evaluates the digital development of a machine learning-based model for detecting cracks surfaces of the historical site documentation, generating digital drawings and models suing collaborated framework among dataset of images, AI, and algorithms. Based on the testing and results, the use of the transfer learning method proved to be appropriate for training a digital model with the used small dataset scale.

The algorithm method called for the automated generation of crack detections highlighted drawing with an overall accuracy of 95%. The best findings were obtained by combining the original images, 3D mesh (represented with STL), and black and white GIF files. The proposed digital model offers a complete solution to the typical damage detection goals found in practice by combining the image modeling algorithms using computation based on multi-temporal images and the model-based boundary detection for the surface cracks realized using a level set-based active contour algorithm. An approximation method for determining continuous crack widths is built based on the obtained level-set crack boundaries.

In practice, it is essential to note that while AI is a step toward automatically inspecting cracks and building disorders, the classification model reflects the experience used during its preparation. This research developed a model restricted to binary classification at a patch level of small images, and further research is being conducted to incorporate a model capable of detecting cracks at the higher levels and large scales. For future work, it is intended to develop a full functioning program that generates specifications with tables and high accuracy.

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