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An approach for the creation of a digital repository of two-dimensional (2D) artefacts in Sri Lanka

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Abstract:

The creation of a digital repository of artefacts has become one of the crucial activities in the cultural heritage domain. The objective of this research is to propose a naval approach to make digital archives of 2D artefacts in Sri Lanka. By analysing a case study of digital archives of Bellanwila Temple documented by Lal Hegoda, authors identified several issues related to digital archives. Therefore, authors continued the literature review in area of digitizing 2D artefacts and identified that panoramic image is the process of combining multiple photographic images with overlapping fields of view of a large artefact. Two software tools: Photoshop and Hugin were tested for creating panoramic images and it was identified some drawbacks. Accordingly, a new algorithm was proposed with steps: image acquisition, pre-processing, sorting, feature detection and matching, homography, blending, fine-tuning, and displaying panorama. Large-scale 2D murals of three temples in Sri Lanka were used as a dataset to evaluate the proposed algorithm. A subjective evaluation of experts in area of visual arts was conducted to determine the level of quality of 2D digital archives developed using the proposed algorithm comparing two software tools. Collected data related to quality attributes: colour balance, noise & distortion with overall quality were analysed. It was identified that percentage of higher level overall quality of generated digital archives using proposed algorithm is 82.66% that is higher than other software tools, Photoshop (12.00%) and Hugin (02.67%) respectively. Moreover, it can conclude that proposed approach is effective for creating digital archives to make a digital repository for 2D artefacts in Sri Lanka.

Keywords: Digital Archive, Digital Repository, Image Stitching, Mural Painting, Two-Dimensional Artefact (2D)

1. Introduction

An archive creation of cultural heritage has become one of the crucial activities in area of cultural heritage. Further, it has been identified that the creation of digital archives is a demanding research area. In the background exploration, it was recognized that the archival of two-dimensional (2D) artefacts would play an important role in the area of cultural heritage. Accordingly, the objective of this research is to propose a naval approach to make a digital repository of 2D artefacts in Sri Lanka.

2. Methodology

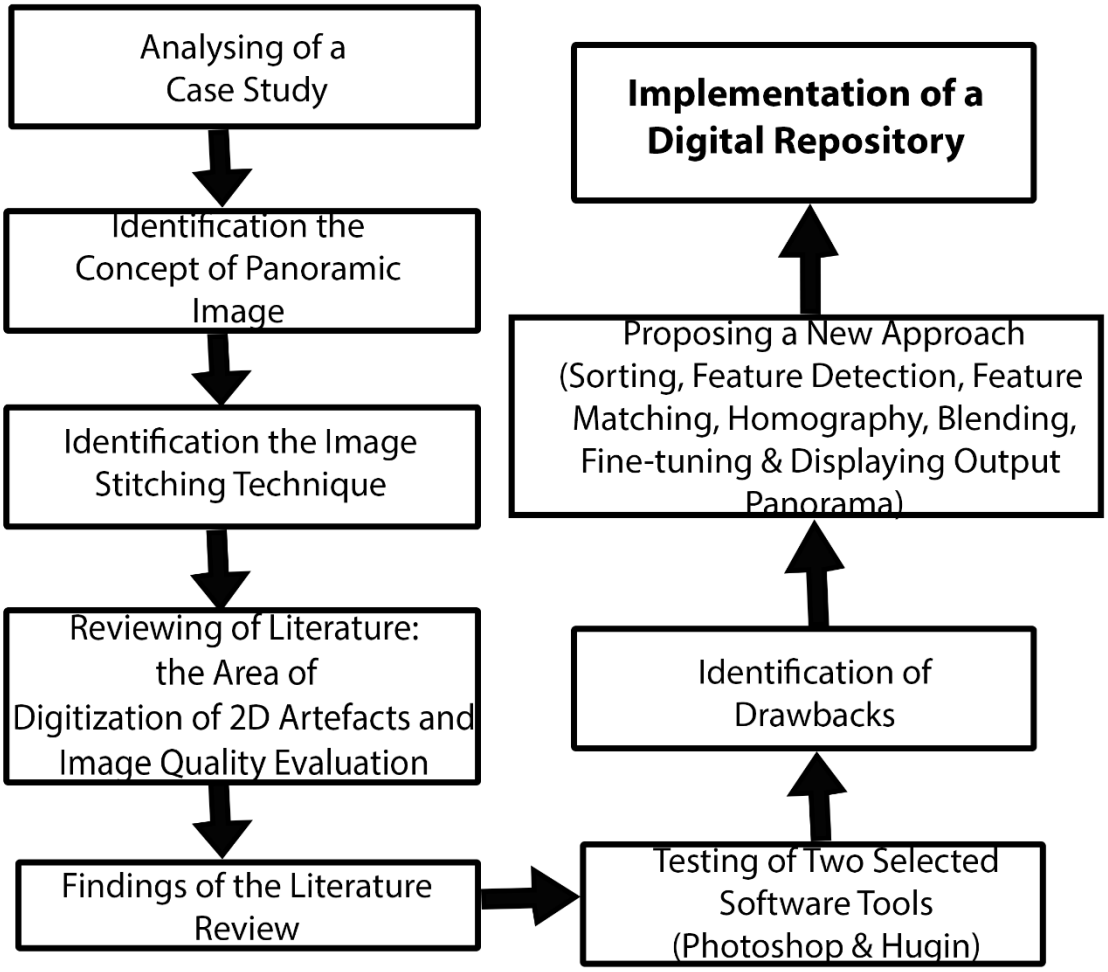

Fig. 1. Research methodology

Fig. 1 shows the research methodology in this research. It consists of a case study, literature review(digitization of 2D artefact, image quality evaluation), findings of literature review, testing software tools for the creation of panoramic images, proposing a new approach, and implementation of a digital repository.

2.1 Case Study

The authors analysed the case study of documentation consisting of digital images of murals in the Bellanwila Rajamaha Viharaya done by Lal Hegoda. Authors applied the interview method to discover background details for the digitization of historical artefacts in this case study. According to the collected details, it was found that due to water leakage from the roof of the Bellanwila Temple to the murals on the wall in the shrine hall and the spreading of fungus on the mural surface, there were major threats to harm the murals gradually. Therefore, a requirement arises to archive them for next generation. In the analysis, it was identified that there are some barriers such as large size of murals, minimum focusing distance, and various lighting conditions to develop the digital images of artefacts. Therefore, an alternative approach was required to overcome the above barriers. The method used to rectify these issues is the image stitching technique. It is a technique in computer vision which is merged a set of series of overlapping image components. Furthermore, it was revealed in the interview that keeping the camera parallel to the wall and ground would help to avoid merging issues at the development process for effective panorama creation. Accordingly, this technique will help to develop a single image called the panoramic image by following a standard algorithm without damaging the original quality of the mural while stopping image distortion and color unbalance.

2.2 Literature Review

2.2.1 Digitization of 2D Artefact

One of the emerging technologies is digitization which is applied to different aspects of human needs. Digitization can be described as converting analog into digital information (Kane *et al.,* 2015). It is applied to the main three categories of society. One is organizational digitalization which changes are done in the organizational process. Another one is technological digitalization which is very crucial in the area of using new digital technologies such as the application of mobile devices, social media, and embedded devices to integrate digital-based solutions for day-to-day lives. The third one is social digitalization which is regarded as anything that affects all aspects of human lives. Accordingly, digitalization is different from digitization (Reis *et al*., 2018). Further, the terms Digital Transformation and digitalization are used interchangeably in general applications.

Digital preservation is to try to keep an archive's content accessible, using different approaches through format migration, emulation, and so on. Providing documentation explaining the archive as well as the structure of its contents is one approach. Providing the same content in different formats is another approach

(Mulder, 2005). Some online platforms facilitate high-resolution digital images and videos of artworks and cultural artefacts from partner cultural organizations throughout the world. Some museums in the world are creating online digital repositories for easy access and exhibition of documents and artefacts while preserving them as an important mechanism using digitization. Google Arts & Culture is a project done in this area through which the public can access high-resolution images of artworks kept in the initiative's partner museums (Google Arts & Culture, n. d.). World Digital Library, is a project implemented by the U.S. Library Congress with the support of the United Nations Educational, Cultural, and Scientific Organization and cooperation with numerous libraries, museums, and other institutions around the world (World Digital Library, n. d.).

Then, the Authors concentrate on the literature in the area of digitization of mural painting (Magaista, 1999). Kafel & Macdonald (2017) talk about digital techniques for documenting and preserving cultural heritage and how to use the applications of digital technologies to the study and preservation of cultural heritage. Documentation was done about the wall paintings in the Château de Germolles, Situated in Burgundy, France, which is the best-preserved residence of the Dukes of Burgundy and was listed as a monument of national importance in 1989 (Degrigny & Piqué, 2017). Then, the Authors discussed the existing literature in the area of digitization of 2D artefacts. Most of the research papers reviewed were about the documentation for the conservation of artefacts. Then, the literature review focused on the digitization of 2D images and it was identified the subject area with more details. In this literature review, Authors have identified image stitching as the main technique of 2D image digitization. Furthermore, it was found that there is a requirement for merging or stitching separately captured portions (tiles) of an object into a single unified digital image in the cultural heritage community (Williams *et al*., 2013). Hence, Authors reviewed existing image stitching techniques in detail for 2D image digitization, practices and tools. Several papers were critically reviewed in the international research arena in the area of image stitching (Jukka, 2011; Preservation and Access the research library group, n. d.; Mattew & David, 2007). Accordingly, it was identified that this requirement arises for maps, negatives, and paintings which are difficult to digitize because of their physical sizes. These can be digitally merged from component images by using image stitching algorithms. In the analysis, it was found that panoramic image creation is an application of image stitching technology (Szeliski, 2006). Authors have identified that image stitching as the main technique of 2D image digitization (Patel *et al*., 2012). Image stitching is a combining process of an overlapping series of images which were taken separately from a large scale image for the purpose of producing a single unified high resolution image (Ebtsam *et al*., 2014).

2.2.2 Image Quality (IQ) Evaluation

Image quality evaluation has two main approaches called subjective evaluation and objective evaluation. The behaviour of the Human Visual System (HVS) is influenced to the subjective evaluation as human

observers are selected for the quality assessment of images. Objective evaluation of image quality is carried out using two approaches. One approach is using a measurement device to get a numerical value. There are physical instruments such as Densitometer, Colorimeter to measure and assess the quality. Another approach is to quantify quality by using algorithms, commonly known as image quality metrics. One of the main applications that is used for quality assessment is the maximization of quality. Another two such applications are quality monitoring applications in real time and comparative analysis between different alternatives. In the process of image quality metrics, the quality of the image is measured with reference to the full or partial reference of the original image. Structural Similarity Index Matrix (SSIM) and Peak Signal-to-Noise Ratio (PSNR) are two examples for quality matrix. According to the Literature review, predicting IQ is a multi-dimensional and a very complex task even though many IQ metrics have been proposed to predict perceived IQ (Pedersen & Hardeberg, 2009).

2.3 Findings of the Literatue Review

2.3.1 Image Stitching Technique to Create Panoramic Images

Image stitching is the technique used in the digitization of 2D artefacts. It is described in the area of computer vision and photography. Further, this technique is used in 2D applications as well as some other applications such as medical imaging, satellite imaging, and video compression (Savita & Reecha, 2014). The stitching process can be described as follows. Suppose that there is an image that is difficult to focus as a single camera shot due to a large field of view. Then, the entire image will be divided virtually into horizontal rectangle components: L1, L2, L3, and L4 (Parts of a single image) with overlapping parts H1 and H2 (Fig. 2). The idea is to combine these L1 & L2 horizontal rectangle image components and L3 & L4 horizontal rectangle image components into two separate images using the common parts which are overlapped (H1 & H2). Then, these two stitched images will be combined using the common overlapped part, V1. When there are several rectangle image components, the same procedure will be applied until a large-scale panoramic image is developed as the output.

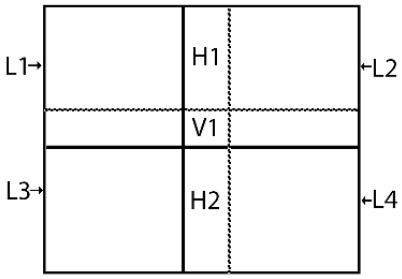

Fig. 2. L1,L2, L3 and L4 image componenets with the common parts being overlapped

In this process, it is required to concentrate on some important aspects to get a quality output. Some of them are: the angle of projection of light on the images, the intensity of the pixels, exposure towards the light, and the alignment of images. Therefore, when the panoramic image is created above factors should be considered and a suitable approach should be incorporated to get a quality final product.

2.3.2 Image Quality Circle

There were different notions related to image quality in history. Since there wasn't a unified view of image quality, it was taken an effort to identify a theory using the existing ideas. Reference Engeldrum (2004) describes a theory related to image quality. (Fig. 3).

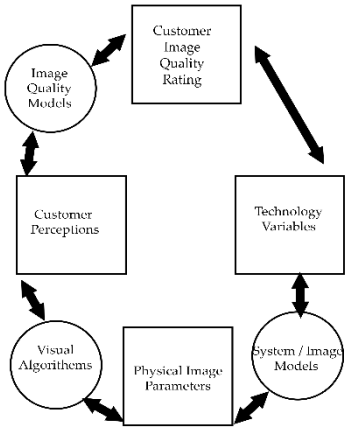

Fig. 3. Image quality circle

At the beginning, it was a four-way approach, and later it is called an image quality circle. This is a framework which is robust and organizes the different ideas together to form the concept of image quality. It can be applied in areas of marketing, technology oriented activities, research and development as a process model. The image quality circle can be diagrammatically shown as above. There are four major components in this circle and those components are linked via one another by three links called, System / Image Models, Visual Algorithms and Image Quality Models. Technology Variables are described to modify the image quality and some of those parameters are toner size, dots per inch (resolution) which are manipulated by the designer. Physical Image Parameters are quantitative aspect of an image which are measurable. Physical image parameters are called objective measures of image quality. There is no limit for this physical image parameters except that they need to be physical and measurable. Customer perceptions are inspired by a set of visual attributes related to the image quality which will form the quality judgment by the customer. Some of the examples are darkness, sharpness, and graininess. Image quality rating given by the customer is the overall image quality of the particular image. This can be expressed as a numerical value or a qualitative value such as "bad", "good", or "excellent".

2.4 Testing Software Tools for the Creation of Panoramic Images

Authors wanted to evaluate whether image stitching method is suitable for the application of panorama creation of digital images. It was planned to test three groups of digital images to test the accuracy and quality of the results. These three groups are 2D digital images, real 2D digital images and 2D real digital images of murals. Authors researched software tools and identified details of such tools (Williams *et al*., 2013). But, most of them can't be used in normal applications due to their unavailability. Photoshop is one of the available tool, which facilitates this image stitching feature. Hugin is another open source software tool that facilitates this feature. Accordingly, Authors started the testing of 2D digital images (taken from internet). According to the observations of the above image stitching method testing by using Photoshop and Hugin open software, it was identified that there were some drawbacks and issues of them. At the testing of stitching method for this group, both Photoshop and Hugin gave approximately the same output. But, during testing for the second group (real 2D digital image set) Photoshop was unable to create a quality stitched image, but Hugin created it. As the third testing group authors planned to test the stitch method for the 2D real digital images of murals. Authors managed to get some real 2D digital images of murals related to three historical temples in Sri Lanka for creating panoramas. Again, the same drawbacks were identified at the comparison of produced outputs using the available algorithms. So, it was identified that there is an inconsistency of the quality of the final output using these two software tools for creating products having issues such as noise and distortions, color unbalance resulting low-quality panorama.

3. Results, Evaluation and Discussion

Authors further continued the research to identify a new method for the above stitching problem. Accordingly, it was proposed a new design and implemented this algorithm for effective panorama creations.

3.1 Results

3.1.1 Proposed Algorithm

Image acquisition
Pre-processing
Sorting the images
Developing a panoramic image
    Detecting features of images
    Matching features
    Homography
    Blending
If panoramic image is created
Then

Fine-tuning the output panorama

Displaying the output panorama

Else

Displaying the error message

Image Acquisition

User should select the target entity or image that is difficult to focus at once due to the larger size physically. Then, multiple overlapping series of images of this target image will be captured from different camera views as input images to the system.

Pre-processing

These images captured by mobile phone or any handheld devices with high resolution camera and translated into images of equal dimension by using a pre-processing algorithm. The required pre-processing operations are done in this step to get the images of equal resolution as the output.

Sorting the Images

Computing time is one of the critical factors in image processing systems. The array data structure is simple structure to manipulate individual images efficiently to minimize the computing time that generates the final output. So, in this program ascending or descending ordered array is used to execute image processing operations required for the stitching process according to the standard algorithm.

Detecting, Matching Features of Images and Calculating Homography

According to the literature review, there are two main approaches used for image stitching called direct and feature-based methods. In direct method, all the pixel intensities of the images will be compared with each other. Therefore, it is computationally complex as it requires comparing each pixel window to the other. In the feature-based method, all feature points in an image of a pair of images are compared with all corresponding features of the other image by using a local descriptor technique. So, this procedure is established a correspondence between points, lines, edges/corners or other entities of the image. One of the important factor is to consider whether the local descriptor is invariant to image noise, blur, scale and rotation. In this algorithm, feature-based method will be used to identify features of images as it is more efficient with the modern image stitching applications. The main principle behind the image matching is to locate the neighbouring set of pixels in an image to find the correctly feature-matching set for that image. It has been identified that RANSAC is one of the better algorithms to estimate parameters for homography matrix of a mathematical model and eliminates outliers (wrong matching points) from a set of observed data (Gopika *et al*., 2020). It is an iterative method to estimate parameters of a mathematical model from a set of observed data that contain outliers.

Blending

The blending of these images together to compensate for exposure differences and other mis-alignments will be the next step of panoramic image creation. Different pixel-blending methods are available for image stitching, such as feathering image blending, gradient domain and Image Pyramid blending. Two popular techniques for blending the images are alpha blending and Gaussian pyramid. Alpha blending takes a weighted average of two images. Comparing these two, alpha blending works extremely well when image pixels are well aligned to each other.

Fine-tuning the Output Panorama

Stitching results may have some quality issues such as not defining a proper border with the required area of the image,unnecessary areas are added. So, final product be fine-tuned to display it as a quality panoramic image of the original large-scale image.

Displaying the Output Panorama

Panoramic image will be displayed as the final output as a result of stitching a series of given sets of images.

3.2 Implementation of the above Algorithm

The best way to implement this algorithm as a program is to follow a criteria to select a suitable programming language and other required things for the above algorithm. The elements of the criteria can be described as follows. The programming language should have easy to learn syntax and data structures that emphasize readability to reduce the cost of program maintenance in the development process. Python is a high-level, interpreted, interactive, and object-oriented scripting language with dynamic semantics. It is a general purpose programming language that became popular very quickly, mainly because of its simplicity and code readability. It enables the programmer to express ideas in fewer lines of code without reducing the readability. To satisfy the above criteria, Python programming language was selected for the implementation. Further, rapid application development was selected as an easiest development mechanism for the above design. PyCharm Community Edition 2020.2.1x64 Integrated Development Environment was selected for the easy development of the program. So, it was guided the developer to try seeing the final output without taking much programming effort. Further, image stitching algorithm is used in this implementation. Therefore, authors researched on a flexible and efficient mechanism to implement computer vision algorithms. Subsequently, it was identified, OpenCV that supports many algorithms related to computer vision and machine learning. As Authors are using Python programming language, OpenCV-Python library will be used in this implementation as Python bindings designed to solve computer vision problems. Accordingly, new algorithm was developed to create panoramic images of 2D artefacts.

3.3 Implementation of the Digital Repository

The term 'digital repository' can be applied to a number of different digital storage initiatives, which are often be referred to as 'institutional repositories', 'digital archives', or 'digital libraries'. Although in practice these terms are expected slightly different functionalities and underlying philosophies, digital repositories are commonly referred to as ‘institutional repositories’ or ‘digital archives’. However, repository solutions are most viable and sustainable when they are built on open standards (LDL: Librarian’s Digital Library, ©2002-2016).

Authors wanted to implement a digital repository by using the above proposed method. Authors followed a criteria for the selection of a development tool which is capable to ensure the general requirement of a digital repository and facilitates required functionality. The elements of the criteria to select a development tool can be described as follows. Development tool should have easy to manage facilities to incorporate the identified functionalities and to reduce the cost of program maintenance in the future changes. Google site is an attractive development platform which is provided by Google for efficient development of standard and customized web pages (Google workspace Learning Center, © 2020). Further, it has several facilities to incorporate the identified functionalities in this repository. Therefore, google site was selected as the development tool for this development. One of the important requirement of this implementation is to store artefact securely and to allow downloading facility only for the authorized users. Further, navigation and zooming of the artefact are two required functionalities. Google drive is one of the free reliable storage mechanism that is facilitated above requirements (TechtargetNetwork, n. d.). Therefore, google drive was selected as the storage mechanism to store artefacts. Furthermore, the embedded facility in the Google site was used to link stored artefacts with the repository in this development.

3.4 Evaluation and Discussion

Authors wanted to introduce a simple mechanism to acquire digital images to avoid the complexity of the photo shooting process. Accordingly, authors used a mobile phone camera to get digital images of murals. So, authors visited three historical temples: Kadawatha Bimbaramaya Temple, Yatiwela Sri Gunananda Temple and Meethanwala Pallegama Temple to get digital images of 2D murals using a mobile phone camera. In the literature review, it was identified that some software tools facilitate image stitching algorithm. Authors researched on a set of image quality attributes that will contribute a quality panoramic image output (Granados *et al*., n. d ; Burns, 2015; Engeldrum, 2004; Engeldrum, 1999). Accordingly, color balance, image noise & distortions were selected as the main quality attributes for the overall quality of the created panorama. Then, authors continued the quality level evaluation of image sets by creating 5x3 panorama images using the above set of digital images for the three main approaches in Photoshop, Hugin and new algorithm for effective comparison of the results(five images for each approach). Aauthors

conducted an experimental evaluation (subjective evaluation) for the above task. Evaluation results show that the higher percentages of responses for color balance and overall quality (in the level of good or excellent) of the final panoramic image will be given by using the proposed algorithm. For example, in the first image set, the highest percentages of 86.67% and 93.34% are given for responses for the color balance and the overall quality comparing other two algorithms. According to the above results, higher percentages for responses for above two image attributes are shown for all 5 image sets under the new proposed algorithm. Further, the higher quality of the final outputs will be further justified by recording the highest percentages for no image noise and distortions of the final images for all 5 cases under the new algorithm. Moreover, it can conclude that the proposed approach is effective for creating digital archives to make a digital repository for 2D artefacts in Sri Lanka.

4. Conclusion

The proposed digital repository can be defined as a convenient digital infrastructure through which to store, manage and re-use digital materials. It can hold a wide range of materials for a variety of purposes and users by supplying required materials for research, learning and administrative processes. Furthermore, these type of repositories are used by a variety of communities to carry out many different functions in many forms. The proposed method of creating digital archive is sustainable, trusted, well-supported and well-managed due to the simple and efficient approach proposed in this research. There are several short-term benefits and long-term values in the applications of digital repositories. Short term benefits are: enabling quick, easy, simultaneous and remote access to digital archives, allowing institutions/organizations to efficiently retain and manage their own intellectual assets, facilitating re-use of deposited materials for new research, education, and learning, minimizing physical storage requirements while increasing the potential mass of deposits and enabling external validation of research results. Some of the long term values are: enabling persistent access to deposits independently of external publishers, increasing institutional research visibility, raising potential and returning on investment from asset creation.

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