Issues and theories behind the conservation of two-dimensional (2D) artifacts in Sri Lanka using digital technology

Dr.W.A.P. Wickramasinghe, Dr.Anusha Jayasiri
Senior Lecturers,
Department of Information Technology, Faculty of Dance and Drama,
University of the Visual and Performing Arts
ajith.w@vpa.ac.lk, anusha.j@vpa.ac.lk

Abetract:

Conservation of cultural heritage is an area of science that describes how to preserve various products of art, architecture and other cultural works. There are different types of valuable artworks required for conservation in Colombo Museum and some historical temples in Sri Lanka. The aim of this paper is to identify issues and theories behind the conservation of 2D artefact in Sri Lanka using digital technology. As the research methodology, a survey, a case study of digital photos of Bellanwila Temple taken by Lal Hegoda and interviews were used to identify the process, issues and techniques applied for conserving 2D artifacts through digitization. In literature search and analysis, image stitching technique was identified as one of the main technologies used in this area and it was well studied in different perspectives in this research. Further, it was able to identify two main approaches for image stitching as feature based method and direct method by reviewing several research papers in the area of image stitching. Further, it was identified steps applied for the process of developing a panoramic image. Furthermore, several feature based techniques were identified for different types of applications in the subject area with the details of their inherent features and limitations. In this paper, findings of the literature review and the results of the above research methods are discussed in different directions with the identification of issues and theories behind the conservation of two dimensional (2D) artifacts in Sri Lanka using digital technology.

Keywords: Conservation, Cultural Resources, Two-Dimensional Artifacts, Digital Technology, Image Stitching

1.0 Introduction

Conservation of cultural heritage is an area of science that describes the interdisciplinary study of how to preserve various products of art, architecture and other cultural works through the use of scientific methods. Those cultural heritage includes tangible culture such as buildings, monuments, landscape, books, work of arts, 2D artifacts and intangible culture such as traditions, language, and knowledge in a society (Culture in development ; International Institute for conservation of historic and artistic works). The International Institute of Conservation, London, has defined conservation as "any action taken to determine the nature or properties of materials used in any kind of cultural holdings or in their housing, handling or treatment, any action to understand and control the causes of deterioration and any action taken the better the condition of such holdings". In this research, it is focused the 2D artifacts conservation in the area of tangible culture. One of the methods of 2D artifact conservation is digitization (De Mulder, 2005). At the literature review, Authors have identified image stitching as the main technique of 2D image digitization (Hetal et al. 2012; Dalwai et al. 2015). As one of the research methods, Authors conducted a survey in the conservation unit of Colombo Museum to identify procedures and techniques related to conservation. With that background knowledge, Authors researched on a suitable case study for collecting more data in that area. As a result, it was identified that there was a case study for the digitization of the murals of Bellanwila Temple as one of the examples in Sri Lankan context (Chandrajeewa 2013). In that case study, it was identified that the digital photos of the murals had been developed by Lal Hegoda for the purpose of conserving artifacts through digitization. Therefore, those 2D murals of Bellanwila Temple were deeply analyzed. Further, it is required to study the theory and philosophy of conservation and explore the basis and framework of conservation, restoration, preservation theory and practice in the globalized world (Australia.icomos.org 2019). Hence, conservation is a broader area and it is a profession dedicated to the preservation of cultural property for the future generation. Accordingly, conservation activities include examination, documentation, treatment and preventive care supported by research and education (Culturalheritage.org 2021).

1.1 Research Problem

It is a known fact that there are several types of valuable artworks in Sri Lanka which are required to be conserved for the next generation in the archeological context. It has been observed that various techniques are used for conservation of those artifacts in most of the places like Colombo museum, some historical temples in Sri Lanka such as Bellanwila Rajamahaviharaya, Kelani Rajamaha Viharaya and Sapugaskanda Rajamaha Viharaya. At the analysis of the methods applied for conservation of valuable artifacts in those places, anyone can understand that they are in primary or secondary level which results some issues such as no regular monitoring and observations to maintain them, no suitable methical approach for 2D artifacts conservation. Further, it was identified that there was no motivation to enhance the research capacity in the area of conservation. As a result of the technological enhancement of the society, digitization has been identified as one of the techniques applied for 2D artifact conservation. Accordingly, Author has identified the problem of this research is "**Issues and theories behind the conservation of two-dimensional (2D) artifacts in Sri Lanka using digital technology**".

1.2 **Aims and Objectives**

Digitization is an emerging technology from the 20th Century. Therefore, it will open the new research avenues for numerous field of studies. Further, it has been proved that the application of digital technology will give tremendous benefits in various dimensions for the different needs of human beings. Accordingly, the objective of this study is to identify issues and theories behind the conservation of 2D artefact in Sri Lanka using digital technology.

2.0 Literature Review
2.1 **Introduction**

In this section, literature review has been done in the area of digitization for conservation in Sri Lanka as well as some other countries for different type of applications. Authors were able to identify the techniques and issues in this broad area. At the beginning, Authors reviewed existing literature in the area of digitization for preservation such as digital repositories. Then, it was reviewed existing literature related to the conservation of 2D images such as mural painting. It was able to recognize that most of the researches were focused on the documentation for conservation of mural paintings. Therefore, literature review was directed to the conservation of 2D artefacts and it was able to identify the subject area with more details by focusing on the different application areas such as digitization of the 2D artifacts in different contexts. At this literature review, Authors have identified that the panorama which is an application of image stitching as the main technique of 2D image digitization. Hence, Authors reviewed existing image stitching techniques in detail for 2D image digitization, practices and the tools. Further, Authors have focused the literature review of 2D artefact conservation through other techniques such as robotics, artificial neural networks.

2.2 **Literature Review on digitization for preservation**

One of the area of 2D artifact conservation is digital preservation (De Mulder 2005). Hence, Authors researched on existing literature in the area of digital preservation (Abd Manaf 2007; Waters 1998; Digital Preservation Handbook 2015; NINCH Working Group on Best Practices, the NINCH Guide to Good Practice in the Digital Representation and Management of Cultural Heritage Materials; Paul et al.; What is Digital Preservation?; Outline of Digital Archiving Project; Preservation and Access and the Research Libraries Group 1996; Maxine 2000).Yeung et al have done a research in the area of preserving art in the digital context. This paper discusses an overview of the broader digital preservation challenges, and then considers new media art within that context. In summary, it has been further identified that the existing issues have not been identified and solved completely. Further, it has been provided only some approaches that lead to minimize the effect of identified issues (Yeung et al. 2008). There are two notions in this field of research as preservation and conservation of valuable artifacts (Jukka 2011). Preservation is the protection of cultural property through activities that minimize chemical & physical deterioration and damage (Preservation and Access and the Research Libraries Group 1996). The digitization for preservation demonstrates as an important mechanism for access and exhibition of documents and artifacts. There are some of the museums in the world that are turning to create online digital repositories which can be accessed easily. Google art is one of the project done in this area. Google Arts & Culture is an online platform through which the public can access high-resolution images of artworks housed in the initiative's partner museums. Actually, it provides people the opportunity to experience artworks individually and a platform to become involved in conservation. It

concentrates on preserving all forms of artwork and developing new applications that can enhance the audience's experience (Google Arts & Culture n.d.). World Digital Library is a project implemented by the U.S. Library Congress with the support of United Nations Educational, Cultural, and Scientific Organization and cooperation with numerous libraries, museums and other institutions around the world. It is another example for the digital repository to make available on the Internet, free of charge and in multilingual format, significant primary materials from cultures around the world, including manuscripts, maps, rare books, musical scores, recordings, films, prints, photographs, architectural drawings, and other significant cultural materials (World Digital Library n.d.). The British Museum has an online inventory of their research catalogues in different area of artifacts. 2000 new images are added every week to the database by expanding the possibility of online searching more artifacts for researches and educators (The British Museum n.d.).

2.3 Literature Review on conservation of 2D paintings (images)

A new initiative to document the historical mural paintings was discussed in a research done by the department of Archeology and identified the exploration of the photography documentation in Sri Lankan history. In addition to the documentation of color, subject, shape of the murals, murals had been drawn by hand for the conservation purpose in the history. Accordingly, historical places such as Ruwanweli seya, Abhayagiriya, Thiwanka Pilimageya were covered using this technique. Manual graphic documentation was started in the year 1982 by the central cultural fund and Gangaramaya, Dambulla, Hindagala murals were documented. In the year 1981, Liver Brothers started the project of black and white photography documentation in 28 temples in Sri Lanka. Due to the drawbacks identified, color photography was started and 50 historical places were covered using this technique (Samaraweera et al. 2017).

Blanca & Orea discuss about the current state of mural painting conservation documentation in Mexico (Blanca & Orea 1999). This paper is an analysis of different documentation levels and it will explain some important elements that documentation should include. Specially, it will emphasize some points such as to understand the causes and effects of deterioration, previous restoration treatments. There are possibilities and limits of visual documentation for mural paintings. Jürgen discusses about the limits of existing documentations and proposes certain elements that should be incorporated for a better documentation for conservation (Jurgen 1999).

2.4 Literature Review on conservation of 2D artefacts

So, these reviews laid the foundation to proceed with the two-dimensional artifact conservation. At the review, it was identified that there are less amount of research works in Sri Lanka under this category. It was able to find out a report written by Schmid. A report was produced by a consultant of the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM): Sri Lanka mission to the UNESCO world heritage site of Sigiriya. It talks about the main points such as the mission background & the objectives, identification of issues and draft strategy for the conservation. According to the report, it had been mentioned that Central Cultural Fund (CCF) and Department of Archeology (DOA) requested international expert in conservation for the evaluation of the condition of Sigiriya Paintings. The report presents about the discussion of main issues of Sigiriya paintings such as lack of documentation, need for monitoring, creation of a permanent record through 3D laser-scanning, protection against rainwater, preliminary scientific investigation and documentation, emergency stabilization,

construction of new visitors' platforms and reduction of number of visitors to the painting pocket. It is proposed some actions and precautions to rectify above issues. Digitization of all existing written and visual documentation and creation of simple computer repository of the existing documentation were proposed as some of the actions for above issues in the area of digital technology (Schmid 2016). This report presents an approach for the conservation of Sigiriya Paintings based on expert consultation.

Furthermore, Authors were able to critically review several researches done in other countries by analyzing the techniques used by them such as panoramic image creation. At the analysis, it was found that panoramic image creation is an application of image stitching technology (Don Williams, Williyamson & Peter D Burns 2013; Richard 2006; Shikha 2015; Kokate et al. 2017). Authors have identified that image stitching as the main technique of 2D image digitization (Hetal et al. 2012; Dalwai et al. 2015). Sruthi, Sruthi & Dinesh explain the idea of panorama image creation. There are two main techniques for image stitching as direct method and feature based method. Further, it talks about the approach and a specific method, called SIFT for detecting local features in an image. After finding local features, overlapping areas are identified. Using dynamic programming method, a minimal cost path is selected to stitch images. Here, seven steps were used for the process of developing a panoramic image. By cutting at the overlapping places, images are merged together to form the final panorama image (Sruthi, Sruthi & Dinesh 2017).This research uses a scientific method for creation of a panorama image. Kokate, Wankhede & Rohit present the idea of image mosaicing based on feature extraction. It explains the idea of panoramic image production. Two approaches, direct and feature based techniques are discussed in this paper. Further, the difference between those two approaches are discussed. Components of image stitching are discussed as calibration, registration and blending. Steps of feature-based image stitching are discussed in detail. This paper talks about two concepts called local feature descriptor and feature detector. Accordingly, two techniques for describing local feature descriptor such as SIFT and SUFR are discussed in this paper by analyzing the individual pixels of the images. Harris corner detector is described as a feature detector with the technical details. RANSAC algorithm is used as the Homography detection algorithm in that research (Kokate, Wankhede & Rohit 2017). This research supports to understand the idea of local feature descriptor and the techniques for feature detection. It talks about two approaches with the comparison of the suitability rather than just applying a particular technique. Ultimately, better approach is selected for image stitching. This comparison helps Authors to analyze the suitability of a particular technique rather than using one technique directly in the stitching process within the research. Matthew & David concern the problem of fully automated panoramic image stitching. It talks about two categories of literature called direct and feature based. It describes an invariant feature-based approach with several advantages over previous approaches. One of the important things of this research is the ability to match image sequence despite rotation, zoom and illumination change in the input images. Further, a high-quality result is taken using multi-band blending to render seamless output panoramas. In this research, steps for creating a panoramic image are described as feature matching, image matching, Robust Homography Estimation using RANSAC, applying probabilistic model for image match verification (Matthew & David 2007). This is a research that is presented an automated panoramic image stitching. It is different than previous approaches. The problem of fully automatic construction of panorama has been considered by the Brown & Lowe. The paper has presented a novel system for the above problem by using SIFT algorithm. That system is robust to the illumination condition, camera zoom (Brown & Lowe, 2003). Szeliski explains how the

image stitching techniques evolved from the past up to the modern level of techniques. Techniques such as image alignment, global alignment are some of the millstones in the techniques developments which were resulted to enhance the quality of the panorama creation process. Further, it has been pointed out the main issues such as seams, ghost effect of the final output as a result of the presence of parallax, lens distortion, scene motion, and exposure differences of panoramas (Szeliski 2010). Ebtsam, Mohammed & Hazem present the idea of panoramic image creation. It talks about a different aspect, called field of view and how it affects for panoramic image creation. The human visual system has a field of view of around 135 x 200 degrees, but a typical camera has a field of view of only 35 x 50 degrees. Therefore, panoramic image mosaicing works by taking lots of pictures from an ordinary camera and stitching them together to form a composite image with a much larger field of view. The purpose of this paper is to present a survey about the feature-based image stitching. The main components of image stitching are described. A framework of a complete image stitching system based on feature-based approaches has been introduced. According to this research, there are many feature descriptors such as SIFT, SURF, HOG, GLOH, PCA-SIFT, Pyramidal HOG (PHOG), and Pyramidal Histogram of Visual Words (PHOW). Some of them are described in detail. Finally, the current challenges of image stitching process have also been discussed in this paper (Ebtsam, Mohammed & Hazem 2014). This paper uses a methodical approach. Actually, it elaborates the concept of feature-based techniques with more details. Levin and Weiss introduce the idea of having a quality panorama image by the evaluation of the techniques used for image stitching. Then, it explains how to measure the quality of image stitching. There, it focuses two area: the similarity of the stitched image to each of the input images and the visibility of the seam between the stitched images. The aim of a stitching algorithm is to produce a visually plausible mosaic with these two desirable properties. Accordingly, the stitched image should be as similar as possible to the input images both geometrically and photometrically and the seam between the stitched images should be invisible. It had been presented several cost functions for these requirements and define the mosaic image as their optimum (Anat Levin & Weiss 2000). Mikolajczyk & Schmid, proposed a method to compare the performance of descriptors for local interested regions. It was calculated for different image transformations such as rotation, scale change, view point change, image blur, JPEG compression and illumination change. Further, experiment was done for the interest region descriptors in the presence of real geometric and photometric transformations. At the experiment, GLOW (Gradient Location and Orientation Histogram) obtains the best results followed by SIFT (Mikolajczyk & Schmid, 2005). Balntas et al. have identified and demonstrated that the existing dataset and evaluation protocols regarding the benchmark have led to the inconsistency in results in the literature. So they have proposed a new public benchmark for local descriptors. They have mentioned that the new benchmark would enable the community to gain new insights since it is more significantly large than any existing dataset in the field (Balntas et al. 2017). Srishty, Utkarsh & Rajat present that the effectiveness of image stitching depends on the overlap removal, matching of the intensity of images and the techniques used for blending the image. In this paper, the various techniques used for image stitching and their applications in the relative places have been reviewed. Intensity-based and Feature-based methods have been discussed. One of the methods called coherent image joining using slope field techniques is also discussed. In this image stitching method, slope that is the change in the intensity between the points of the images is taken into consideration to combine two images. Accordingly, gradient domain or intensity domain can be used depending on the type of the application required. Two versions (GIST1&, GIST2) of

gradient domain algorithm GIST (Gradient-domain seamless stitching) were discussed in this paper (Srishty, Utkarsh & Rajat 2016).

Ryan Maponga presents that the image stitching has a lot of researches in the area of medical imaging, computer vision, satellite imaging and video conferencing. It talks about two main approaches: direct method and feature-based method. Direct approach utilizes all the pixels of the image but it has disadvantages such as quite inflexible and greatly affected by exposure differences of the same object in different images to be stitched. Furthermore, it is undesirable for real time applications as it performs slowly and need a lot of initialization which means there must be lot of human interactions to make sure the stitching occurs correctly. Feature-based technique performs better depending on what exactly feature-based technique was implemented. Several techniques such as SIFT, SURF and PHOW were discussed. Advantages and Disadvantages were discussed (Ryan Maponga 2017). Khan, Maqsood & Khan Present that the idea of Image mosaicing is considered as an active research area in the fields of computer vision and computer graphics. It describes a large number of different algorithms for features detection and description. In this paper, it is studied image stitching technique called SIFT algorithm which is rotation, scale invariant as well as more effective in presence of noise. However, it needs high computational time. Further, the SURF algorithm is studied and it is invariance for execution time and illumination and the ORB algorithm which is rotation and scale invariant with improved execution time but its performance is poor in presence of noise (Khan, Maqsood & Khan 2015). Praveena & Menaka present that many methods of image stitching require almost precise intersects between images and identical illumination to get picture perfect outcomes. Further, it says that Image stitching and video stitching are the current research area in the fields of computer vision, computer graphics and Photographic. This paper outlines the aspects of Image and Video stitching techniques, different process stages and approaches adapted, along with different views of those areas. Video stitching techniques such as Registration, calibration and Blending are also highlighted in this paper (Praveena & Menaka 2016). Patil & Gohatre present various techniques for the process of image stitching under various light conditions. Results obtained shows that for the day light condition SIFT works better and for night light condition it is shown that Harris / Hessian detector performs better than SIFT detector (Patil & Gohatre 2017).

2.5 **Literature Review on conservation of objects through other techniques**

Don Williams, Williyamson, Peter D Burns discuss about post-processing solutions for creating quality digital images by combining captured portions of objects. Further, some alternative approaches such as robotic systems and some linear array scanners that is moved through the large images by stitching image components were also discussed. Even though they are high accurate, they are high expensive systems. This paper talks about digitization environment which affects the post-processing for the stitching procedure. Furthermore, it elaborates basic operations for image stitching and some software tools that can be used for panorama creation (Don Williams, Williyamson & Peter D Burns 2013). This paper is more important in terms of getting idea for alternative approaches for image stitching. It is really important to consider the digitization environment and the software tools which can be used for panorama creation in this research. Sarlin et al. have presented a new way to think about the feature matching problem. In most of the above applications, methods have been used by using local feature detecting and matching for stitching technique. But, in this paper, idea has been changed to use novel neural architecture to learn the matching process from pre-existing local features (Sarlin et al. 2020).

2.6 **Findings of the literature review**

At the analysis of the findings, authors were able to identify main four important findings. Image stitching technique was identified for the digitization of 2D artifacts for conservation. Further, panoramic image is an application of this technique. There are two main approaches for stitching called direct methods and feature based methods. Literature review says that feature based approach is used in most of the applications in modern stitching operations as it has several methods which are more efficient and reliable in most of the applications. Furthermore, literature review reveals that there are several software tools available to facilitate panoramic image creation and depending on the requirement of the application and the availability of the software program, user has to select the suitable tool.

2.6.1 Image Stitching

As the results of the literature review, Authors were able to discover some theories behind the conservation of 2D artifacts. It was found that panoramic image creation is an application of image stitching technology which is the main technique of 2D image digitization. In the literature review, Authors were able to research on this technique as the initiative for the purpose of understanding of how to create such panoramic image for different 2D artifact. It was revealed that image stitching is the process that is used for panorama creation. Image stitching is an inevitable process in this application as well as some other applications such as medical imaging, satellite imaging and video compression (Hau et al. 2009; Savita & Reecha, 2014). In this process, it is required to concentrate some important aspects to get a quality output such as the angle of projection of light, the intensity of the pixels, exposure towards the light and the alignment of the images.

2.6.2 Approaches for image stitching

There are two main approaches used for image stitching called direct methods and feature based methods (Srishty et al. 2016). In direct methods, all the pixel intensities of the images will be compared each other. Therefore, it is computationally complex as it requires to compare each pixel window to other. But there is an advantage in terms of making use of all the information available by measuring the contribution of every pixel of the image. Disadvantage is not invariant for image scale and rotation and has limited range of convergence. 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 is established a correspondence between points, lines, edges / corners or other entities of the image. One of the important things is to consider whether the local descriptor is invariant to image noise, blur, scale and rotation. Panoram**ic** image creating can be digramically shown as in figure 02.
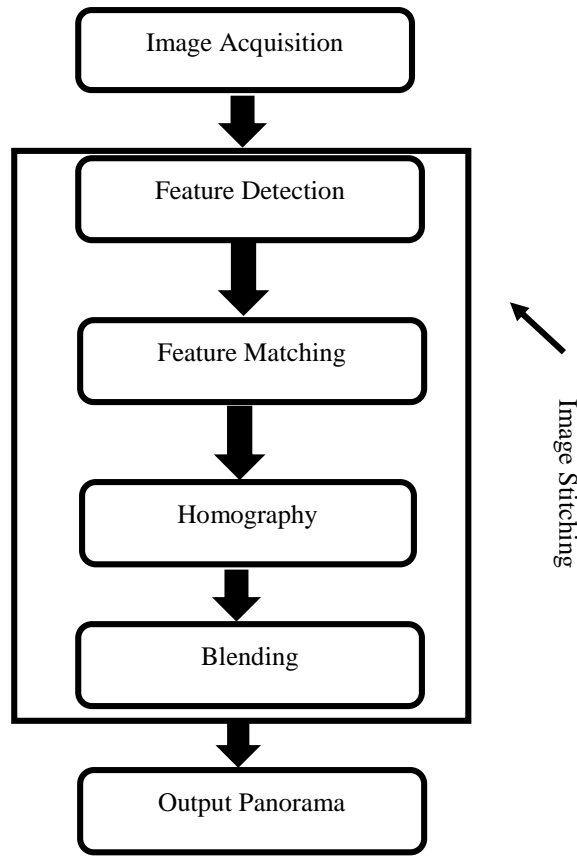
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Figure 02. Steps for panorama image creation

Image acquisition

First step in the panorama image creation. This is the process of retrieving images from the sources. After images are taken, various processing methods are applied to obtain a quality product. As a prior requirement, acquired images are assumed to have enough overlapping to combine them to form the final product.

Feature detection and feature matching

These are the main steps of image stitching process. Actually, features of the image are the elements of the particular image. Basic idea is to consider special points in the image (not the whole image) by applying feature detection methods (Ebtsam et al. 2014). There are key point (feature) detection methods such as Harris detector. In this case, speed at which the features in an image are detected is crucial for some applications. Detected feature points are needed to be described separately so that the correspondence between multiple views can be computed reliably and efficiently. Edges or corners of image pairs are better features for sufficiently matching. Local feature descriptors describe a pixel in an image with its local content (Ebtsam et al. 2014). Some key point descriptors can be indicated as Scale Invariant Feature Transform (SIFT), Speeded Up Robust Features (SURF), Features from Accelerated Segment Test (FAST), Binary Robust Independent Elementary Features (BRIEF), Oriented FAST and Rotated BRIEF(ORB). Following table 1 shows description, advantages and drawbacks of feature detectors / descriptors

Table 1. Description, advantages and drawbacks of feature detectors / descriptors

Key point detectors /descriptors	Description	Advantages	Draw backs
Harris detector	Key point detector Mathematical operator that finds key points in an image	It is simple to compute, and is fast enough to work on computers	It is not invariant to scale
Scale Invariant Feature Transform (SIFT)	Detect interesting key points using difference of Gaussion method (areas of image where variation excepts a certain threshold) Create vector descriptor	Robust matching technique as Scale invariant, rotation invariant and intensity change invariant Quite effective	Not invariant to light color change Too big when storing each SIFT (128 dimensions). So, computationally expensive
Speeded Up Robust Features (SURF)	Feature descriptor Detect interesting key points using the Hessian approach. It uses Hessian Matrix approximation and the sum of Haar Wavelet responses for orientation assignment	Developed to improve the speed of a scale invariance feature detection	
Features from Accelerated Segment Test (FAST)	Key point detection only	Can be efficiently used in real time applications	
Binary Robust Independent Elementary Features (BRIEF)	Feature descriptor	Computes feature descriptor quickly than SIFT and SURF Recommended for very fast applications	
Oriented FAST and Rotated BRIEF(ORB)	Combines both FAST and BRIEF Developed in OpenCV Lab		

According to the above comparison, it can conclude that SIFT technique is robust and effective in the presence of noise. Specially, when we are looking at the 2D artefact available in Sri Lanka, we can observe that there are quality issues as a result of existing some noises and distortions. So, if any digital applications which are used to conserve them should be applied a suitable type of techniques such as SIFT. Therefore, that technique can be recommended for any application. Further, techniques such as BRIEF, FAST and Rotated BRIEF (ORB) can also be recommended

for the development of any stitching operations depending on the required robustness, accuracy, speed, effectiveness and the type application(real time or not).

Homography
After detection of features, this information is used for image matching. The main idea of image matching is to find out which pixel is neighbor of another pixel and find the correctly feature matching set for that image. RANSAC algorithm is used to estimate parameters for homography matrix of a mathematical model and eliminate outliers (wrong matching points) from a set of observed data (Matthew & David 2007). In the literature review, RANSAC algorithm was identified as a suitable method to estimate parameters of a mathematical model from a set of observed data which contains outliers. It is an iterative and probabilistic algorithm in the sense that it produces a reasonable result only with a certain probability.

Blending
The final step of panoramic image creation is blending these images together. Many different pixel blending methods are available. Two popular methods of blending the images are alpha blending and Gaussian pyramid. Alpha blending takes weighted average of two images. Comparing these two, alpha blending works extremely well when image pixels are well aligned to each other and the only difference between two images is the overall intensity shift and it will merge two images seamlessly. Gaussian pyramid approach, essentially merges the images at different frequency bands and filters them accordingly. Further, it is needed to choose a compositing surface such as flat, cylindrical and then decide how to blend these images to form an attractive panorama.

2.6.3 Software tools and features

Some popular commercially supported tools for image stitching applications are Hugin, Autopano Pro, PTGUI Pro, Adobe Lightroom Classic CC, ArcSoft Panorama Maker, Panoweaver, Kolor Autopano, Affinity Photo, GigaPan Stitch, Microsoft ICE, iFoto Stitcher, PhotoStitcher, WidsMob Panorama, Pixtra PanoStitcher, PhotoFit Harmony, PTAssembler, autostitch, Panorama Tools, Image composite Editor, Adobe photoshop CC and OpenCV. Following table 2 will show the pros and cons of some of the tools.

Table 2. Pros and Cons of some software tools

Software Tools	Pros	Cons
Hugin	Hugin has now reached a stable state: the software is recommended for general use Can be used in Windows, MacOS and Unix Free versions available	
Adobe Lightroom Classic CC	A wide range of tools for picture editing 1TB of cloud storage	Paid subscription

	Possibility to change pictures with Photoshop	
Adobe photoshop CC	An impressive toolkit for design

Excellent software for image manipulations and photo retouching

Edit not just photos | Not designed particularly for stitching purposes |
| PTGUI Pro | Runs on Windows and MacOS, being a good multiplatform option
Allows creating gigapixel pictures

Capability to import hundreds of files and stitch together several panoramas simultaneously

Supports most image formats including RAW and has a large variety of export formats | Mac support is offered only to PCs powered by Intel CPUs

Offered control point technique requires time and patience when working with dozens of photographs stitching

Can be a bit too complex

Too high price for personal use |
| Autopano Pro | Multiplatform support

Trial version available

Innovative functions like distortion correction

Several blending modes | Isn't beginner-friendly |
| ArcSoft Panorama Maker | Full-screen previews

Photo and video editing functions

Several exports option

RAW files support | Doesn't provide options for editing raw image |

Panoweaver	Can easily switch between different panorama modes Software allows you to export and save stitched photographs in a broad array of formats	• Stitching often lacks precision • • The price is too high in comparison to other options
Kolor Autopano	• Exposure settings and color blending modes • • Panoramic recognition • • Freehand shooting support	Stability issues

Reference: http://fixthephoto.com/best-photo-stitching-software.html

According to the pros and cons of these software tools, user has to evaluate the type of software tools with respect to the critical facotors such as the platform to be used, precision required, processing time, flexibility of the tool, purchasing cost, reliability and the availability of the tool before taking the decision of the suitable tool for the application required for creating panoramas. At the literature review, it was identified that there are various types of software tools (some of them as showing in table 02) for the creation of panoramic images. But the majority of the software are commercial oriented tools and highly expensive. Some examples are Autopano Pro, PTGUI Pro, Adobe Lightroom Classic CC. Further, some of the tools such as Autopano Pro, Panoweaver and Kolor Autopano are having issues in the areas of user friendliness, pression and stability. Therefore, requirement arises to find out available tools for the general applications which require the creation of the panoramic images. Photoshop is one of the available tool in the market which facilitates the creation of panoramic images. Hugin which is an open source software tool that facilitates the same feature.

3.0 Research Methodology

Qualitative approach was used in this research. Authors used qualitative data collection methods such as a survey, a case study and interviews in this research. A survey was done at the conservation unit of the Colombo museum for the purpose of identifying the techniques used for the conservation of historical resources. When Authors researched on a suitable case study to analyze, it was able to find the digital photos of Bellanwilla Temple murals developed by Lal Hegoda. Those digital photos were taken as the case study to analyze the techniques used for the conservation of two-dimensional artifacts. Interviews were held with Lal Hegoda and his team to identify the background details of the conservation of artifacts. Digital images of the murals in Bellanwila Temple documented by Lal Hegoda were deeply analyzed theoretically and technically as the main case study to identify the techniques used for the process of conservation of two-dimensional artifacts.

3.1 Survey done at the conservation unit of the Colombo Museum

Authors conducted a survey by designing a questionnaire in the area of conservation for the purpose of collecting data in that area. Further, Authors were able to conduct interviews / direct discussions to get more details at the Colombo Museum which is one of the important places in Sri Lanka where historical and valuable artifacts have been kept for safeguarding them for the next generation. The questionnaire, interviews and discussions were mainly based on several areas such as the attitude level of museum staff for the task of conservation, type of artifacts available for the conservation, general preservation / conservation techniques available, factors which are directly affected for the deterioration of artifacts, specific restoration methods used for damaged artifacts, resources allocated for conservation process, ongoing programmes available for acknowledging new techniques, main issues (critical problems) identified in this area, usage of advanced techniques for the process of preservation/conservation and the initiatives taken by them to use digital technology for conservation.

3.2 Case Study: Digital images of murals in Bellanwila Temple developed by Lal Hegoda

Bellanwila Temple is considered as a place of great sanctity and veneration due to its sacred Bodhi Tree. An important and valuable addition to the temple is the mural set that adorn the inner walls of the shrine hall (Bellanwila Rajamaha Viharaya 2019).Those murals painted by the artist Somabandu Vidyapathy in the duration 1990 – 1998 depict in different strokes the life of the Buddha and Buddhism. In this research, digital images of Bellanwila Temple murals developed by Lal Hegoda were taken as a case study. Four main murals and sixteen other paintings had been taken by him for digitization.

3.3 Interviews held with Lal Hegoda and his team members

Authors used interview method to discover the background details for the conservation of historical artifacts in this case study. Accordingly, it was able to interview Lal Hegoda and some of his team members who gave their contribution to shoot mural paintings and to develop final products of digital images by using a computer software.

4.0 Analysis of Data

4.1 Analysis of survey data

Collected qualitative data were analyzed. At the analysis, authors were able to find the nature of artifacts / objects, factors of deterioration, the concept of preservation and the technology used for the conservation. All the objects can be mainly classified into two broad categories as inorganic and organic. Accordingly, stone, ceramic, porcelain are of inorganic nature and wood, leather, paper, textiles with other objects derived from living being and plants are organic. At the same time there can be many objects that containing both inorganic and organic parts. Due to this nature of object, organic materials are needed a greater care for the preservation than inorganic materials. There are varies deterioration factors that affect for the two-dimensional artworks. They can broadly be categorized as climate factors, chemical factors and biological factors. This main three categories can be further elaborated as shown below. Chemical factors include climate condition,

light, atmospheric pollution and the biological factors include fungi, insects. Furthermore, Physical factors include accidental damage, scratch. It was identified that these factors must be controlled by analyzing the environmental conditions in case of chemical factors. Accordingly, temperature, humidity and the day light are harmonious if they are not controlled using standard values that were recommended by the conservators. Further, fungi, insects are always ready to attack especially organic type of objects and their damages can be managed by using some prescribed chemicals as well as using some traditional mechanisms used in Asian countries. In the conducted survey, it was identified that above factors are common for all type of art objects. Therefore, curators or the personnel have the responsibility to control the effect of them in the places where they are kept. Accordingly, depending on the type of materials of the objects there are certain standard set of values of temperature, humidity and lax value (light) that should be maintained for the preservation. The primary goal of preservation is to prolong the existence of cultural property. Some of the rich culturally important artifacts are considered as national heritage in any country. There can be different types of artworks such as sculpture, any artistic wooden object, textile, painting, manuscript under this category. According to the data collected, it was found that there is a requirement to preserve those items for not being corrupted or damaged. Currently, they are using some manual techniques to protect them in the places such as Museums in Sri Lanka and some other countries in Asia. Technology applied by them for the conservation depends on the type of the art objects to be restored. One of the important principles is to ensure the International Charter for the Conservation and Restoration of Monuments and Sites (International Charter for the Conservation and Restoration of Monuments and Sites (ICOMOS); The Australia ICOMOS Charter for Places of Cultural Significance, the Burra Charter). It means that any conservation techniques should ensure that conserved object can be brought to the original state before conservation without loss of the informational content of the objects. Therefore, any materials that are thick in nature such as concrete are not used for the restoration in case of inorganic objects. At the same time any chemical which are harmonious to the object such as acid are not used for the restoration. Always, they start with the level of distil water liquids in case of cleaning any dust or damaged area of the artifact especially for the organic type of objects. The reason behind this method is to avoid the prolong damage of the information or the surface due to the applied chemical for the purpose of restoration the error of the artifact. It was identified that resources allocated in terms of human, equipment, materials and technology are not enough to fulfil a quality service to satisfy the national requirement. Further, it was noted that having some link programmes with other countries like India to update the technological knowledge of the personnel in the subject area is very important for the management of this type of places such as museums.

4.2 Analysis of the case study

At the analysis of the selected case study, it had been identified that the application of digital technology would be more suitable as a mechanism to conserve artifacts (murals) for the nation. But, there were some critical issues that prevent digitization of murals such as the difficulty to cover the entire area of some murals due to very large size (more than 30 feet length / width) at the shooting process, no sufficient background space in the temple to focus them correctly and the availability of natural and turnstone lights mixture within the temple area that is seriously affected to get actual existing color and contrast of the mural. Therefore, a special approach was required to minimize the above issues and to obtain digital images with all existing details such as color, contrast while stopping the image distortion and color unbalance. In this scenario, the idea of panoramic image (Sruthi & Sruthi 2017) was used to avoid identified first and second issues. It is

an image which is created by combining overlapping set of images using defined techniques through a computer software. Accordingly, a sequence of overlapping images (segments of a large mural) was created instead of focusing the entire mural at once. For that process, each and every segments of the artifact were focused separately to get overlapped set of digital images for the purpose of producing a panoramic image of the mural. As a solution for the third issue, it was proposed to do some photo shootings in the night with the condition of balanced background day light. Finally, all the segments were merged to produce the full image with all required details using Photoshop software. Again, there were two major difficulties in this panoramic image creation. First one is to face merging issues of image segments and the second one is the color distortion. Therefore, an alternative method had been used in the photo shooting procedure by using a gray scale card in foreground of each and every segments of the image. Accordingly, color distortion was minimized by balancing all the image segments to the level of known gray foreground color.

4.3 Analysis of interview data

According to the collected details in interviews, it was found that due to the water leakage from the roof of the Bellanwila Temple to the murals on the wall of 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 conserve them for the next generation. Further, at the interview, it was revealed that keeping the camera parallel to the wall and the ground to avoid merging issues at the panorama creation. Further, as far as photography is concerned, although the actual color of the image is stored correctly in the sensor of the digital camera, printing process doesn't confirm the output of actual color of the image without color distortion.

5.0 Results and Discussion

Identified issues in the area of digitization for conservation

According to the qualitative analysis results of the survey and the case study, authors have identified several issues which are directly affect to the area of conservation of 2D artefact through digital technology. One of the issues is that there are difficulties to access past details of the artifact in the conservation process. This will result some difficulties to search required details related to any activity in the conservation process. Another issue is non-existing of digital repositories of 2D archived artefact and the lack of digitized documentation. Also, there is a difficulty to apply the conservation techniques for large scale 2D artefact due to not having a suitable technique for that. Furthermore, there is a common issues in the developing countries like Sri Lanka not adapting advanced techniques for the conservation process. Even though, such techniques are available in developed countries, there are less appropriate researches which are going on how to apply those techniques for the conservation process to replace the existing mechanisms.

Another three main issues were identified related to the case study analysis. It was clear that mural paintings of Bellenwila Viharaya were digitized and final outcome was achieved with a tiresome effort within a considerable long period of time and a manpower. This issues will prevent the sustainability of the process which is really affect to a methodical conservation procedure of the 2D artefacts conservation in the temples and other historical places in Sri Lanka. There is another side effect of this tiresome effort having some quality issues of the final outputs due to varies

difficulties of getting individual segments of the murals. Furthermore, authors have identified that there is no thorough study of panorama creation methods, tools and techniques in the selected case study. Photoshop software has been just used for developing final output without searching and comparing other suitable approaches, techniques and theories which are giving insights and proper foundation to apply the digitization process for the panorama creation technique. In this case study, another issue is not having a digital repository consisting of digital achieves of mural paintings and documentations for the usage of researchers, artists or any other interested party. Another crucial issue which was identified in the case study was the difficulty to apply the conservation techniques for large scale 2D artefacts.

6.0 Conclusion and Future Enhancements

In this paper, results of the literature review, survey, case study and interviews were presented. Specially, literature review was presented by including several existing researches in different related areas by evaluating and accessing the techniques, tools and theories. Authors identified issues in the area of digitization for conservation in different perspectives in the qualitative data analysis of survey, case study and interview. Further, Authors were able to identify the algorithms, advantages and drawbacks of the techniques applied for image stitching. Moreover, it was identified software tools used for creation of panorama with the features and limitations of them. There, it was identified that the majority of the software tools are commercial oriented and they are not available for general application development. At the analysis of the collected data, it had been identified that the application of digital technology is more suitable as an approaches to conserve artifacts (murals) for the nation. Further, Authors observed and concluded the requirement of this type of a research which fulfil the capability to apply the findings for the area of digitization for conservation to overcome the identified issues. As a future enhancement of this research, It can be recommended that the proposing a simple method through digital technology is a crucial requirement in the area of 2D artefact conservation in Sri Lanka.

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