Timescape-Based Panoramic View for Historic Landmarks

H. Ali, A. Whitehead

Abstract**—**Providing a panoramic view of famous landmarks around the world offers artistic and historic value for historians, tourists, and researchers. Exploring the history of famous landmarks by presenting a comprehensive view of a temporal panorama merged with geographical and historical information presents a unique challenge of dealing with images that span a long period, from the 1800's up to the present. This work presents the concept of temporal panorama through a timeline display of aligned historic and modern images for many famous landmarks. Utilization of this panorama requires a collection of hundreds of thousands of landmark images from the Internet comprised of historic images and modern images of the digital age. These images have to be classified for subset selection to keep the more suitable images that chronologically document a landmark's history. Processing of historic images captured using older analog technology under various different capturing conditions represents a big challenge when they have to be used with modern digital images. Successful processing of historic images to prepare them for next steps of temporal panorama creation represents an active contribution in cultural heritage preservation through the fulfillment of one of UNESCO goals in preservation and displaying famous worldwide landmarks.

Keywords**—**Cultural heritage, image registration, image subset selection, registered image similarity, temporal panorama, timescapes.

I. Introduction

EFFORTS of archeologists and historians to discover and maintain historical sites have been widely varied through time with dramatic changes in technology and other scientific developments. In the field of cultural and human heritage, researchers have benefited greatly from advances in multimedia storage and processing techniques. Technology evolution and wide spread huge storage capabilities combined with high resolution scanning and displays provide an excellent means to preserve and share the cultural heritage. This paper establishes a means to integrate the temporal panorama concept with the historical documentation of a landmark in a novel temporal panoramic concept we dub as a timescape.

Timescapes

The aim of time travel has been the realm of science fiction writers often realized by sending a person through time to revisit locations in the past. While the ultimate goal of time travel remains elusive, a substantially smaller subset of this vision may be realized by bringing instances of the past to the time traveler. Recordings of various instances of images of landmarks captured by photographers provide such an alternative. Rather than send a person to a specific location in time, we examine what happens when discrete events in time; images, videos, and other media, are delivered to a person [1]. On the massive scale, we aim to bring a complete timeline to people that is predicated on their geographic location on the planet. This will provide answers to the user about what happened in the past in the place they are currently standing by reviewing an entire timeline of information [2].

A contextual bond of space and time is facilitated through the access of historical layers allowing one to visualize the history of this place. We call this experience a timescape [2]. Timescapes can be made conceivable with any measure of content, sound, video, in various mixed media introduced [2]. The possibility of a timescape does not need to be constrained to pictures that can be outwardly adjusted. Images of related documents and textual explanations can also be provided. To conclude, the timescape is a coherent linear timeline presentation and must be in chronological order. A showcase of arbitrarily requested chronicled certainties or records is lacking to be considered a timescape as it would not present an intelligible vista through time [2]. This work presents a system of the registration and alignment of image content for timescape presentations of many famous landmarks around the world.

The concept of a timescape does not need to be constrained to pictures that can be outwardly adjusted [2]. Images of related documents and textual explanations can also be provided. To conclude, the timescape is an intelligent straight course of events show and must be in sequential request. A showcase of haphazardly requested authentic realities or records is inadequate to be considered a timescape as it would not present an intelligent vista through time [2]. This work presents a system of the registration and alignment of image content for timescape presentations of many famous landmarks around the world.

Panoramas

Panorama, in its comprehensive concept can strongly contribute to cultural heritage documentation, preservation, and sharing [3]–[5]. In this work, hundreds of thousands of historic and modern images have been collected and efficiently processed to present a temporal panorama.

This has been demonstrated through an integrated system based on the concept of timescapes and a high quality historic to modern image registration technique. This work contributes

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in cultural heritage efforts and fulfills one of the UNESCO goals in cultural heritage preservation.

The term panorama in its common meaning refers to a wide-ranging view of space or location. The formal definition of the term panorama in the Oxford Dictionary encapsulates two main concepts: time and space [16]. The first concept as “an unbroken view of the whole region surrounding an observer” [16] orchestrates the spatial sense of the viewer, while the second concept as “a complete survey or presentation of a subject or sequence of events” [16] combines both the spatial sense by referring to the subject as well as the temporal sequence of events presented to the viewer. We next describe the different panorama types with a review of panorama literature.

II. Background and Related Work

Panoramic view building and display research has been given special interest from researchers. We classify our preview of related work to three main categories: panorama systems, large data set classification for subset selection, and the image aligning and preparation for panorama display.

Panorama Building

The developing and building of a comprehensive view of locations which includes historic landmarks have motivated historians, archeologists, and computer vision researchers to integrate spatial and temporal panorama systems.

Creating 2D or 3D spatial panoramas have traditionally received the bulk of researchers’ effort [10]. Martin-Brualla et al. [11] built and showed a high quality video created using photos captured in the period 2005 to 2015 by modern digital capture techniques, while [10] constructed 3D panorama for many scenes in Rome in a mosaic base. Whitehead et al. [2] merged the geographic information of the GPS system with alpha-blended images from available media to offer history exploration through the timescape concept. The difficult task of building temporal panoramas with historical and modern photographs has not been examined in detail.

Image Subset Selection

The selection of image subsets from a larger set depends widely on the image type and contents. Thorough analysis of image contents has to be done to extract the salient features and characteristics that are common in an image set [12]. This extraction depends on the conditions under which the image was taken [13]. Traditional image set selection and classification mainly relies on the analysis of the low-level features of the image to determine high-level content semantics [14]. To optimize the feature detection and extraction process, the researchers have worked to support their efforts using non-traditional techniques. Machine learning techniques like artificial neural networks (ANN) has obtained popularity in image subset selection [15].

Image Alignment

We aim to present registered modern and historical images in a precise way, overcoming the difficulties of different capture environments such as illumination change, variations of scale and rotation, multiple viewpoints, and differing capture technologies. Image registration represents an important method that has many applications in computer vision, aerial sensing and medical applications [1]. Ma et al. [16] implemented an automatic image registration of multi-angle CHRIS/Proba data on satellite images using the normalized cross correlation (NCC) to define a non-rigid thin-plate spline model, while [17] worked on a set-based registration of aerial images through constraint graphs optimization of pairwise image registration. Optical flow [18] and stereo based [19] methods were used on the computation of the correspondence between images to extract the brightness constancy assumption.

III. System Structure

In this work, our main objective is to introduce and develop techniques that facilitates the new panorama concept known as a timescape. Our contribution is to participate effectively in cultural heritage preservation via the implementation of a timelined image display of historic and modern images of many landmarks around the world with a temporal panoramic view of these landmarks that merges geographical and historical information.

Cultural Heritage Preservation

The cultural heritage is the legacy of sites, groups, or societies for tangible or intangible attributes which is inherited from past generations, maintained in the present, and safely entrusted for the future generations [20]. All tangible attributes (such as buildings, landscapes, books, and artefacts) and intangible attributes (such as folklore, traditions, language, and knowledge) have to be preserved from the past and presented to the future with a reasonably acceptable reputation; this is known as cultural heritage preservation [20]. Since these objects; tangible and intangible, represent part of the study of history, the preservation process determines the importance of the past and the cultural objects that can validate the history [21].

As a part of the UNESCO interest in the world cultural heritage, five things were noted that highly help in the preservation of cultural heritage [22]:

- Partner: Any person or organization can be a UNESCO partner and get involved in preservation activities.
- Volunteer: participate in the volunteering or interning programs of the UNESCO.
- Travel: Respecting global or local culture sites and customs by participating sustainable tourism that do not damage sites through visiting.
- Spread Awareness: Participate in preservation process by introducing and sharing multimedia, news, or links through social networking or public sharing websites.
- Donate: Financial support through donations is important to support these projects.

Our participation is to spread awareness and to stimulate virtual visitation opportunities by presenting a cultural heritage site or object through technology by introducing and implementing a timescape display of many famous landmarks around the world. Moreover, we have created a precise method for processing historic images of these landmarks (captured with old analog cameras and subsequently digitized) in order to combine them with modern images (captured with modern digital cameras) to produce a timescapes display.

System Overview

To realize the above objectives, a system has been designed, implemented, and tested. The system overview is shown in Fig. 1.

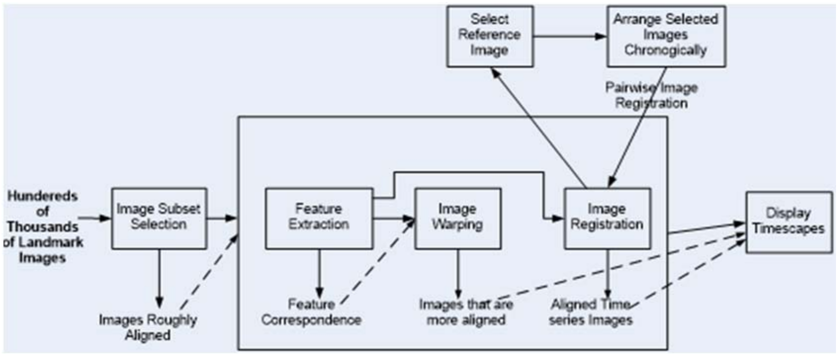

Fig. 1 System structure to implement timescape panorama

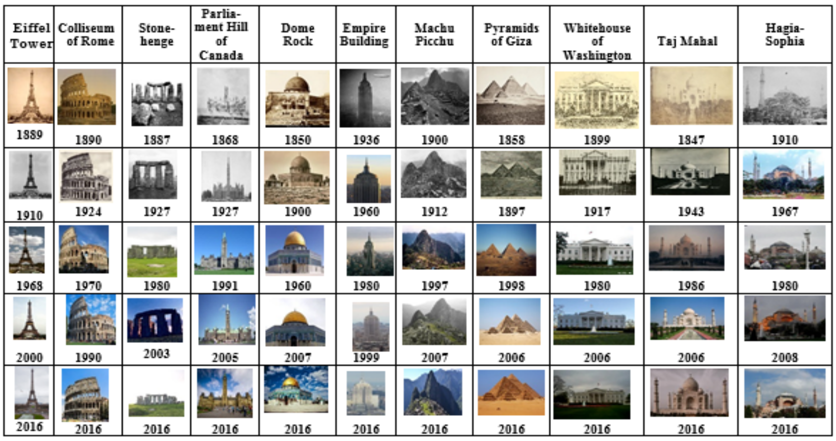

Fig. 2 Samples of the image data sets for the 11 landmark images containing mix of historic and modern images

IV. Image Subset Selection

A programmed technique for the defining and picking up of subsets of pictures, both current and memorable, out of an arrangement of milestone extensive pictures is performed in this progression. This choice relies upon the extraction of predominant highlights utilizing Gabor separating. Highlights are chosen painstakingly from a fundamental picture set and sustained into a neural system as preparing as training data then processes these images to classify them as landmark and non-landmark images [12].

Timelined-Based Image Data Set

A system has been developed to classify the captured images and select highly relevant images of these landmarks. This process kept many hundreds of images for each landmark in chronological order with many images belonging to the same year in the data set. The best image from each year that fit the required viewpoint was selected. Dozens of historic and modern images for each landmark; between 21 to 79 images of an era represent the core photo set to be processed in the next step: creating a high quality timescape. Samples of these images are shown in Fig. 2.

Gabor Filters

Gabor filters depend on the Gabor wavelets which are framed from a complex sinusoidal transporter set under a Gaussian envelope. These wavelets depend on the Gabor rudimentary unction displayed by D. Gabor in 1946 [23]. Numerous types of the 2-D Gabor filter have been introduced. The 2-D Gabor filter G(x, y) can be defined as [24]:

$$G(x,y)=e^{-\left(\alpha^2 x_p^2+\beta^2 y_p^2\right)}\, e^{j2\pi f_0 x_p} \qquad (1)$$

where α is the time duration of the Gaussian envelope and the plane wave, f_0 is the frequency of the carrier, $x_p = x\cos\theta + y\sin\theta$, $y_p = -x\sin\theta + y\cos\theta$ and θ and β are the sharpness values of the major and minor axes of the Gaussian envelope. Fig. 3 summarizes the feature extraction process [12].

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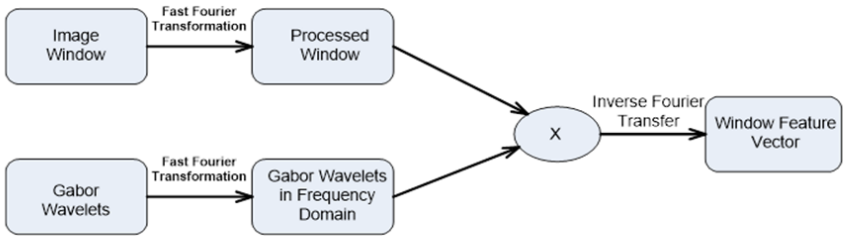

Fig. 3 Feature Extraction Process

Neural Networks

A multi-layer feed-forward neural system has been utilized in preparing an informational collection on info designs. A three-layer arrangement was utilized: the info layer, a shrouded layer and the yield layer. For the info layer, the information highlight vectors originate from the Gabor channel include extraction arrange portrayed beforehand and comprises of 100 neurons connected to the neural system. A solitary example p to be tried or bolstered to the neural system can be considered as a vertical vector of components (highlights). At that point t is known as the objective for this example and you need to realize t ahead of time and to utilize it alongside its conjugate example with the end goal of system preparing.

In the preparation period of the neural system, two arrangements of pictures are connected; a component picture set and non-highlight picture set. The element picture set comprises of 100-150 pictures containing the element to be tried, while the non-highlight picture set is 50 non-include pictures. To encourage the arrangement procedure, all milestone pictures are contemplated precisely to choose the most astounding discernible highlights with Gabor separating to be the applicant highlights. For instance, the Eiffel Tower pictures contain two areas which are expected to have precisely discernible highlights.

The picture sets of these locales are bolstered into the neural system as the component picture set. For the Eiffel Tower milestone, the system yield neurons will be set to two [4]. These yields show up in a fundamentally unrelated premise, i.e. if the highlights exist in a picture, one of the yields will be more prominent than 0.8 or not exactly - 0.5 and the other way around.

V. Image Alignment

Image registration, alignment, and correspondence are central processes in computer vision, medical applications, and remote sensing imagery. The type and level of image alignment completely depends on the application. To prepare the historic and modern images of landmarks for a timescapes display, both image warping and registration have been examined. We present the result of image registration here.

Image Registration

Modern to historic image registration is a challenging problem due to difficulties of capture environments and the various technologies of cameras used to capture these images. For example, an early image is captured on a chemical plate with imprecise lenses and transferred to paper which has subsequently degraded over time before being digitized. Inspired by optical flow in which an image pair is aligned [25], and SIFT descriptor [26] are used to inspect the feature flow which is used to precisely register the images over a long timeline.

The SIFT descriptor [26] is calculated to facilitate a descriptor matching scheme which produces a general correspondence in a preregistration step. To optimize the correspondence search, a discrete optimization method is formulated through an energy function.

To construct the energy function of the SIFT descriptor flow three parts have to be considered. The data part of the function describes the SIFT descriptor to be matched with the flow vector [26].

$$E_{data}(\boldsymbol{f}) = \sum_{\boldsymbol{g}} \| \; sd_1(\boldsymbol{g}) - sd_2(\boldsymbol{g}+\boldsymbol{f}(\boldsymbol{g})) \; \|_1 \qquad (2)$$

where $\boldsymbol{g} = (x,y)$ are the coordinates of reference and sensed images, sd_1 and sd_2 are the descriptor of SIFT features for reference and sensed images, respectively.

The second constraint is the displacement data for the sensed image in order to find the optimal label for each pixel.

$$E_{displacement}(\boldsymbol{f}) = \sum_{\boldsymbol{g}} \eta \,(|\, u(\boldsymbol{g})| + v(\boldsymbol{g})| + \sum_{(\boldsymbol{g},\boldsymbol{q})\in\boldsymbol{\varepsilon}} \min(\alpha |u(\boldsymbol{g}) - u(\boldsymbol{q})|, d) \qquad (3)$$

where $\boldsymbol{f}(\boldsymbol{g}) = (u(\boldsymbol{g}), v(\boldsymbol{g}))$ is the flow vector at $\boldsymbol{g}$, the set ε contains the spatial vicinities, and η is the weighting factor, which measures how the point $\boldsymbol{g}$ contributes in the displacement field d [27]. The third is the smoothness constraint that controls the adjacent pixels to be similar [27],

$$E_{smoothness}(\boldsymbol{f}) = min\,(\alpha \,|\, v(\boldsymbol{g}) - v(\boldsymbol{q})|, d) \qquad (4)$$

The three parts comprise the energy function,

$$E\,(\boldsymbol{g}) = E_{data} + E_{displacement} + E_{smoothness} \qquad (5)$$

The efficient belief propagation optimization algorithm is basically a message passing algorithm, which performs inference on graphical models, applied efficiently for stereo matching [28] in a coarse-to-fine image registration process [29] and which is applied in this paper. In (2), the norm is used to catch and discard any outliers from SIFT matching stage, while the norm threshold d is used in (4) to account for pixel displacement field discontinuity.

Fig. 4 shows the registration process of two images of the Eiffel Tower set; the historic image was taken in 1889 and the digitization parameters are unknown. The modern image was taken in 2010 with a modern digital camera [1].

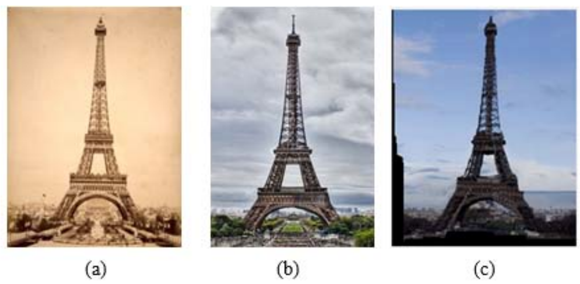

Fig. 4 Modern to historic image registration (a) Historic image from 1889 (b) Modern image from 2010 (c) Registered image

We believe that these results are quite good, and when standard techniques and existing software is used, the results are generally quite poor as shown in Fig. 6 row (c). This shows the results of registration process using two of the standard feature extraction and matching techniques SURF [30] and BRISK [9] applied on different images of (1) Coliseum of Rome, (2) Parliament Hill of Canada, (3) Stonehenge of England, and (4) Whitehouse of Washington.

Fig. 5 row (d) shows more registration examples of the different images of the landmark datasets for a mixed combination of historic and modern images using this paper's method. Images of row (1) show the technical differences between the two images which depicts the low quality of image from 1911, but the SIFT descriptors matched effectively along the flow vectors which produced better matching. Row (2) shows the variations of scale and viewpoint between the two images, while row (3) and row (4) show a matching process of images that are nearly using the same technology and are not that far apart in time and the registration results are quite good.

Registration Evaluation

The modern and historic images are put into a timescape presentation by first building a registration table for each image pair showing the precision of the registration process [8]. The SSIM measure between two windows x and y each of NxN size is:

$$SSIM = \frac{(2\mu_x \mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \tag{6}$$

where μ_x and μ_y are the average of x and y, respectively; σ_x^2 and σ_y^2 are the variance of x and y, respectively; c_1 and c_2 are two constants to stabilize the divisions with weak denominator.

The Root Mean Square Error (RMSE) calculates the differences between the predicted values (reference image) and the observed values (sensed image) and is widely used as a measure of accuracy [6]; the RMSE of two images x and y:

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(x_t - y_t)^2}{n}} \tag{7}$$

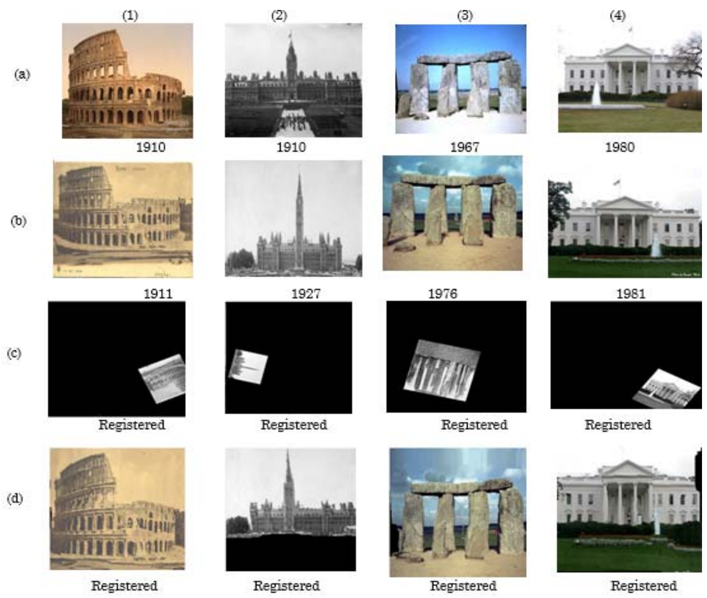

Fig. 5 Image registration using two standard feature extraction techniques SURF and BRISK applied on images of (1) Coliseum of Rome (2) Parliament Hill (3) Stonehenge (4) Whitehouse of Washington

VI. TIMELINED PANORAMA DISPLAY (TIMESCAPES)

The timelined panorama display, or timescape, presents the registered historic and modern images. To evaluate this work performance with existing software packages, three software packages have been applied on images from our datasets as shown in Fig. 6. Figs. 7 (a)-(c) show the poor images resulted from using various types of panorama software on images of landmarks dataset.

To display the registered images in timelined panorama display, the best reference image for the timescape has to be selected. An NxN table of registration errors is generated by registering each image to all the remaining images in the dataset.

To select the reference image for timescape, the following three equally weighted selection criterion were applied:

- The least registration error in all rows of lowest RMSE table.
- The least registration error image in all columns of the table.
- The minimum sum of the RMSEs of each column in the table.

The image that has the highest score using the above criterion will be selected as the reference image for the timescape presentation. The timescape continues to show a timeline of registered images of the landmark proceeding downward to old history or upward to modern years depending on the mouse scroll movement. The selection criterion has been applied on the image sets.

TABLE I
SIMILARITY TESTS USING RMSE AND SSMI APPLIED TO ALL LANDMARK DATA SETS

		RMSE			SSIM		
Land-mark	**No. of Images**	**% Registered Images with ≤ 0.25 % Error (Good)**	**% Registered Images with > 0.25 & <0.65 Error (Acceptable)**	**% Registered Images with > 0.65 % Error (Poor)**	**% Registered Images with ≥ 0.65 % Similarity (Good)**	**% Registered Images with < 0.65 && >0.35% Similarity (Acceptable)**	**% Registered Images with < 0.35 % Similarity (Poor)**
Eiffel Tower	45	67.1	31.1	1.7	60.3	27.2	12
Coliseum	51	74.9	25	0	74.7	22.8	2.4
Stonehenge	50	79.8	20.2	0	55.2	22.3	22.4
Parliament Hill	21	69.6	30.1	0.2	47.8	32.9	19.9
Dome Rock	33	48.8	20.3	30.7	36,8	27.4	35.7
Empire Building	79	68.9	11.3	19.7	51.4	25.8	22.7
Machu Picchu	35	65.5	15.1	19.2	54.3	20.6	45.6
Pyramids of Giza	31	53.9	21.3	24.7	52.5	22.4	24.9
White-House	50	54	22.1	23.8	48.7	20.4	30.8
Taj Mahal	24	56.9	14.5	28.4	56.2	13.3	30.3
Hagia Sophia	38	69.3	15.6	15.6	48.5	15.7	42.6

Fig. 6 Panorama software used on modern and historic images (a) PTGui Panorama Software used with images of Parliament Hill of Canada (b) ArcSoft Panorama maker used with images of Coliseum of Rome (c) Autopano Giga Panorama software on the Whitehouse images

A timescape panoramic display in chronological order displays the registered images by moving deeper into history or forward towards the present through mouse scrolling. This interface provides historical information (and change over time) about the landmark from the same viewpoint and important kind of contextual historical information.

User Experience

The implemented timescape image panorama offers an opportunity to the user to explore a number of famous landmarks around the world. The exploration could be used by the user through the possibility to select certain landmark from a given menu. The demonstration website [7] enables the user to explore the historical landmarks panorama.

To start the navigation, locate the mouse cursor on the upper image of the landmark and start navigation by moving the mouse wheel. To explore the older images, move the mouse wheel up. To go to recent years, move the mouse wheel down. Fig. 7 shows a screenshot of the timescape panorama for Machu Picchu landmark.

VII. CONCLUSIONS

This system aims to create a temporal panoramic display; timescapes, exploiting the available multimedia resources and providing an exploring means to the users to experience the deep history and linking of modern events and circumstances with historic ones. This linkage requires the collection of huge amount of videos, photos, paintings, and/or documents which represents a real challenge to extract the most suitable media to this project.

To our knowledge, this is the first automated system which offers an opportunity for the historians and researchers to merge the historic view with the geographic information. A high-quality image registration was performed using optical flow of SIFT features which resulted in better matching and registration that overcomes the difficulties of the data set which includes the traditional registration complexities such as illumination and geometric issues, but also the technological differences in the capture processes. This work contributes in the efforts of maintaining the cultural heritage by successfully generating timescape presentations of the media of historic landmarks and places from around the world.

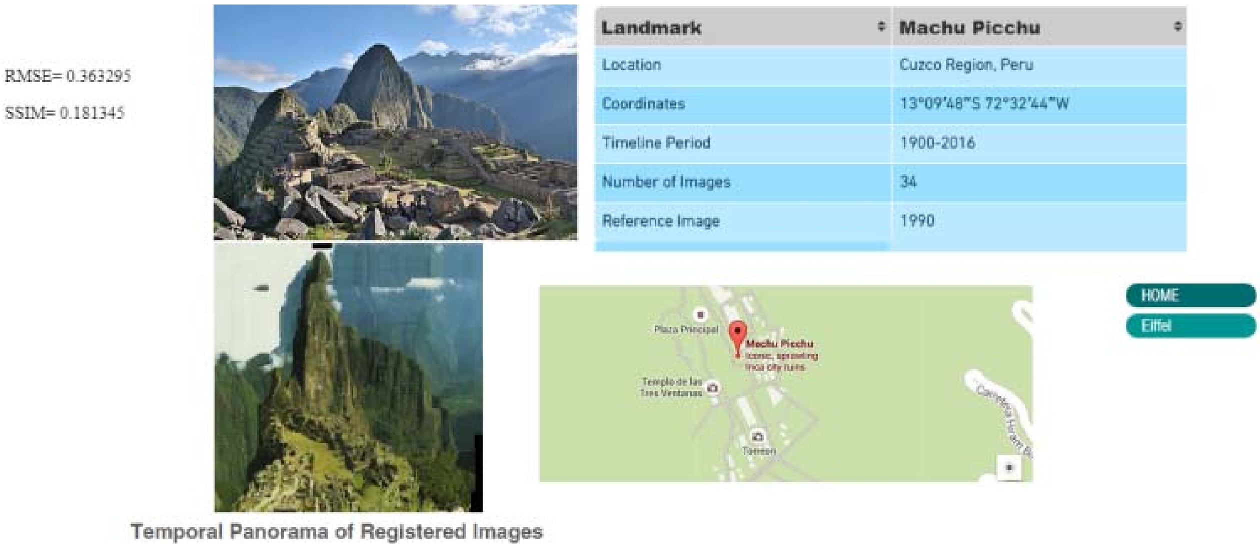

Fig. 7 Screenshot of a website demonstrating the timescape panorama of Machu Picchu landmark

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