COMPARISON OF GEOGRAPHIC IMAGES WITH SSIM AND MSE ALGORITHMS

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ABSTRACT

This research, a system for comparing geographic images in the University of Phayao is proposed. The essential objective is developing an aerial photographic database system to support the future planning of the university's area development. Our application system development was separated into 2 modules: the first part is a database system for storing the selected university area map at different times, along with information regarding the photograph's area name, time, location and so on. The second part is a map image processing with two techniques: an algorithm of a perception-based model or structural similarity index measure (SSIM), and the mean squared error (MSE). QGIS, Python, PHP, MySQL was utilized all of most development as tools. The experimental results of the image processing and the similarity of a map comparison system are shown in term of mean (X-Bar) and standard deviation (SD), as well as the outcome of all sample area locations are excellent and to be satisfy.

Keywords: Geospatial database, GIS, Map comparison, SSIM, MSE

1. INTRODUCTION

In the private precincts of the university along with other environments and landscape in terms of their aesthetic appeal is indispensable to develop continuously. Most landscape developers or university administrators require a glance at both current and past data to plan the development of expansion construction to be appropriate for those area. In this research case, we desired to create a database system on web that could compare images and produce academic numerical results with some acceptable techniques for administrative support within the University of Phayao. This university is in Phayao Province at the north of Thailand, around 700 kilometers far from Bangkok as a capital. The campus area is approximately 9.12 square kilometers and is surrounded by agricultural fields, forests and mountains as backgrounds with a beautiful environment. This project is a system that consists of two parts: the first part is a database management system, which emphasized on map images preservation. Most of information would store in a form of image file at a different durations time. Thereafter, the second part is a different images calculation system at the same area maps with structural similarity index measure (SSIM) and the Mean Squared Error (MSE) techniques to compare between two different image maps instead of visually looking by sight. The algorithms intended to compare images of geographic regions in terms of specific images from past to present. While nowadays, image map comparison can be done in a number of methods that available on internet including in group of GIS applications or other algorithms. Some methods are complicated, difficult to apply, but in this research focus on two techniques as mentioned above that can be attributed to our database system and issue numerical results of map differences as images to support easy-to-understand executive decision-making. For this reason, the SSIM, and the MSE were used as tools in this work.

The rest of this paper is organized as follows. After backgrounding introduction, follows by a brief review of previous related research, the methodology with SSIM and MSE to apply the comparing both map images and illustrates overall the system, the experimental results are demonstrated with the real area from the testbed, and finally is conclusion.

2. A BRIEF REVIEW

Comparison of aerial photographs or from satellite, it is one of the crucial works in the development of the area from the past until the present by using various techniques and methods in many ways since usage of various programs, both open source and commercial. All of programs can be used to assist with GIS work as well. In which those programs have different functions and techniques. We review from the previous research works as the following.

Anju Asokan and his colleges reviewed of the satellite image analysis with various processing techniques in terms of efficiency, quantitative and qualitative such as Peak-Signal-to-Noise Ratio (PSNR), MSE, Feature Similarity Index (FSIM), and SSIM and F-measurements (Anju, 2020).

In addition, there are other methods, which are common photographic comparison techniques, the SSIM method or a statistical method to determine the best image quality. The history and origins of SSIM are also discussed in detail for this research (Jim, 2020).

Another study is a program creation was called FLIP, it focused on image quality as well as the differences between rendered images and corresponding ground truths (Pontus, 2020).

Regarding the map comparison section to evaluate the image quality is a combination of methods, which divided into 4 groups: 1) Classical statistical methods : Fuzzy Kappa, Diagonal Proportion, and Geodetector, 2) Entropy-based methods : Symbolic Entropy, Average Mutual Information and V-measure, 3) Polygon-based methods : Mapcurves (V-measure), 4) Bivariate spatial association methods : Bi-Moran's I. and Lee's L. (Yue, 2020).

The K-Mean clustering algorithm is a technique to solve the segmentation problem of color images and to compare images for determine image quality also (Sadia, 2020).

A group of Umme Sara, they find out the different image quality metrics by to comparing two images between original images and the corresponding noisy and denoise with different noise levels. These experiments were not only considered on noise effects but also emphasizes on pixel-by-pixel comparison two images values with various methods of the SSIM, MSE, PSNR and FSIM (Umme, 2019).

In 2017, Jake Snell and team have researched learning to visualize with perceptual similarity metrics. They examined the consequences of replacing pixel loss functions like MSE and MAE with grounded loss functions in SSIM and MS-SSIM recognition in neural networks that synthesize and transform images (Jake, 2017).

An interesting paper in 2014 of Anil Wadhokar, research on quality evaluation and comparison of the image capturing from different cameras by using SSIM values. They were focus on the different features values of images and comparison each image of Original (no distortion), Blurred image, Gaussian noise distortion, Salt & Pepper noise distortion, Poisson noise distortion and Speckle noise (Anil, 2014).

Some researches that involved concentrating on Full Reference (FR), Image Quality Assessment (IQA)-Both test and original images methods with SSIM and MSE (Swati, 2013).

Furthermore, there is also research that uses SSIM with to replace the PSNR/MSE as the optimization criterion in image processing applications, a more accurate perceptual image measure, by incorporating it into the framework of sparse signal representation and approximation. By combine perceptual image fidelity measurement with optimal sparse signal representation in the context of image denoising and image super-resolution to improve two state-of-the-art algorithms in these areas. To solve for the optimal coefficients for sparse and redundant dictionary in maximal SSIM sense (Abdul, 2012).

This research presents a full reference of image quality indicators for assessment in the spatial domain. This combines some standard image metrics to assess the full image distortion by formulating Image distortion simulation including distortion of structure, contrast, and edges, and image deterioration which caused by noise contamination, contrast adjustment, blurring, rotation, or compression. This method provides a more accurate estimate of the deterioration compared to conventional MSE (PSNR) and SSIM methods in terms of efficiency (Akshat, 2011).

In another study, the subject was analyzed on image quality metrics by using the PSNR and SSIM measurements with various types of image degradation such as Gaussian blur, Gaussian white noise, enhancement by compression of jpeg and jpeg2000, and retrieved those image data from the Kodak database as a resource. This research have shown that the PSNR and the SSIM are more sensitive to additive Gaussian noise than Gaussian blur, jpeg and jpeg2000 compression (Alain, 2010).

As for the tools used in the development of Spatial Data Infrastructures (SDI) are separated in six categories; 1) Server software or web map and GIS servers: MapServer, QGIS, etc. 2) Spatial DBMS (Data Base Management Systems) and storages: PostGIS, SpatialLite, etc. 3) Registry/catalogue and metadata software: GeoNetwork, Deegree, MDWeb. 4) Client software: desktop GIS clients. 5) Web-GIS development toolkits: MapBender, MapFish, GeoMajas, SharpMap, etc. 6) Desktop GIS: Quantum GIS, GRASS, MapWindow, etc. (Erwan, 2012).

In addition, there are other development tools for image comparison with various programming for examples C, C++, MS Virsual C, Phython (NumPy, SciPy, PyTorch), Java, PHP and so on. Moreover, the popular database systems that employed to create GIS works such as Informix, MySQL, Oracle Spatial, SAP HANA, etc. (Stefan, 2009).

Another one of interesting research is a review of many projects with various platforms in which emphasize a diversity of Free and Open Source Software (FOSS) on desktop computers (Stefan, 2009).

3. THE METHODOLOGY WITH SSIM AND MSE

3.1 Structural Similarity Index Matrices (SSIM):

In 2001, SSIM based on the name Universal Quality Index (UQI), which is published in April 2004 as a measure tool for image quality and is highly regarded in the field of image processing (Zhou, 2002). In addition, SSIM is still a popular technique and usage as a reference by considerable researchers for scholarly literature (Jim, 2020). The SSIM is a method for predicting of any picture quality from various sources for measuring the similarity between two images on an initial uncompressed or distortion-free image as reference. In the other word, SSIM is a model of perception-based that speculates, the structure change of information cause of image degradation, while also incorporating crucial perceptual phenomena, including veiling terms of both contrast and luminance. Hence, there are three parameters to effects as a consideration. The SSIM index method, a quality measurement metric is calculated based on the computation of three major parameters as mentioned. If we consider two non-negative images x and y where x is original discrete signal and y is distorted discrete signal, then SSIM index method can be expressed through these three terms as a formula equation (1) below (Umme, 2019).

$$\text{SSIM}(x, y) = [l(x,y)]^{\alpha} \,.c[(x,y)]^{\beta}.s[(x,y)]^{\gamma} \qquad (1)$$

with : l = luminance, c = contrast, s = structure
α, β and γ are the positive constants.

where:

$$l(x,y) = \frac{2\mu_x\mu_y + c_1}{\mu_x^2 + \mu_y^2 + c_1} \qquad (2)$$

$$c(x,y) = \frac{2\sigma_x\sigma_y + c_2}{\sigma_x^2 + \sigma_y^2 + c_2} \qquad (3)$$

$$s(x,y) = \frac{\sigma_{xy} + c_3}{\sigma_x\sigma_y + c_3} \qquad (4)$$

For above definitions: c_1 and c_2 are two variables to stabilize the division with weak denominator as $c_1 = (0.01*L)^2$, $c_2=(0.03*L)^2$, and $c_3= c_2/2$. Where: L is the dynamic range of the pixel-values and μ_x, μ_y are the local means, σ_x, σ_y are the standard deviations, and σ_{xy} is the cross-covariance for images x, y respectively. If $\alpha = \beta = \gamma = 1$, then the index can be in a form of equation (5) as the following form by using Equations (2)-(4):

$$\mathrm{SSIM}(x,y)=\frac{\left(2\mu_x\mu_y+C_1\right)\left(2\sigma_x\sigma_y+C_2\right)}{\left(\mu_x^2+\mu_y^2+C_1\right)\left(\sigma_x^2+\sigma_y^2+C_2\right)} \quad (5)$$

The values of SSIM is between ranges 0 to 1, which 1 is a perfect value of both the original image and the duplicate image.

3.2 **Mean Squared Error** (MSE)

Mean squared error (MSE) or Mean Squared Deviation (MSD) is derived from a comparing between an unknown quality estimation and random errors with a chance game by de Laplace Pierre Simon and Gauss Carl Friesrich in the early 19th century. MSE is the *Mathematical expectation* as the average of sum of squared difference between actual value and the predicted or estimated value (Yadolah, 2008). This method can be applied to many fields in estimating errors between two things, especially in many researches as mentioned in previous part. Particularly, popular works are used to compare identical images two pictures. Human would be able to inform a different two image in draft by them sense only. However, they cannot present in term of error values or different evaluation of image quality. Therefore, to find the error values for two images: *I* (the original image) and *K* (the second image) by using the equation formula (6) as below (Swati, 2013). The perfect value result of this method is reach to zero (Dominic, 2018).

$$MSE=\frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2 \quad (6)$$

Where:

I : the matrix data of original image
K : the matrix data of copied or degraded image
m : the numbers of rows of pixels and i = the index of row
n : the number of columns of pixels and j = the index of column

4. EXPERIMENTAL RESULTS

This research presents a database system development on web technology for landscape map collection of University of Phayao. The main intent is to support executive and planning section. Most of sample image maps are from Google Earth at different time. The proposed system developed by using Visual Studio Code with Python, PHP, XAMPP and My SQL for database management system. The application consists of two main parts. The first part is a task of web and database system for administrator and users to view the image maps as information. The second part is a mechanism for comparison the same areas between two different time of image maps. The scope of research focuses on ten places in the university and the overview of the system operation displays in Figure 1. There are five stages of development the proposed system as the following.

- Stage 1: Requirement gathering
  In this stage, collect all relevant information from executive and planning section, then take any area photo with ten map samples from Google Earth. Preparing information to develop the application, and make ensuring to meet user expectations. Typically,

emphasizes on gather all related information with the software requirement specification (SRS) document for future reference.

- Stage 2: Design and data preparing into Server
  At this point, the requirements from the SRS document references to create the software architecture and confirm outline a model. After that, all information are entered into the database system and high-angle photographs would resized in the determined dimension at 4800x2707 pixels to prepare for comparison process in next step.
- Stage 3: Coding and Implementation
  This phase, the design is translated into source code. This is when software developers go in, implement the code, and revamp any algorithm code of SSIM and MSE with Python. Moreover, the database system part developed by various tools such as Visual Studio Code, PHP, HTML, QGIS and MySQL for managing our database. Finally, retest process is ran until to satisfy.
- Stage 4: Deployment
  At this point, the software deployed into at planning section with executive of the university.
- Stage 5: Evaluation
  This stage is a process of performance testing for overall programs, which the result shows in Table. 1.

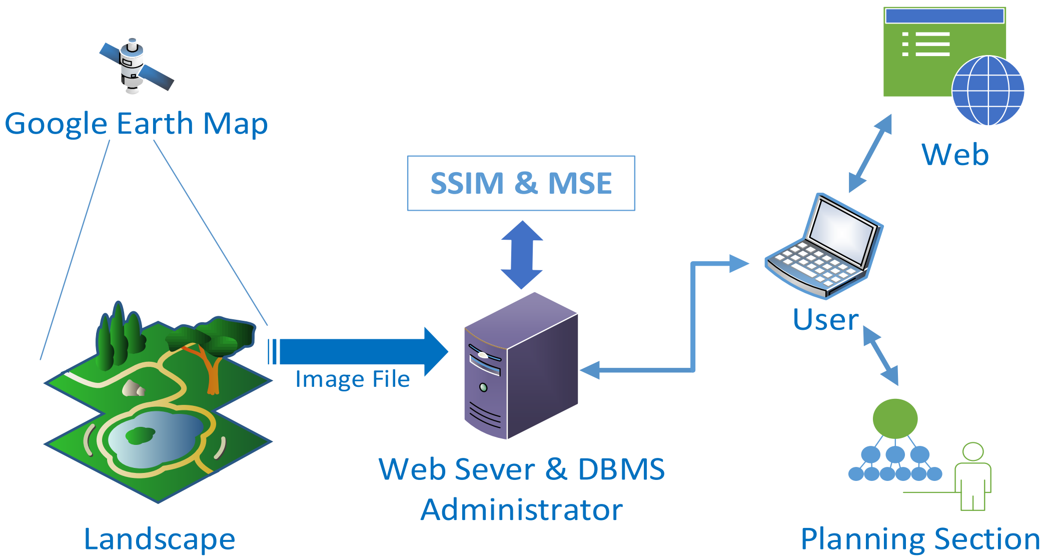


Figure 1. Overview of the system

A sample website screen of the university presents in Figure 2 as the user interface with the result of comparison on two different image maps at the right picture screen. The values of similarity (SSIM) and difference (MSE) display at the top of map as the both values multiply by 100 that to present in percentage.

Figure 2. User interface

The operation of proposed comparison system can brief in process as Figure 3. According to area image A is the present map or original image, on the other hands, area image B is a map of previous time. Then, load two image files are into the system. Next step is convert the image colors into grayscale. Afterward, pass the grayscale values are into to the computational operation by SSIM and MSE modules. Finally, the result of similarity and difference reveal out.

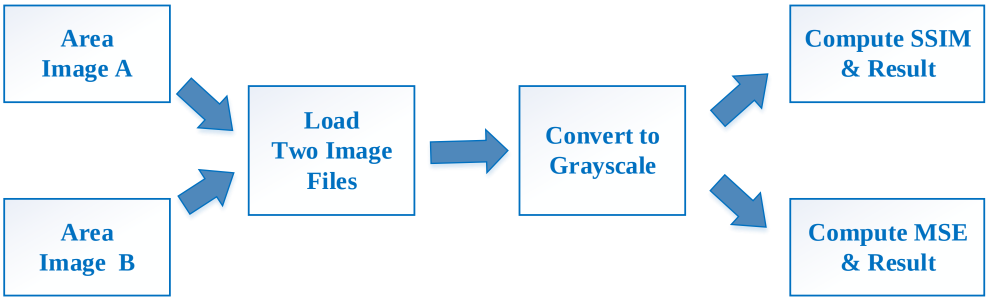
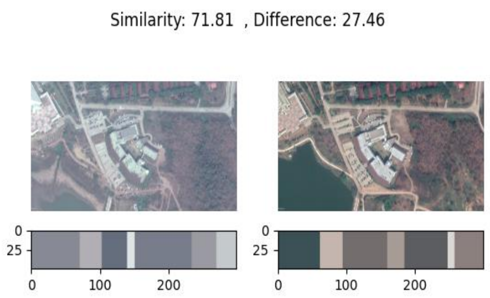
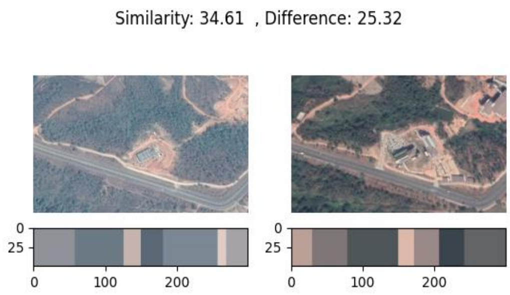


Figure 3. Image comparison process

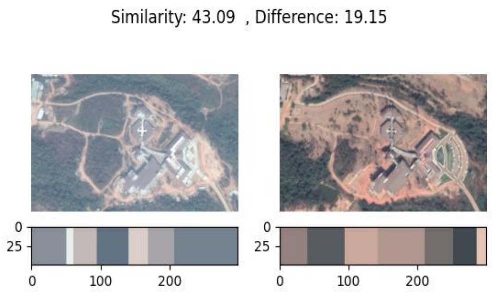
For this research, we surveyed ten places of different time from Google Earth and comparison together, which shows in Figure 4 that composes of each place area from *a-j*.



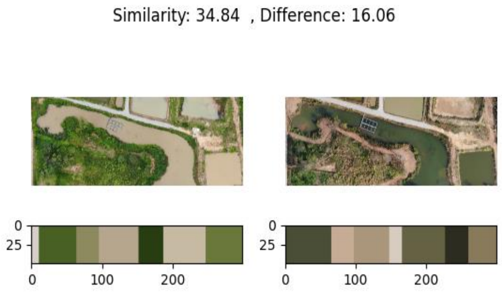
a. ICT Building (2016 & 2019)



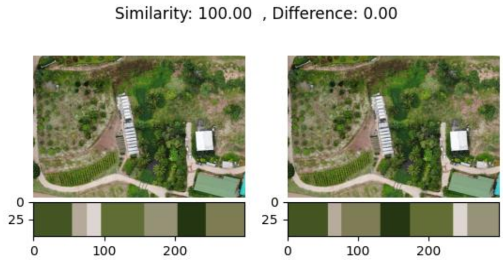
b. Dentist hospital (2016 & 2019)



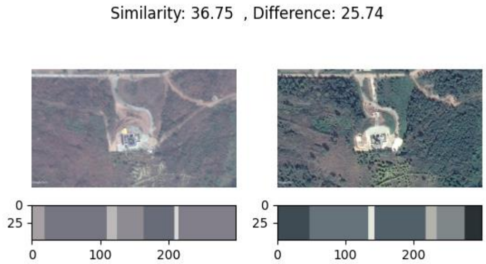
c. University of Phayao Hospital (2016 & 2019)



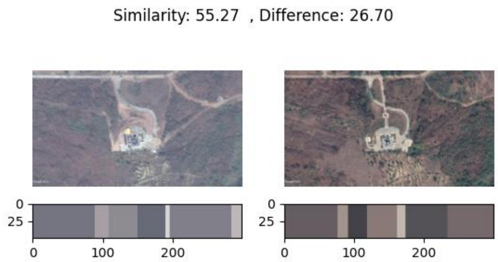
d. Pond of agriculture faculty (Feb. 2020 & Sep. 2020)



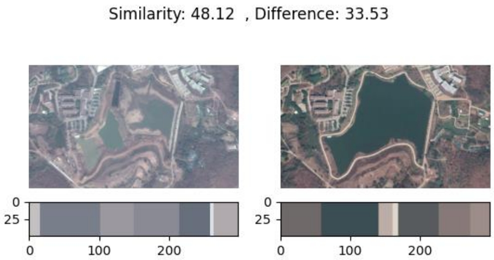
e. Agriculture Faculty (Feb. 2020)



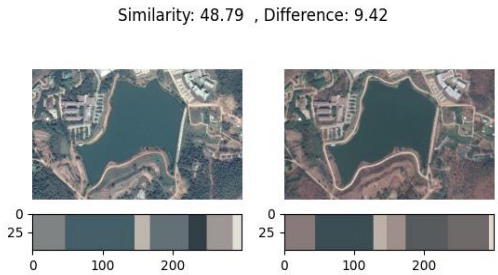
f. Ong Nakpok hill (2016&2017)



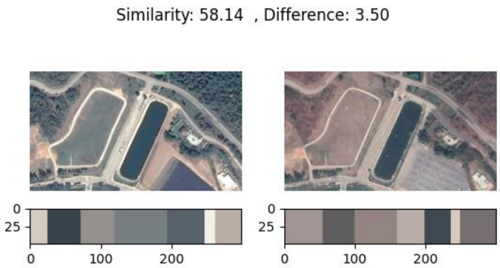
g. Ong Nakpok hill (2016&201 9)



h. Arng Luang lake (2016&2019)



i. Arng Luang lake (2017 &2019)



j. Sri Khorm Kam Entrance Gate (2 Feb. 2017&5 Mar.2019)

Figure 4. The image maps of each area comparison

5. CONCLUSION

In this article, we present a system development for comparing two images of ten places within the university. The propose system focuses on the study of using the method of comparing map images by SSIM method to find a similarity value and the difference value between two image map from Google Earth to support the user in planning section in campus. The results of each place are listed in Table 1.

Table 1. The results of the experiment to find SSIM and SME.

Map	Image Map Comparisons	(Similarity) SSIM	(Difference) SME
a.	ICT Building (2016 & 2019)	0.7181	27.46
b.	Dentist Hospital (2016 & 2019)	0.3461	25.32
c.	University of Phayao Hospital (2016 & 2019)	0.4309	19.15
d.	Pond of Agriculture Faculty (Feb. 2020 & Sep. 2020)	0.3484	16.06
e.	Agriculture Faculty (Feb. 2020)	1.00	0.00
f.	Ong Nakpok hill (2016 & 2017)	0.3675	25.74
g.	Ong Nakpok hill (2016 & 2019)	0.5527	26.70
h.	Arng Luang lake (2016 & 2019)	0.4812	33.53
i.	Arng Luang lake (2016 & 2019)	0.4879	9.42
j.	Sri Khorm Kam Gate (2 Feb.2017 & 5 Mar.2019)	0.5814	3.53

The experiment result as above demonstrates the SSIM or similarity values of mean (*X*-Bar) = 0.5314 with standard deviation (*SD*) = 0.2018 respectively. On the other hands, the MSE or different values of *X*-Bar = 18.68 with *SD* = 11.19.

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