# computer visoin image similarity calculation applied to the analysis of bridge structure deterioration degree

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## Abstract

In recent years, there have been frequent accidents of building collapses, especially bridges. Bridges are important hubs for transportation. If a bridge accident occurs, the level of impact will not only be in public safety, but it will also seriously affect the economy. For example, at 9:30 am on October 1, 2019, the Nanfang-ao Bridge in Yilan, Taiwan had a serious collapse accident. Unfortunately, the accident killed 6 people, injured 12 people, and damaged three fishing boats and a tanker. In addition, the collapse of the bridge barred nearby residents from sailing, causing economic losses to fishermen. Even worse, the government announced that it would take three years for the bridge to be repaired. Therefore, our team uses PYTHON program syntax and OPENCV library to design a bridge decay degree judgment program. Here our team will use a variety of detection methods to determine the degree of bridge decay. Then show the difference in results from different judgment methods. Our team hopes to help prevent bridge accidents. Looking forward to reducing serious bridge collapse accidents in the future. To allow the public to commute safely on bridges. No more worrying about collapse crises.

**Keywords: Bridge, Decay, Detection, Collapse.**

## 1. INTRODUCTION

### 1.1 Taiwan Nanfang-ao Bridge Accidents Introduction

Nanfang-ao Bridge is a bridge that crosses Nanfang-ao Fishing Port in Suao Town, Yilan, Taiwan. It is an important construction linking the Nanfang-ao Circular Route and it is also a famous landmark in the area.

At 9:30 a.m. on October 1, 2019, a bridge accident occurred, causing three fishing boats under the bridge to be crushed and oil tankers to fall and catch fire. The accident caused 2 serious injuries, 1 person was injured, 10 people were slightly injured, and 6 people were killed. The casualties included 8 Filipino migrant workers, 7 Indonesian migrant workers, 1 Taiwanese tanker driver, 2 Taiwanese sea patrol officers, and 1 Taiwanese rescue association member. The victims were all foreign crew members trapped on board.

After the tanker truck crossed the bridge, the sixth steel cable broke first, which was the starting point of the accident (Figure 1). Then the remaining steel cables broke one after another (Figure 2).


Figure 1　The sixth steel cable broke

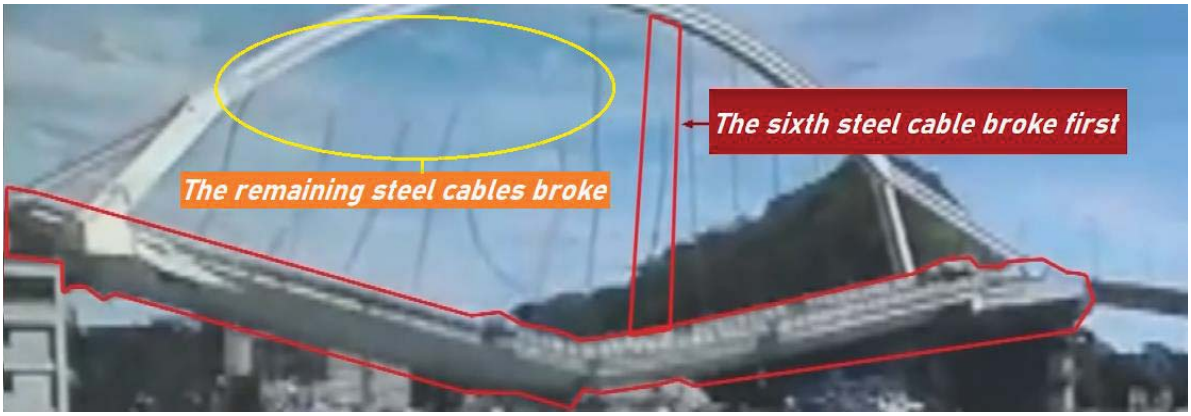


Figure 2　The remaining steel cables broke

It is inferred that most of the steel cables are damaged. After the first steel cable is broken, the remaining steel cables are stressed, causing a series of continuous fractures and causing the bridge to finally collapse.

After the Nanfang-ao Bridge collapsed, the Ministry of Transport planned to complete the reconstruction within three years. Adopt the current highest bridge safety standards such as 100 years of durability, salt corrosion resistance and earthquake resistance level 7. The new bridge reconstruction cost is roughly estimated at 530 million Taiwan dollars.

### 1.2 Corroded Steel Cable Of Bridge

According to reports, the collapse of Nanfang-ao Bridge is mainly caused by corrosion of steel cables. Nanfang-ao Bridge is located on the sea and has been eroded by sea wind for many years [1]. Sea wind contains a lot of salt, so it will cause greater corrosion effects on bridges[2]. In the sea wind environment, if you neglect to maintain[3] the bridge for a long time, it will greatly increase the risk of bridge collapse[4]. Below are some ways to judge the deterioration.

#### 1.2.1 Judging the degree of deterioration by the D value[5]

The D value[5] describes the severity of cable deterioration (Figure 3). For bridges, the more severe the degradation, the higher the priority should be dealt with.

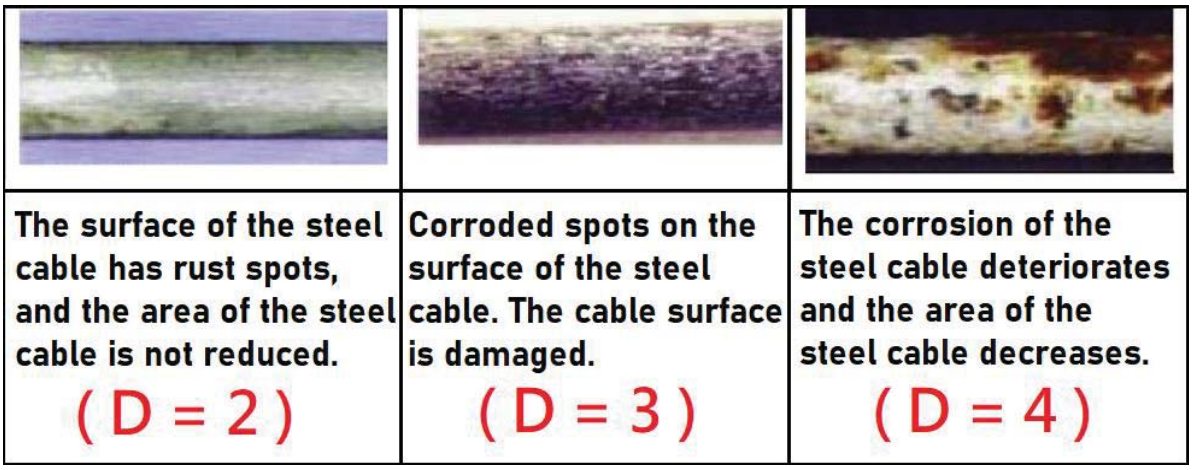


Figure 3 Illustration of the degree of cable deterioration of D value[5]

### 1.2.2 Judging the range of deterioration by the E value

E value[5] is the range of cable deterioration degree (Figure 4), which can be expressed as a percentage (Figure 5). The size of the degradation range indicates the condition of the bridge, but it does not indicate the degree of damage.

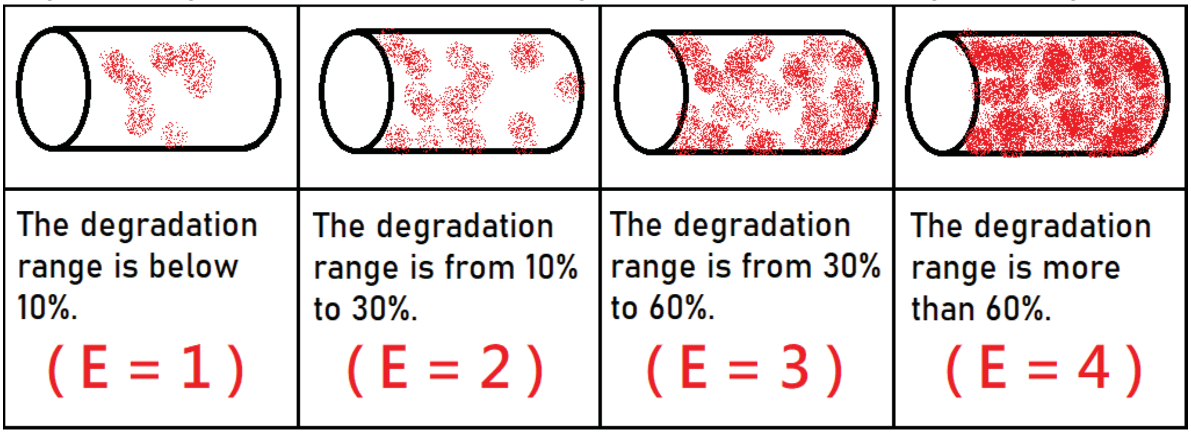


Figure 4 Illustration of the range of cable deterioration of E value[5]

$$\text{Formula} = \frac{\text{Damage area}}{\text{Building area}}$$

Figure 5 Deterioration formula[5]

### 1.3 Camera Drone And Purpose

Drone is a small air vehicle without personnel[6]. Usually use remote control, guidance or automatic driving to control[7]. It can be used in scientific research, site exploration, military, leisure, entertainment and use.

At present, the most commercialized drone[8] is Unmanned Aerial Vehicle (UAV). UAV with built-in cameras or external cameras are often referred to as "camera drone." Camera drone can be used for people search, terrain exploration, bridge steel cable exploration (Figure 6), street view photography, landscape photography, entertainment ... etc.

Figure 6　Camera drone take picture from bridge node

Here our team uses camera drone to get a picture of the bridge steel cable node 1 (Figure 7). We take photos from different days (Figure 8). In order to understand the changes of the bridge steel cable before and after, to determine the degree of corrosion of the steel cable.

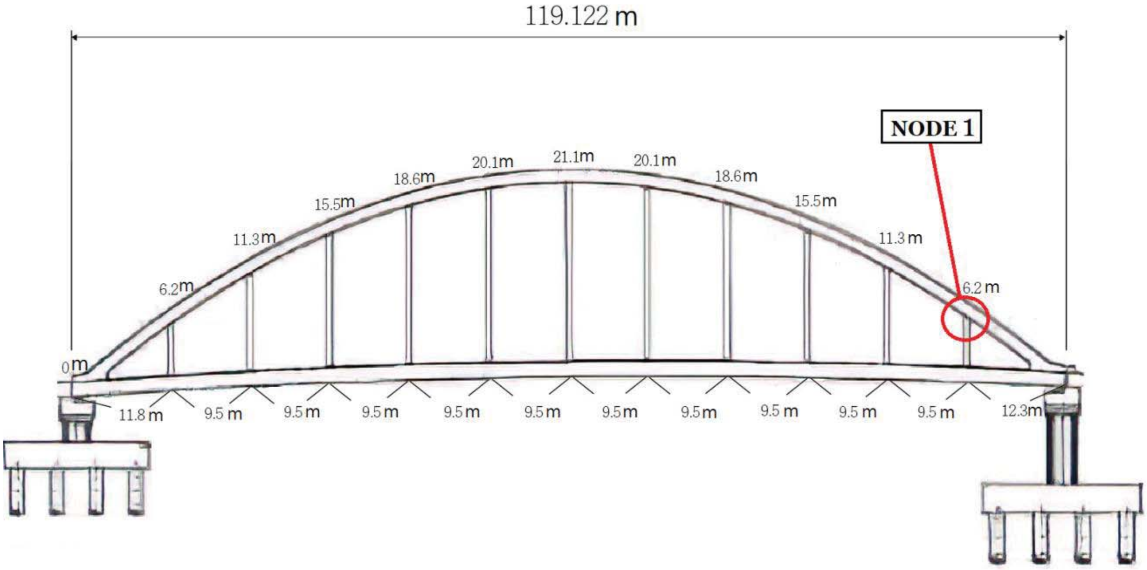


Figure 7　Location of bridge steel cable node 1


Figure 8　Bridge cable node 1 images between March 2nd and March 9th

### 1.4　Research Motivation And Purpose

The bridge collapse[9] threatened the live[10] of many people and caused significant economic losses to nearby residents. In addition, it causes inconvenience in transportation. The reconstruction of the bridge takes a long time to repair. It also seriously affects the government's financial burden.

Therefore, our team wrote a bridge image comparison program (Figure 9) with the PYTHON program syntax and the OPENCV library, and uses this program to determine the degree of bridge decay, hoping to help prevent bridge accidents. Looking forward to reducing serious bridge collapse accidents in the future. To allow the public to commute safely on bridges. No more worrying about collapse crises[11].

We use a variety of inspection methods to determine the degree of bridge corrosion, such as perceptual hash algorithms, average hash algorithm, difference hash algorithm ... and so on. Use different results to judge the condition of the bridge. Find out if the bridge is stable or not.

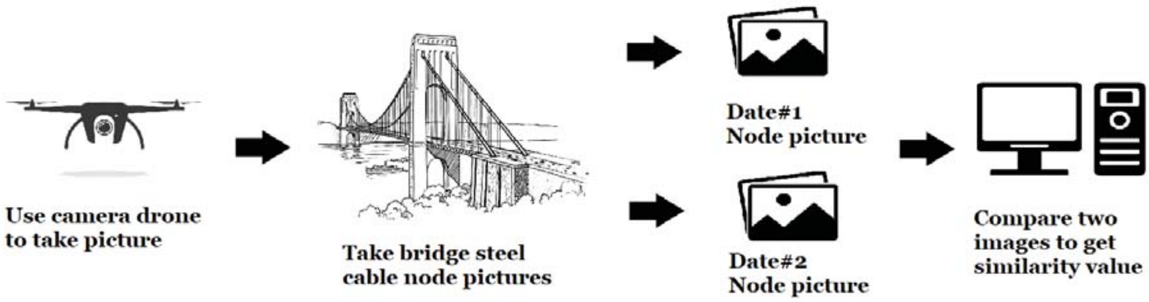


Figure 9　Bridge image comparison programme simple procedures

**1.5　Bridge Image Comparison Program**

This program will load a picture of the bridge cable nodes and compare it with pictures from other dates. Our team used the picture of the bridge steel cable obtained by the camera drone, and then used the program to analyze the similarity of the photos on different days. We use the similarity result calculated by the program to judge the degree of corrosion of the bridge. If the similarity is too low, it indicates that the bridge steel cable needs to be maintained. If the degree of similarity is high, it means that the current condition of the steel cable is still good.

We use many algorithms to calculate the similarity (Figure 10), in order to be able to comprehensively judge the condition of the bridge. Through several similarity values, the degree of decay of the steel cable can be judged, and suitable algorithms and inappropriate algorithms can also be found.

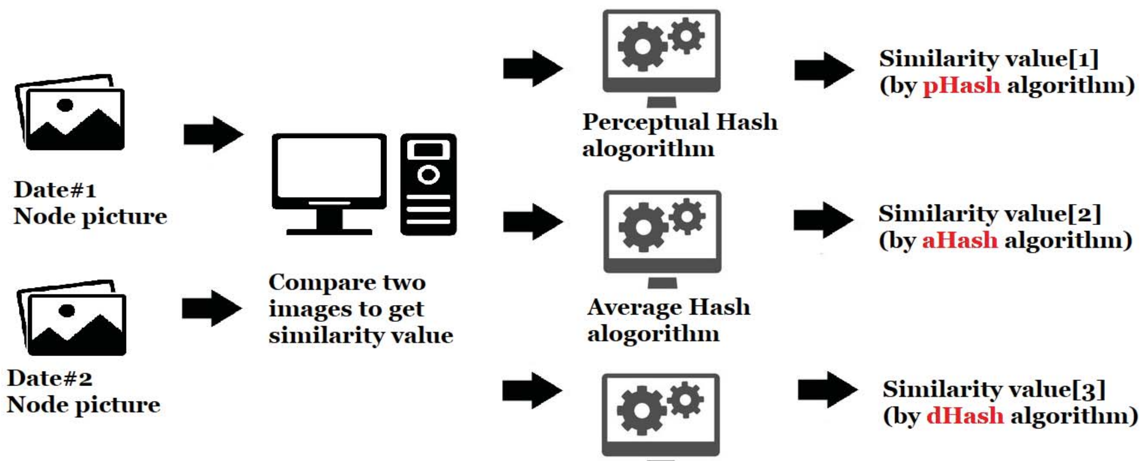


Figure 10　Bridge image comparison programme utilize various algorithm to get similarity values

In the final stage, our bridge program will show pictures of bridge nodes on different days and at which point on the bridge, and the value of similarity (decay degree) can be provided to users for reference, whether the bridge is dangerous or not (Figure 11).


Figure 11 The result includes the bridge node number, the pictures of different days and the similarity of the comparison.

## 2. PROGRAMME TOOLS AND MATERIALS

### 2.1 New Changan Bridge

Our team uses the New Changan Bridge as a photography location (Figure 12). New Changan Bridge is located in 221 New Changan Bridge, Xizhi District, New Taipei City, Taiwan.

The new Changan Bridge project crosses the Keelung River, starting from north Xiangyou Street to the left bank of Changxi Township. The new Changan Bridge has a length of 231 meters, 122 meters of approach roads, and a total length of 353 meters. It is designed with a Roger-style steel arch bridge and is equipped with two-way lanes and sidewalks. The construction period is about 1 year and 8 months, and it was completed and opened to traffic on November 17, 2012, with a total cost of NT $ 350 million.

Figure 12 New Changan Bridge with camera drone image

### 2.2 Camera Drone

We use camera drone to take picture of the 11 rope nodes on the New Changan Bridge (Figure 13).

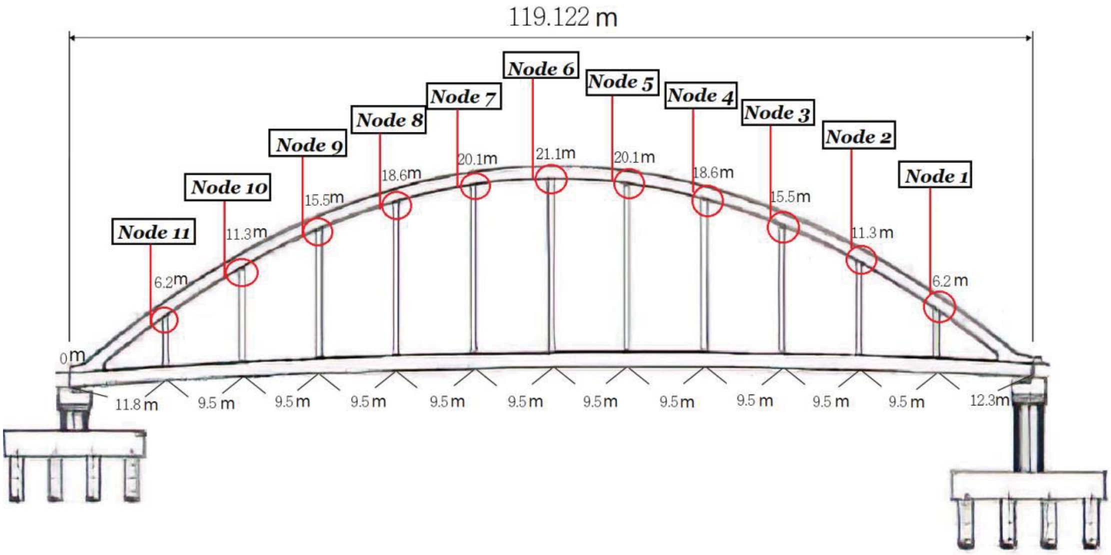


Figure 13 Bridge and steel cable nodes illustration

### 2.3 Python

We use Python programme syntax to write our bridge detection programme[12].

### 2.4 OpenCV

We import OpenCV library to resolve images problems[13].

### 2.5 Visual Studio Code

We adopt Visual studio code as our development environment to compile[14].

## 3. Methonds

### 1.3 Take Pictures Of 11 Bridge Rope Nodes By Camera Drone

First, take a picture of the 11 rope nodes on the New Changan Bridge with a camera drone. The new New Changan Bridge has a total length of 119.122 meters. There are 11 steel cables on one side, and the spacing of each steel cable is 9.5 meters (Figure 14).

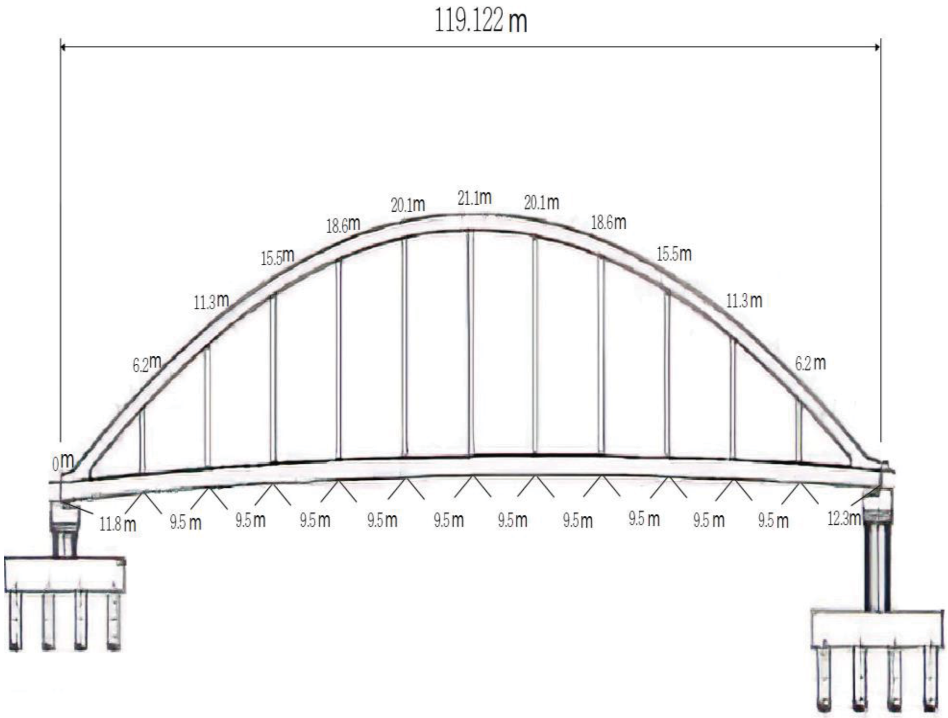


Figure 14 Bridge image and scale

### 3.2 Load Pictures Of 11 Bridge Rope Nodes with Different Dates

We import 11 different date pictures of the bridge rope nodes, because we need to use the images in the next work (Figure 15).


Figure 15 Bridge node images between different date

### 3.3 Use Different Algorithms to Calculate Similarity

We use many algorithms to calculate the similarity of bridge rope nodes at different times. Our team uses algorithms such as Perceptual Hash algorithms, Average Hash algorithm, Difference Hash algorithm…and so on.

For the Histogram comparison algorithm, when the color information has a greater weight in object recognition, this algorithm is very reliable. The Histogram algorithm does not need to accurately separate the object from its background, and it is robust to obscuring the object in the foreground. Histogram is the distribution of pixel values in a digital image. It is represented in the form of an image. The distribution of pixel values is a way to express color information. In the HVS color model, the distribution of pixel values represents the saturation of colors. Under different viewing angles, scales, and occlusion conditions, when moving slowly, the histogram is somewhat robust to changes.

Cosine similarity is used to measure the similarity of two documents in the field of information retrieval. In information retrieval, each term is assigned a different dimension, and a dimension is represented by a vector, and the value of each dimension corresponds to the frequency of the term appearing in the document. The cosine similarity can therefore give the similarity of the two documents in terms of their subject. In addition, it is usually used for file comparison in text mining. The most common application is to calculate text similarity. According to their words, two texts are used to create two vectors, and the cosine value of these two vectors is calculated, so that the similarity of the two texts in statistical methods can be known.

The SSIM similarity algorithm is close to the results of human subjective evaluation, and the SSIM algorithm has a good effect. First, the statistical characteristics of the image are usually unevenly distributed in space; second, the distortion of the image also changes in space; third, within normal viewing distance, people can only focus on the image. Within a region, local processing is more in line with the characteristics of the human visual system; fourth, local quality detection can obtain a mapping matrix of the change in image space quality, and the results can be served to other applications.

The principle of pHash algorithm is different from aHASH and dHASH, because the pHash adjusts the image size to 32X32, while the others are only 8X8 and 8X9, so it has higher accuracy, more data, and longer calculation time, which is the slowest of the three.

The aHash algorithm adjusts the image size to 8X8, while others have 32X32 and 8X9, so it has lower precision, less data, and the shortest calculation time. It is the fastest of the three.

In the dHash algorithm, the result is generated based on whether the left pixel of each row is larger than the right pixel, rather than using a single average value. Compared with aHASH, it produces fewer errors.

### 3.3.1 Use Perceptual Hash algorithm to Calculate Similarity

The principle of pHash algorithm is different from aHASH and dHASH, because the pHash adjusts the image size to 32X32, while the others are only 8X8 and 8X9, so it has higher accuracy, more data, and longer calculation time, which is the slowest of the three.

In Perceptual Hash[15] *procedures* (Figure 16), first we convert the image into a gray value image, then convert the picture size to a 32x32 picture (Figure 17).


Figure 16 Perceptual Hash covert image procedures

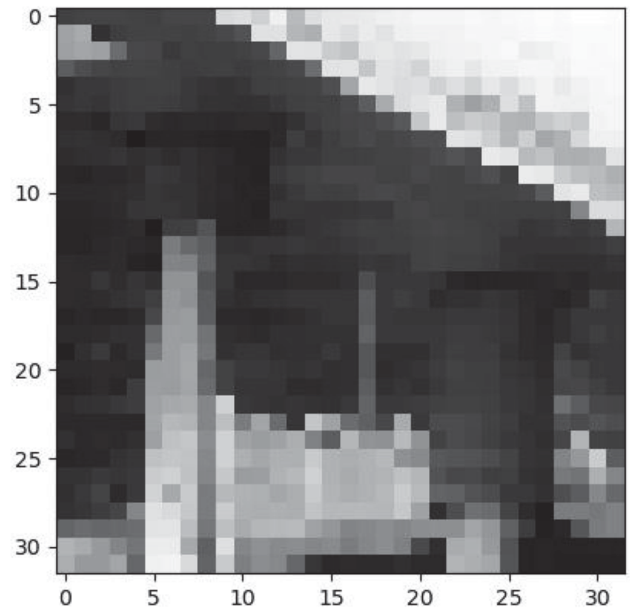


Figure 17 32x32 grey picture

To the image we apply a discrete cosine transform[16] (DCT) (formula 1), obtain a 32 × 32 DCT coefficient matrix. Then we take an 8 X 8 matrix in the upper left corner. Then calculate the mean of 64 DCT coefficients.

$$X_k = \sum_{n=0}^{N-1} 2n * \cos\left(\pi * k * \frac{2n+1}{2N}\right) \quad \forall \mathrm{k} \in [0, \mathrm{N}] \tag{1}$$

Discrete cosine transform formula: Discrete cosine transform, often used in signal processing and image processing, is used for data compression of signals and images. Discrete cosine transform can be used in JPG, JPEG and MPEG image compression, and also used in MP3 audio compression.

In the next step, we compare the 64 gray values with the mean value generated in the previous step. If it is greater than the mean, set it to 1; if it is less than the mean, set it to 0. And get a hash code with 64 elements.

In the final step, we compare the hash codes of the two pictures and calculate their Hamming distance[17] to determine the similarity of the two pictures.

For example, to calculate the Hamming distance, we assume that we have two arrays of 64 binary integers from the two pictures of the previous step (Figure 18).

A:{1111111100111100000110100001110100011100011011000000000010000000}
B:{1001111010011000100010001111001010000011101110000111010011111110}

Figure 18 64 binary integers from the two pictures

Hamming distance is equal to a XOR b (a⊕b), you can find that there are 36 different, so the similarity is (64-36) / 64 = 43.75%.

### 3.3.2 Use Average Hash algorithm to Calculate Similarity

The aHash algorithm adjusts the image size to 8X8, while others have 32X32 and 8X9, so it has lower precision, less data, and the shortest calculation time. It is the fastest of the three.

In Average Hash procedures (Figure 19), First we convert the image into a gray value image. Then convert the picture size to a 8x8 picture (Figure 20).


Figure 19 Average Hash covert image procedures

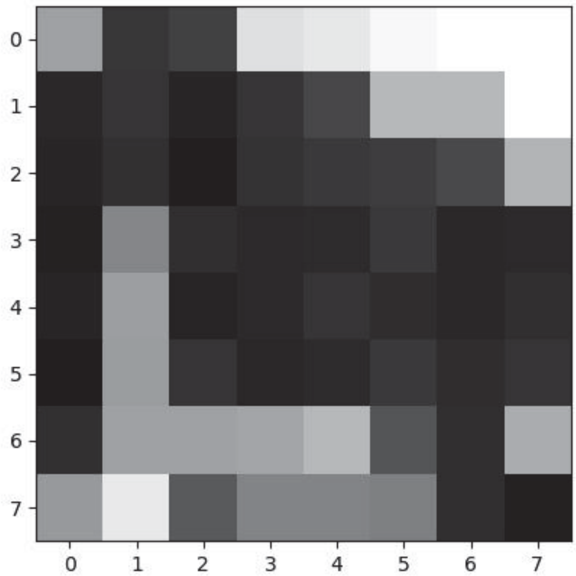


Figure 20 8x8 grey picture

In the next step, we Calculate the average of 64 gray values. Then we compare the 64 gray values with the average value generated in the previous step. If it is greater than the average value, set it to 1; if it is less than the average value, set it to 0. And get a hash code with 64 elements.

### 3.3.3 Use Difference Hash algorithm to Calculate Similarity

In the dHash algorithm, the result is generated based on whether the left pixel of each row is larger than the right pixel, rather than using a single average value. Compared with aHASH, it produces fewer errors.

In Difference Hash procedures[18] (Figure 21), first we convert the image into a gray value image. Then convert the picture size to a 9x8 picture (Figure 22).


Figure 21 Difference covert image procedures

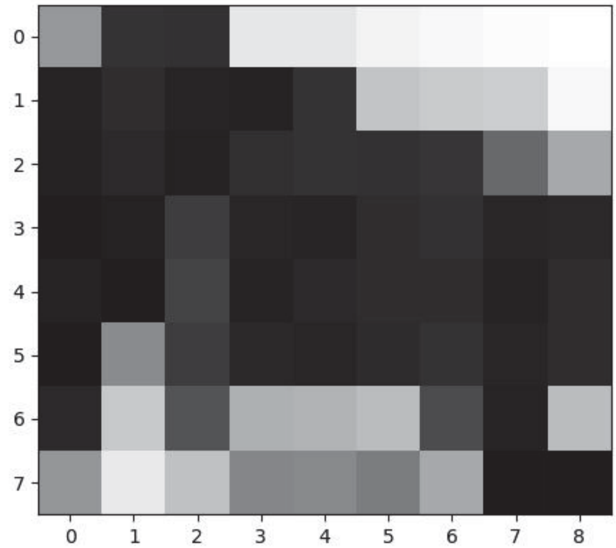


Figure 22 9x8 grey picture

The difference of 9 pixels in each line is used to obtain 8 difference values, for a total of 64 difference values.

In the next step, we compare the 64 gray values with the difference value generated in the previous step. If it is greater than the difference value, set it to 1; if it is less than the difference value, set it to 0. And get a hash code with 64 elements.

In the final step, we compare the hash codes of the two pictures and calculate their Hamming distance to determine the similarity of the two pictures.

### 3.4 Output The Similarity Value And Images

Finally, we output the two compared pictures and the similarity data (Figure 23). The result includes the bridge node number, the pictures of different days and the similarity of the comparison.


Figure 23 Bridge node images between different days and similarity value

# 4. RESULT

From the data results between March 2nd and March 9th (Table 1), we find that the results of the Cosine algorithm[19] are much closer to 100% (Figure 24). Because the interval between days is short, the result should be close to 100%. Therefore, we believe that the results of the COSINE algorithm are the most appropriate.

Table 1 Similarity data of various algorithms between March 2nd and March 9th

| | SSIM | Histogram | Cosine | pHash | aHash | dHash |
|---|---|---|---|---|---|---|
| Node1 | 75.24% | 66.24% | 97.1% | 73.44% | 82.81% | 59.38% |
| Node2 | 76.12% | 72.92% | 95.23% | 87.5% | 67.19% | 51.56% |
| Node3 | 74.74% | 43.7% | 96.14% | 84.38% | 75% | 57.81% |
| Node4 | 79.01% | 58.99% | 98.06% | 90.62% | 62.5% | 57.81% |
| Node5 | 89.79% | 71.55% | 97.77% | 85.94% | 56.25% | 62.5% |
| Node6 | 88.9% | 62.9% | 96.91% | 73.44% | 79.69% | 71.88% |
| Node7 | 97.38% | 67.16% | 99.55% | 95.31% | 82.81% | 76.56% |
| Node8 | 90.44% | 73.24% | 96.72% | 73.44% | 87.5% | 65.62% |
| Node9 | 88.65% | 58.12% | 97.71% | 90.62% | 81.25% | 73.44% |
| Node10 | 87.94% | 58.69% | 96.99% | 92.19% | 87.5% | 67.19% |
| Node11 | 87.02% | 71.62% | 97.94% | 73.44% | 82.81% | 70.31% |
| Mean | 85.0209% | 64.1027% | 97.2836% | 83.6654% | 76.8463% | 64.9145% |
| SD | 7.4987% | 8.9222% | 1.1265% | 8.6233% | 10.43% | 7.79331% |
| P-Value | | 2.244E-05 | 0.00011 | 0.97118 | 0.05756 | 1.841E-05 |

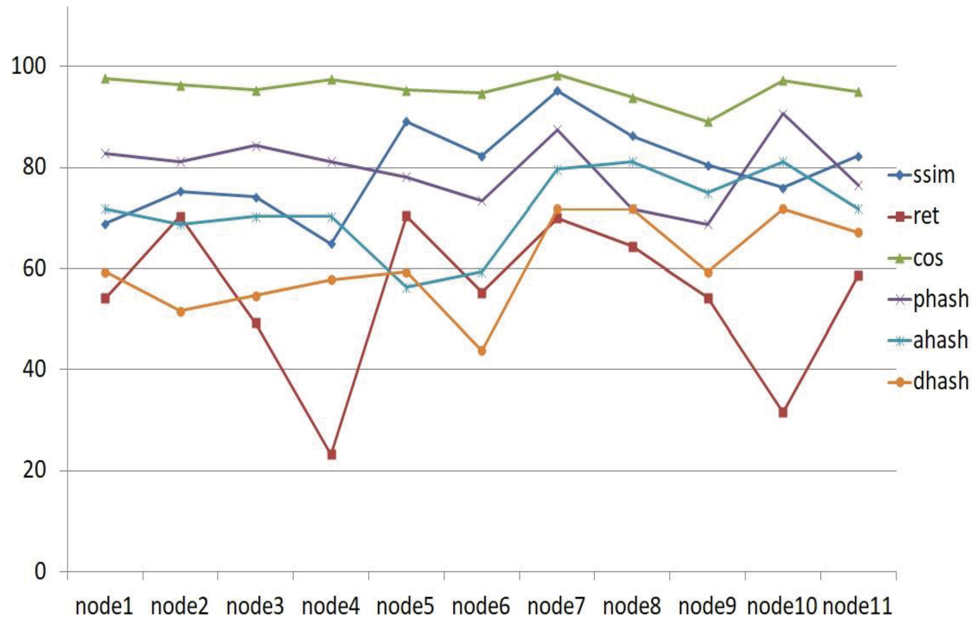


Figure 24 Image of Table 1 figures

From the data results between March 2nd and March 12th (Table 2), we find that the results of the Cosine algorithm are much closer to 100% (Figure 25). Because the interval between days is short, the result should be close to 100%. Therefore, we believe that the results of the COSINE algorithm are the most appropriate.

Table 2 Similarity data of various algorithms between March 2nd and March 12th

| | SSIM | Histogram | Cosine | pHash | aHash | dHash |
|---|---|---|---|---|---|---|
| Node1 | 68.89% | 54.17% | 97.67% | 82.81% | 71.88% | 59.38% |
| Node2 | 75.35% | 70.27% | 96.39% | 81.25% | 68.75% | 51.56% |
| Node3 | 74.23% | 49.31% | 95.32% | 84.38% | 70.31% | 54.69% |
| Node4 | 64.97% | 23.24% | 97.51% | 81.25% | 70.31% | 57.81% |
| Node5 | 89.15% | 70.42% | 95.35% | 78.12% | 56.25% | 59.38% |
| Node6 | 82.36% | 55.25% | 94.71% | 73.44% | 59.38% | 43.75% |
| Node7 | 95.27% | 70% | 98.42% | 87.5% | 79.69% | 71.88% |
| Node8 | 86.25% | 64.4% | 93.94% | 71.88% | 81.25% | 71.88% |
| Node9 | 80.47% | 54.28% | 89.14% | 68.75% | 75% | 59.38% |
| Node10 | 75.97% | 31.57% | 97.27% | 90.62% | 81.25% | 71.88% |
| Node11 | 82.31% | 58.77% | 95.05% | 76.56% | 71.88% | 67.19% |
| Mean | 79.5654% | 54.6981% | 95.5245% | 79.6872% | 71.45% | 60.7981% |
| SD | 8.8628% | 15.4558% | 2.5487% | 6.7012% | 8.1213% | 9.1516% |
| P-Value | | 0.000506 | 4.6E-05 | 0.84917 | 0.06401 | 0.000231 |

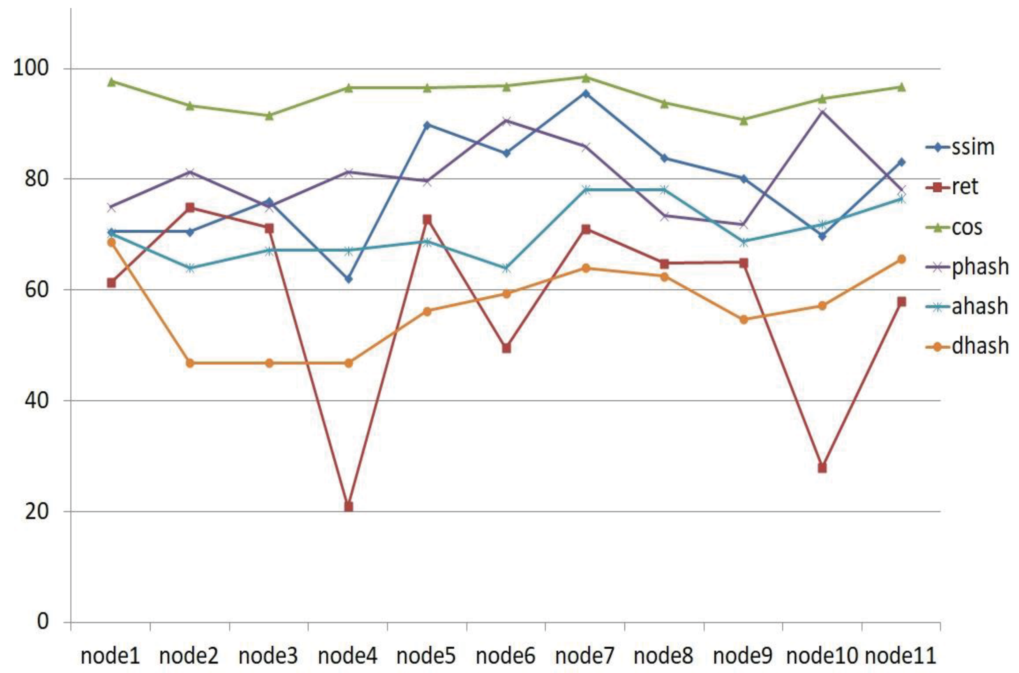


Figure 25  Image of Table 2 figures

From the data results (Table 3) [20], we found that the Mean value of COSINE algorithms is quite higher than the others (Mean > 95%). Therefore, when we judge the similarity of the two pictures, we need to consider the differences of the various algorithms used. The similarity judged by different algorithms may have different results, which needs to be carefully evaluated.

Table 3  P-value data of various algorithms between Table 1 and Table 2

| | SSIM | Histogram | Cosine | pHash | aHash | dHash |
|---|---|---|---|---|---|---|
| T1 Mean | 85.0209% | 64.1027% | 97.2836% | 83.6654% | 76.8463% | 64.9145% |
| T1 SD | 7.4987% | 8.9222% | 1.1265% | 8.6233% | 10.43% | 7.79331% |
| T2 Mean | 79.5654% | 54.6981% | 95.5245% | 79.6872% | 71.45% | 60.7981% |
| T2 SD | 8.8628% | 15.4558% | 2.5487% | 6.7012% | 8.1213% | 9.1516% |
| p-Value | 0.134793 | 0.095839 | 0.04923 | 0.2410845 | 0.190858 | 0.269478 |

In addition, because the date of the photo is very close, the similarity should be high. However, we found that only the COSINE algorithm yielded the highest results (Figure 26), while other algorithms produced lower similarities (Mean < 90%). Therefore, from the results, we think that the COSINE algorithm is the most suitable for calculating the degree of corrosion of the bridge.

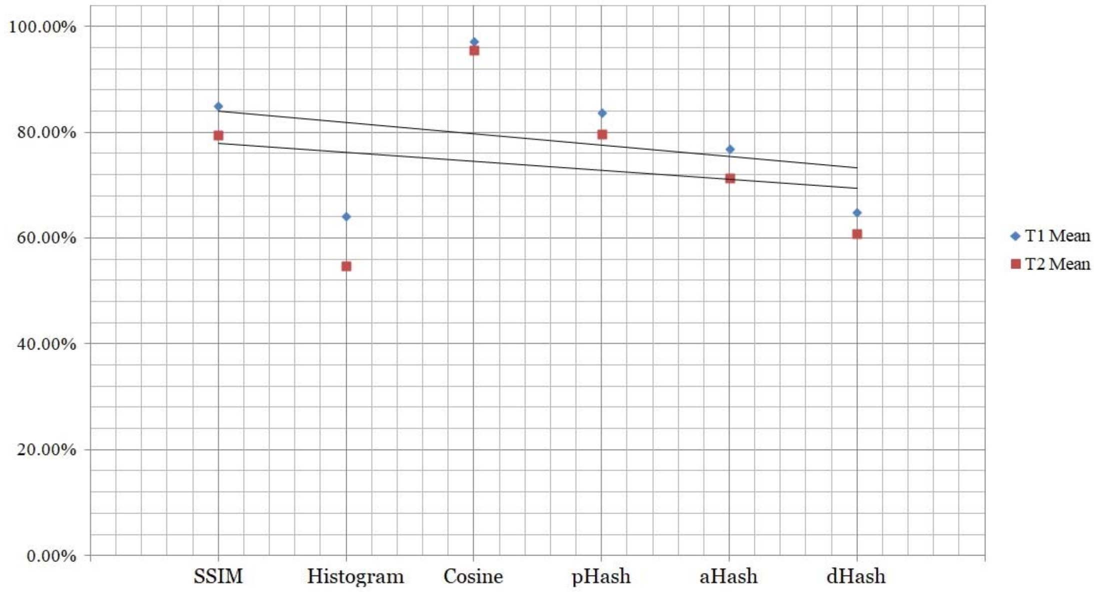


Figure 26 Image of Table 3 T1 Mean and T2 Mean

From the COSINE results (Mean>95%), according to the E-VALUE and D-VALUE classification methods we mentioned before, we can classify the results as the degree of E = 1 and D = 2 (Figure 27), indicating that the degree of deterioration of the bridge steel cable is low. The degree of deterioration is less than 10%, and there is only a little embroidery on the surface, which does not damage the area.

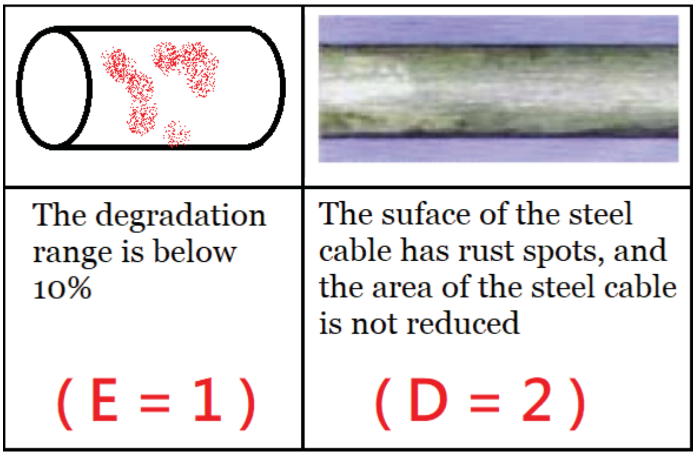


Figure 27 E-VALUE and D-VALUE[5] classification from COSINE results

## 5. CONCLUTION AND DISCUSSION

In order to deal with the collapse of the Nanfang-ao Bridge in Taiwan, our team designed a bridge image comparisom program. We use the similarity of bridge nodes at different times to judge the degree of bridge corrosion. In addition, in order to analyze the bridge from different aspects, we use many different algorithms to judge the similarity.

From this study, we know that the results of different algorithms may be quite different. So when we choose the algorithm, we need to think clearly.

The results shown by different algorithms allow us to make a comprehensive judgment on the degree of bridge corrosion. With the degree of bridge corrosion, we hope that the government can maintain bridges in advance to reduce the chance of collapse accidents. So that people can safely pass through the bridge.

Because the date of the photo is very close, the similarity should be high. From the results, we know that the COSINE algorithm has a high similarity (Mean > 95%), so it may be more suitable for calculating the corrosion degree of the bridge.

The image comparison method can be applied not only to the judgment of the deterioration degree of bridge steel cables, but also to other parts. For example, to judge the degree of embroidering of water pipes, you can also use image comparison to make a basic judgment. In addition, the degree of deterioration of the steel bar of the house can also be compared with images to understand the status of the steel bar. Therefore, image comparison can be widely used in the judgment of building materials and parts. It is hoped that in the future it will be possible to prevent the collapse of various buildings and protect people's safety.

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