Global Coral Health Levels Analysis Database with Semantic Computing and 5D World Map

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Abstract. Global warming and climate change affect not only all living things but also many non-living things. Furthermore, those phenomena caused extreme disasters that become impossible to ignore. Coral bleaching is a phenomenon to show ocean warming due to climate change. This paper presents the analysis and visualization of the coral health levels database by using 5D World Map System. Coral health levels are analyzed using a coral-knowledge image that includes coral with a coral health chart. We use image processing and color semantic distance to interpret coral health levels. We have implemented an actual space integration system to access environmental information resources with coral health levels and image analysis that the results have been shown on the 5D World Map System. As for the experiment study, the study areas of coral health levels analysis are located in the ocean close to Thailand's islands as Ko Ha (Five Island), Ko Bon, Ko Hin Ngam, Ko Tarutao, Ko Thalu, and Ko Samaesarn.

Keywords. coral health levels, semantic computing, coral health levels database, coral-knowledge image, image processing, global environmental analysis, 5D World Map.

1. Introduction

Global warming and climate change affect not only all living things but also many non-living things. Furthermore, those phenomena caused extreme disasters such as stronger storms, rising seas, and ocean warming that become impossible to ignore. Global warming is very close to us because everything in this world is dependent on each other. That is why everyone on this planet should start to be aware and understand the impacts of the future. Coral bleaching is a phenomenon to show ocean warming due to climate change. Our motivation is promoting healthy reefs by engaging the global community in monitoring coral health and coral bleaching with 5D World Map System. The 5D World Map System is globally utilized as a Global Environmental Semantic Computing System for disaster, natural phenomena, ocean-water analysis with local and global multimedia data resources.

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This paper presents the analysis and visualization of the coral health levels database by using 5D World Map system. Coral health levels are analyzed using an image that includes coral with a coral health chart. We use image processing and color semantic distance to interpret coral health levels. Our environmental-semantic computing system realizes integration and semantic-search among environmental-semantic spaces with coral health levels and image databases. We have implemented an actual space integration system for accessing environmental information resources with coral health levels and image analysis. We clarify the feasibility and effectiveness of our method and system by showing several experimental results for coral health levels analysis databases.

This paper is organized as follows: Section 2 describes the research related to our study. Section 3 introduces the proposed methods of the system. Section 4 shows results and discussion. Section 5 then presents the conclusion. Finally, Section 6 closes with the acknowledgment.

2. Related Works

In this section, we introduce the works that related to our study

2.1 5D World Map System

The 5D World Map System is globally utilized as a global environmental semantic computing system for disaster, natural phenomena, ocean-water analysis with local and global multimedia data resources. This system, based on the semantic associative computing system (MMM) [1], is a collaborative knowledge sharing, analyzing, searching, integrating, and visualizing data, such as images, videos, audio, etc., onto 5D time-series which temporal (1 Dimension), spatial (2-4 Dimension), and semantic (5 Dimension). In addition, this system integrates and visualizes the analyzed results as multi-dimensional axes dynamic historical atlas. The main feature of this system is to dynamically create various context-dependent environmental patterns according to a user's viewpoints. This system supports the composition of images as the image retriever and enables to realize that users find out the images that show the particular situations of the environment [2-8].

2.2 Coral-Knowledge Image

Coral-knowledge image [9] in Figure 1 consists of two essential elements:1) Coral image in the center and 2) Coral health chart [10]. The coral health chart is based on the actual colors of bleached and healthy corals, that each color square corresponds to a concentration of symbionts contained in the coral tissue is directly linked to the health of the coral. This chart represents the most common colors of corals and helps our eyes to make an accurate match. The color is divided into four groups (B, C, D, and E) and classified into six levels (1-6) for each side. The highest level (level 6) represents the best healthy coral, and the lowest (level 1) means the worst healthy coral. The health status and mortality percentages from the coral health chart are shown in Table 1 [11].
Table 1. The health status and mortality percentages from the coral health chart.

| Level | State of health | Healthy percentage | Mortality percentage |
|-------|-----------------|--------------------|---------------------|
| 1     | Worst           | 16.67              | 83.33               |
| 2     | Poor            | 33.33              | 66.67               |
| 3     | Declining       | 50.00              | 50.00               |
| 4     | Fair            | 66.67              | 33.33               |
| 5     | Good            | 83.33              | 16.67               |
| 6     | Best            | 100.00             | 0.00                |

3. Proposed Methods

3.1. Implementation of a prototype system

This section explains our system's concept of creating an automatic database in semantic space to analyze, interpret, and visualize coral health levels using the 5D World Map system.

The concept of the system is shown in Figure 2:

Step 1: Image data must be coral-knowledge images [8], including coral images and coral health charts.

Step 2: Edge detection is a process to retrieve and detect the coral health chart by using SIFT algorithm (Scale Invariant Feature Transform) to get four corner points and one point at the eye of the coral health chart [9].

Step 3: Find the chart's color and identify 24 color codes as B1-B6, C1-C6, D1-D6, and E1-E6.

Step 4: Getting the color value of coral using k-means clustering to determine the dominant color in coral-knowledge images. The highest score has been chosen to represent the coral color.

Step 5: Interpretation of meaning by color distance computing. We are finding color semantic distance in HSV color space; the result gives the meaning of the coral
health-level according to the distance ordering of "minimal value" between the color of coral and the closed color code of the chart.

Step 6. Show the coral health level of the coral-knowledge image in 5D World Map System.

Figure 2. The concept of system.

3.2. Color semantic distance computing

We use the color semantic distance calculation to show the color distance between 24 color codes in the coral health chart and coral color value. In HSV color space, we use Eqs. (1) – (4) to find distance between 2 pixels: \( P_0(h_0,s_0,v_0) \) and \( P_1(h_1,s_1,v_1) \) as follows:

\[
\begin{align*}
    dh &= \min(\text{abs}(h_1-h_0), 360-\text{abs}(h_1-h_0)) / 180.0 \quad (1) \\
    ds &= \text{abs}(s_1-s_0) \quad (2) \\
    dv &= \text{abs}(v_1-v_0) / 255.0 \quad (3) \\
    \text{distance} &= \sqrt{dh^2 + ds^2 + dv^2} \quad (4)
\end{align*}
\]

When \( dh \), \( ds \) and \( dv \) are the distance between \( P_0 \) and \( P_1 \) in H (Hue), S (Saturation), and V (value) color space, respectively. Each of these values will be in the range [0,1]. In the color distance, the smaller result is the higher similarity.

3.3. K-means Clustering

Given a set of observations \((x_1, x_2, ..., x_n)\), where each observation is a d-dimensional real vector, k-means clustering aims to partition the n observations into k (\( \leq n \)) sets \( S = \{S_1, S_2, ..., S_k\} \) to minimize the within-cluster sum of squares.
Where $\mu_i$ is the mean of points in $S_i$. This is equivalent to minimizing the pairwise squared deviations of points in the same cluster:

$$\arg\min_{S} \sum_{i=1}^{k} \sum_{x \in S_i} ||x - \mu_i||^2 = \arg\min_{S} \sum_{i=1}^{k} |S_i| \text{Var} S_i$$

The equivalence can be deduced from identity

$$\sum_{x \in S_i} ||x - \mu_i||^2 = \sum_{x \neq y \in S_i} (x - \mu_i)^T (\mu_i - y)$$

In HSV color space, we use k-means clustering to determine the dominant color of the coral in a coral-knowledge image by using 10x10 pixels in the center of the image, as shown in Figure 3.

![K-means clustering to determine the dominant color.](image)

3.4. Data Sources

The data sources that we use in coral health levels analysis are coral-knowledge-images. The image consists of coral in the center, and the coral health chart can be up, down, left, or right of the coral. All of the coral-knowledge-images have been taken underwater environment.
3.5. Description of study areas

The study areas of coral health levels analysis are located in the ocean close to Thailand’s islands as Ko Ha (Five Island), Ko Bon, Ko Hin Ngam, Ko Tarutao, Ko Thalu, and Ko Samaesarn. The descriptions of the coral-knowledge images are shown in Table 2.

| Coral-knowledge-image | Date       | Time   | Island       | Latitude     | Longitude    |
|-----------------------|------------|--------|--------------|--------------|--------------|
| 8/25/2019 14:17       | Ko Samaesarn | 12.57107812 | 100.9461504184105 |
| 4/14/2021 8:54        | Ko Ha       | 8.1502651  | 98.755861     |
| 4/14/2021 12:20        | Ko Bon      | 7.7564336  | 98.332116     |
| 11/14/2020 15:11      | Ko Hin Ngam | 6.5148976  | 99.2624372    |
| 11/13/2020 15:52      | Ko Tarutao  | 6.5913175  | 99.6564092    |
| 11/13/2020 11:45      | Ko Thalu    | 11.0762275 | 99.560394     |
| 8/25/2019 14:17       | Ko Samaesarn | 12.57107812 | 100.9461504184105 |
| 4/14/2021 12:40        | Ko Bon      | 7.7564336  | 98.332116     |
3.6. Data Structure

We collected 311 files in CSV form and added semantic and spatiotemporal metadata such as category, location, date, and description for each image data. The data structures are based on 5D World Map System, as shown in Figure 4.

Figure 4. The data structures are based on 5D World Map System.
4. Results and Discussion

To clarify the feasibility and effectiveness of our method and system by (1) showing several experimental results for coral health levels analysis databases and (2) showing several experimental results for coral health levels analysis with a semantic interpretation method and 5D World Map System.

| coral id        | Human eyes | K-means in HSV color space | coral-knowledge image |
|-----------------|------------|---------------------------|-----------------------|
| P8250068-E1     | E1         | D1                        |                       |
| P8250135-C2     | C2         | B2                        |                       |
| P8250128-E3     | E3         | E3                        |                       |
| P8250025-E4     | E4         | E4                        |                       |
| P8250048-E4     | E4         | E4                        |                       |
| P8250028-B5     | B5         | B5                        |                       |
| P8250168-E5     | E5         | E5                        |                       |
| P8250035-D6     | D6         | D6                        |                       |

*Figure 5.* The result of the coral health levels analysis experiments.
4.1. Coral Health Levels Analysis Databases

We have implemented our coral health levels analysis with coral-knowledge image retrieval, using k-means to determine the dominant color in a coral image and color semantic distance computing system for coral-knowledge image datasets. The accuracy of the experiment is 85.0%. Some of the results of the experiment are shown in Figure 5.

4.2. Coral Health Levels Analysis with Semantic-Interpretation Method and 5D World Map.

We realized the mapping and visualization results of coral health levels analysis in 5D World Map System and applied the coral-knowledge image. Our experimental results have shown a semantic associative computing system based on semantic computing in the global environmental analysis shown in Figures 6-9.

Input keywords = coral health level, Categories = climate change, coral reef environment, ocean pollution

Figure 6. Global coral health levels analysis in 5D world map system:
(a) Keywords search by "coral health levels",
(b) Spatiotemporal analysis (global overview of geographical distribution and the time-series),
and (c) Example of coral-knowledge images in climate change, coral reef environment, and ocean pollution categories.
Input keywords = E4, Categories = climate change, coral reef environment, ocean pollution

**Figure 7.** Global coral health levels analysis in 5D World Map System:
(a) Keywords search by coral health levels "E4", (b) Spatiotemporal mapping in the global overview of geographical distribution, and (c) The coral-knowledge images that have health at "E4" (Fair health) in climate change, coral reef environment, and ocean pollution categories.

Input keywords = good health, Categories = climate change, coral reef environment

**Figure 8.** Global coral health levels analysis in 5D world map system:
(a) Keywords search by coral health "Good health", (b) Spatiotemporal mapping in the global overview of geographical distribution, (c) The coral-knowledge images that have health at "good health" (level B5, C5, D5, and E5) in climate change and coral reef environment categories.
5. Conclusion

We have presented a new environmental-semantic computing system for coral health levels analysis database and coral-knowledge image spaces with 5D World Map. The main feature of our approach is to realize integration and semantic-search among global environmental-semantic spaces based on the concept of coral health levels analysis space. This system enables creating an automatic coral health level analysis in semantic space for the ocean environment. It makes artificial intelligence vision cognitive functions using image processing with semantic computing instead of the human eye.

As future work, we will extend the coral health levels analysis semantic space realized onto the 5D world map system to global knowledge-sharing on the ocean environment worldwide.

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