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A Coral-Color Analysis System for Observing Environmental Situation and Change with K-means Clustering and Semantic Classification

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Abstract

The impact of rapid ocean warming due to climate change poses a serious risk to the survival of coral reefs. Our motivation is to promote healthy reefs by engaging the global community in monitoring coral health and coral bleaching with Global Environmental Semantic Computing System. We have already proposed a new "Coral-health-level interpretation method" with coral image, coral-chart, and semantic computing. Based on this method, this paper presents an actual implementation of this method with an advanced Coral-Color Analysis System for Observing Environmental Situation and Change. This paper proposes to apply K-means clustering to HSV color systems and Semantic Classification for Coral-health levels with high precision. We clarify our method, system's feasibility, and effectiveness by showing several experimental results on Coral-health levels and color semantic distance between coral and coral health chart colors.

Keywords : Coral-Color Analysis; Coral-health-level; K-means Clustering; Semantic Classification; Coral health chart; Color distance

Introduction

Human activities impact many physical environment issues such as deforestation, burning fossil fuels, and land-use changes contributing to climate change by causing changes in Earth's atmosphere in greenhouse gases. The impact of rapid ocean warming due to climate change poses a severe risk to the survival of coral reefs. It has already led to sharply increased rates of coral bleaching, killing vast areas of reef, and predicted to increase in frequency and severity in the future.

Coral bleaching is a devastating global environmental issue. Our motivation is promoting healthy reefs by engaging the global community in monitoring coral health and coral bleaching with 5D World Map System, proposed by Y. Kiyoki and S. Sasaki in [1-3], is globally utilized as a Global Environmental Semantic Computing System, in SDGs 9, 11, 14, United-Nations-ESCAP: (https://sdghelpdesk.unescap.org/toolboxes), as a

KEIO-MDBL-UN-ESCAP Joint system for disaster, natural phenomena, ocean-water analysis with local and global multimedia data resources [4-8].

We have already proposed a new "Coral-health-level interpretation method" with coral image, coral-chart, and semantic computing [8] that works on RGB and HSV color-system. In this paper, we present an advanced Coral-Color Analysis System for Observing Environmental Situation and. This paper proposes to apply K-means clustering to HSV color systems and Semantic Classification for Coral-health levels with high precision. This method is based on coral-image-knowledge detection using image processing and color semantic distance using the distance between coral and coral health chart colors.

Methodology

Related Works

1. 5D World Map System

The 5D World Map System is globally utilized as a Global Environmental Semantic Computing System, in SDGs 9, 11, 14, United-Nations-ESCAP: as a KEIO-MDBL-UN-ESCAP Joint system for disaster, natural phenomena, ocean-water analysis with local and global multimedia data resources. This system is a collaborative knowledge sharing, analyzing, searching, integrating, and visualizing system with control mechanisms with multi-dimensional map [3, 9-11]. This system analyses multimedia such as images, videos, audio, etc., by semantic, temporal, and spatial information. Also, this system integrates and visualizes the analyzed results as multi-dimensional axes, dynamic historical atlas. This system's main feature is to create various context-dependent patterns of environmental/cultural stories according to a user's viewpoints dynamically.

2. Coral Health Chart

Coral Health Chart was developed by CoralWatch in 2002. [12] CoralWatch is a not-for-profit citizen science program based at The University of Queensland working with volunteers worldwide to increase understanding of coral reefs, coral bleaching [13], and climate change. Coral Health Chart in **Figure 1** to estimate health status. The color of each side is divided into four groups (B, C, D, and E) and classified into six levels (1-6) for each side. In level 1 represents coral in worst health, and level 6 represents coral in the best health. The health status and mortality percentages from the coral health chart shows in **Table 1** [14].

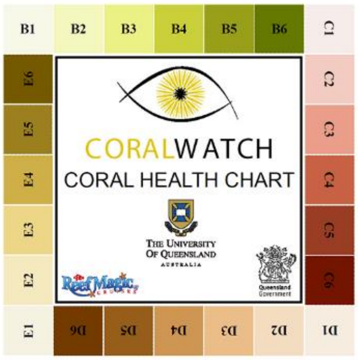

Figure 1 Coral Health Chart
(https://coralwatch.org/index.php/product/coral-health-chart/ [15])

Table 1 The health status and mortality percentages from the coral health chart

Level	Remark	Health status percentages	Mortality percentages
1	Worst health	16.67	83.33
2	Poor health	33.33	66.67
3	Declining health	50.00	50.00
4	Fair health	66.67	33.33
5	Good health	83.33	16.67
6	Best health	100.00	0.00

Concept and Prerequisites of System

We explain our system's concept and prerequisites that create an automatic coral health level analysis in semantic space for the ocean environment and create cognitive functions of artificial intelligence vision using image processing with semantic computing instead of the human eye.

Figure 2 shows the concept of the system: (1) Image data has to be coral-knowledge that includes coral in the center of the image and coral health chart can be up, down, left, or right of the coral as shown in **Figure 3**., (2) Image Processing is processed to retrieval and edge detection of the coral health chart, (3) Finding the chart's color and identifying 24 color codes (B1-B6, C1-C6, D1-D6, E1-E6), (4) Getting the color value of coral at the center of the image (10x10 pixels), and (5) Interpretations of meanings by color distance computing.

Implementation of a prototype system

this system consists of 3 processes: (a) Coral-knowledge detection, (b) Creation color of coral and coral health chart in color space, and (c) Color semantic distance computing. The procedure of the proposed idea is represented in **Figure 4**.

(a) Coral-knowledge detection

In the process, we apply image processing on coral-knowledge-base-image. Then we using SIFT algorithm (Scale Invariant Feature Transform) to get 4 corner points and 1 point at the eye of the coral health chart, as **Figure 5**.

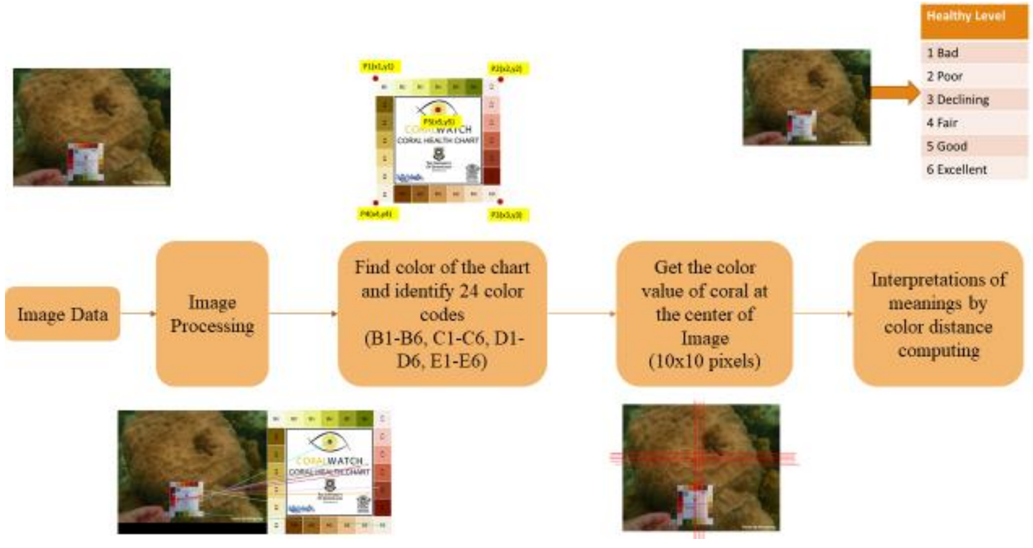

Figure 2 The concept of system

Figure 3 Coral-knowledge image

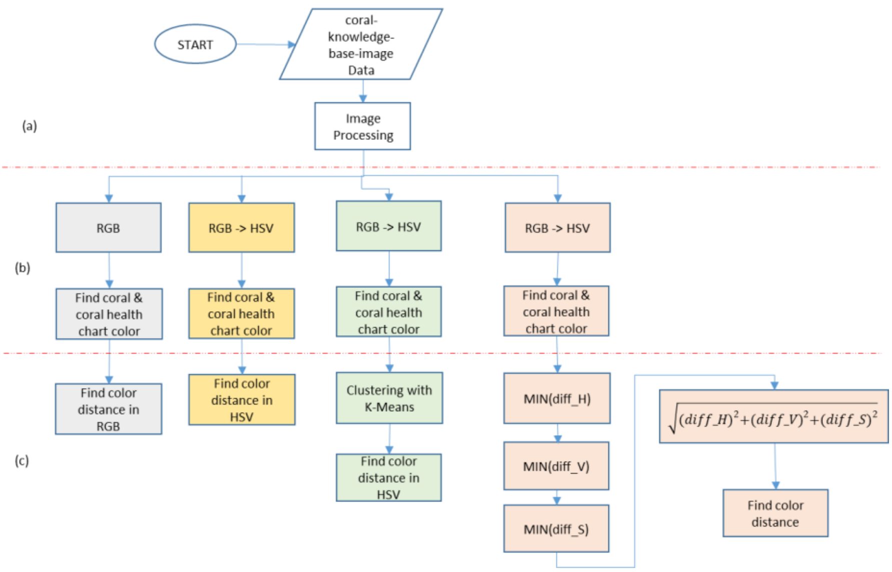

Figure 4 System overview and operating procedure

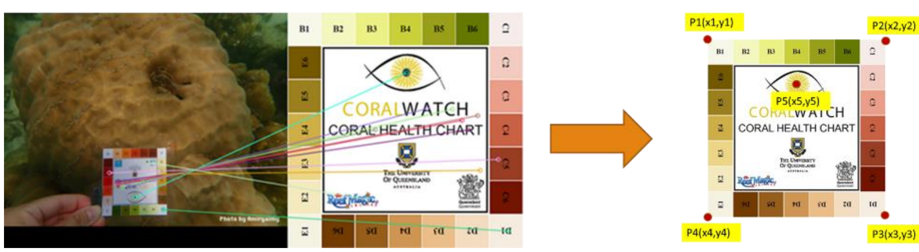

Figure 5 Coral-image-knowledge detection by using SIFT algorithm

(b) Creation color of coral and coral health chart in color space

After that, we find the color of the chart and identify 24 color codes and get the color value of coral at the center of the image. Then create color in RGB color space or HSV color space depending on the experiment.

(c) Color semantic distance computing.

In RGB color space, we use the Euclid distance calculation to show the color distance between 24 color codes in the coral health chart and coral color value. Equation (1) is the Euclidean distance calculation

$$d(p,q) = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2} \qquad (1)$$

When p, q = two points in Euclidean n-space
q_i , p_i = Euclidean vectors, starting from the origin of the space (initial point)
n = n-space

In HSV color space, we use Equation (2) – (5) to find distance 2 pixels $P_0(h_0,s_0,v_0)$ and $P_1(h_1,s_1,v_1)$ as follows:

$$dh = \min(abs(h_1-h_0), 360-abs(h_1-h_0))/180.0 \quad (2)$$

$$ds = abs(s_1-s_0) \quad (3)$$

$$dv = abs(v_1-v_0) / 255.0 \quad (4)$$

When dh, ds and dv are the distance between P_0 and P_1 in H (Hue), S (Saturation), and V (value), respectively. Each of these values will be in the range [0,1]. we can compute the length of this :

$$distance = \sqrt{dh^2 + ds^2 + dv^2} \quad (5)$$

In the color distance in RGB or HSV color space, the smaller result is the higher similarity.

In HSV color space, we use k-means clustering to determine the dominant colors in a coral image by using 10x10 pixels in the center of the coral-knowledge-base-image as shown in **Figure 6**.

Results and Discussions

We clarify our method's feasibility and applicability by implemented our coral health levels with coral-knowledge-base-image retrieval and color semantic distance computing system for coral-knowledge image datasets. We conducted four experiments. Experiment 1 is finding color semantic distance in RGB color space. Experiments 2-4 are used in HSV color space: Experiment 2 finds color semantic distance in HSV color space. Experiment 3 uses k-means clustering to determine the dominant colors in coral images before finding color semantic distance in HSV color space. Experiment 4 is using k-means clustering to assess the dominant colors in coral images. After that, divide HSV color space into 3 subspaces and find the color distance in subspace H, subspace V, and subspace S, respectively.

In Experiments 1 to 4, we use the same coral-knowledge image shown in **Figure 7** that inspect by human eyes. The result gives the meaning of the coral health-level as "E4" (corresponding to "Fair-coral in health-level").

Experiment 1

We are finding color semantic distance in RGB color space of **Figure 8**. The execution result of the coral-knowledge image with extracting coral-chart codes and coral-color is shown in Figure 8. This result gives the meaning of the coral health-level as "D3" (corresponding to "declining -coral in health-level"), according to the distance ordering of "minimal value" between coral-color and the closed color code.

There is some limitation in the underwater environment by using a 3-color-elements or RGB color system. Under this light situation, creating shadow, highlight, and reflection on either coral or chart or both. Therefore, leading to misinterpretation in the result of coral health level.

Experiment 2

We are finding color semantic distance in HSV color space of figure 7. The execution result of the coral-knowledge image with extracting coral-chart codes and coral-color is shown in **Figure 9**. This result gives the meaning of the coral health-level as "C5" (corresponding to "good-coral in health-level"), according to the distance ordering of "minimal value" between coral-color and the closed color code.

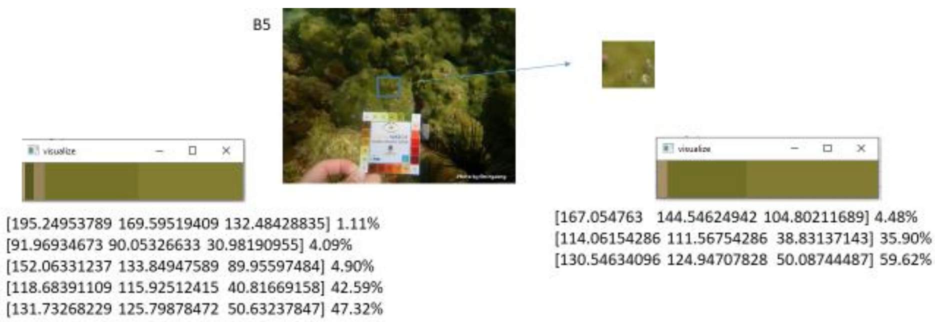

Figure 6 k-means clustering to determine the dominant colors

Figure 7 Coral-knowledge image

	R	G	B
B1	146.977	154.068	168.545
B2	164.977	130.091	98.909
B3	177.000	97.114	40.455
B4	171.682	63.159	28.000
B5	135.250	48.114	23.409
B6	116.909	56.364	36.818
D1	55.114	39.455	13.068
D2	78.068	54.795	20.773
D3	129.773	99.591	47.773
D4	134.864	102.023	50.318
D5	137.682	101.636	47.477
D6	120.500	81.909	29.136
E1	132.909	131.909	141.614
E2	137.227	86.386	77.727
E3	140.386	26.000	11.432
E4	132.000	12.523	10.250
E5	100.545	18.250	17.114
E6	69.864	31.727	36.455
C1	55.432	43.000	13.250
C2	41.227	38.318	13.500
C3	31.682	32.864	12.159
C4	25.682	25.477	10.205
C5	16.614	16.818	6.591
C6	107.568	76.159	62.477

colorid	Score
D3	8.027972
D1	9.218148
C5	11.918220
D2	12.374717
B5	14.351353
C4	14.736412
B2	15.379204
D4	17.602525
B1	18.959285
C3	19.827303
B4	22.082736
B3	27.400321
C6	29.100239
B6	32.690991
E6	42.032430
D5	49.054968
C2	71.531889
D6	79.741235
E1	94.168258
C1	94.486443
E2	108.372755
E3	116.736389
E4	123.918203
E5	132.781850
(24 rows)	

Figure 8 The execution result of coral-knowledge image with extracting coral-chart codes and coral-color in RGB color space

	HUE	Saturation	Value
B1HSV	0.611872	0.127967	168.5455
B2HSV	0.078661	0.400468	164.9773
B3HSV	0.069158	0.771443	177
B4HSV	0.040784	0.836908	171.6818
B5HSV	0.036815	0.82692	135.25
B6HSV	0.040673	0.68507	116.9091
D1HSV	0.104595	0.762887	55.11364
D2HSV	0.098969	0.733916	78.06818
D3HSV	0.105322	0.631874	129.7727
D4HSV	0.101927	0.626896	134.8636
D5HSV	0.100067	0.655167	137.6818
D6HSV	0.096269	0.758204	120.5
E1HSV	0.683841	0.068528	141.6136
E2HSV	0.024255	0.433587	137.2273
E3HSV	0.018829	0.918569	140.3864
E4HSV	0.003111	0.922348	132
E5HSV	0.00227	0.829792	100.5455
E6HSV	0.97934	0.545869	69.86364
C1HSV	0.117547	0.760968	55.43182
C2HSV	0.14918	0.672547	41.22727
C3HSV	0.17618	0.630014	32.86364
C4HSV	0.164464	0.602655	25.68182
C5HSV	0.17	0.608108	16.81818
C6HSV	0.050571	0.419184	107.5682

colorid	Score
C5	17.649512
C4	18.743346
C3	24.704066
B3	34.34524
D2	38.110734
C6	49.185427
B2	50.787924
E6	56.688788
B4	60.328599
B6	67.62282
B5	73.102594
D1	91.556598
D3	97.231108
C2	97.962288
D4	110.951172
D5	112.869596
D6	115.23381
B1	122.070598
E1	124.148843
C1	126.481209
E2	137.654072
E3	148.538761
E4	157.863857
E5	170.79295

Figure 9 The execution result of the coral-knowledge image with extracting coral-chart codes and coral-color in HSV color space

Experiment 3

A similar coral-knowledge image has been used in Experiment 3. By using k-means to determine the dominant colors in coral images, the highest score has been chosen to represent the coral color. Then finding color semantic distance between coral color and coral chart codes in HSV color space. When k = 3 and 5, both result shows in **Figure 10**.

This result of k=3 and k = 5 gives the meaning of the coral health-level as "E6" (corresponding to "Excellent-coral in health-level"), according to the distance ordering of "minimal value" between coral-color and the closed color code.

Experiment 4

A similar coral-knowledge image has been used in Experiment 4. But the method is different. By using k-means when k =3 to determine the dominant colors in the coral image. We use k-means clustering to determine the dominant colors in the coral image before finding color semantic distance in HSV color space. In HSV color space, we find the color distance in H, the color distance in S, and the color distance in V in order. The result of this experiment shows in **Figure 11**. For this experiment, The result gives the meaning of the coral health-level as "E4" (corresponding to "Fair-coral in health-level"), same as the human eye's result.

From Experiment 1-4, the result of experiment 4 is close to the human eye. We use 30 coral-knowledge-base-images to experiment with our proposed method. The accuracy of experiment 1 to 4 are 41.2%, 50.0%, 70.0%, and 85.0% , respectively. In **Table 2** shows the result of some coral-knowledge-base-images that we use in our experiments.

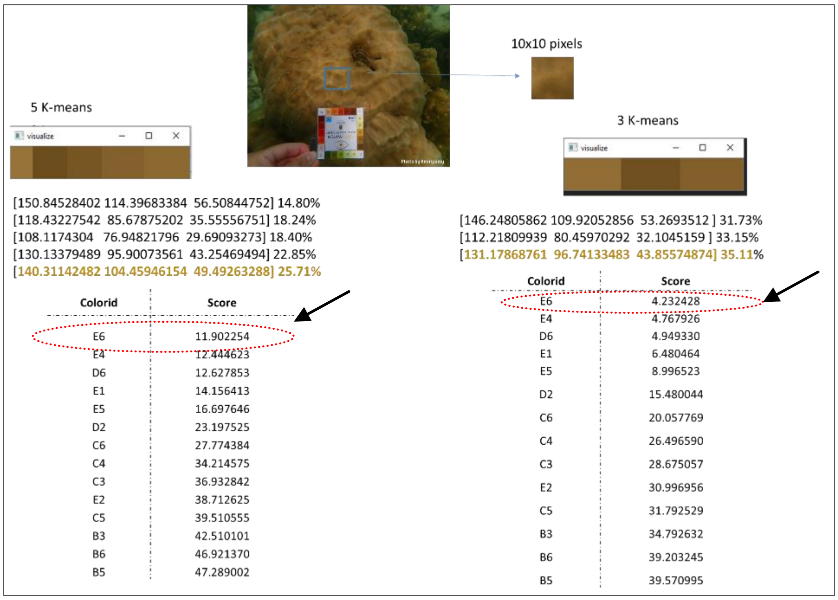

Figure 10 The execution result of coral-knowledge-base-image with extracting coral-chart codes and coral-color in HSV color space using k-means

Chart	H	S	V	Diff_H
B1HSV	224.00000000	7.42574257	79.21568627	186.5
B2HSV	71.48936170	27.97619048	65.88235294	33.98936
B3HSV	80.35714286	38.35616438	57.25490196	42.85714
B4HSV	70.62500000	96.00000000	39.21568627	33.125
B5HSV	60.00000000	89.65517241	22.74509804	22.5
B6HSV	70.58823529	82.92682927	16.07843137	33.08824
C1HSV	223.20000000	15.82278481	61.96078431	185.7
C2HSV	356.25000000	11.94029851	52.54901961	318.75
C3HSV	10.63829787	97.24137931	56.86274510	26.8617
C4HSV	0.83333333	92.90322581	60.78431373	36.66667
C5HSV	1.66666667	95.57522124	44.31372549	35.83333
C6HSV	3.80952381	80.76923077	30.58823529	33.69048
D1HSV	221.73913043	13.29479769	67.84313725	184.2391
D2HSV	32.59259259	47.92899408	66.27450980	4.907407
D3HSV	27.89808917	90.75144509	67.84313725	9.601911
D4HSV	13.81578947	92.12121212	64.70588235	23.68421
D5HSV	15.14563107	85.83333333	47.05882353	22.35437
D6HSV	18.94736842	79.16666667	37.64705882	18.55263
E1HSV	240.00000000	3.66972477	85.49019608	202.5
E2HSV	51.76470588	23.94366197	83.52941176	14.26471
E3HSV	50.34482759	41.42857143	82.35294118	12.84483
E4HSV	38.28220859	84.45595855	75.68627451	0.782209
E5HSV	32.85714286	82.89473684	59.60784314	4.642857
E6HSV	30.43478261	74.19354839	36.47058824	7.065217
CORAL_HSV	37.50000000	61.93548387	60.78431373	

Chart	H	S	V		diff_V
D2HSV	32.59259259	47.92899408	66.27450980		5.490196
D3HSV	27.89808917	90.75144509	67.84313725		7.058824
E3HSV	50.34482759	41.42857143	82.35294118		21.56863
E4HSV	38.28220859	84.45595855	75.68627451		14.90196
E5HSV	32.85714286	82.89473684	59.60784314		1.176471
E6HSV	30.43478261	74.19354839	36.47058824		24.31373
				min	1.176471
				sd	11.56863

Chart	H	S	V	diff_S
E5HSV	32.85714286	82.89473684	59.60784314	20.95925
D2HSV	32.59259259	47.92899408	66.27450980	14.00649
D3HSV	27.89808917	90.75144509	67.84313725	28.81596
E4HSV	38.28220859	84.45595855	75.68627451	22.52047

E5	188.4449262
E4	39.9493564
D2	45.42090601

ANSWER	E4

Figure 11 The execution result of coral-knowledge-base-image with extracting coral-chart codes and coral-color in HSV color space using k-means and find the distance in H, S, and V in order

Table 2 The result of experiments 1-4 of 10 coral-knowledge-base-images

coral id	human eye	RGB experiment 1 100 pixels	HSV experiment 2 100 pixels	HSV experiment 3 k-means	HSV experiment 4 diff_H	Coral-Knowledge-Base-Image
P8250068_E1	E1	E2	D1	E2	D1	
P8250135-C2	C2	E6	B3	B2	B2	
P8250128-E3	E3	E6	E3	E2	E3	
P8250025-E4	E4	D3	C5	E6	E4	
P8250048_E4	E4	E5	E5	E4	E4	
P8250028-B5	B5	B3	D3	B6	B5	
P8250129_D5	D5	D6	D6	D6	E5	
P8250168-E5	E5	E6	E6	E5	E5	
P8250005_E6	E6	E5	D5	D6	E6	
P8250035-D6	D6	C5	C3	D4	D6	
Accuracy (%)_		**41.20**	**50.00**	**70.00**	**85.00**	

Conclusion

This paper proposes applying K-means clustering to HSV color systems and Semantic Classification to observe environmental situations using coral color analysis. As future work, we will 1) create an automatic coral health level analysis in semantic space for the ocean-environment, 2) create cognitive functions of artificial intelligence vision by using image processing with semantic computing instead of a human eye, and 3) extend the number of various application systems integration with the environmental multimedia computing system and the 5D World Map system to improve coral-knowledge images.

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