



“5-Dimensional World Map”: An Environmental AI System with Global Knowledge-Sharing, Analysis and Propagation for Resilient Nature and Society

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Abstract

Humankind faces the essential and indispensable mission; we must endeavor on a global scale to perpetually restore and improve our natural and social environments. One of the essential computations in environmental study is context-dependent semantic-computing to analyze the changes of various situations and phenomena in a context dependent way with a large amount of environmental information resources.

It is also significant to memorize those situations and phenomena to analyze and recognize environment changes in various aspects and contexts, in order to discover what are happening in the nature of our planet. We have proposed a multi-dimensional computing model, as a global environmental system, realizing “5-Dimensional World Map System” for realizing knowledge and information resource memorization, integration, search, analysis and visualization of environmental situations and phenomena in ocean and land. We have presented the concept of “SPA (Sensing, Processing and Analytical Actuation Functions)” for realizing a global environmental system, to apply it to 5-Dimensional World Map System. This concept is effective and advantageous to design environmental systems with Cyber-Physical integration to detect environmental phenomena as real data resources in a physical-space (real space), map them to cyber-space to make analytical and semantic computing, and actuate the analytically computed results to the real space with visualization and actuation for realizing analytical environmental phenomena, causalities and influences. Currently, the 5D World Map System is globally utilized as a Global Environmental Semantic Computing System for Ocean and river environments in SDG14, United-Nations-ESCAP, (<https://sdghelpdesk.unescap.org/toolboxes>).

This concept of “SPA-based 5D World Map System” is effective and advantageous to design environmental systems with Cyber-Physical integration to detect environmental phenomena as real data resources in a physical-space (real space), map them to cyber-space to make analytical and semantic computing, and actuate the analytically computed results to the real space with visualization for expressing environmental phenomena, causalities and influences. Semantic computing in SPA-based 5D World Map System is an important and promising approach to semantic analysis for various environmental phenomena and changes in the real world. We have presented a new concept of “*Water-quality Analysis Semantic-Space for Ocean-environment*” for realizing global water-environmental analysis with semantic computing. This space and the semantic computing method are realized with database creation for analyzing and interpreting environmental phenomena and changes

occurring in the oceans in the world. We have focused on seawater quality data with water-quality-analysis sensors, as an experimental study for creating “*Water-quality Analysis Semantic-Space for Ocean-environment*”.

This paper summarizes and integrates our studies on “SPA-based 5-Dimensional World Map System” with semantic computing functions,” as a global and environmental AI system.

Keywords : Global Environmental Analysis; Semantic Computing; SPA; 5-Dimensional World Map System; Data Mining; Artificial Intelligence

Introduction

As an important global environmental system, we have proposed a multi-dimensional data mining and visualization system. In the design of this global environment-analysis system, we focus on methodology for searching and analyzing environmental media data (images, sound, movies, documents and sensing data) related to environmental situations and phenomena. This system realizes semantic computing and search for media data and it is applied to compute semantic correlations between keywords, images, sensing data, sound data, documents and sensing data dynamically, according to user's contexts and analysis-points in a context-dependent way. The main feature of this system is to realize semantic computing in the multi-dimensional semantic space with semantic distance functions. This space is created for dynamically computing semantic equivalence, similarity and difference as distance functions.

Our “SPA-based 5D World Map System” realizes “Global Environment-Analysis,” as a Cyber-Physical System, shown in **Figure 1**, which aims to realize SPA processes to realize global and environmental knowledge and information resources to memorize, integrate, search, analyze, evaluate and visualize various influences caused by natural phenomena and disasters in global environments. Our experimental system has shown the feasibility and effectiveness of the semantic computing system in global environmental analysis. We

have presented “SPA-based 5D World Map System for seawater quality [1-3]”, for sharing and analyzing environmental situations with “environmental multimedia data sharing,” as a new platform of collaborative and global environment analysis [2, 4, 5]. This system is used to realize a remote, interactive and real-time environmental and academic research exchange among different areas.

As an important global environmental system, we have proposed a multi-dimensional data mining and visualization system. The main feature of this system is to realize semantic data mining, visualization and analysis in the “multi-dimensional semantic space” and “semantic-distance computing” with semantic functions. This space is created for dynamically computing semantic equivalence, similarity and difference as distance functions.

The important applications of the semantic computing system is “Global Environment-Analysis” for making appropriate and urgent solutions to global environment changes in terms of short and long-term changes. The “six functional-pillars” are essentially important with “environmental knowledge base creation” for sharing, analyzing and visualizing various environmental phenomena and changes in the real world.

- 1) Cyber & Physical Space Integration
- 2) SPA-function
- 3) Spatio-Temporal computing
- 4) Semantic computing
- 5) World map-based visualization
- 6) Warning message propagation.

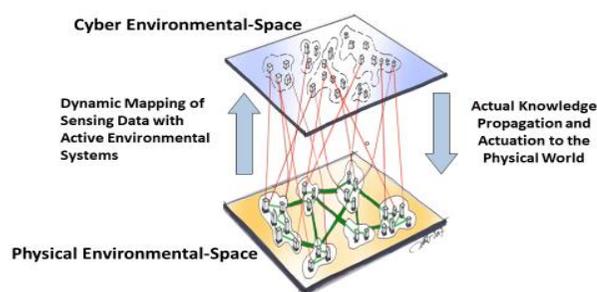


Figure 1 Global & Environmental System with “Cyber & Physical Spaces”

The 5D World Map System realizes Cyber-Physical-Spaces integration, as shown in **Figure 2**, to detect environmental phenomena with real data resources in a physical-space (real space), map them to the cyber-space to make knowledge bases and analytical computing, and actuate the computed results to the real space with visualization for expressing environmental phenomena, causalities and influences. The 5D World Map System and its applications create new analytical circumstance with the SPA concept (Sensing, Processing and Analytical Actuation) for sharing, analyzing and visualizing natural and social environmental aspects. This system realizes “environmental analysis and situation-recognition” which will be essential for finding out solutions for global environmental issues. The 5D World Map System collects and facilitates a lot of environmental information resources, which are characteristics of ocean species, disasters, water-quality and deforestation.

Methodology

1. Global Environmental Analysis with Semantic Computing

We have introduced the architecture of a multi-visualized and dynamic knowledge representation system “5D World Map System”, applied to environmental analysis and semantic computing. The basic space of this system consists of a temporal (1st dimension),

spatial (2nd, 3rd and 4th dimensions) and semantic dimensions (5th dimension, representing a large-scale and multiple-dimensional semantic space that is based on our semantic computing system [6]. This space memorizes and recalls various multimedia information resources with temporal, spatial and semantic correlation computing functions, and realizes 5D World Map for dynamically creating temporal-spatial and semantic multiple views applied for various “environmental multimedia information resources.”

2. 5D World Map System with Spatio-Temporal and Semantic Computing in SPA

We have introduced the architecture of a multi-visualized and dynamic knowledge representation system “5D World Map System,” applied to environmental analysis and semantic computing. The basic space of this system consists of a temporal (1st dimension), spatial (2nd, 3rd and 4th dimensions) and semantic dimensions (5th dimension, representing a large-scale and multiple-dimensional semantic space that is based on the semantic computing system. This space memorizes and recalls various multimedia information resources with temporal, spatial and semantic correlation computing functions, and realizes “5D World Map System” for dynamically creating temporal-spatial and semantic multiple views applied for various “environmental multimedia information resources.”

We apply the dynamic evaluation and mapping functions of multiple views of temporal-spatial metrics, and integrate the results of semantic evaluation to analyze environmental multimedia information resources. The main feature of this system is to create world-wide global maps and views of environmental situations expressed in multimedia information resources (image, sound, text, video and sensing data) dynamically, according to user’s viewpoints. Spatially, temporally, semantically and

impressively evaluated and analyzed environmental multimedia information resources are mapped onto a 5D time-series multi-geographical space. The basic concept of “5D World Map System” is shown in **Figures 2 and 3**. The 5D World Map system applied to environmental multimedia computing visualizes world-wide and global relations among different areas and times in environmental aspects, by using dynamic mapping functions with temporal, spatial, semantic and impression-based computations [1, 2, 4, 5].

3. SPA: Sensing, Processing and Analytical Actuation Functions in 5D World Map

“SPA” is a fundamental concept for realizing environmental system with three basic functions of “Sensing, Processing and Analytical Actuation” to design an environmental system with Cyber-Physical integration. “SPA” realizes a significant function to detect environmental phenomena as real data resources in a physical-space (real space) in in 5D World Map, maps them to cyber-space to make analytical and semantic computing, and actuate the analytically computed results to the

real space by visualization for expressing environmental phenomena with causalities and influence. This concept is applied to global water-quality and coral-analysis with semantic computing in 5D World Map System [2, 7-9] as shown in **Figures 3**.

Results and Discussion

1. Global and Environmental Coral-Analysis and Visualization in 5D World Map

This section focuses on semantic computing for Coral analysis with a “**Semantic-Interpretation method**”. We realized the experimental system using SPA function in 5D World Map and applied the coral-image data. Coral-leaf analysis has been done in a lot of coral-leaf research projects, as discussed in [2, 7]. One of the important applications of the semantic computing system is “Global Environment-Analysis,” which aims to evaluate various influences caused by natural disasters in global environments. Our experimental results have shown the feasibility and effectiveness of our semantic associative computing system

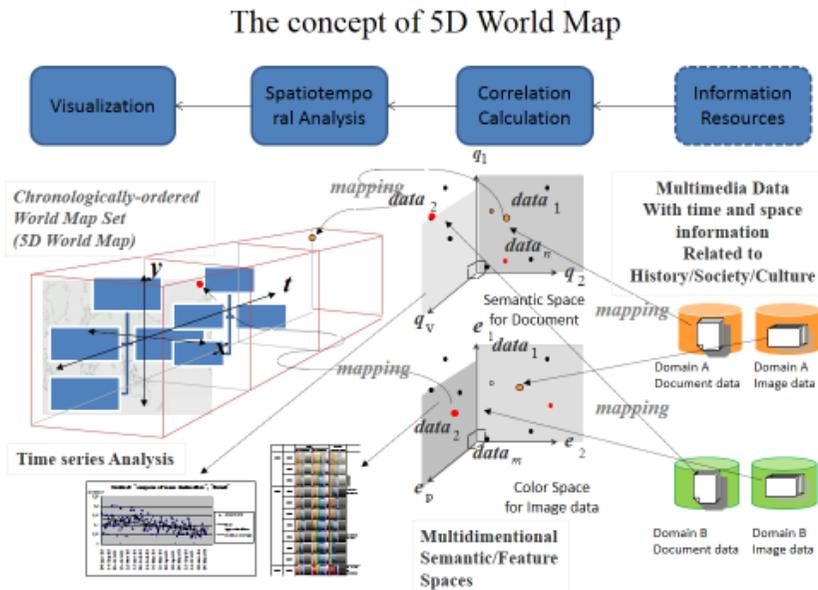


Figure 2 5D World Map System with multi-dimensional semantic-computing functions (AI functions) for world-wide viewing with Global Environmental Analysis

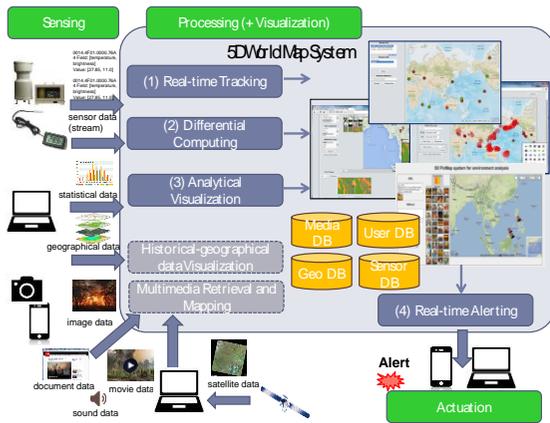


Figure 3 Basic SPA (Sensing, Processing and Analytical Actuation) functions integrated with 5D World Map System

based on our semantic computing in global environmental analysis. We have constructed "SPA-based 5D World Map System" for sharing and analysing environmental situations with semantic functions applied to "environmental multimedia data sharing," as a new platform of collaborative environment analysis [1, 2, 4, 5]. This platform enables to create a remote, interactive and real-time environmental and academic research exchange among different areas. We visualized the important factor of water-quality for coral on 5DWMM which it shown in **Figure 4**.



Figure 4 Global Environmental Analysis of "Coral" in "5D World Map System": (a) Image search by color information, (b) Spatiotemporal analysis (global overview of geographical distribution)

2. Water-Quality Analysis-Space Integration for Global and Environmental Knowledge and Information resources of local phenomena and situations with 5D World Map

The most important feature of 5D World Map System is "global knowledge and information resource integration" with "multi-dimensional semantic space" and "semantic computing" from "local environmental phenomena and situations." Our experimental studies for local environmental phenomena and situations in several remote places in Ocean have applied 5D World Map System to make global integration of Ocean environmental sensing, analysis and visualization in different Islands with the SPA architecture, shown in **Figures 5 and 6** from local environmental phenomena to the global viewpoint on Ocean environment analysis and recognition. This integration shows the possibility of global and environmental knowledge-sharing, analysis, visualization and propagation for realizing resilient nature and society. This section shows the integration of two different experimental studies [1-5, 7, 8] of water-quality analysis around coral reefs in two remote islands, as global environmental analysis and visualization.

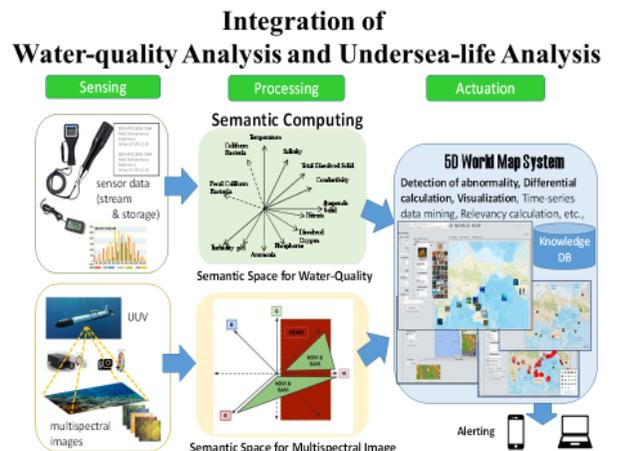


Figure 5 SPA architecture of Environmental Semantic Computing for Integration of Water-Quality Spaces

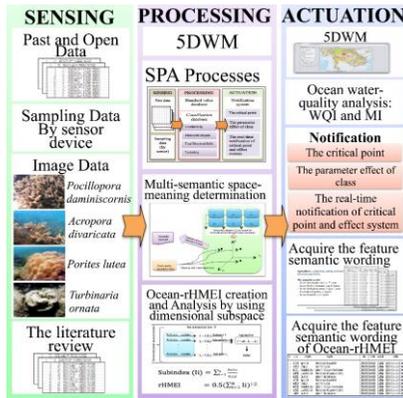


Figure 6 SPA functions for Ocean Environment-analysis with multi-dimensional control in 5D World Map System [1-4]

3. Experiment of SPA Function in 5D World Map for Sea-Water Quality Data in “Coral Areas” of “Si chang-Islands

We have realized the experimental system using SPA function in 5D World Map and applied the collected seawater quality data from points Si-Chang-Island [2, 5, 7]. The main issue of seawater quality in Si chang-Islands is an effect of seawater pollution to the coral life. For this issue, we integrate the following data sources from Si-Chang-Island, and water quality data period from 2011 – 2015, which it collected from Aquatic Resources Research Institute, Chulalongkorn University, Thailand [2, 5, 7-9] We upload them to 5D World Map as image and text data with spatial and temporal dimensions. For the result of effect of seawater pollution to the coral life, we found that temperature, pH, Suspended Solid, Ammonia, Nitrate and Phosphorus are important factors in term of essential nutrient, quantities and equilibrium of the coral life. And we visualized the important factors of water-quality for coral on 5DWM which it shown in **Figures 7** [3-4].

5D World Map memorizes these seawater quality data in combination of environmental coral-image data to make correlation analysis of Ocean environment in this area with context-oriented semantic computing.

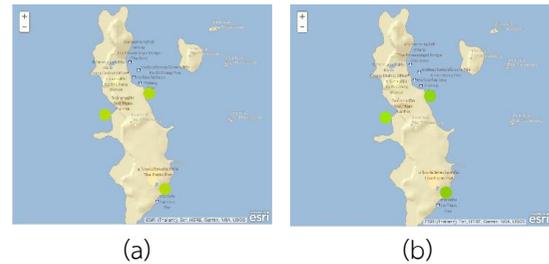


Figure 7 Visualization for water-quality analysis of "Si chang-Island" in 5D World Map (a) Temperature (b) Salinity

4. Water-Quality Analysis-Space in Hawaii Islands

In this section, we introduce a "*Water-quality Analysis Semantic-Space for Ocean-environment*" in 12 dimensions [4], based on the water-quality analyses. In this implementation, this space is used to compare seawater quality. As the first step, this space is applied to seawater and it is expandable to multiple spots in Ocean-areas to analyze and compare their water quality situations in the global scope for Ocean-environmental analysis.

The parameters in the corresponding places in each water resource are mapped as the value of the corresponding axis. For example, when "Spot-S" in some place is mapped into 12-dimensional *Water-quality* space, the values of the *Water-quality* in each axis are mapped onto this space with 12 dimensional-vector values. That is, 12 values are defined for Spot-S in 12 axes in this *Water-quality* space, and we can apply semantic computing to the multi-dimensional space. This semantic space and its implementation are introduced in [1-4] in detail.

The 12-dimentional "*Water-quality Analysis Semantic-space*" consists of 12 axes, each of which corresponds to a single water-quality parameter obtained with the water-quality analytical sensors.

(1) Water-quality Parameters

Generally, seawater containing different pollutants such as biological, physical and chemical has significant adverse effect on human health and water-born diseases. The Bacteria contamination

(Coliform bacterial and Fecal Coliform Bacteria) makes a health impact, as an opportunistic pathogenic, and causes a variety of nosocomial infections of the urinary tract, respiration tract, blood, normal sterile in patients, food poisoning, gastroenteritis, urinary tract infections and neonatal meningitis. The physical pollutants, as conductivity, total solid, total dissolved solid and turbidity, are possible in short-term (when more that standard value) and long-term (when less that standard value) of hazardous impact. The chemical pollutants exist as dissolved oxygen (impossible in nitrification when less than 4.0 mg/L), biological oxygen demand (impossible effect to aquatic life and cause of sewage) and nitrate (the high nitrate level can cause methemoglobinemia or blue baby syndrome and eutrophication).

We have realized the “Water-quality Analysis space” in 12 dimensions in the 5D World Map system. The “Water-quality parameter value in the corresponding “Spot” is mapped as the value of the corresponding axis. This process realized to integrate the specific knowledge of water quality in environmental analysis and the other functions to actuate the results of processing as notification of warning. The SPA applied into water quality analysis is shown in **Figures 8-10**. Experiment of SPA Function in 5D World Map for Seawater Quality Data in Hawaii-Islands.

We have implemented an experimental system using the SPA functions in 5D World Map and applied the collected seawater quality data from points Hawaii-Islands. The major issues of seawater quality in Hawaii-Islands are followings, issue-1) Issue of seawater pollution after flash flood for sea creatures, and issue-2) Issue of seawater pollution after flash flood for human. For the issue-1, we integrate the following data sources, flash flood warning text from Hawaii State, and water quality data period from the time of warning issued to the time of 1 week after the warning. The warnings are issued from NOAA National Weather Service Weather Forecast Office. We can upload them to 5D World Map as

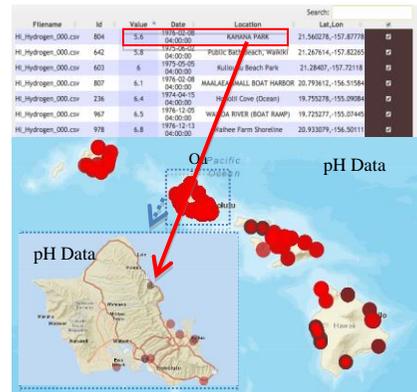


Figure 8 Water-quality data in Hawaii mapped onto 5D World Map. (This figure shows that an experiment of the pH data visualization on the 5D-map by using colors reflected its value. Dark color is expressing lower pH, and it means high hazard for sea creatures.)

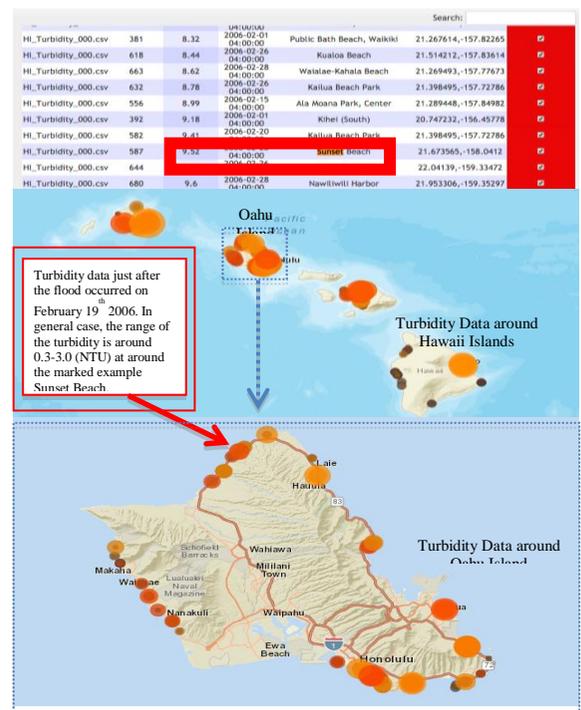


Figure 9 Water-quality data in Hawaii mapped onto 5D World Map in case of a heavy flood on February 2006. (This figure shows that an experiment of the turbidity data (NTU) visualization on the 5D-map by using colors reflected its level of hazard. The results are also projected by its location and time.)

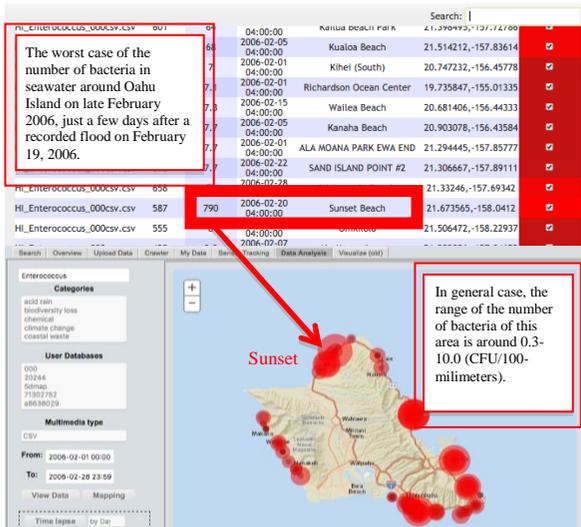


Figure 10 Water-quality data in Hawaii mapped onto 5D World Map in case of a few days after the heavy flood on February 2006. (This figure shows that an experiment of bacterial data (CFU/100-milimeters) visualization.)

text data with time stamp and location data. In typical case of pollution for sea creatures around coastal area of seawater, to keeping the appropriate pH value is one of the requirements to keep high survival ratio of sea creatures like corals at around coastal area. We realized that to visualize pH values right after the period of flash flood. The snapshot of output of our system is shown in **Figures 9, 10**. By this experiment, we can see the polluted point of area after flash flood on 5D World Map and it can be applicable to make actuation of warnings for users at institutes of NGO, NPO that are doing to protect the sea creatures.

For the issue-2, to find the period of risk for human in seawater from bacterial pollution, it is mostly impossible by using only by the visual aspect from human (ex. Turbidity). For the issue, we integrate the following data sources, flash flood warning text from Hawaii State, and water quality data period from the time of warning issued to the time of 1 week after the warning. The warnings are issued from NOAA National

Weather Service Weather Forecast Office. We can upload them to 5D World Map as text data with time stamp and location data. In typical case of pollution for human in seawater, to keeping low bacterial value is one of the requirements to keep low ratio of occurring disease of human like swimmers at around coastal area. We realized that to visualize Turbidity and Bacterial values right after the period of flash flood. The snapshots of output of our system are shown in **Figures 9 and 10**. In this experiment, we can show the time difference of the two values, Turbidity value and bacterial value after flash flood on 5D World Map and it can be applicable to make actuation of warnings directly for users and indirectly for lifeguards sectors in Hawaii State to protect the human in seawater.

Conclusion

We have presented the integration of our environmental system studies with 5D World Map System for realizing environmental semantic spaces and semantic computing, applied to "Water-quality Analysis Semantic-space" for realizing global water-environmental analysis. The most important feature of 5D World Map System is "global knowledge and information resource integration" with "multi-dimensional semantic space" and "semantic computing" from "local environmental phenomena and situations." Our experimental studies for local environmental phenomena and situations in several remote places in Ocean have applied 5D World Map System to make global integration of Ocean environmental sensing, analysis and visualization in different Islands with the SPA architecture, from local environmental phenomena to the global viewpoint on Ocean environment analysis and recognition. This integration shows the possibility of global and environmental knowledge-sharing, analysis, visualization and propagation for realizing resilient nature and society. We have shown the

integration of two different experimental studies of water-quality analysis around coral reefs in two remote islands, as global environmental analysis and visualization.

This space is created for dynamically computing semantic relations between water-quality data resources in different places. We have applied this system to Si Chang-Island and Hawaii for sharing, integrating and visualizing water quality data resources as new experiments on Pacific Islands for ocean environment analysis. This system realizes a remote, interactive and real-time environmental research exchange among multiple and different remote spots in ocean areas. We have created a semantic-space for seawater quality analysis in Hawaii-Islands with 12-dimensional axes (water-quality parameters). As the first step, this space is expandable to multiple spots in Ocean-areas to analyze and compare their water quality situations in the global scope for Ocean-environmental analysis. We applied 5-Dimensional World Map System to seawater quality analysis in Si Chang-Island and Hawaii-Islands, as an international collaborative platform for Ocean-environment analysis with spatio-temporal and semantic analyzers.

As our future work, we will extend the *Water-quality Analysis Semantic-space* realized onto 5-Dimensional World Map System to an international and collaborative research and education system for realizing mutual understanding and global knowledge-sharing on seawater-quality in the world-wide scope.

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References

- [1] Kiyoki, Y., Chen, X., Veasommai, C., Sasaki, S., Uraki, A., Koopipat, C., Chawakitchareon, P. and Hansuebsai, A. 2018. An Environmental-Semantic Computing System for Coral-Analysis in Water-Quality and Multi-Spectral Image Spaces with "Multi-Dimensional World Map". *Information Modelling and Knowledge Bases*. 29: 52-70.
- [2] Kiyoki, Y., Chawakitchareon, P., Rungsup, S., Chen, X. and Samlansin, K. 2020. A Global & Environmental Coral Analysis System with SPA-based Semantic Computing for Integrating and Visualizing Ocean-Phenomena with "5-Dimensional World-Map". *Information Modelling and Knowledge Bases*. 32: 76-91.
- [3] Kiyoki, Y., Uraki, A. and Veasommai, C. 2016. A Seawater-Quality Analysis Semantic-Space in Hawaii-Islands with Multi-Dimensional World Map System. *Proceeding of the 18th International Electronics Symposium (IES2016)*. Bali, Indonesia. on September 29-30 2016. 48-53.
- [4] Veasommai, C., Kiyoki, Y., Sasaki, S. and Chawakitchareon, P. 2016. Wide-Area River-Water Quality Analysis and Visualization with 5D World Map System. *Information Modelling and Knowledge Bases*. 27: 31-41.
- [5] Kiyoki, Y., Chen, X., Sasaki, S. and Koopipat, C. 2017. A Globally-Integrated Environmental Analysis and Visualization System with Multi-Spectral & Semantic Computing in "Multi-Dimensional World Map". *Information*

- Modelling and Knowledge Bases. 27(1292): 106-122.
- [6] Kiyoki, Y. and Ishihara, S. 2002. A Semantic Search Space Integration Method for Meta-level Knowledge Acquisition from Heterogeneous Databases. *Information Modeling and Knowledge Bases*. 13(73): 86-103.
- [7] Rungsupa, S., Chawakitchareon, P., Hansuebsai, A., Sasaki, S. and Kiyoki, Y. 2018. Photographic Assessment of Coral Stress: Effect of Low Salinity to *Acropora* sp. *Goniopora* sp. and *Pavona* sp. at Sichang Island, Thailand. *Information Modelling and Knowledge Bases*. 29(301): 137-148.
- [8] Chawakitchareon, P., Ladsavong, K., Kiyoki, Y., Sasaki, S. and Rungsupa, S. 2018. Global Sharing Analysis and Visualization of Water Quality by 5D World Map: A Case Study at Sichang Island, Thailand. *Information Modelling and Knowledge Base*. 29(301): 216-227.
- [9] Sasaki, S., Takahashi, Y. and Kiyoki, Y. 2010. The 4D World Map System with Semantic and Spatiotemporal Analyzers. *Information Modelling and Knowledge Bases*. 21(206): 1-18.