<<Taikichiro Mori Memorial Research Fund>>
Graduate Student Researcher Development Grant Report

Research Project: An Automatic Human-interpreting Analysis System by creating a Semantic Analysis Function for analyzing levels of health and hygiene impact attributable in water resource

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Research outline

In this research, I create the semantic analysis function for analyzing levels of health and hygiene impact attributable in water resource and we realize a river water-quality analysis system as an automatic human-interpreting system by integrating special knowledge of environmental engineering and semantic computing. The innovativeness of this research is to extract new water-quality features for water-quality analysis system, which is based on knowledge specialists, and calculate the semantics of the feature for various environment issues on the water-quality semantic space. The originality of this research is in a multi water-parameter analysis with a multi-dimensional semantic space, which is a new human-interpretation of environments to inform the actual quality level of the water body to the society by transforming the sensor value-information to language-information. The objective of this research is to apply a new automatic human-interpreting analysis-system with semantic computing to the environments in water-quality areas by integrating the fundamental important parameters of water quality for creating the new meaning to society. The feature of this research is to interpret the levels of health and hygiene impact attributable in water quality in a multi-dimensional space for current environmental issues in some water-quality research fields to obtaining the meaningful words in the category of agriculture and irrigation. The basic method of this research has been proposed in several journal papers as follows: "Wide-Area River-Water Quality Analysis and Visualization with 5D World Map System" (Veesommai C. et.al, 2016 on Information Molling and Knowledge Bases XXVII, vol 280, p. 31-41). "River Water-quality Analysis: Critical Contaminate Detection, Classification of Multiple-water-quality-parameters Values and Real- time Notification by rSPA Processe" (Veesommai C. and Kiyoki Y. 2015 International Electronics Symposium (IES) co-sponsored IEEE, vol. 17, p. 212- 217). "The rSPA Process Realization: The Creation of River Heavy Metal Evaluation Index (rHMEI) by Using Dimensional Subspace of Heavy Metal" (Veesommai C. et.al, 2016 on International Transaction Journal of Engineering, Management, & Applied Science & Technologies, Vol 7 (3), 189– 203). "A Multi-dimensional River-water Quality Analysis System for interpreting Environmental Situations" (Veesommai C. et.al, 2017 on Information Modelling and Knowledge Base XXVIII, Vol. 281. p. 31-43). We concern over environmental issues as a water-quality analysis system and continue to improve the method and implement a real practical system with automatics human level interpretation of water quality by the semantic analysis function.

Research abstract

The rapid temporal and spatial changes of human population and technology development have resulted in the expansion of agriculture, industrial activity, and deforestation. Those massive expansions affect water resources, especially river. Since the river is the main resource of water in human life, it is crucial to analyze the river water-quality in order to detect the water contamination. In this paper, we present an automatic system for water-quality analysis using several databases and different contexts in dynamic sub-space selection contexts. This system obtains information resources by transforming the sensor-value information to language information. This system aims to monitor, analyze and evaluate the Global Water-quality by using Semantic-ordering functions both in single and multiple parameters. Semantic-ordering is used for spatial-dynamics environmental changes in multiple contexts (aquatic life, agricultural, drinking, fish, industrial usage, and irrigation context). As for the experimental study, four places have been selected as study areas; (1) Hawaii (USA), (2) Pori, (Finland), (3) Riga (Latvia), and (4) Vientiane (Laos). The data resource was acquired from March to September 2016. The result shows that this system is able to analyze and identify the ordering of the different water-quality on different places in the global point of view level and to present the global-scale ranking of water quality.

Keywords. Semantic-analysis, Global water-quality Analysis System, Multi-dimensional semantic spaces, Sensing Processing Actuation (SPA) process, Spatial Dynamics.

Research challenges

Currently, there are many research challenges taking place in water-quality areas.
This research focuses on:

- Using understandable words for public utilization: how to capture the analyzed results in simple words?
- Actuation system: how to implement the reporting and notification as a flexible system in local and global areas?
- Integration of knowledge: how to integrate the knowledge bases of environmental engineering and semantic computing for a promising water-quality analysis system?
- Professional knowledge: how to acquire the analyzed results at a professional level?

Expected Results

- Database: the user can acquire the knowledge and essence by using the database system of water quality.
- Processes: the user can acquire the newly interpreted environmental situations.
- Function: the user can acquire the results and receive the notification of environmental situations.
- Feature word: the user can acquire the in-depth water-quality analysis at the level of professional knowledge by using simple scientific word interpretation.

Contribution

This research proposed an automatic system of water quality analysis in different contexts of dynamic subspace selection according to context. The proposed method addressed in 3 significant advantage points that have not been solved by previous research:

(1) river-water-quality comparison in the global scale and broader water-quality analysis. (2) Extracting water-quality features in different views and in dynamic sub-space selection in contexts. (3) Interpretation of waterquality by transforming the sensor value-information to the language-information for making the results more understandable to public users in the feature semantic wording. Furthermore, this dissertation is established a professional knowledge level database in the water-quality analysis and the world water-quality notification system for discovering the critical points from multiple areas and timelines.
By all means, the river water-quality analysis system can be a tangible tool for assessment on the worldwide scale and several main targets for public users.

This research study proposed the automatic system for water-quality analysis using several databases and different contexts in dynamic sub-space selection according to contexts. This system is the new approach of water-quality interpretation to lead the water-quality analysis field by transforming from the sensor-valueinformation to the language-information, which is a useful way to understand the water situation and highly effective to the global water-quality analysis and assessment. The feature of this research are given by effective tools as below:

- System applications for the water-quality analysis of rivers all over the world (World river water-quality reporting system)
- Integration of various professional knowledge resources and the experts on water-quality analysis
- Memory recall of water-quality situations from all over the world, which is related to any interests expressed in language
- An automatic human-interpretation system by integrating knowledge of environmental engineering and semantic computing.
- A proposed dynamic-dimensions for river-water-quality interpretation for making the system high potential, analyzing all the independent aspects

Our system and analysis with implementation studies are highly significant to societies and those research results can be broadly used in data-analysis, observations and visualizations in the water-quality resource issues.

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Result results

This research will publish in the international journal of Information Modelling and Knowledge Base XXIX, Vol. 282.

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Stament of Macbook pro repair

The current Macbook pro is important for my research because it is keep all of research data and program for analysis. So I decide to repair this Macbook for getting back all important data, analysis method, and results.

Chidisa Veesommai

Oct 11, 2017

Spatial Dynamics of The Global Water Quality Analysis System with Semantic-ordering functions

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Abstract. The rapid temporal and spatial changes of human population and technology development have resulted in the expansion of agriculture, industrial activity, and deforestation. Those massive expansions affect water resources, especially river. Since the river is the main resource of water in human life, it is crucial to analyze the river water-quality in order to detect the water contamination. In this paper, we present an automatic system for water-quality analysis using several databases and different contexts in dynamic sub-space selection contexts. This system obtains information resources by transforming the sensor-value information to language information. This system aims to monitor, analyze and evaluate the Global Water-quality by using Semantic-ordering functions both in single and multiple parameters. Semantic-ordering is used for spatial-dynamics environmental changes in multiple contexts (aquatic life, agricultural, drinking, fish, industrial usage, and irrigation context). As for the experimental study, four places have been selected as study areas; (1) Hawaii (USA), (2) Pori, (Finland), (3) Riga (Latvia), and (4) Vientiane (Laos). The data resource was acquired from March to September 2016. The result shows that this system is able to analyze and identify the ordering of the different water-quality on different places in the global point of view level and to present the global-scale ranking of water quality.

Keywords. Semantic-analysis, Global water-quality Analysis System, Multi-dimensional semantic spaces, Sensing Processing Actuation (SPA) process, Spatial Dynamics.

1. Introduction

1.1. Water-quality analysis

The most important water resource of a country is existing in the river, which can be used for human consumption and ecosystem. The pollutant and wastewater effluence has been accumulated in the water resource and affected on water resource in quality and quantitative. The effect on water resource leads to several problems in human care, ecosystem and public utility, such as irrigation and industry.

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Water-quality analysis plays an essential role for human societies and it is related not only for designing environmental systems but also for environmental management systems. There are several implementations in previous water-quality analysis research, which have been studied as the significant parts of the analysis results: (1) local situation water-quality analysis and assessment results, indicating which information is not provided to the public globally, (2) data collection from different areas, indicating which scholars use different criteria and frameworks, and (3) complicated analytical results for the public use. The feasible tools and spatial dynamics analysis of river require fundamental understanding of water quality characteristics through analytical results for the water-quality monitoring data.

1.2. Semantic computing and related work on semantic computing

Semantic computing is a technology for composing information content based on meaning, numeric, symbols, notations, concepts, functions, and vocabulary, which are included in the software. Information content on semantic creation is shared by the specialists in various fields via a computer for the design and operation of the information system. Semantic computing is an important technology for semantic analysis in various fields [1].

Semantic computing in MMM [2] is computing based on semantics in terms of context meaning. Semantic computing in MMM is a useful technology in multidisciplinary research to compose the information context and to share between users. Many researchers have been proposed semantic in an attempt to describe what meaning of context. Y. Kiyoki et al. (1994) created the new method and the system of meta-database for extracting appropriate image refer to impress of user and content of the image by using mathematical model meaning [1]. Y. Kiyoki and S. Ishihara (2003) proposed a metadatabase knowledge system with a new search system of the semantic associative base on mathematical model meaning [3]. Y. Kiyoki and M. Kawamoto (2007) created the medical semantic spaces in medical knowledge filed by realizing semantic space integration and a domain-specific semantic associative searching [4]. And Y. Kiyoki et al. (2014) created space or/and multi-space to analyze the meaning of word, sentence and numeric and simulation of environmental change and also semantic computing has been applied to biological, chemical [5], GIS system as 5D World Map System, medicine and music field (Y. Kiyoki et al., 2014) [6, 7].

2. Proposed Method

This study proposes functions for analyzing and evaluating the water quality by establishing the professional knowledge level databases in water-quality analysis, semantic space creation: a proposed dynamic dimension for river water-quality interpretation, a semantic space parameter-relatedness weighting method of diverse river water-quality variability, and semantic-ordering functions creating for multiple parameters from the increasing and decreasing parameters.

2.1. *Created semantic context and an automatic human-interpreting system*

This study creates the semantic context that is based on deep knowledge of environmental system design and water-quality assessment. The step to create the semantic context is outlined as follows:

I. Design Raw Data Vector (RAV)

The study creates the raw data vector of multiple water-quality parameters, in particular the focusing on the significant parameters in term of physical and chemical characteristics as an important feature for analyzing and the water-quality evaluation. The raw data vector in this subsection consists of pH, Dissolved Oxygen (DO), Conductivity (Cond), Salinity, Total Dissolved Solid (TDS), and Turbidity. The RAV is shown in Table 1.

Table 1. Design Raw Data Vector (RAV) of multiple water-quality parameters.

P_a	P_b	P_c	P_d	...	P_n	RDV
P_{a1}	P_{b1}	P_{c1}	P_{d1}	...	P_{n1}	RDV_1
P_{a2}	P_{b2}	P_{c2}	P_{d2}	...	P_{n2}	RDV_2
P_{a3}	P_{b3}	P_{c3}	P_{d3}	...	P_{n3}	RDV_3
P_{a4}	P_{b4}	P_{c4}	P_{d4}	...	P_{n4}	RDV_4
P_{a5}	P_{b5}	P_{c5}	P_{d5}	...	P_{n5}	RDV_5
P_{a6}	P_{b6}	P_{c6}	P_{d6}	...	P_{n6}	RDV_6

Where
P_a is pH
P_b is Conductivity (Cond),
P_c is Dissolved Oxygen (DO),
P_d is Salinity,
P_e is Total Dissolved Solid (TDS),
P_f is Turbidity,
RDV is raw data vector of factor set

II. Realize and create the knowledge related interpret context based on deep knowledge in design environmental system and water-quality assessment.

The study realizes the water-quality criteria based on scientific evidence and technical information based on professional knowledge for the particular water resource component in numerical data and semantic features data (narrative descriptions). The main purpose of this subsection is to create an automatic human-interpreting system by integrating professional's knowledge from environmental engineering and semantic computing, which is a new human interpretation of environments to inform the actual water-quality level of the water body for society by transforming the sensor-value information into language information.

The professional's knowledge is represented in new knowledge from this study. It integrates the international standards in targeted areas to reflect the real ground condition of water by using the value/range from scientific experimental study. It is shown in Figure 1 and Table 2-3.

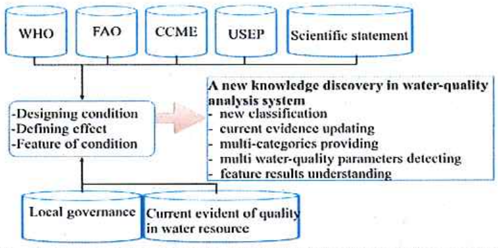

Figure 1 The strategy and process to establish new knowledge representation of Specialist's knowledge in water-quality analysis field

Table 2 Creation of the knowledge related interprets context based on deep knowledge for environmental system design

Context category	$Factor_1$ (Cond)	$Factor_2$ (DO)	$Factor_3$ (pH)	$Factor_4$ (Sal)	$Factor_5$ (TDS)	$Factor_6$ (Turb)	Semantic meaning
Agriculture							
I	0 – 29			0-0.14	0-149		Excellent for agriculture
II	30 – 74			0.14-0.49	150-499		Hazard for sensitive crop
III	75 – 224			0.5-1.49	500-1499		Hazard for low tolerance crop
IV	225 - 499			1.5-2.9	1500-3199		Hazard for high tolerance crop
V	500-749			3.0-4.9	3200-5119		.tisfactory for livestock and poultry
VI	750-1999			5.0-6.9	5200-7039		Hazard for poultry
VII	2000-15999			7.0-9.9	7040-10239		Unfit for agriculture
VIII	16000-50000			10-50	10240-20000		Suddenly toxic for agriculture
Aquatic life							
I		7.0 – 15.0					Abundant aquatic life
II		6.0 - 6.9					Support growth and activity for aquatic life
III		5.0 – 5.9					Support spawning
IV		3.0 – 4.9					Hazard for aquatic life
V		0.0 – 2.9					All aquatic life extinction
Drinking							
I			6.5-8.4		0 - 199	0-1.9	Optimum for drinking
II			5.0 – 6.4, 8.5-9.1		200-599	2.0-4.9	Hazard and chronic toxic for drinking
III			0.0 – 4.9, 9.2-14		600-1000	5.0-10.0	Unfit and toxic for drinking
Fish							
I			6.5-8.1				Abundant for fish
II			6.0-6.4				Optimum for fish and shrimp
III			5-5.9				Bacteria and plankton being disappear
IV			4.0 – 4.9, 8.2-10.4				Hazard for fish and salmon dying
V			0-3.9, 10.5-14.0				All fish extinction
Industry							
I	0-29		6.5-7.9		0-199		Optimum for industrial process
II	30-49		6.0-6.4, 8.0-8.9,		200-349		Slightly corrosive scaling and fouling
III	50-119		5.0-5.9, 9.0-9.9		350-799		Moderate corrosive scaling and fouling
IV	120-249		4.0-4.9, 10.0-11.9		800-1599		Highly corrosive scaling and fouling
V	250-1000		0.0-3.9, 12.0-14.0		1600-10000		Unfit for industrial process
Irrigation							
I	0-69			0-0.4	0-499		Excellent for irrigation
II	70-299			0.5-1.9	500-1999		Moderate hazard for irrigation
III	300-10000			2.0-15.0	2000-10000		Hazard for irrigation

Table 3 Creation of semantic context based on the knowledge related interprets context in deep knowledge for environmental system design

Context category	$Factor_1$ (Cond)	$Factor_2$ (DO)	$Factor_3$ (pH)	$Factor_4$ (Sal)	$Factor_5$ (TDS)	$Factor_6$ (Turb)
C_{x1}	1	0	0	1	1	0
C_{x2}	0	1	0	0	0	0
C_{x3}	0	0	1	0	1	1
C_{x4}	0	0	1	0	0	0
C_{x5}	1	0	1	0	1	0
C_{x6}	1	0	0	1	1	0

Where

- C_{x1} is the context of "agriculture". In this context, the crucial features are $feature_1$ (cond), $feature_4$ (sal), and $feature_5$ (tds). These features are neglected because they are readily available in quality of water supplies or/and water resources. We point out the specific condition context for different quality needs in the agricultural field. The different ranges of features are damaged and reduced yield results [8 - 14].
- C_{x2} is a context of "aquatic life". In this context, feature2 (DO) is an imperative feature of most aquatic organisms as it maintains and provides them with oxygen to carry out and accomplish cellular respiration and the process of photosynthesis [13], [15 – 19].
- C_{x3} is a context of "drinking". In this context, three features, which are $feature_3$ (pH), $feature_5$ (tds), and $feature_6$ (turb), are used for evaluating the quality and suitability of the water for drinking. The concentration of these features affects dehydration of the tissues (skin), unpleasant mineral taste, hazard and chronic damage to several functions in the human body [20 – 24].
- C_{x4} is the context of "fish". In this context, $feature_3$ (pH) strongly affects to fish. Because small changes in pH can cause hazard to many kinds of fish, which cannot survive or/and reproduce outside of the optimum range [16], [19].
- C_{x5} is a context of "industry". In this context, we provide the specific factors of water-quality constituents as $feature_1$ (cond), $feature_3$ (pH), and $feature_5$ (tds). Those features play an important role in industrial processes, equipment and structure, impairment of product quality, and the amount of treated or disposed of wasted generated [12], [19].
- C_{x6} is a context of "irrigation". In this context, we are concerned with the factors of $feature_1$ (cond), $feature_4$ (sal), and $feature_5$ (tds). Those features are required both qualitatively and quantitatively and are significant factors for determining water availability for irrigation [16 - 17], [25 - 30].

Inner product (characteristic of RDVi) = $RAVn \times Cxn$

III. Design multi-dimension intervals of water-quality.

From the semantic context for human interpretation, we design multi-dimension intervals of the water-quality analysis system of each factor as below

Context = $\{Cx_1, Cx_2, Cx_3, \ldots, Cx_i, Cx_q\}$ (In this implementation $q = 6$)

Each context $\{Cx_1, Cx_2, Cx_3, \ldots, Cx_i, Cx_q\}$ has several levels. The number of levels is different depending on the level (L) of the context Cx_i, which is represented as

$LCx_i = \{LCx_1, LCx_2, LCx_3, \ldots, LCx_i, LCx_q\}$

A. For dimension interval for agriculture context (Cx_1), level-judgment function for aquatic life f_{agr} is described as below;

$$f_{agr}(cons, tds, sal) = \begin{cases} LC_1, & \{(cond, tds, sal) \in R^3: 0.0 < cond_{obs} \le 250.0, 0.0 < tds_{obs} \le 150.0, 0.0 < sal_{obs} \le 0.15\} \\ LC_2, & \{(cond, tds, sal) \in R^3: 250.0 < cond_{obs} \le 750.0, 150.0 < tds_{obs} \le 500.0, 0.15 < sal_{obs} \le 0.50\} \\ LC_3, & \{(cond, tds, sal) \in R^3: 750.0 < cond_{obs} \le 2250.0, 500.0 < tds_{obs} \le 5000.0, 0.50 < sal_{obs} \le 1.50\} \\ LC_4, & \{(cond, tds, sal) \in R^3: 2250.0 < cond_{obs} \le 5000.0; 1500.0 < tds_{obs} < 3200.0; 1.50 < sal_{obs} < 3.00\} \\ LC_5, & \{(cond, tds, sal) \in R^3: 5000.0 < cond_{obs} < 7500.0; 3200.0 < tds_{obs} < 5120; 3.00 < sal_{obs} < 5.00\} \\ LC_6, & \{(cond, tds, sal) \in R^3: 7500.0 < cond_{obs} < 10^4; 5120.0 < tds_{obs} < 7040; 5.00 < sal_{obs} < 7.00\} \\ LC_7, & \{(cond, tds, sal) \in R^3: 2.0\times10^4 < cond_{obs} < 1.6\times10^5; 7040.0 < tds_{obs} < 10340; 7.00 < sal_{obs} < 10.00\} \\ LC_8, & \{(cond, tds, sal) \in R^3: 1.6\times10^5 < cond_{obs} \le 5.0\times10^5; 10340.0 < tds_{obs} < 2\times10^4; 10.00 < sal_{obs} < 50.00\} \end{cases}$$

Where

f_{agr}(cond, tds, sal) = $\{LC_1, LC_2, LC_3, LC_4, LC_5, LC_6, LC_7, LC_8 \leftarrow$ {Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, Suddenly toxic for agriculture},

$cond_{obs}$ = the observation value of conductivity parameter,

tds_{obs} = the observation value of total dissolved solid parameter,

sal_{obs} = the observation value of salinity parameter

B. For dimension interval for aquatic life context (Cx_2), level-judgment function for aquatic life f_{aq} is described as below;

$$f_{aq}(do) = \begin{cases} LC_1, & \{do \in R: 7.0 \leq do_{obs} < 15.0\} \\ LC_2, & \{do \in R: 6.0 \leq do_{obs} < 7.0\} \\ LC_3, & \{do \in R: 5.0 \leq do_{obs} < 6.0\} \\ LC_4, & \{do \in R: 3.0 \leq do_{obs} < 5.0\} \\ LC_5, & \{do \in R: 0.0 \leq do_{obs} < 3.0\} \end{cases}$$

Where

$f_{aq}(do) = \{LC_{x1}, LC_{x2}, LC_{x3}, LC_{x4}, LC_{x5} \leftarrow$ {Abundant aquatic life, Support growth and activity for aquatic life, Support spawning, Hazard for aquatic life, All aquatic life extinction},

do_{obs} = the observation value of dissolved oxygen parameter

C. For dimension interval for drinking context (Cx_3), level-judgment function for aquatic life f_{dri} is described as below;

$$f_{dri}(pH, tds, turb) = \begin{cases} LC_1, & \left\{ \begin{matrix} (pH, tds, turb) \in R^3: 6.50 < pH_{obs} < 8.50; 0.0 < tds_{obs} < 200.0; \\ 0.0 < turb_{obs} < 2.0 \end{matrix} \right\} \\ LC_2, & \left\{ \begin{matrix} (pH, tds, turb) \in R^3: 4.00 < x < 6.50 | 8.50 < pH_{obs} < 9.20; 200.0 < tds_{obs} < 600.0; \\ 2.0 < turb_{obs} < 5.0 \end{matrix} \right\} \\ LC_3, & \left\{ \begin{matrix} (pH, tds, turb) \in R^3: 0.00 < pH_{obs} < 4.00 | 9.20 < pH_{obs} < 14.00; 600.0 < tds_{obs} < 1000.0; \\ 5.0 < turb_{obs} < 10.0 \end{matrix} \right\} \end{cases}$$

Where

$f_{dri}(pH, tds, turb) = \{LC_{x1}, LC_{x2}, LC_{x3} \leftarrow$ {Optimum for drinking, Hazard and chronic toxic for drinking, Unfit and toxic for drinking},

pH_{obs} = the observation value of potential of hydrogen ion (pH) parameter,

tds_{obs} = the observation value of total dissolved solid parameter,

$turb_{obs}$ = the observation value of turbidity parameter

D. For dimension interval for fish context (Cx_4), level-judgment function for aquatic life f_{fish} is described as below;

$$f_{fish}(pH) = \begin{cases} LC_1, & \{pH \in R: 6.5 < pH_{obs} \leq 8.2\} \\ LC_2, & \{pH \in R: 6.0 < pH_{obs} \leq 6.5\} \\ LC_3, & \{pH \in R: 5.0 < pH_{obs} \leq 6.0\} \\ LC_4, & \{pH \in R: 4.0 < pH_{obs} < 5.0 | 8.2 < pH_{obs} < 10.5\} \\ LC_5, & \{pH \in R: 0.0 < pH_{obs} < 4.0 | 10.5 < pH_{obs} < 14.0\} \end{cases}$$

Where

$f_{fish}(pH) = \{LC_{x1}, LC_{x2}, LC_{x3}, LC_{x4}, LC_{x5} \leftarrow$ {All fish extinction, Hazard for fish and salmon dying, Bacteria and plankton being disappear, Optimum for fish and shrimp, Abundant for fish},

pH_{obs} = the observation value of potential of hydrogen ion (pH) parameter

E. For dimension interval for industry context (Cx_5), level-judgment function for aquatic life f_{ind} is described as below

$$f_{ind}(pH, cond, tds) = \begin{cases} LC_1, & \{(pH, cond, tds) \in R^3: 6.5 < pH_{obs} \leq 8.0; 0.0 < cond_{obs} < 30; 0 < tds_{obs} < 200.0\} \\ LC_2, & \left\{ \begin{matrix} (pH, cond, tds) \in R^3: 6.0 < pH_{obs} < 6.5 | 9.0 < pH_{obs} < 10.0; 30.0 < cond_{obs} < 50.0; \\ 200.0 < tds_{obs} < 350.0 \end{matrix} \right\} \\ LC_3, & \left\{ \begin{matrix} (pH, cond, tds) \in R^3: 5.0 < pH_{obs} < 6.00 | 8.0 \leq pH_{obs} < 900; 50.0 < cond_{obs} < 120.0; \\ 350.0 < tds_{obs} < 800.0 \end{matrix} \right\} \\ LC_4, & \left\{ \begin{matrix} (pH, cond, tds) \in R^3: 4.0 < pH_{obs} < 5.0 | 10.0 < pH_{obs} < 12.0; 120.0 < cond_{obs} < 250.0; \\ 800.0 < tds_{obs} < 1.6 \times 10^4 \end{matrix} \right\} \\ LC_5, & \left\{ \begin{matrix} (pH, cond, tds) \in R^3: 0.0 < pH_{obs} < 4.0 | 12.0 < pH_{obs} < 14.0; 250.0 < cond_{obs} < 1000.0; \\ 1.6 \times 10^4 < tds_{obs} < 1.0 \times 10^4 \end{matrix} \right\} \end{cases}$$

Where

$f_{ind}(pH, cond, tds) = \{LC_{x1}, LC_{x2}, LC_{x3}, LC_{x4}, LC_{x5} \leftarrow$ {Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, Unfit for industrial process},

pH_{obs} = the observation value of potential of hydrogen (pH) parameter,
$cond_{obs}$ = the observation value of conductivity parameter,
tds_{obs} = the observation value of total dissolved solid parameter

F. For dimension interval for irrigation context (Cx_6), level-judgment function for aquatic life f_{irri} is described as below;

$$f_{irri}(cond, tds, sal) = \begin{cases} LC_1, & \{(cond, tds, sal) \epsilon R^3: 0.0 < cond_{obs} < 700.0; 0.0 < tds_{obs} < 500.0; 0 < sal_{obs} < 0.5\} \\ LC_2, & \{(cond, tds, sal) \epsilon R^3: 700.0 < cond_{obs} < 3000.0; 500.0 < tds_{obs} < 2000.0; 0.5 < sal_{obs} < 2.0\} \\ LC_3, & \{(cond, tds, sal) \epsilon R^3:: 3000.0 < cond_{obs} < 10000.0; 2000.0 < tds_{obs} < 10000.0; 2.0 < sal_{obs} < 20.0\} \end{cases}$$

Where
$f_{irri}(pH, cond, tds) = \{LC_{x1}, LC_{x2}, LC_{x3} \leftarrow$ {Excellent for irrigation, Moderate hazard for irrigation, Hazard for irrigation},
$cond_{obs}$ = the observation value of conductivity parameter,
tds_{obs} = the observation value of total dissolved solid parameter,
sal_{obs} = the observation value of salinity parameter

2.2. *Create Water-quality Factor for Semantic-ordering function (parameter-relatedness weighting method in the diverse river-water-quality variability analysis)*

I. Calculation Sub-factor

Several water parameters with different units and dimensions are converted into sub-factor P with a simple scale. The scale of each sub-factor is in the range of 0 to 100 [31].

P = $\{P_1, P_2, P_3, \ldots P_i, P_r\}$, when the number of sub-factor is r

Where
P_i is a sub-factor of parameter,
X_i is the value of the observation parameter data,
k is a total number of level (class) in a context,
j is a level (class) of observation data,
C_{i0} is the minimum value of level of class (for case a) and the maximum value of j[th] level (for case b),
C_{ij} is the upper limit (for case a) and the lower limit (for case b) of the j class,
Cik is the maximum value (for case a) and the minimum limit of level

A. In the case that a smaller value means better water-quality such as conductivity, total dissolved solid, the sub-factor value *Pi* is represented as below;

$$P(i) = \begin{cases} 100, & if\ X_i < C_{i0} \\ \frac{100\times(k-j)}{k} + \frac{100}{k}\frac{C_{ij} - X_i}{C_{ij} - C_{i(j-1)}}, & if\ C_{i(j-1)} \le X_i < C_{ij} \\ 0, & if\ X_i \ge C_{ik} \end{cases}$$

Eq. 1

B. In the case that a bigger value means better water-quality such as dissolved oxygen, the sub-factor value *Pi* is represented as below;

$$P(i) = \begin{cases} 100, & if\ X_i > C_{i0} \\ \frac{100\times(k-j)}{k} + \frac{100}{k}\frac{C_{ij} - X_i}{C_{ij} - C_{i(j-1)}}, & if\ C_{ij} < X_i \le C_{i(j-1)} \\ 0, & if\ X_i \le C_{ik} \end{cases}$$

Eq. 2

II. Assigning weight sub-factor

The weight of the assessment sub-factors is calculated based on their relative significant to overall in water-quality.

Where
Wi is the weight of sub-factor value Pi,
qi is a level of sub-factor value Pi

The method for calculating the weight of sub-factor is Eq. 3

$$W_i = \frac{q_i}{\sum_{i=1}^{n} q_i}$$

Eq. 3

III. Calculating Factor (P) Calculating Factor' total value F

Where
F is a factor's total value for context, which is calculated as a summation of the sub-factor value Pi with weighting.

The method for calculating the total value F is represented as Eq. 4

$$F = \sum_{i=1}^{n} P_i W_i$$

Eq. 4

IV. Time-series data structure

After the observation data are represented in the form of time series, the system orders the results by descending order in multiple contexts, to show a time-series environmental change. The set of time-series total value F is described as

$$\{F_{t-1}, F_t, ..., F_\infty\}$$

2.3. Realization of river Sensing Processing Actuation (rSPA) process based on Sensing Processing Actuation (SPA) process

Sensing Processing Actuation (SPA) process is a supporting concept for the definition of rules for automatically performing it [5]. The river Sensing Processes Actuation was realized from the SPA concept. The sensing meaning is the part of input data of water-quality as a numeric data. The processing meaning is the parts of analysis and knowledge databases. The actuation meaning is the part of output action for feature wording and updating the information of current situation.

The main purpose of this subsection is: (1) to analyze and summarize the spatial-dynamics of global water resources data, and (2) to create the semantic-ordering function for spatial-dynamics of the global water resource.

In this study, we proposed the semantic-ordering functions on Multiple-water-quality-parameters for spatial-dynamics of global water resources analysis leads to the new research direction in environmental engineering fields. In this implementation, we create a multi-dimensional semantic space for singular and multiple-water-quality-parameters analysis in spatial-dynamics of global water resources. The processing function includes semantic computing and semantic-ordering on single and multiple-water-quality-parameters values.

3. Implementation

3.1. Study areas and description

The water samples were collected from different places to determine the level of pollution of the water resources. The process of sampling the water follows the standard of ISO 5667-6 [32]. Water quality data were collected from significant water resource located in Hawaii (USA), Pori (Finland), Riga (Latvia), and Vientiane (Laos) from March to September 2016. The geographic location and sampling points of data are shown in figure 2 - 5.

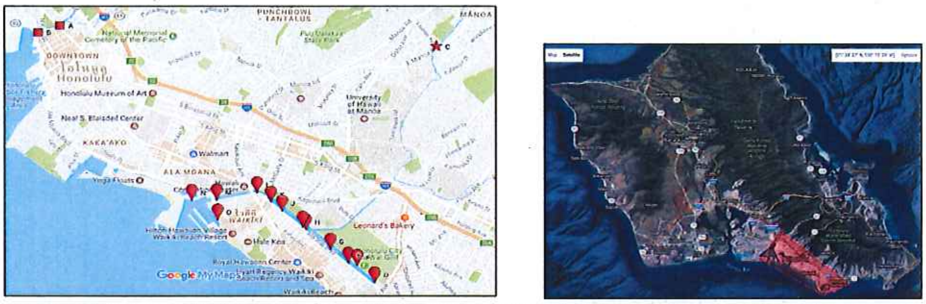

Figure 2 The geographic location and sampling data point in Hawaii, USA. (Left figure courtesy of Google and Right figure of United States Geological Survey, USGS)

Figure 3 The geographic location and sampling data point in Pori, Finland. (Left figure courtesy of Google and Right figure of United States Geological Survey, USGS)

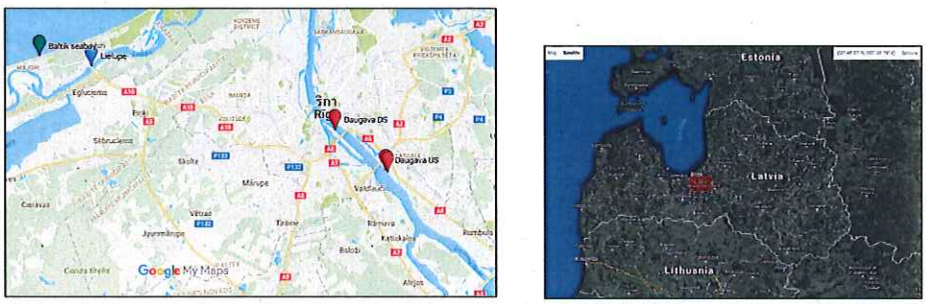

Figure 4 The geographic location and sampling data point in Riga, Latvia. (Left figure courtesy of Google and Right figure of United States Geological Survey, USGS)

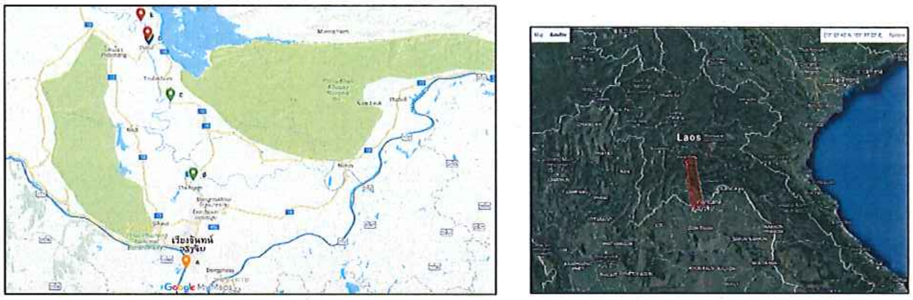

Figure 5 The geographic location and sampling data point in Vientiane, Laos. (Left figure courtesy of Google and Right figure of United States Geological Survey, USGS)

Figure 2 shows the geographic location and sampling points of data in Hawaii, USA and 15 representative monitoring points of 3 water resources: Nuuanu river, Manoa river, and Manoa canal.

Figure 3 shows the geographic location and sampling points of data in Pori, Finland and 12 representative monitoring points of Kokenäenjoki river.

Figure 4 shows the geographic location and sampling points of data in Riga, Latvia and 4 representative monitoring points of 2 water resources: Daugava river, and Lielupe river.

Figure 5 shows the geographic location and sampling points of data in Vientiane, Laos and 6 representative monitoring points of 3 water resources: Mekong river, Nam Lik river and Nam Ngum river.

3.2. Data preparation

Data preparation of this study is consist of water-quality sampling data, language tools (PostgreSQL) and data structure of single and multiple-dimensional semantic space. The characteristic of water-quality sampling data, language tools, and data structure describes as below

I. The water-quality sampling data, in this step we sampling water-quality data from 9 rivers: (1) 3 rivers located in Hawaii, USA (Nuuanu river, Manoa river and Manoa canal), (2) 1 river located in Pori, Finland (Kokenäenjoki river), (3) 2 rivers located in Riga, Latvia (Daugava river, and Lielupe river), and (4) 3 rivers located in Vientiane, Laos (Mekong river, Nam Lik river, and Nam Ngum river) with multi water parameter sensor. The water parameter that we sampling is temperature, pH, dissolved oxygen (DO), conductivity, salinity, total dissolved solid, turbidity, oxidation-reduction potential (ORP) and GPS. The process of water quality sampling is according to the standardization of ISO 5667-6 [32, 33].

II. The language, we design to use PostgreSQL for creating single and multi-dimensional semantic space and Semantic-ordering functions to analyze spatial dynamics of global water-quality in details.

III. A data structure of multiple-dimensional semantic space, the data structure is a series of features and word in matrix form.

3.3. *System Architecture of this study*

The system architecture for water-quality analysis system based on SPA processes [5] and outlined as follows: (1) Sensing (s) part is a water-quality sampling data by using multi water-parameters sensor (Horiba sensor). (2) Processing part is a semantic computing and semantic-ordering functions for single and multiple water-quality parameters analysis, which realized and created the database of semantic meaning for water-quality [8 - 30]. (3) Actuation is semantic words as a result of system. The system architecture is shown in figure 6.

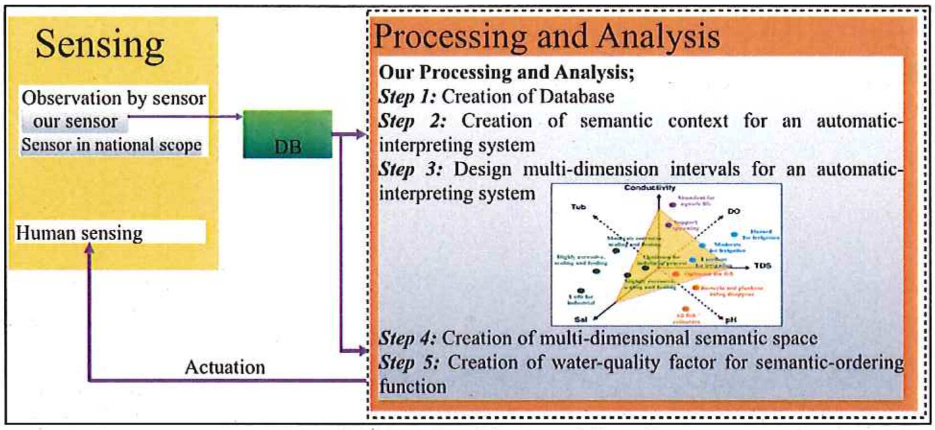

Figure 6 The system architecture of this study

Then we create the database of single-multi water-quality parameters. The creation step for the database of single-multi water-quality and analysis step with Semantic-ordering functions are as follows:

Step 1: Database creation.

This procedure creates multiple water-quality databases.

Step 2: Creation of raw data vector and semantic context for an automatic human-interpreting system.

This procedure creates a semantic context based on deep knowledge in water-quality analysis and assessment field.

Step 3: Designing of multi-dimension intervals for filtering and analyzing in system.

This procedure creates a multi-dimension interval based on an inner product of characteristic of RDVi and semantic context.

Step 4: Creation of multi-dimensional semantic space.

This procedure creates multiple-water-quality-parameters from spatial-dynamics of global water resources.

Step 5: Creation of water-quality factor for semantic-ordering function.

This process create and computes a factor, then ordering of factor, executes feature word, and semantic-ordering for the spatial dynamics water-quality.

4. Experimental results

4.1. Experimental results of Water-quality Analysis System with Semantic-ordering functions on Single parameter

As the result from sampling water quality data, we have analyzed the water-quality with semantic-ordering functions on a single parameter by several points. In the analyzed results by a single parameter, we have analyzed in 4 important parameters as a dissolved oxygen, conductivity, turbidity and total dissolved solid. An example of results (in turbidity parameter) is shown in figure 7.

From the results of water-quality analysis with semantic-ordering functions by turbidity parameter, the critical levels of water-quality sanitation and hygiene intervention in very high effect are detected at Kokemäenjoki river point A (Pori, Finland), Alawai point D and F (Hawaii, USA), and Nam lik river point E (Vientiane, Laos). From the table for the first row ranking of turbidity parameter at Daugava river point A (Riga, Latvia) on June 2, 2016, and it showed the levels of water- quality sanitation and hygiene intervention are completely safe for water resource. From the table in second row to sixty-four row ranking of turbidity parameter at Alawai river point E, G, H, K, L, M, N and O (Hawaii, USA) on March 26 -27, 2016, Kokemäenjoki river (Pori, Finland) point A, B, C, D, E, G and F on May 26 - July 11, 2016, Lielupe river and Daugava point C (Riga, Latvia) on June 2, 2016, and it showed the levels of water-quality sanitation and hygiene intervention are completely safe for water resource.

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semanticordering	meaning	totaldissolvedsolid	ndate	location	latitude	longitude
1	Completely safe	0	2016-06-19	B-Kokemaenjoki	61.493654	21.827547
2	Completely safe	11.26666667	2016-03-25	C-Manoa ST	21.311147	-157.808813
3	Completely safe	37.21052632	2016-05-30	G-Kokemaenjoki	61.498453	21.783121
4	Completely safe	53.05	2016-05-26	C-Kokemaenjoki	61.492496	21.810902
4	Completely safe	53.05	2016-05-26	G-Kokemaenjoki	61.498453	21.783121
6	Completely safe	55.35	2016-05-26	E-Kokemaenjoki	61.492974	21.794521
7	Completely safe	56.975	2016-05-26	B-Kokemaenjoki	61.493654	21.827547
8	Completely safe	57	2016-05-26	H-Kokemaenjoki	61.490005	21.781944
9	Completely safe	57.35	2016-05-26	D-Kokemaenjoki	61.491615	21.801848
10	Completely safe	59	2016-05-30	E-Kokemaenjoki	61.492974	21.794521
11	Completely safe	59.1	2016-07-11	C-Kokemaenjoki	61.492496	21.810902
12	Completely safe	59.95238095	2016-05-26	A-Kokemaenjoki	61.491747	21.837152
13	Completely safe	60.04761905	2016-05-30	D-Kokemaenjoki	61.491615	21.801848
14	Completely safe	60.65	2016-05-30	H-Kokemaenjoki	61.490005	21.781944
15	Completely safe	61	2016-06-19	F-Kokemaenjoki	61.496545	21.788986
16	Completely safe	61.05	2016-07-11	D-Kokemaenjoki	61.491615	21.801848
16	Completely safe	61.05	2016-05-30	C-Kokemaenjoki	61.492496	21.810902
18	Completely safe	61.15	2016-06-13	C-Kokemaenjoki	61.492496	21.810902
19	Completely safe	61.3	2016-06-27	F-Kokemaenjoki	61.496545	21.788986
20	Completely safe	61.5	2016-06-19	G-Kokemaenjoki	61.498453	21.783121
		≈≈				
71	Low effect	536.1578947	2016-06-02	LIELUPE	56.973479	23.861068
72	Very high effect	1624.285714	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818
73	Very high effect	18061.90476	2016-03-27	F-Alawai	21.277616	-157.81996
74	Very high effect	18457.14286	2016-03-27	K-Alawai	21.287292	-157.8321
75	Very high effect	21276.19048	2016-03-27	L-Alawai	21.288718	-157.834047
76	Very high effect	25633.33333	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874
77	Very high effect	26323.80952	2016-03-27	J-Alawai	21.28593	-157.83054
78	Very high effect	27410	2016-03-27	M-Alawai	21.287627	-157.83978
79	Very high effect	27800	2016-03-27	E-Alawai	21.277997	-157.821242
80	Very high effect	27831.57895	2016-03-27	O-Alawai	21.284561	-157.839613

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Figure 7 The results of semantics word of turbidity with semantic-ordering functions on single water-quality parameters

4.2. *Experimental results of Water-quality Analysis System with Semantic-ordering functions on Multiple parameter*

As the result from sampling water quality data, we have analyzed the water-quality with semantic-ordering functions on multiple parameters by several points. In the analyzed results by a single parameter, we have analyzed in 6 categories. An example of calculation results (in context of agriculture) of Pfactor is shown in figure 8.

From the results of water-quality with semantic-ordering functions for the context of agriculture, the critical levels of health and hygiene impact attributable to water quality as suddenly toxic for agriculture was detected at Nuuanu river point B (Hawaii, USA). For the critical levels of health and hygiene impact attributable to water quality in unfit for agriculture were detected at Nuuanu river point A, Alawai river point D, E, F, I, J, K, L, N, M and O (Hawaii, USA). The critical levels of health and hygiene impact attributable to water quality as the hazard for the sensitive crop were detected at L-kemira Oyj-2 (Pori, Finland). For the first ranking is Manoa river point c (Hawaii, USA) and it showed to the excellent for agriculture. From the table in second row to sixth-sever row.

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semanticordering	factor	keyword	ndate	location	latitude	longitude	conductivity	totaldissolvedsolid	salinity
1	99.21407406	Excellent for agriculture	2016-03-25	C-Manoa ST	21.311147	-157.808813	17.26666667	11.26666667	0.006666667
2	98.01725146	Excellent for agriculture	2016-05-30	G-Kokemaenjoki	61.498453	21.783121	56.94736842	37.21052632	0
3	97.17138889	Excellent for agriculture	2016-05-26	C-Kokemaenjoki	61.492496	21.810902	81.3	53.05	0
4	97.16555556	Excellent for agriculture	2016-05-26	G-Kokemaenjoki	61.498453	21.783121	81.65	53.05	0
5	97.04166667	Excellent for agriculture	2016-05-26	E-Kokemaenjoki	61.492974	21.794521	85.25	55.35	0
6	96.95527778	Excellent for agriculture	2016-05-26	B-Kokemaenjoki	61.493654	21.827547	87.725	56.975	0
7	96.9525	Excellent for agriculture	2016-05-26	H-Kokemaenjoki	61.490005	21.781944	87.85	57	0
8	96.93527778	Excellent for agriculture	2016-05-26	D-Kokemaenjoki	61.491615	21.801848	88.3	57.35	0
9	96.84444444	Excellent for agriculture	2016-05-30	E-Kokemaenjoki	61.492974	21.794521	91	59	0
10	96.84	Excellent for agriculture	2016-07-11	C-Kokemaenjoki	61.492496	21.810902	91.1	59.1	0
11	96.8021164	Excellent for agriculture	2016-05-26	A-Kokemaenjoki	61.491747	21.837152	91.95238095	59.95238095	0
12	96.79470899	Excellent for agriculture	2016-05-30	D-Kokemaenjoki	61.491615	21.801848	92.23809524	60.04761905	0
13	96.76111111	Excellent for agriculture	2016-05-30	H-Kokemaenjoki	61.490005	21.781944	93.25	60.65	0
14	96.73888889	Excellent for agriculture	2016-06-19	F-Kokemaenjoki	61.496545	21.788986	94	61	0
15	96.73555556	Excellent for agriculture	2016-06-13	C-Kokemaenjoki	61.492496	21.810902	93.95	61.15	0
16	96.735	Excellent for agriculture	2016-05-30	C-Kokemaenjoki	61.492496	21.810902	94.15	61.05	0
17	96.73333333	Excellent for agriculture	2016-07-11	D-Kokemaenjoki	61.491615	21.801848	94.25	61.05	0
18	96.72055556	Excellent for agriculture	2016-06-27	F-Kokemaenjoki	61.496545	21.788986	94.6	61.3	0
19	96.71583333	Excellent for agriculture	2016-06-19	G-Kokemaenjoki	61.498453	21.783121	94.55	61.5	0
20	96.69444444	Excellent for agriculture	2016-06-19	D-Kokemaenjoki	61.491615	21.801848	95	62	0
21	96.67555556	Excellent for agriculture	2016-06-13	A-Kokemaenjoki	61.491747	21.837152	96.05	62.05	0
22	96.66919192	Excellent for agriculture	2016-05-30	F-Kokemaenjoki	61.496545	21.788986	95.90909091	62.36363636	0
23	96.66777778	Excellent for agriculture	2016-07-11	B-Kokemaenjoki	61.493654	21.827547	96.1	62.3	0
24	96.66237374	Excellent for agriculture	2016-07-11	G-Kokemaenjoki	61.498453	21.783121	96.09090909	62.5	0
25	96.65083333	Excellent for agriculture	2016-06-19	C-Kokemaenjoki	61.492496	21.810902	96.45	62.7	0
26	96.64611111	Excellent for agriculture	2016-07-11	F-Kokemaenjoki	61.496545	21.788986	96.65	62.75	0
27	96.645	Excellent for agriculture	2016-06-13	D-Kokemaenjoki	61.491615	21.801848	96.3	63	0
28	96.64388889	Excellent for agriculture	2016-07-11	A-Kokemaenjoki	61.491747	21.837152	96.7	62.8	0
29	96.64318182	Excellent for agriculture	2016-06-13	E-Kokemaenjoki	61.492974	21.794521	96.40909091	63	0
30	96.64035088	Excellent for agriculture	2016-06-19	H-Kokemaenjoki	61.490005	21.781944	96.57894737	63	0
≈≈									
68	84.91156463	Hazard for sensitive crop	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344	364.7619048	237.0952381	0.2
69	22.82111011	Unfit for agriculture	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818	25214.28571	1624.285714	15.37142857
70	17.86818182	Unfit for agriculture	2016-03-27	D-Alawai	21.274992	-157.817526	46480	28355	30.16
71	17.69323921	Unfit for agriculture	2016-03-27	I-Alawai	21.283438	-157.82764	45772.72727	27922.72727	29.64545455
72	17.66177399	Unfit for agriculture	2016-03-27	N-Alawai	21.28756	-157.843219	45645	27845	29.55
73	17.66071903	Unfit for agriculture	2016-03-27	O-Alawai	21.284561	-157.839613	45647.36842	27831.57895	29.58421053
74	17.64339827	Unfit for agriculture	2016-03-27	E-Alawai	21.277997	-157.821242	45571.42857	27800	29.5
75	17.49775884	Unfit for agriculture	2016-03-27	M-Alawai	21.287627	-157.83978	44985	27410	29.085
76	17.04172679	Unfit for agriculture	2016-03-27	J-Alawai	21.28593	-157.83054	43142.85714	26323.80952	27.75238095
77	14.98602092	Unfit for agriculture	2016-03-27	L-Alawai	21.288718	-157.834047	34871.42857	21276.19048	21.92857143
78	14.5452032	Unfit for agriculture	2016-03-27	K-Alawai	21.287292	-157.8321	30219.04762	18457.14286	18.71428571
79	14.46598696	Unfit for agriculture	2016-03-27	F-Alawai	21.277616	-157.81996	29161.90476	18051.90476	17.90095238
80	10.55399557	Suddenly toxic for agriculture	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874	41850	25633.33333	26.74166667

(stdin):

Figure 8 The results of semantics word of agriculture with semantic-ordering functions on multiple water-quality parameters

5. Conclusion

In this paper, we presented the rSPA process in the SPA concept. The essence of this process is using semantic computing in MMM for applying it to river-water-quality interpretation and semantic space featuring (parameter-relatedness weighting) in the diverse river-water-quality variability analysis. This new knowledge can be created as a database in the water-quality field at the professional knowledge database level. By this system, new knowledge can be created in the water-quality field at the professional knowledge database level, and the semantics of the feature for various environmental issues on the water-quality semantic space can be computed. The processing function includes semantic computing and semantic-ordering on multiple-water-quality-parameters.

The future direction of this research is to realize the function for deep interpretation in the automatic human-interpreting system.

6. Acknowledgement

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