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Title: Towards a Great Design of Conceptual Modelling

Year: 2020

Version: Accepted version (Final draft)

Towards a Great Design of Conceptual Modelling

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Abstract. Humankind faces a most crucial mission; we must endeavour, on a global scale, to restore and improve our natural and social environments. This is a big challenge for global information systems development and for their modelling. In this paper, we discuss on different aspects of conceptual modelling in global environmental context. The paper is the summary of the panel session "The Future of Conceptual Modelling" in the 29th International Conference on Information Modelling and Knowledge Bases.

Keywords. Conceptual modelling, model suites, multi-agent system, artificial intelligence, machine learning, semantic computing, data mining, 5D World Map System, context computing, environmental ICT, globalization.

Introduction

Conceptual modelling has been one of the essential academic subjects in the computer science area and includes highly significant topics not only in academic communities related to information systems, but also in the area of environmental and globalization studies.

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 research activities in environmental study is conceptual modelling to express, share, analyze and visualize the environmental and social phenomena of various situations. It is essentially significant to create new conceptual modelling for making appropriate and urgent solutions to various environmental changes and social situations in the nature and society.

The nature and society are expecting our activities to cover environmental research areas, towards "Environmental Artificial Intelligence" with sensing-data processing, big-data analysis, machine learning, deep learning, spatio-temporal computing, GIS

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(Geographical Information Systems) processing and semantic computing. From the viewpoint of conceptual modelling, much research activity should focus on environmental issues for realizing sustainable nature and society.

To promote discussion on the future trends and challenges of conceptual modelling, we organized a panel session on "The Future of Conceptual Modelling" during the 29th International Conference on Information Modelling and Knowledge Bases (EJC2019). The panelists were Professor Yasushi Kiyoki (panel moderator and chair), Professor Bernhard Thalheim, Professor Marie Duží Professor Hannu Jaakkola and Professor Petchporn Chawakitchareon. In the panel session, we focused on discussions on new conceptual modelling towards Environmental Artificial Intelligence. Open questions to this aim are:

- How to give actual interpretations and understandings to the nature and societies? Nature cannot interpret the meanings of situations/phenomena by itself. Only the human can interpret the meaning of nature's situation by our senses with brain.
- How to give meanings to environmental phenomena in computational processes?

The paper is based on the presentations of the panelists' own viewpoints on the panel session topic. The paper is organized as follows. In Section 1, Professor Thalheim introduces model suites as a maintained collection of associated models. In Section 2, Professor Duží describes communication in a multi-agent world based on the Transparent Intensional Logic (TIL). In Section 3, Professor Jaakkola discusses on artificial intelligent (AI) in modelling landscape and technological changes in conceptual modelling. In Section 4, Professor Kiyoki and Professor Chawakitchareon present the 5D World Map System and its applications to global environmental engineering.

1. Model Suites as a Maintained Collection of Associated Models

Most disciplines simultaneously integrate a variety of models or a society of models. The theory of model suite has been developed in [1, 2, 3]. A model suite is essentially a well-associated and coherent ensemble of models. The models in a model suite coexist, co-evolve, and support solutions of subtasks. A *model suite* [3] consists:

- of set of models which are defined within a common language understanding on the basis of several modelling languages,
- of an association or collaboration schema among the models,
- of controllers that maintain consistency or coherence of the model suite,
- of application schemata for explicit maintenance and evolution of the model suite, and
- of tracers for the establishment of the coherence.

We observe three opportunities of building a model suite:

- *Horizontal model suites*: Horizontal model suites use the same level of abstraction and reflect different but integratable viewpoints or foci or scopes on the basis of different languages. Computer science and engineering modelling is mainly modelling at the same abstraction layer. The model ensemble used in UML (Unified Modelling Language) separates modelling into several concerns such as use case, classes, interaction, packaging, and collaboration. Model-based engineering can be based on a five-level model suite [4]. Business (layer) data models and conceptual (layer) data models are a typical example of a horizontal model suite since the first one is typically business-oriented and the second one can be considered to be a refinement of the first one. The binding among these models is often implicit. We may however enhance the two models by a mapping that maps the first model to the second one. This mapping combines and harmonizes the different views that are used at the business user layer. A good example is a model suite consisting of a global conceptual model and a rather large number of conceptual viewpoints that reflect the needs of database system users.

- *Vertical model suites*: Vertical model suites combine models that have different abstraction levels, that vary in their level of detail and complexity, and that reflect different time and space abstractions. At the same time they are coupled through some kind of mapping mechanism and within a specific coupling style. Typical well-known vertical model suites are: (a) strategic, tactical and operational models used in business informatics, (b) OLTP-OLAP-Data_Mart decision support systems (OLTP= On-line Transaction Processing, OLAP= On-line Analytical Processing) and (c) database structure pattern. The OSI (Open Systems Interconnection Reference Model) layering model is a good example of a well-associated model suite. Another example is the vertical model suite consisting of models for micro-data, meso-data, and meta-data for instance in decision support systems. Data streaming data and big data applications might become another example of model suite support. These applications can use a data stream profile, a task model that allows to derive the data collection portfolio, a model of analysis-driven data exploration, and a model for data collectors according to the analysis space. A typical example of a sophisticated model suite is the model suite of the human heart. It consists of a 5-layer model of the heart. At the genes layer the networks of genes are given by molecular functions. Proteins form the elementary units, define the chemistry, and their composition. Cell structures are the basis elements for explanation of functions and key organizational unit with biological processes and pathway models. The tissue model describes the structure and function and with cellular components. The human heart as an element of the body is described by a system of myocardial activation.
- *Collection of models at some abstraction layers*: Model suites may also consist of associated models at various abstraction layers. These models are combinations of observations or thought models. A categorization of models at abstraction layers is given in Figure 1.

The third opportunity is less obvious. We thus consider the wide class of mental, semantical, and semantical scientific models as displayed in Figure 1. Mental models can be graphical (iconic, representation) ones. Semantical models are internal ones (perception, cogitative) or external ones (linguistic, meta-, meta-meta-, meta-meta-meta-models). Semantic scientific models are formal scientific, empirical scientific, technological, or praxeological ones [5]. The categorization may be extended to technical models (physico-technical, other technical or engineering models) which are not considered in [5].

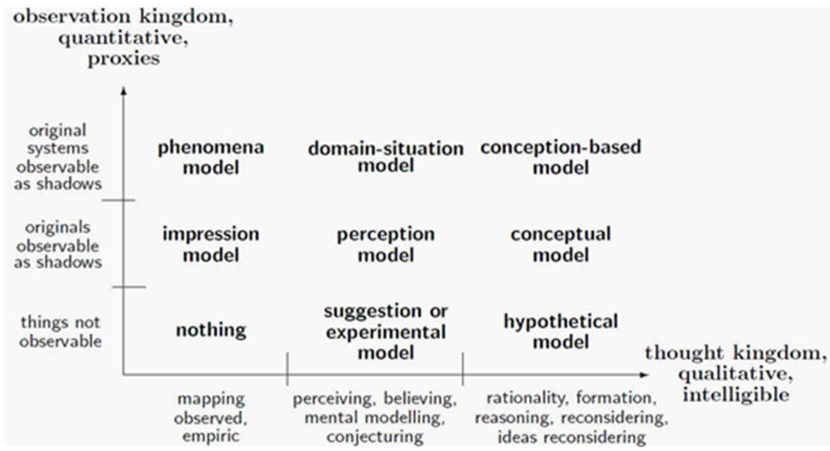

Figure 1. Models at abstraction layers.

The eight kinds of models in Figure 1 show a categorization of model kinds that generalizes the classification in [6, 7]. The classification has been developed after analysis of classical Greek thoughts about models. The main sources are Platon's Politeia [8] and C. Lattmann's [9] and our analysis of the analogies of sun, of the divided line, and of the cave. It allows a categorization into a combination of *observation or empirical quantitative models* and *qualitative intelligible models of thought*. Observations are some kind of reflection, i.e. shadows according to [8]. Intelligible models are based on different modes and qualities of reasoning first of all by one thinker (or a community of thinkers) after perceiving, believing, and digesting observations or beliefs. They are also based on proper and matured thoughts including rationality, formation and reconsideration of ideas. The eight models in Figure 1 are summarized as follows:

- *Impression models*: Humans are observing their environment and summarize their observations on things in models according to their interest, their tasks, their knowledge, and their profile.
- *Phenomena models*: Humans are considering their observations on their system environment, use pragmatic reasoning schemata, and internalize the entities around them. Phenomena models only represent what has been observed and not what is false, in each possibility.
- *Suggestion or experimental models*: Humans might have concluded that some their thoughts so far and develop based on that suggestion models that might be the basis for a falsification process esp. on the basis of experiments.
- *Perception models* are reflecting human understanding on entities observed by a human and are based on the setting of a human, esp. the orientation and the priming. They combine mentalistic concepts that are intuitively formed according to some (empirical) human understanding.
- *Domain-situation models* represent the common worldview on systems that are commonly observed, are governed by shared knowledge and beliefs, and reflect a shared opinion within a community of practice. The modelling method is governed by communication and human interaction.

- *Hypothetical models* mediate between quantitative theories and qualitative theories. They are applied to hypothetical and investigative scenarios, should support causal reasoning as well as network-oriented reasoning, and are developed in an empirical framework.
- *Conceptual models* are models that are enhanced by concepts from concept spaces, are formulated in a language that allows well-structured formulations, are based on mental/perception/situation models with their embedded concept(ion)s, and are oriented on a modelling matrix that is commonly accepted [10].
- *Conception-based models*: Conceptions are consolidated systems of explanation. A model is enhanced by such systems of explanation and provides a generalizing and consolidated viewpoint.

Humans synchronously use a number of models according to their tasks, according to the model functions in task resolving scenarios, according to the collaboration needs, according to their actual context, and according to their partners. Models must not be coherent in the general case. Humans use various models for various purposes. The models might be contradicting and inconsistent as a model society. A model suite however must however be coherent. It is then concise and precise consolidation of all function-relevant structural and behavioral features of systems under investigation. It is represented in a number of predefined formats, e.g. modelling languages such as diagrammatic languages.

2. Communication in a Multi-Agent World

We learn, communicate and think by means of concepts; and regardless of the way in which the meaning of an expression is encoded, the meaning is a concept2. Yet in our background theory, i.e. Transparent Intensional Logic (TIL), we do not define concepts within the classical set-theoretical framework. Instead, we explicate concepts as abstract procedures that can be assigned to expressions as their structured meaning3. In particular, complex meanings, which structurally match complex expressions, are complex procedures whose parts are sub-procedures. The moral suggested here is this. Concepts are not flat sets that cannot be executed and lack a structure; rather, concepts are algorithmically structured abstract procedures. Unlike sets, concepts have constituent parts, i.e. sub-procedures that can be executed in order to arrive at the product the procedure is typed to produce. Not only particular parts of a concept matter, but also the *way of combining* these parts into one whole 'instruction' that can be followed, understood, executed, learnt, etc., matters[4].

Having accepted semantic conception as described above, fundamental questions arise. How to reach those *abstract* procedures? How to examine their structure, how to derive what is entailed by them and not to derive what is not entailed? How to compute

[2] To avoid misunderstanding, we also explicate the meaning of a *sentence* as the *concept* of a proposition denoted by the sentence. For more arguments in favour of structured procedural concepts as the means of our communication, see [11].

[3] For details, see [12] and [13, §2.2].

[4] This had been known already to Bernard Bolzano who criticized the classical Port-Royal school and the law of inverse proportion between the content (intension) and extent (extension) of a concept. The content itself does not determine the concept, the *way of combining* its parts matters; see [14: §120].

their products? There are two possibilities. Either not to do it and instead just specify axioms and rules of using them. Or, *do* it in a systematic way using a language fine-grained enough. In TIL, we vote for the second strategy. To this end, we apply the language of TIL λ-terms that denote these procedures and mirror their structure in an isomorphic way. To give just a hint of our conception, in Figure 2 there is a simple example of a valid argument formalized in TIL.

<u>Tilman is seeking an abominable snowman</u>
Tilman is seeking something abominable

$$\frac{\lambda w \lambda t\ [{}^{0}\mathit{Seek}_{wt}\ {}^{0}\mathit{Tilman}\ [{}^{0}\mathit{Abominable}\ {}^{0}\mathit{Snowman}]]}{\lambda w \lambda t\ \exists x\ [{}^{0}\mathit{Seek}_{wt}\ {}^{0}\mathit{Tilman}\ [{}^{0}\mathit{Abominable}\ x]]}$$

Figure 2. An example of a valid argument formalized in TIL

All the entities of TIL ontology receive a type within a ramified hierarchy of types, which makes it possible to distinguish different levels of abstraction. In our example, the variable *x* must not range over individuals; this would turn logic into magic, and we would prove the existence of yetis. Instead, *x* ranges over *properties* of individuals. In addition, TIL is a typed, *hyperintensional* partial λ-calculus. Our procedures (concepts) are structured wholes that can occur in two fundamentally distinct modes, namely executed and displayed (for details, see [15]). When dealing with natural language, we need to operate not only within an extensional or intensional level, but also within *hyperintensional* level where substitution of analytically equivalent terms fails, because the very *meaning procedure* is *displayed* as the object of predication. Hyperintensional context is introduced inter alia by agents' attitudes like knowing, believing, designing, seeking and finding, computing, and many others[5]. Thus we come to the second issue, which is a cogent argumentation in favour of multi-agent systems.

In [17] the authors introduce the system for disaster resilience. Protecting nature, environment and people against disasters is very important and primary goal, of course. Yet, there are critical situations such as an unexpectable air disaster, natural disaster, traffic collapse, and so like, in which we can hardly do any more but to minimalize damages and harms by providing well-organized, professional *disaster relief*. In these situations, multi-agent systems are successfully applied.

Multi-agent systems are dynamic, distributed applications that run on many computers over the network. There can be thousands of agents who are *active* in their perceiving environment and acting in order to achieve their individual as well as collective goals. In general, there is no central dispatcher and the system is driven only by messaging. The agents communicate with their fellow agents by exchanging *messages* and they *learn by experience*. They are resource bounded, yet less-or-more intelligent and rational.

A multi-agent system should be designed in such a way that it is apt for handling *critical situations* where a centralised system is prone to a chaotic behaviour or even collapse. While behaviour of a centralised system heavily depends on the centralised

[5] For a summary on hyperintensionality, see the Introduction to the special issue of Synthese [16].

control so that its fail causes the fall of the whole system, in a multi-agent system there are still some other agents who can act reasonably even in a very critical situation; in the worst case they can at least send a warning message to the public.

The theory formalizing reasoning of agents has to be able to *'talk about'* and *quantify over* the objects of agents' *attitudes*, i.e. *structured meanings* of the embedded clauses, *iterate attitudes* of distinct agents, express *self-referential statements*, respect different *inferential abilities* of resource bounded agents. While this is beyond the capacity of first-order logic systems, we have the theory at hand; it is Transparent Intensional Logic (TIL). Thus, the content of agents' messages is formalized in TIL so that all the above issues are successfully dealt with. Each active agent has its own *ontology* and *knowledge base.* While an agent's knowledge base usually contains dynamic empirical facts, formal ontology is a result of the *conceptualization* of a given domain. It contains definitions (i.e., complex concepts) of the most important entities, forms a conceptual hierarchy together with the most important attributes and relations between entities. Due to TIL ramified hierarchy of types, the agents can reason about concepts themselves, learn new compound concepts via refinement of less complex concepts and exhibit an adequate dynamic behaviour.

In the multi-agent and multi-cultural world procedurally structured *concepts* are central to our communication. We model such concepts as TIL *procedures*, coined *constructions.* Flexible systems that we need to deal with critical situations in our rapidly changing dynamic world are best modelled and implemented as *multi-agent systems* composed of autonomous, resource-bounded yet less or more rational agents who communicate by messaging. In our systems, the content of a message is formalized in terms of concepts, i.e. in the language of TIL constructions.

Acknowledgements. This research has been supported by the Grant Agency of the Czech Republic, project No. GA18-23891S "Hyperintensional Reasoning over Natural Language Texts".

3. AI in Modelling Landscape - Technological Changes in Conceptual Modelling

The role of information modelling as a part of information systems (IS) development is to transfer human knowledge of the requirements of the system to the IS implementation. Along the development path, first step is to create a *conceptual model*. It represents the joint view of the interest groups of the IS's data in a structured way. This structure is manipulated in the evolution path of the IS first to reflect to the needs of *requirements engineering*, further to include the *architectural design* related aspects, then technical aspects coming from *technical design* and finally the elements of *implementation*. During the whole life cycle it is question on the data model of the same IS, but from different points of view. The purpose of the models is to transfer IS related decisions through the life cycle from phase to phase and from interest group to interest group. In addition, it is the key issue for communication in IS development.

Data modelling is always done in its context. The context covers technologies available, tools, development processes – in general, a huge amount of environmental issues of modelling. If we look at the history of computing and IS development as a part of it, it is easy to see dramatical changes in technologies; IS development and data modelling at the principal level have remained the same, the purpose of modelling has remained the same, but technological progress has changed the environment of it. The key enabler in the progress of ICT (Information and Communication Technology) is the improvement of VLSI technology. According to Moore's Law [18] the packing density of VLSI circuits doubles every 15 months. It reflects directly to the *processing capacity* of computers (doubles in 18 moths), memory capacity (doubles in 15 months), data transmission capacity (doubles in 20 months) and mass memories (capacity doubles in 18 months). If we compare the time of birth of systematic data modelling (from early 1960s) to the situation today, we have currently the computing environment having processing capacity of 2^{40}-, memory size of computers 2^{49}-, mass memory size 2^{40}- and data transmission capacity 2^{36}-times compared with the computing environment of early 1960s. In spite of this progress, it is acceptable to say that data modelling has more or less remained the same over the decades – or has it?

The progress introduced above is handled in more detail in [19] from the point of view of AI (Artificial Intelligence). AI has one of the key roles in the current era of data modelling. In [20] the era of systematic data modelling is divided (by binding it to the progress of database management) in four phases (quoted from the original article):

- *Phase I* (from roughly the 1960s to 1999) included the development of Database Management Systems (DBMS) known as hierarchical, inverted list, network, and during the 1990s, object-oriented Database Management Systems.
- *Phase II* (starting about 1990) relates to relational databases, SQL and SQL products (plus a few nonSQL products).
- *Phase III* (starting also around 1990 simultaneously to the Phase II) supported Online Analytical Processing (OLAP), along with specialized DBMSs.
- *Phase IV* (started 2008) introduced NoSQL and supported the use of Big Data, non-relational data, graphs, etc.

If we simply analyze the progress above, it is easy to notice that data modelling varies over the phases. D*evelopment tools* are an essential part in IS development. In the development process, we aim to look at the system structure "through the glasses" of the tool. Because of that it is easy to agree that also tools create a part of the IS development context and aim to guide the data modelling.

One interesting view to the changes in data modelling can be found in the traditional classification of data related concepts. The DIKW pyramid[6] (the good overview of it is available in [21]) represents structural and/or functional relationships between the concepts data, information, knowledge, and wisdom:

- Data: facts and figures relaying something in a non-organized way.
- Information: Contextualized, categorized, organized data.
- Knowledge: know-how, understanding, experienced, insight, intuition, contextualized information.
- Wisdom: Knowledge applied in action.

The hierarchy, in addition to help understanding about the role of the data in information systems, gives a view to the progress in data modelling. Without hesitance, it is possible to say that during the decades it is easy to see the transfer of the modelling target from lower towards upper levels. Nowadays, in the new era of AI, we should be able to model the connections between items of wisdom, instead of the traditional (data) concepts.

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[6] The origin of the DIKW Pyramid is not unanimously specified. The classification is handled in several articles; based on a simple literature review the author reviewed e.g.: http://www.infogineering.net/data-information-knowledge.htm; http://www.knowledge-management-tools.net/knowledge-information-data.html; https://www.ontotext.com/knowledgehub/fundamentals/dikw-pyramid/

What are the current trends in data and information systems modelling? This topic is handled in [22]. The author of the aeticle points out the important role of cloud platforms, coupled with Big Data and IoT technologies powered by AI and Machine Learning (ML), providing professional means for non-professionals - citizen data analysts. The article gives nice scene to the data modelling of 2019. We list some of the most important aspects of it as follows:

- Tools embedding AI and ML change the modelling landscape. Built in intelligence in the tools decrease the amount of human work. Model analytics decreases the opportunity for human errors and increases the quality of models. Automatic model generation decreases the amount of human work
- Gartner's predicts 40 percent automation in data science tasks. In data analytics, the role of citizen data analysts is growing. It indicates the changing role of the experts. Two types of data models are needed: one for data professionals and one for citizen users to be used for quick solutions in a plug and play manner.
- There is transfer from problem specific to problem area specific instruments and towards framework dominance. It indicates higher abstraction of the IS models.
- The increasing role of Robotic Process Automation (RPA; Software Robotics) indicates the growing importance of business process modelling.
- Transfer out of relational databases, especially in new types of applications. New technologies - NoSQL databases, data lakes, algorithmic intelligence, self-describing data formats, standardized data models - initiate new challenges for and take place of data modelling. Cloud dominance affects in data structures.
- The growing role of ”on-line” continuous data handled dynamically without knowing its structure in advance.
- Globalization of IS business indicates complexity in the Data Management ecosystem and unknown Data Governance issues. Data landscape becomes distributed, having a wide variety of data sources in applications. The importance of interoperability issues runs towards commonly used standardized data structures and models. Importance of interfaces and interface modelling will be an essential part of data modelling.

As a summary, it is easy to see the growth of modelling complexity, transfer of data (modelling) related tasks from professionals to end-users and AI to support human work. In basic level, data modelling remains as it has always been, but in practice, a lot of new challenges will appear.

4. Applications of AI in Global Environmental Engineering

4.1. Conceptual Modelling with Semantic Computing for Environmental Analysis

Humankind, the dominant species on Earth, faces the most essential and indispensable mission; we must endeavor on a global scale to perpetually restore and improve our natural and social environments. It is essentially significant to apply conceptual modelling and knowledge computing to global environment-analysis for finding out difference and diversity of nature and livings with a large amount of information resources in terms of global environments.

The 5D World Map (5DWM) System has introduced the concept of “SPA (Sensing, Processing and Analytical Actuation Functions)” for realizing a global environmental system [23, 24, 25, 26]. The 5DWM system has been proposed by Kiyoki and Sasaki in [24, 25], and its architecture has been implemented as a multi-visualized and dynamic knowledge representation system. The 5DWM is a system for visualizing the data resources to the map, which can be analyzed with multi-dimensional axes. Environmental Knowledge Base creation with 5DWorld Map is implemented for sharing, analyzing and visualizing various information resources to the map, which can display and facilitate the comparisons in multidimensional axes.

This system realizes Physical-Cyber integration, as shown in Figure 3, 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 circumstances with the SPA concept (Sensing, Processing and Analytical Actuation) for sharing, analyzing and visualizing natural and social environmental aspects, as shown in Figure 4. 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 many environmental information resources, which are characteristics of ocean species, disasters, water-quality and deforestation.

As conceptual modelling for making appropriate and urgent solutions to global environment changes in terms of short and long-term changes, "*six functional-pillars*" are essentially important with "*environmental knowledge-base creation*" for sharing, analyzing and visualizing various environmental phenomena and changes in a real world: (1) Cyber & Physical Space Integration, (2) SPA-function, (3) Spatio-Temporal computing, (4) Semantic computing, (5) World map-based visualization, and (6) Warning message propagation

As an actual implementation of the SPA architecture, 5D World Map System Project has presented a new concept of *"Water-quality Analysis Semantic-Space for Ocean-environment*" for realizing global water-environmental analysis [26]. The semantic space and the computing method have been implemented with knowledge-base creation for water-quality-analysis sensors for analyzing and interpreting environmental phenomena and changes occurring in the oceans in the world. We have focused on sea-water quality data, as an experimental study for creating *"Water-quality Analysis Semantic-Space for Ocean-environment*" [26].

4.2. International Collaborative Research Activities with SPA-based 5D World Map System

The 5D World Map System focuses on sharing, analyzing and visualizing various environmental influences and changes caused by natural phenomena and disasters in global environments with "environmental multimedia data resources." As a new meta-level system of international collaborative environment analysis, this system creates a remote, interactive and real-time academic-research exchange in global scopes and areas [24, 25]. Applications of 5DWorld Map for global sharing analysis of environmental situations and changes were studied as case studies in the international collaborative research activities with KEIO University (Japan) and Chulalongkorn University (Thailand).

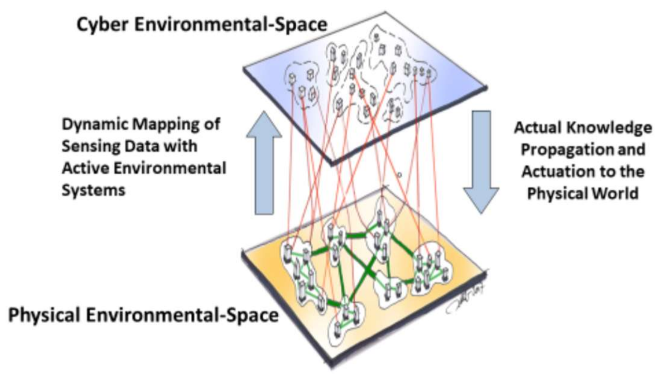

Figure 3. Global & Environmental System with "Cyber & Physical Spaces"**.**

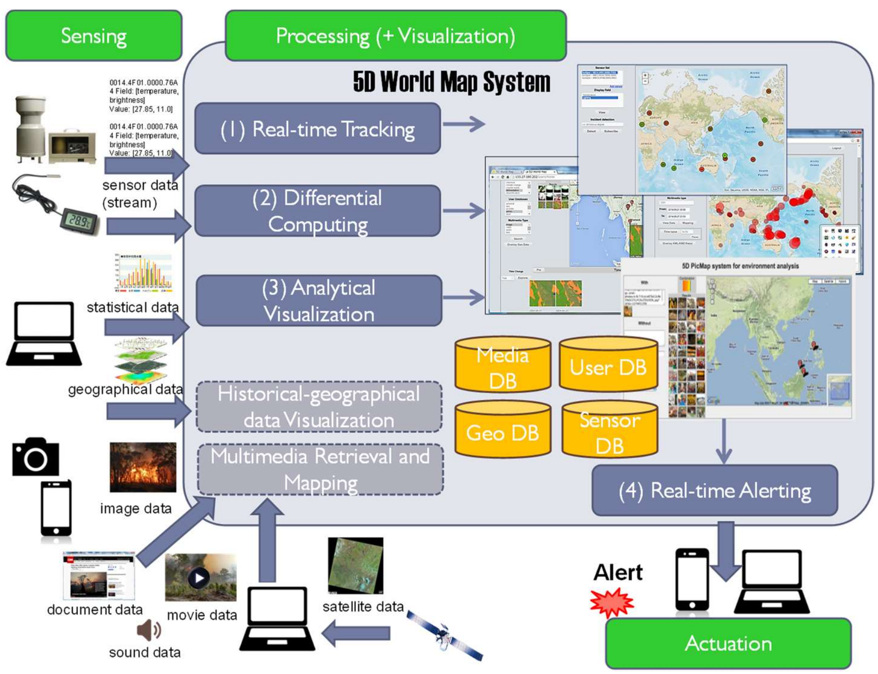

Figure 4. Basic SPA functions in 5D World Map System.

An actual international and collaborative research project on the 5D World Map System started in 2011 with Chulalongkorn University [26, 27, 28]. This project focuses on the global coral-analysis with multi-visualized knowledge sharing with 5D World Map System, applied to "coral-health-level analysis with images and water-quality data".

This project [27] stared at Sichang Island, Thailand. Those coral information resources and research results have been mapped onto the 5D World Map system [24, 25]. Three species of corals at Sichang Island i.e. *Acropora sp. Goniopora sp.* and *Pavona sp.* were subjected to a stress test with low salinity and normal salinity at concentration 10, 20 and 30 psu, respectively. Under water photographs and eye observation of coral activity were recorded at 12, 24 and 48 hours. The entropy or surface roughness and percent polyp activity were analyzed with comparison to eye observation of coral activity. The experiment was carried out under continuous water temperature and underwater light intensity controlled. The results indicated that "Healthy" entropy values for Acropora sp. are 1.57-1.62 and for *Goniopora sp.* are 4.26-4.46. In contrast, for *Pavona sp.*, short polyp coral, there was no "Healthy" entropy value resulted from any photographic assessment in this study. The "Healthy" value of *Acropora sp.* evaluated from percent active polyp was more than 52.4.

This collaborative project focuses on the effects of temperature and ammonia to coral health levels on *Acropora sp., Turbinaria sp., Porites sp.* by coral health levels evaluation with Coral Health Chart [28]. It was a standardized color reference card, which is a flexible tool that anyone can use for rapid, wide-area assessment of changing coral condition. The acute toxicity of ammonia concentration that affects to bleach coral more than 50% (50% Lethal Concentration: LC_{50}) was calculated by Probit analysis and coral bleaching analysis by polyp image analysis.

In addition to coral-analysis in this place, this project integrated a global sharing analysis and visualization of water quality analysis [29], with 5D World Map system. This integration is a typical and advantageous result to be realized with 5D World Map system, as typical and effective integration between different subjects with high relationships each other. The data resources in this research were collected from Sichang Island, Chonburi province, Thailand during 1990 to 2002. Six input parameters of water quality i.e. chlorophyll a, ammonia, nitrite, nitrate, phosphate and silicate were collected and displayed in 5D World Map system. The total location-sites were 21 stations, which situated around Sichang Island. All data of water quality were added and displayed with 5D World Map system in order to visualize and share the water quality from 1990 to 2002. Our results showed that 5D World Map system integrates environmental analysis with the coral-analysis subject related to the coral health level. 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**.** 5D World Map System for world-wide viewing of global environmental analysis with coral-analysis and water quality around Sichang Island in Thailand was reported in this study.

To conclude, we have introduced a conceptual modelling methodology for realizing global environmental analysis with ″5D World Map System." This methodology is essential to make appropriate and urgent solutions to global environment changes in terms of short and long-term changes. We have applied this methodology to "international and collaborative environmental-system research and education" as a new platform of environmental computing. This platform realizes remote, interactive and real-time academic research exchanging for international and collaborative research activities, and this system is currently utilized as an international and environmental research platform. This system is also expected to create several new original approaches to global environmental-knowledge sharing, analysis and visualization with "spatio-temporal & semantic computing." This system concept will be a basic structure to create new international and collaborative research and education for making important solutions and knowledge sharing on global environmental issues in the world-wide scope.

Acknowledgements: We would like to appreciate Dr. Xing Chen, Dr. Shiori Sasaki, Dr. Asako Uraki, Dr. Chalisa Veesommai and Dr. Irene Erlyn Wina Rachmawan, "5D World Map System Project" members and Dr. Sompop Rungsupa for their significant discussions and experimental studies.

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