Earth Observation Satellite: Big Data Retrieval Method with Fuzzy Expression of Geophysical Parameters and Spatial Features

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***Abstract*—A method for fuzzy retrievals of Earth observation satellite image database using geophysical parameters and spatial features is proposed. It is confirmed that the proposed method allows fuzzy expressions of queries with sea surface temperature, chlorophyll-a concentration and cloud coverage as well as circle, line and edge, for instance "rather cold sea surface temperature and a sort of circle feature". Thus users, in particular, oceanographers may access the most appropriate image data from the database for finding of cold cores (circle features), fronts (arc and line features), etc. in a simple manner. Although this is just an example for oceanographers, it is found that the proposed method allows data mining with fuzzy expressions of geophysical queries from the big data platforms of the earth observation satellite database.**

Keywords*—Fuzzy retrieval; earth observation satellite; big data; geophysical parameter; oceanographer; circle feature; arc feature; line feature; fuzzy expression

I. Introduction

These remote sensing satellite data are totally big data. One of the problems on the big data analysis is how to retrieve most appropriate satellite data. In this paper, Earth observation satellite data retrieval method with fuzzy expression of geophysical parameters and spatial features is proposed.

Conventional search engine allows search objects with some multimedia of keywords, images, voices, etc. In terms of Earth observation data retrieval, there is strong demand on satellite imagery data search with geophysical features and spatial features (for instance, "rather cold sea surface temperature and a sort of circle feature"). Such this flexible data search engine is required for the remote sensing imagery data users.

Space development agencies (NASA, NOAA, NASDA, ESA, IRS, CNES, etc.) that are building databases of earth observation satellite data have developed WWW or proprietary search software as a user interface for database search and provide it to users. Search requests from these are translated to be effective in databases based on unique structures and languages (most institutions are Oracle databases (relational databases) [1] and are translated into search requests in SQL language) [1].

The database consists of the earth observation satellite image data to be searched (the unit of search is called a granule), the inventory data that is its catalog information, and the browse image data with reduced resolution to know the outline of the database (this is called browsing) and their location information and metadata as granule attribute information.

To search for a granule, first, the inventory is searched from the inventory database, and the browse image data that matches the search conditions is searched from the browse image database via the metadata in the meta database. From the database, since location information and the like are linked between these databases, the user only needs to set conditions for retrieving inventory and browse images. In the current space development agency database system, the conditions for inventory search start with the satellite name, sensor name, ground station name, and indicate the observation date and time, location, data quality, cloudiness, etc.

From the inventory data candidates that meet these conditions, the one closest to the desired one is selected, the browse image is displayed and confirmed, and this is repeated until the desired data is reached. However, since neither the inventory data nor the browse image contains information on the physical quantity, which is the evaluation criterion for the user data, the number of repetitions until the desired data is reached is not small.

The retrieval method of the Earth Observation Satellite Image Database: EOSID proposed in this paper aims to reduce the time required for retrieval by adding physical quantities and spatial features of images to inventory data. There are many physical quantities and spatial features of earth observation satellite image data, but here I limited them to those in the marine field as an example. In other words, sea surface temperature and chlorophyll-a concentration are used as physical quantities, and edges, lines, circles, and arcs are selected as spatial features, and based on these quantities, The search conditions were narrowed down.

Furthermore, when specifying these physical quantities and spatial features as search conditions, it is assumed that it is impossible to give them in a limited manner, and a search based on fuzzy theory with a very, slightly, etc., language hedge should be used. This search based on fuzzy theory with language hedging has already been proposed by, for example, Isomoto [2], and is not new at all. And the search method must be devised. For example, Sobue et al. have proposed a method for searching catalog information of earth observation satellite data using physical quantities as fuzzy search targets [3].

NASA has also applied this to text search for data and information on the global environment. Here, the author proposes a method of further narrowing down the search items by referring to the spatial features by further developing [3]. The author reports the effectiveness of the proposed search method using a virtual Earth observation satellite image database.

In the following section, research background and related research works are described. Then, the proposed method and system is described followed by experimental set-up together with experimental results. After that, concluding remarks and some discussions are described.

II. Research Background

The demand for satellites related to remote sensing has grown significantly, especially in emerging countries where many countries do not have launch vehicles. In emerging countries, there is about four times the demand in the last ten years and the next ten years. It is announced that Metaps, who supports app monetization using artificial intelligence, will start joint research on a big data analysis system using micro satellites in cooperation with space shift. Many new and old players (Google, Facebook, etc.) are promoting market and customer development with various approaches such as resolution, shooting frequency, analysis, cost, etc., the global satellite remote sensing market.

Microsoft and the United States Ocean Atmosphere Agency (NOAA), a joint R & D agreement to develop the best way to extract data from internal systems. This will allow Microsoft to provide weather, water, and oceans provided by NOAA scientists and weather data hosted on Azure cloud platform. This collaboration is an important step in realizing the promise of open data and innovation, which allows governments and businesses to leverage NOAA data aggregated in cloud repositories and then availability of large amounts of computing resources Partners and customers develop new solutions for citizens and customers. Digital Globe, a satellite image provider (34 cm spatial resolution) founded in 1992, signed a long-term contract with the US government in 2002, and merged with GeoEye in 2012, with sales of approximately 60 billion JYen. The company is a major customer of NGA (National Geospatial-Intelligence Agency), and the government business accounts for over 80% of sales. On the other hand, vendors providing mapping services such as Google and Nokia are also customers. Skybox Imaging, which was acquired by Google, will consider releasing satellite data, combining satellite HD video data with map APIs to instantly see the movement of the ground “satellite video”. It can be used to monitor the movement of airplanes and ships, and to identify illegal deforestation, etc.

Planet Labs is a company that sells satellite photos collected from a network of 87 small satellites, and with this acquisition, RapidEyes has a six-year archive of six billion square kilometers of global land images, More than 177 Dove satellites are launched on orbit, and a large number of constellations that shoot the same spot at least once a day (multiple earth observation satellites are thrown in the same orbit, high frequency observation and then provided free of charge by Creative Commons (CC) license Start. The CC license is a new copyright rule for the Internet age, a tool for the author of publishing works to indicate that "you are free to use my work if you comply with these conditions."

Spire, a satellite venture, uses a group of small satellites called satellite constellations to collect various data and analyze geospatial information such as world trade and weather.

Descartes Labs mainly does the analysis of satellite images to understand what is there and to educate the system to extract specific crops from satellite images, extracting significant data from them, Adapt to the yearly satellite imagery. Predict actual yield by applying statistical model to extracted crops. Specifically, take out corn grown on the farm from satellite image and predict the amount of harvest for that year.

Facebook embarks on accurate mapping of the world by using artificially captured images (remote sensing images) and artificial intelligence technology (AI). How many people live in which region of which country know exactly what it is and optimize its global broadband offering, the Connectivity Lab uses AI technology for approximately 14.6 billion satellite images in 20 countries around the world to identify man-made structures etc., how many houses are along the river and along the road, and what communities We analyzed what was formed. Efforts to use "Computer Vision: Business Intelligence" where CIA-affiliated companies can work with Amazon to peek into Earth information at an unprecedented level of detail.

Omni Earth is planning a satellite system consisting of 18 units, and in the future, it will assume an earth observation data volume of 60 petabytes /year. The company is characterized by a partnership, and in 2014, partnered with Dynetics for satellite design and manufacturing, Draper Laboratory for systems engineering, and Spaceflight for launch service. The company emphasizes solution development using satellite image analysis, and acquired the US IRIS maps in August this year, and launched a business solution integrating earth observation images and other data for agriculture, forestry, energy and public sector provide on a cloud basis. The combination of advanced satellite infrastructure and advanced application development can create new innovations.

Services such as Google Maps, Microsoft's Bing, and MapQuest will display various satellite images cut and pasted. On the other hand, in the map box, we use the vast array of satellite image data of NASA and take an approach of stacking innumerable images taken from one area as a layer, to realize a clear image without a seam. A similar framework was born in Europe in February 2016. ESA concludes LOI (Letter of Intent) with SAP for rapid and efficient utilization of huge earth observation data. As satellite observation data by the Earth observation program “Copernicus” advanced by ESA is huge, data processing is difficult with conventional technology. Build an innovative approach to data processing and analysis by leveraging SAP's cloud platform "SAP HANA Cloud". ESA launches TEP and promotes practical use in six fields, Disaster prevention, Coast, forest, Water resources, Polar region, Cities and infrastructure. One example (coastal): Supporting the Aquaculture Fisheries Industries (SAFI) is a fishery data server for aquaculture companies and fishermen. Such these platforms provide kinds of big data. More importantly, data mining from the big data platform has to be done in efficient and effective manner. The proposed method would like to provide a sophisticated manner of data mining with fuzzy expression of geophysical parameters.

III. Related Research Works

Vague search of earth observation image database based on Fuzzy theory using physical quantities and spatial features is proposed [4] together with earth observation satellite image database system allowing ambiguous search requests [5]. On the other hand, user friendly and efficient catalog information management for earth observation data is proposed and well reported [6].

Remote sensing satellite image database system allowing image portion retrievals utilizing principal component which consists spectral and spatial features extracted from imagery data is proposed [7]. Meanwhile, data collection and active database for tsunami warning system is proposed [8].

A review of Chinese Academy of Science (CASIA) gait database as a human gait recognition dataset is conducted [9] together with gait recognition method based on wavelet transformation and its evaluation with CASIA gait database as human gait recognition dataset [10]. Meanwhile, visualization of 3D object shape complexity with wavelet descriptor and its application to image retrievals is proposed and validated [11] together with visualization of 3D object shape complexity with wavelet descriptor and its application to image retrievals [12].

Wavelet based image retrieval method is proposed and evaluated its usefulness [13]. On the other hand, DP matching based image retrieval method with wavelet Multi Resolution Analysis: MRA which is robust against magnification of image size is proposed [14]. Meanwhile, Free Open-Source Software: FOSS based Geographic Information System: GIS for spatial retrievals of appropriate locations for ocean energy utilizing electric power generation plants is proposed [15].

Error analysis of air temperature profile retrievals with microwave sounder data based on minimization of covariance matrix of estimation error is conducted [16]. Meanwhile, visualization of link structure and URL retrievals utilization of interval structure of URLs based on brunch and bound algorithms is well reported [17]. Method for image portion retrieval and display for comparatively large scale of imagery data onto relatively small size of screen which is suitable to block coding of image data compression is also proposed [18].

Content based image retrieval by using multi-layer centroid contour distance is proposed [19]. On the other hand, remote sensing satellite image database system allowing image portion retrievals utilizing principal component which consists spectral and spatial features extracted from imagery data is proposed [20].

Image retrieval and classification method based on Euclidian distance between normalized features including wavelet descriptor is proposed [21]. Also, numerical representation of web sites of remote sensing satellite data providers and its application to knowledge-based information retrievals with natural language is proposed [22]. Image retrieval based on color, shape and texture for ornamental leaf with medicinal functionality, meanwhile, is proposed [23]. Also, comparison contour extraction based on layered structure and Fourier descriptor on image retrieval is proposed and evaluated its effectiveness [24].

Pursuit Reinforcement Competitive Learning: PRCL-based online clustering with tracking algorithm and its application to image retrieval is proposed [25]. Also, image retrieval method utilizing texture information derived from Discrete Wavelet Transformation: DWT together with color information is proposed [26].

Metadata definition and retrieval of earth observation satellite data is proposed [27]. On the other hand, Open GIS with spatial and temporal retrievals as well as assimilation functionality is proposed [28]. Meanwhile, Geographic Information System: GIS based on neural network for appropriate parameter estimation of geophysical retrieval equations with satellite remote sensing data is proposed [29].

Image retrieval method based on hue information and wavelet description-based shape information as well as texture information of the objects extracted with dyadic wavelet transformation is proposed [30]. Wavelet based image retrievals is attempted [31]. Also, image retrieval method based on back projection is proposed [32].

For the Fuzzy logic related research works, there are the following papers,

Fuzzy Genetic Algorithm (GA) for prioritization determination with techniques for order performance by similarity to ideal solution is proposed [33]. On the other hand, smart grid photovoltaic system pilot scale using sunlight intensity and state of charge (SoC) battery based on Mamdani fuzzy logic control is also proposed [34]. Satellite image database search engine which allows fuzzy expression of geophysical parameters of queries is proposed [35]. Meanwhile, operation of light tracker movement using Fuzzy logic control information and communication technology is proposed [36].

IV. Proposed Method

A. Search Procedure

The search procedure in the current database system of most space development agencies is as follows:

1) As a condition for inventory search, start with satellite name, sensor name, ground station name, and specify observation date and time, location, data quality, cloudiness, etc. The user inputs a standardized search key according to a request from the terminal.

2) Search for inventory information based on the input search conditions.

3) Search for metadata corresponding to the searched inventory information.

4) Based on the retrieved metadata, a browse image that matches the search condition is retrieved from the database where it is located and presented to the user.

5) If there is no browse image desired by the user, the process returns to step 1. If there is a desired browse image, the original image data corresponding to the selected browse image is further searched.

6) Return the searched image data to the user as a search result.

In contrast, the search procedure proposed here is as follows:

1) Inventory search conditions include: satellite name, sensor name, ground station name, observation date and time, location, data quality, cloudiness, sea surface temperature, chlorophyll-a concentration, and other physical quantities and edges, lines, circles, and arcs. And other spatial features. At this time, for the search condition items below the cloud cover, search requests with ambiguous expressions by language hedging are allowed.

2) Search for inventory information based on the input search conditions.

3) Analyze the given ambiguous search condition and find the threshold that matches the condition using fuzzy logic.

4) If there is an image in the database that contains data between the threshold value calculated in 3 and the maximum value of the target membership function, it is assumed that the condition is met and the result is retained. .

5) Process image data with data that meets all the given conditions to create a browse image and display it as a candidate for search results along with attribute data such as sea surface temperature of the image.

6) The original of the browse image data selected by the user display the image data as a result. That is, the points different from the current search method are listed as follows.

a) The physical quantities and spatial features are included in the inventory data, and search conditions can be set based on these.

b) The use of attribute information included in the browse image database to confirm the matching of search conditions for physical quantities and spatial features eliminates the need for a meta database.

c) It is allowed to set ambiguous search conditions for these physical quantities and spatial features.

B. Setting Search Key Items

Since the earth observation field is wide-ranging, the ocean observation data is taken up with particular attention to the ocean field. The concept of the basic search method is common to each field. The search key items used this time are as follows,

1) Sea surface temperature, chlorophyll-a content, cloudiness,

2) Number of edges, number of circles, number of arcs, number of lines from spatial features.

The author chose, in particular, by enabling search using this spatial feature, it is thought that it is useful for search of the earth observation satellite image database by ocean dynamics researchers, topographical geological researchers, etc. For example, those who study ocean dynamics pay attention to the tides and the shape of the current axis when watching the movement of warm and cold currents. This tide is located in the convergence zone of the ocean current, where the temperature difference of seawater is sharp.

The sea conditions in this tidal sea area fluctuate greatly both temporally and spatially, and both hot and cold-water masses are disturbed and local convergence, subsidence areas, divergence, and upwelling areas are complicatedly arranged. In this area, the fishery is generally rich in nutrients and high in productivity and it is easy to gather both cold and warm schools of fish due to the flow, making it a good fishing ground. When this tide is captured as data, there are various shapes such as line, arc, circle, line pair, and the like. For example, looking at a line, there are various factors such as size, angle, and location. There are several of these shapes in one tide. To look at the tide from various angles and know the movements of the warm and cold-water flows, it is necessary to extract the necessary tide locations and images from the database.

In addition, if it becomes possible to search using the spatial characteristics of circles, it can be expected that cold water chunks, etc., which are known for forming good fishing grounds, can be easily searched. As other search key items, the observation place and observation date adopted by the current

Earth observation satellite image database systems were used. These search key items and various quantities of the browse image to be searched are as follows,

1) Image number << No. 1 ~ No. 100 >>
2) Sea surface temperature << 0-30 degrees >>
3) Chlorophyll-a content (0 mg / m3-35mg / m3)
4) Number of edges << 0 ~ 14 >>
5) Number of circles << 0 ~ 4 >>
6) Number of arcs << 0 ~ 5 >>
7) Number of lines << 0 ~ 4 >>
8) Observation place << random >>
9) Observation date << random >>
10) Cloud Cover << 1% ~ 100% >>

As described above, one browse image holds ten attribute values.

C. Search Engine Based on Fuzzy Theory

1) Membership function: In order to perform a search based on ambiguous search requests from users, a membership function is defined using fuzzy theory that can handle ambiguity. Assemble the search conditions using the defined membership function and perform the search together with observation location, observation date, etc.

It is considered that the analyst to search for is determined by the amount of cloud and is not specified vaguely. Therefore, the author considers a search method that allows ambiguous expressions for the remaining seven items. Therefore, it is necessary to define a membership function for each physical quantity and space feature that we have taken up this time. However, how people perceive certain terms is different. Therefore, there is a problem that the membership function cannot be determined uniquely. Therefore, here, a questionnaire survey was conducted for members of the Information System Subcommittee of the Forum of the Earth Science and Technology Agency, and the membership function of each search condition item was determined. The exponential function of Eq. (1) was used as the function system.

$$\mu(x) = \int_a^b e^{-c(x-d)^2/x}\, dx \quad (1)$$

where, x is the value of each search condition item, and a, b, c, d are coefficients of the membership function shown in Table I.

2) Definition of the language hedge: The language hedge is a modifier attached to attribute information and is an operator that converts into attribute information (fuzzy set) having a qualifying meaning. The language hedge used this time is as follows:

a) Pretty

b) Very (Very)

c) To some extent (A sort of)

d) Somewhat (Rather)

e) Some (More or less)

f) Slightly

TABLE I. COEFFICIENTS OF THE MEMBERSHIP FUNCTION FOR EACH KEYWORD

Search Keywords	Attributes	a	b	c	d
Sea Surface Temperature	Warm	0	30	0.015	30
	Cool	0	30	0.15	0
Chlorophyll-a Concentration	Concentrated	0	1	0.003	35
	Sparse	0	1	30.0	0
Cloud Coverage	Concentrated	0	100	0.034	17
	Sparse	0	100	3.0	0
No. of Edges	Many	0	14	0.5	5
	Little	0	14	0.32	0
No. of Circles	Many	0	5	0.25	5
	Little	0	5	0.15	0
No. of Arcs	Many	0	6	0.3	6
	Little	0	6	0.2	0
No. of Lines	Many	0	4	0.6	4
	Little	0	4	0.5	0

Membership function: Number of lines "less"

There are six types. In order to calculate the centroid value from the membership function during the search, these were defined as follows respectively,

a) Pretty A = NORM (INT (A) and not TNT (CON (A)))

b) Very A = CON (A)

c) A sort of A = NORM (not CON (A) 2 and DIL (A))

d) Rather A= NORM (TNT (A))

e) More or less A = DIL (A)

f) Slightly A= NORM (A and not (very A))

where, "A" means a fuzzy set, and not means a negation operation and a product operation. Also, CON, DIL, NORM, and INT are called centralization, enlargement, normalization, and contrast enhancement, respectively.

$$CON(A) = A^2, \mu_{con(A)}(x) = \mu^2(x), DIL(A) = \sqrt{A}, \quad (2)$$

$$\mu_{DIL(A)}(x) = \sqrt{\mu(x)}, NORM(A) = \frac{A}{\mu_{max}}, \quad (3)$$

$$\mu_{NORM(A)}(x) = \frac{\mu(x)}{\mu_{max}}, \quad (4)$$

$$\mu_{INT(A)}(x) = 2\mu^2(x), 0 < \mu(x) < 0.5$$

$$= 1 - 2(1-\mu(x))^2, 0.5 < \mu(x) < 1.0 \quad (5)$$

where, x is a search condition item (physical quantity and spatial feature).

3) AND, OR, NOT in search condition: In order to allow a combination of multiple different search conditions, a logical operation such as AND, OR, and NOT of search conditions was devised. Center of gravity value. When a search request is issued, the physical quantity and spatial shape data of each image are examined using a membership function corresponding to ambiguous conditions. However, since all data are examined, all data are search results. Therefore, a threshold is set, and if *x* is included between the threshold and the maximum value of the membership function, it is considered that the condition is met. This time, the threshold value adopted the value using the center of gravity (CG) of the fuzzy set. The center of gravity of the fuzzy set is calculated by the following equation,

$$CG = \int_x x\, \mu_A(x)dx / \int_x \mu_A(x)dx \quad (6)$$

If there is no data that satisfies the condition input by the user, the data closest to the barycentric value is output as a search result.

4) Data and browse image search: In advance, edges, circles, arcs, and lines, which are spatial features, were extracted from the earth observation satellite image, and an index was constructed. For the extraction of the spatial features of these images, we used a combination of simple image classification, edge extraction by the relaxation method, and thinning as a method to extract such spatial features.

For the form on the browser that actually performs input and output, select the form from which the search conditions are actually written from the keyboard, and the conditions that apply to the image you are looking for from the given word group I have prepared two formats that can be searched by pressing the button. In the former, the conditions are entered on the keyboard, and complicated conditions containing AND, OR, and NOT conditions can be entered. Therefore, the operation became a little difficult. On the other hand, the latter makes it possible for anyone to easily search for images and prepares the one that saves the trouble of inputting conditions as much as possible. Therefore, only one mode was selected from the AND, OR, and NOT conditions, and the entered condition was searched according to the mode.

From the homepage (Home Page of the proposed Earth observation satellite image database retrieval system), from which you can select either "text input" or "button input". If "text input" is selected here, it will transition to the input form (the menu for retrieval keyword input in text form) as shown in Fig. 1. Here, the conditions are assembled from the example shown, input from the keyboard, and the search is performed. When "button input" is selected, the screen shifts to the input form (Menu for retrieval keyword input by clicking mouse button) as shown in Fig. 2. In this case, the input method is simpler than "text input", but it is not possible to input complicated conditions with complicated conditions.

Text Input System
Available Items

A:	SST	1:	pretty	a:	Large
B:	Chlorophyll-a	2:	more_or_less	_	
C:	No.of_Edge	3:	very	_	
D:	No.of_Circle	4:	rather	b:	Small
E:	No.of_Arc	5:	normal	_	
F:	No.of_Line	6:	sort_of	_	
_	_	7:	slightly	_	
Operator:	and_or_not				

Fig. 1. Menu for retrieval keyword input in text form.

Please key in your keyword below,
Search
Example of combination SST is pretty high: A1a

Large chlorophyll-a concentration and (more or less of the number of edge or sort of the number of circle): B5a and (C2b or D4b)

V. Experiment

In this experiment, the browse image size was set to 64 by 64 pixels, and 100 images were prepared. These are a part of the original NOAA-11 / AVHRR[1] image of 3:37 GMT on April 25, 1990.The spatial features are extracted and compiled into a database by the method of reference, and the pixel interval of 1 km is also calculated. An 8 by 8 pixels average filter was used to create a browse image with a pixel interval of 8 km. Here, the condition "A7a and C3a (sea surface temperature is slightly warm, and the number of edges is very large)" is given as a search example.

Fig. 3 shows the example. An example of the retrieval for Sea Surface Temperature is slightly high and the number of edges is very large. The user can select a desired image from a given browse image and data of the image. An example of the retrieved results (Extract image No. 12 from the candidates of the browse images) shows the result of selecting image number 12. Fig. 4 shows an example of the retrieved results (Extract image No. 12 from the candidates of the browse images).

Sea Surface Temp. "Use" "Not use"
"Pretty" "more or less" "very" "rather" "normal" "sort of" "slightly"
"Large" "Small"
"AND" "OR"
Sea Surface Temp. "Use" "Not use"
"Pretty" "more or less" "very" "rather" "normal" "sort of" "slightly"
"Large" "Small"
"AND" "OR"
Chlorophyll-a "Use" "Not use"
"Pretty" "more or less" "very" "rather" "normal" "sort of" "slightly"
"Large" "Small"
"AND" "OR"
Number of edge "Use" "Not use"
"Pretty" "more or less" "very" "rather" "normal" "sort of" "slightly"
"Large" "Small"
"AND" "OR"
Number of circle "Use" "Not use"
"Pretty" "more or less" "very" "rather" "normal" "sort of" "slightly"
"Large" "Small"
"AND" "OR"
Number of arc "Use" "Not use"
"Pretty" "more or less" "very" "rather" "normal" "sort of" "slightly"
"Large" "Small"
"AND" "OR"
Number of line "Use" "Not use"
"Pretty" "more or less" "very" "rather" "normal" "sort of" "slightly"
"Large" "Small"
"AND" "OR"

Fig. 2. Menu for retrieval keyword input by clicking mouse button.

Searching A7a and C3a
=>Search Result

Image_No.	Browse	SST	Chlorophyll-a	Edge	Circle	Arc	Line
5		22	33.405	11	2	5	3
12		24	33.757	12	3	5	3
21		21	33.445	14	4	5	4
44		27	5.157	11	3	3	4
49		20	29.005	14	4	5	4
58		21	9.669	11	4	3	3
73		23	9.317	11	3	5	2

Submit Reset

Fig. 3. An example of the retrieval for sea surface temperature is slightly high and the number of edges is very large.

In addition, in the present search system, when there is no image satisfying the condition presented by the user, the image closest to the condition presented by the user is searched by gradually increasing the search width.

[1] https://en.wikipedia.org/wiki/Advanced_very-high-resolution_radiometer

The element of the image is as follows,

Image No.: 12

SST: 24

Chlorophyll-a: 33.757

No. of Edge: 12

No. of Circle: 3

No. of Arc: 5

No. of Line: 3

Fig. 4. An example of the retrieved results (Extract image No. 12 from the candidates of the browse images)

Fig. 5 and 6 show examples of browse images and their spatial features extracted as search results. Fig. 6 is obtained from the extracted lines, edges, arcs and circles from the image of Fig. 5 based on the relaxation method[2] with the thinning algorithm.

Fig. 5. Details of the retrieved browse image (64 by 64 pixels with 8 km of pixel size extracted from the NOAA/AVHRR images).

Furthermore, when 30 subjects who did not have prior knowledge about remote sensing were asked to use the proposed search system, the number of language hedges was too large.

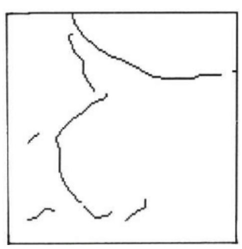

Fig. 6. Extracted spatial features (From the image of Fig.5, lines, edges, arcs and circles are extracted using the relaxation method with the thinning algorithm).

VI. Conclusion

A method for fuzzy retrievals of Earth observation satellite image database using geophysical parameters and spatial feature is proposed. It is confirmed that the proposed method allows fuzzy expressions of queries with sea surface temperature, chlorophyll-a concentration and cloud coverage as well as circle, line and edge, for instance “rather cold sea surface temperature and a sort of circle feature”. Thus users, in particular, oceanographers may access the most appropriate image data from the database for finding of cold cores (circle features), fronts (arc and line features), etc. in a simple manner.

According to the retrieval method proposed in the paper, physical quantities and spatial features extracted from the earth observation satellite image to be retrieved are added to the inventory data, and retrieval can be performed faster and more efficiently using these. In addition, the search condition setting of those physical quantities and spatial features was allowed to be ambiguous, and the user's freedom of search was expanded. It also simplifies the method used by the user to enter conditions and displays browse images and their data as search results so that they can be easily viewed on the WWW, making it easy to visually confirm the results.

Future Research Works

In the future, the proposed search method will be constructed as a database system and made public through WWW (http: //www.kyuic.grjp/), and further improvement proposals from users will be made to be more practical.

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References

[1] Ulrich Geske, Optimization and Simulation of Complex Industrial Systems, Proceedings of the 11th International Conference on Application of Prolog, INAP'98 (http: //www.oracle.com/).

[2] Isomoto, M., Nozaki, H., Yoshine, K., Nagai, H., Information Retrieval Techniques for Accumulated Data with High Fuzziness, Journal of the Japan Fuzzy Society, Vol. 8, No. 2, pp. 284-293, 1996.

[3] Shinichi Sobue, Kohei Arai, Bunra Yoshida, Osamu Ochiai, Mina Ogawa, Mineo Sekiguchi, Tomotaka Sekiya, Masao Takagi, "A User-Friendly and Efficient Catalog Information Management and Provision Method for Earth Observation Satellite Data", Procedings of Advanced Database System Proceedings of the Symposium'94 Symposium on Information Processing, Vol.94, No.13, pp.111-116, 1994.

[4] Kohei Arai, Manabu Arakawa, Hirofumi Eto, Vague Search of Earth Observation Image Database Based on Fuzzy Theory Using Physical Quantities and Spatial Features, Journal of the Japan Society of Photogrammetry, Vol. 38, No. 4, pp. 17-25, Aug. 1999.

[5] Kohei Arai, Hirofumi Eto, Tomoko Nishiyama, Earth Observation Satellite Image Database System Allowing Ambiguous Search Requests, Journal of the Japan Society of Photogrammetry, Vol.38, No.4, pp.47-52, Aug.1999 .

[6] Shin-ichi Sobue, Kohei Arai, Fumiyoshi Yoshida, User Friendly and Efficient Catalog Information Management for Earth Observation Data, Information Processing Society of Japan, Advanced Database Workshop, pp. 111-116, December 1994, 1994

[7] Kohei Arai, Remote sensing satellite image database system allowing image portion retrievals utilizing principal component which consists spectral and spatial features extracted from imagery data, International Journal of Advanced Research in Artificial Intelligence, 2, 5, 32038, 2013.

[8] Kohei Arai, Data collection and active database for tsunami warning system, Proceedings of the 1st International Workshop on Knowledge Cluster Systems, 2007.

[9] Rosa Andrie, Achmad Basuki, Kohei Arai, A review of Chinese Academy of Science (CASIA) gait database as a human gait recognition dataset, Proceedings of the IES: Industrial Electronics Seminar, at EEPIS, 1-8, 2011.

[2] https://en.wikipedia.org/wiki/Relaxation_(iterative_method)

[10] Kohei Arai, R.Andrie, Gait recognition method based on wavelet transformation and its evaluation with Chinese Academy of Science (CASIA) gait database as human gait recognition dataset, Proceedings of the Information Technology for Next Generation: ITNG conference 2012, 213, 2012

[11] Kohei Arai, Visualization of 3D object shape complexity with wavelet descriptor and its application to image retrievals, Journal of Visualization, DOI:10.1007/s, 12650-011-0118-6, 2011.

[12] Kohei Arai, Visualization of 3D object shape complexity with wavelet descriptor and its application to image retrievals, Journal of Visualization, 15, 2, 155-166, 2012.

[13] Kohei Arai, C.Rahmad, Wavelet based image retrieval method, International Journal of Advanced Computer Science and Applications, 3, 4, 6-11, 2012.

[14] Kohei Arai, DP matching based image retrieval method with wavelet Multi Resolution Analysis: MRA which is robust against magnification of image size, International Journal of Research and Review on Computer Science, 3, 4, 1738-1743, 2012.

[15] Kohei Arai, Free Open Source Software: FOSS based GIS for spatial retrievals of appropriate locations for ocean energy utilizing electric power generation plants, International Journal of Advanced Computer Science and Applications, 3, 9, 95-99, 2012.

[16] Kohei Arai, Error analysis of air temperature profile retrievals with microwave sounder data based on minimization of covariance matrix of estimation error, International Journal of Advanced Computer Science and Applications, 3, 9, 85-89, 2012.

[17] Kohei Arai, Visualization of link structure and URL retrievals utilization of interval structure of URLs based on brunch and bound algorithms, International Journal of Advanced Research in Artificial Intelligence, 1, 8, 12-16, 2012.

[18] Kohei Arai, Method for image portion retrieval and display for comparatively large scale of imagery data onto relatively small size of screen which is suitable to block coding of image data compression, International Journal of Advanced Computer Science and Applications, 4, 2, 218-222, 2013.

[19] Kohei Arai, Cahya Rahmad, Content based image retrieval by using multi-layer centroid contour distance, International Journal of Advanced Research in Artificial Intelligence, 2, 3, 16-20, 2013.

[20] Kohei Arai, Remote sensing satellite image database system allowing image portion retrievals utilizing principal component which consists spectral and spatial features extracted from imagery data, International Journal of Advanced Research in Artificial Intelligence, 2, 5, 32038, 2013.

[21] Kohei Arai, Image retrieval and classification method based on Euclidian distance between normalized features including wavelet descriptor, International Journal of Advanced Research in Artificial Intelligence, 2, 10, 19-25, 2013.

[22] Kohei Arai, Numerical representation of web sites of remote sensing satellite data providers and its application to knowledge based information retrievals with natural language, International Journal of Advanced Research in Artificial Intelligence, 2, 10, 26-31, 2013.

[23] Kohei Arai, Indra Nugraha Abudullar, Hiiroshi Okumura, Image retrieval based on color, shape and texture for ornamental leaf with medicinal functionality, International journal of Image, Graphics and Signal Processing, Vol.6, No.7, June 2014

[24] Cahya Rahmad, Kohei Arai, Comparison contour extraction based on layered structure and Fourier descriptor on image retrieval, International Journal of Advanced Computer Science and Applications, 6, 12, 71-74, 2015.

[25] Kohei Arai, Pursuit Reinforcement Competitive Learning: PRCL Based Online Clustering with Tracking Algorithm and Its Application to Image Retrieval, International Journal of Advanced Research on Artificial Intelligence, 5, 9, 9-16, 2016.

[26] Kohei Arai, Cahya Rahmad, Image Retrieval Method Utilizing Texture Information Derived from Discrete Wavelet Transformation Together with Color Information, International Journal of Advanced Research on Artificial Intelligence, 5, 10, 1-6, 2016.

[27] S.Sobue and Kohei Arai, Metadata Definition and Retrieval of Earth Observation Satellite Data, Proceedings of the IEEE Metadata Conference, 1997.

[28] Kohei Arai, Open GIS with spatial and temporal retrievals as well as assimilation functionality, Proceedings of the Asia Pacific Advanced Network Natural Resource Workshop, Utilization of Earth Observation Satellite-Digital Asia Special Session 1,p8,2003.

[29] Kohei Arai, Geographic information system: GIS based on neural network for appropriate parameter estimation of geophysical retrieval equations with satellite remote sensing data, Proceedings of the IEEE Geoscience and Remote Sensing, PID 220128, 2006.

[30] Kohei Arai, Yuji Yamada, Image retrieval method based on hue information and wavelet description based shape information as well as texture information of the objects extracted with dyadic wavelet transformation, Proceedings of the 11th Asian Symposium on Visualization, ASV-11-08-10, 1-8, 2011.

[31] Kohei Arai, C.Rahmad, Wavelet based image retrievals, Proceedings of the 260th conference in Saga of Image and Electronics Engineering Society of Japan, 243-247, 2012.

[32] Kohei Arai, Image Retrieval Method Based on Back-Projection, Proceedings of the Computer Vision Conference 2019.

[33] Kohei Arai, Tran Xuang Sang, Fuzzy Genetic Algorithm for prioritization determination with techniques for order performance by similarity to ideal solution, International Journal of Computer Science and Network Security, 11, 5, 1-7, 2011.

[34] Kamil Fagih, Wahyu Primadi, Anik Nur Harayani, Ari Priharta, Kohei Arai, Smart grid photovoltaic system pilot scale using sunlight intensity and state of charge (SoC) battery based on Mamdani fuzzy logic control, Journal of Mechatronics, Electrical Power and Vehicular Technology, 10, 36-47, 2019.

[35] Kohei Arai, Satellite Image Database Search Engine Which Allows Fuzzy Expression of Geophysical Parameters of Queries, International Journal of Advanced Computer Science and Applications IJACSA, 11, 5, 69-73, 2020.

[36] Luffi Mahardika, Anik Nur Hendayani, Heru Wahyn Herwanto, Kohei Arai, Operation of light tracker movement using Fuzzy logic control information and communication technology, Proceedings of the International Conference on IACT (ICOIACT 2018), Yogyakarta, 3D Parallel Session 3-D, 2018.

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