A Semantically-Related Information-Extraction System of Living Things by Spatial, Temporal and Color Analyzers

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Abstract

This paper presents a semantically related information-extraction system of living things by the global analysis of spatial, temporal and color information of images. The progress of multimedia, mobile and GIS technology makes it possible to create and share various information resources globally. Various kinds of information resources on natural environments of the real world are also existing in a cyber space, and it is becoming possible to support users to acquire the valuable knowledge that bridge user's fragmentary information about the real world and adequate information on the cyber space. This system realizes the functions for identifying unknown living things contained in a picture image input by a user, through the global analysis of temporal, spatial and color information of images within a user-selected domain. Given a picture image of a living thing with temporal and spatial information, this system evaluates it using temporal and spatial contexts to select the scope of possible candidates of living things. This system also analyzes color information by calculating correlations between the color distribution of an input image and corresponding sample image data. By these processes, users acquire detailed information such as the name, the habitant and the active period of the living things contained within the given images.

KEY WORDS
Multimedia Database, Image Retrieval, Spatiotemporal Contexts, Color Information, Knowledge Acquisition

1. Introduction

Recently, we can use various kinds of information and specialized knowledge about natural environments of the real world, which exist on a cyber space. However, it is difficult to specify the information related to user's fragmentary data from enormous sources of information of knowledge. Thus, it is important to support users to acquire valuable knowledge that bridge user's fragmentary information about the real world and adequate information on the cyber space.

Generally, we can find various information resources by using keyword-based search. However, if we do not know the keyword related to what we want to know, we cannot find appropriate information. It is difficult to obtain any knowledge of unknown things. For example, even when we have an image of a living thing and want to know the information about it, it is difficult to search the details of it if we do not have related information such as the name.

The objective of our research is to create a kind of "Multimedia Encyclopedia", which can be implemented as e-book in the ubiquitous situations. In this paper, we propose a knowledge acquisition system of living things in the real world by the specification and identification of the living things within images which users take by their own digital cameras or mobile phones. Given a picture image of a living thing with temporal and spatial information, the system evaluates it using temporal and spatial contexts to select the scope of possible candidates of living things, and provides the related knowledge about the identified living things.

As related work, the technique of calculating the similarity between images using the color information [1],[2],[3]. Most of the studies in the field of image retrieval [4],[5],[6],[8], the color information of images is used. Our system also uses the color information of images because it is easier and faster to extract than other image features such as shape features and structure features by edge detection.

Regarding the spatiotemporal database search and integration, several research results have been shown on landmark information mapping [7], meta-level integration of spatiotemporal databases [9], 4D World Map System with semantic and spatiotemporal analyzers [10], and 5D World PicMap [11].[12]. The features of these systems are to enable users to retrieve media data and semantically related information of unknown places according to their spatiotemporal context, and analyze the synchronism and the time-series variation of media data.

Based on these previous researches, to manage the images effectively for the analysis of natural environments in the real world, we apply the spatiotemporal analyzers for images, which utilize exchangeable image file format (Exif) of image data. Exif is a specification for the image data with the addition of specific metadata tags. Though the metadata tags defined in the Exif cover a broad spectrum, the most used tags in recent academic researches and online applications are geolocation tags. In our system, we use not only geolocation information but also the time tags to construct spatiotemporal analyzers for specification and identification of target living things.

This system makes it possible for users to increase the chance of knowledge acquisition. The users of this system are able to acquire not only the name, habit, active period/season of living things within a picture image which they take, but also the related valuable knowledge such as other living things living in the same area and season, and irregular events and situations related to the living things.

2. Basic Idea

Our semantically related information-extraction system of living things is able to be defined as a system to specify and identify a living thing within an image as an object by using only spatiotemporal and color-based appearance feature of living things, and provide the detailed information such as the name, the habitant and the active period of the living things, which is not able to be retrieved by keyword-based search methods.

Our system is composed by two main functions: (1) living things identification function, and (2) visualization function with every property of living things.

By the identification function, the living things in an image can be identified not using keywords like existing search system but using multimedia such as images, movies, sounds and so on. The system provides the calculation results as a ranking of similar images from database. In this step, a user chooses an image which he/she thinks correct from the ranking of candidate images.

After the identification of living things, visualization function provides the global view of knowledge of living things database from each property of living things such as habitat, active period, appearance features, ecotype, e.t.c. with world map interface.

The architecture of our system is represented in Figure 1.

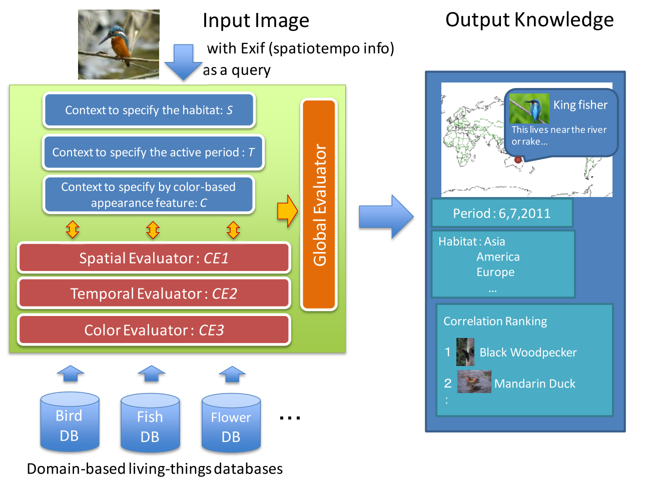

Figure1. System architecture of our information-extraction system of living things

2.1 Living things database with spatiotemporal and color information

In this method, the following databases and contexts are defined to specify the object within an image input by a user.

S: Context to specify the habitat of living things
T: Context to specify the active period of living things
C: Context to specify the color-based appearance features of living things
K: Living-things database (1)

S is a spatial context to specify the habitat of living things. It is specified by the location information attached to a picture which a user takes and inputs. By the comparison and matching between *S* and the attribute information stored in the living things database (*K*), the candidates of living things who has the possibility to be taken in the picture in the relevant region are selected.

Figure.1 System architecture of our information-extraction system of living things

T is a spatial context to specify the active period of living things. It is specified by the time information attached to a picture which a user takes and inputs. By the comparison and matching between T and the attribute information stored in the living things database (*K*), the candidates of living things who has the possibility to be taken in the picture in the relevant time are selected.

C is a context to specify the color-based appearance features of living things. It is specified by the color information attached to a picture which a user takes and inputs. By the calculation of pixel numbers of each color within the image and an area distribution of all pixels within the image as color histogram vector, the color-based appearance feature of the image is calculated.

K is a living-things database. It stores the knowledge resources of information which enables a multi-view biological analysis for living things such as habitat and active period.

2.2 Living things identification function

In addition to living-things database with spatiotemporal and color information contexts, the following identification functions are defined in order to enable users to acquire

$$CE1: spatial\ evaluation(s_h, k_m) \rightarrow boolean \quad (2)$$

Table 1 Living-things database *K*（Living things area is defined as polygon, living things active period is defined as on a month basis, attribute information about seeming feature color of living things is defined as130 original colors.）

Name	Active period	Habitant	Color-based Appearance Feature
Ruddy Kingfisher	January	(40.44694705960048, 143.525390625), (13.923403897723346,89.6484375),…	ruddy_kingfisher1=[BG/Dp0.00,BG/Dl0.00,…P/Lgr0.30,…,],…
	:		
Ioujima White-Eye	January	(45.30580259943578, 138.33984375), (43.22453232123465, 136.55231056)	ioujima_white_eye1=[BG/Dp0.00, BG/Dl0.00,…,BG/Dgr0.032,…,], …
	:		
	November	(40.44694705960048, 143.525390625), (13.923403897723346,89.6484375),…	
	:		

CE1 is a function to identify the habitat of the target living thing. The inputs are the context to specify the habitat of living things s_h, which is attached to the image input by a user, and a certain living thing k_m (*m* is one of the living things of all *n* kinds) in living-things database *K*. If k_m has a possibility of being taken in a certain area, the function returns true, otherwise it returns false. In actual retrieval, the function is used to evaluate the possibility of activity of all *n* kinds of living things.

$$CE2: temporal\ evaluation(t_i, k_m) \rightarrow boolean \quad (3)$$

CE2 is a function to identify the active period of the target living thing. The inputs are the context to specify the active period of living things t_i, which is attached to the image input by a user, and a certain living thing k_m (*m* is one of the living things of all *n* kinds) in living-things database *K*. If k_m has a possibility of being taken in a certain period or season, the function returns true, otherwise it returns false. In actual retrieval, the function is used to evaluate the possibility of activity of all *n* kinds of living things.

$$CE3: color\ evaluation(c_j , k_m) \rightarrow cor \quad (4)$$

CE3 is a function to calculate the color-based appearance features of the target living things. The inputs are the context to calculate correlation *cor* of the color-based appearance of living things c_j, which is extracted from the image input by a user, and a certain living thing km (*m* is one of the living things of all *n* kinds) in living-things database *K*. In actual retrieval, the function calculates the correlation of color histogram within living-thing image input by a user $c_j = (c_1, c_2, \ldots, c_p)$ and the color histogram extracted from an image of a certain living thing k_m in living-things database *K* $c_m = (c_1, c_2, \ldots, c_p)$.

By the global evaluation for the results of these functions *CE1*, *CE2* and *CE3*, the provision of the detailed information *I* of unknown living things contained within the given images, such as the name, the habitant, the activity period, the range of inhabitation, the life span and the period of high activity can be specified and provided.

$$f_{\mathrm{global}}(s_h, t_i, c_j) \rightarrow \{I = Op(s_h, t_i, c_j)\}$$
$$Op = (\cup, \cap)$$

2.3 Visualization function

This function is constructed to provide user a more visual observation of database and retrieved results by spatial and temporal information. Each result image and associated information *I* will be used for mapping by a method *m* on the map. Spatial information provides address or latitude/longitude information for mapping image to a place on the map, and temporal information provides date taken time of image.

$$f_{\mathrm{visualization}}(I, m) \rightarrow screen$$

3. Implementation

In this implementation, we use PostgreSQL to construct a living-things database which stores the knowledge of the target domain such as attribution information about the name, the habitat, the range of inhabitation, the life span, the period of high activity and the color-based feature of appearance based on the method described in Section 2.1. Then, we implemented the functions described in 2.2 by using polygon functions and operators of PostgreSQL, and calculating the cosine correlation among the color histogram vectors of images.

- Input: an image file with spatiotemporal context information
- Step 1: analysis of living-things information by using spatial context
- Step 2: analysis living-things information by using temporal context
- Step 3:correlation calculation of color histograms extracted from images of living-things
- Output: detailed information about the object within the image

At first, an image file of living things is input into the system. In Step 1, lat/long information is extracted from Exif and used for the specification of the habitat. In step 2, temporal information is extracted from Exif and used for the specification of the active period. In step 3, the color-based information of the image is extracted from the image and used for the correlation calculation between the input image and images in the database. When the kind of living things in the image is identified, then the related detailed information is provided.

For the correlation calculation of color histograms of images, we create color histograms by using 130 basic colors defined by Color Image Scale [4].130 basic colors are defined as 120 chromatic colors and 10 achromatic colors. In this case, to create color histograms to focus and represent the object part in the target images, we apply the method to eliminate the background from images [8][9] This method is a kind of color filtering to calculate the frequently-used colors (iif) in a certain image collection statistically, and eliminate from each image as background colors.

4. Experiments

In this section, we present the example results of several retrieval experiments to evaluate the feasibility of our identification system for living things using time, location and color information of images.

4.1 Experiment environment

The data prepared for the experiments are as follows.

We selected 22 kinds of bird as the target domain of living things database, then defined the habitat and active period of them according to an encyclopedia. We also prepared 104 sample images including 3-5pictures for each kind of 22 kinds, and extracted the color information as color histograms (Table 1).

The experiment was conducted by the following steps.

(1) We input the image files and time-specific context information as queries. The system calculates the degree of similarity between a vector of input picture as query and vectors of 104 sample images by using color information of images. After calculation, the system picks up the bird name which is above threshold of correlation values. (The threshold is set as 0.2 in this experiment)

Normalized color histograms are used as a vector to calculate the similarity in order to make superiority among images of color information equal, then cosine similarity is used as a correlation calculation method among image data.

(2) Bird information is specified by using spatiotemporal information.

(3)Bird information is specified by using color-based information within the images. We examined the feasibility to identify a living-thing object within an image by the experiments based on the following 3 queries Q1, Q2 and Q3.

(4)Global evaluation of the result of spatiotemporal context information and color-based information identifies the bird information within the image. In this experiment, the bird information in the images is identified by using "AND", and the result selected by using spatiotemporal context and color-based information is provided as a final output.

Q1: [[43.02071359427862,141.35009765625]（Sapporo, Hokkaido）] as the context to specify the habitat of living things *S*, [February] as the context to specify the active period of living things *T* and the image of [Mandarin Duck(mandarin_duck4.jpg)] as the context to specify by color-based appearance features of living things *C* are input data (Figure 2).

Q2: [(26.194876675795218,127.67211914062)（Naha, Okinawa）] as the context *S*, [November] as the context *T* and the image of [Rainbow Bee-eater(rainbow_bee_eater1.jpg)] as the context *C* are input data (Figure 4).

Q3: [(35.334172889944156,139.4879150390625)（Fujisawa, Kanagawa）] as the context *S*, [January] as the context *T* and the image of [Ruddy Kingfisher(Ruddy_kingfisher4.jpg)] as the context *C* are input data (Figure 6).

4.2 The experimental result

The experimental results are indicated in Table2, Table3, Table4 and Figure2, Figure3, Figure4, Figure 5 and Figure 6 and Figure 7.

Table 2 shows a list of the names of bird as the results of specification in Q1 by spatiotemporal contexts: a context to specify the habitat of living thing *S*=[(43.02071359427862,141.35009765625)](Sapporo, Hokkaido) and a context to specify the active period of living things *T*=[February]. Figure 2 indicates the color information as a context to specify the color feature of living things *C* of input image, mandarin_duck4.jpg. The left image of histogram in Figure 2 represents the original color information of input data, and the right image of histogram represents the color histogram created by background elimination. Figure 3 shows the results of image retrieval targeting the list of images specified by Table 2 as a ranking of top 10, according to the color distribution of input image"mandarin_duck1.jpg" as a query in Q1. (a) is the retrieval results by the original color histogram of images of Q1, and (b) is the retrieval results by using a color histogram

Table 2 Specified names of bird in the database by the place "Hokkaido (the Northernmost tip of Japan)", and the time "February"

Ruddy Kingfisher	Common Scoter
Blue-and-White Flycatcher	Long-tailed Rosefinch
Mandarin Duck	Eurasian Siskin
Narcissus Flycatcher	Black-capped Kingfisher

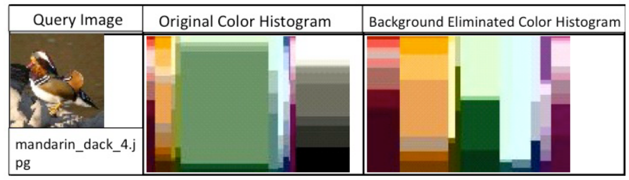

Figure 2. Color information of input image Mandarin_duck2.jp

rank	bird_name	correlation
1	Narcissus Flycatcher2	0.7245
2	Mandarin Duck2	0.72
3	Mandarin Duck1	0.7183
4	Ruddu Kingfisher1	0.6972
5	Narcissus Flycatcher4	0.6894
6	Mandarin Duck5	0.6712
7	Black-capped Kingfisher4	0.667
8	Black-capped Kingfisher5	0.6486
9	Blue-and-White Flycatcher1	0.6327
10	Common Scoter1	0.6171

(a)

rank	bird_name	correlation
1	Mandarin Duck2	0.72
2	Mandarin Duck1	0.7183
3	Ruddu Kingfisher1	0.6972
4	Narcissus Flycatcher4	0.6894
5	Mandarin Duck5	0.6712
6	Black-capped Kingfisher4	0.667
7	Black-capped Kingfisher5	0.6486
8	Blue-and-White Flycatcher1	0.6327
9	Eurasian Siskin5	0.6256
10	Common Scoter1	0.6171

(b)

Figure 3. (a) Retrieval results by the original color histogram of input image of Q1, and (b) retrieval results by using a color histogram with background elimination of Q1. The orange rows are indicating the correct result.

with background elimination of Q1. The orange rows in Figure 3 are indicating the correct result.

As shown in (b), the correct name "Mandarin Duck" is retrieved more above than just using original histograms of input image "mandarin_duck1.jpg"(2 to1, 3 to 2 and 6 to 5).

As another example of experiment of Q2, Table 3 shows a list of the names of birds as the result of specification in Q2 by spatiotemporal context: a context to specify the habitat of living thing *S*=[(26.194876675795218, 127.67211914062)](Naha,Okinawa) and a context to specify the active period of living things *T*=[November]. Figure 4 indicates the color information as a context to specify the color feature of living things *C* of input image, rainbow_bee_eater4.jpg. The left image of histogram in Figure 4 represents the original color information of input data, and the right image of histogram represents the color histogram created by background elimination.

Figure 5 shows the results of image retrieval targeting the list of images specified by Table 3 as a ranking of top 10, according to the color distribution of input image "rainbow_bee_eater1.jpg" as a query in Q2. (a) is the retrieval results by the original color histogram of images of Q2, and (b) is the retrieval results by using a color histogram with background elimination of Q2. The orange rows in

Figure 4 are indicating the correct result. As shown in (b), the correct name "rainbow_bee_eater" is retrieved less above than just using original histograms of input image"rainbow_bee_eater1.jpg"(1 to 1 and 3 to 7). Though this cannot be indicated to retrieve the name of "rainbow bee eater" by using color-based appearance features, this can retrieve the name of "rainbow bee eater" by selecting spatiotemporal information.

Finally, Table 4 shows a list of the names of birds as the result of specification in Q3 by spatiotemporal context: Context to specify the habitat of living thing *S*=[(35.38807,

Table 3 Specified names of bird in the database by the place "Okinawa (the Southernmost tip of Japan)", and the time "November"

Ruddy Kingfisher	Common Emerald Dove
Indian Peafowl	Rainbow Bee-eater
Mandarin Duck	Eurasian Siskin
Narcissus Flycatcher	Black-capped Kingfisher

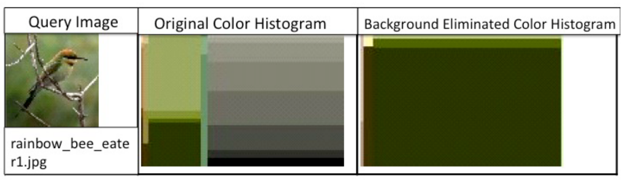

Figure 4. Color information of input image rainbow_bee_eater1.jpg

ran k	bird_name	correla tion
1	Rainbow Bee-eater2	0.999
2	Common Emerald Dove3	0.9625
3	Rainbow Bee-eater4	0.9291
4	Ioujima White-Eye2	0.9074
5	Indian Peafowl1	0.8428
6	Common Emerald Dove5	0.8395
7	Mandarin Duck2	0.8288
8	Black-capped Kingfisher5	0.8004
9	Narcissus Flycatcher4	0.7968
10	Mandarin Duck1	0.7862

(a)

ran k	bird_name	correla tion
1	Rainbow Bee-eater2	0.9977
2	Narcissus Flycatcher3	0.9695
3	Common Emerald Dove3	0.9427
4	Black-capped Kingfisher5	0.9279
5	Ruddu Kingfisher 1	0.7614
6	Ruddu Kingfisher3	0.6277
7	Rainbow Bee-eater3	0.4975
8	Common Emerald Dove2	0.4952
9	Common Emerald Dove5	0.4741
10	Black-capped Kingfisher2	0.418

(b)

Figure 5. (a) Retrieval results by the original color histogram of input image of Q1, and (b) retrieval results by using a color histogram with background elimination of Q2. The orange rows are indicating the correct result.

139.427576)](Fujisawa,Kanagawa) and context to specify the acrive period of living things *T*=[Janualy]. Figure 6 indicates the color information of input image ruddy_kingfisher5.jpg as a query in Q3, Figure 6 indicates the color information as a context to specify the color feature of living things C of input image, ruddy_kingfisher5.jpg. The left image of histogram in Figure represents the original color information of input data, and

Table 4 Specified names of bird in the database by the place "Kanagawa (the mid of Japan)" and the time "January"

Ruddy Kingfisher	Black-naped Oriole
Ioujima White-Eye	Chinese Bamboo Partridge
Japanese Grosbeak	Common Shelduck
Chinese Grey Shrike	Long-tailed Rosefinch
Blue-and-White Flycatcher	Common Pochard
Mandarin Duck	Eurasian Siskin
Common Kingfisher	Lesser Sand Plover
Green Pheasant	Black-capped Kingfisher
Narcissus Flycatcher	

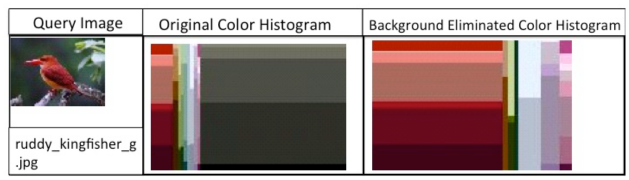

Figure 6. Color Information of Input Image ruddy_kingfisher5.jpg

rank	bird_name	correlation
1	Common Kingfisher4	0.9839
2	Narcissus Flycatcher5	0.9556
3	Mandarin Duck5	0.9171
4	Black-naped Oriole3	0.901
5	Mandarin Duck3	0.8703
6	Ruddy Kingfisher2	0.8678
7	Black-capped Kingfisher5	0.8513
8	Ioujima White-Eye3	0.8215
9	Long-tailed Rosefinch4	0.7949
10	Long-tailed Rosefinch1	0.775

(a)

rank	bird_name	correlation
1	Rudduy Kingfisher2	0.8642
2	Green Pheasant1	0.6151
3	Common Pochard1	0.5949
4	Long-tailed Rosefinch2	0.5922
5	Mandarin Duck2	0.5668
6	Common Shelduck1	0.3696
7	Ioujima White-Eye2	0.3586
8	Mandarin Duck4	0.3263
9	Ruddy Kingfisher 1	0.3033
10	Common Kingfisher4	0.2925

(b)

Figure 7. (a) Retrieval results by the original color histogram of input image of Q3, and (b) retrieval results by using a color histogram with background elimination of Q3. The orange rows are indicating the correct result.

the right image of histogram represents the color histogram created by background elimination.

Figure 7 shows the results of image retrieval targeting the list of images specified by Table 4 as a ranking of top 10, according to the color distribution of input image "rainbow_bee_eater1.jpg" as a query in Q3. (a) is the retrieval results by the original color histogram of images of Q3, and (b) is the retrieval results by using a color histogram with background elimination of Q3. The orange rows in Figure 5 are indicating the correct result. As shown in (b), the correct name "Ruddy kingfisher" is retrieved less above than just using original histograms of input image "rainbow_bee_eater1.jpg"(6 to 1 and outside the range to 9). Though this cannot be indicated to retrieve the name of "rainbow bee eater" by selecting spatiotemporal information, this can retrieve the name of "rainbow bee eater" by using color-based appearance feature.

4.3 Analysis of the experimental results

By the experimental results shown in Table 2, Table 3 and Table 4, it can be said that living things (birds) were identified by using spatiotemporal context information by analysis of input image and in bird image database to a certain extent. As shown in Figure 3, Figure 5 and Figure 7, the correct bird names were ranked in the ranking of candidates by using color-based appearance feature of image.

Figure 3, Figure 5 and Figure 7 indicate that the background elimination filter increases the degree of accuracy of identification of living things. Q1 indicates that the correct image, "Mandarin Duck" can be output at the top-rank by the result of using color-based appearance feature analysis and spatiotemporal analysis. Q2 indicates that the image of "Rainbow Bee-eater" can be retrieved by spatiotemporal analysis, though the image of "Rainbow Bee-eater" cannot always be retrieved well by only using color analysis of image. Q3 indicates that the correct answer can be retrieved in the candidate list by using color analysis, though the image of "Ruddy Kingfisher" cannot be searched just by spatiotemporal analysis.

5. Conclusion

This paper has presented a semantically related information-extraction system of living things by the global analysis of spatial, temporal and color information of images. Given a picture image of a living thing with temporal and spatial information, this system evaluates it using temporal and spatial contexts to select the scope of possible candidates of living things. This system also analyzes color information by calculating correlations between the color distribution of an input image and the corresponding sample image database. As a result, users acquire the detailed information of the living things contained within the given images such as the name, the habitant and the active period. By the experiments using a bird database, we have examined the feasibility of analytical functions to identify the object by spatiotemporal and color information of images.

As a future study, we will examine the real applicability for several kinds of living things, by a quantitative analysis using a large amount of images. We will also develop more effective input system to focus on the domain of living things.

This system enables users to expand the possibility of knowledge acquisition. By applying it to the analytic research field of the global environment, the users of this system are able to acquire not only the name, habit, active period/season of living things, but also the related valuable knowledge, such as other living things living in the same area and season, and situations related to the living things.

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