시각신경계의 개념을 이용한 도로정보의 특징추출

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요 약

정보의 다양화와 고도화에 따라 지도정보 시스템 구축에 대한 요구가 급격히 대두되고 있다. 본 논문에서는 생체 시각신경계(Optical Neural Field)의 처리과정에서 시각영역의 특징추출 기구인 수용영역 즉, RF(Receptive Field) 모델을 이용하여 지도도형의 도로정보를 추출하는 방법을 제안한다. 지형도에는 각종화상 정보가 다양하게 중첩 포함되어 있는데 대한 복잡한 정보의 분리추출과 계층화 및 데이터베이스화등 시각적으로 더욱 명백한 처리과정이 필요하다. 본 기법의 특징은 일반적인 처리과정에서 사용한 평행선 추출수법과 윤곽선 추출방법과는 달리 새로운 접근에 의한 특징추출방법으로 국소적인 처리에서 얻어진 도로정보를 대국적인 처리로 통합 추출하는 것으로서 실제 국립 지리원에서 발행한 1/25000 지도에 적용하여 가능성을 확인할 수 있었다.

Feature Extraction of Road Information by Optical Neural Field

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ABSTRACT

Maps are one of the most complicated types of drawings. Drawing recognition technology is not yet sophisticated enough for automated map reading. To automatically extract a road map directly from more complicated topographical maps, a very complicated algorithm is needed, since the image generally involves such complicated patterns as symbols, characters, residential sections, rivers, railroads, etc. This paper describes a new feature extraction method based on the human optical neural field. We apply this method to extract complete set of road segments from topographical maps. The proposed method successfully extract road segments from various areas.

1. Introduction

Recently, based on the Optical Neural Field, there are many studies[1] in the area of both psychology and physiology to solve the mechanism of information processing. In those studies, it has been reported that the optical neural field of human beings has a superior system over any current information processing systems including even the computer system. In particular, studies of pattern recognition and knowledge processing have attracted great interest and a wealth of information is now available on their processing characteristics. Some work have shown

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that those methods still have short comings in processing these fields.

With investigators in advanced countries as central figure, many active studies are on going in these fields such as GIS (Geographic Information System) and Drawing recognition system using database system to control and by referencing of maps, electronics drawings, and mechanical drawings.

The Mapping system or so called Computer mapping[2], which generates a map through a computer, is found to have established a database in order to use the information stored from the map that has many applications in the areas of transportation, administration, boom, agriculture, marketing, natural resource development, environment control, disease distribution survey, communication monitoring, and car navigation.

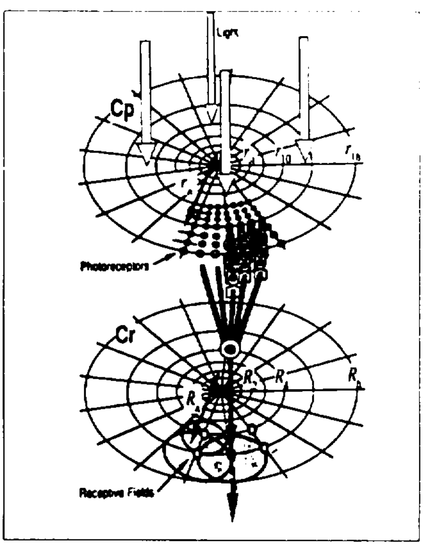
This paper presents a new algorithm which automatically extracts mapping information through the Spatial Filter model utilizing the Feature Extraction mechanism, and which has been evidenced from the Mechanism of Optical Information Processing by the human. This method differs from Outline Trace Method[3] or Parallel Vector Trace Method[4].

(Fig. 1) shows the outline for the road information extraction from various maps through main mechanism of Convolution of Neuron Input and Threshold process method using the Feature Extraction Method model [5, 6] of Optical Neural Field of retina and cerebrum Spatial Summation. This system is applied to 1/25000 scale topographical map published by the National Geographic Institute.

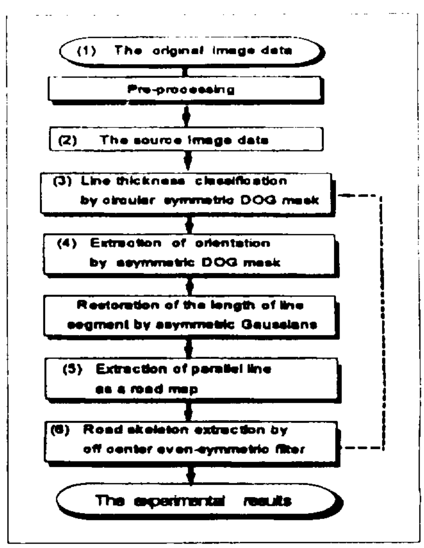
2. Feature Extraction

2.1. Synopsis of Feature Extraction method

(Fig. 2) shows the flow diagram of Road Information Extraction systems applied by a processing technique. The main objective of this work is to extract the Road skeleton ob-



(Fig. 1) Signal summation over a retina ganglion cell receptive field



(Fig. 2) The flow of extraction system

tained from the topographical map that contains road feature. Each process shown in (Fig. 2) represents several steps of Spatial Filtering which contains Retinal Ganglion Cell Receptive Field with each selectivity of orientation. The experimental results of Level(1)-(6) are shown in (Fig. 8).

2.2. Road Information Extraction by Spatial Filtering

As mentioned before, this processing method is used to extract relatively noiseless road information. The feature of road shape is shown by two parallel lines segments on the maps. The width of the segments is relatively clear and is drawn by different symbols on the map.

2.2.1 Classification by segment.

There are several symbols on the map that have different meaning. In case of recognizing the map through human optical mechanism, the meaning of each symbols is understood by the extraction of line feature on the map.

For examples, in the case of road and contour line whose line width and curve feature are alike, the line thickness is used to identify contour lines from roads.

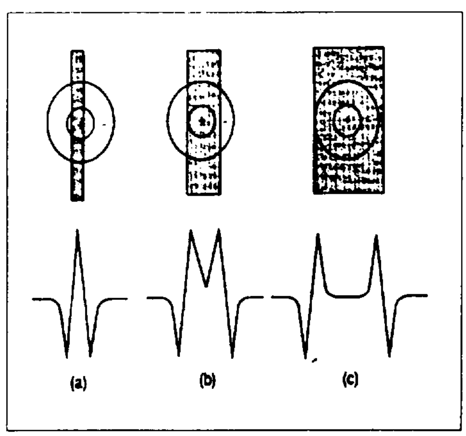
It is well known that there are six classification of line width. (Based on Scale factor 1 : 25,000 no.1 : 0.05, no.2 : 0.075, no.3 : 0.10, no.4 : 0.2, no.5 : 0.30, no.6 : 0.4mm)[7]. This classification can be performed by spatial filtering. A set of two dimensional DOG(Difference Of two Gaussians) functions is used for the spatial filters.

The function is defined by

$$DOG(\sigma_e, \sigma_i, \gamma) = \frac{1}{2\pi\sigma_e^2} \cdot e^{-r^2/2\sigma_e^2} - \frac{1}{2\pi\sigma_i^2} \cdot e^{-r^2/2\sigma_i^2} \quad (1)$$

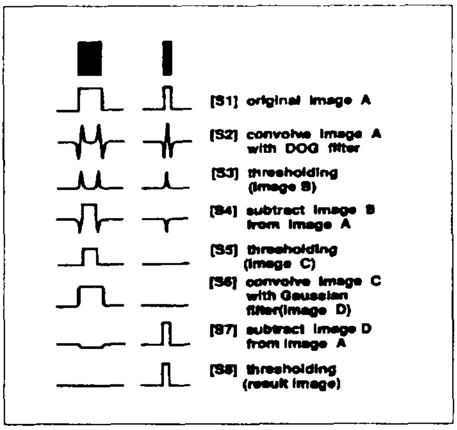
where r represents distance from the origin, σ_e represents the space constant of excitatory region and σ_i represents that of inhibitory region. This filter corresponds to an on-center and off-surround receptive field found in mammal retinal[8, 9]. The ratio of space constants σ_e / σ_i is set to 1.6 for all filters. This ratio gives a close approximation to the ideal Laplacian operator[9]. As shown in (Fig. 3) and (Fig. 4), we get the filtered output profile of input image and mask. Output is changed according to the line thickness.

For the thin line, two assistant peaks with one principal one(Fig. 3(a)), but in the case of the thick line, two assistant peaks are shown with two principal peaks(Fig. 3(b)). And for the very thick line, there is portion of 0 between two principal peaks(Fig. 3(c)). Also this nature depends on standard deviation of DOG function.



(Fig. 3) Relationship between line thickness and filtered output profile

Even in drawing of the same line segments when standard deviation is small, it becomes like (c), and when it has larger value it results as (a). In other words, the relation between width of DOG standard deviation and the size of road shape (line segment) determines the resultant output pattern. By this feature, we can classify the line segment using DOG function with a different standard deviation.



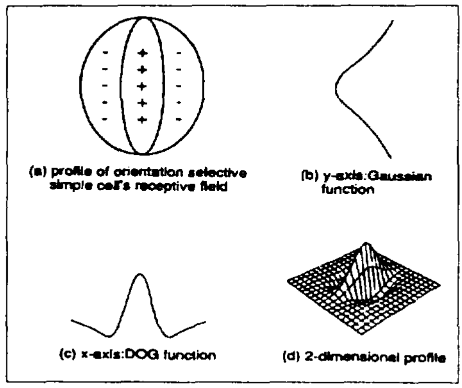
(Fig. 4) Conception according to process of line thickness classification

2.2.2 Extraction of Straight line.

The road shape on the map is composed of two parallel lines or soft curved lines with the same width. There are no symbols between two parallel lines describing roads. But it would be some situations where contour lines cut through the roads. Therefore we can extract the road pattern by the detecting method of two mutually parallel line patterns which described in Section 2.1 segment classification.

(1) Straight line extraction of specific orientation.

The straight lines of specific orientation are detected by filtering out on the image data classified by both of line thickness and handling of threshold value θ from asymmetric detection filter in (Fig. 5).



(Fig. 5) Two-dimensional profile of and filtered output profile asymmetric DOG Filter

This filter approximates Cell Receptive Field of Cerebral optic boundary[8]. The sensitivity distribution of Receptive Field in direction of optimum bearing is formed by one dimensional Gaussian function and Receptive Field Sensitivity distribution for vertical direction is very similar to DOG function. For the mathematical expressions of 8 directional selective asymmetric detection filter $DOG\phi(x,y)$ are given as follow;

$$DOG(x,y) = \left(e^{-x^2/2\sigma_e^2} - \frac{\sigma_e}{\sigma_i} \cdot e^{-x^2/2\sigma_i^2}\right) \cdot e^{-y^2/2\sigma_{en}^2} \quad (2)$$

$$DOG_\phi(x,y) = D(x\cos\phi - y\sin\phi,\ x\sin\phi + y\cos\phi) \quad (3)$$

$$\phi = \frac{\pi}{8} \times d\ [rad],\quad d = 0, 1, \cdots, 7 \quad (4)$$

where σen is a parameter defined for the length of optimal direction. σe and σi are parameters for the width of excitatory region and inhibitory region respectively. They are joined perpendicularly from each directions and the rate should be $\sigma i/\sigma e = 1.6$ [9, 10, 11, 12]. We prepare the angle of 8 directional filter by $\pi/8$ and Asymmetric detection filter from 0 to π.

(2) Blurring of extracted straight line.

By working on resultant of (1) continuity of straight line, the partially damaged line segment can be reconstructed with Filtering process of Gaussian Filter and handling of threshold value θ . On this process, line segments disjointed due to the classification of line width can be somewhat revived and through suitable critical value assignment, noise could be removed, and next step of extraction of parallel lines could be performed efficiently. The definitions of Gaussian filter for 8 different directional orientation, which each of them has selective straight line Blurring process Eq. are as follows;

$$Gauss(x, y) = e^{-x^2/2\sigma_i^2} \cdot e^{-y^2/2\sigma_m^2} \tag{5}$$

$$Gauss_\phi(x, y) = G(x\cos\phi - y\sin\phi,\ x\sin\phi + y\cos\phi) \tag{6}$$

where σ_{in} is the length of optimal orientation, σ_s is a parameter defining perpendicular receptive field. And ψ is derived from Eq.(4).

2.2.3 Extraction of parallel line(Extraction of straight line pair with specific distance)

By the processes of step (1) and (2) in Section 2.2.3 the road extracted is straight parallel line pair. Let 'w' be the road interval, and let $p(xi)$be a binary function which takes 1 when the pixel xiblack and takes zero when it is white. Let $P(xi)$ be a binary logical function which takes 1 when xiconstitutes a road and takes zero when it is not. This operation can easily be mapped to a neural network. The 'w' can be extracted by following logical operation;

$$P(x_i) = p(x_i)\ AND\ [\ \{p(x_{i-w}) AND \neg p(x_{i-w/2})\}\ XOR \{p(x_{i+w}) AND \neg p(x_{i+w/2})\}] \tag{7}$$

The width 'w' of parallel line is calculated from right angle to optimum orientation for ψ of filter DOGϕ and Gaussϕ. nspection points for both '$x_{i-w/2}$' and '$x_{i-w/2}$' are pixel taken from the original image data, and are used to determine the existence of road pattern between two parallel lines. where $-p(x_i)$ represents negation of $p(x_i)$. When more than two multiple parallel lines with the same width exists, it would be eliminated by the process of expression in Eq.(7). First process leaves only out-most two lines and in second process the rest of the lines are also removed.

The above mentioned process of straight line extraction and parallel line extraction are performed from 0 until π for eight different directions for $\pi/8$ each time. At each directional process time, by logical operation of input image and by removing a part of which is not original image, it could be extracted the roads substantially close to the original image.

But extracted road shapes are still not complete and contain noise. Therefore there is a need to join the disconnected line segment and remove of noise by using the threshold value θ which was described in step (2) of Section 2.2.2. We can remove the noise and repair the disconnected line segment by repeat τ times for the step 2.1 (1).

(2) and step 2.3 by changing θ. For the first repeating process, the high threshold value θ_{2h} is used to remove the noise. And also repaired by applying low threshold value θ_{2L}.

2.2.4 Extraction of road skeleton for parallel lines

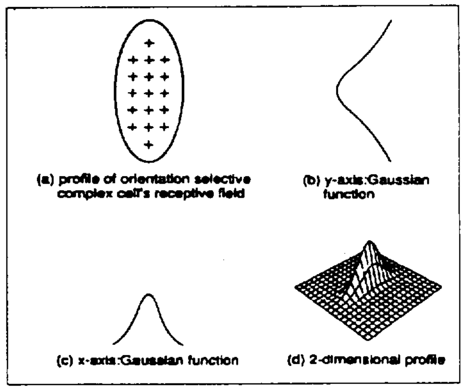
In this method, to be able to restore the un-extracted part, it is easier to extend a single line rather than two parallel lines. Therefore we will use road skeleton instead of parallel lines. In composite of neuron cerebral optic boundary reception field of simple type cell, the central restraint boundary narrowed out to two sides of excitation boundaries. The long side direction of excitation boundary follows optimum orientation. Therefore in this study we apply skeleton detection right symmetrical simple type cell like feature (which has orientation selection that OFF centered) on the parallel lines. Sensitivity distribution of receptive field, becomes closer by combining two different Gaussian functions that have different stardard deviation of sensitivity distribution of central restraint boundary and excitation boundary of both sides. The extraction of the skeleton is performed by a set of even symmetric filters with eight preferred orientations. $S\phi(x,y)$ is given as follow;

$$G(\sigma, x) = e^{-x^2/2\sigma^2} \quad (8)$$

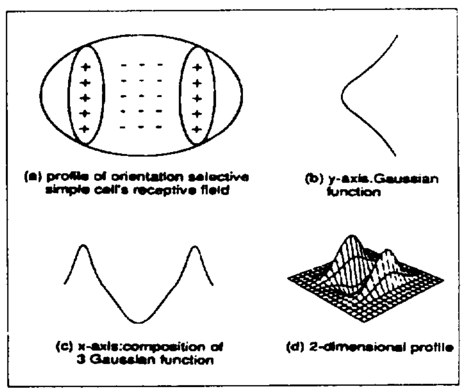
$$S(x, y) = (G(\sigma_e\ ,\ x-l) - G(\sigma_i\ ,\ x) + G(\sigma_e\ ,\ x+l)) \cdot G(\sigma_{en}\ ,\ y) \quad (9)$$

$$S_\phi(x,\ y) = S(x\cos\phi - y\sin\phi,\ x\sin\phi + y\cos\phi) \quad (10)$$

σ_{en} is the parameter defines the length of optimum orientation. σ_1 and σ_2 are parameters representing the width of excitation boundary and restraint boundary and they are joined perpendicularly from each direction. γ is the distance from the center of filter to the primary peak. And ϕ is derived from Eq.(4). The proposed even symmetrical skeleton extraction filter profile is shown in (Fig. 7). Road skeleton is extracted by filtering out from 8 directional filter $S\phi$ against the resultant of parallel lines extraction and by handling of threshold value.



(Fig. 6) Two-dimensional profile of Gauss



(Fig. 7) Even-symmetric skeleton filter extraction filter

3. Experimental result and Consideration.

The map used to verify the effectiveness of this process method is the topographical map issued by the Republic of Korea National Geographic Institute, and its scale factor is 1 : 25,000. (Fig. 8(a)) is an example of the original image. First, the map is read by image scanner which has resolution of 400 DPI multi-value image and converted to two value system (Black pixel '1', White pixel '0'). The size of picture image is 256 x 256 pixel size. The repetition numbers γ used with threshold value θ and in the experiment were the result of the experimental assignment. Following shows the experiment result by processing order.

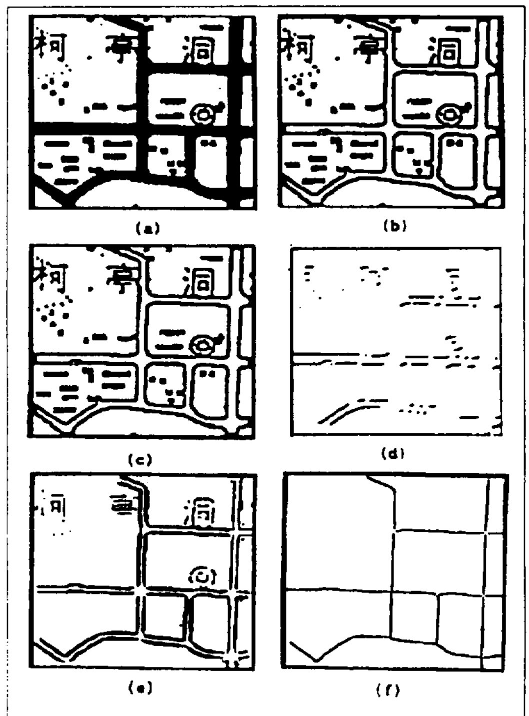
3.1 Line width classification

(Fig. 8(c)) is the result of line width classification on Input image of (Fig. 8(b)). The thin line right here which is less than 3 image-element and symbols of houses which has bigger than 13 pixel will be eliminated. In this picture verify only the roads that have line-width 3 ~ 13 pixel and character size printed with 0.2mm and symbols were extracted. In this case, the change is hardly noticeable since only limited part of the input image is shown. DOG and Gauss filter will form matrix according to the size of diameter of pixel(3 , 13). The values of DOG function standard deviation σ_i and σ_e can be obtained from the radius r of the filter $\sigma_i = r/3$, $\sigma_e = \sigma_i /1.6$ and Gauss function standard deviation value $\sigma = r/3$.

3.2 Extraction of parallel lines

(Fig. 8(e)) is the parallel extraction result of operations of threshold value and repetition process (repeat number $\gamma = 5$) on the line-width classification result 8(c). And the extracted road which road-width is about 10 pixels is shown. Straight line detection filter's size is 19 x 19 pixels. In DOG function, two values of standard deviation are $\sigma_i = 11/6$, $\sigma_e = \sigma_i /1.6$. The pixel of primary peak region is 3 and it will fit into the center of line-width. The value of standard deviation of Gauss function σ_{en} is 15/6. Total value of integral of Filter is 0 and integral value of primary peak region is about 10.

In straight line blurring Gauss filter, the width and length is 19 x 19 pixels and two



(a) Original image
(b) Source image(prep-rocessing)
(c) Extraction of line segments according to their widths
(d) Extraction of line segments according to their orientation(Direction = 4th)
(e) Extraction of parallel line segments
(f) Extraction road skeletons

(Fig. 8) Experimental results urban district area

Gaussian function's standard deviations are $\sigma_x = 5/6$ and $\sigma_{cn} = 15/$. The excitation region width of center of the filter is 5 pixels and the integral value of whole filter is about 10.

3.3 Skeleton Extraction from Parallel line.

(Fig. 8(f)) is skeleton road extracted from parallel road of (Fig. 8(e)). While each width of parallel lines in (Fig. 8(e)) is not even, the uniform road skeleton is being extracted. If the internal edge of the parallel lines are even, due to the effect on restraint area of skeleton extraction filter center, the skeleton lines become thin. In the case of the internal edge is straight according to the parallel lines (Fig. 8(e)), uniform width skeleton is extracted. Like in the picture, there is no noise but the disconnections are shown at the bottom part.

The skeleton extraction filter's distance between primary peaks is about 10 pixels for the width of the road. And standard deviations of Gaussian function are given as $\sigma_1 = 11/6$, $\sigma_2 = 2\sigma_1$ and $\sigma_{cn} = 15/6$. The integral value of whole filter is about 0 and the integral value of primary peak region is about 30. From the experimental results show, the quality road extraction from the various map pattern is possible and the effectiveness could be verified.

4. Conclusion

A new approach for the extraction of features from images is proposed. An attempt is made to extract road network from the map by applying the method on the real topography and the effectiveness is confirmed. The theme of this study is that feature extraction of targeted road information should be done relatively easily without noise unlike spatial filtering process. But there are still unresolved problems such as construction of the filter to respond to the changes of various road width, suitable critical value handling, complete road diagram, connection of disjointed roads where the parallel lines cut through and repair of the roads severed by the characters and symbols. At the present, the study is further in progress to deal these issues.

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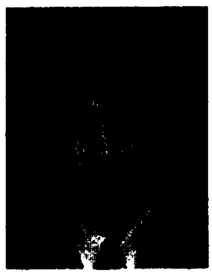

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