HOW MAP DESIGNERS CAN REPRESENT THEIR IDEAS IN THEMATIC MAPS: EFFECTIVE USER INTERFACES FOR THEMATIC MAP DESIGN

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ABSTRACT

Problem analysis in designing thematic maps and user interfaces which assist map designers in incorporating their ideas into maps are presented.

Problems in designing choropleth maps are analyzed from the map designers point of view. A graphical user interface, called "Histogram Interface" is implemented as a countermeasure for problems in designing choropleth maps. The user interface can assist the map designers in representing their ideas and achieving the desired resulting maps through the designing process. The user interface operations, which correspond to the map designer's ideas, are explained. The user interface effectiveness is confirmed by resulting map examples and the corresponding graphical patterns of the interface.

A concept is proposed concerning the importance in any computer graphics field, which the designers should consider in designing how to incorporate their ideas into pictures.

KEYWORDS: thematic map, user interface, computer mapping, human factor

1.Introduction

Computer mapping systems (e.g. Dutton,1983; Tsurutani,1980) are effectively used, especially in the regional planning field. Planners who are concerned in regional planning in local governments often use thematic maps in order to explain some ideas. For example, population density maps, housing maps and geological features maps are often used for explaining the regional planning. Planners may also use the thematic maps when they intend to emphasize their ideas to map viewers, such as mayors, members of a regional planning committee and citizens. The important effect of using thematic maps is that the maps can effectively convey the planners' intentions to map viewers.

However, there are cases wherein the thematic maps do not always agree with actual circumstances or planner's intention. For example, based on experience in designing choropleth maps (Miyashita,1984), which showed a relative comparison of earthquake danger, there was a case where two neighboring areas, which were considered as being identically in danger under normal circumstances, were classified into different groups. If planners design thematic maps without considering the representation of their ideas, the resulting maps will not always be appropriate to convey their intentions. An inappropriate map is not able to effectively convey designers' intentions to the map viewers. It can also easily cause misunderstanding.

With the advent of computer mapping, thematic maps are becoming used actively. As many people, such as planners in local governments, have been using thematic maps, undesirable problems are increasing. Therefore, problems in designing these kinds of maps must be carefully considered.

In this paper, as a case study on idea representation, the problems and developed Histogram Interface effectiveness for designing choropleth maps are described, including the results obtained from an actual experiment. The concept regarding how computer graphics designers can incorporate their ideas into resulting pictures is also discussed.

2.Problems and Analysis

Choropleth maps are used for regional situation investigation, information presentation activities and market surveys. Figure 1 shows a choropleth map example which shows Tokyo population distribution. It is easily understood that the population increases closer to the outlying areas.

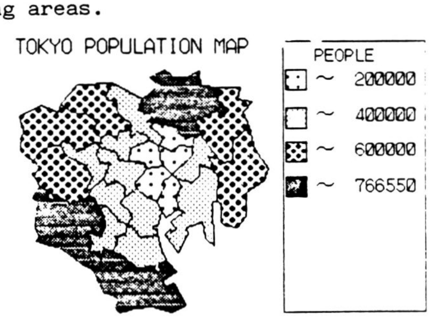


Figure 1. Choropleth map example.

In recent years, as these kinds of maps are designed actively in computer systems, it becomes important to pay attention to the problems in designing choropleth maps. For example, though a planner designed a choropleth map according to his intention, there were cases where the resulting map cannot reflect his ideas. By analyzing this sort of problems, in regard to representation of map designers' ideas and/or intentions, problems are categorized as follows:

(1) Excessively detailed or too all-inclusive information.
(2) Disagreement relating to differences in statistical values for specific areas.
(3) Unsuitable color or pattern impression.

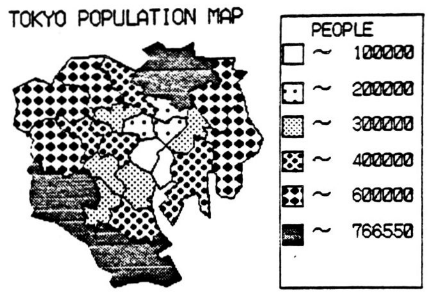
First problem and analysis.

Excessively detailed or too all-inclusive information, compared with the planner's intention, is often expressed in a choropleth map. Figure 2A shows a choropleth map, which is an example of the excessively detailed information problem. A planner classified the statistical value range into six groups, in order to express the rough population distribution tendencies. However, the impression presented by the map has become too complicated for the viewers to readily understand the rough tendencies. On the contrary, if a designer represents the data too all-inclusively, the map viewers cannot understand much of the information presumed to be supplied by the designed choropleth map.
Classifying data into too many classes makes the information complicated. Also, classifying data into too few classes obscures the information. The number of classes influences the understanding of the regional tendencies portrayed in the entire map.

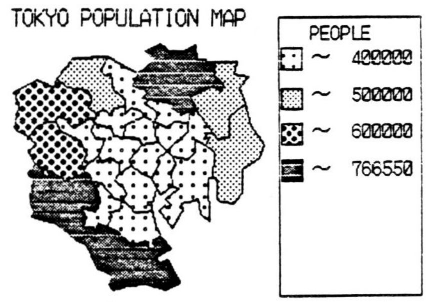
Second problem and analysis.

The statistical distribution represented in painting patterns on the map does not often agree with the planner's intentions. Utilization of such maps is attended by the danger that the information which the planner intends to present therein could be misunderstood. Figure 2B shows a choropleth map which is an example of the second problem. The lowest class statistical value range is too wide for the viewers to readily understand the population differences between areas. If a planner intends to express population differences between areas, the impression presented by the map does not agree with the planner's intention.

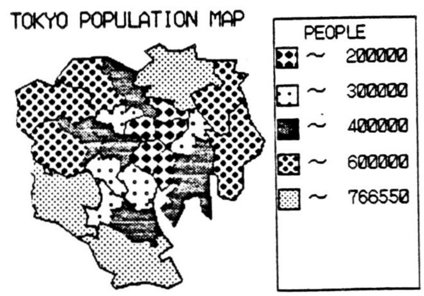
Inappropriate classification causes cases wherein elements, which should be classified into the same group, are classified into different groups. It also causes the opposite cases concerning elements which should be classified into different groups. According to the statistical value classifications, which are determined by the lower and upper boundaries, the number of areas belonging to each class gives a map a unique impression. Therefore, the lower and upper boundaries are important factors.



A. First problem choropleth map example. Map includes excessively detailed information.



B. Second problem choropleth map example. The difference in statistical value for areas expressed in the map does not agree with planner's intention.



C. Third problem choropleth map example. Pattern assigned to each class causes difficulty in understanding the statistical distribution.

Figure 2. Choropleth map examples which show the choropleth map designing problems.

Third problem and analysis.

Figure 2C shows a choropleth map example of an unsuitable pattern impression problem. Though a planner intends to express the population distribution, the pattern assigned to each class causes difficulty in understanding where dense and sparse population areas are. In population maps, in general, an impressive pattern should be assigned to the classes whose statistical value representations are denser than other classes if the planner intends to express the quantitative relations.

Patterns can be ranked according to their own impressions. As several patterns are assigned according to the statistical data represented in a choropleth map, the mutual relationship between individual patterns must be considered (e.g. Cleveland,1983; Vertin,1982). If it is necessary to emphasize a specific feature in a set of statistical data, a stronger impressive pattern should be assigned to the classes to be highlighted.

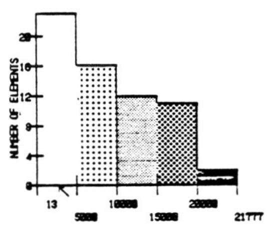
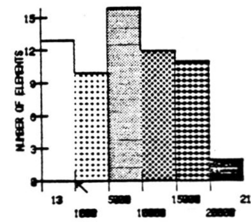
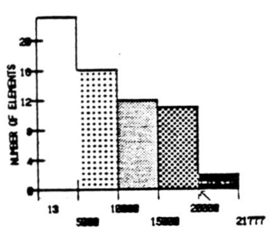
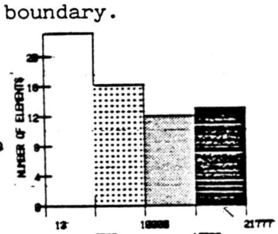
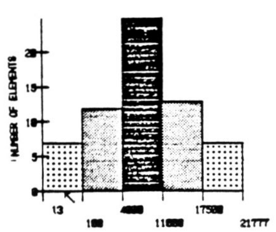
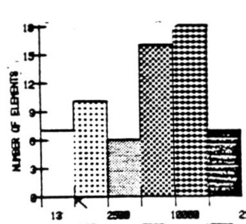
Unsuitable pattern assignment causes difficulty in understanding the information represented in the map, even if the other important designing factors were appropriately satisfied.

The following three important factors in designing a choropleth map are extracted from the problems and analysis described above.

(1) Number of classes.
(2) Lower and upper boundaries for classes.
(3) Pattern impression order.

Planners must satisfactorily recognize the factors during the map designing process. If planners designed the maps in consideration of these factors during the designing process, maps could be designed sophisticatedly. However, if planners do not recognize the factors, they may fail to effectively represent their ideas.

Table 1. Intentions and corresponding Histogram Interface operations.

Intentions	Operations	Histograms	
Emphasizing statistical differences between areas and characteristics for specific areas.	Adding Adding means to increase the number of classes. Designers set a boundary by moving a cursor which indicates the statistical value corresponding to a new boundary. B indicates a reworked A.	 A. Initial histogram.	 B. Histogram after adding operation. Statistical value 1000 is a new boundary.
Obscuring the statistical differences between areas and emphasizing the rough statistical distribution tendencies.	Deleting Deleting means to decreasing the number of classes. Designers delete a boundary by moving a cursor. D indicates a reworked C.	 C. Initial histogram.	 D. Histogram after deleting operation. Statistical value 20000 has been deleted.
Considering the pattern impression and what is to be expressed.	A pattern selected from a palette is assigned to a corresponding class in a histogram, as shown in E and F. In E, patterns are assigned to show statistical value variation from average value. In F, impressive patterns are assigned to higher classes.	 F. Pattern assignment example.	 E. Pattern assignment example.

3.Histogram Interface

Taking these factors into consideration, the Histogram Interface allows the designers to classify the statistical data according to their intentions.

Histogram Interface functions are:

(1) Indicating the statistical distribution tendencies to planners.

(2) Allowing designers to control, according to the planners' intention, the statistical distribution in the form of a histogram.

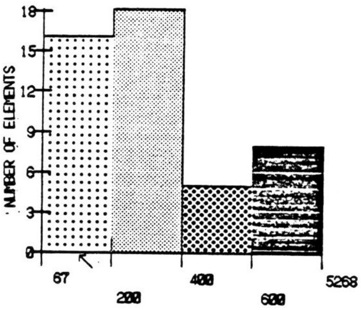
(3) Providing the tool for pattern assignment.

The first function enables the designers to change the number of classes. By this function, designers can easily recognize the statistical distribution. Map impression can be controlled according to the designers' intentions, expressing detailed differences or rough tendencies. The function also provides the maximum, minimum and average value to the designers, so that they can set up the appropriate number of classes. This function reflects the factor for the number of classes.

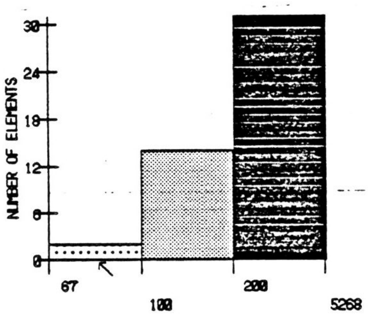
The second function enables adding and deleting the boundaries and showing the number of elements in each class. The designer can clearly indicate a change in the number of elements in each class by moving the histogram boundaries. Designers can estimate the resulting maps, with reference to the statistical distribution shown in a histogram pattern. This function reflects the factor for the lower and upper boundaries.

The third function enables the designers to assign a pattern to each class and to confirm the pattern contrast. Designers can assign appropriate patterns, according to their intentions and the statistical contents which they are representing. This function reflects the factor for pattern impression order.

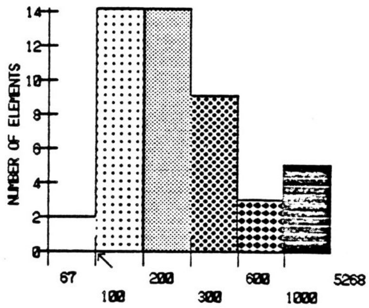
Some intentions and corresponding operations for the Histogram Interface are shown in Table 1. Typical designer intentions, emphasizing and obscuring, are indicated in this table.



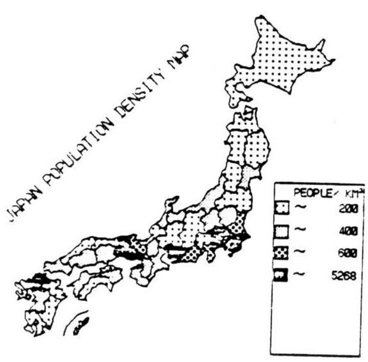
A.Histogram. Dense population areas are emphasized.



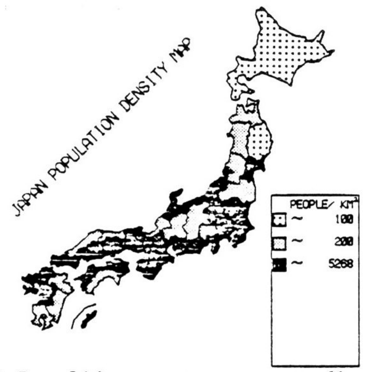
C.Histogram. Sparse population areas are emphasized.



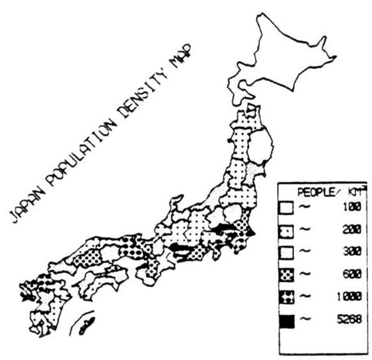
E.Histogram. Population density differences are emphasized.



B.Resulting map corresponding to histogram A.



D.Resulting map corresponding to histogram C.



F.Resulting map corresponding to histogram E.

Figure 3.Histogram patterns and resulting maps corresponding to ideas for experiment 1.

4. Experiment

Experiment 1.

In order to confirm the Histogram Interface effectiveness, the Histogram Interface is applied to Japan population density map design. The following designers' intentions are assumed in this experiment.

(1) Emphasize dense population areas.
(2) Emphasize sparse population areas.
(3) Emphasize population density differences between areas.

In this experiment, maps were designed in consideration with expressing the statistical distribution tendencies in addition to the designer's above purposes.

Histogram patterns and resulting maps are summarized in Fig. 3.

Intention (1), which involves emphasizing dense population areas, is performed as shown in histogram 3A and resulting map 3B. The higher population areas, such as Tokyo and Osaka, are well recognized from the characteristics in resulting map 3B.

In histogram 3C, there are a few areas in the lowest population density class. In corresponding choropleth map 3D, two light colored areas are emphasized as extremely sparse population areas.

In histogram 3E and resulting map 3F, the rough population distribution tendencies presented throughout the map are not easily recognized, but the population density differences between areas can be well recognized.

Experiment 2.

In order to show another Histogram Interface use, the Histogram Interface is applied to a practical regional planning problem. It is assumed that Tokyo regional area planner designs a population density choropleth map for regional development to represent the suitable areas to develop. It is also assumed that the planner well recognizes tendencies that the eastern areas in the Tokyo region have excessively dense populations and the population density becomes sparser closer to the western areas.

The histogram patterns and resulting maps are summarized in Fig. 4.

Figures, from 4A to 4D, represent histograms and maps which are obtained by the following general classifying methods A and B.

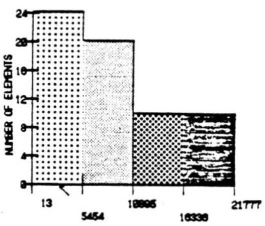
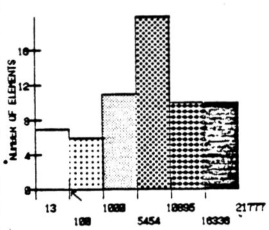
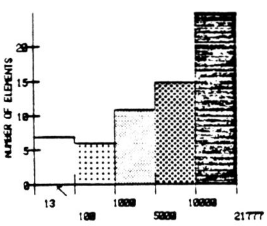
A. Set up the statistical boundaries so that the range for each class would be identical.
B. Set up the statistical boundaries so that the number of elements in each class would be identical.

The Tokyo regional area population distribution can be understood from these maps. However, it is difficult to understand the details about western areas from the maps, in which all of the western areas are painted in the same pattern.

Figures 4E and 4F are a histogram and a resulting map obtained according to the planner's idea. Table 2 shows the processes and corresponding histograms to obtain the relevant map. The intermediate class in Table 2C shows the object areas for development.

The designer can classify the statistical data by using the Histogram Interface in order to express his idea on a map, as shown in the examples. As the user interface function graphically indicates important factors, designers can easily recognize and handle the factors according to their ideas. The Histogram Interface is considered as an effective tool to incorporate the intentions into maps in designing thematic maps.

Table 2. Designing process and histogram patterns for experiment 2.

Design process	Histograms
Intention: Understand the rough statistical distribution tendencies. Operation: Divide the statistical data into four groups. Impression: It is difficult to understand the characteristics of the areas in the lowest class.	 A. Initial histogram. ↓
Intention: Classify the areas in the lowest class into several classes so that the characteristics in the western area can be expressed. Operation: Select 100 and 1000 people per square kilometer as the boundaries. Impression: The areas belong to the fourth class are considered as the object for development. The higher classes are classified too detailed though the areas in the classes are not objects for development.	 B. Intermediate histogram example. ↓
Intention: Emphasize that the most crowded areas are spreading over a wide area. Operation: Delete two higher boundaries and select 10000 people per square kilometer as an appropriate boundary.	 C. Final histogram.

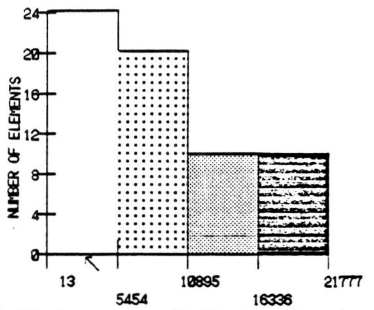
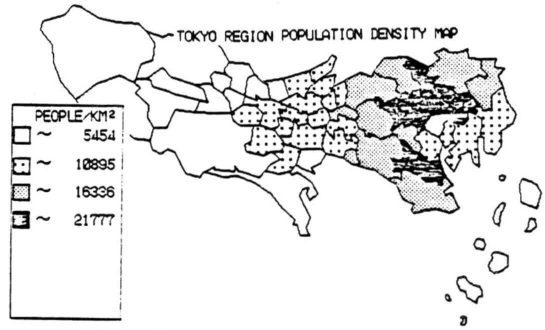
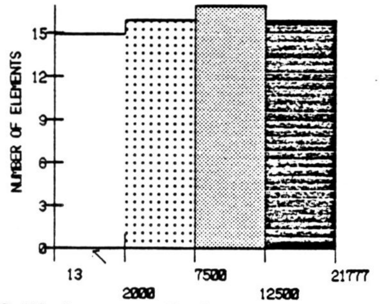
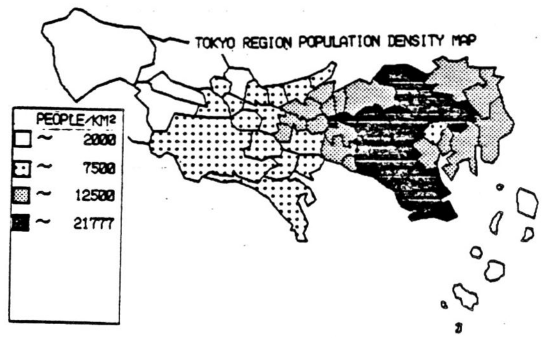
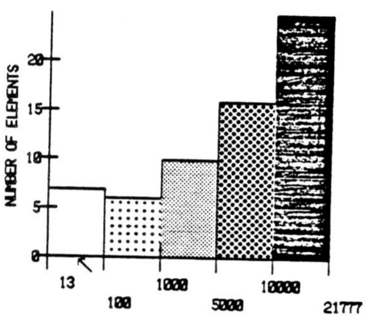
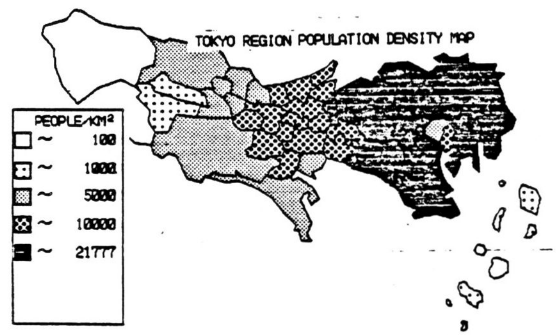
Intentions	Histogram patterns	Resulting maps
Set up the boundaries so that the range for each class would be identical.	 A.Histogram. Individual statistical value ranges are identical.	 B.Resulting map corresponding to histogram A.
Set up the boundaries so that the number of elements in each class would be identical.	 C.Histogram. Number of elements in each class is nearly identical.	 D.Resulting map corresponding to histogram C.
Show the suitable areas for regional development.	 E.Histogram obtained according to planner's intention.	 F.Resulting map corresponding to histogram E.

Figure 4. Intentions, histogram and resulting maps for experiment

5.Discussion

Histogram Interface limit.

Idea representation on choropleth maps can be effectively carried out by using the Histogram Interface concerning one kind of statistical data. However, more detailed consideration is needed for designing multiple kinds of maps, which have statistical relationships each other.

For example, how can the population density change in time dimension be represented? Figures 5A, 5B and 5C represent 1960, 1970 and 1980 population density maps for the Tokyo regional area, respectively. No changes can be observed from patterns on these maps. It seems as if there were no changes in the past twenty years. The reason why the change cannot be expressed is that the designer has designed a choropleth map without paying attention to the statistical relationships between resulting maps.

From another point of view, the Histogram Interface limit is considered. In actuality, the Histogram Interface allows designers to effectively represent their ideas into maps for any kind of statistical data and geographical data. However, in order to perform better classification using the Histogram Interface, it is desirable that designers should know the relations between statistical distribution and corresponding geographical circumstances. For example, experimental results described in this paper show that the designer's knowledge for Tokyo population distribution was very useful in designing a better map. As the Histogram Interface alone does not possess a function which directly shows the relations between statistical data and geographical circumstances, designers might not create appropriate maps unless they know about the regional circumstances.

With reference to the example, the Histogram Interface has a limit for using. Therefore the designer needs to consider how to use the Histogram Interface so that the resulting map can represent what he intends to express therein during the designing process.

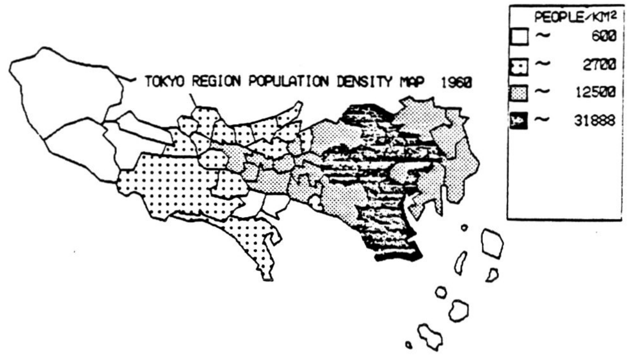
Map drawing selection.

In the choropleth map case study, a method to express designer intentions on choropleth maps was presented. Another important issue, in regard to expressing designers' ideas on maps, is a pertinent selection of a relevant kind of thematic map. For example, pie-charts, shown in Fig. 6, are often used in representing statistical data on a map. The size of a pie-chart corresponds to the total amount of statistical values. In this case, map viewers cannot easily understand the differences between statistical values A and B. If the planner intends to indicate a statistical difference between the elements, using pie-charts is not appropriate. Choosing an appropriate map drawing method is also one of the important factors with reference to this example.

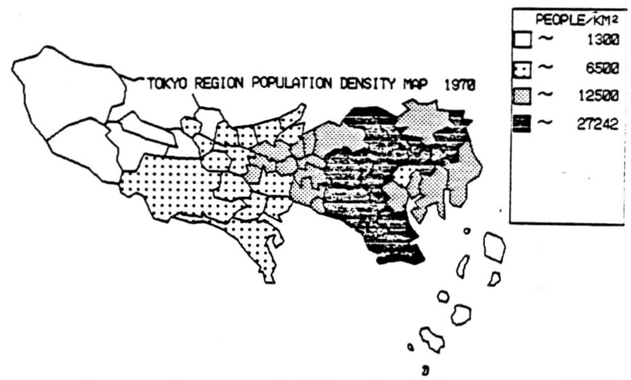
Extension to other computer graphics fields.

At present, user interfaces design has been centering around a concept which is represented by a term, "user friendliness". However, a user interface, based on user friendliness alone, does not always sufficiently assist designers in expressing their ideas.

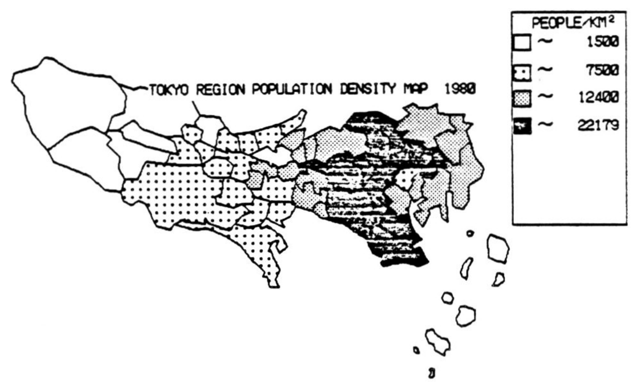
In computer graphics fields, designers have their own intentions, which must be emphasized according to the objective for designing a picture. They are emphasizing, extending, or obscuring and so on. For example, in displaying the result of simulation experiments, the precise movement derived from the experiment result is not always appropriate. The movement is often too fast or too slow for the viewers to understand. This is a case where the speed for representing



A.Tokyo region population density map on 1960.



B.Tokyo region population density map on 1970.



C.Tokyo region population density map on 1980.

Figure 5. Inappropriate map examples to show the population change in the past twenty years.

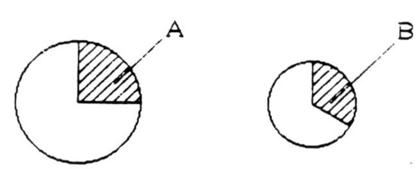


Figure 6. Pie-charts used in thematic maps.

the movement of things is an important factor and it must be changed to be readily understood by viewers. The important factors to express designers' ideas must be considered during the designing process, in the same manner as when designing thematic maps.

The concept, which the designers should consider in determining how they can incorporate their ideas into pictures, is very important for any computer graphics field, as well as the case of thematic maps design.

Subjects for future study.

Several subjects are considered for future study. An important one among them is the pattern impression problem to be projected such as color or hatched pattern. At present, the designers select arbitrary patterns according to their own sense. However, pattern meanings need to be shown to the designers during the designing process. The impression projected by different patterns, such as heavy, light, strong and weak, must be corresponded to the statistical meanings.

6.Conclusion

As a case study for representation of designers' ideas into resulting pictures, a choropleth map designing process is described. The problems in designing choropleth maps are (1) excessively detailed or too all-inclusive information, (2) disagreement relating to differences in statistical values for specific areas, and (3) unsuitable color or pattern impression.

The Histogram Interface was developed to cope with the problems. It enables to control three important factors (1) number of classes, (2) lower and upper boundaries for classes, and (3) pattern impression order.

By using the interface, designers' ideas are effectively expressed on the maps. However, some limits can be considered for using it. Detailed consideration in multiple maps designing and assistance of knowledge concerning relations between statistical distribution and regional circumstances are necessary. Map drawing selection is another important factor in designing thematic maps.

In any other field of computer graphics, the concept, which the designers should consider in determining how they can incorporate their ideas into pictures, is very important.

Acknowledgment

The authors would like to express appreciation for continuous encouragement from Dr. Masaru. Naniwada. They are particularly grateful to Mr. Yoshichika. Koyama of NEC Scientific Information System Development, Ltd. and NEC Software, Ltd. members involved in this project, for their assistance and cooperation in this collaboration.

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