Extraction and Recreation of Design Changes Using a Neural Network

Hiroaki FUJITA*, Hidekazu TSUJIAI**, Sadahiko NAGAE***

Graduate School of Biology-Oriented Science and Technology, Kinki University
930 Nishimitani Uchita-cho Naga-gun Wakayama 649-6493 JAPAN,
* *cfako400@jtw.zaq.ne.jp*
** *tsujiai@info.waka.kindai.ac.jp*
*** *nagae@info.waka.kindai.ac.jp*

Abstract: Generally speaking, how things appear depends on our viewpoint and how we look at them. In works of art and products, exact forms may be intentionally distorted by the creator's subjectivity or due to the purpose of the product. This expressive technique is called deformation design. In works of art, deformation designs which reflect the individuality of the creator are very popular. However, it is difficult for a person without design knowledge to imitate such design. In this research, we investigated how to extract and recreate design changes. This was done by extracting the design changes produced by changing scale, using a miniature toy called "CHORO Q". Deformation design was used in the miniaturization of CHORO-Ｑ. So the design changed dramatically from that of an actual car. In our research, we first defined the design features to be preserved. Then we used a neural network to learn and recreate design changes. Using this technique, we taught a neural network the design change patterns for multiple cars to make it capable of adapting to new models. First, we built a neural network for extracting design features from two corresponding pictures (one of CHORO-Q and one of an actual car). We also created a design extraction algorithm suitable for neural network learning. This algorithm defines the design features to be extracted, like coordinate values and curvilinear forms. Accurate neural network learning was achieved as a result of the experiment. We recreated outline models, and this shows the usefulness of this technique in form recreation.

Key words: *deformation, feature extraction, recreation, neural network*

1. Introduction

The purpose of this research was to specify the design changes which accompany a change of scale, and develop the simplest possible algorithm for extracting and recreating such changes. In this research, it investigated into the design change accompanying miniaturization. We used CHOR-O Q as an example of a miniature. CHORO-Q is well known as a miniature toy in Japan. The charming design of CHORO-Q is very popular. The design of CHORO-Q can see some regularity. We are very interested in the regularity. An understanding of the regularity can help an understanding of sensitivity.

Miniatures are one method of recreating a large object or a scene. Examples of miniatures include: dollhouses, plastic models and ornaments. In miniaturization, the design is often dramatically changed to make features easier to see, or due to the intentions of the designer. All designers have their own original techniques and design algorithms. However, since their designs incorporate the features of the full-size object, there is no misunderstanding of what the miniature depicts. The design and design changes are influenced by designer's sensibilities and intention. Therefore, it is difficult for a person with no artistic knowledge to copy and recreate such design changes. It is also difficult to express the design algorithm numerically or by modeling.

Many previous studies of design and form analysis have looked at techniques using curvilinear analysis, process-grammar, and Fourier transforms [1-3], but no studies have specified the design changes accompanying changes in scale. Naturally, no study uses CHORO-Q. Furthermore, the conventional techniques can be used to analyze form, but it is hard to use them to create forms.

In our experiment, we performed the following things. First, we define some design features which we should preserve. Secondly, we define an algorithm to extract the design changes. The extracted features can be classified into three main groups. Thirdly, we built a neural network which learns the design changes from two corresponding pictures. The neural network learns the design change algorithm from data obtained from CHORO-Q and an actual car. The same neural network system can perform both design change extraction and recreation. We created an outline model, which inherited the design features of CHORO-Q, from a photograph of an unknown actual car. Only in the final place, we performed application experiment that used the photograph of the actual vehicle photo with the digital camera. In this way we investigated preservation and recreation of the design changes accompanying miniaturization and demonstrated the usefulness of our technique.

2. CHORO-Q and its design

2.1 What is CHORO-Q?

CHORO-Q® [4] is a very popular Japanese miniature toy made by TAKARA Co., Ltd. The concept of CHORO-Q is to "miniaturize today's car-based society". Many kinds of CHORO-Q have been marketed, including models of cars, trains and motorcycles. A notable feature of CHORO-Q is that it is driven by a pull-back spring motor. It has a charming deformation design [5,6] which expresses the features of an actual car to the greatest degree possible within the pre-determined scale (total length: 48mm, total height: 31mm, total width: 30mm). In this research, we use the term "CHORO-Q-ization" to creation of models which inherit the design characteristics of CHORO-Q. Also, we limit the discussion to the side view of CHORO-Q and a passenger car. The following two figures show examples of CHORO-Q and an actual car.

Fig.1 A picture of CHORO-Q

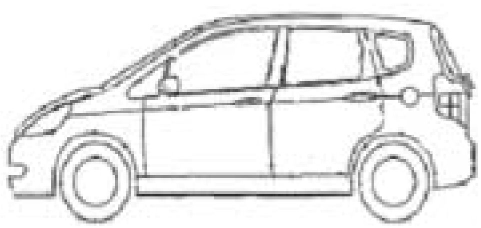

Fig.2 Side view of an actual car

2.2 Deformation design in CHORO-Q

As the first step in our analysis, we investigate the deformation accompanying scale change when miniaturizating an actual car into a CHORO-Q. Design changes can be roughly divided into four classes[7]:

1. Changes in curve design
2. Changes in the size ratio (relative to an actual car) distinctive to CHORO-Q
    - Total length：Total height：Total width＝1：0.689：0.667
    - Total length：Front tires(diameter)：Rear tires(diameter)＝1：0.244：0.311
    - Total length：Wheelbase＝1：0.533　[In this research, we do not consider the license plate.]　etc.

3. Exaggerated parts

- Tires
- License plate (rear) etc.

4. Omitted parts

- Rearview mirror
- Wipers etc.

3. Algorithm for design change extraction

We created an algorithm for extracting the design changes in CHORO-Q. In neural network learning, design changes are extracted using a simple method which gives the maximum consideration to CHORO-Q's design features. The new model should inherit design features from CHORO-Q, as described in the previous Section. Coordinates value changes are used as the elements for extracting design changes. In this research, we divided design changes into the following three classes, and extracted each separately. The methods used for each class are explained below.

(1) Extraction of coordinate changes (Extraction of size ratios and rough contour features)
(2) Extraction of curvilinear forms
(3) Extraction of tires

(1) Extraction of coordinates changes for size ratios and rough contour features

In Step (1), basic information about the critically important body shape is extracted. In this experiment, we sampled 29 coordinates where line segment orientations change significantly. The coordinates of the same point are acquired in two corresponding pictures. The neural network is taught the change in corresponding coordinate values. This Step enables extraction of changes in the rough contour, and in the size ratios between the original car and CHORO-Q (i.e. the most important design change information). The black dots in Fig.3 show the positions of the sampled coordinates.

All coordinates changes are taught simultaneously in neural network learning. Coordinate change values are normalized so they can be used by the neural network. Normalization, in this case, is done by dividing the given coordinate values by 1000. Moreover, neural network learning is performed separately for x and y coordinates.

Fig.3 Black dots indicate sample points in Step (1)

(2) Extraction of curvilinear form

For the curvilinear form between coordinates, we use the following methods to teach the network, not the coordinate values themselves. An example is shown in Fig. 4. First, straight lines are drawn between the coordinate points in Step (1). Second, we divide those lines into five equal segments at fenders, and three equal segments at other parts. The neural network is taught the difference in y coordinate values where the x coordinate is the same in the line or curve. If the inclination of a curve is large, we teach the difference in x coordinate values where the y coordinate is the same in the line or curve. When extracting rough curvilinear form, learning is generally thought to be easier if it is done in the above way rather than by calculating the coordinate values themselves. Almost all cars have the same basic form, and this makes learning extremely easy in our experiments using CHORO-Q. Our extraction method for curvilinear form is used for only 14 curves. At the end of this Step, we perform normalization, where we divide values by 100. If the difference values become uniformly positive or negative, the neural network is taught without distinguishing + and – because this makes the task easier. However if there is mixture of both positive and negative values, the values cannot be handled as is by the neural network, so we use expression [1].

$$Y = \frac{X + |X_{\min}|}{X_{\max} + |X_{\min}|} \qquad [1]$$

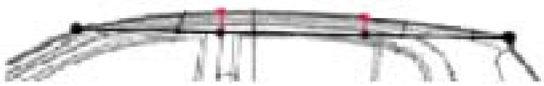

Fig.4 Extraction of curvilinear form (when inclination is small)

(3) Extraction of tires

The size of tires is predetermined in CHORO-Q. In our experiment, we only taught the center coordinates of the tire. This was done in order to maintain the size ratio between the original car and CHORO-Q. Tire size is obtained from the total length found in Step (1) and the tire center coordinates. The ratio of tire diameter and total length is as indicated in Section 2.

4. Processing using the Neural Network [8]

4.1 General knowledge regarding neural networks

Neural networks are known to be particularly effective for capturing the structure of non-linear, ambiguous systems whose relationships are difficult to extract using linear mathematical techniques. Because of this characteristic, neural networks are used in fields like pattern recognition and in design inference.

4.2 The neural network model used in this research

In this research, we built a neural network adapted for the extraction algorithm described in Section 3. An explanation of the constructed neural network is given below.

The neural network has three layers. The number of neurons in each layer of the neural network model used for learning is: 30 neurons in the input and output layers, and 60 neurons in the single hidden layer. The network learns using the Back Propagation method. For learning, the input data was obtained from a picture of the side view of an actual car, and the teaching signals were obtained from a side view photo of CHORO-Q taken with a digital camera. All neurons have weights. The relationship of input and output is numerically stored in the weights of the neurons. The optimal weights for CHORO-Q-ification are found out by learning. The same weights can also be used for an unknown model.

5. Learning experiment

5.1 Pictures used in the experiment

This Section explains the experiment procedure, which is shown in Fig.6. To obtain input value data for this experiment, we used a picture of the dimension drawing of an actual car, captured with a scanner. To capture teaching signal data, we used a picture of CHORO-Q taken with a digital camera. However, there was distortion in the CHORO-Q picture. Therefore, the target values (ratio of CHORO-Q to the actual car) to be preserved by learning were changed.

- Total length : Total height =1:0.626
- Total length: Front tire (diameter): Rear tire (diameter) =1:0.273:0.361
- Total length: Wheelbase =1:0.525

5.2 Picture preprocessing and data acquisition

If the size of the car in the picture varies, the efficiency of neural network learning declines. Therefore, the picture is normalized to improve learning efficiency. In this research, we resized the total length of the car. After resizing, the actual car is 600 pixels and CHORO-Q picture is 500 pixels. The positions of the rear tire lowermost part (x = 600 pixels, y = 500 pixels) are aligned and stuck to the background. Data is then sampled from these pictures. Data normalization is discussed in the previous Section.

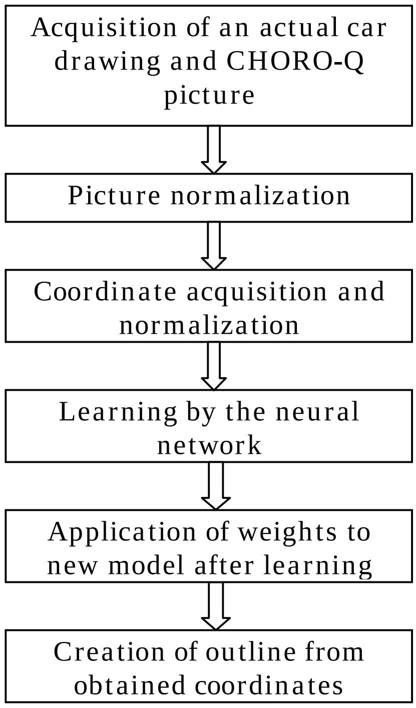

Fig.5 Design extraction experiment procedure

5.3 Learning by the neural network

Four cars were used for learning. First the teaching order was determined. The number of teaching sessions was increased depending on the learning convergence situation. We also tested while teaching to check whether the values obtained using the learned weights were approaching the target values. , We used one of the cars used in learning for testing. Neural network learning was terminated when test results satisfied the following formulas.

(1) Extraction of size ratios and rough contour

$$1.0 * e^{-8} \le (t-n)^2 \quad [2]$$

(2) Extraction of curvilinear form

$$1.0 * e^{-7} \le (t-n)^2 \quad [3]$$

（t ：target value, n ：value obtained by neural network learning）

5.4 Creation of CHORO-Q-ized picture

After learning, we use the obtained weights to derive coordinates for an unknown model, and an outline model was created using the paint software "pixia". This software interpolates between the obtained coordinates using straight lines and spline curves. Circles are drawn for tires using the diameter, and the center coordinates obtained by learning

5.5 Learning experiment results

First, an outline model was created using test data obtained from Fig. 2, and the weights acquired through learning. The result is shown in Fig. 6. The outline creation results almost perfectly preserve the vertical and horizontal size ratios characteristic of CHORO-Q (total length：total height＝1：0.628, error rate 0.32%; and total length：wheelbase＝1：0.515, error rate 1.90%). Next, we applied the system to an unknown model. An outline model was created using the data obtained from Fig. 7. The result is shown in Fig.8.

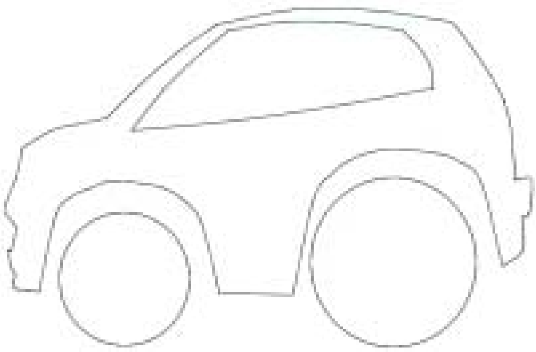

Fig. 6 Outline model created using data obtained from Fig.2

Fig. 7 Picture for sampling data

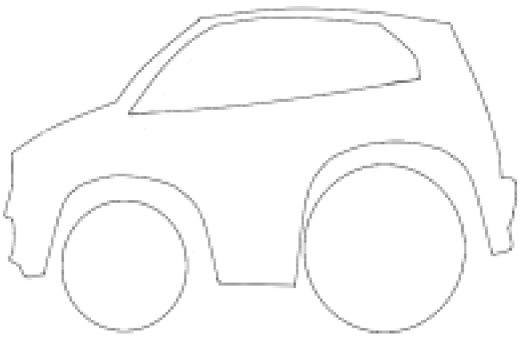

Fig. 8 Outline created from data obtained from Fig. 7

Accuracy was lower in Fig. 6 than in Fig. 8 (total length：total height＝1：0.610, error rate 2.56%; total length： wheelbase＝1：0.516, error rate 1.71%). In particular, there were some parts in curvilinear sections which did not become smooth. We also found that deviation of the sampled coordinates has a significant effect on learning results. Therefore, we must improve re-definition of the sampled coordinate points, the method of picture acquisition, and the pictures used. In outline creation, there is room for improvement in areas like how we connect curves.

6. Conclusions

Our results show that it is possible to create an outline model which inherits the design features of CHORO-Q, by applying the weights learned from CHORO-Q to an unknown model. However, topics for future discussion include: improvement of neural network learning accuracy, and construction of an optimal algorithm which can grasp overall features. Our results suggest that our technique can be applied to common objects other than cars, provided a picture and a photograph is available for sampling coordinates values. Further research will be required for applications involving complicated and 3-D forms. In addition, the experiment about the sensitivity of human being by the image of CHORO-Q and design change is also a future research.

References

1. Nobuyuki NAKASHIMA, Yusuke KURIHARA, Toshinobu HARADA, Saeko TAKAGI, Fujiichi YOSHIMOTO: Development of Shape Design System Using Curves with Designer’s Intention, Information Processing Society of Japan technical report, Computer Graphics and Cad(CG), No.104-8, 29-36(2001).
2. Yoshiki UJIIE, Akihiro HOSOI, Takashi ASANUMA, Yoshiyuki MATSUOKA: Shape-Generation Method Using Curvature Entropy Based on Markov Processes, BULLETIN OF JSSD, Vol.48, No.1, 39-48(2001).
3. Leyton M: A Process-grammar for Shape, Artificial Intelligence, Vol.34, 213-347(1988).
4. Kazuhide UENO: Encyclopedia of CHORO-Q, NEKO PUBLISHING, (1998).
5. Tetsuo AIGA: World Fine-arts Large Encyclopedia Vol.4, SHOGAKUKAN, 28(1989).
6. Yasuhiro OBARA: A Geometrical Layout Method by A.M..Cassandre: Focusing on Productions up to the 1930’s , BULLETIN OF JSSD, No.138, 47-56(2000).
7. Wakayama University, Faculty of Systems Engineering, Department of Design and Information Science : Primer of Design Information Science, Japanese Standards Association, 234-257(2000)
8. Bahman Kermanshahi: Design and Applications of Neural Networks, SHOKODO, 12-57(1998)