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Abstract

Purpose – User-centered product designs have been attracting increasing attention, particularly in digital design. In interacting with the design support system, designers may face problems such as changing demands (e.g. unclear demands) and insufficient descriptions of these demands (e.g. data scarcity). The purpose of this paper is to build a design support system prototype for demonstrating the feasibility of meeting the high involvement of users in digital products.
Design/methodology/approach – Interactive evolutionary computation is applied.
Findings – A prototype of self-design greeting card system (SDGCS) was proposed. It provides professional design layouts, offers users numerous self-design models, and allows nonprofessional users to easily design greeting cards. The results of this study show that users were satisfied with the functionality, usefulness, and ease-of-use of the SDGCS.
Research limitations/implications – This study used digital card design as an example for demonstrating the feasibility of satisfying the unclear needs of uses, enabling users to design a digital card creatively and complete their designs quickly. However, the current system only supports the design of static objects and layout of card. And the evaluation sample size was small, which might affect generalizability of the findings.
Practical implications – In practice, greeting card web operators can image the feasible business models by providing the attraction of self-design functionalities.
Originality/value – In current human-centric marketing era, consumers have begun to request interaction with designers in creating the value of a product. However, very few previous studies have provided support for digital product self-design. This study demonstrated the feasibility of satisfying the needs of self-design.

Keywords Information systems, Artificial intelligence, Genetic algorithm, Evolution
Paper type Research paper

1. Introduction

The growth of the internet and advancements in information technology has led to an increasingly competitive product market. In this environment, companies must compress product life cycles to gain market opportunities more quickly. Businesses no longer focus only on product manufacturing; they have begun prioritizing consumer and user-centered product design. In marketing 3.0 (also called the "human-centric era"), consumers request increasing participation in value creation and pursue values of products. Sophisticated collaboration occurs when consumers design and create products for themselves. Consumers are no longer satisfied by merely owning a product; they expect that the product can satisfy their needs and give desirable emotional experiences (Kotler *et al.*, 2010). Therefore, businesses should provide personalized and customized products to meet the specific needs of consumers. However, consumers typically cannot describe their needs clearly (von Hippel, 1986);

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they do not know which products or elements they want to have (Mandl *et al.*, 2011), or even if they know what they want, they cannot clearly or completely transfer relevant information, such as product specifications, to the manufacturer (Thomke and von Hippel, 2002).

Recommender systems have been widely used, for example, for books, documents, images, movies, music, medicine, e-commerce, gastronomy, entertainment, and e-learning (Park *et al.*, 2012). It is expected that recommender systems could produce individualized recommendations or has the effect of guiding the user in a personalized way to identify interesting and useful products among numerous opinions (Burke, 2002). Traditionally, three recommender system categories exist (Adomavicius and Tuzhilin, 2005), namely, content-based filtering (CBF), collaborative filtering (CF), and hybrid filtering. CBF enables the recommendation of products or services on the basis of the preferences of consumers, which are specified by consumers or from the system inferences of the past experiences (such as shopping records) of the consumers. CF enables recommendations on the basis of the similarity among consumers (such as shared shopping habits or preferences). Hybrid filtering combines CBF and CF. In the past decade, recommender systems have exhibited certain limitations characterized by sparse data, overspecialization, sparse ratings, and cold starts (Bobadilla *et al.*, 2013). Overspecialization means recommending overly similar products to the user. Sparse rating means a lack of rating data for a product. Cold starts means sparse data or nonexisting records because a user is new (has no previous shopping behavior), a product is new (has little connection with existing products), or a system is new.

It is possible that some customers have innovative abilities for developing products (von Hippel, 2005), which means that they can customize products. This type of persons should be treated as a part of the co-creation value chain of a product. The concept of co-creation value is akin to that of do-it-yourself (DIY) value (Tang and Meersman, 2012), according to which a consumer can be treated as a "prosumer" who provides valuable input regarding the production procedure. Co-creation value is a "hard customization" concept. In other words, a consumer is involved in the product design process, not only in the selection of a product (as "soft customization") (Coates and Wolff, 1995). The data (also called "sticky information") from consumers are required for product development. However, because of bounded rationality, consumers might not clearly describe their needs and do not possess problem-solving abilities (Simon, 1957). To meet consumer needs, information systems supporting product design are necessary, particularly in support of digital product design (Koga *et al.*, 2013). Physical goods require molding and manufacturing; to the contrary, digital products are manufactured using information technology and can be downloaded from the internet. Businesses should determine the needs of consumers by providing artificial intelligence-based services that enable some self-design. Thus, cooperation between consumers and businesses can fulfill the needs of consumers and guide the development of customized digital products. It is anticipated that such cooperative circumstances avoid aforementioned recommender system problems.

This paper presents an artificial intelligence-based self-design greeting card system (SDGCS) that considers uncertainty needs and creativity concerns. The remainder of this paper is organized as follows. Section 2 reviews relevant literature. Section 3 proposes the main ideas and system framework of this study. Section 4 elucidates the evaluation and experimental design and presents the results. Finally, Section 5 presents a discussion, conclusions, and suggestions for future research.

2. Literature review

2.1 Genetic and interactive genetic algorithms (IGAs) and their applications

The core concept of this study involves an IGA, which involves interactive evolutionary computation (IEC). Evolutionary computation describes a search heuristic that generates solutions to optimization problems by using techniques inspired by natural evolution such as inheritance, selection, crossover, and mutation. It includes genetic algorithm (GA), evolutionary strategies, genetic programming, and evolutionary programming (Takagi, 2001). However, if an objective function cannot be clearly defined, the optimal solution cannot be determined.

Rodriguez *et al.* (2010) proposed using IGA to create a color design system that collects and trains rating data from users to construct a fitness function (also called an objective function), and subsequently predicts the favorite color of the user. Their research results indicated that users were satisfied with the system. By involving with a human, IGA can solve the problem that an objective function cannot be clearly specified.

Further, Kosorukoff (2001) proposed human-based genetic algorithms (HBGA) that involve outsourcing all primary genetic operators to human agents. The outsourced GAs use both human evaluations and the human ability for innovation. The advantage of HBGA is their ability to address complex problems in which evaluating individuals or identifying a favorable representation for them is difficult. HBGA allows more participation of users; enable users to operate genetic operators such as crossover, duplicate, and delete (Bush and Sayama, 2011).

2.2 Information systems for support product design

In the literature, there are some systems to support product design. For example, Balakrishnan and Jacob (1995) applied several techniques including GA to build a decision support system for package design and marketing of a bar soap. Kim and Cho (2000) developed a design aid system for women's dress by incorporating the domain-specific knowledge into the genotype of IGA. Renner and Ekárt (2003) described serval GA applications to engineering design. Lee and Chang (2010) proposed a creative evolutionary system for conceptual design of a mobile phone based on the affective responses of customers. Cluzel *et al.* (2012) proposed an encoding method for a 2D closed curve, which was intended to represent the essential style features of a car profile. Their system supported designers in designing the outline of a car's shape according to the data obtained using an IGA.

Ho and Huang (2009) indicated that the involvement of a customer in the final assembly plays a crucial role in numerous manufacturing industries. However, the expected users of most of the above systems are designers, not final customers of products. Few systems are for supporting DIY of customers. Mok *et al.* (2013) proposed a customized fashion design system for nonprofessional users (i.e. customers) to create a clothing product (e.g. shirt) in a user-friendly manner. First, users indicated their preference for waist and hem level; subsequently, a set of design sketches was displayed. Second, users selected their preferred designs. This process was repeated until users were satisfied with the design. Since clothes are physical goods, the output of designs must be passed to some factory for concept realization.

Regarding digital product design, very few studies have provided support. One system was reported in the literature; Koga *et al.* (2013) used IEC to enable users to create music. In the proposed IEC for creating a melody, after the presentation, the user could operate the individual at will. In other words, the melody could be changed (part of key of music notes) by the user. After completing the operation, the user inputted the fitness value and the system performed genetic operators (selection, crossover, and mutation) until a melody was created. However, the system did not provide other flexible mechanisms; therefore, users had to invest additional effort to complete the melody. That is, this system function is still not sufficient to support the design.

3. Proposed system

This paper presents a SDGCS for digital card design based on the DIY concept (allowing users to operate genetic mechanisms freely), image processing methods, and IEC. The proposed SDGCS employs a tagging method to extend image content for image analysis, and the correlations between images are calculated for efficient searching. The degree of customization of the proposed SDGCS is high, because users can operate several mechanisms (such as keeping favorable individuals, crossover, and mutation). The system was built using Windows 7 64-bit, Adobe Flash Professional CS6, the programming language ActionScript 3.0, and the web environment XAMPP 1.8.3 for Windows. Figure 1 shows the system framework of the SDGCS.

3.1 Data preprocessing

There are several steps in data preprocessing as follows:

(1) Identification of greeting card components: a total of 459 birthday greeting cards were collected from six widely used Taiwanese websites. After reviewing these cards, we identified the following most common concepts as major components: greeting words, cakes, gift boxes, decoration (including plants), 12 Chinese zodiacs, and animals.

(2) A total of 1,067 images were collected from purchased CDs and websites according to the greeting card components. The design space was large if the above six components were freely combined. Thus, the task of designing a greeting card was complex and time-consuming.

(3) The image processing included size adjustment, tagging, classification, color analysis, and similarity calculation. In addition to size, color, and format, the most crucial part of an image is its feature. A tagging technique involving content analysis enabled the performing of identification and classification by using a bottom-up approach, allowing the image data to be analyzed using similarity calculations. Each image had two similar data sources: tagging and color.

(4) To tag data, the ontological "has-a" and "is-a" concept was employed to identify whether an image had (or was) a specific concept tag. After identification, a two-dimensional matrix was constructed (rows representing the image number and columns representing the tag number) to record image information. For example, if an image contained a hippo (has-a concept), value 1 is assigned to its corresponding field of the matrix; otherwise, the value is 0. If an image belongs to the big animal category (is-a concept), value 1 is assigned to its corresponding field of the matrix; otherwise, the value is 0.

(5) There are numerous color data representation systems, such as RGB, HSV, HSL, etc. The RGB color model is an additive color model in which three basic color, red, green, and blue light, are added together in various ways to reproduce a broad array of colors. HSL and HSV are the two most common cylindrical-coordinate representations of points in an RGB color model;

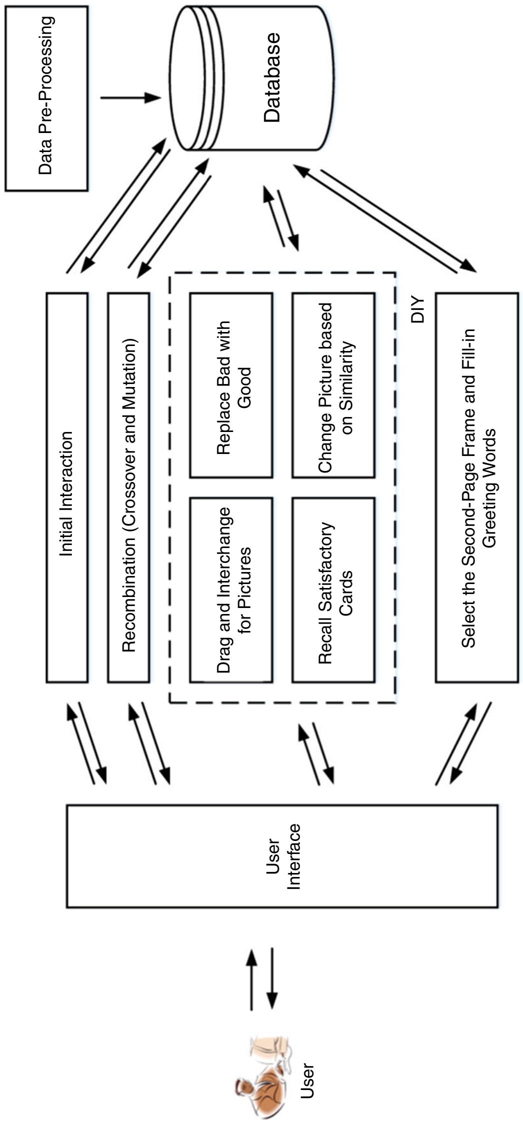

Figure 1.
System framework
of the SDGCS

H stands for hue and S stands for saturation; L in HSL stands for lightness which is the amount of white; V in HSV stands for value which is the perception of the amount of light or power of the source. In this study, HSV was used for color expression. An image cannot be represented by a single color. In this study, each image was divided into 10×10 blocks. There are many pixels in each block. The RGB value of each pixel was first extracted and then used to calculate the average RGB value of each block. Each image comprises 100 blocks, and thus has its 100 RGB values. Following the algorithms proposed by Smith (1978), we obtained 100 HSV values for each image.

(6) The similarity between two images (α and β) was calculated using Formula 1 proposed by this study. In Formula 1, the variable a represents the total number of tagging concepts which both images α and β have (i.e. values as 1); the variable b represents the total number of tagging concepts which image α has not (i.e. value as 0), but image β has; the variable c represents the total number of tagging concepts which image α has, but image β has not; and the variable d represents the total number of tagging concepts which neither image α nor β has. The variable n is the number of blocks of an image (i.e. 100); the variable A_i represents the HSV value of image α in block i; and the variable B_i represents the HSV value of image β in the block i:

$$similarity(\alpha, \beta) = 0.5 \times \frac{a+d}{a+b+c+d} + 0.5 \times \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2}\sqrt{\sum_{i=1}^{n} (B_i)^2}}$$

Formula 1. Similarity between images α and β.

3.2 Initial interaction

Users would first select the intended recipient of a card (such as a parent or friend). Next, they would select the recipient's gender, zodiac, and favorite color. It is reported that the color of a product exerts considerable influence on its sales performance (Holtzschue, 2006). Inferior products featuring favorable color designs sell well, and superior products with unfavorable color designs may sell poorly. Lai *et al.* (2006) also suggested that product color can be more influential than product style. Therefore, the proposed system adds color as a greeting card design element (in the front page and background page). A user is asked to choose six preferred selections (same color with different chroma treated as different selections).

In the greeting card design process, the system generates six greeting card covers based on the selected colors, birthday zodiac, and four greeting card layouts designed by experts. Users must rate (from 1 to 10) the cover of the greeting card. A small scale (1-10) was used as the measurement tool to reduce user fatigue (Takagi, 2001). Therefore, at the beginning, users need to set a threshold, which enables the retaining of favorable greeting cards. For example, if the threshold is set at 8, then all greeting cards with a score higher than 8 will be retained. Users can reclaim the old satisfactory cards if feeling the current card not better than old ones.

3.3 System recombination

After users give rating of the card cover designs and click the "random recombination by system" button, the system would further generate six new card covers. This is the operation to ask the system to perform the mechanisms of tournament selection, crossover and mutation. In this study, each generation has six cards, each of them representing a chromosome containing 18 genes: 13 alphabets (h,a,p,p,y,b,i,r,t,h,d,a,y), cake, receiver's zodiac, animal, gift box, and decoration. The encoding of a chromosome consists a sequence of numbers. Each number represents the different form (phenotype) of a gene. For example, 07-22-14-13-27-06-23-18-16-23-09-05-18-49-92-05-30-097 means the first gene is seventh image object of alphabet "H," the second gene is 22th image of alphabet "A," and so on.

For diversity, there are three types of six new covers. One card of the first type retains the highest rating from the previous round. Two cards of the third type are generated by the random mechanism, i.e., the system would randomly decide each of 18 genes of one card by choosing its phenotypes from the image database. Three cards of the second type are generated after recombination mechanism, which includes tournament selection, crossover and mutation's mechanism, and are further described as follows:

(1) Choose the candidate card for recombination: tournament selection is applied to keep the individual with the highest rating score among two chromosomes chosen at random from the previous population. There is no system-specified fitness function; user gives scores as fitness to each individual instead of fitness function.

(2) Judge whether the candidate card needs to perform the crossover: the system would randomly generate a number. If the number is less than or equal to the crossover rate 0.8, then the crossover in steps 3 and 4 would be performed. If not, jump to step 5.

(3) Choose the partner for the above crossover: the system would choose the partner based on tournament selection. The partner should not be same as the candidate; otherwise, the tournament selection would be performed again until the suitable partner is generated.

(4) Determine the crossover range and perform crossover: the system would randomly generate a number between 1 and 18. For example, if 5 is generated, the offspring would be generated by combining the genes from the first gene to the fourth gene of the candidate with the genes from the fifth gene to the 18th gene of the partner.

(5) Repeat 18 times to judge whether each gene of the candidate needs to perform the mutation: the system would randomly generate a number. If the number is less than or equal to the mutation rate 0.1, then the step 6 mutation would be performed for the gene.

(6) Perform the mutation: the system would replace the original gene value of the above candidate by randomly generating a number, e.g., 3, which represents the third object in the image database of the gene. The constraint is the generated number cannot be same as the original gene value.

3.4 DIY

Takagi (2001) indicated that there is a distance between the parameter space of IEC and the solution space in a user mind. This distance can be bridged directly by involving users in the design process. In addition, Sumi *et al.* (2012) asserted that crossover mechanisms should be implemented carefully, particularly in small population sizes. Therefore, the DIY concept was integrated into the SDGCS to enable users to change the design content for increasing personal creativity. Various DIY functions exist, such as moving, replacing, changing, and reviewing. These DIY functions correspond to the crossover, mutation concepts operated by a human in the HBGA.

3.4.1 Moving images. The user can reduce the distance between the parameter and solution spaces through moving card images. The SDGCS allows two types of image movement: inside (image movement within a greeting card) and outside (image movement from one greeting card to another). In each greeting card, there are always 18 image objects, including 13 alphabets (h,a,p,p,y,b,i,r,t,h,d,a,y), cake, receiver's zodiac, animal, gift box, and decoration. Therefore, moving an image from Card *A* to Card *B* would cause the system automatically moving a corresponding image object from Card B back to Card A (i.e. the operation indeed is exchange between two image objects in different formats). For example, as shown in Figure 2, two different tigers (zodiac) are exchanged between Cards A and B by the movement of the tiger from Card B to Card A.

3.4.2 Replacing greeting cards. The SDGCS enables users to fix the evolution direction by replacing any one of the current greeting cards with a favorable card in the previous generations. Thus, the SDGCS corrects the parameter space when users implement the replacement function.

3.4.3 Changing greeting cards. The SDGCS provides 11 levels (from 0 percent no change to 100 percent total change) of image change. Users could set a desirable change level and then search for matching images. For example, if users set the desirable change as 30 percent, the system would give them those images that are changed to be 70 percent similar to the original image according to Formula 1. As an example, in Figure 3, since a user selects 30 percent change of the tiger in Card F, the image of the tiger is changed.

3.4.4 Reviewing and undoing. The review function of the SDGCS enables the user to review all elitism cards from previous generations. This function was inspired by Geyer-Schulz *et al.* (2000), who retained a series of favorite alternatives of users. Thus, the reviewing function enables transcending the limitation of a single elitism for obtaining a global solution of IEC. Therefore, the SDGCS can reduce the problem of fatigue of IEC (Takagi, 2001). In addition, the user can recreate a former greeting card by clicking the undo button.

3.5 Second-page frame and greeting words

A greeting card has a cover and an inside page. The main operations of the inside page of a greeting card are selecting a frame and filling-in greeting words (as shown in Figure 4). The SDGCS provides a choice of 49 frames, and users can write the greeting words. Tools are available to customize design facets such as font type, color, and size and to move the placement of the greeting words anywhere within the page.

4. System evaluation

After constructing the prototype of SDGCS, we recruited volunteer testers from social networking websites (e.g. Facebook). A total of 37 persons participated, with ages ranging from 17 to 60 years. Most participants were aged 31-35 (32.4 percent) or 21-25 (21.6 percent) years. Most participants had a college education or were currently students (43.2 percent); in addition, most participants were female (78.4 percent).

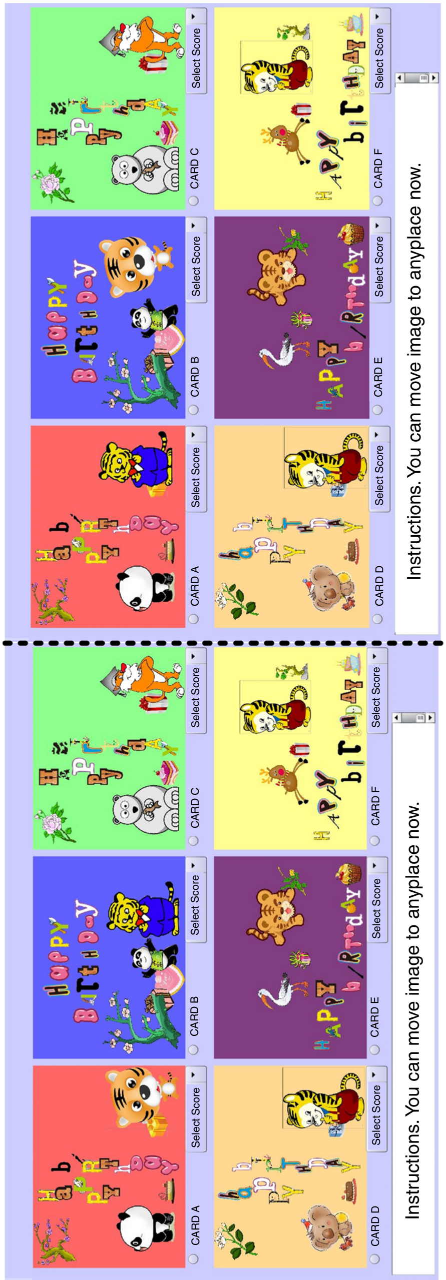

Figure 2.
Moving image

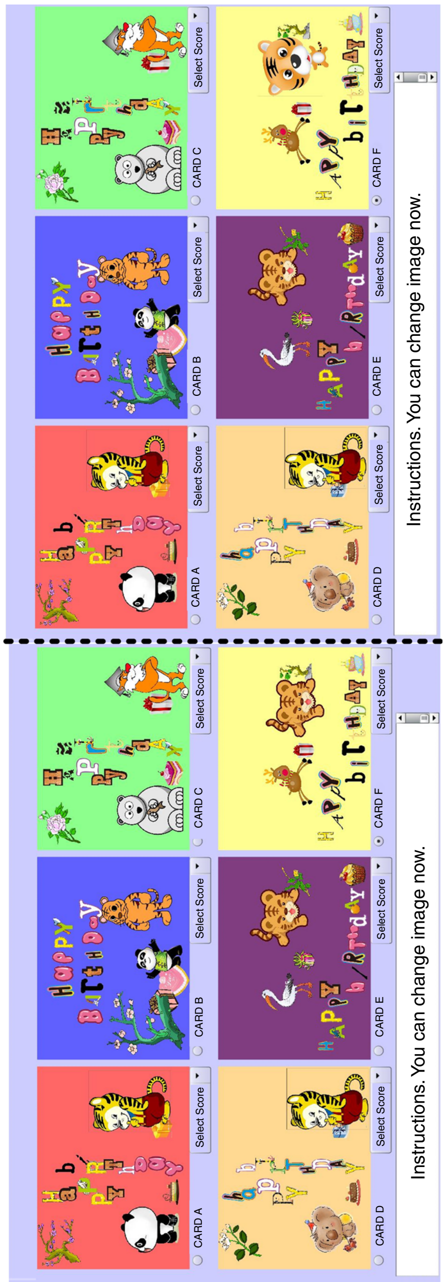

Figure 3.
Changing image

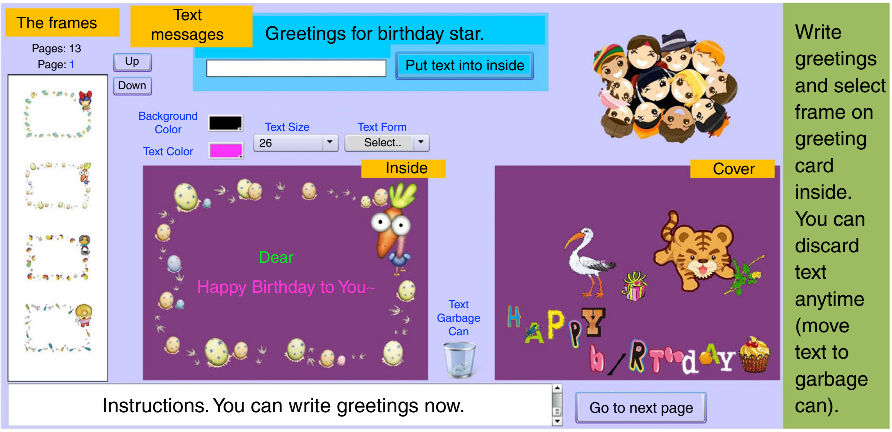

Figure 4.
Inside page of a greeting card

Several tests were performed to these persons. First, all participants' information capability, DIY intention, and artistic ability were evaluated using a questionnaire with five Likert-type scales. Subsequently, the participants were contacted through e-mails and asked to design a greeting card. The participants were free of time limits and allowed to use the system until they were satisfied with the greeting card. Finally, all the participants completed a questionnaire regarding the functions, usefulness, and ease-of-use of the system. We designed the evaluation questionnaires with seven Likert-type scales by referring the literature (Davis, 1989). The Cronbach's α of each variable of the questionnaires (three pre-experiment and three after-experiment variables) exceeded 0.8, thus demonstrated acceptable reliability.

The time that the participants required to design their greeting cards were recorded. The average time of color selection, cover design, and inside page design were found to be 143.96, 269.27, and 139.29 seconds, respectively. The questionnaire scale average values of perceived functions, usefulness, and ease-of-use were 5.70, 5.24, and 4.80, respectively. The statistical results revealed that all of them were higher than the middle value 4 (with 1-7 scale) at the significant level of 0.05. The after-experiment in-depth review also confirmed the high satisfaction of the participants.

The number of times that the participants used each function was also recorded, and usage frequency is shown in Table I. Image movement (inside) was the most frequently used function, followed by color chroma adjustment, image changing, frame selection, font color changing. The participants responded positively to the DIY-related functions; the average frequency of perform DIY-related functions was high. Some users even did not require the system to perform system recombination so that its average frequency was only 1.

According to the participants' operational data, the following observations can be made. First, the DIY functions could stimulate the customization demands of the participants (e.g. a high frequency of image movement) and solve the problem of unclear demands (e.g. by replacing images). Second, the information searching loading of participants was mitigated; on average, the participants changed images fewer than 11 times. Third, the data scarcity problem was solved because evolutionary data were collected. Fourth, digital content can be analyzed by combining tagging and HSV analysis techniques. Fifth, the most used function was image movement and image changing,

Table I. Frequency of the function used

Function	Times used	Average times used	Maximum times used	Minimum times used
Image movement (inside)	1,668	45.08	46	0
Color chroma adjustment	525	14.19	19	0
Changing image	380	10.27	286	0
Frame selection	333	9	21	0
Changing font color	210	5.68	270	0
Changing background color	188	5.08	13	0
Frame browsing	162	4.38	7	0
Image movement (outside)	114	3.08	24	0
Changing font size	80	2.16	45	0
Adding greeting words	70	1.89	35	0
Changing font	55	1.49	8	1
Reviewing	54	1.46	10	0
System recombination	37	1	16	0
Replacing	18	0.49	30	0
Deleting greeting words	12	0.32	3	0

Note: $n = 37$

indicating that the participants exhibited high-DIY intention and that the image search method provided by our system was useful. Therefore, the SDGCS can avoid the unclear needs and creativity problems often encountered in digital product customization.

Furthermore, all the participants were divided into two groups (high or low) according to their average information capability, DIY intention, and art ability scores. As shown in Table II, there are some interesting observations as follows. First, we can

Table II. Evaluation of various user groups

	Higher group	Lower group
Grouped by different level of information capability		
Information capability	4.74 ($n = 17$)	3.92 ($n = 20$)
Function[a]	5.32	6.02
Usefulness[a]	4.74	5.68
Ease-to-use	4.29	5.24
Grouped by different level of DIY intention		
DIY intention	4.49 ($n = 19$)	3.33 ($n = 18$)
Function[a]	5.30	6.12
Usefulness[a]	4.78	5.73
Ease-to-use[a]	4.08	5.57
Grouped by different level of artistic capability		
Art capability	4.17 ($n = 24$)	2.69 ($n = 13$)
Function	5.58	5.94
Usefulness	5.06	5.58
Ease-to-use	4.46	5.44

Notes: Grouping criteria are according to the mean value of the pre-experiment variables. For example, higher group of information capability are those 17 participants, whose information capabilities were higher than the average of 37 participants. [a]Indicates that two groups exhibited statistically significant differences regarding the specified variable examine the means of these three pre-experiment variables (information capability, DIY intention, and art ability) of these groups. It was found that even for these two low groups, either information capability (mean 3.92) or DIY intention (mean 3.33) still exceeded the middle value 3 (with scale 1-5), which implies that either the information capabilities or DIY intention of these low groups were favorable. Only the art ability of the low group was statistically lower than the middle value 3. Second, we can examine the perceived level of three evaluation variables (functionality, usefulness, and ease-of-use). Almost all these 18 values (those values, e.g. 5.32, in gray-background) exceeded the middle value 4 (with scale 1-7). It implies that these participants of all groups were satisfied with the functionality, usefulness, and ease-of-use of the system. The only insignificant numbers are the values (4.29, 4.08, 4.46) of ease-of-use of three high groups; but they were still higher than 4. After-interviews indicated that those participants with higher capability or intention would expect the system could further improve its flow and interface. Third, The perceived satisfaction on the functions and usefulness of the low group regarding information capability (or DIY intention) exceeded that of the high group regarding information capability (or DIY intention), respectively. There was no difference in terms of ease-of-use. According to after-interviews, the high groups wished to have more freedoms of DIY and expected that the system could provide more DIY functions in the future.

5. Conclusions and future research

This study addressed the unclear needs and concerns of creativity regarding digital product customization by proposing an SDGCS based on IEC. The experimental results indicated that the proposed SDGCS supports users in designing and customizing a digital greeting card. Our system allow more DIY functions to stimulate nonprofessional users creativity.

However, this study has several limitations. First, the current system only supports the design of static objects and layout of card. Second, the evaluation sample size was small, which might affect generalizability of the findings. Future card design system could consider tagging images using a polysemous method (Milicevic *et al.*, 2010), allow the learning mechanism of the system, provide advanced dynamic design functions (e.g. allowing embedded flash programs or even augmented reality functions), and establish a connection between colors, images, and greeting words to further facilitate the customization of products by users. Future research may also explore DIY applications other than digital cards or try other metaheuristics.

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