

A Web-based Photo Management System for Large Photo Collections with User-Customizable Quality Assessment

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ABSTRACT

The affordability of digital cameras, storages, processors and the advances in these areas are encouraging people to take hundreds of photos at once. However, managing the large number of photographs involves arduous tasks such as selecting good quality photos and classifying and labeling each photo. Generally, users put their photos into certain user-designated folders on their local PC without considering any classified information. One of the main problems related to this management method is that users do not create their photo folders systematically because they are carelessness and apathetic. This practice results in confusion when users want to find their photos. One method to overcome this problem is to construct a central photo management system that can manage many photos on the user's local PC. It also can provide smart functions such as automated clustering and summarized visualization for many photos. This paper describes an integrated photo management system coupled with a database on the web, which provides users with an automated photo clustering and visualization function that allows photo overlaps. Our system also provides users with an automated photo quality evaluation based on Depth of Field (DOF) and blur. In order to evaluate our system, we conducted a user study on user-friendliness based on a questionnaire.

Categories and Subject Descriptors

I.4.8 [IMAGE PROCESSING AND COMPUTER VISION]: Scene Analysis; I.5.4 [PATTERN RECOGNITION]: Clustering

General Terms

digital photo, visualization, clustering, assessment

Keywords

photo management, web, photo clustering, Exif

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1. INTRODUCTION

The affordability of digital cameras, storage and processors and the advances in these areas are making people accustomed to taking many photos at once. However, this practice involves burdensome tasks such as selecting good quality photos, and classifying and labeling them after they have been taken. Since these tasks are time-consuming and tedious, most people organize their photos using copy operations and paste them into a certain designated folder on their local PC from a digital camera. But users who do not construct their photo folders organizationally spend lot of time finding their photos, since they do not consider any photo classification information when they create folders. One method to overcome this problem is to construct a central photo management system that can manage many photos on the user's local PC.

Recently, numerous central photo management systems with useful functions (e.g. photo refinement, red-eye reduction and sharing photos with friends) have emerged. However, they do not provide automated photo management functions, for example, automated clustering and good quality photo selection. Although iPhoto [2] and Picasa [7] provide automated clustering based on face recognition, they sometimes produce the wrong results. This is a result of technical limitations of face detection arising from issues such as whether glasses are worn or not, rough facial angles and abnormal exposures.

In order to manage photos stored in the user's local PC centrally, portal sites (e.g., Google and Flickr) provide a web server coupled with a database, as shown in Figure 1. Google provides users with an independent client program, Picasa, which can connect to the web server (Picasa Web Album) and cluster photos based on face recognition [7]. This system can manage photos that are stored in the user's local PC as well as uploaded photos on the web server. iPhoto also provides users with an independent client application running on a Mac platform [2]. This application can transfer user photos to Facebook and Flickr's database using the photo transmission APIs provided by the portal sites. BookSmart provides a work interface to generate a book album, as shown in Figure 1(b). It can use the user transferred photos on a Flickr and Picasa web album.

This paper describes an integrated photo management system coupled with a database on the web. Our system provides users with the following three automated functions: 1) temporal and spatial photo clustering, 2) photo visualization layout that allows overlaps and 3) selecting good quality photos. In order to evaluate our system, we conducted a user

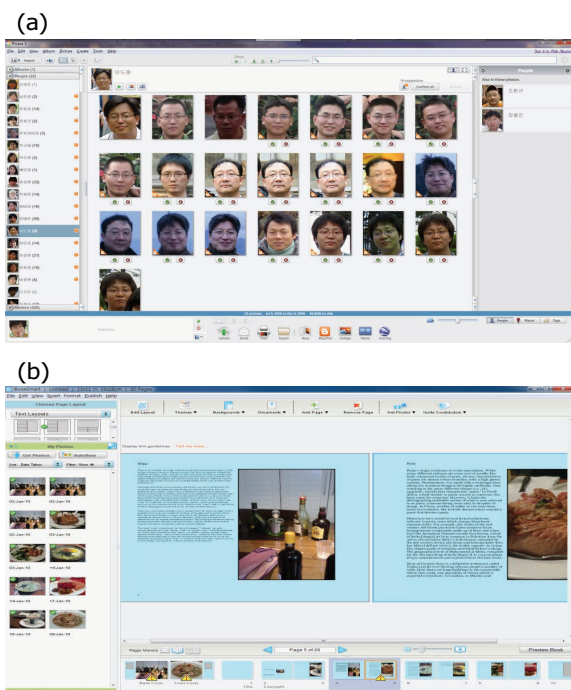


Figure 1: Screenshots of two typical photo management frameworks based on the web. (a) Picasa consists of an independent client application to connect to the Picasa Web Album [7]. It sometimes produces wrong clustering results due to the technical limitations of face detection. **(b) BookSmart** is classified as a third party photo management program [3]. These can make a book style photo album using photos from the Flickr server and the Picasa Web Album.

study on user-friendliness based on a questionnaire.

2. RELATED WORK

Numerous photo management systems which provide useful functions for photo management have emerged. In this paper, we draw on related work from two areas: Photo management systems based on the web and smart photo management studies.

2.1 Web-based Photo Management Systems

Most portal sites play a leading part in photo management through the web, for example, Google, Yahoo and Apple. These systems can be classified into three kinds of scheme according to the method used to connect to the web database:

1. Server and client : This framework consists of an independent server and client program e.g. Picasa [7].
2. Web server : Users can upload and download their photos through a web browser without any client application e.g., Flickr [20].
3. Third-party application : Portal sites such as Yahoo [20] and Facebook inc. [8] provide photo database

server connection APIs. We called a photo management application that uses other server connection APIs a third-party photo management program.

Table 1: Photo management system working with web. Eval. : Evaluation, Cls. : Clustering, S/C : Server and Client, S/A : Stand Alone, Web : Web server, T/P : Third Party program, N/A : Not Available, F/D : Face Detection, T/G : Thumbnail Grid, B/A : Book Album

System	Vendor	Frame	Eval.	Cls.	Layout
Picasa [7]	Google	Web, S/C	N/A	F/D	Zoom
Flickr [20]	Yahoo	Web	N/A	N/A	T/G
iPhoto [2]	Apple	S/A	N/A	F/D	T/G
Book-Smart [3]	Blurb	T/P	N/A	N/A	B/A

In this paper, we described four typical web-based photo management systems in Table 1. Picasa and iPhoto provide useful functions to cluster the user's photos automatically according to face recognition. However, they sometimes produce incorrect results due to the technical limitations of face detection we mentioned. Flickr provides the user with a photo album (set and collection) that they create via manual operations. It also visualizes photos on a map using geographic locations provided by the user's manual drag operations.

Third party programs are developed applications using the sever connection APIs provided by the portal sites. Many third party photo management programs use these APIs to transmit their photos to a portal web server, to share photos with friends or to develop other more specialized services (e.g. making a book from a photo album [3]).

2.2 Issues in Massive Photo Management Systems

Most studies related to photo management cover how to deal with clustering and visualizing many photos. We summarize photo management studies in Table 2. Most studies use photo taken time as a clustering criterion for automatic clustering of many photos. Kentaro proposed an application built on top of the WWMX (World Wide Media eXchange) which is a lightweight travelogue-authoring tool providing auto-clustering functions according to geographic location tags [18]. Cooper proposed temporal clustering with a criterion of photo taken time for automatic clustering of many photos [4]. He also visualizes his clustering result using a DCT matrix.

Many clustering studies consider more than two clustering criteria (another clustering criterion based on photo taken time, e.g. color similarity between image block and color histogram). Jang proposed temporal clustering with photo color similarity [9]. He first clusters photos using sequential photo shoot time, then, rearranges the clustering results considering color similarity between the expanded photo block. PHOTOLAND also considers two criteria, photo taken time and a 25 color histogram distribution for comparing two

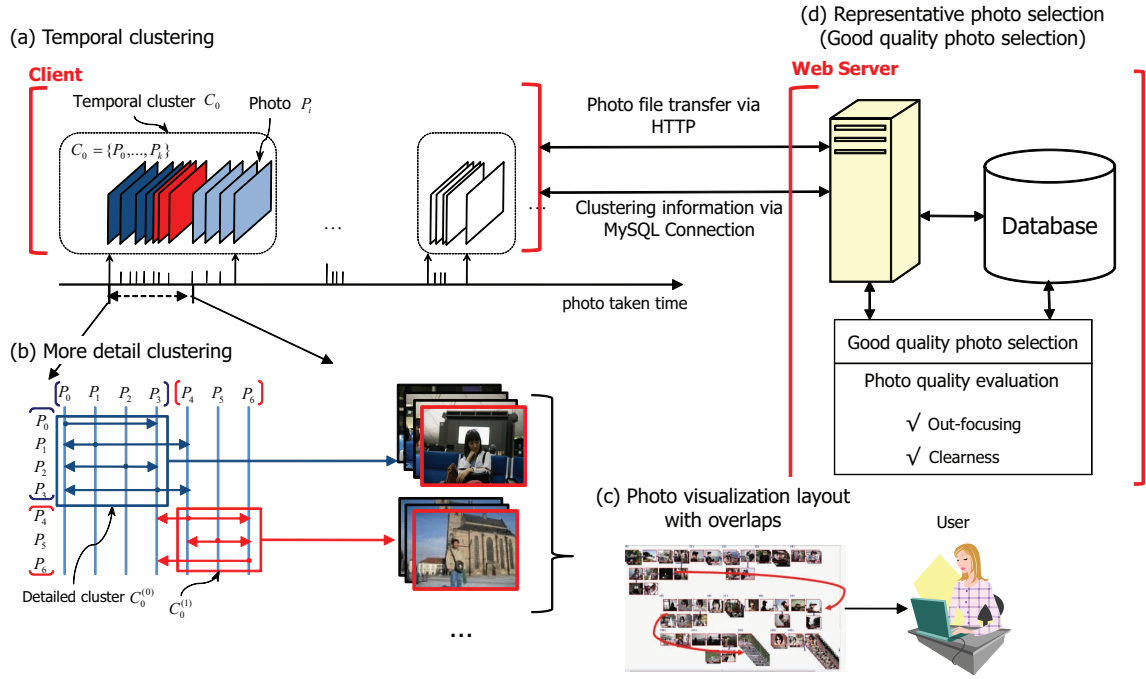


Figure 2: Overview of our photo management system. Our system communicates with a web server to transfer the result of clustering information via a MySQL connection using HTTP (HyperText Transfer Protocol) to transmit photo files. (a) Temporal clustering for photos stored on the local PC or web server. For temporal clustering, we can obtain the photo taken time from Exif. (b) More detailed clustering using maximal clique decomposition. The red boxes surrounding the photo thumbnails depict the representative photos selected by our evaluation method. (c) Photo visualization layout with overlaps. Since the regrouped photos have similar color histograms, we place them in such a manner as to allow overlaps. (d) We select a good quality photo as the representative photo of each detailed cluster considering Depth of Field and blur.

clusters [15]. It can provide a hierarchical clustering interface based on a grid.

How to visualize the clustering result has been also considered important. As the number of photos increases, the limited screen space results in the need for lots of manual operations such as dragging and scrolling tasks. MediaGLOW provides a stack interface to visualize hierarchical clustering [6]. It places the clustered photos on a 2D space using a force-directed layout. Schaefer proposed a globe view which can generate fast and intuitive browsing on large image collections [16]. He visualizes many photos in globe form surrounded with photos sorted by hue value. Since each of the photos are transformed to an HSV representation users can find their photos using hue value.

Good quality photo selection is one of the most burdensome tasks. In order to assist this work, Ke designs high level semantic features to measure perceptual differences [10]. His method considered the spatial distribution of edges, color distribution, hue count and photo blur. Luo considers a composition that depicts the organization of all graphic elements within a photo [17]. In order to extract the subject region, he uses a log-likelihood of derivatives with a blurring kernel of size $k \times k$ ($1 \leq k \leq 50$).

3. SYSTEM FRAMEWORK

We designed an integrated photo management system that can communicate with a web server to manage user photos

centrally. The overview of our proposed system framework is shown in Figure 2. It provides temporal and more detailed clustering for users, then, places the regrouped photos in such a manner as to allow overlaps. Since they have similar color histogram distributions, we can grasp the contents of regrouped photos at once. The clustering results are transferred to our database through a web server. The server side process based on a socket plays the role of making thumbnails for the transferred photos and measuring photo quality according to their DoF (Depth of Field) and blur.

3.1 Temporal and Spatial Clustering

As the number of photos to be managed increases, the photo classification tasks become increasingly burdensome. Besides, widespread distribution of digital cameras is making people accustomed to taking many photos at once. Accordingly, there is a high chance of taking several pictures of the same models or scenes. For screen space utilization, all these kinds of similar photos do not need to be displayed, since they consist of similar photos having similar color histogram distributions.

Our clustering scheme consists of two phases; temporal and more detailed spatial clustering. The goal of the first phase of temporal clustering is to organize trivial photo clusters based on the photo event. There is little coherence in terms of photo taken time for photos classified into events between their photo groups [4]. Therefore, the photo taken time is a very important factor for estimating the clustering

Table 2: Related work about photo management.
rep. means representative.

Study	Criteria	Description
PhotoTOC 2003 [13]	Photo taken time & content.	- Content based clustering. - Table Of Contents interface.
Kentaro 2003 [18]	Geographic location tags.	- Query based interface for large number of photos.
Cooper 2005 [4]	Photo taken time.	- Visualization of clustering result using DCT.
Jang 2009 [9]	Photo taken time & content.	- Temporal clustering. - Color similarity clustering based on a photo taken time.
MediaGL-OW 2009 [6]	Photo taken time & color similarity.	- Force-directed Layout. - Stack interface to visualize hierarchical clustering result.
Gerald 2010 [16]	Hue in HSV color model.	- Globe view according to hue value. - A hierarchical zooming interface.
PHOTOLAND 2010 [15]	Photo taken time & 25 color histogram.	- Hierarchical clustering based on a grid. - Common <i>rep.</i> photo selection.

results. To this end, we adopt Cooper’s clustering criterion to group many photos into small groups. In this paper, we set the scale factor K for the exponential function to 3,600 seconds (one hour). This means that we want to classify our photos using a time gap of one hour as the criterion for clustering.

In the second phase, detailed clustering is used to organize similar color photos from the previous clustered photos. Instead of displaying all of these regrouped photos, our system displays their representative photos in order to improve the screen space utilization. In order to construct more detailed clusters, we use an interval graph with maximal clique decomposition. The interval graph is the intersection graph of a multiset of intervals on the real line. It has one vertex for each interval in the set, and an edge between every pair of vertices corresponding to intervals that intersect [19].

Given already clustered n photos $C_i = \{P_i, P_{i+1}, \dots, P_{i+n-1}\}$, which are ordered by photo shooting time, we can construct an interval graph $G = (V, E)$ where V consists of intervals $I_k = [P_i, P_m]$ between photo sequence. The interval of G is generated by photo sequences with more color similarity than the user-defined threshold u , where $0.0 \leq u \leq 1.0$. For color comparison, we used 25 color bins proposed by Prasad [14] and defined this as

$$SC(P_i, P_j) = 1 - \frac{\sum_k^{25} (|Q_k(P_i) - Q_k(P_j)|)}{\min(pixels(P_i), pixels(P_j))}, \quad (1)$$

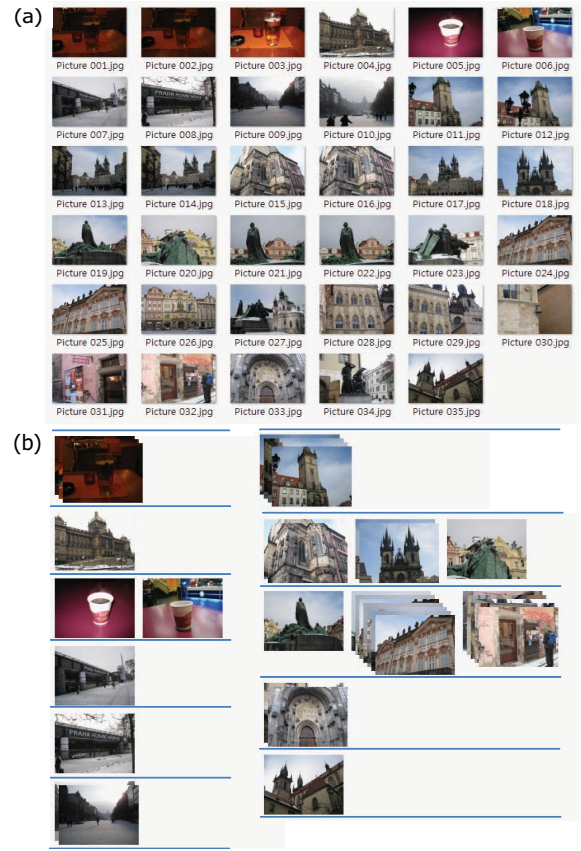


Figure 3: Clustering results (a) 35 Input photos taken at Czech Prague. (b) Results of temporal and more detailed spatial clustering. The blue lines depict the temporally clustered photos. The detailed clustered photos are placed in such a manner that they overlap each other.

where Q_k and $pixels(P_i)$ denote the pixel number of the i -th quantized color and the number of pixels stored in photo P_i .

The photo sequence clustered by temporal information generates intervals from consecutive photos C_i with more color similarity to each other than the user-defined threshold u . Then the constructed interval graph is used for photo placement allowing overlapping between photos. And, the temporal order is maintained between each of the cliques by using the interval graph. For a more detailed explanation, we describe the following example. Table 3 shows the color similarity for the pairs of sequential photos, $P_0 \sim P_6$.

We assumed that user set the color similarity u as 0.7. This enables us to construct the interval graph as shown in Figure 2 (b), since the consecutive photo sets are $P_0 \sim P_3$ and $P_4 \sim P_6$, as shown in Table 3. Therefore, we can obtain two detailed clusters, $C_0^{(0)}$ and $C_0^{(1)}$, by maximal clique decomposition. The clustering results are shown in Figure 3. We can obtain a more detailed clustering result by using the user-defined similarity threshold u . If u is high, the clustering results are classified in detail and vice versa.

One of the fundamental ideas presented in this paper is finding the maximal clique cover set $C_i^{(k)}$ of this interval graph. This clique set consists of more detailed consecutive photo clusters having similar colors to each other. Also, it

Table 3: Color similarity for temporally clustered photo set, $P_0 \sim P_6$. We can obtain two detailed clusters $P_0 \sim P_3$ and $P_4 \sim P_6$.

S_C	P_0	P_1	P_2	P_3	P_4	P_5	P_6	...
P_0	1.00	0.85	0.92	0.75	0.68	0.87	0.45	...
P_1	0.85	1.00	0.75	0.72	0.78	0.37	0.75	...
P_2	0.92	0.75	1.00	0.84	0.58	0.77	0.55	...
P_3	0.75	0.72	0.84	1.00	0.78	0.37	0.75	...
P_4	0.68	0.78	0.58	0.78	1.00	0.82	0.85	...
P_5	0.87	0.37	0.77	0.37	0.82	1.00	0.75	...
P_6	0.45	0.75	0.55	0.75	0.85	0.75	1.00	...
...

can maintain the temporal order between each of the cliques at the same time. Generally, for general graphs, the computation of all maximal cliques is an NP-hard problem, since it can be reduced to the maximum clique problem, which is again a classical NP-complete graph problem [5]. However, searching for maximal cliques in the interval graph can be done in a time that is linear to the size of the graph.

3.2 Evaluation of Photo Quality

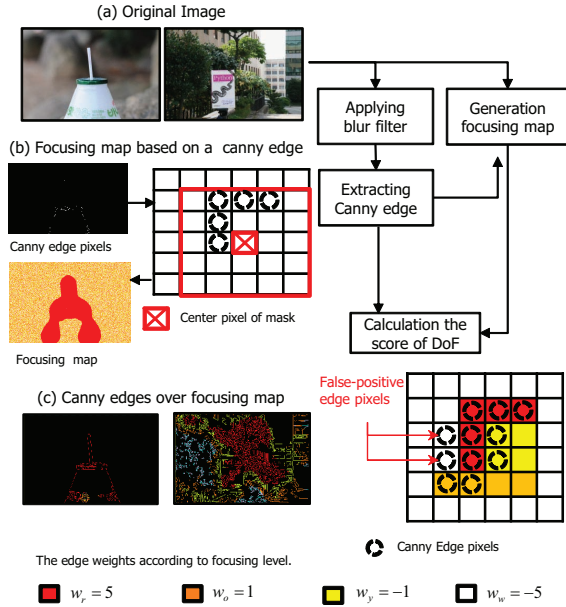


Figure 4: Workflow of photo quality assessment in terms of DoF.

Good quality photo selection is one of the most burdensome tasks due to the large number of photos. Generally, high quality photos satisfy three principles: a clear topic, a focus of attention on the subject, and the removal of objects that distract attention from the subject [12]. Most studies related to photo assessment consider color contrast and blur caused by camera shaking. In this paper, we propose a novel evaluation method to measure blur and DoF (Depth of Field). Blur is one of most common features of photo evaluation.

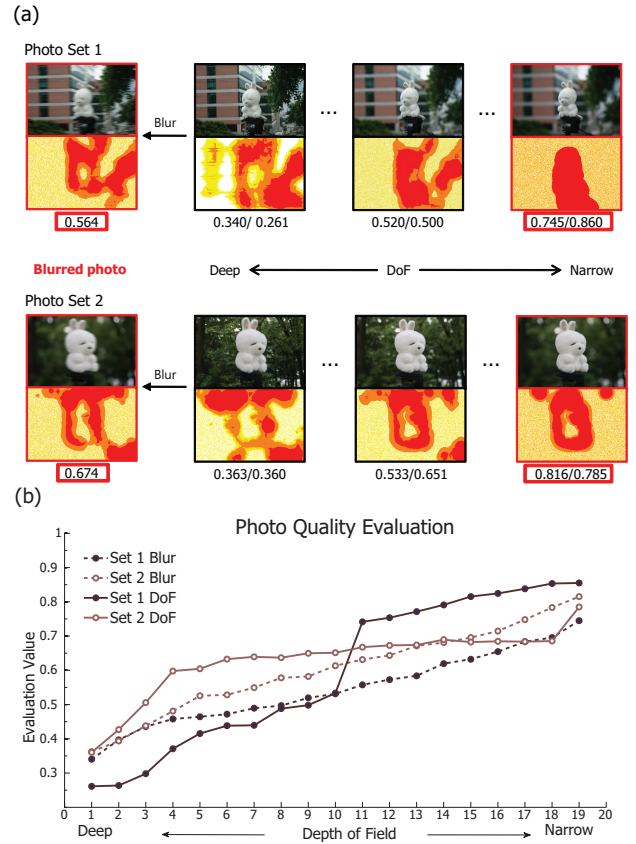


Figure 5: Result of good quality photo evaluation. (a) Two series of photo sets are sorted in DoF order and their focusing map by controlling the f-numbers. In order to compare our assessment measure with the blur measure, we generate blurred photo by applying a Gaussian blur filter from deep DoF photos (photos with red boxes). (b) Result of our photo quality assessment (Blur / DoF).

In fact, the first criterion of photo quality assessment is blur. Related works on photo blur have been already carried out. In this paper, we decided to use Ke et al.'s blur estimation technique [10]. They can estimate the maximum frequency of the image by taking its two-dimensional Fourier transform and counting the number of frequencies having a power greater than some threshold θ .

The second photo assessment criterion, DoF (Depth of Field), is also an important feature. Most professional photographers intentionally make a blurred area in the background region with a shallow DoF [11]. However, as DSLR cameras are increasing in popularity, not only professional photographers but also people in general are becoming accustomed to taking high quality photos, considering shallow DoF, thus DoF is also a significant photo assessment criterion.

We propose a DoF assessment measure based on a photo focusing map and canny edge. Since canny edge extraction considers the direction of pixel variation and double thresholding, we can extract human recognizable edges from photos more easily than the other edge extraction methods. Generally, photos with a shallow DoF have edge pixels in the on-focus region, and vice versa for the other regions. The

main idea of our DoF photo assessment method is how to consider whether the extracted edges from a photo image are in the on-focus or out-of-focus region. If edge pixels can be obtained from the on-focus region but no edge pixels can be obtained from the out-of-focus region simultaneously, it indicates that this photo is a shallow DoF photo.

Figure 4 shows the process of our photo quality evaluation method. In order to remove the noise edge pixels, we first apply a blur filter to the original image, as shown in Figure 4 (a). Then, we generate a focusing map using the extracted canny edge pixels, in order to consider an edge distribution which depicts the level of focus. To calculate the focusing value of every pixel p of the focusing map, we use the adjacent canny edge pixels in the mask(m) and their distances as shown in Figure 4 (b). Our proposed focusing value, $f(p)$, is defined by :

$$f(p) = \sum_{np \in m} \frac{pixels(np)}{|dist(p, np)|}, \quad (2)$$

where $dist(p_i, p_j)$ means the Manhattan distance between two pixels (p_i, p_j) . We classified focusing map pixels into four regions, R_k , consisting of red, orange, yellow and white ($k \in \{r, o, y, w\}$) according to the level of focus. We assume that the red (R_r) and orange region (R_o) is on-focus, while the other regions are out-focus regions. The other regions contain less important information than R_r and R_o , since there are no edge pixels. However, we also need the other regions (R_y, R_w) to determine the false-positive case, as shown in Figure 4. Finally, we calculate the total score of the edge pixels according to the level of focus by :

$$E(P_i) = \sum_{p \in P_i} (w_k(p) \cdot f(p)) / pixels(e_c(P_i)), \quad (3)$$

where e_c , $pixels(I)$ and $w_k(p)$ are the extracted edge pixels using canny edge detection, the number of pixels stored in region I and the weights according to the level of focus as shown in Figure 4, respectively.

Figure 5 shows the result of our proposed photo quality assessment method. The DOF is controlled by the lens aperture diameter, which is usually specified as the f-number. We take a series of photo sets sorted in DoF order by controlling the f-numbers. Figure 5 (a) shows the input photos and their focusing map. It can be seen that the proposed focusing maps display the focus regions of photos properly. The result of our photo quality assessment is shown in the graph of Figure 5 (b). In order to check whether our method can identify the blur and DoF, we also generated blurred images by applying a Gaussian filter to photos with a deep DoF, as shown in Figure 5 (a). The comparison of quality evaluation measures shows that our photo quality assessment method can identify blur and DoF.

3.3 Proposed Photo Layouts

Photo visualization is an important feature of the interface view for photo management. Our system provides three different types of layouts, as shown in Figure 6 and Figure 7 (a). Our layouts place each photo thumbnail in such a manner as to allow overlaps. We summarize the three different types of photo visualization methods as follows:

1. Grid view : This layout is one of the most common



Figure 6: Two different types of photo layout based on a photo thumbnail ($u = 0.7$). (a) A sequential layout allowing photo overlaps. The red arrows depict the temporal sequence of photo clusters. (b) A row-by-row layout allowing photo overlaps.

photo layouts. It sequentially arranges photo thumbnails in a row-by-row manner (Figure 7 (a)).

2. Sequential view : We place each temporal cluster in such a manner as to maintain their sequence (Figure 6 (a)). It can provide the users who grasp the contents of photo sets with a convenient interface that they can use to find their photos.
3. Row-by-row view : This divided photo clusters in a row-by-row manner according to the user-defined time gap. The user can show their photos with a user-designated time gap (Figure 6 (b)).

Figure 7 shows the screenshot of our system interface. It consists of an independent client program and web sites coupled with a database. The client application (Figure 7(a)) provides user database connection functions which can transmit photo files and an automated clustering. The server-side process based on a socket has the role of making a thumbnail and photo quality assessment. In our framework, photo quality assessment needs a lot of time to generate a focusing map, as we mentioned. Finally, our web site displays the result of clustering and photo quality assessment,

as shown in Figure 7(b). We provide a video clip to demonstrating our system at the below URL.
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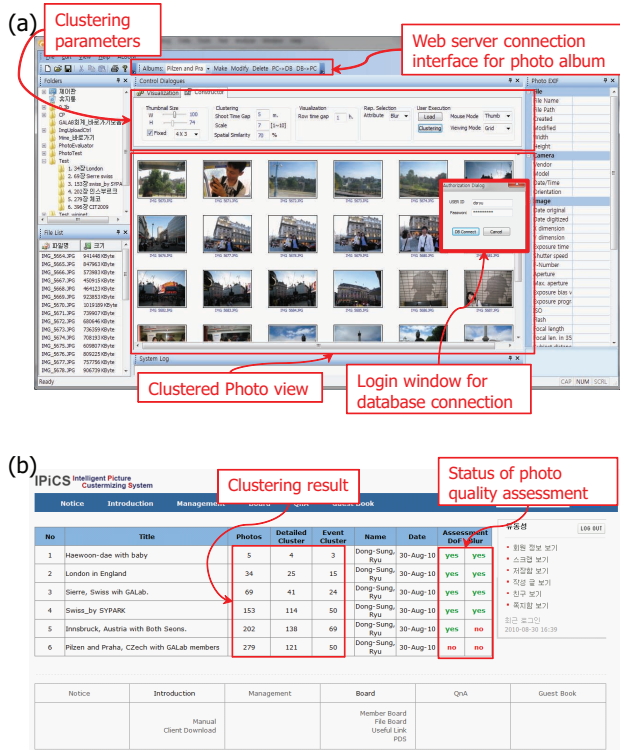


Figure 7: Screenshot of our system interface. (a) The client application consists of a database connection dialog and visualization screen. (b) An album board for clustering results on a web server.

4. EXPERIMENT

In order to evaluate our system utilization, we conducted one experiment and user studies based on a questionnaire in terms of space efficiency, photo classification ability and photo assessment. The space efficiency depicts how effectively the screen space of the monitor is used. Since users just can deal with several tens photos displayed in a screen at once, low space efficiency can result in the need for many scrolling operations. Therefore, the low space efficiency can confuse users due to the low screen coherence.

Table 4: Input photo sets. The ‘S. Cls.’ item means the number of spatially-clustered photo groups using our maximal clique decomposition.

Label	Photos	S. Cls.	Label	Photos	S. Cls.
A	34	25	D	202	136
B	69	41	E	279	118
C	153	114	F	396	208

We calculate the screen area that is used by each part of our system layout, grid, sequential and row-by-row, as

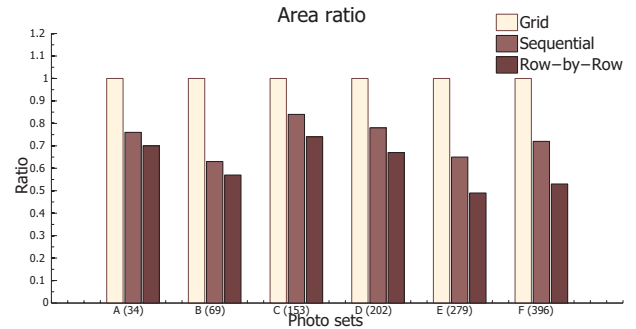


Figure 8: The result of area ratio our system layouts used.

shown in Figure 8. For sequential layout, we calculate the convex area ratio surrounding all photos when the area of grid layout equals 1.0. Similarly, we calculate all of row photo area for the area ratio of row-by-row layout. The input photo sets we used are described in Table 4. Although, the photo set *E* consists of many more photos than *D*, photo set *E* consists of photos having similar color distribution more than *D*. Therefore, we can improve the screen space in the case of photo set *E*, efficiently.

We also invited twelve participants to participate in our user study in order to evaluate our system utilization. The participants were computer science students. We were asked them to classify and find some randomly selected photos using our program and ACDSee Photo Manager [1]. Then, we asked users to complete a simple questionnaire according to the following criteria : clustering and photo quality assessment. As a benchmark, we include an ACDSee Photo Manager [1] item in our questionnaire sheet.

- Q1. How conveniently do you think you could classify your photos? (0 : Bad , 5 : Good)
- Q2. In terms of allowing your photos to be shared with your friend, how useful do you think our photo management system is? (0 : Bad , 5 : Good)
- Q3. What level of satisfaction do you have with the proposed photo quality assessment system? (0: Bad, 5 : Good)

We can establish that our system is better suited to providing more convenient photo classification and an interface to enable the user to manage photos than ACDSee, as shown in Table 5. Our photo quality assessment system also satisfies users.

5. CONCLUSION

In this paper, we proposed a web-based photo management system with an automated clustering and photo assessment considering blur and DoF. Especially, our photo quality measure in terms of DoF considers the distribution of edge pixels in order to consider the level of focusing. Our system also can organize user photos on a local PC automatically, and assist in filtering low quality photos in terms of DoF. Our system provides three major functions to the user:

Table 5: Evaluation result of our system. $avg.$ and σ means the average and standard variation of user scores, respectively.

	Layout	Avg.	σ
Q1	Grid	3.27	2.2
	Sequential	4.18	4.2
	Row-by-Row	3.99	1.7
Q2	Grid	3.32	2.6
	Sequential	4.08	3.3
	Row-by-Row	3.83	1.9
Q3	Blur	3.92	2.4
	DoF	3.56	1.9

1. Web-based system : Our system can communicate with a web database to manage photos on a local PC.
2. Automated clustering : We first group photos using temporal clustering, then, we regroup the temporally clustered photos for more detailed clustering.
3. Photo assessment : Our system provides photo assessment based on DoF and blur.

Our system also has several drawbacks. The invited participants complain that it takes too much time to transmit photo files from the local PC to the web server. Although we do transfer mid-sized photos to display album photos, this is very time consuming work. In order to alleviate this problem, we should develop a more optimized file transfer module. Our proposed photo quality assessment method produces wrong results when evaluating photos having a larger number of edges from the region of focus than a certain threshold. As a further work, this should be also fixed for photo quality assessment method.

6. ACKNOWLEDGMENTS

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