Pictogram Retrieval Based on Collective Semantics

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Abstract. To retrieve pictograms having semantically ambiguous interpretations, we propose a semantic relevance measure which uses pictogram interpretation words collected from a web survey. The proposed measure uses ratio and similarity information contained in a set of pictogram interpretation words to (1) retrieve pictograms having implicit meaning but not explicit interpretation word and (2) rank pictograms sharing common interpretation word(s) according to query relevancy which reflects the interpretation ratio.

1 Introduction

In this paper, we propose a method of pictogram retrieval using word query. We have been developing a pictogram communication system which allows children to communicate to one another using pictogram messages [1]. Pictograms used in the system are created by college students majoring in art who are novices at pictogram design. Currently 450 pictograms are registered to the system [2]. The number of pictograms will increase as newly created pictograms are added to the system. Children are already experiencing difficulties in finding needed pictograms from the system. A pictogram retrieval system is needed to support easy retrieval of pictograms.

To address this issue, we propose a pictogram retrieval method in which a human user formulates a word query, and pictograms having interpretations relevant to the query are retrieved. To do this, we utilize pictogram interpretations collected from a web survey. A total of 953 people in the U.S. participated in the survey to describe the meaning of 120 pictograms used in the system. An average of 147 interpretation words or phrases (including duplicate expressions) was collected for each pictogram.

Analysis of the interpretation words showed that (1) one pictogram has multiple interpretations, and (2) multiple pictograms share common interpretation(s). Such semantic ambiguity can influence recall and ranking of the searched result. Firstly, pictograms having implicit meaning but not explicit interpretation word cannot be retrieved using word query. This leads to lowering of recall. Secondly, when the human searcher retrieves several pictograms sharing the same interpretation word using that

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interpretation word as search query, the retrieved pictograms must be ranked according to the query relevancy. This relates to search result ranking.

We address these issues by introducing a semantic relevance measure which uses pictogram interpretation words and frequencies collected from the web survey. Section 2 describes semantic ambiguity in pictogram interpretation with actual interpretations given as examples. Section 3 proposes a semantic relevance measure and its preliminary testing result, and section 4 concludes this paper.

2 Semantic Ambiguity in Pictogram Interpretation

Pictogram is an icon that has clear pictorial similarities with some object [3]. Road signs and Olympic sports symbols are two well known examples of pictograms which have clear meaning [4]. However, pictograms that we deal with in this paper are created by art students who are novices at pictogram design, and their interpretations are not well known. To retrieve pictograms based on pictogram interpretation, we must first investigate how these novice-created pictograms are interpreted. Therefore, we conducted a pictogram survey to respondents in the U.S., and collected interpretations of the pictograms used in the system. Below summarizes the objective, method and data of the pictogram survey.

Objective. An online pictogram survey was conducted to (1) find out how the pictograms are interpreted by humans (residing in the U.S.) and to (2) identify what characteristics, if any, those pictogram interpretations have.

Method. A web survey asking the meaning of 120 pictograms used in the system was conducted to the respondents in the U.S. via the WWW from October 1, 2005 to November 30, 2006.[1] Human respondents were shown a webpage similar to Fig. 1 which contains 10 pictograms per page, and were asked to write the meaning of each pictogram inside the textbox provided below the pictogram. Each time a set of 10 pictograms was shown at random and respondents could choose and answer as many pictogram question sets they liked.

Data. A total of 953 people participated in the web survey. An average of 147 interpretations consisting of words or phrases (duplicate expressions included) was collected for each pictogram. These pictogram interpretations were grouped according to each pictogram. For each group of interpretation words, unique interpretation words were listed, and the occurrence of those unique words were counted to calculate the frequency. An example of unique interpretation words or phrases and their frequencies are shown in Table 1. The word "*singing*" on the top row has a frequency of 84. This means that eighty-four respondents in the U.S. who participated in the survey wrote "*singing*" as the meaning of the pictogram shown in Table 1.

In the next section, we introduce eight specific pictograms and their interpretation words and describe two characteristics in pictogram interpretation.

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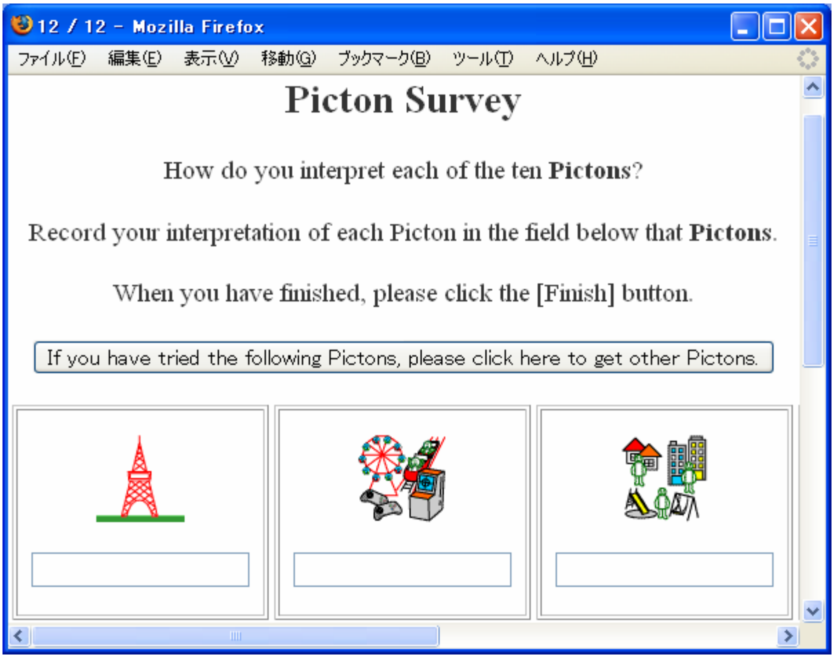


Fig. 1. A screenshot of the pictogram web survey page (3 out of 10 pictograms are shown)

Table 1. Interpretation words or phrases and their frequencies for the pictogram on the left

PICTOGRAM	INTERPRETATIONS	FREQ.
	singing	84
	sing	68
	music	4
	singer	4
	song	2
	a person singing	1
	good singer	1
	happy	1
	happy singing	1
	happy/singing	1
	i like singing	1
	lets sing	1
	man singing	1
	music/singing	1
	musical	1
	siging	1
	sign	1
	sing out loud	1
	sing/singing/song	1
	singing school	1
	sucky singer	1
	talking/singing	1
	TOTAL	179

2.1 Polysemous and Shared Pictogram Interpretation

The analysis of the pictogram interpretation words revealed two characteristics evident in pictogram interpretation. Firstly, all 120 pictograms had more than one pictogram interpretation making them polysemous. That is, each pictogram had more than one meaning to its image. Secondly, some pictograms shared common interpretation(s) with one another. That is, some pictograms shared exactly the same interpretation word(s) with one another.

Here we take up eight pictograms to show the above mentioned characteristics in more detail. For the first characteristic, we will call it *polysemous pictogram interpretation*. For the second, we will call it *shared pictogram interpretation*. To guide our explanation, we categorize the interpretation words into the following seven categories: (i) people, (ii) place, (iii) time, (iv) state, (v) action, (vi) object, and (vii) abstract category. Images of the pictograms are shown in Fig. 2. Interpretations of Fig. 2 pictograms are organized in Table 2. Interpretation words shared by more than one pictogram are marked in *italics* in both the body text and the table.

People. Pictograms containing human figures (Fig. 2 (1), (2), (3), (6), (7), (8)) can have interpretations explaining something about a person or a group of people. Interpretation words like "*friends*, fortune teller, magician, prisoner, criminal, strong man, bodybuilder, tired person" all explain specific kind of person or group of people.

Place. Interpretations may focus on the setting or background of the pictogram rather than the object occupying the center of the setting. Fig. 2 (1), (3), (4), (7) contain human figure(s) or an object like a shopping cart in the center, but rather than focusing on these central objects, words like "church, jail, prison, grocery store, market, gym" all denote specific place or setting related to the central objects.

Time. Concept of time can be perceived through the pictogram and interpreted. Fig. 2 (5), (6) have interpretations like "night, *morning*, dawn, evening, bed time, day and night" which all convey specific moment of the day.

State. States of some objects (including humans) are interpreted and described. Fig. 2 (1), (3), (4), (5), (6), (7), (8) contain interpretations like "*happy*, *talking*, stuck, raining, basket full, *healthy*, sleeping, strong, *hurt*, tired, weak" which all convey some state of the given object.

Action. Words explaining actions of the human figure or some animal are included as interpretations. Fig. 2 (1), (5), (6), (7) include interpretations like "talk, *play*, sleep, *wake up*, exercise" which all signify some form of action.

Object. Physical objects depicted in the pictogram are noticed and indicated. Fig. 2 (4), (5), (7) include interpretations like "food, cart, vegetables, chicken, moon, muscle," and they all point to some physical object(s) depicted in the pictograms.

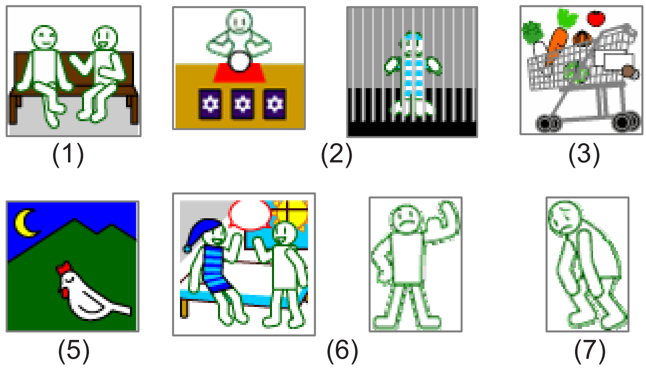


Fig. 2. Pictograms having polysemous interpretations (See Table 2 for interpretations)

Table 2. Polysemous interpretations and shared interpretations (marked in *italics*) found in Fig. 2 pictograms and their interpretation categories

PIC.	INTERPRETATION	CATEGORY
(1)	*friends* / church / *happy*, *talking* / talk, *play*	Person / Place / State / Action
(2)	fortune teller, magician / fortune telling, magic	Person / Abstract
(3)	prisoner, criminal / jail, prison / stuck, raining	Person / Place / State
(4)	grocery store, market / basket full, *healthy* / food, cart, vegetables / shopping	Place / State / Object / Abstract
(5)	night, *morning*, dawn, evening, bed time / sleeping / sleep, *wake up* / chicken, moon	Time / State / Action / Object
(6)	*friends* / *morning*, day and night / *happy*, *talking* / *play*, *wake up*	Person / Time / State / Action
(7)	strong man, bodybuilder / gym / strong, *healthy*, *hurt* / exercise / muscle / strength	Person / Place / State / Action / Object / Abstract
(8)	tired person / tired, weak, *hurt*	Person / State

Abstract. Finally, objects depicted in the pictogram may suggest more abstract concept. Fig. 2 (2), (4), (7) include interpretations like "fortune telling, magic, shopping, strength" which are the result of object-to-concept association. Crystal ball and cards signify fortune telling or magic, shopping cart signifies shopping, and muscle signifies strength.

We showed the two characteristics of pictogram interpretation, *polysemous pictogram interpretation* and *shared pictogram interpretation*, by presenting actual interpretation words exhibiting those characteristics as examples. We believe such varied interpretations are due to differences in how each respondent places his or her focus of attention to each pictogram. As a result, polysemous and shared pictogram interpretations arise, and this in turn, leads to semantic ambiguity in pictogram interpretation. Pictogram retrieval, therefore, must address semantic ambiguity in pictogram interpretation.

3 Pictogram Retrieval

We looked at several pictograms and their interpretation words, and identified semantic ambiguities in pictogram interpretation. Here, we propose a pictogram retrieval method that retrieves relevant pictograms from hundreds of pictograms containing polysemous and shared interpretations. In particular, human user formulates a query, and the method calculates the similarity of the query and each pictogram's interpretation words to rank pictograms according to the query relevancy.

3.1 Semantic Relevance Measure

Pictograms have semantic ambiguities. One pictogram has multiple interpretations, and multiple pictograms share common interpretation(s). Such features of pictogram interpretation may cause two problems during pictogram retrieval using word query. Firstly, when the user inputs a query, pictograms having implicit meaning, but not explicit interpretation words, may fail to show up as relevant search result. This influences recall in pictogram retrieval. Secondly, more than one pictogram relevant to the query may be returned. This influences the ranking of the relevant search result. For the former, it would be beneficial if implicit meaning pictograms are also retrieved. For the latter, it would be beneficial if the retrieved pictograms are ranked according to the query relevancy. To address these two issues, we propose a method of calculating how relevant a pictogram is to a word query. The calculation uses interpretation words and frequencies gathered from the pictogram web survey.

We assume that pictograms each have a list of interpretation words and frequencies as the one given in Table 1. Each unique interpretation word has a frequency. Each word frequency indicates the number of people who answered the pictogram to have that interpretation. The ratio of an interpretation word, which can be calculated by dividing the word frequency by the total word frequency of that pictogram, indicates how much support people give to that interpretation. For example, in the case of pictogram in Table 1, it can be said that more people support "*singing*" (84 out of 179) as the interpretation for the pictogram than "*happy*" (1 out of 179). The higher the ratio of a specific interpretation word of a pictogram, the more that pictogram is accepted by people for that interpretation.

We define *semantic relevance* of a pictogram to be the measure of relevancy between a word query and interpretation words of a pictogram. Let $w_1, w_2, \ldots, w_n$ be interpretation words of pictogram e. Let the ratio of each interpretation word in a pictogram to be $P(w_1|e), P(w_2|e), \ldots, P(w_n|e)$. For example, the ratio of the interpretation word "*singing*" for the pictogram in Table 1 can be calculated as $P(singing|e) = 84/179$. Then the simplest equation that assesses the relevancy of a pictogram e in relation to a query w_i can be defined as follows.

$$P(w_i|e) \tag{1}$$

This equation, however, does not take into account the similarity of interpretation words. For instance, when "*melody*" is given as query, pictograms having similar interpretation word like "*song*", but not "*melody*", fail to be measured as relevant when only the ratio is considered.

PICT	SR	INTERPRETATION WORDS
	0.331	**music**[109] **music notes**[3] **singing**[3] **song**[3] **melody**[2] **musical**[2] a song[1] beats[1] daze[1] flowing music[1] free music[1] jazz[1]
	0.230	**singing**[84] **sing**[68] **music**[4] **singer**[4] **song**[2] a person singing[1] good singer[1] happy[1] happy singing[1] happy/singing[1] i like singing[1]
	0.152	**singing**[38] **music**[34] **sing**[18] **band**[4] **choir**[4] **chior**[2] **concert**[2] a boy singing[1] a child singing[1] american idol[1] arts[1] audition[1]
	0.006	**talking**[16] **praying**[15] **thinking**[13] **speaking**[8] **lonely**[5] **singing**[5] **talk**[5] **pray**[3] **question**[3] **reading**[3] **speaker**[3] **talking to self**[3]

Fig. 3. Semantic relevance (*SR*) calculations for the query "*melody*" (in descending order)

To solve this, we need to define $similarity(w_i,w_j)$ between interpretation words in some way. Using the similarity, we can define the measure of *semantic relevance* $SR(w_i,e)$ as follows.

$$SR(w_i,e)=P(w_j|e)similarity(w_i,w_j) \quad (2)$$

There are several similarity measures. We draw upon the definition of similarity given in [5] which states that similarity between A and B is measured by the ratio between the information needed to state the commonality of A and B and the information needed to fully describe what A and B are. Here, we calculate $similarity(w_i,w_j)$ by figuring out how many pictograms contain certain interpretation words. When there is a pictogram set E_i having an interpretation word w_i, the similarity between interpretation word w_i and w_j can be defined as follows. $|E_i \cap E_j|$ is the number of pictograms having both w_i and w_j as interpretation words. $|E_i \cup E_j|$is the number of pictograms having either w_i or w_j as interpretation words.

$$similarity(w_i,w_j)=|E_i \cap E_j|/|E_i \cup E_j| \quad (3)$$

Based on (2) and (3), the *semantic relevance* or the measure of relevancy to return pictogram e when w_i is input as query can be calculated as follows.

$$SR(w_i,e)=P(w_j|e)|E_i \cap E_j|/|E_i \cup E_j| \quad (4)$$

We implemented a web-based pictogram retrieval system and performed a preliminary testing to see how effective the proposed measure was. Interpretation words and frequencies collected from the web survey were given to the system as data.

Fig. 3 shows a search result using the semantic relevance (*SR*) measure for the query "*melody*." The first column shows retrieved pictograms in descending order of *SR* values. The second column shows the *SR* values. The third column shows interpretation words and frequencies (frequencies are placed inside square brackets). Some interpretation words and frequencies are omitted to save space. Interpretation word matching the word query is written in blue and enclosed in a red square. Notice how the second and the third pictograms from the top are returned as search result although they do not explicitly contain the word "*melody*" as interpretation word.

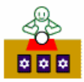
PICT	SR	INTERPRETATION WORDS
	0.304	cards[90] card game[7] playing cards[6] poker[6] game[5] card[4] games[4] ace[2] aces[2] deck of cards[2] gambling[2]
	0.256	video games[42] games[22] video game[11] game[6] computer[5] computer game[3] computer games[3] vidio games[3]
	0.209	fortune teller[18] magic[8] game[6] fortune telling[5] psychic[5] cards[4] gypsy[4] religion[4] bowling[3] magician[3]
	0.169	colors[62] art[13] paint[7] color[5] painting[5] color chart[2] different colors[2] paint colors[2] game[1]
	0.168	comics[11] super hero[9] entertainment[8] cartoons[6] cartoon[5] superhero[4] learning[3] superman[3] games[2] game[1]
	0.155	winner[49] winning[11] champion[9] first place[8] cheering[5] win[4] event[3] proud[3] award[2] olympics[2] game[1]
	0.093	sports[108] sport equipment[2] active[1] all sports[1] ball games[1] ballgames[1] balls and a bat[1] balls/sports[1] games with balls[1]

Fig. 4. Semantic relevance (*SR*) calculations for the query "*game*" (in descending order)

Since the second and the third pictograms in Fig. 3 both contain musical notes which signify melody, we judge both to be relevant search results. By defining similarity into the *SR* measure, we were able to retrieve pictograms having not only explicit interpretation, but also implicit interpretation.

Fig. 4 shows a search result using the *SR* measure for the query "*game*." With the exception of the last pictogram on the bottom, the six pictograms all contain the word "*game*" as interpretation word albeit with varying frequencies. It is disputable if these pictograms are ranked in the order of relevancy to the query, but the result gives one way of ranking the pictograms sharing a common interpretation word. Since the *SR* measure takes into account the ratio (or the support) of the shared interpretation word, we think the ranking in Fig. 4 partially reflects the degree of pictogram relevancy to the word query (which equals the shared interpretation word). A further study is needed to verify the ranked result and to evaluate the proposed *SR* measure.

One of the things that we found during the preliminary testing is that low *SR* values return mostly irrelevant pictograms, and that these pictogram(s) need to be discarded. For example, the bottom most pictogram in Fig. 3 has an *SR* value of 0.006, and it is not so much relevant to the query "*melody*". Nonetheless it is returned as search result because the pictogram contains the word "*singing*" (with a frequency of 5). Consequently, a positive value is assigned to the pictogram when "*melody*" is thrown as query. Since the value is too low and the pictogram not so relevant, we can discard the pictogram from the search result by setting a threshold.

As for the bottom most pictogram in Fig. 4, the value is 0.093 and the image is somewhat relevant to the query "*game*."

4 Conclusion

Pictograms used in a pictogram communication system are created by novices at pictogram design, and they do not have single, clear semantics. To find out how people interpret these pictograms, we conducted a web survey asking the meaning of 120 pictograms used in the system to respondents in the U.S. via the WWW. Analysis of the survey result showed that these (1) pictograms have polysemous interpretations, and that (2) some pictograms shared common interpretation(s). Such ambiguity in pictogram interpretation influences pictogram retrieval using word query in two ways. Firstly, pictograms having implicit meaning, but not explicit interpretation word, may not be retrieved as relevant search result. This affects pictogram recall. Secondly, pictograms sharing common interpretation are returned as relevant search result, but it would be beneficial if the result could be ranked according to query relevancy.

To retrieve such semantically ambiguous pictograms using word query, we proposed a semantic relevance measure which utilizes interpretation words and frequencies collected from the pictogram survey. The proposed measure takes into account the ratio and similarity of a set of pictogram interpretation words. Preliminary testing of the proposed measure showed that implicit meaning pictograms can be retrieved, and pictograms sharing common interpretation can be ranked according to query relevancy. However, the validity of the ranking needs to be tested. We also found that pictograms with low semantic relevance values are irrelevant and must be discarded.

Acknowledgements. We are grateful to Satoshi Oyama (Department of Social Informatics, Kyoto University), Naomi Yamashita (NTT Communication Science Laboratories), Tomoko Koda (Department of Media Science, Osaka Institute of Technology), Hirofumi Yamaki (Information Technology Center, Nagoya University), and members of Ishida Laboratory at Kyoto University Graduates School of Informatics for valuable discussions and comments. All pictograms presented in this paper are copyrighted material, and their rights are reserved to NPO Pangaea.

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This paper marks in red corrections made to the LNCS paper (p.35, p.37). - Cho

Pictogram Retrieval Based on Collective Semantics

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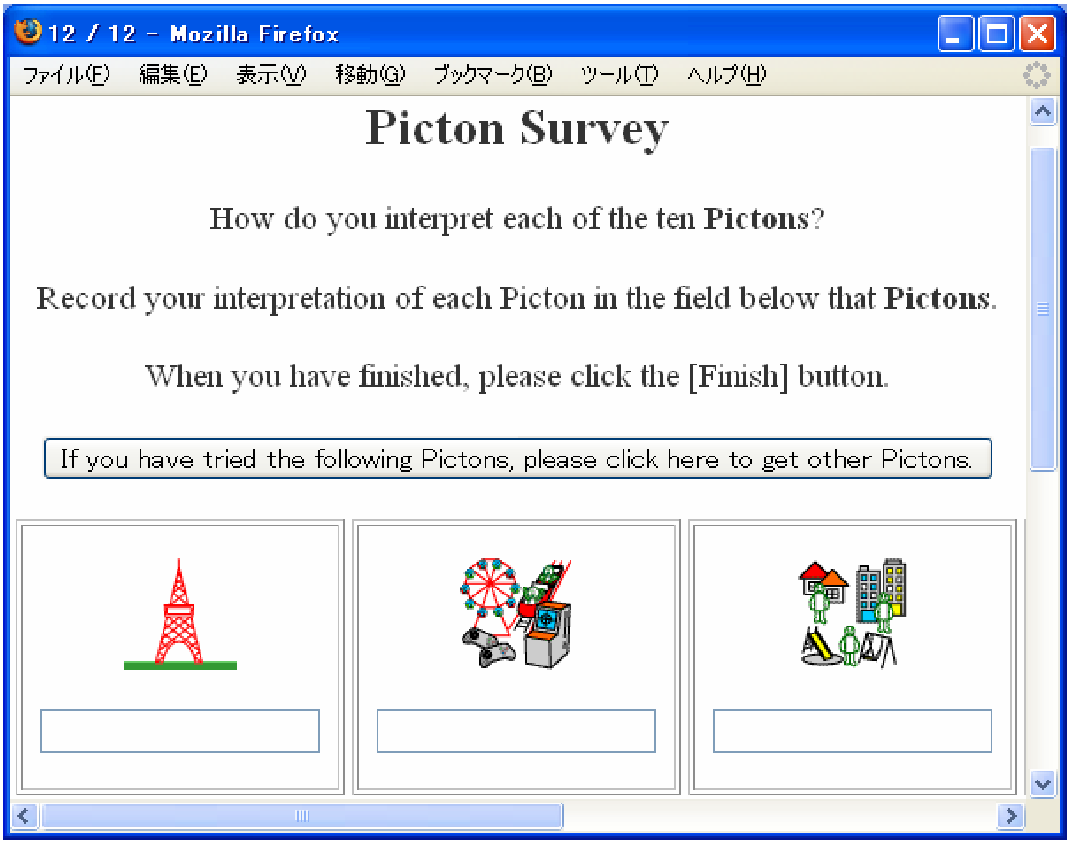

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	lets sing	1
	man singing	1
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	musical	1
	siging	1
	sign	1
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	sing/singing/song	1
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Place. Interpretations may focus on the setting or background of the pictogram rather than the object occupying the center of the setting. Fig. 2 (1), (3), (4), (7) contain human figure(s) or an object like a shopping cart in the center, but rather than focusing on these central objects, words like "church, jail, prison, grocery store, market, gym" all denote specific place or setting related to the central objects.

Time. Concept of time can be perceived through the pictogram and interpreted. Fig. 2 (5), (6) have interpretations like "night, *morning*, dawn, evening, bed time, day and night" which all convey specific moment of the day.

State. States of some objects (including humans) are interpreted and described. Fig. 2 (1), (3), (4), (5), (6), (7), (8) contain interpretations like "*happy*, *talking*, stuck, raining, basket full, *healthy*, sleeping, strong, *hurt*, tired, weak" which all convey some state of the given object.

Action. Words explaining actions of the human figure or some animal are included as interpretations. Fig. 2 (1), (5), (6), (7) include interpretations like "talk, *play*, sleep, *wake up*, exercise" which all signify some form of action.

Object. Physical objects depicted in the pictogram are noticed and indicated. Fig. 2 (4), (5), (7) include interpretations like "food, cart, vegetables, chicken, moon, muscle," and they all point to some physical object(s) depicted in the pictograms.

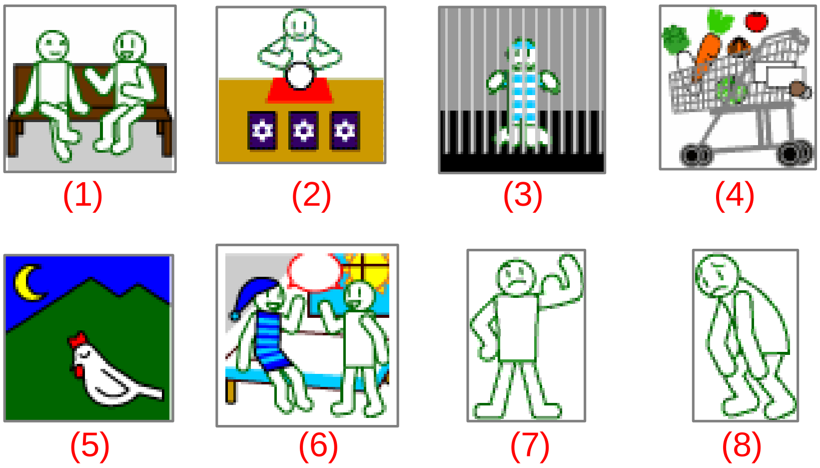


Fig. 2. Pictograms having polysemous interpretations (See Table 2 for interpretations)

Table 2. Polysemous interpretations and shared interpretations (marked in *italics*) found in Fig. 2 pictograms and their interpretation categories

PIC.	INTERPRETATION	CATEGORY
(1)	*friends* / church / *happy*, *talking* / talk, *play*	Person / Place / State / Action
(2)	fortune teller, magician / fortune telling, magic	Person / Abstract
(3)	prisoner, criminal / jail, prison / stuck, raining	Person / Place / State
(4)	grocery store, market / basket full, *healthy* / food, cart, vegetables / shopping	Place / State / Object / Abstract
(5)	night, *morning*, dawn, evening, bed time / sleeping / sleep, *wake up* / chicken, moon	Time / State / Action / Object
(6)	*friends* / *morning*, day and night / *happy*, *talking* / *play*, *wake up*	Person / Time / State / Action
(7)	strong man, bodybuilder / gym / strong, *healthy*, *hurt* / exercise / muscle / strength	Person / Place / State / Action / Object / Abstract
(8)	tired person / tired, weak, *hurt*	Person / State

Abstract. Finally, objects depicted in the pictogram may suggest more abstract concept. Fig. 2 (2), (4), (7) include interpretations like "fortune telling, magic, shopping, strength" which are the result of object-to-concept association. Crystal ball and cards signify fortune telling or magic, shopping cart signifies shopping, and muscle signifies strength.

We showed the two characteristics of pictogram interpretation, *polysemous pictogram interpretation* and *shared pictogram interpretation*, by presenting actual interpretation words exhibiting those characteristics as examples. We believe such varied interpretations are due to differences in how each respondent places his or her focus of attention to each pictogram. As a result, polysemous and shared pictogram interpretations arise, and this in turn, leads to semantic ambiguity in pictogram interpretation. Pictogram retrieval, therefore, must address semantic ambiguity in pictogram interpretation.

3 Pictogram Retrieval

We looked at several pictograms and their interpretation words, and identified semantic ambiguities in pictogram interpretation. Here, we propose a pictogram retrieval method that retrieves relevant pictograms from hundreds of pictograms containing polysemous and shared interpretations. In particular, human user formulates a query, and the method calculates the similarity of the query and each pictogram's interpretation words to rank pictograms according to the query relevancy.

3.1 Semantic Relevance Measure

Pictograms have semantic ambiguities. One pictogram has multiple interpretations, and multiple pictograms share common interpretation(s). Such features of pictogram interpretation may cause two problems during pictogram retrieval using word query. Firstly, when the user inputs a query, pictograms having implicit meaning, but not explicit interpretation words, may fail to show up as relevant search result. This influences recall in pictogram retrieval. Secondly, more than one pictogram relevant to the query may be returned. This influences the ranking of the relevant search result. For the former, it would be beneficial if implicit meaning pictograms are also retrieved. For the latter, it would be beneficial if the retrieved pictograms are ranked according to the query relevancy. To address these two issues, we propose a method of calculating how relevant a pictogram is to a word query. The calculation uses interpretation words and frequencies gathered from the pictogram web survey.

We assume that pictograms each have a list of interpretation words and frequencies as the one given in Table 1. Each unique interpretation word has a frequency. Each word frequency indicates the number of people who answered the pictogram to have that interpretation. The ratio of an interpretation word, which can be calculated by dividing the word frequency by the total word frequency of that pictogram, indicates how much support people give to that interpretation. For example, in the case of pictogram in Table 1, it can be said that more people support "*singing*" (84 out of 179) as the interpretation for the pictogram than "*happy*" (1 out of 179). The higher the ratio of a specific interpretation word of a pictogram, the more that pictogram is accepted by people for that interpretation.

We define *semantic relevance* of a pictogram to be the measure of relevancy between a word query and interpretation words of a pictogram. Let $w_1, w_2, \ldots, w_n$ be interpretation words of pictogram e. Let the ratio of each interpretation word in a pictogram to be $P(w_1|e), P(w_2|e), \ldots, P(w_n|e)$. For example, the ratio of the interpretation word "*singing*" for the pictogram in Table 1 can be calculated as $P(singing|e) = 84/179$. Then the simplest equation that assesses the relevancy of a pictogram e in relation to a query w_i can be defined as follows.

$$P(w_i|e) \quad (1)$$

This equation, however, does not take into account the similarity of interpretation words. For instance, when "*melody*" is given as query, pictograms having similar interpretation word like "*song*", but not "*melody*", fail to be measured as relevant when only the ratio is considered.

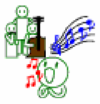
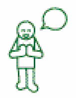
PICT	SR	INTERPRETATION WORDS
	0.331	**music**[109] **music notes**[3] **singing**[3] **song**[3] **melody**[2] **musical**[2] a song[1] beats[1] daze[1] flowing music[1] free music[1] jazz[1]
	0.230	**singing**[84] **sing**[68] **music**[4] **singer**[4] **song**[2] a person singing[1] good singer[1] happy[1] happy singing[1] happy/singing[1] i like singing[1]
	0.152	**singing**[38] **music**[34] **sing**[18] **band**[4] **choir**[4] **chior**[2] **concert**[2] a boy singing[1] a child singing[1] american idol[1] arts[1] audition[1]
	0.006	**talking**[16] **praying**[15] **thinking**[13] **speaking**[8] **lonely**[5] **singing**[5] **talk**[5] **pray**[3] **question**[3] **reading**[3] **speaker**[3] **talking to self**[3]

Fig. 3. Semantic relevance (*SR*) calculations for the query "*melody*" (in descending order)

To solve this, we need to define $similarity(w_i,w_j)$ between interpretation words in some way. Using the similarity, we can define the measure of *semantic relevance* $SR(w_i,e)$ as follows.

$$SR(w_i,e)=\sum P(w_j|e)similarity(w_i,w_j) \qquad \textbf{(2)}$$

There are several similarity measures. We draw upon the definition of similarity given in [5] which states that similarity between A and B is measured by the ratio between the information needed to state the commonality of A and B and the information needed to fully describe what A and B are. Here, we calculate $similarity(w_i,w_j)$ by figuring out how many pictograms contain certain interpretation words. When there is a pictogram set E_i having an interpretation word w_i, the similarity between interpretation word w_i and w_j can be defined as follows. $|E_i \cap E_j|$ is the number of pictograms having both w_i and w_j as interpretation words. $|E_i \cup E_j|$is the number of pictograms having either w_i or w_j as interpretation words.

$$similarity(w_i,w_j)=|E_i \cap E_j|/|E_i \cup E_j| \qquad \textbf{(3)}$$

Based on (2) and (3), the *semantic relevance* or the measure of relevancy to return pictogram e when w_i is input as query can be calculated as follows.

$$SR(w_i,e)=\sum P(w_j|e)|E_i \cap E_j|/|E_i \cup E_j| \qquad \textbf{(4)}$$

We implemented a web-based pictogram retrieval system and performed a preliminary testing to see how effective the proposed measure was. Interpretation words and frequencies collected from the web survey were given to the system as data.

Fig. 3 shows a search result using the semantic relevance (*SR*) measure for the query "*melody*." The first column shows retrieved pictograms in descending order of *SR* values. The second column shows the *SR* values. The third column shows interpretation words and frequencies (frequencies are placed inside square brackets). Some interpretation words and frequencies are omitted to save space. Interpretation word matching the word query is written in blue and enclosed in a red square. Notice how the second and the third pictograms from the top are returned as search result although they do not explicitly contain the word "*melody*" as interpretation word.

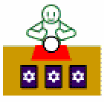
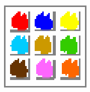
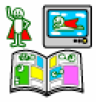
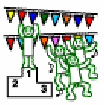
PICT	SR	INTERPRETATION WORDS
	0.304	cards[90] card game[7] playing cards[6] poker[6] game[5] card[4] games[4] ace[2] aces[2] deck of cards[2] gambling[2]
	0.256	video games[42] games[22] video game[11] game[6] computer[5] computer game[3] computer games[3] vidio games[3]
	0.209	fortune teller[18] magic[8] game[6] fortune telling[5] psychic[5] cards[4] gypsy[4] religion[4] bowling[3] magician[3]
	0.169	colors[62] art[13] paint[7] color[5] painting[5] color chart[2] different colors[2] paint colors[2] game[1]
	0.168	comics[11] super hero[9] entertainment[8] cartoons[6] cartoon[5] superhero[4] learning[3] superman[3] games[2] game[1]
	0.155	winner[49] winning[11] champion[9] first place[8] cheering[5] win[4] event[3] proud[3] award[2] olympics[2] game[1]
	0.093	sports[108] sport equipment[2] active[1] all sports[1] ball games[1] ballgames[1] balls and a bat[1] balls/sports[1] games with balls[1]

Fig. 4. Semantic relevance (*SR*) calculations for the query "*game*" (in descending order)

Since the second and the third pictograms in Fig. 3 both contain musical notes which signify melody, we judge both to be relevant search results. By defining similarity into the *SR* measure, we were able to retrieve pictograms having not only explicit interpretation, but also implicit interpretation.

Fig. 4 shows a search result using the *SR* measure for the query "*game*." With the exception of the last pictogram on the bottom, the six pictograms all contain the word "*game*" as interpretation word albeit with varying frequencies. It is disputable if these pictograms are ranked in the order of relevancy to the query, but the result gives one way of ranking the pictograms sharing a common interpretation word. Since the *SR* measure takes into account the ratio (or the support) of the shared interpretation word, we think the ranking in Fig. 4 partially reflects the degree of pictogram relevancy to the word query (which equals the shared interpretation word). A further study is needed to verify the ranked result and to evaluate the proposed *SR* measure.

One of the things that we found during the preliminary testing is that low *SR* values return mostly irrelevant pictograms, and that these pictogram(s) need to be discarded. For example, the bottom most pictogram in Fig. 3 has an *SR* value of 0.006, and it is not so much relevant to the query "*melody*". Nonetheless it is returned as search result because the pictogram contains the word "*singing*" (with a frequency of 5). Consequently, a positive value is assigned to the pictogram when "*melody*" is thrown as query. Since the value is too low and the pictogram not so relevant, we can discard the pictogram from the search result by setting a threshold.

As for the bottom most pictogram in Fig. 4, the value is 0.093 and the image is somewhat relevant to the query "*game*."

4 Conclusion

Pictograms used in a pictogram communication system are created by novices at pictogram design, and they do not have single, clear semantics. To find out how people interpret these pictograms, we conducted a web survey asking the meaning of 120 pictograms used in the system to respondents in the U.S. via the WWW. Analysis of the survey result showed that these (1) pictograms have polysemous interpretations, and that (2) some pictograms shared common interpretation(s). Such ambiguity in pictogram interpretation influences pictogram retrieval using word query in two ways. Firstly, pictograms having implicit meaning, but not explicit interpretation word, may not be retrieved as relevant search result. This affects pictogram recall. Secondly, pictograms sharing common interpretation are returned as relevant search result, but it would be beneficial if the result could be ranked according to query relevancy.

To retrieve such semantically ambiguous pictograms using word query, we proposed a semantic relevance measure which utilizes interpretation words and frequencies collected from the pictogram survey. The proposed measure takes into account the ratio and similarity of a set of pictogram interpretation words. Preliminary testing of the proposed measure showed that implicit meaning pictograms can be retrieved, and pictograms sharing common interpretation can be ranked according to query relevancy. However, the validity of the ranking needs to be tested. We also found that pictograms with low semantic relevance values are irrelevant and must be discarded.

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