

AN EFFICIENT WEB SEARCH ALGORITHM FOR MOBILE TERMINAL

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Abstract - We propose a fast Web search method for mobile terminals such as mobile phones. We need to input some terms for Web searching usually. A typical mobile phone has only about 12 keys. It is less than the kinds of alphabet characters. Therefore, it is difficult to input search-terms and search the intended Webpage on mobile terminals. In our proposed method, a user is able to rapidly input terms because our proposed method needs only one keystroke per character. Character-strings inputted by the user are ambiguous because each string corresponds to not only the intended term but also other terms. However, the ambiguous strings are not translated into the intended terms in our proposed method. The system based on our proposed method directly searches Webpages by the ambiguous strings and outputs the searched result based on co-occurrence. Thus, we are able to find the intended Webpage on a mobile phone rapidly and easily. In the result of the evaluation experiment, the Web search accuracy was 80[%] and the system was able to search Webpages by the correct terms at 90[%]. It was proved that our proposed method was effective for mobile terminals.

Keywords— Web Search, Mobile Terminal, Mobile Phone, Co-occurrence, Number-string, Disambiguation

I. INTRODUCTION

Recently, performance of mobile terminals such as mobile phones is greatly increasing. Some kinds of mobile phones have so high performance that they connect the Net and enable us to search Webpages. They have a Web browser. In Web search procedure, we need to input search-terms and choose the intended page generally. The processes have to be performed on a small device for a mobile phone.

We usually input some terms for the Web searching. A typical mobile phone has only about 12 keys. It is less than the kinds of characters. English has 26 alphabet characters and Japanese has about 50 *Kana* characters and so on. Therefore, it is difficult to input the terms and search Web pages rapidly and easily on mobile terminals such as a mobile phone.

A mobile phone excels in portability because the typical size is small. It has only number keys, which are 0, 1, ..., 9, * and #, because of its own size. A growing number of Smartphones, e.g. iPhones, Blackberries and so on have full QWERTY keyboards. It is not easy to press the intended key because the key size is small. Moreover, a user needs to press a few keys per *Kana* character since one *Kana* character generally consists of a few alphabets in Japanese. Therefore, we focus on 12 keys layout on mobile phones.

To input characters into a mobile phone, the letter cycling input method is most commonly used. The inputted character is decided by the chosen key and the number of pressing it. For example, a user chooses the key “2” and presses three times in order to input the alphabet “c”. It is troublesome for users since the input method needs several keystrokes per character. Therefore, a method is demanded which enable to promptly and easily input terms for Web searching.

Some input methods for mobile phones have been proposed [1][2] and the systems have been developed: e.g.

T9¹. T9 enables us to input one alphabet per key press on the keypad of 9 keys. Since three or four letters are assigned to each key of 9 keys, the specific letter intended by one key press is ambiguous. This system disambiguates the pressed keys on word-level. However, the system is for English mainly. Some input methods have been proposed for Japanese [3]–[7]. The methods enable us to input one *Kana* character per key press. Since about five *Kana* characters are assigned to each key on a mobile phone, the specific character intended by one key press is ambiguous. The methods disambiguate by dictionaries. Therefore, they are not able to translate the number-strings into words not included into the dictionary. Some predictive input methods have been proposed [8]–[10]. The methods output word-candidates by prediction or completion. The number of key presses increases to select the intended word when there are many word-candidates. Therefore, we focus on a text input method without prediction.

These input methods enable us to search Web pages by translation on a mobile phone. We are able to search Web pages to translate the inputted number-strings into the intended terms by the input methods for a mobile phone: i.e. number-*Kanji* translation in Japanese. However, it is troublesome for users to choose the intended terms in some candidates for each number-string.

We consider that the ambiguity of number-strings is able to be resolved by co-occurrence among search-terms in Web pages without translation. The system based on our proposed method is able to disambiguate the number-strings by the co-occurrence and enables us to find the intended Web pages on a mobile phone rapidly and easily.

¹Nuance Communications, Inc. has developed T9.
<http://www.nuance.com/>

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This paper shows the processes of our proposed method and the result of evaluation experiment for our proposed method.

II. WEB SEARCH WITH TRANSLATION

We are able to search Web pages by translation on a mobile phone without our proposed method. However, the Web searching with translation is troublesome for a user. Fig. 1 shows the procedure of the Web searching with translation.

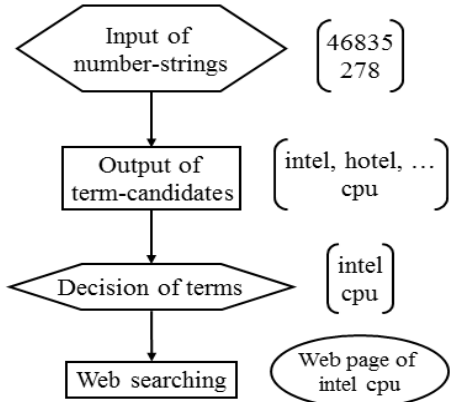


Fig. 1 Procedure of Web search with translation

A user inputs the number-strings for the intended terms. In Fig. 1, the search-terms intended by the user are “intel” and “cpu”. TABLE I shows how to input alphabet characters on a mobile phone.=

TABLE I CORRESPONDENCE OF NUMBER TO ALPHABET

1: .?-'	2: ABC	3: DEF
4: GHI	5: JKL	6: MNO
7: PQRS	8: TUV	9: WXYZ
*: .	0: .	#: space

The assignment of alphabet characters is commonly used and the system needs only one keystroke per alphabet character. The inputted number-strings are “46835” and “278” in this case. The system translates each number-string into term-candidates. In Fig. 1, the term-candidates for “46835” are “intel”, “hotel” and so on. The user needs to choose the intended one in some candidates. The user chooses “intel” in Fig. 1. Then, the system searches the Web page by the query of the terms chosen by the user. In Fig. 1, the query used for searching by the system is “intelANDcpu”. Although the user is able to input the number-strings for the search terms rapidly, it is troublesome for the user to choose the intended term in many candidates for each number-string.

We consider that ambiguity of number-strings is able to be resolved by co-occurrence among the search-terms in Web pages without translation. A term for a string co-occurs with a term for another one of the number-strings in Web pages. Therefore, the system based on our proposed method is able to disambiguate the number-strings by the co-occurrence and enables us to find the intended Web page on a mobile phone rapidly and easily.

III. OUTLINE OF OUR PROPOSED METHOD

Fig. 2 shows the procedure of our proposed method.

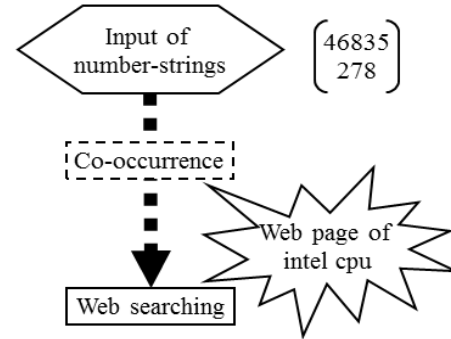


Fig. 2 Procedure of Web search without translation

A user inputs the number-strings for the intended terms. TABLE I shows how to input alphabet characters on a mobile phone. The assignment of alphabet characters is commonly used. Moreover, the system based on our proposed method needs only one keystroke per alphabet character. Therefore, the user is able to input characters rapidly and easily.

In Fig. 2, the user inputs the number-strings “46835” and “278”. The inputted number-string has ambiguity because the number-string “46835” corresponds to not only “intel” but also “hotel” and so on. However, the system based on our proposed method does not need to translate the number-strings into the terms intended by the user. The system directly searches Web pages by OR-query of the terms for each number-string.

In Fig. 2, the system based on our proposed method performs Web search by the query “{intelOR hotel} ANDcpu”. The search term “intel” co-occurs with the term “cpu” in Web pages because the searched result has many pages. On the other hand, the search term “hotel” does not co-occur with the term “cpu” in Web pages because the searched result has a few or no pages.

Our proposed method is able to disambiguate the number-strings on Web searching. The searched result is shown as a list of Web pages related to the search terms, with the most relevant page appearing first, then the next, and so on. Thus, the user is able to find the intended page on mobile terminals such as mobile phones rapidly and easily.

Then, the system extracts the terms from the Web page selected by the user. The system uses the extracted terms for generating the search-query in the next search. Because the terms are learned, the system is able to adapt to the user gradually.

We are able to find the intended page by the same method in Japanese also. Error! Not a valid bookmark self-reference. shows how to input Japanese Kana characters on a mobile phone²³. The assignment of Kana characters is

commonly used in Japanese. Moreover, the system based on our proposed method needs only one keystroke per Japanese *Kana* character. Therefore, a user is able to input characters rapidly and easily in Japanese.

TABLE II CORRESPONDENCE OF NUMBER TO KANA

1: <i>a, i, u, e, o</i>	2: <i>ka, ki, ku, ke, ko</i>	3: <i>sa, si, su, se, so</i>
4: <i>ta, ti, tu, te, to</i>	5: <i>na, ni, nu, ne, no</i>	6: <i>ha, hi, hu, he, ho</i>
7: <i>ma, mi, mu, me, mo</i>	8: <i>ya, yu, yo</i>	9: <i>ra, ri, ru, re, ro</i>
*: Voiced Sound, P-Sound	0: <i>wa, wo, n</i>	#: space

When the terms intended by the user are “北海道(*hotukaito***u*⁴; a proper noun)” and “大学(*ta***ika***ku*; the university)”, the user inputs the number-strings “64214*1” and “4*12*2”. The inputted number-string has ambiguity because the number-string “64214*1” corresponds to not only “大学(*ta***ika***ku*)” but also “同額(*to***uka***ku*; the same amount)”, “土井垣(*to***ika***ki*; a person's name)” and so on. Our proposed method disambiguates the number-strings on Web searching. The search-term “北海道(*hotukaito***u*)” co-occurs with the term “大学(*ta***ika***ku*)” in Web pages because the searched result has many pages. On the other hand, the search-term “北海道(*hotukaito***u*)” does not co-occur with the term “同額(*to***uka***ku*)” in Web pages because the searched result has a few or no pages.

Our proposed method uses OR-queries in order to realize the Web search. In this case, the system based on our proposed method performs Web search by the query “北海道(*hotukaito***u*) AND {大学(*ta***ika***ku*) OR 同額(*to***uka***ku*)

OR 土井垣(*to***ika***ki*)}”. The searched result is shown as a list of Web pages related to the search terms, with the most relevant page appearing first, then the next, and so on. Thus, the user is able to rapidly and easily find the intended page on mobile terminals such as mobile phones in even though Japanese and so on.

IV. PROCESSES

Fig. 3 shows the processes for our proposed method. The procedure consists of the number-strings input, the search-query generation, the Web searching, the Web page Choice and the term extraction in this order.

A. Number-Strings Input Process

In this process, a user inputs the number-strings for the intended terms. The key assignment is shown in TABLE I for English and in

³ Japanese *Kana* characters are written in *italics*.
⁴ “北海道” is generally expressed as “*hokkaido*” in Japanese pronunciation. However, “*hokkaido*” is translated into “64214*1” and the “64214*1” also corresponds to “*hotukaito***u*” in the system. Therefore, “*hokkaido*” is expressed as “*hotukaito***u*” in this paper.

Then, the system extracts the terms from the Web page selected by the user. The system uses the extracted terms for generating the search-query in the next search. Because the terms are learned, the system is able to adapt to the user gradually.

We are able to find the intended page by the same method in Japanese also. **Error! Not a valid bookmark self-reference.** shows how to input Japanese characters on a mobile phone. The assignment of *Kana* characters is commonly used in Japanese. Moreover, the system based on our proposed method needs only one keystroke per Japanese *Kana* character. Therefore, a user is able to input characters rapidly and easily in Japanese.

TABLE II for Japanese. The assignment of characters is commonly used. Moreover, the system based on our proposed method needs only one keystroke per alphabet character. Therefore, the user is able to input terms as number-strings rapidly and easily.

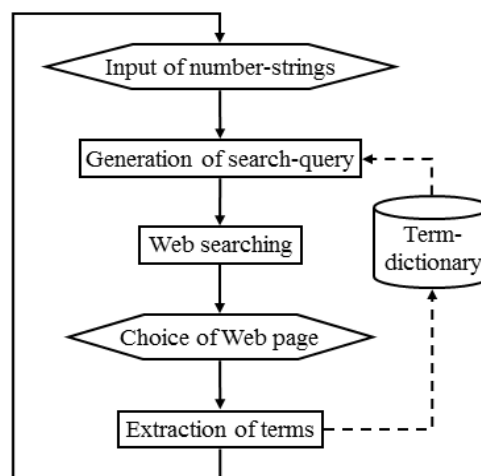


Fig. 3 Processes of our proposed method

B. Search-Query Generation Process

The number-strings inputted by the user have ambiguity because each number string corresponds to some term-candidates. However, the system based on our proposed method does not translate the number-strings into the terms intended by the user. The system directly searches Web pages by OR-query of the terms for each number-string. The system looks up each number-string in the term-dictionary. The example of the dictionary is shown in TABLE III.

TABLE III EXAMPLE OF TERM-DICTIONARY

Number-string	Term
:	:
46835	intel
46835	hotel
:	:
278	cpu
:	:

When the number-string agrees with the one in the term-dictionary, the term which corresponds to the number-string

is added to the search-query. Then, the search-query is generated by the term-dictionary.

C. Web Searching Process

The system searches Web pages by the query generated in the previous process. The searched result is shown as a list of Web pages related to the search terms, with the most relevant page appearing first, then the next, and so on.

D. Web Page Choice Process

The user needs to choose the intended Web page in the result because the searched result has many pages ordinarily. The user is able to immediately find the intended Web page when the rank of the Web page is high in the searched result.

E. Term Extraction Process

In this process, the system extracts the words in the chosen page as the terms. Then, the extracted terms are registered into the term-dictionary with the number-strings. The system is able to find the number-strings for the terms by the key assignment for the input in English.

However, it is difficult to find the number-strings for the terms in Japanese because Japanese has a lot of kinds of characters and Japanese sentences are not segmented ordinarily. The system uses “ChaSen” for the segmentation. “ChaSen” is a Japanese morphological analysis system[11]. The system is able to extract the terms and the number-strings because “ChaSen” segments the sentences and outputs the words and its *Kana* characters in Japanese. The system is able to find the number-strings for the *Kana* characters by the key assignment for the input in Japanese. The extracted number-strings and terms are registered into the term-dictionary.

The terms in the dictionary are used for the next searching. The selected Web page is suitable for the user. The words in the page are also suitable for the user. Therefore, it is available to use the extracted words for the next searching. Because the words are learned, the system is able to adapt to the user gradually.

V. EVALUATION EXPERIMENT

The system based on our proposed method has been developed for the experiment. The system searches Web pages in Japanese.

A. Data and Procedure

The data for extracting terms has 20 pages. They are included in the bookmark of the author of this paper. The system extracts the terms from the 20 pages. The result of the extraction is shown in TABLE IV.

TABLE IV LEARNED DICTIONARY

Kinds of terms	3,561
Kinds of number-strings	2,297
Average of perplexity per number-string	1.55
Entropy [bit]	10.74

In TABLE IV, the kinds of terms are 3,561 and the kinds of number-strings are 2,297 in the term-dictionary. The average of perplexity is 1.55 per number-string. Entropy H of the dictionary is calculated as follows:

$$H(x) = - \sum_{i=1}^N P(x_i) \log_2 P(x_i)$$

$$P(x_i) = \frac{C(x_i)}{T}$$

where N expresses the kinds of number-strings in the term-dictionary. N is 2,297 in the experiment. T is the number of terms in the dictionary. T is 3,561 in the experiment. x_i means a number-string in the dictionary. $C(x_i)$ is the appearance frequency of the number-string in the dictionary. $P(x_i)$ is the probability of the number-string.

The system searches 20 Web pages by the learned dictionary. The 20 pages are included in the author’s bookmark and are different from the 20 pages for extracting terms. We evaluate the search results by each title of the 20 pages. Each title is segmented by “ChaSen”. The system searches Web pages by the query based on the number-strings which corresponds to each segmented title. The search-query is generated by the terms which are looked up by the number-strings in the term-dictionary.

The average of the terms included into a query is 7.67 because the average of words in a segmented title is 4.95 and the average of perplexity per number-string is 1.55 in TABLE IV. The system needs to disambiguate the perplexity for Web searching correctly.

B. Results and Considerations

TABLE V shows the experiment result.

TABLE V SEARCH RESULT

	Rate[%]
First place	65.0 (13/20)
First page	80.0 (16/20)
Others	20.0 (4/20)
Search by the correct terms	90.0 (18/20)

The searched result is shown as a list of Web pages related to the search terms, with the most relevant page appearing first, then the next, and so on. When there is the intended Web page at the top of the list, it is “First place” in TABLE V. When the intended page is in the first 10th places of the list, it is “First page” in TABLE V. The list at the first page of the searched result has the links to 10 pages. We were able to find the intended Web pages at 80[%] at the first page in the searched result. It was proved that the system based on our proposed method was able to disambiguate number-strings by co-occurrence among search-terms in Web pages without translation and enabled us to find Web pages rapidly.

In the experiment, the intended pages at 20[%] were not found. The titles of 2 pages in the not found pages had proper nouns which were not included in the dictionary of “ChaSen”. The proper nouns were not registered into the term-dictionary and the search-query did not have them as the terms. Therefore, the system was not able to find the Web

pages. It is necessary to improve a Japanese morphological analysis system.

The ranks of 2 pages in the not found pages were low in the searched result. However, the queries of the 2 pages were correct. The system was able to disambiguate the inputted number-strings because the queries consisted of the terms intended by the user. Thus, the system was able to search the Web pages by the correct terms at 90%. The search system needs to more adapt to the user for searching the intended page.

VI. CONCLUSIONS

In this paper, we proposed a fast Web search method on mobile terminals such as mobile phones and evaluated Web search performance in the system based on our proposed method.

Some kinds of mobile phones enable us to search Web pages. We usually input some terms for Web searching. A typical mobile phone has only about 12 keys. It is less than the kinds of alphabet characters. Therefore, it is difficult to input the search-terms and search Web pages on mobile terminals such as mobile phones. Our proposed method needs only one keystroke per character. Then, the user is able to rapidly input terms. The key assignment is much the same as the commonly used one. So, the user is able to easily input terms.

The terms inputted by the user are expressed as number-strings. The system based on our proposed method searches Web pages by the number-strings for the search terms. Each number-string inputted by the user corresponds to many terms and has ambiguity. However, the system is able to disambiguate the inputted number-strings by the co-occurrence among the terms in Web pages. Therefore, we are able to find the intended Web page on a mobile phone rapidly and easily.

In the result of the evaluation experiment, the Web search accuracy was 80% and the system was able to search Web pages by the correct terms at 90% even though the inputted number-strings for Web searching were ambiguous. It was proved that our proposed method was effective for Web searching on mobile terminals such as mobile phones.

One of future work is to apply our proposed method to other languages. Because our proposed method is fundamentally independent of language property, our proposed method is able to apply to not only Japanese but also English and so on. Then, we need to evaluate the system based on our proposed method in other languages.

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