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One Touch Character: A Simplified Japanese Character Input Method for Mobile Computing

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***Abstract*— This paper reports that useful search applications can be developed around "One-Touch-Character", a simplified method using digit keys originally developed for display-free touch-tone-telephones. Several input methods created in Japan have transformed into cultures characterized by their specific operations. "One-Touch-Character", one of the oldest methods, was born in 1990s and is seen as obsolete in the smartphone era. This paper introduces and compares input methods developed over the last 25 years. The drastic changes in appearance and features, from touch-tone telephones to smartphones through mobile phones, have strongly influenced input style. Though young people learnt quickly and became experts, those who could not catch the innovations became IT illiterates. To help them become positive users, we return to "One-Touch-Character". After investigating several different databases, we clarify what database characteristics suit "One-Touch-Character".**

Keywords—One-Touch-Character, character input method, smartphone application, information retrieval, overlap ratio, degeneration ratio

I. Introduction

Nowadays, we enjoy e-mail communications and information retrieval services on the Internet using personal computers at home or mobile phones outside. Character input operations to enter Japanese are inevitable to complete such activities.

Japanese input methods strongly depend on hardware specifications such as the number of keys and their layout. We note that text communication began with pagers and touch-tone-telephones. The recent adoption of the phonetic style became possible only with recent smart phones.

Quite different approaches to Japanese character input have emerged and transformed into quite specific cultures. Many other countries, especially in Asia, have their own style of character input reflecting their syllabaries (vowels and consonants) [1] [2].

To enter a Japanese word or a phrase, we usually need two steps: First, we enter yomigana (pronunciation spelling in hiragana strings) for a word or a phrase using Roman letters and press a key for translation. Second, we select one of the candidates translated and expressed in a mixed style of kanji and hiragana (Japanese syllabary) shown in the display. Though using a keyboard for Japanese character input is not a tough task, realizing input via devices with fewer keys needs some special ideas.

Young Japanese started to send short messages from touch-tone-telephones in the 1990s. "Coded-Character" [3] and "One-Touch-Character" [4] [5] [6] were developed for touch-tone-telephones and "Multi-Touch-Per-Character" [7] was introduced when e-mail via mobile phones entered service at the end of the 1990s.

When iPhones were put on the market in 2008, the innovative input method called "Flick" [8] [9] was provided and quickly prevailed, especially among students and young adults. These methods strongly depend on hardware specifications and the recent trend in Japanese character input methods reflects the quick and drastic changes of hardware specifications. The emergence of a new device or an innovative input method impacts the behavior of users in the same as a medium media alters user habits [10].

When we developed a precursor to the automated directory assistance service in 1998 using "One-Touch-Character"; touch-tone-telephones were used as keyword input devices [4]. At that time, we decided to use "One-Touch-Character" because we considered this method to be "easy-to-learn" and "easy-to-operate" to all Japanese, regardless of age or sex. This service was very successful with more than 16 million users until it was terminated in 2007 mainly due to users shifting to keyword searches on the Internet.

After our experience, though follow-on research in 2002 [6] and the release of an open source IME (Input Method Editor) with "One-Touch-Character" in 2012 [7] are observed, these proposals did not attract many users. These facts suggested that the "One-Touch-Character" method was considered obsolete by users and that make "One-Touch-Character" attractive again was to select suitable applications. When we developed this method in 1990s, we expected that it would be widely applied to information retrieval applications by all generations. Given the current popularity of smartphones, we have to take care of those users who have failed to keep abreast of the drastic technical changes and have become IT illiterates, especially the elderly.

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To serve these users, we again weighed pros and cons of the "One-Touch-Character" method and the characteristics of the database used in the automated directory assistance system and some other databases to clarify what conditions would "One-Touch-Character" applications useful and well accepted.

II. Character Input Methods in Japan

In western countries, QWERTY keyboards from typewriters are widely used in both the office and the home. As people of all generations are well trained and experienced in keyboard use, they never thought of using the digits of mobile phones to input text, even when mobile phones appeared in the market.

When they gained the ability to access to the Internet and edit e-mails via mobile phones, keyboards were implemented on mobile phones such as Blackberry terminals. When smartphones emerged, software keyboards were displayed on the screen for text entry. To enter words or sentences, they just touched the alphabet keys. As keyboard culture has so deeply penetrated western countries, using key-scarce devices such as touch-tone-telephones or mobile phones as input devices as never caught on.

On the contrary, Japanese generally do not learn to use keyboards as character input devices until they enter high school or college, and start using personal computers at home. Office workers have already learned in school to enter Japanese characters via Roman letters (see Table 1) and use keyboards as input devices in daily business.

Recently, most school children receive mobile phones or smartphones from their parents for family communications. They also enjoy social network services or information retrieval over the Internet. Thus Japanese students usually begin to learn to enter text via digit keys on mobile phones or smartphones.

Four input methods have been developed in Japan as is described in the Introduction.

(a) Coded-Character method,
(b) One-Touch-Character (Single-Tap-Per-Character) method,
(c) Multi-Tap-Per-Character method,
(d) Flick method.

A brief explanation of the characteristics of each method is given below:

(a) In the "Coded-Character" method, each Japanese character is coded as 2 digits: For example, vowels "あ(a), い(i), う(u), え(e), お(o)" are coded as "11, 12, 13, 14, 15" , and consonant column "k" with "か(ka), き(ki), く(ku), け(ke), こ(ko)" are coded as "21, 22, 23, 24, 25". Voiced sound marks in Japanese characters (" °", " ゛ " in "が(ga)", "ぱ(pa)") are separated from the original character "か(ka)", "は(ha)"and coded as "04" and "05".

This method emerged in the 1990s to send short messages to pagers and was frequently used by high school and college students. However, the appearance of mobile phones made this method old fashioned.

The big disadvantage was that most user terminals of that period had no display, so a user sending a short message had no way to confirm the characters entered. The message service took the digit sequence from the sender, translated it into a character string, and then displayed it on the receiver's pager.

(b) In the "One-Touch-Character" method, 71 Japanese hiragana characters (Japanese syllabary: 46 basic voiceless sound and 25 voiced sound characters) were assigned to ten digits of touch-tone-keys (Table 1).

TABLE I. Japanese syllabary and assignment to digits

あ(a)	い(i)	う (u)	え(e)	お(o)	Vowels→1
か(ka)	き(ki)	く(ku)	け(ke)	こ(ko)	k→2
さ(sa)	し(si)	す(su)	せ(se)	そ(so)	s→3
た(ta)	ち(ti)	つ(tu)	て(te)	と(to)	t→4
な(na)	に(ni)	ぬ(nu)	ね(ne)	の(no)	n→5
は(ha)	ひ(hi)	ふ(fu)	へ(he)	ほ(ho)	h→6
ま(ma)	み(mi)	む(mu)	め(me)	も(mo)	m→7
や(ya)		ゆ(yu)		よ(yo)	y→8
ら(ra)	り(ri)	る(ru)	れ(re)	ろ(ro)	r→9
わ(wa)				を(wo)	w→0
ん(nn)					nn→0
が(ga)	ぎ(gi)	ぐ(gu)	げ(ge)	ご(go)	g→2
ざ(za)	じ(zi)	ず(zu)	ぜ(ze)	ぞ(zo)	z→3
だ(da)	ぢ(di)	づ(du)	で(de)	ど(do)	d→4
ば(ba)	び(bi)	ぶ(bu)	べ(be)	ぼ(bo)	b→6
ぱ(pa)	ぴ(pi)	ぷ(pu)	ぺ(pe)	ぽ(po)	p→6

Basically, the five voiceless sound characters sharing the same consonant were assigned to the same digit as is shown in fig.1. Two basic ideas were proposed to distribute voiced sound characters: one allocated a voiced consonant row with similar hiragana image to the same digit (ex. "は(ha)", "ば(ba)","ぱ(pa)"→digit 6), the other forced the user to additionally touch the " * " key to indicate that the first touched unvoiced sound character should be changed to a voiced sound character (ex. "か(ka)"+" * "→"が (ga)"). The first idea is used in this paper.

To input a character, the user only needed to touch a digit key once to indicate the intended character. Confusion among the five characters was resolved by ambiguity resolution process of the input system using the sequence of characters entered. If the system was unable to eliminate ambiguity, the user was asked to select the intended word from the presented candidates.

This method is a very easy-to-learn and easy-to-operate input method compared with other methods. This method can be also accepted by the elderly and children who are not experienced with using a touch tone key set as an input device.

Fig.1 Assignment of hiragana characters to digits

This method was originally developed to input keywords to an automated directory assistance service via display-free touch-tone-telephones in Japan. In this sense, this input method focused on information retrieval and was not intended to work as an IME.

The system receives the user-entered keywords for directory search as digit sequences and uses these sequences to find the desired subscriber. The subscriber's name is then translated into yomigana characters and spoken to the user. For this purpose, the directory database has an additional directory database that holds numeral codes for yomigana combinations. This input system requests additional preparatory work on the target database.

In the original directory assistance system, users could not see the input digit sequence because most touch-tone-telephones did not have a display. Even if a phone had a display, users only see the digit sequence entered [5][6].

(c) "Multi-Tap-Per-Character" method uses the same character assignment as "One-Touch-Character". In this method, the second idea mentioned above is generally used to specify the voiced sound.

Users need to press the same digit multiple times until they get the intended character on the display (e.g.; Press digit 2 once to get "か (ka)", twice to get "き (ki)" and three times to get "く (ku)" and so on).

This method was used by mobile phone users mainly to exchange mail messages. They also used this input method to get information on the Internet by using search engines such as Yahoo or Google.

The main purpose of this input method is to enter Japanese texts and sentences including mail messages as a Japanese IME. In this method, a user enters a word or a phrase in yomigana (hiragana strings) and presses the translation key to change it into a regular expression of kanji and hiragana.

This method was widely used by everyone regardless of age or sex with the emergence of mobile phones in the 1990s. This was dominant input method until smartphones with flick input appeared and was adopted by young users.

(d) The "Flick" method was popularized by the "iPhone" which entered service in 2008 in Japan. It provides users with an innovative input method by taking full advantage of software touch tone keys displayed on the screen.

This method can identify the intended character among the candidates shown in extra key images that pop up around the first touched key. A user need only flick his/her finger in the direction of the intended character (e.g.: Press "2" and flick "down" to get "こ (ko)". Press "2" and flick "right" to get "け(ke)") as is shown in fig. 2.

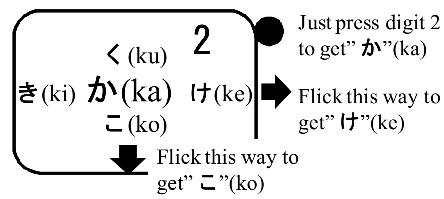

Fig. 2 Examples of the "Flick" method operation on digit 2

Though this method basically needs two operations to get the intended character, it was quickly adopted by students and young adults who are heavy users of smartphones. Thus young users rapidly shifted to the "Flick" method from "Multi-Touch-Per-Character" while the older more conservative users stuck with the "Multi-Tap-Per-Character" method. This method is also intended to be used as a Japanese IME.

Among these four input methods, we choose to extend the "One Touch Character" method to better utilize the smartphone features and to develop useful search applications to be accepted by wide range of users even in the smartphone era.

The "One-Touch-Character" method must overcome the ambiguities derived from its operation as collisions can occur when a keyword is entered as digits. To make the search operations of an application user-friendly, we must investigate the original data and its numeral codes in advance and minimize collision possibilities so that the user has little need to resolve ambiguities.

III. INVESTIGATION OF DEGENERATED KEYWORDS

In the automated directory assistance system, we use address fragments and personal names (subscribers) as the keywords for directory search. Since "One-Touch-Character" input method is adopted, all characters are entered as numeral codes, and are added to the original character data. In addition, a personal name database from Wikipedia Japan and a Japanese word dictionary from an open Japanese dictionary for machine translation are collected and edited for investigation.

A. Address Database

Address fragments (prefecture, city, town, street, block name, etc.) are used to restrict the search area. Given that the target database for search holds over 40 million subscribers, using personal names as search keywords is not effective. We needed to narrow the search area down to city or town level. Users were requested by the system to confirm the address parts.

(Prefecture Level)

In Japan, we have 47 prefectures, 3988 cities (including wards, counties), and 342 thousand towns and villages. As for prefectures, all of the names are different both in kanji and yomigana combinations and have no collision, but once transformed into digit sequences, two prefectures collide: “Yamagata-ken(やまがたけん)” and “Yamaguchi-ken(やまぐちけん)” has the same digit sequence “982420”.

We define the average overlap ratio (OL) and degeneration ratio (DG) % of combination A to combination B as follows:

OL_{AtoB} = (number of unique items in A combination) / (number of unique items in B combination)

$DG_{AtoB} = (1- 1/ OL_{AtoB})$ *100 (%).

For prefecture names as example,

$OL_{Kanji\text{-}to\text{-}Yomigana} = 1.0$

$DG_{Kanji\text{-}to\text{-}Yomigana} = 0\%$

$OL_{Yomigana\text{-}to\text{-}Digits} = 47/46 = 1.021$

$DG_{Yomigana\text{-}to\text{-}Digits} = (1\text{-}1/1.021)*100 = 2.1\%$

Regarding the city name level and the town name level, we can clearly see the characteristics of these values.

Though entering a keyword at prefecture level as a yomigana or even as digits inevitably yielded the correct prefecture name in kanji or hiragana, this information was not so effective in narrowing down the search area. Users were requested to enter additional address details down to the city or town level.

(Town & Village Level)

Here, we plot the possibility of yomigana combinations versus input string length in Fig. 3, taking the town level data as an example. Note that this figure uses a logarithmic vertical scale

Since we have 71 yomigana characters in Japan listed in Table 1, the number of possible combinations of N yomigana strings are 71**N (line A). Similarly, the number of possible combinations of N digits are 10**N (line B). However, the extant number of yomigana strings (line C) or numeral digits (line D) at town and village level are very small in the real world compared with the possible numbers as is shown in Fig. 3.

We can also see that the number of extant yomigana combinations almost matches the number of extant digit combinations in the range where N≥8, which means that few collisions occur in this area. It is easily understood that collisions are likely occur for N≤ 7 (Though Line C diverges from line D for N≤7, Line C overlaps Line D for N≥8).

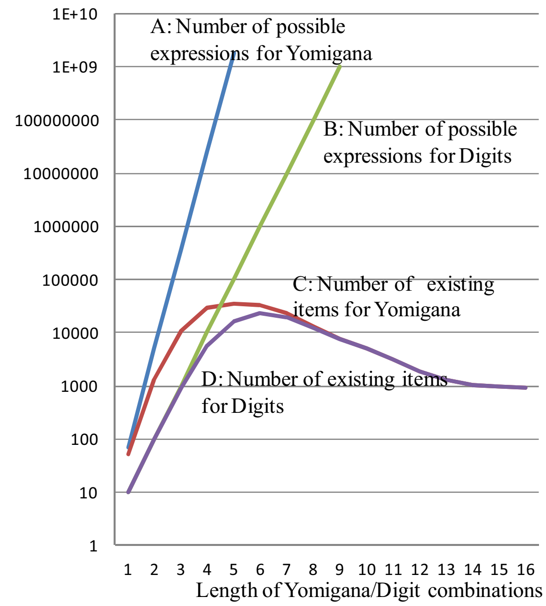

Fig. 3 Possible combinations/extant items vs. combination length

The same situation is shown in Fig. 4 which uses a linear vertical scale, deleting the possibility lines (Line A, B) and adding the line of extant kanji combinations. The situation of the average overlapping ratio (OL) and degeneration ratio (DG) can be examined from two aspects: Kanji-to-Yomigana, and Yomigana-to-Digits.

At town and village level, the following facts are clarified;

$OL_{Kanji\text{-}to\text{-}Yomigana}$ (1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
= (11.1, 7.1, 4.1, 3.1, 2.1 1.5, 1.4, 1.1, 1.05, 1.03),

$DG_{Kanji\text{-}to\text{-}Yomigana}$ (1, 2, 3, 4, 5, 6, 7, 8, 9. 10)
= (91, 86, 76, 68, 51, 33, 27, 8.8, 5.2, 3.1) %,

$OL_{Yomigana\text{-}to\text{-}Digits}$ (1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
= (5.1, 13.0, 12.1, 5.4, 2.2, 1.4, 1.2, 1.05, 1.01, 1.00),

$DG_{Yomigana\text{-}to\text{-}Digits}$ (1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
= (80, 92, 92, 81, 54, 30, 17, 4, 7, 1.7, 0.7) %.

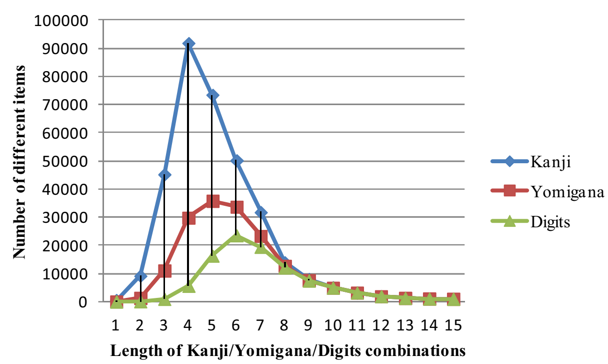

Fig. 4 Address data distributions: town and village level
(A kanji item is classified according to its yomigana length)

Left-side values in parentheses are the number of yomigana characters or digits. The right side values are the average overlap ratio (OL) or the degeneration ratio (DG).

OL values are nearly 1.0 and DG values approach 0% if N exceeds 8. This means that in the range of N≥8, there are few collisions in the database of digit sequences.

Concerning the $OL_{Yomigana\text{-}to\text{-}Digits}$ and $DG_{Yomigana\text{-}to\text{-}Digits}$ at the town and village level, in the range of N≤7, both $OL_{Yomigana\text{-}to\text{-}Digits}$ and $DG_{Yomigana\text{-}to\text{-}Digits}$ values are comparatively high. If OL≥2, there almost occurs collision when a digit keyword is entered. If OL=1, no collision occurs, which means that a unique yomigana is returned for any given digit keyword. In the case of 1<OL≤ 2, collision occurs at the probability of ($OL_{Yomigana\text{-}to\text{-}Digits}$ -1).

Most of town and village level (94.6%) names fall into the range of 3≤N≤12 and the collision probability is 1.0 in the range of 3≤N≤5. In the range of 9≤N≤12, the collision probability is almost 0. The collision probabilities are 0.43, 0.20, and 0.05 for N=6, 7, 8, respectively. When a collision occurs, a single digit keyword returns more than two yomigana candidates, which often come up to ten depending on the overlap degree in the range of 3≤N≤8. (e.g., We have 4 yomigana candidates, "さたちよう(sa-ta-chi-yo-u)", "さだちよう(sa-da-chi-yo-u)", "しどちよう(si-do-chi-yo-u)", "せとちよう (se-to-chi-yo-u)", for the input digit keyword "34481". Only the last one "せとちよう(se-to-chi-yo-u)" has a kanji candidate "瀬戸町" in two different prefectures, "愛媛県(Ehime-ken)" and "岡山県(Okayama-ken)". Each of the remaining candidates has a unique kanji combination.)

This indicates that, at this address level, lots of yomigana candidates might be returned for a single digit keyword in the range of 3≤N≤8 (N: number of digits), a range that most of the items in the database fall into. This also implies that we will need additional time and operations for selecting the true target from among several candidates.

Considering the OL and DG combinations for Kanji to Yomigana shown above, similar difficulties for obtaining a target kanji combination from yomigana are expected. To summarize, at this address level, entering a keyword as a digit string to locate the target yomigana and final kanji target is not a good strategy because of the time consuming operations needed.

(City, Ward and County Level)

The numbers of extant items (kanji, yomigana and digits) is shown in Fig.5 as functions of yomigana and digit length.

We have 3988 different items in kanji combinations and 3728 different items in yomigana combinations and 3108 different items in digit combinations. The average overlap ratio of Kanji-to-Yomigana is 1.069 and the same ratio for Yomigana-to-Digits is 1.199.

Most of the 3988 address items have yomigana/digit lengths from 3 to 9 and we can see that there is a big difference from Fig. 4. OL and DG ratios of the City and County Level are much smaller than that of the Town and Village Level. The details are as follows:

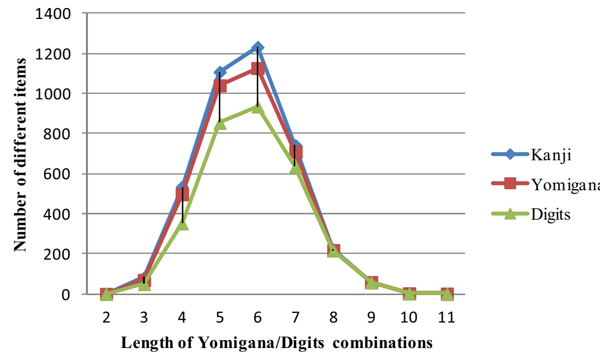

Fig.5 Address data distributions: city and county level
(A kanji item is classified according to its yomigana length)

$OL_{Kanji\text{-}to\text{-}Yomigana}$ (2, 3, 4, 5, 6, 7, 8, 9, 10)
= (1, 1.18, 1.07, 1.06, 1.09, 1.04, 1.02, 1, 1),
$DG_{Kanji\text{-}to\text{-}Yomigana}$ (2, 3, 4, 5, 6, 7, 8, 9. 10)
= (0, 16, 6.9, 6.0, 8.5, 4.4, 2.2, 0, 0) %,
$OL_{Yomigana\text{-}to\text{-}Digits}$ (2, 3, 4, 5, 6, 7, 8, 9, 10)
= (1, 1.4, 1.4, 1.2, 1.2, 1.1, 1.0, 1, 1),
$DG_{Yomigana\text{-}to\text{-}Digits}$ (2, 3, 4, 5, 6, 7, 8, 9, 10)
= (0, 28, 29, 18, 17, 10, 0.46, 0, 0) %.

$OL_{Kanji\text{-}to\text{-}Yomigana}$ values are very small for yomigana lengths of 3 to 8 and only 12.9% of city or county names (expressed as digits) have lengths of 3 to 4 occur collisions with the probability of 0.3. About 78% digits for 5 to 7 length occurs collisions with probability of only 0.15. (e.g.: we have 6 yomigana candidates,"いいだし(i-i-da-si)" "うえだし(u-e-da-shi)", "うおづし(u-o-du-si)", "おおたし(o-o-ta-si)", "おおだし(o-o-da-si)", "おおつし(o-o-tu-si)", for the input digit keyword "1143". We only have one solution of "おおたく(o-o-ta-ku)", for the input digit keyword "1142".)

This suggests that users will generally get a unique yomigana solution by inputting a digit sequence at this level. We can conclude that entering address information at the city or county level is the best way for the "One-Touch-Character" method to identify the intended address in Japan.

B. Personal Name Database in Directory

We prepared a set of personal names in Fukui prefecture in Japan by automatically collecting and editing the telephone directory used in the directory assistance service. About 260 thousand subscriber names (family name and given name) were collected and translated into numeral codes. This size of database is normally used as a search area for the directory assistance service.

(Family Name Level)

In this database, there are 13,700 different family names in kanji, and 10,600 unique yomigana combinations and 3,700 unique digit combinations. The distributions of family name lengths are shown in Fig. 6.

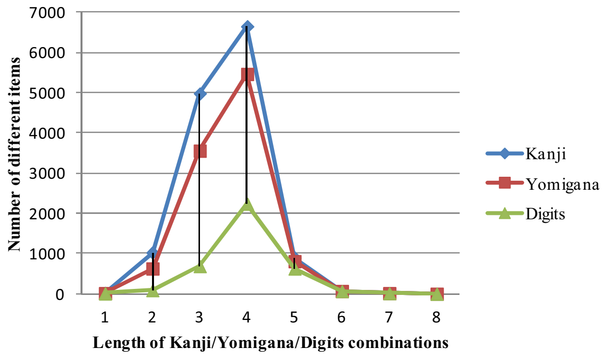

Fig. 6 Family name distributions (length)
(A kanji item is classified according to its yomigana length)

This figure shows that 99% of surnames in Japan consist of 3 to 5 yomigana and that $DG_{\text{Kanji-to-Yomigana}}$ ratios are small though $DG_{\text{Yomigana-to-Digits}}$ ratios are large. This suggests that using numeric keywords to locate a family name by using yomigana or kanji combinations is a very tough task and this kind of search job is not suitable for the "One-Touch-Character" input method. For example, we have 4 yomigana candidates, "おおしま(o-o-si-ma)", "あおしま(a-o-si-ma)", "うえしま(u-e-si-ma)", "うおずみ(u-o-zu-mi)", for a given digit keyword "1138". We also have 4 kanji candidates, "上島", "上嶋", "植嶋", "植島", for a given yomigana keyword, "うえしま (u-e-si-ma)".

(Given Name Level)

We have 39,000 different kanji combinations of given names, 10,600 different yomigana combinations, and 3,800 digit combinations. About 99% of given names consist of 2 to 6 in yomigana. Quite a different view can be seen in Fig. 7 which shows the distribution of given names in the same manner. $DG_{\text{Kanji-to-Yomigana}}$ ratios are big and $DG_{\text{Yomigana-to-Digits}}$ ratios are small. These remarkable points are derived from the fact that Japanese given names draw on a relatively small selection of yomigana while we are free to allocate kanji characters to a yomigana given name. As a result, many kanji combinations are possible for a single yomigana given name.

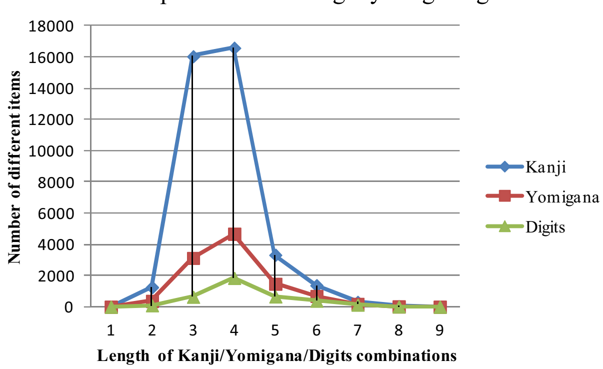

Fig.7 Given name distributions (length)
(A kanji item is classified according to its yomigana length)

This suggest that returning a yomigana given name from a keyword in digits is not as tough a task as getting a yomigana family name from a keyword in digits, but it is also a tough task to get an intended kanji/hiragana combination from a given name in digits. (e.g.; We have 6 candidates, "ゆうこ(yu-u-ko)", "ようこ(yo-u-ko)", "やえこ(ya-e-ko)", "ゆうき(yu-u-ki)", "ゆいこ(yu-i-ko)", "やおこ(ya-o-ko)", for the given digit keyword "812". We have lots of kanji candidates for each name up to more than 70 in total.

This kind of search task is also not appropriate for the "One-Touch-Character" input method. From the above investigations, we can recognize the difficulties and inefficiencies in entering personal names by digits with separate entry of family name and given name.

(Full Name = Family Name + Given Name)

Next, we check the database of full names in the directory. There are 221 thousand different kanji combinations 178 thousand unique yomigana combinations, and 135 thousand unique digit combinations. Their distributions are shown in Fig. 8.

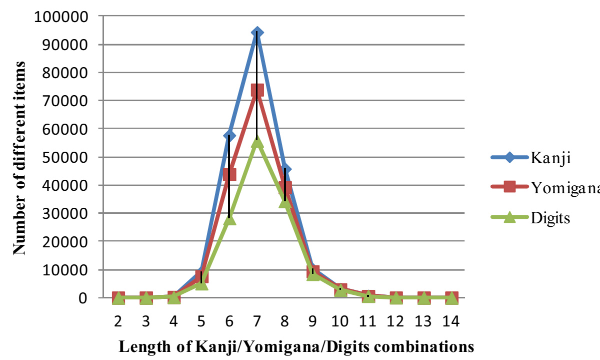

Fig.8 Full name distributions (length)
(A kanji item is classified according to its yomigana length)

About 97% of full names have lengths of 5 to 9. The OL and DG ratios for Yomigana-to-Digits are listed below:

$OL_{\text{Yomigana-to-Digits}}$ (3, 4, 5, 6, 7, 8, 9, 10)
= (1, 1.0, 1.5, 1.6, 1.3, 1.1, 1.1, 1.0),

$DG_{\text{Yomigana-to-Digits}}$ (3, 4, 5, 6, 7, 8, 9, 10)
= (0, 4, 33, 36, 25, 13, 10, 6) %.

Though the DG ratios are a little bit high for lengths from 5 to 7, the corresponding OL ratios are small (less than 1.6). This fact shows that the disambiguation task of selecting the target yomigana from those returned by a digit keyword is not tough for users. A similar trend is seen for disambiguating kanji combination s returned from yomigana keywords.
This also suggests that for this size of database, it is an easy task to locate a target personal name by entering a digit string.

C. Personal names in the Wikipedia; Who's Who

We collected personal names from the Japanese Wikipedia (open source) and added translated numeric codes to create a database for "One-Touch-Character" use. This database contains about 130 thousand entries covering Japanese historical person, statesman, scholars in various areas, movie/TV talents, athletes in various fields, people in the spotlight. The distributions are shown in Fig.9.

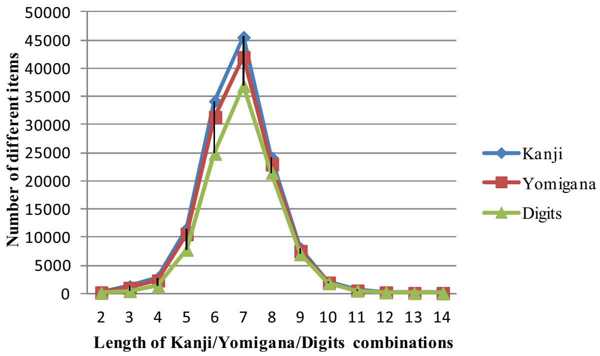

Fig.9 Who's Who name distributions (length)
(A kanji item is classified according to its yomigana length)

About 99% names have lengths from 3 to 10. A check of the data showed that 65% of personal names with different yomigana were converted into different digits. The remaining names collide. The OL and DG ratios for Yomigana-to-Digits are listed below;

$$OL_{\text{Yomigana-to-Digits}}(3, 4, 5, 6, 7, 8, 9, 10) = (2.4, 1.8, 1.4, 1.3, 1.1, 1.1, 1.1, 1.0),$$

$$DG_{\text{Yomigana-to-Digits}}(3, 4, 5, 6, 7, 8, 9, 10) = (58, 46, 26, 21, 12, 7, 7, 2)\ \%$$

The plots have similar shape, but the big difference is that OL and DG ratios of names in the Who's Who are smaller than those of names in the directory, which means that searching the Who's Who is much easier than the directory. (e.g.; We have only one solution "あべしんぞう(a-be-si-nn-zo-u), prime minister of Japan" for the given digit keyword "163031" and 2 candidates, "わたなべけん(wa-ta-na-be-ke-nn), a famous actor", "わたなべかん(wa-ta-na-be-ka-nn), a historian", for the digits keyword "045620".)

This kind of search task is very appropriate for the "One-Touch-Character" input method.

D. Japanese Dictionary

We prepared a Japanese dictionary using data from a machine translation project. Nouns, verbs, adjectives, adverbs, conjunctives etc. were collected and coded into digits, by excluding proper nouns such as place names, landmarks, points of sightseeing and personal names. About 100 thousand words were collected. There are 55 thousand unique yomigana combinations and 22 thousand unique digits combinations. The length distributions are plotted in Fig. 10.

The words in the dictionary are quite short. About 97% of the words have lengths of 2 to 7. The OL and DG for Yomigana-to-Digits are listed below:

$$OL_{\text{Yomigana-to-Digits}}(1, 2, 3, 4, 5, 6, 7, 8, 9, 10) = (6.7, 18, 12, 4.5, 1.6, 1.1, 1.0, 1.0, 1.0, 1),$$

$$DG_{\text{Yomigana-to-Digits}}(1, 2, 3, 4, 5, 6, 7, 8, 9, 10) = (85, 94, 92, 78, 38, 11, 2, 1, 1, 0)\ \%.$$

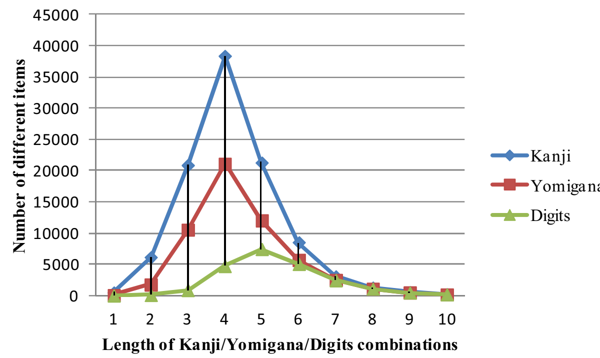

Fig.10 Distributions of Japanese dictionary entries
(A kanji item is classified according to its yomigana length)

These ratios mean that a lot of disambiguation would be needed if we used the "One-Touch-Character" as the input method. This explains why prior research [3][4] that used the "One-Touch-Character" method for editing Japanese texts or e-mails were not successful.

IV. Discussions

We can summarize our investigation of using the "One-Touch-Character" method to enter search keywords as follows;

1) Address input at prefecture level creates no ambiguity, but prefecture level information is not good enough to identify the desired subscriber. More address information must be input to narrow down the search area.
2) Address input at town or village level yields frequent collision, and disambiguation is needed.
3) Address input at city and county level is the best solution, because the collision probability is small.
4) To identify a person in a personal name database using either family name or a given name is not a good strategy. It is much more efficient to enter full personal names.
5) To identify a person in a personal name database collected from Japanese Wikipedia is an easy task because the collision probability is small.
6) To identify a word in a Japanese word dictionary is a very tough task because the collision probability is high for both yomigana search using digit keywords and kanji search by yomigana keywords.
7) In every case, collision is more prevalent if the string length is small. Collision probability falls dramatically when the string length exceeds 8 or 9.

The results of this study suggest that to ensure wide service acceptance of the "One-Touch-Character" input method we must

a) Select databases that evidence minimal collision:

b) Request users to input related information for disambiguation:

If more than three candidates are returned, the user is prompted for additional digit keywords. A connectivity check on the two groups of candidates returned by the two digit keywords excludes meaningless pairs leaving the correct candidate.

Given that modern smartphones have large displays, the restriction of b) will be eased as more candidates, say up to ten, can be displayed for user selection.

Reviewing our research results for address parts and Who's Who, the collision probability should be less than 0.35 as a tentative target. As this probability falls, fewer candidates will be presented for resolution.

V. CONCLUSION

In Japan, we have a 35 year history of character input technologies. A variety of input methods have been developed and offered to the public in this time period. Some of the methods mentioned in this paper grew to into booming technologies and formed a sort of Japanese input culture, especially among young adults and students. Method preference strongly depends not only on the pros and cons of the operations but also on the hardware and software performance and features reflecting the continual hardware innovations.

Among the inputs methods, we adopted the "One-Touch-Character" method, with which we had success in 2000s and tried to promote this method by examining database optimization.

To ensure that the "One-Touch-Character" input method is widely used by all generations, we investigated a database that showed the method to its best advantage and other two potential databases which can be used as services on smartphones.

One key issue for the pronoun database is that the degeneration ratio should be very small to ensure that the collision probability is small. This means that most searches would return a single result, and that, even in the case of collision, we can easily select the target from the small number of candidates displayed on the screen.

Another issue for consideration would be whether the application is atractive or not. But this is not a technical issue.

As for potential users, we expect physically handicapped patients suffering ALS (amirotrophic lateral sclerosis) who have difficulties in touch operations and small preschool children who are not experienced in touch operations.

Who's Who will be a good potential database for a search application, unlike Japanese word dictionaries. Thus, we developed a search application for Who's Who retrieval, and installed it on smartphones with software-based touch-tone-keys designed on the screen. and are now evaluating its usability and popularity for users.

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