Invited Paper

Keyboards for Inputting Japanese Text and Training Methods for Touch Typing

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The most important issue for inputting Japanese text into computer is making touch typing popular, because without experience in this skill, discussions in this paper cannot be properly understood. Therefore, it is first shown that such skill may be obtained only by two or three hours of training. A cognitive model is also shown for typing which is useful for designing a CAI system of typing. Then, keyboards for inputting Japanese text and code input method for direct input of Kanji are reviewed. A critique of input methods is also shown. Finally, comments are made on standardization of keyboards.

1. Introduction

For the input of Japanese text with its unique mixture of Kanji and Kana there have been many methods suggested and used [1], [2]. However, only two methods, input of characters by codes, and kana to Kanji conversion remain.

Coded Input In this method, every character has a unique code. To input the desired character, its code is typed in. Any code may be constructed provided that the desired character is always uniquely determined from the input.

Kana-Kanji Conversion: In this method the Kana pronunciation of the desired characters is input. At a fixed point (for example the end of each phrase) the Kana are converted into Kanji. As there are many possible such conversions for a single piece of input, it is necessary to interactively prompt the user to choose the correct characters.

It is possible to input Japanese text by typing in the Roman alphabet instead of Kana. However the dictionary is not indexed by Roman letters. Therefore, it is not necessary to set up a separate method for Roman alphabet to kanji conversion, as it may be included in Kana-Kanji conversion.

Among conversion methods there are methods of indicating which type of characters are being entered while typing (for example, the 'M-type' keyboard [3]).

There is also a method where kanji can be input by typing the pronunciation in Kana, and then using a keyboard arrangement displayed on the screen to select the correct Kanji [4]. This methods may become coded input method when user's skill is established in such a way that Kanji may be uniquely determined by typing without seeing the displayed screen.

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In this paper, topics on learning blind typing is first presented, because without experience in this skill, discussions in this paper cannot be properly understood. Then, various keyboards for inputting Japanese text and coded input for Kanji are reviewed and several experiments for evaluating these methods are shown. Finally, comments are made on standardization of connection between the keyboard and the computer instead of that of the keyboard itself.

Most of the materials are taken from the recent review article [5] by one (H. O.) of the authors, but the section four for various keyboards are newly written by the other author (H. T.).

2. An Easy Method for Learning Blind Typing

Generally, it is thought that the purpose of typing training is simply to become a professional typist. A typist can simply enter words without any need to explicitly consider the actions necessary, like how we talk without having to consciously direct the actions of our mouths. To make the typing motions automatic, it is normally necessary to practice with tens of thousands of everyday words. To develop these reflexes takes about 400 hours of training and 1000 hours of typing experience.

Consider a computer programmer who has not been trained in typing. Because only a limited vocabulary is used, a lesser amount of training is sufficient. Also, although a typist is expected to be able to type at high speed at work, this speed is not necessary for personal tasks.

Memorizing the position of individual keys is at least important in blind typing. Also, blind typing is particularly useful for persons of middle age with reduced vision.

Therefore, training for specialist typists and training for general users is quite different cases. However, because there are generally only study aids designed for specialist typists, the courses are planned around long practice. Among such books, there exist a book [6] in which only five hours is spent for memorizing the position of the keys.

A particularly important feature of this book written by P. S. Pepe is that all the example words to be practiced are real English words from the very beginning. This use of real words encourages the feeling that the student is on the road to becoming a real typist.

Following the course of the book, in five to ten hours the positions of the keys should be memorized, and the learner should be able to type without watching his/her hands. Afterwards, while using these basics, the learner should become able to type without consciously directing the typing movements.

For memorizing the arrangement of the keys, masuda [7] has recently proposed a more efficient method. While the memorization of keys is still considered a mental task, blind typing is the task of having the fingers become trained so that the typing motions are reflexive.

To make sure that the method has been properly memorized, it is necessary to repeat lessons as revision. However, by only repeating the same simple texts, the connection between the letters typed and the relevant finger movements will not be reinforced. This will only lead to a mechanical typing movement and not to a reflexive ability. A set of texts for practice must therefore be carefully designed.

Masuda claims that some fingers are difficult to move while others are easy. The forefinger is considered the easiest to move but this finger is assigned twice as many keys as other fingers. Therefore, the middle finger is considered the easiest to move in typing. The forefinger is the next. Furthermore, the third, and smallest finger gradually become less useful for typing. A new training method is examined from the viewpoint of the ease of use of these fingers.

For learning blind typing, at first the "home position" must be located. The left hand will be on the keys 'ASDF', and the right hand will be on the keys 'JKL;'. For other keys it is necessary to move either individual fingers or the whole hand and strike the key with the designated finger. Using this method with repeated practice, the positions of the keys should be memorized.

As a concrete example of the method, to memorize the position of the 'K' key, a learner would type 'KK', 'JK', 'HK', 'LK', ';K'. then the learner would type 'IK', 'UK', 'YK', 'OK', 'PK'. Finally, ',K', 'MK', 'NK', '.K', '/K'. For keys other than 'K', the learner is doing preparatory exercises as part of this practice, so to speak. Simply by typing these exercises, the position of the key should become memorized in a natural manner. For keys other than 'K', an easy to type order has been chosen. This ordering does not follow the arrangement of the keyboard but has been chosen to make the task of memorizing easier, and less of a burden. Also, it is considered that this is a method which will lead to a natural style of typing movement of the finger.

Next the 'J' key' position is memorized. To do this, the learner types 'KJ', 'JJ', 'HJ', 'LJ', ';J', 'IJ', 'UJ', 'YJ', 'OJ', 'PJ', ',J', 'MJ', 'NJ', '.J', '/J'. The next key to practice is 'H'. This memorization method has a fixed order of keys, 'KJHL; IUYOP, MN./', chosen according to easiness of typing motion. After practicing with the right hand, the same method is used for the left.

Because this is a mechanical method of training, initially it can be frightening. For this reason, Masuda's method may be used with the recorded voice which designates the keys to type. This technique was first adopted in the so-called "Slight and Sound" method, which is claimed to allow a learner to master typing in 13 hours. Comparing this to the situation where text is being read by eye while typing, listening to a tape is less difficult for the learner. Furthermore, this method encourages concentration because if a letter is not heard it is missed. This concentration improves the results of practice. When reading a text, because a letter can always be read again, the learner is likely to be too much relaxed and will tend to fail to concentrate sufficiently.

For memorizing the positions of the keys, this method is perhaps the best. With efficient practice it should be possible to memorize the keys in little more than an hour. Like swimming, riding a bicycle, and other physical training, if the learner stops practicing immediately after learning the skill it will be forgotten. To be able to use a keyboard unconsciously, like talking, it is needed to add layer upon layer of training.

3. A Cognitive Model of Typing

While it is easy to memorize the arrangement of an English language keyboard, this only allows the typing of text in a character by character manner. In training for typing it is natural to learn to read whole words and phrases at a time and type them without conscious effort. For the recognition and typing of normal English words and phrases by reflex, it is said that even Americans and Europeans need a thousand hours of experience.

Also, there is another important point which results in an increase in speed. According to Salthouse [8], for an experienced typist who can type a normal key in 250 milliseconds or less, the reaction time for a key struck by the forefinger was about 500 to 600 milliseconds. This was in response to a stimulus indicating left or right. If a typist types character by character in response to a stimulus, speed of experienced typist would never be obtained.

When a Computer Aided Instruction (CAI) system for typing was developed by one (H. O.) of the authors, a cognitive model shown in Fig. 1 was used [9]. In this model, information read by the eye is converted into finger movements and stored in an output buffer.

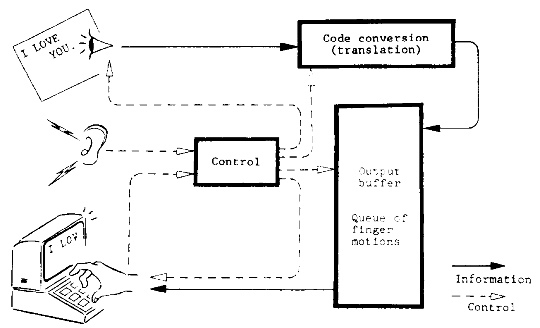

Fig. 1 A Cognitive Model of Typing.

Because this buffer is storing characters in a queue, the eye will be several characters ahead of what is being typed. A beginner who has only just memorized the positions of the keys cannot perform this buffering activity. However, the number of characters that can be "buffered" will increase along with practice.

An experienced typist will buffer words and phrases as single chunks. The typist's fingers will naturally start typing from the first letter of each chunks, and type letters one by one almost regularly. The eye will read the next chunk before the buffer is empty. Then, the speed of typing is limited by the speed of finger movement and not by that of reading.

As described, after learning the positions of the keys, it is necessary to train the learner so that s/he develops this buffering ability. Furthermore, from the very beginning, for example common words like "the", an unconscious typing method will be developed.

Most typing CAI systems that have been developed produce some sort of alarm sound when a mistake is made. They will then wait for correct input before continuing. However, this discourages the development of a buffering approach. It is normal for a beginner to make mistakes. By allowing the learner to continue without worrying about mistakes, rapid progress should result.

One important reason for lack of progress in typing training is that the learner is psychologically unable to bear mistakes and decides to look at his/her hands while typing. This allows for typing without making mistakes but will not lead to the learner's finger becoming trained in blind typing.

The learner's finger will become trained, so that typing can be performed unconsciously. This not only allows the learner to type documents without excessive concentration, but also the learner will tend to realize when a mistake has been made. Then, it is possible to correct mistakes if made. Because this sensitivity is not present with hunt and peck methods, it is not possible to find typing errors without re-reading the typed text.

4. Keyboards for use with Japanese Language Text

In this section, keyboards for Japanese word processing machines and word processing software on personal computers are discussed for inputting Japanese text.

In the following text we will consider a keyboard as being described by the following three aspects.

(1) Character key (for Kana input) arrangement, or code key (for code input) arrangement

(2) Mechanical function key (all other keys apart from character or code keys) arrangement

(3) The physical arrangement of the keys

4.1 Character Key Arrangement

There have been many possible key arrangements proposed for the input of Kana text. Although for inputting Japanese text, not only Kana but also Kanji (chinese character) must be handled. However, as the most popular methods for inputting Japanese text is Kana-Kanji conversion, key arrangements for Kana are of primary importance. Some arrangements which can be seen in (common or rare) use are described as follows:

JIS.S Arrangement: (Word processors, personal computers. Shift key at each end of the bottom row of keys)

JIS.P Arrangement: (Toshiba word processors. Prefix key at the left of the upper row and the right side of the middle row)

OASYS Arrangement: (Fujitsu word processors. "Thumb" shift key arrangement)

New JIS.S Arrangement: (Word processors. Shift key at each end of the bottom row)

New JIS.P Arrangement: (Word processors, Prefix key at each end of the bottom row)

QWERTY Arrangement: (Word processors and personal computers)

M-type (KAISOKU) Arrangement: (Word processors and personal computers)

SKY Arrangement: (Personal computer software)

TUT Arrangement: (Personal computer software, Kana input is a part of code-input of Kanji)

'mykey' Arrangement: (Personal computer software)

With input by Kana, just counting the Kana (including the voiced and half voiced syllables), there are 81 characters that must be able to be entered directly from the keyboard. A keyboard simply doesn't have enough keys for each of these characters to be assigned a unique key. Therefore it is necessary to assign multiple keys to a character.

Keyboards designed for such a problem can be divided into three types: the sequential key-press method, a shift method, and pressing multiple keys simultaneously.

The Sequential Key-Press method: Multiple keys are pressed one by one to input a single character. As an example:

か (ka) and then the voicing consonant key (note 1) produces が (ga). JIS.S, JIS.P, New JIS.S, New JIS.P.

は (ha) and then the half voicing consonant key (note 2) produces ぱ (pa). JIS.S, JIS.P, New JIS.S, New JIS.P.

'Kana Symbol' key (note 3), then や (ya) produces ゃ (small ya). JIS.P.

Table Tabe of Key Arrangements Characteristics* for 83 Kana (including punctuation marks).

	Name of key arrangement	JIS.S	JIS.P	OASIS	New JIS.S	New JIS.P	Q'TY	SKY	KAISOKU***	TUT	mykey
	No. of key-strokes /kana	1.23	1.23	1.40	1.25	1.25	1.70	1.48	1.66	2.20	2.00
	Seq. Key-Press	1.11	1.23	1.00	1.11	1.25	1.70	1.48	1.66	2.20	2.00
	Shift	0.12	—	0.01	0.14	—	—	—	—	—	—
	Mult. Key Simul.	—	—	0.39	—	—	—	—	—	—	—
	Alternate hands	47%	56%	46%	58%	69%	42%	93%	86%	90%	100%
	Same hand	53%	44%	54%	42%	31%	58%	7%	14%	10%	—
	Modified key-strokes**	0.94	0.89	1.08	0.99	0.82	1.34	0.79	0.85	1.21	1.00
	No. of keys for Kana	50	50	35	34	34	24	33	24	17	20
No. and percentage of keys in each row	Top row	13	13	—	—	—	1	1	1	—	—
		15%	15%	—	—	—	0%	0%	0%	—	—
	Upper row	12	13	11	11	11	9	11	6	7	10
		34%	41%	19%	25%	25%	54%	21%	28%	40%	28%
	Home row	12	13	10	11	11	7	11	10	9	10
		21%	25%	44%	47%	47%	32%	68%	56%	58%	72%
	Lower row	13	11	12	12	12	8	10	7	—	—
		30%	19%	10%	28%	28%	14%	11%	16%	—	—
	Thumb	—	—	2	—	—	—	—	—	1	—
		—	—	27%	—	—	—	—	—	2%	—
No. and percentage of keys of each finger	Little Finger	5	5	4	4	4	2	3	1	2	2
		10%	10%	7%	10%	10%	15%	8%	6%	4%	7%
	Ring Finger	4	4	3	3	3	3	3	1	2	2
		10%	10%	6%	8%	8%	7%	11%	9%	7%	10%
	Middle Finger	4	4	3	3	3	2	3	2	2	2
		12%	12%	10%	10%	10%	8%	12%	11%	14%	15%
	Index Finger	8	8	6	6	6	5	6	4	4	4
		18%	18%	12%	16%	16%	15%	19%	25%	20%	18%
	Thumb	—	—	1	—	—	—	—	—	—	—
		—	—	12%	—	—	—	—	—	—	—
	Left hand	21	21	17	16	16	12	15	8	10	10
		50%	50%	47%	44%	44%	45%	50%	51%	45%	50%
	Thumb	—	—	1	—	—	—	—	—	1	—
		—	—	15%	—	—	—	—	—	2%	—
	Index Finger	8	8	6	6	6	5	6	6	3	4
		14%	14%	13%	19%	19%	23%	19%	23%	23%	18%
	Middle Finger	4	4	3	3	3	3	3	3	2	2
		7%	7%	10%	12%	12%	19%	13%	10%	20%	15%
	Ring Finger	4	4	3	3	3	2	3	3	1	2
		8%	8%	7%	12%	12%	13%	12%	8%	10%	10%
	Little Finger	13	13	5	6	6	2	6	4	—	2
		21%	21%	8%	13%	13%	0%	6%	8%	—	7%
	Right hand	29	29	18	18	18	12	18	16	7	10
		50%	50%	53%	56%	56%	55%	50%	49%	55%	50%

*Calculation is based on the data published by Japan Electronic Industry Development Association (March 1983).
**Modified key-strokes=No. of Press/Kana × (Rate of alt. hands/2 + Rate of the same hand)
***KAISOKU is a modified M-type arrangement for kana input on the standard keyboard.

'Shift' (note 4) and か (ka) produces へ (he). New JIS.P. 'K' and then 'A' produces か (ka). QWERTY, M-type (KAISOKU), SKY, TUT, mykey.

Notes 1, 2: Because this key is typed after character keys, it is referred to as the "Postfix" key. This Postfix key is the same in operation as other character keys.

Note 3, 4: Because this key is struck before character keys but is not required to be pressed until character keys are typed, it is naturally referred to as the "Prefix" key. It also is the same in operation as character keys, and in this respect differs from the Shift key.

The Shift Method: In this method while a special key is continuously pressed, other keys are struck entering a

single character each. For example:
while 'Shift' (note 5) is being pressed, や (ya) is typed. The result is ゃ (small ya). JIS.S.
while 'Shift' (note 6) is being pressed, か (ka) is typed. The result is へ (he). New JIS.S.
While 'Little Finger Shift' (note 7) is being pressed, は (ha) is typed. The result is ぱ (pa). OASYS.

Notes 5, 6, 7: These keys are not just pressed before another key but must be held down until the following key is released. This is similar to the normal typewriter 'Shift' key but is only used for this type of input.

Pressing Multiple Keys Simultaneous: This is pressing several keys at the same time to input a character. For example:
か (ka) and the same hand 'Thumb Shift' (note 8) at the same time produces え (e). OASYS.
か (ka) and the opposite hand 'Thumb Shift' at the same time produces が (ga).
'K' and the opposite hand 'Thumb Shift' at the same time designate "KY" sound part of a kanji. M-type.
'A' and the opposite hand 'Thumb Shift' at the same time designate "AN" sound part of a Kanji. M-type.

Note 8: Because this key is pressed at the same time as other keys, it is referred to as the "Simul" key. this makes it different from the usual 'Shift' key.

When trying to design the most suitable key arrangement for the input of Kana, the following subjects may be considered:

(1) The number of key-strokes necessary for one Kana input

(2) The movements the fingers will make when operating the keyboard

(1) must be considered to achieve efficiency of operation. It is an important consideration no matter what input method is used. We may see that 'Shift' and 'Simul' keys were proposed to minimize this number if we do not count the key-strokes of these keys.

(2) is the reason that comes from the fact that touch-typing has become popular. Furthermore, from a viewpoint of ergonomics much emphasis has been put on this subject. A few points to do with this are outlined as follows:

(2.1) Necessary horizontal finger movements during keyboard operation. It is better if few such movements are needed.

(2.2) The number of keys assigned to a single finger. Once again, the fewer the better.

(2.3) The number of special purpose keys such as 'Shift' and 'Simul' which are necessary for operation. It is better not to use such keys.

(2.4) Keys that either precede or follow other keys. It is better if alternate keystrokes are divided between the two hands, rather than being typed by the same hand.

When considering point (2.3), even if pressing multiple keys at the same time, it is inconvenient to use both hands or to use the thumb of one hand with a different finger. It is much better to use neighboring fingers (such as the middle and forefingers).

For point (2.4), even when typing successive strokes with one hand, it is best to use neighboring fingers on the same level. For example, the middle and forefingers.

4.2 The Arrangement of Coded Input Keys

The arrangements of the keys in a coded input methods currently in use are shown. Details of coded input methods are described in [1] and also in section five. We can divide the codes into groups based on the following three properties:

(1) Code length: There are codes with a code length of two strokes, or a mixture of two and three strokes.

(2) How the code is designed: Use Kanji-teletypewriter arrangement. The association method and no-association method, whether there is a logical connection between the codes and characters.

(3) Whether Kana is entered separately: Whether all characters are entered by the same mechanism, or there is a separate input method only for Kana. When there is a separate method for Kana, what arrangement of the keys is used for Kana.

Some systems in current use (common or rare) can be classified by the above criteria as follows:

Rainputto: Two stroke, Association code, Kana separate (note 1).
Yamura Shinko: Two stroke, Kanji-teletypewriter arrangement used, Kana not separate.
Hitachi/Ricoh: Two stroke, Association code, Kana not separate
T-Code: Two stroke, No-association code, Kana not separate
TUT-code: Two or three strokes, No-association code, Kana separate (note 2)

Note 1, 2: In both methods Kana's are input in the same mode as Kanji through two-stroke codes on the keyboard. Although the consonant characters and the vowel characters are entered in both methods, different key assignments are used.

4.3 Arrangement of Function Keys

Function keys, that is cursor motion keys (left, right, up, down), all mechanical operation keys, are distributed in a wide range around the keyboard on both Japanese word processors and personal computers. The many different arrangements make large movements of the hands necessary. Whether the user's finger has reached the desired key, and then whether the original guide keys have been returned to must be often checked by looking. Among function keys, there are keys that are struck even higher than some character keys. Because of this, the arrangement of such function keys has important influences on efficiency, in both Kana-Kanji conversion and code input typing methods.

Presently the only system to target the placement of function keys is the 'mykey' system [10]. Even suggestions on how to design such a system are rare. With the 'mykey' key arrangement, ten keys in the bottom row are used so there is absolutely no need to move the horizontal level of the hand.

4.4 Physical Placement of the Keys

The arrangement of the character and function keys may be determined by the software instead of hardware used. However, it is simply a problem of hardware where to physically place the keys. Both Kana and coded-input methods have been designed around previously existing keyboards. Special keyboards redesigned for Japanese text include the OASYS [11], M-Type [3], and TRON [12] keyboards. Special features are:

OASYS: The thumb is used for the SIMUL key
M-Type: The keys are separated into two groups, one slanted left and one right. The keys are aranged into rows to fit all the fingers from the forefinger to the little finger.
TRON: Similar to the M-Type keyboard except that the keys are in a radial pattern similar to the open hand of a baby.

When using keys, the fingers from the forefinger to the little finger, having two joints, can bend to an angle of about 90 degrees. When striking the key under the fingertip, it is advantageous that the finger are not quite straight and that the gaps between the fingers are barely open. This is better than having the finger strike a key directly under where the fingertip would be in a relaxed state. Also, in the same way as a short stick can pivot around a fulcrum faster than a long one, if the distance from the finger's fulcrum is made shorter, faster movements can be made.

The biggest problem with previous keyboards has been that the key's slant has been to the left. This forces the left hand into inconvenient positions. Also, the degree of the slant is different for each row. The reason for these were the primitive technology of early typewriters where a rod connected the key to the mechanism for typing. There is no good reason for this twisting, and removing it is a high priority for better ergonomic keyboard.

There have been suggestions that the keys for the left hand should be slanted to the right, as opposed to the current situation. However, it is more natural to have the four fingers moving in a straight line along their axis, like they are in the M-type keyboard.

However, we may wish for the groups of keys assigned to each hand to be separated out, as they are in the M-Type keyboard. It would be even better if the angle between the two groups was adjustable.

It is not necessary to have a horizontal curve to fit the length of the fingers as in M-type and TRON keyboards. This is because all four fingers can easily flex to strike the desired key since the fingertips may stay in a straight line.

If such small improvements are to be made, switching between them is not so difficult but it must be considered that both old and new style keyboards exist, to avoid causing confusion.

5. The Input of Kanji

Along with the popularity of Japanese word processors, Kanji (Chinese idiographic characters) have been input by typing the pronunciation in a phonetic alphabet (the Japanese Kana) and converting the Kana into the actual Kanji after typing. However, it would be far better to be able to enter Kanji directly. With the 48 keys of a JIS keyboard, with a two key-press code, 2403 characters can be entered directly. One of the first attempt along these lines was made by A. and T. Kawakami's with their Rainputto system [13]. Now, many such systems are in actual use.

These input systems are designed so that the codes for respective Kanji are easy to remember. For example the Kanji 愛 is encoded uniquely by one of its normal pronunciations in Kana アイ (ai), 鏡 by ミラ (mira, phonetic equivalence of mirror) etc. Because each Kanji is encoded by two Kana, with a meaningful connection between the code and the Kanji, this is called an association two-stroke input method. However, this is not generally a useful method of memorizing codes for the direct input of Kanji. This is because the memorization of codes is performed by developing the reflexes of the learner's fingers themselves, rather than by consciously memorizing logically connected association codes. Apart from this problem, after the Kanji is read in the text, there is a reaction time while the typist has to recall the association code before typing.

Furthermore it is easy to make mistakes when typing. Considering these problems, Yamada and his associates developed a two-stroke input code (called T-Code) where there is no association between the input code and the associated Kanji [1], [14].

Although this type of two-stroke input method was developed for specialist typists, a two stroke input method for general typing use has been developed by one (H. O.) of the author's group. This code is called TUT-Code, and is commercially available as the "Touch Type" system [15]. This code uses a 30 key keyboard identical to that used for English text.

The advantages of TUT-Code stem from the fact that a rational method for inputting Kana using a Roman alphabetical keyboard is used. The left hand is used for 10 keys to input consonants, while the right hand is only used for the 5 vowels and an extra key used for the entering of voiced sounds. These 16 keys are all easy to reach keys in the middle and upper rows. It is possible to memorize the positions of the keys for blind typing in as little as one hour.

For the input of Kanji, Keys that are not used for Kana are used. 725 different Kanji can be input with two keystrokes, and a further 1800 Kanji can be entered with three keystrokes. For example, typing the key sequence 'HD' in QWERTY keyboard produces the Kanji 東, 'IR' produces 京. Similarly, 'YMR' is 漢, 'NO' is 字. In order to design a code to allow for rapid typing of normal language, the most frequently occurring Kanji are assigned two stroke codes.

It is pointed out by Yamada [14] that separating the consonants used in TUT Kana code will cause an effect similar to that of an association code for inputting Kanji. This drawback of TUT Kana code may be eliminated by carefully designing the training method.

In T-Code, there is no separation at all among the Hiragana, Katakana (the two phonetic Kana alphabets), and the Kanji. Considering all possible types of user who may not be inputting Japanese every day, it is likely that the T-Codes for individual Kana are apt to be forgotten. This is the "it's on the tip of my tongue" problem of momentarily forgetting codes.

With TUT-Code, the keys for inputting Kana are a few and arranged in groups, distributed between the left and right hands. Because they are arranged in an order that is natural to the Japanese language, it is unlikely they will be forgotten. If the code for a Kanji has been forgotten, it can be entered by typing in Kana, and then converting to Kanji. It is very important that such a backup system exists to allow the user to relax while using the system.

One of the distinguished feature of TUT-Code is that it is most preferred by users in their fifties and older although such methods are commonly understood as that for young specialists. Since eyesight of an elderly user is usually not perfect, being able to input Kanji without looking at the screen is of great assistance to these users. In actual practice, it is these users who learn the most Kanji codes.

Togasi proposed an input system [4] in which Kanji with different readings are assigned to each key and the desired Kanji may be specified by super multi-shift operation performed by entering its reading. In other words, the user inputs a Kanji by typing in its pronunciation as Kana, and then uses a key (displayed on the screen) to select a single Kanji from among the many Kanji that might have that particular pronunciation. This method is a natural link between the methods of inputting Kanji by pronunciation, and the direct multi-keystroke input method.

6, Critique of Input Methods

There have been many suggested methods for inputting Japanese language text. However, general interest is to determine which of these methods is best. In this field of research the most basic consideration is the form of the keyboard itself.

Shiratori experimentally compared three types of symmetrical keyboards that are in current use [16]. However, it may be premature to state that some type of keyboard is superior to the others, although it is clear that the shape of the keyboard does have some effect on input speed.

With the TRON keyboard the position of the hand is supposed to be fixed by putting the palm somewhere and each finger should only strike keys in a limited range. At least this was the basic intention behind the original design of the keyboard. However, in reality, because of the difficulty of using the little finger the hand is actually moved. for other fingers, depending on the finger, there is also some movement of the whole hand in addition to the movement of individual fingers. These hand movements, when using the radially expanded TRON keyboard, are different for each finger, which could be inconvenient.

With the presently used standard keyboard, one problem is the presently used electronic keyboards which were based on the mechanical keyboards. There is only a 1/4 key difference between the middle and upper rows and a 1/2 key difference between the middle and lower rows. The fact that the row of numeric keys is difficult to reach is not only due to its distance from the home position, but also probably due to the fact that there is a 1/2 key difference between it and the upper row.

It is believed by Shiratori, as well as the author, that the bottom row of keys is also hard to strike because of the difference between rows. In Shiratori's experiments this feature of the bottom row of the one type of keyboards of his experiment was improved, and its better performance may be due to this fact.

As stated above, the experiments were performed with the intention of comparing the keyboards. It is necessary to make statistically valid experiments with many people over a long time if we are to generate useful hypotheses. However, it is extremely expensive and substantially impossible to carry out.

Morita made a study on the efficiency of various input methods measured from the viewpoint of beginners and other non-specialists in his 'difficulty in memorizing key-arrangement'. He also considered the case of specialist or experienced typists in his 'input speed of the experienced'. He compared three methods, the M-type keyboard, the New JIS system, and Romanized Kana input with conversion to Kanji after typing. He concluded that the M-type keyboard was the best [17]. However, we feel that the TUT Kana code is better than M-type keyboard if his two criterions are used.

Nakayama and Kurosu chose six different input methods among Kana to Kanji conversion methods and two-stroke code input methods, and constructed a model for describing input speed of these methods during training [18]. They confirmed that their model is a good agreement with the experiment for 100 hours of training of Kana keyboard and 130 hours of training for QWERTY keyboard.

With reference to this experimental work, Nakayama and Kurosu suggested that using training software was especially effective. The effectiveness of training also varied greatly with different training method. He felt that without developing training methods with respect to several input methods it would be difficult to produce and objective comparison.

Okadome and Yamada compared input speed of Romanized Kana to Kanji conversion method and that of a code-input method (TUT-Code) using a group of 12 specialist typists for each method. The results are as follows [19].

conversion method: 262.6 keystrokes/minute input speed on average 26.6 years old typists.

TUT-Code method: 368.6 keystrokes/minute input speed on average 25.0 years old typists.

There was a large difference between the input speed on the two groups, but in the TUT-Code group two typists had only three months experience, seven had eight months, one had one and a half years experience. (The stated time periods include the two months training period). Only two of them had over three years of experience. Therefore they did not especially chose typists with particularly fast input times.

Okadome and Yamada also reported that for copy typing the two-stroke input method was mentally and physically less demanding even if conversion method is most effectively used. It is one (H. O.) of the author's opinion that the Kana-Kanji conversion method should be used as the two-stroke method's backup, if a Kanji's code has been forgotten, or has never been memorized.

7. Standardizing Keyboard Input

The popularity of inputting Japanese text from keyboard is partly being hampered by the existence of many diverse approaches. There is considerable argument about the best method to be used. The New JIS keyboard will have been determined from the basis of this approach.

However, deciding which is the best input method is confused by the fact that there is not a single best method for all situations. Even just considering the New JIS keyboard, there is as yet little basic research that would allow us to make decisions from a scientific viewpoint.

It would be better to have a standard method for connecting a keyboard to a computer [16], [20]. If we can realize this, then a user can always use a previously learnt input method on all the different computing environments s/he might use. It should be noted that even if it is inefficient, a user will be unwilling to change from an already mastered input method.

Also, standardization activity would get better changes for comparing different input techniques. If we could produce such an environment, then without any particular experiments, data on the various methods could be obtained from observing the actual experience of Japanese language input in the general community. Therefore unsuitable methods will be found automatically. At present because the different input methods are not embedded in the same computing environment, it is extremely difficult to make an objective comparison.

However, deciding on a connection standard between the keyboard and the computer itself is not a simple task. From the cable itself, for example, what information should be transmitted depend upon the operating system (OS) and the final application program itself. It is necessary to investigate many of these problems. This is one example of standardization of communication/transmission protocols. Universality and actual ability to transmit information should be carefully considered, distinctions between different classes of user should be clarified, and it is further necessary to gradually introduce a standard.

8. Conclusion

At present it is not possible to decide on a single best method for inputting Japanese text. It is still more important to encourage the use of blind typing techniques for Kana input. This requires less than then hours of practice for success. For learning another new input method, almost the same hours of effort are required, if the user chooses to do so. Therefore, changing input method is not a serious problem at all.

For people who are not experienced in blind typing, even when carefully explained, the full importance of this point is not usually understood. When discussing the merits and demerits of blind typing methods if the participants are not experienced in blind typing, any conclusion is likely to be inaccurate.

It is often said that we are living in an "information oriented society". The way in which the Japanese language is input is likely to have a major effect on this society. Learning blind typing methods is a first step towards such a society.

Acknowledgments

The authors are grateful to R. P. Clement for translating the Japanese text into the early version of this paper.

References

1. YAMADA, H. Certain Problems Associated with the Design of Input Keyboards for Japanese Writing, in W. E. Cooper (ed.) Cognitive Aspects of Skilled Typewriting, Springer-Verlag, New york (1983), 305–407.
2. YAMADA, H. A Historical Study of Typewriters and Typing methods: From the Position of Planning Japanese Parallels, *Journal of Information Processing* **2** (1980), 175–202.
3. MORITA, M. Japanese Text Input System, *COMPUTER* (May 1985), 29–35.
4. TOGASI, M. Super Multi-shift Japanese Keyboard, Workshop Paper 9–2, Special Interest Group on Japanese Text Input Methods, *IPS Japan* (1986), in Japanese.
5. OHIWA, H. Input Methods of Japanese Text Through Keyboard,

Computer Software **5**, 3 (July 1988), 2-11, in Japanese.
6. PEPE, P. S. Personal typing in 24 Hours (5th ed.), Gregg Division/McGraw-Hill Book Co., New York (1987).
7. MASUDA, T. A Method for Mastering Keyboards in Three Hours, Nikkei Newspaper Co., Tokyo (1987), in Japanese.
8. SALTHOUSE, T. A. The Skill of Typing, *Scientific American* **250**, 2 (1984), 94-99.
9. OHIWA, H. and TAKASHIMA, T. A Touch Typing Training System Using TSS, Workshop Paper ET79-12, Special Interest Group for Education Techniques, *Institute for Electronics and Communication Engineers of Japan* (1980), 37-42, in Japanese.
10. TATUOKA, H. Proposal on the New Keyboard Layout 'mykey', Workshop Paper 16-3, Special Interest Group on Document Processing and Human Interface, *IPS Japan* (Jan. 1988), 9 pp., in Japanese.
11. KANDA, Y. Computer: Essay on an Intellectual Tool, NHK Books No. 478, *Publishing Society for Japan Broadcasting Corporation*, Tokyo (1985), in Japanese.
12. SAKAMURA, K. Method to Input Japanese Characters in BTRON Environment—Design of TRON Keyboard—, Workshop Paper 7-2, Special interest Group on Japanese Document Processing, *IPS Japan* (July, 1986) 8 pp., in Japanese.
13. KAWAKAMI, A. and KAWAKAMI, T. Human Factors in Rainputto Keyboard for Kanzi Input, *Proc. 1st USA-Japan Computer Conf.* (1972), 292-295.
14. YAMADA, H. Progress of Study on Input Methods for Professional Typists, *Computer Software* **2**, 1 (Jan. 1985), 54-64, in Japanese.
15. OHIWA, H., TAKASHIMA, T. and SHIBATA, T. Touch-Typing of Japanese Text, *Proc. Int. Conf. Text Processing with a Large Charter Set*, Tokyo (Oct. 1983), 203-208.
16. SHIRATORI, and OBASHI, F. Design of a Key Layout for the Roman Alphabet Based Japanese Input System and Its Evaluation, Trans. *IPS Japan* **28**, 6 (June, 1987), 658-667, in Japanese.
17. MORITA, M. Quantitative Comparisons on Performances of Various Japanese Text Input Systems, Transaction of the Institute of Electronics, *Information and Communication Engineers of Japan* **J70-D** (Nov. 1987), 2182-2190, in Japanese.
18. NAKAYAMA, T. and KUROSU, M. Research on Evaluation Method of Japanese Text Entry Systems, *J. IPS Japan* **26**, 11 (Nov. 1985), 1390-1397, in Japanese.
19. OKADOME, T. and YAMADA, H. A Comparative Study of Input Method for Japanese Text and Typing, *Proc. Symp. on Human Interface for Computer Systems—Model, Evaluation, and Prospects—*, *IPS Japan* (1988), 133-143.
20. TAKASHIMA, T. Realization of 'My Keyboard'—Essay on Standardization of Keyboard Interface—, *Proc. Summer Symp. on Human Friendly Systems, IPS Japan* (July, 1986), 93-103, in Japanese.

(Received September 18, 1989)