The R² System
Ming Hsu and Yun Hsu

Abstract
We introduce R², a novel system for the input of the Chinese language. Existing input systems do not capture the 2-dimensional nature of the Chinese language. Specifically, in R², each word in the Chinese language is not only represented by which basic elements (strokes) are involved, but also by where they are placed in relation to each other. Thus two distinct words may share identical strokes, and only their relative positions tell the difference. We designed R² specifically to overcome this challenge. With R², the user is able to mimic their natural writing style and write any character that is capable of being written. Because of this simplicity and naturalism, R² is ideally suited for use in handheld devices.

Introduction
Computer science has had a difficult time with the Chinese languages. It is one of the few visual languages that is widely used, as opposed to the phonetic Romance languages that dominate much of the computing landscape. Existing technique for computer input has proved to be either tedious and cumbersome, or too complex for the lay person to use efficiently.

This is an especially pronounced problem with handheld devices or other devices where the input devices are inherently limited. In the document below we discuss a new input system for the Chinese language that solves the problems listed above. In the next sections, we discuss the existing input systems and their shortcomings, followed by a presentation of the R² system and its basis in the “natural” way of writing Chinese. We conclude the document with a summary of the shortcomings and potential of the R² system.

Current Chinese Input Systems
Pinyin and other phonetic input systems
By far the most popular inputting method has been pinyin and its Taiwanese cousin, zhuyin. Both are attempts to phoneticize the Chinese language. Pinyin uses the Roman alphabet to represent the sound of the Chinese language, whereas zhuyin uses different symbols for the same set of sounds. One major advantage of a phonetic system is its low learning curve. Most Chinese speakers know the basics of pinyin, and anyone who knows how to type can be expected to write reasonably with pinyin.

The problem with pinyin and other phonetic implementations can be traced to the redundancies in the Chinese language. In particular, it is well known that many words share the same pinyin or zhuyin representation, even accounting for tonal differences. For example the sound han4 contains 14 homonyms, all of which have different meanings, and three of which, 汗汉旱, are commonly used.

Given the high redundancy in the system, it is often necessary to first input the pinyin representation of the character, and then pick out the character out of the subset of
characters that share the same sound. In the example above, to write the word sailboat (帆船), one would write fan1chuan2 or simply fanchuan. Depending on the sophistication of the computer program, 帆船 may or may not be the unique element. There are a number of compound words or phrases, however, where uniqueness is simply impossible, e.g., 设施, 摄氏.

The attention necessary to do this task is very taxing, as anyone who has written in pinyin will attest to. Much effort therefore has been given to simplifying this task. The most popular solution is to use a system where several characters are inputted at the same time; thus using syntax to determine words, such as commonly used phrases. This system solves some of the problems, but a certain amount of choosing after typing is still necessary, especially in terse language such as poems or classical prose.

**Wu-bi and other radical based system**

There have also been implementations of "radical-based" methods, including 五笔 (wu-bi, or five strokes) and 四角 (si-jiao, or four corners).

This method eliminates the redundancies inherent in any phonetic input system. Wu-bi is able to represent every character with a few key-strokes (for example the character 程序 can be written by typing in keys “tk” and “yc”).

This method, however, necessarily requires the user to remember hundreds of radicals in the Chinese language. Additionally many common Chinese characters do not have radicals. To compensate, Wu-bi introduced shortcuts for high frequency characters, increasing its complexity. It is taxing, to say the least, on one's memory. It is not uncommon to hear people who have stopped using the wu-bi system for a while to have forgotten how to write many characters.

Because of the proliferation of radicals that need to be remembered, wu-bi and other radical based system have a high cost of initial acquisition. This has hampered its ability to become widespread, and to this day very few people, mostly those who type Chinese very often, use it.

**The R² system**

All of the existing systems fail to address a fundamental difference of the Chinese language—that is 2 dimensional with a plethora of homonyms. By ignoring this, we are stuck with either simple systems with much redundancy, or uniqueness at the cost of great complexity.

The current system takes advantage of the spatial aspect of the Chinese language. As is well known, Chinese logographs can be represented by several basic "strokes." By arranging these basic strokes in various ways, we can derive every Chinese character. In fact, this is how all Chinese characters are written.

The average strokes per simplified Chinese characters is somewhere between 7-9 strokes. That of traditional characters is substantially more. Therefore we will focus on simplified Chinese characters.
It is a detriment to us that our system is likely to be useful for only those using the simplified system. In our defense, we claim that the simplified system is what the majority of Chinese speakers use. Furthermore, the proliferation of strokes in traditional Chinese characters introduces a number of redundancies in the logographs, i.e., a number of strokes can be either omitted or cursive while not sacrificing the integrity of the character. In short, the number of strokes that actually determine a character may be no more than 7-9.¹

Because this is a new system, it is not known the speed at which an average person can input the Chinese language. However, we can still speculate. Assume an average touch typist can type about 40 words per minute, assume a conservative estimate of about 5 letters per word, which equals 200 letters per minute. This translates into about 25-30 Chinese words per minute, which is better than what most people adept at pinyin can achieve.

R² is also simpler to learn than wu-bi or similar radical based systems. It is not as easy to learn as pinyin, because of the overwhelming base of pinyin users.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Phonetic-based</th>
<th>Radical-based</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention</td>
<td>High</td>
<td>Low</td>
<td>Low/Medium</td>
</tr>
<tr>
<td>Memory</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Learning curve</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Speed</td>
<td>Low/Medium</td>
<td>High</td>
<td>Medium/High</td>
</tr>
<tr>
<td>Intuitive</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Retention</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 1 Comparison of different input systems.

**Rules of the Chinese Language**

We take advantage of the basic rules of the Chinese language, which are taught in elementary schools throughout the country. They are, in order of precedence,

1. Horizontal before vertical
2. Left before right
3. Top before bottom
4. Outside before inside
5. Top right before bottom left
6. Dot in top right is written last

As these are heuristics, there are exceptions. However, they represent the way most Chinese writers write characters.

¹ This may be the reason why people who are fluent in one system but not the other can nonetheless read characters written in the other perfectly well.
A more in depth look at R²

We partition the Chinese language into two aspects, location and stroke. A user will have one hand control the location, while the other hand control the actual writing. The location proceeds according a determined order. Much of it is intuitive to any writer of the Chinese language. This involves writing to left to right, from top down. There will be some counterintuitive steps, but those are necessary for the determination of the language.

The location of strokes will be handled by a device that is able to detect the direction of movement. Thus, anything from a joystick, touchpad, arrow keys, or mouse, will suffice. There are 12 strokes in our system, few enough to be placed in any number pad in existing full sized keyboards.

R² is designed to mimic the natural writing style of the Chinese language. In general terms, characters are written from left to right, from top down. This allows us to make R² as intuitive as possible. There are, however, a few instances where functionality requires us to sacrifice intuitiveness. We will discuss those points in turn.

Location

The ability to specify where to place various strokes within a character is by far the most important feature of the R² system. It is this ability that separates our system from all other Chinese input systems. It is easy to see why this has never been done before. The structure of the Chinese language renders this very difficult. For example, a character may consist of several nested layers of different strokes, making it very difficult to specify the location of each stroke. Strokes can also intersect, and the same strokes can look quite different depending on their position. As we shall see, however, we have designed the language such that all characters are a trivial application of R².

To achieve this, R² does not actually specify the actual location of each stroke. To do so would require an extraordinary amount of computation and user care, which is perhaps why previous attempts have given up, although we do not actually know of any previous attempt to do the same thing. R² avoids this by using an "additive" approach.

Imagine writing a logograph, one begins by writing a stroke, anywhere in a box of a certain size. We then add in another stroke, relative to the previous one, but usually always to the right or below, and continue doing so successively until we have a completed logograph. The idea under R² is the same---we begin by writing a stroke, but now we have to move the previous stroke to make place for the current one. So in this sense R² is writing Chinese backwards. Whereas normal writing chooses the location before writing, R² chooses writing before location. This is the breakthrough or R². This is what allows us to create an incredibly flexible system that is computationally feasible and user-friendly.

It is perhaps easiest to visualize this via an example.

Example

We write the logograph 成 (success).
First we distinguish between absolute and relative movements. As we have said already, the complexity of Chinese logographs lie in their "nested" nature. A character may be left-right structured, and the right part has a three-layered top-bottom structure. Direction keys are used to navigate through the writing area.

- **Right** creates a new radical to the right of the existing writing. Move everything that had been written to the left.
- **Down** creates a new radical to the bottom of the existing writing. Move everything that had been written up.
- **Up** creates a nested level within the radical.
- **Left** creates a nested level to the right of the radical
- **Counterclockwise** goes inside the radical
- **Clockwise** moves outside the radical

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### Table 2 Sequence of stroke and location to construct the logograph 成.

<table>
<thead>
<tr>
<th>Stroke</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>一 一 一</td>
<td>Start with heng Push up Put in pie</td>
<td>Go inside, and the heng and pie are completely determined to form the “factory” radical</td>
</tr>
<tr>
<td>厂  厂  厂</td>
<td>Put in hengzhe Push hengzhe to the left</td>
<td></td>
</tr>
<tr>
<td>厂 成 成</td>
<td>Put in na, and simultaneously push it up to make it intersect the heng above</td>
<td></td>
</tr>
<tr>
<td>成</td>
<td>Put in pie, and simultaneously push it up to make it intersect the na above.</td>
<td></td>
</tr>
<tr>
<td>成</td>
<td>Go outside and put in the dian, at which point the character is completely determined to be 成</td>
<td></td>
</tr>
</tbody>
</table>
• Intersection Many Chinese characters involve intersection of two or more strokes. In R² this is achieved through simultaneous pressing of two or more strokes.

Strokes

There are a number of other special rules in R², designed to improve the writing speed. Most of them are quite intuitive.

1. Pressing 2 strokes simultaneously creates an intersection. For example, pressing 7 and 8 will create an intersection of the horizontal and vertical strokes, creating the word 十.

2. Pressing arrow key with a basic stroke creates an intersection with other radicals.

Example Program

Below is a screen capture of a program implementing the R² system. This example was designed with a cell phone’s capabilities in mind. It can be trivially adapted to a computer number pad as well.

The location keys are well suited for existing directional button on a cell phone, either in a joystick format, or a button format. This program should be included in the CD containing this document. Otherwise it is available for download on http://www.hss.caltech.edu/~mhsu/R2.

![Example Program](image)

Figure 1: Example program implementing the R2 language.
**Advantage of R²**

We now summarize the advantages of the R² system.

- **Completeness.** This is perhaps the most basic requirement for any inputting system—one must be able to represent the complete set of words in a language. It is true that by sacrificing completeness one might be able to achieve substantial functional improvements, but to us this is not a worthwhile goal.

- **Uniqueness.** We cannot emphasize this point enough, for this is the primary advantage R² has over pinyin. Uniqueness allows the user to concentrate on the text without having to divert attention to choosing characters. It also eliminates the need to shift from doing one task to another—input and then search.

- **Intuitiveness.** If uniqueness is the advantage that R² has over pinyin, intuitiveness is what it has over wu-bi. It is well known that people are much more adept at learning and retaining complex motor, implicit behavior than verbal or explicit behavior. R² is primarily the former, whereas wu-bi the latter. To type, users of R² need to remember how to punch in a 12 key keypad and use a joystick with precision. As millions of video game players can attest to, this is both a very easy system to learn and master.

**Challenges to R²**

The primary difficulty with R² is due to the programming complexity of the task. Technically, it is possible for the user to write a character using R² without any visual feedback. However, memory and attention constraints make this difficult. It is critical, therefore, to provide the user with good visual feedback to the characters. The complication is that the look and feel of a character depends crucially upon the relative size and location of the strokes.

For example, characters may look very different depending upon how they are written—from familiar to altogether incomprehensible. Yet, the location and stroke are broadly correct. (For example, \( \nspace{10} \) is not readily recognizable as \( \nspace{10} \))

The main challenge therefore will be to create a user-interface that allows the user to feel as close to the actual experience of writing Chinese as possible.

**Potential for adoption**

The de facto standard today is the pinyin system; any system that is attempting to become the standard will have to be superior to it. The advantages of the R² have already been listed above. Whether this is enough to overcome the entrenched status of pinyin remains to be seen.

Because there will be some initial investment to this system, widespread adoption may be difficult. R² is unequivocally superior, in our view, to wu-bi and related radical based methods. The problems in these radical based methods are legion. We are confident

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2 “It’s like riding a bike!” is a common saying.

3 Imagine how difficult it would be to type in English if words do not appear until after the space bar is pressed.
therefore that this system will create at least a niche in the Chinese input world, and possible much more, including becoming the standard.

**Conclusion**

With $R^2$, the Chinese language will for the first time have an input system designed specifically for it, instead of cumbersomely adapting the phonetic input system to a writing system that is fundamentally not phonetic, or brute-force put the entire Chinese language into a keyboard.