Chinese Characters as Sketch Diagrams Using a Geometric-Based Approach

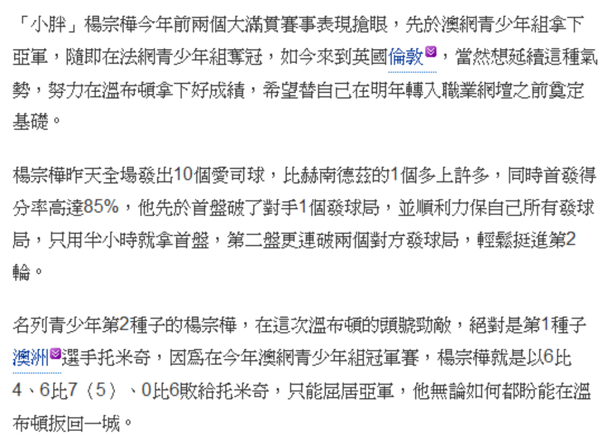
Paul Taele, Tracy Hammond
Sketch Recognition Laboratory
Department of Computer Science
Texas A&M University
Mail Stop 3112
College Station, TX 77839
{ptaele, hammond}@cs.tamu.edu

Abstract

Knowledge of over a thousand Chinese characters is necessary to effectively communicate in written Chinese and Japanese, so writing patterns such as stroke order and direction are heavily emphasized to students for efficient memorization. Pedagogical methods for Chinese characters can greatly benefit from sketch diagramming tools, since they can automate the task of critiquing students' writing technique. Falling cost and greater advances made in pen-based computing device even allow language programs to afford deploying these systems for augmenting their existing curriculum. While current vision-based techniques for sketching Chinese characters could be adopted for their high visual recognition rates, they do not directly support technique recognition and are unable to provide feedback for critiquing technique. A geometric-based approach can accomplish this task, though visual recognition rates have largely been untested. For our paper, we analyze the feasibility of a geometric-approach in visual recognition, as well as discuss its feasibility for use in a learning tool for teaching Chinese characters.

1. Introduction

Ideograms form the basis of written communication in the Chinese language, and they also play a significant role in the written component of the Japanese language. This ideogram set consists of at least tens of thousands of characters [19], and fluency of characters in that set demands a working knowledge of no less than a thousand characters [7] before learners can effectively read and write entirely in Chinese and partially in Japanese (Figure 1). Despite the high number of characters necessary for understanding written Chinese and Japanese, patterns in writing (e.g., stroke order and direction) and reading (e.g., sub-character components called radicals) have historically been taught as a way to ease the burden that students faced in regards to character memorization [2][3][9].


「小胖」楊宗樺今年前兩個大滿貫賽事表現搶眼，先於澳網青少年組拿下亞軍，隨即在法網青少年組奪冠，如今來到英國倫敦，當然想延續這種氣勢，努力在溫布頓拿下好成績，希望替自己在明年轉入職業網壇之前奠定基礎。

楊宗樺昨天全場發出10個愛司球，比赫南德茲的1個多上許多，同時首發得分率高達85%，他先於首盤破了對手1個發球局，並順利力保自己所有發球局，只用半小時就拿首盤，第二盤更連破兩個對方發球局，輕鬆挺進第2輪。

名列青少年第2種子的楊宗樺，在這次溫布頓的頭號勁敵，絕對是第1種子澳洲選手托米奇，因為在今年澳網青少年組冠軍賽，楊宗樺就是以6比4、6比7（5）、0比6敗給托米奇，只能屈居亞軍，他無論如何都盼能在溫布頓扳回一城。

Figure 1. A sample online article written in Chinese (source: yahoo.com.tw).

Contemporary language programs for the secondary language acquisition of Chinese and Japanese traditionally rely on workbooks and assignments, consequently engaging students in rote memorization of characters through repetitious character writing (Figure 2). While the paper-and-pen method is an established practice for its simplicity and cost-effectiveness, its disadvantages include the lack of oversight by instructors on repetitious student-made sketches of Chinese characters. Not only does this paper-and-pen method offer no direct feedback to students for indicating the correctness of their writing techniques, but it is also detrimental to their memory absorption of characters in the long term. This is

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because it does not prevent students from repetitiously writing characters with incorrect stroke order and direction.

Figure 2. Example of a traditional paper-based workbook for practicing Chinese characters.

Possible workarounds for enabling instructors to gauge the correctness of character writing technique involve either having students enumerate the order and label the direction of their strokes, or having the instructors themselves physically monitor the students' character sketching. The former is largely ineffective since it burdens students with extraneous and unnatural sketching. Evaluating this labeling scheme also becomes more tedious as the number of Chinese characters increase greatly in number. On the other hand, the latter is no less largely ineffective for the instructors as the task becomes much more time-consuming when scaled up to a typical classroom-sized teaching environment. The task similarly becomes burdensome on the instructor when the set of characters to teach are restricted to just a hundred characters.

Given these lingering issues in the current state of teaching written Chinese characters, the use of sketch diagramming tools is one avenue worth exploring. One significant reason is that sketch diagramming tools have been successfully implemented in other domains for shifting pen and paper sketching onto pen-based computing devices [1][6][10]. By successfully adapting these tools for the domain of written Chinese at the pedagogical level, highly frequent critiquing of minute yet crucial characteristics in student-sketched Chinese characters by the instructors can instead be transferred and automated by sketch diagramming tools themselves. Advantages of an automated process include freeing instructors to focus their teaching towards other important components in the Chinese or Japanese languages, as well as enabling uniform critiquing of student sketches by a single system instead of variable critiquing by multiple instructors. With decreasing cost and increased power and reliability of pen-based computing devices, the hardware necessary for accommodating sketch diagramming tools becomes an affordable and highly viable option for improving current methods in teaching written Chinese characters.

Desired sketch diagramming tools geared towards the teaching of Chinese characters would of course need to surpass existing teaching methods overall. In order to do so, they must effectively handle both the visual recognition case (i.e., how correctly similar the sketch looks to a model sketch) and the written technique recognition case (i.e. how correctly drawn the sketch look technique-wise) on student sketches for those very Chinese characters. Vision-based sketch recognition systems specific to Chinese characters (Figure 3) currently attain high recognition rates [8][14][15], and geometric-based sketch recognition systems are capable of classifying and providing feedback on written technique correctness based on various metrics including stroke order and stroke direction [16]. Ideally, sketch diagramming tools would need to just merge the capabilities of vision-based and geometric-based sketch recognition systems.

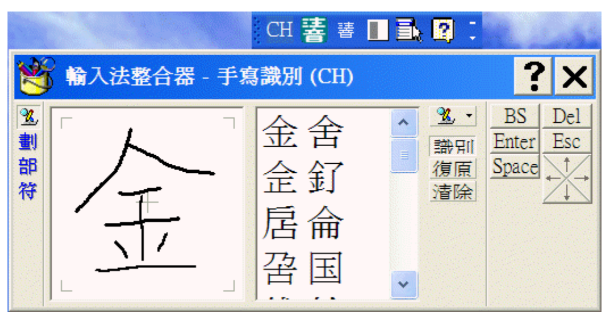

Figure 3. The user interface for Microsoft's vision-based character recognition system.

Unfortunately, merging the essential functionalities from both of these approaches for developing the envisioned sketch diagramming tool is not a trivial task. Existing vision-based sketch recognition systems for Chinese characters are ill-suited for adapting written technique (e.g., stroke order and direction) recognition approaches, since they were designed solely for pure vision recognition [3]. Conversely for available geometric-based sketch recognition systems, the feasibility of adapting robust visual recognition to them for diagrams like Chinese characters have been relatively unexplored due to the complexity of describing them geometrically [11].

The focus of our paper concerns exploring the latter case by determining how well a geometric-based approach can handle visual recognition of Chinese characters. Our system approximates these characters as a collection of polylines, and our method utilizes the Sezgin primitive shape recognizer and the LADDER sketching language for polyline recognition and spatial relationships between those lines, respectively. After we discuss our implementation, we then test the robustness of our proposed approach on natural sketches taken from both novice and expert users of Chinese characters. Lastly, we discuss the feasibility of relying on a geometric-based approach for handling visual recognition in a domain as complex as Chinese characters, as well as elaborate on the steps still needed to develop a sketch diagramming tool reliably equipped for instruction of sketching Chinese characters.

2. Related Work

Our paper concerns results generated from a geometric-based sketch recognition implementation for Chinese characters, since literature on similar geometric-based sketch recognition systems specifically for written Chinese is lacking. There is ample literature on geometric-based approaches for other domains though, as well as a plethora of research work in regards to vision-based systems designed specifically for Chinese characters. We briefly summarize below works from both related areas.

2.1. Vision-based Systems

Due to the growing influence of the Chinese language and the complexity of inputting its written language into a computer, various research labs from technology companies such as Microsoft and IBM have poured significant resources in Chinese handwriting research [7]. Publicly available tools from this research include Input Method Editors (IMEs), programs which allow users to input symbols in East Asian languages using input devices such as a keyboard, mouse, or stylus [7].

Vision-based approaches for Chinese characters vary in nature when it comes to the type of machine learning techniques they employ. This range includes genetic algorithms [15] and neural networks approaches [5][8]. Similar in functionality to IMEs for the Chinese and Japanese language, an interface using a vision-based algorithm performs eager recognition on drawn characters by outputting the closest matches to what was partially or completely sketched by the user. Such algorithms can generally yield over 95% accuracy for sketched Chinese characters.

At the pedagogical level, a significant downside of vision-based systems is that it is not helpful to language students during the nascent stage of learning Chinese characters. Vision-based systems were designed so that users could rapidly while naturally sketch Chinese characters into a computer, regardless of their written Chinese skill level. For novice users such as Chinese and Japanese language students, such a system may be beneficial for partially sketching an unknown Chinese character for later querying of its meaning. However, if students are too dependent on these vision-based systems and rely on them solely for inputting Chinese characters, their writing ability may consequently degrade since they would: (i) become too accustomed with having the recognition system finish their partial sketches, or (ii) develop bad habits in using incorrect stroke order and thus negatively affect their long-term memorization in writing Chinese characters.

Moreover, vision-based systems for written Chinese concentrate on the visual recognition of Chinese characters. Therefore, recognition of written technique attributes that would aid language students in the learning process are ignored in favor of obtaining the closest visual match to sketched characters. The consequence of vision-based systems having this latter property is that these algorithms do not keep track of either the geometric property or temporal data of individual strokes, data which are prerequisite for handling written technique recognition. Even if vision-based systems were able to trivially handle written technique recognition for Chinese characters, it would be more desirable for these systems to provide greater feedback than simply output whether or not a sketched character was both visually and technically correct. In this case, an alternative approach would be needed for handling written technique recognition of Chinese characters.

2.2. Geometric-based Systems

A number of papers have been written in regards to the general area of sketch recognition for domains such as circuit [1] and math [6] sketches. One area of interest from researchers in the field of sketch recognition – especially geometric-based ones – test is primitive shape recognition. Recognizers would determine if a pen stroke is a particular type of primitive shape such as a point, line, polyline, or ellipse. Each primitive shape is assigned an independent classifier to aid these recognizers, and strokes are segmented into their respective line components for the case of the polyline classifier. One popular segmenter by Sezgin [12] uses pen velocity and curvature data to find the corners of pen strokes for later segmentation. The classified stroke can then be referenced and used later for another aspect of sketch recognition called domain shape recognizers.

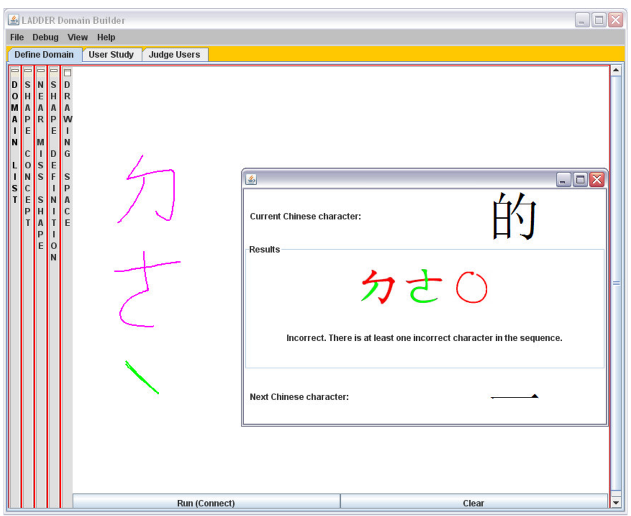

Figure 4. An application using our geometric-based technique for the simpler Mandarin Phonetic Symbols I domain (source: [16]).

In domain shape recognizers, knowledge-based shape recognizers are used to understand the geometric properties of shapes for a variety of domains. One such system is LADDER [4], a sketching language for describing how sketched shapes can be drawn, displayed, as well as edited. Shapes are described using a set of geometric constraints, and sketches which best fulfill a particular shape description are described as such. A previous work of ours [16] made use of LADDER and the Sezgin recognizer for the domain of Mandarin Phonetic Symbols I (MPS1), a symbol set of simple and simplified Chinese characters for representing the pronunciation of Chinese characters in Chinese Mandarin. In addition, we created an educational tool using our geometric-based approach that teaches and reviews the shapes in MPS1 classified by our recognizer (Figure 4). Our approach not only was capable of reasonable visual recognition of MPS1 shapes, but it also succeeded in handling recognition of stroke order correctness and could be extended for handling stroke direction and proportions. And unlike vision-based approaches, which can only do all-or-nothing recognition feedback, our application can provide additional feedback to users when shapes were drawn visually correctly but technically incorrect.

Our geometric-based recognition system for MPS1 contains features which we desire in a system for teaching Chinese characters: visual recognition, written technique recognition, and useful feedback for critiquing the correctness of both visual structure and written technique. The challenge is transitioning our system from the domain of MPS1 to Chinese characters, since shapes in MPS1 are an extreme simplification of ideograms in the Chinese character set. For example, MPS1 shapes have at most three strokes, while it is not uncommon for typically-used Chinese characters to have over a dozen strokes. The rest of this paper explores the feasibility of adapting our previous geometric-based system for Chinese characters.

3. Implementation

Our previous system for the MPS1 domain demonstrated that written technique recognition can be successfully achieved with a geometric-based sketch recognition approach. Since the process from that work can easily be carried over to a sketch recognition system for the domain of Chinese characters, we concentrate our implementation on testing the visual recognition capabilities which uses a geometric-based approach. This is done by exploiting the visual recognition technique in our previous work and extending it to handle the more complex domain of Chinese characters, since the previous system was only tailored for the less complex MPS1 shapes.

3.1. Resources

We observed that strokes in Chinese characters can be approximated entirely as a collection of lines, so we desired a primitive shape recognizer which had high accuracy rates on polylines specifically. In this case, the Sezgin recognizer fulfilled our needs for this task. We desired a domain shape recognizer to handle the task of correctly combining recognized polylines to their recognized forms. The LADDER sketching language fit the criteria in allowing us to approximately describe Chinese characters geometrically using lines for our recognition system.

3.2. Radicals

In order for Chinese characters to be classified in the LADDER sketching language, we created a set of constraints which would geometrically describe each character. Yet creating shape descriptions for every ideogram in the Chinese character set is both highly time-consuming and excessive for demonstrating the effectiveness of a geometric-based approach in visual recognition. Therefore, we focused on a set of Chinese characters called radicals instead.

Written Chinese differs from other written languages (i.e., English) in that the characters do not directly contain phonetic information, thus it would be impossible for a person to reference the meaning of an unknown character by its pronunciation if that person did not know that character's pronunciation as well. To resolve the problem, section headers (i.e., sub-Chinese character components) contained within Chinese characters called radicals can be used instead to visually reference a Chinese character [7]. These components can be Chinese characters as well, and traditional characters in written Chinese make use of 214 of these radicals for referencing in typical Chinese dictionaries [18]. For this paper, we created shape descriptions for a smaller subset of approximately ten percent of the commonly-used radicals for gauging visual recognition performance [13], since we believe this smaller subset sufficiently represented the entire radical set.

3.3. Constructing Shape Descriptions

A shape description in LADDER generally consists of a set of geometric constraints that sketches need to fulfill in order to be classified as that shape. For example, the labeled components of two radicals can be found in Figure 5, and the shape description of one of those radicals can be found in Table 1.

As can be seen in Figure 1, three important attributes make up a shape description in LADDER: the components, the constraints, and the aliases. For components, primitive shapes (e.g., lines, arcs, curves, circles, other shapes) that make up a shape are declared. In our domain of Chinese characters, components consist of either lines or other radicals. We create descriptive names for the lines containing general spatial location and orientation type in order to provide faster referencing when we are defining the constraints.

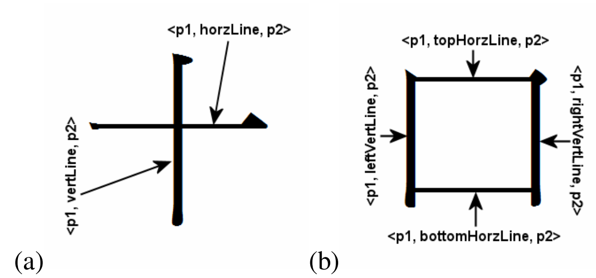

Figure 5. (a) Radical #24, which can also translate to "ten." (b) Radical #31, which can also translate to "mouth."

Table 1. Shape Description for 十.

components:		
Line	horzLine	
Line	vertLine	
constraints:		
horizontal	horzLine	
vertical	vertLine	
leftOf	horzLine.p1	horzLine.p2
above	vertLine.p1	vertLine.p2
leftOf	horzLine.p1	vertLine.center
rightOf	horzLine.p2	vertLine.center
below	horzLine.center	vertLine.p1
above	horzLine.center	vertLine.p2
sameX	horzLine.center	vertLine.center
sameY	horzLine.center	vertLine.center
aliases:		
Point	leftPoint	horzLine.p1
Point	topPoint	vertLine.p1
Point	rightPoint	horzLine.p2
Point	bottomPoint	vertLine.p2

Constraints are defined next, which is where all the preconditions that need to be fulfilled for proper classification are created. We generally segment constraints into three sections for easier readability. The first section explicitly defines the orientation of the lines, which can either be horizontal, vertical, positive-sloped, negative-sloped, or a negation of one of the sloped orientations (i.e., to handle the case of strokes in user-created sketches which our system could interpret as either being diagonal or not). The second section explicitly defines the spatial relationship of endpoints in lines, since line endpoints in LADDER are automatically labeled as *p1* and *p2*. One reason we desire explicit definition of the spatial relationship between the endpoints is because we could reference the endpoints unambiguously. We exploit this information if we wish to handle recognition of stroke direction correctness [16]. The last section is the spatial relationship between the different components. This section is usually the most complex of the three sections, since these set of constraints distinguish the character from other characters. It should be noted that not all three sections are defined in every shape description. For complex characters which consist completely of simpler characters, there are no lines to declare since they are already declared in the descriptions of the simpler shapes. Therefore, only the third section is defined for these complex characters.

Lastly, aliases can be used in a shape description. These are user-created synonyms of components which allow for components to have multiple names. One benefit of aliases is that they can simplify descriptions of constraints in a shape when used in another shape description. For example, a shape which uses the 十 radical as a component would find aliases like, say, *rightPoint* more descriptive than *horzLine.p2*. Another advantage is that they can serve as labels of strokes to determine written recognition correctness, such as how stroke order correctness was checked in our previous work.

3.4. Incorporating Other Shapes

A common phenomenon in written Chinese is that the more complex characters are often composed of simpler Chinese characters or variants of them [18]. Rewriting shape descriptions of simple characters in shape descriptions for more complex characters that incorporate them is an inefficient process. Fortunately, simple characters can be imported into complex characters as components instead, and constraints that need access to components of those simple characters can be done so through aliases. An example of this can be seen in the radical 田, which is composed of the 口 and 十 radicals. The components and aliases used in the 田 radical, as well as its corresponding shape description can be found in Figure 6 and Table 2, respectively.

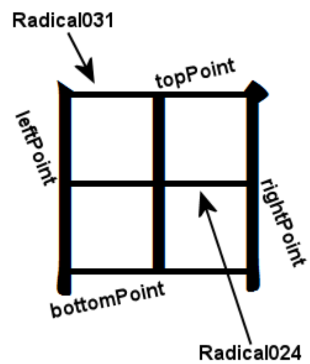

Figure 6. Radical #102, which translates to "rice field."

Table 2. Shape Description for 田.

components:		
Radical024	r024	
Radical031	r031	
constraints:		
sameX	r024.leftPoint	r031.leftPoint
sameY	r024.leftPoint	r031.leftPoint
sameX	r024.topPoint	r031.topPoint
sameY	r024.topPoint	r031.topPoint
sameX	r024.rightPoint	r031.rightPoint
sameY	r024.rightPoint	r031.rightPoint
sameX	r024.bottomPoint	r031.bottomPoint
sameY	r024.bottomPoint	r031.bottomPoint
aliases:		
…		

4. Results

A sketch recognition system designed for use in teaching Chinese characters must be very robust in handling visual structure recognition of those characters. Therefore, we desire high recognition rates on visual structure from sketches made by expert users in Chinese characters. Additionally, the purpose of our recognition system is to teach written technique of Chinese characters, so we would like to choose representative characters typically found in an introductory East Asian language curriculum.

We thus conducted a user study which incorporated these traits to determine the feasibility of our recognition system for pedagogical purposes. The user study was done by five university international students of Chinese, Taiwanese, and Japanese descent, because their corresponding native languages utilize complete or heavy use of written Chinese characters. For the representative data set mentioned earlier, we selected the non-trivial Chinese characters from a list of introductory Chinese characters in a novice-level language textbook [2] (Figure 7).

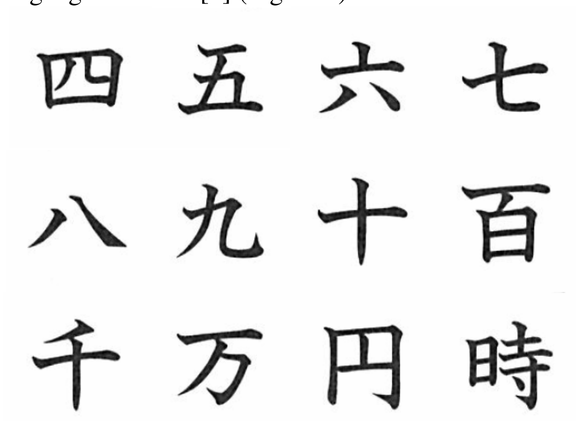

Figure 7. Representative data set used in our user study.

User study data was collected from a Tablet PC, where participates sketched one example of each character using a stylus. Since we also desire test data that would serve as a model for students learning Chinese characters, we asked participates in our user study to draw the characters as if though they were showing a novice user how to draw them. From the five examples sketched for each representative character in the test data, their recognition rates can be found in Table 3.

Table 3. Recognition rates for the representative data set. For accuracy, the left and right number corresponds to the number of correct and total examples, respectively.

Characters	Accuracy	Characters	Accuracy
四	5/5	四	5/5
五	5/5	五	5/5
六	5/5	六	5/5
七	5/5	万	5/5
八	5/5	円	5/5
九	4/5	時	5/5

In addition, sample sketches by the user study participants for each of the characters in the representative data set and were recognized by our system can be found in Figure 8.

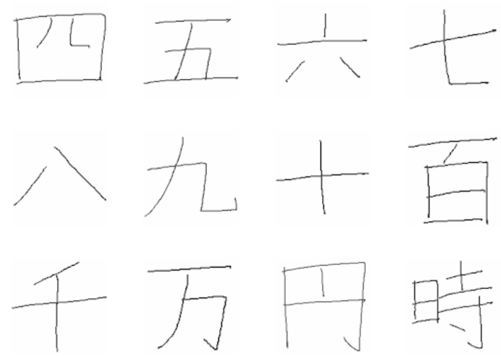

Figure 8. Subset of sketches made by the user study participants.

5. Discussion

From the sketching variations generated by the five participants in our user study, our recognition system only misclassified one sketch in our representative test data set. The original misclassified sketch for the character 九 and the geometric approximation by our system can be found in Figure 9.

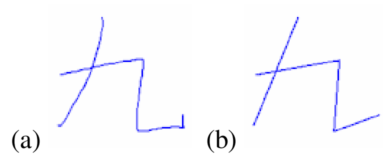

Figure 9. (a) Misclassified sketch. (b) Our system's geometric approximation of the misclassified sketch.

This isolated misclassified case is due to our system's recognition of strokes on the bottom-right side of the sketch. Notice that in the original misclassified sketch, the bottom-right portion of the character contains two lines (i.e., a coincidence of a horizontal line and a vertical line). Yet in the geometric approximation made by our system, those two lines were treated as a positively-sloped line. Upon observation of this misclassified sketch, we soon discovered two reasons behind the misclassification. The first reason can be attributed to the very short size of the last vertical stroke made in the sketch. Despite the last stroke's short length, this aspect alone would not have been responsible for the misrecognition.

This thus leads to the second reason, which was the rapid speed of the sketch made by the user. This phenomenon is natural for expert users, since their fluency of Chinese characters would naturally allow them to accurately sketch them rapidly. When we asked this user responsible for the misclassified sketch to repeat the sketch in our recognition system, we discovered the rapid sketching behavior and the shortness of the last stroke caused our system to merge the last two strokes as a single diagonal line. We believe that this behavior would not be a problem for recognition by language students in general, since we expect them to accentuate strokes more for better visual clarity, as well as input their sketches more slowly due to their novice knowledge of the domain. This was confirmed when we asked the original user to sketch more slowly to emulate how a novice user learning Chinese characters would draw, and our system accurately classified the repeated sketch.

Based on our user study for the representative data set tested, our recognition system achieved an acceptable accuracy rate of 98.3%. Since our system succeeded in recognition for a reasonably diverse data set, we believe this behavior will provide similarly high results for other Chinese characters typically taught in the language curriculum.

6. Future Work

Our previous work in [16] demonstrated that our geometric-based sketch recognition approach can handle domain-independent classification of correct written technique (e.g., stroke order and stroke direction). Additionally, our approach can be adapted at the visual recognition level for a smaller and more simplistic subset of Chinese characters (Figure 11).

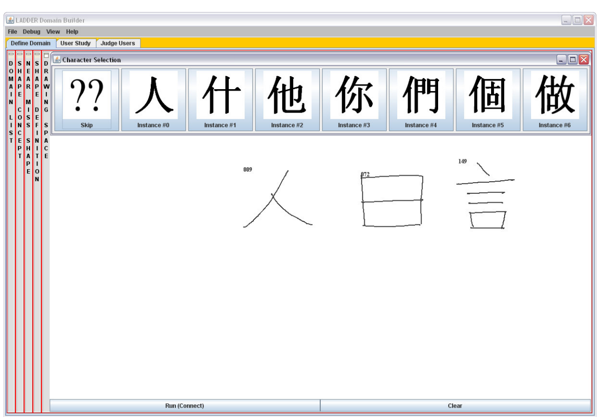

Figure 10. An application for looking up characters by its radical using our recognition system [17].

Since the results in this paper shows that a geometric-based sketch recognition approach can be feasibly adapted for the more complex domain of Chinese characters at the visual recognition level, the next step in our research is to merge our refined visual structure recognition approach and our previous written technique recognition approach for interfaces geared towards teaching Chinese characters used in introductory East Asian language programs.

7. Conclusion

Traditional methods for teaching Chinese characters to Chinese and Japanese language students still rely on the paper-and-pen method. Sketch diagramming tools can improve upon traditional teaching methods such as giving tailored feedback to writing style, having a uniform evaluator on student sketches so student results are graded on the same scale, and also introducing an automotive process for teaching Chinese characters in order to give instructors that extra time to concentrate their teaching on other aspects of the language. We demonstrated in a previous work that a geometric-based sketch recognition system can provide correctness feedback on written techniques, functionality that is both highly difficult to implement and severely limiting in a vision-based system. In terms of the other key component in teaching Chinese characters, visual recognition itself has not been sufficiently explored. Our paper thus analyzed the performance of visual recognition for a geometric-based recognition system and concluded that this approach is still feasible for use in an application in teaching Chinese characters.

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