Enhancing Instruction of Written East Asian Languages with Sketch Recognition-Based "Intelligent Language Workbook" Interfaces

Emerging Technology Research Strand

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1. Abstract

For American higher education students studying one of more of the major East Asian languages that are Chinese, Japanese, and Korean (CJK) as a second language, one of the major challenges that students face is the mastery of those languages' various written scripts due to their vast contrasts from written English. Conventional pedagogical resources for written CJK frequently rely on languages instructors, whom provide in-person demonstrations of those languages' written scripts and real-time assessment of students' written attempts; papers workbooks, which offer guided instructional drills and supplementary knowledge on the written component; and practice sheets, which enable students to repetitiously practice writing areas of the written scripts for memorization purposes. Unfortunately, these techniques also present their own inherent disadvantages: language instructors are constrained by time to focus on the written component for typical classroom sizes, workbooks are static instructional materials lacking real-time intelligent feedback and assessment, and practice sheets result in monotonous practice to students and are vulnerable to students repeatedly practicing on potential writing mistakes if left unsupervised.

In this paper, we describe our work behind "intelligent language workbook" interfaces which combine the benefits of stylus-driven tablet devices and state-of-the-art sketch recognition algorithms for developing intelligent computer-assisted instructional interfaces catered towards written CJK instruction. We evaluated our interfaces on their capabilities to provide instructor-emulated feedback and assessment on the visual structure and writing technique of users' input for several written scripts, and our findings demonstrate strong results for supporting the incorporation of educational applications supporting written CJK instruction.

2. Problem Statement and Context

For the major East Asian languages consisting of Chinese, Japanese, and Korean (CJK), the written scripts that make up those languages' written component greatly differ from written English for reasons including the vast quantity, diverse variety, and visual complexity of their symbols (i.e., letters, characters). As a result, American higher education students enrolled in CJK language courses and lacking prior knowledge of those languages understandably struggle when first exposed to their written component. In order to address these difficulties, CJK language instructors employ different techniques that take advantage of the inherent properties of the written component. Some of those commonly-employed techniques include stroke order and direction, which constrains the user on how the strokes of those symbols should be written for reducing the burden of memorization; brute force memorization, which repeatedly introduces the symbols to users so that they may more effectively retain them in long-term memory; and knowledge of subcomponents, which introduces users to the meanings or sounds of the inner components within CJK symbols so that they may more intuitively understand the symbols [1, 3].

The traditional curriculum resources for assisting students in the mastery of the written CJK languages largely rely on a variety of sources. Language instructors are able assist students by providing in-person demonstrations of the symbol's proper written technique (i.e., stroke order and direction) with accompanying explanations and insights for better understanding those symbols, as well as providing proper real-time assessment on students' written input. Paper workbooks serve as supplementary educational materials which provide guided instructional drills for students to test their knowledge on the actual meaning and usage of those symbols. Moreover, practice sheets enable students to repetitiously practice writing the symbols in order to positively affect the muscle memory in writing them and absorb large quantities of symbols into their memory more effectively. While these resources have been consistent staples in the written CJK language instruction, they also possess lingering issues [9]. Limited classroom time for typical student class sizes constrain instructors from sufficiently assisting students with expert feedback and assessment of their input and from demonstrating the writing of more symbols. The static nature of paper notebooks means that students would not be able to receive real-time feedback of their written responses and instructors would not be able to gauge the written technique correctness of students' delayed written responses. Furthermore, drilling students with repetitiously writing characters on practice sheets is a monotonous task for students and also increases the risk of students potentially practicing and memorizing mistakes in their writing if left unsupervised.

As a result of the existing limitations of conventional educational resources for written CJK instruction, we explored three key research questions in this paper. In response to the time constraint issues of language instructors, how do we achieve the benefits offered from valuable in-classroom instruction of written CJK language instruction by language instructors beyond their existing time constraints? In response to the static nature of paper workbooks, how do we incorporate feedback of students' written input onto existing supplementary educational resources employed outside of the classroom? In response to the lack of oversight from practice sheets, how do we assist students in properly assessing the correctness in the visual structure and written technique of their written input absent input from human language instructors?

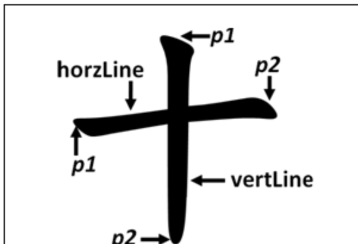
3. Method Employed

3.1. Stylus-Driven Tablet Environment

In order to address the core aspects of the key research questions, we propose a solution that is defined through an "intelligent language workbook" interface, combining the accessibility aspects offered by paper workbooks and practice sheets with the feedback capabilities of human language instructors. As a result, we chose to develop such an educational tool on a stylus-driven tablet environment for several reasons: it provided flexibility for use in various environments such as with instructor supervision within the classroom, instructor assistance within the language lab, or self-study outside the classroom; maintained the prehensile skills and sketching surfaces already extant in writing symbols on paper; and enabled the use of state-of-the-art sketch recognition algorithms for developing tablet-based intelligent user interfaces to emulate human instructor-level feedback [6].

3.2. Sketch Recognition Techniques

For symbols in the written CJK languages, the properties of visual structure (i.e., how they look) and written technique (i.e., how they are written) are heavily emphasized by language instructors in order for students to effectively understand those languages' written component. As a result, instructors provide valuable feedback and assessment to students on improving the correctness of and preventing bad writing habits in their written symbols' visual structure and written technique. In developing the "intelligence" aspects of our proposed intelligent language workbook interfaces for the written CJK languages, we adopted a sketch recognition-based approach over alternative handwritten recognition-based approaches, since the former allows for students' written symbols to be recognized more stringently on their visual structure correctness and can differentiate the correctness of their written technique [6].



Name:

TenKanji

Components:

Line	horzLine
Line	vertLine

Constraints:

Horizontal	horzLine	
Vertical	vertLine	
LeftOf	horzLine.p1	horzLine.p2
Above	vertLine.p1	vertLine.p2
EqualLength	horzLine	vertLine
SameX	horzLine.center	vertLine.center
SameY	horzLine.center	vertLine.center

Aliases:

Point	horzLine.p1	leftPoint
Point	horzLine.p2	rightPoint
Point	vertLine.p2	bottomPoint
…		

Figure 1: A shape description for classifying students' written input of a specific kanji.

3.2.1. Visual Structure Recognition

We observed that symbols contained within the several written scripts in the CJK languages – especially those introduced in the novice language courses – demonstrate strong visual geometric structure, so we determine the visual structure correctness of students' written input by comparing them to specifications of the target symbol's pre-defined geometric structure. This insight motivated us to employ the LADDER sketching language [2] to classify students' written input based on shape descriptions that define their geometric specifications. Shape descriptions in LADDER (see Figure 1) are composed of various specifications including *components*, which are either primitive geometric shapes or user-defined shapes (e.g., inner components of existing symbols) which we manually label by their orientation or their meaning, respectively; *constraints*, which define the spatial relationships between those geometric shapes; and *aliases*, which provide alternative label names to the components and which we manually label by their enumerated stroke order to be later exploited for written technique recognition.

After constructing shape descriptions that correspond to target symbols for a particular lesson, we can determine visual structure correctness of the students' written input by first processing the original strokes of the students' written input into their interpreted geometric representation; then locating corners from various metrics of the original stroke's spatial and temporal information using the Sezgin recognizer [5], and finally extracting the written input's recognized composition of primitive geometric shapes from those the corner information using the PaleoSketch recognizer [4]. From this extracted geometric structure, our approach determines the visual structure correctness by comparing the processed original strokes of the students' written input to the components and constraints in the target shape description. If the original strokes' recognized geometric components and constraints match the target shape description, then our approach determines the students' written input to have correct visual structure; otherwise, the written input is determined as having incorrect visual structure.

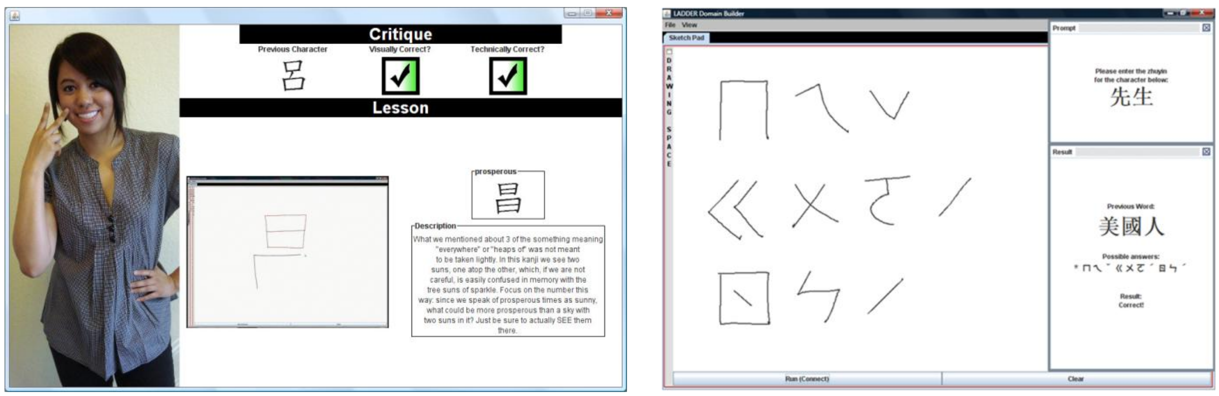
3.2.2. Written Technique Recognition

For visual structure recognized as correct, our approach proceeds to determining the written technique correctness by the correctness of the stroke order and direction. In LADDER shape descriptions, each recognized *component* of the students' written input is assigned a given label name with pre-defined endpoints. We also previously assigned for each stroke an *alias* label name with their stroke order enumeration in the shape description (see Figure 1). This LADDER feature is exploited by first retrieving the timestamp of when each stroke was made by the user and sorting them sequentially, and then extracting and listing each stroke's corresponding *alias* label names, and finally checking if the enumerations from each stroke's *alias* label name is in order sequential order to determine if correct stroke order was followed. We similarly check for correctness in stroke direction with manually assigned label names for the defined starting and ending stroke endpoints. If the students' written input is recognized as having correct stroke order and direction, then it is subsequently recognized as having correct written technique.

3.3. The "Intelligent Language Workbook" Interfaces

Based on our proposed methodology and additional feedback received from several East Asian language faculty members at our university, we developed two specialized "intelligent language workbook" interfaces that focused on distinct separate written CJK language scripts which little linguistic and visual overlap: Hashigo for the instruction of the Japanese kanji character script instruction and LAMPS for the instruction of the Chinese zhuyin phonetic script. The generalized format of our intelligent language workbook interfaces – which summarizes the overall structure shared by our specialized instances of Hashigo and LAMPS– consists of two main parts: the sketch layout, which is where the users write the prompted symbols; and the feedback layout, which provides automated feedback and assessment of the users' written input.

When users first begin using the intelligent language workbook interfaces, they are prompted to first choose a lesson, which consists of a set of symbols taken from an existing textbook chapter; and a mode, which either enables (i.e., practice mode) or disables (i.e., review mode) accompany information prior to each prompted question. After the selections have been made, the user is taken to the sketch layout with a canvas to write the solution and a sidebar with the prompted task. After the user completes and submits their written input, the user is taken to the feedback layout, which provides a critique of the user's performance in terms of visual structure and written technique correctness, an animation of the expected solution, and an accompanying paragraph that provides instructor-level assessment of the user's performance. The user continues through each question until completion, where a final feedback window grades the entire performance of the user for that particular lesson.



(a) **(b)**

Figure 2: Screenshots of developed "intelligent language workbook" interfaces: (a) Hashigo for Japanese kanji instruction [7] and (b) LAMPS for Chinese zhuyin instruction [8].

4. Results and Evaluation

We summarize here the separate evaluations of our Hashigo and LAMPS intelligent language workbook interfaces on their effectiveness of several metrics, with our first metric being visual structure correctness. For Hashigo, we recruited eleven international graduate students fluent in the characters of the domain, since we desired the benchmark of our model input to match those of those from expert users. The result of our preliminary study for a set of nineteen characters from a selected textbook chapter using cross-validation yielded 93% accuracy, which was on par with alternative recognition techniques. A similar study was performed with nine distinct users with similar demographics, expertise, and parameters for LAMPS, which yielded 95% accuracy.

Our subsequent metric was on written technique correctness, and we conducted a study on a group of five users – all with no prior knowledge of writing characters in the domain – to write a set of characters from a textbook chapter with only a visualization of those characters and no information on how they are written. While the users achieved 99% accuracy on the visual structure of those characters given an accompanying visual aid, they achieved 6% accuracy on their written technique that we attributed to their lack of familiarity of the characters. We received similar results when the study was conducted again for LAMPS.

As a subsequent study to the written technique correctness, we conducted a pilot study of Hashigo on the metric of learning tool viability using the same set of novice users by using the interface three complete times (i.e., preview, learn, and review) for a particular textbook chapter lesson. Following their third use, we analyzed the interface's critique of users' written input for visual structure and written technique correctness. Their results showed that the users were 100% accurate on their visual correctness and 97% accurate on their written technique after using our interface. These results showed positive impact on the potential of Hashigo's viability as a learning tool since these novice users improved their written technique correctness during those sessions from 6% to 97%.

5. Future Work

Promising results from our emerging technology research work related to our initial intelligent language workbooks interfaces encourage us to continue working with East Asian language faculty members at our university on possible next steps for initially deploying these interfaces in the classroom and language lab settings. We strongly desire for our interfaces to complement the instructors' existing curriculum as opposed to replicating their existing pedagogical methods, so we aim to coordinate more directly with the faculty members in our university for our interfaces to better accommodate the instructors' and their students' existing needs. Additionally, we would like to expand our intelligent language workbooks to incorporate other CJK language scripts such as the Korean phonetic written script and the remaining Japanese written scripts.

6. References

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