CGI'19

Intelligent Chinese Calligraphy Beautification from Handwritten Characters for Robotic Writing

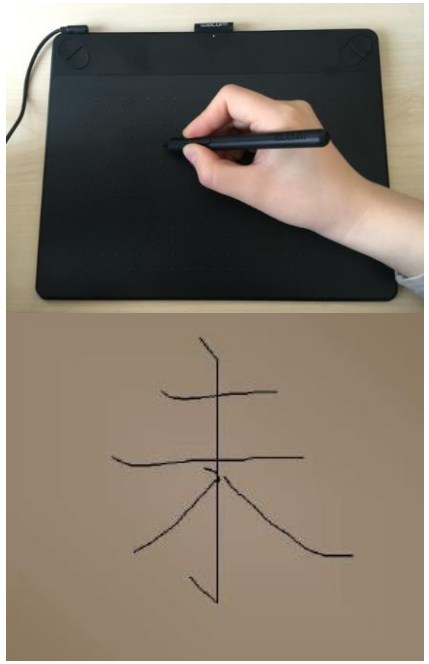
Xinyue ZHANG[a] , Yuanhao LI[a] , Zhiyi ZHANG[a] , Kouichi KONNO[b] , Shaojun Hu[a]

[a] Northwest A&F University, China

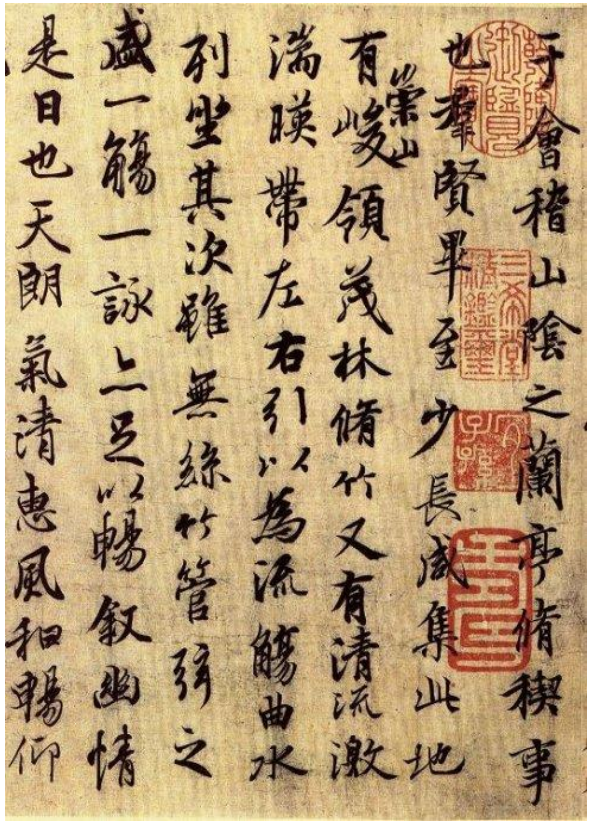
[b] Iwate University, Japan

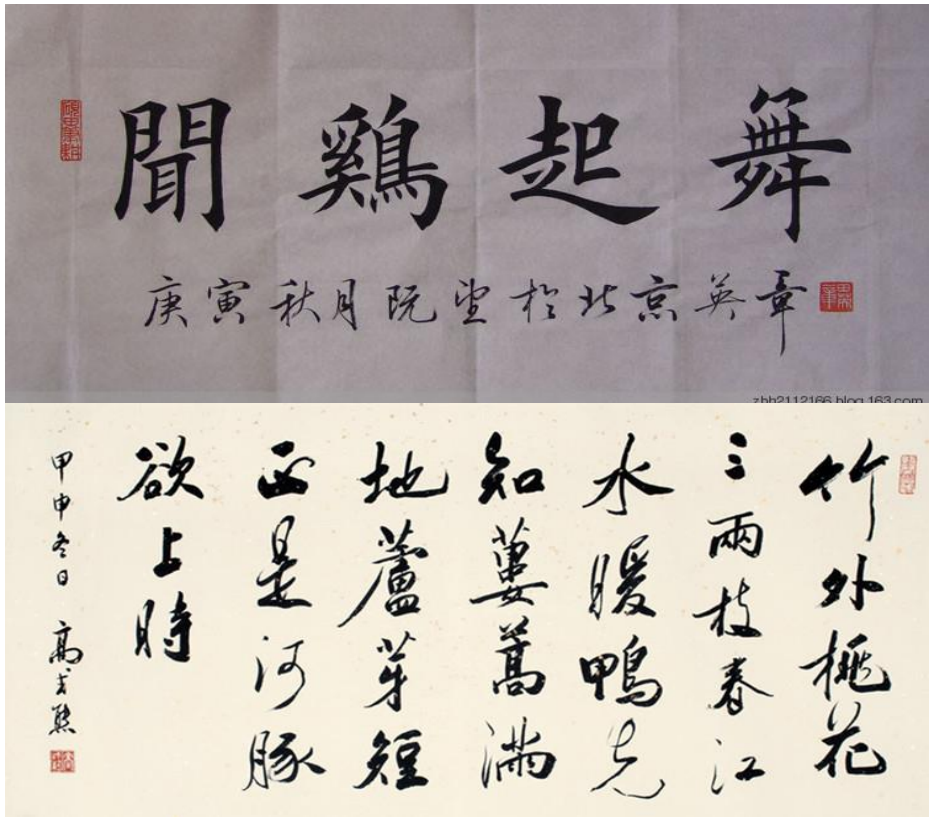
June, 2019

Calgary, Canada



Chinese calligraphy artworks



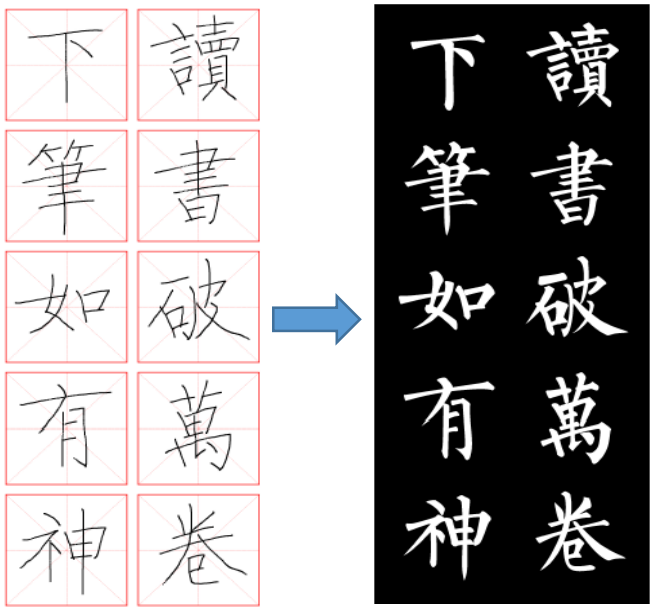


How to do for common people ?

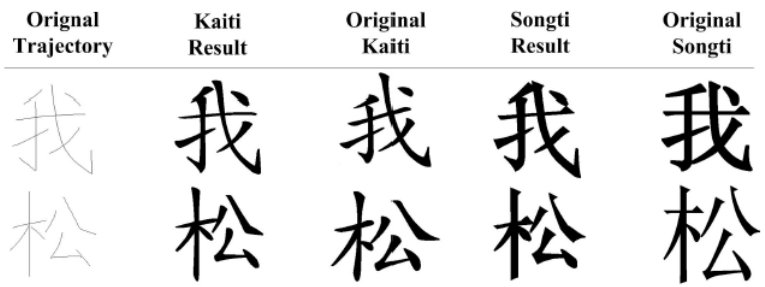
Related work

- Studies based on conversion from user's handwritten characters to digital calligraphy [Zhang et al. 2010], [Yi et al. 2014], [Li et al. 2012]

(a)



(b)

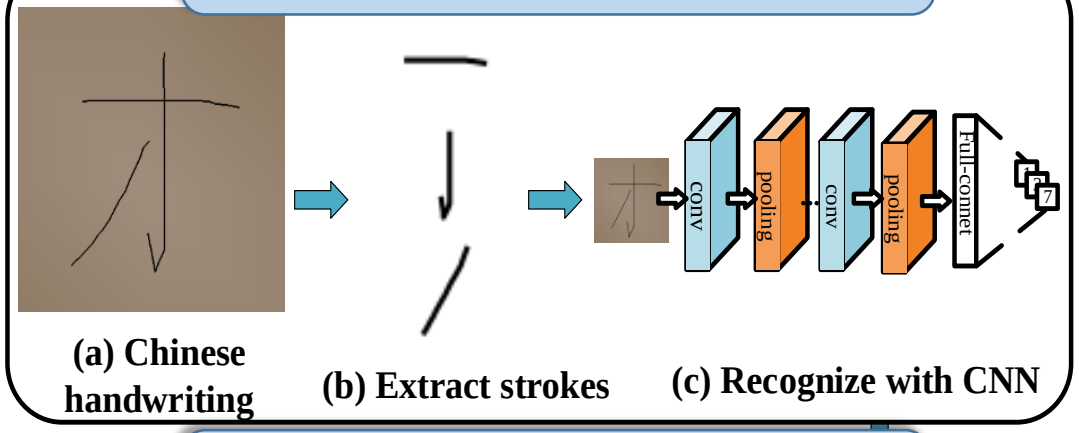


(c)

Digital ink

Overview

Part 1:Handwritten character

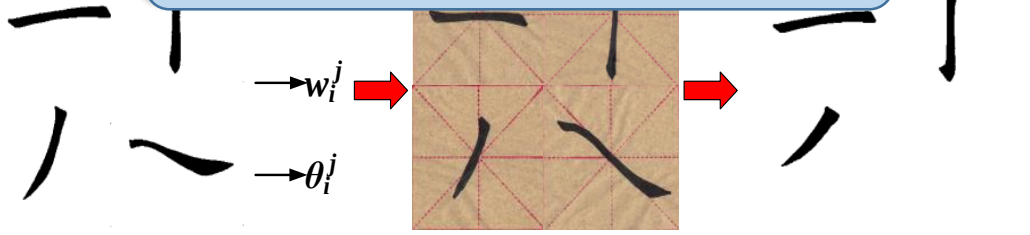


(a) Chinese handwriting

(b) Extract strokes

(c) Recognize with CNN

Part 2:Calligraphy strokes

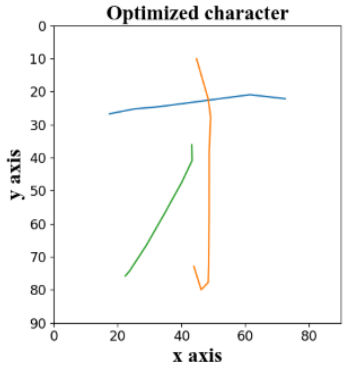


(d) Extract parameters

(e) Calligraphy database

(f) Corresponding stroke

Part 3:Beautification



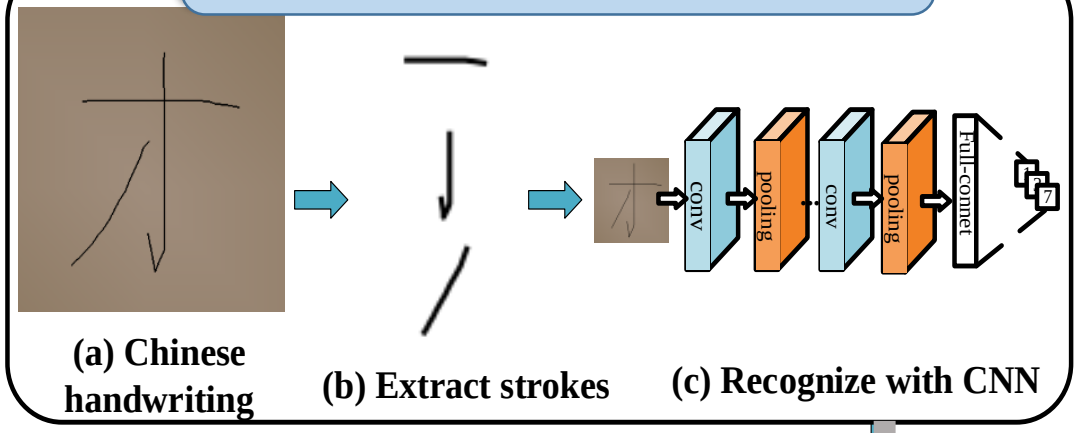
(g) Optimized character

Part 4: Robotic writing

(h) Write by robotic arm

1. Handwriting input and recognition

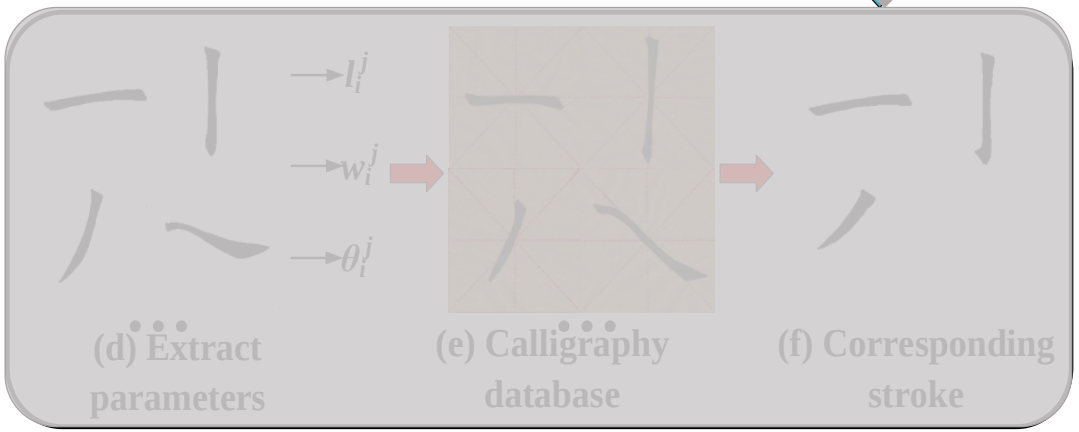
Part 1:Handwritten character



(a) Chinese handwriting

(b) Extract strokes

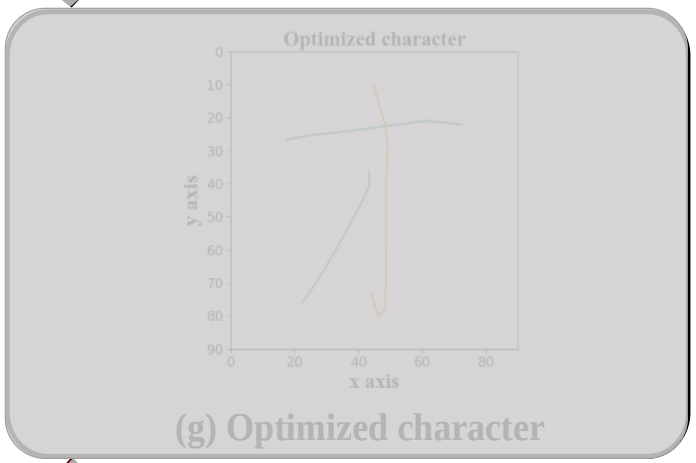
(c) Recognize with CNN



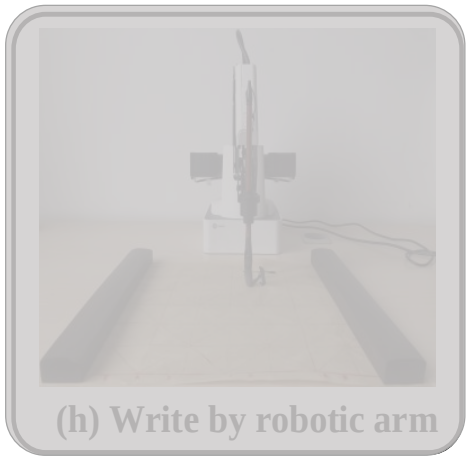
(d) Extract parameters

(e) Calligraphy database

(f) Corresponding stroke



(g) Optimized character

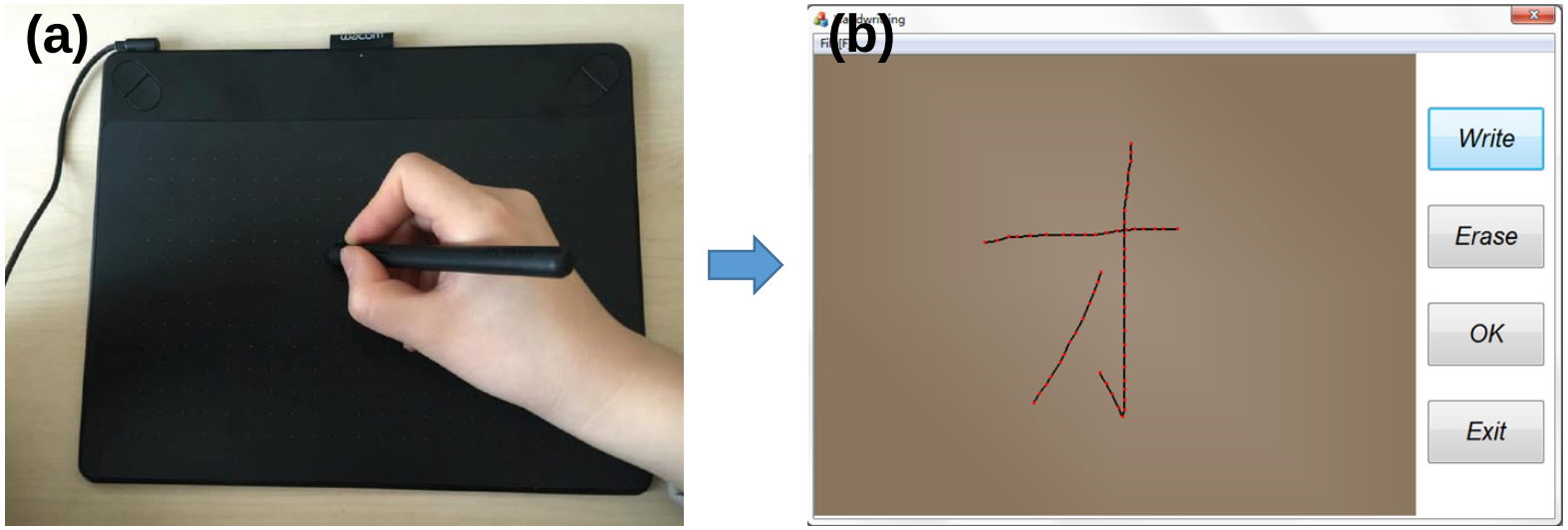


(h) Write by robotic arm

Obtain handwritten character & strokes

- **Input:** mouse or touch pad
- **Extraction:**

→ extract stroke coordinates directly from a user interface. It's easy to record the stroke coordinates and sequences.



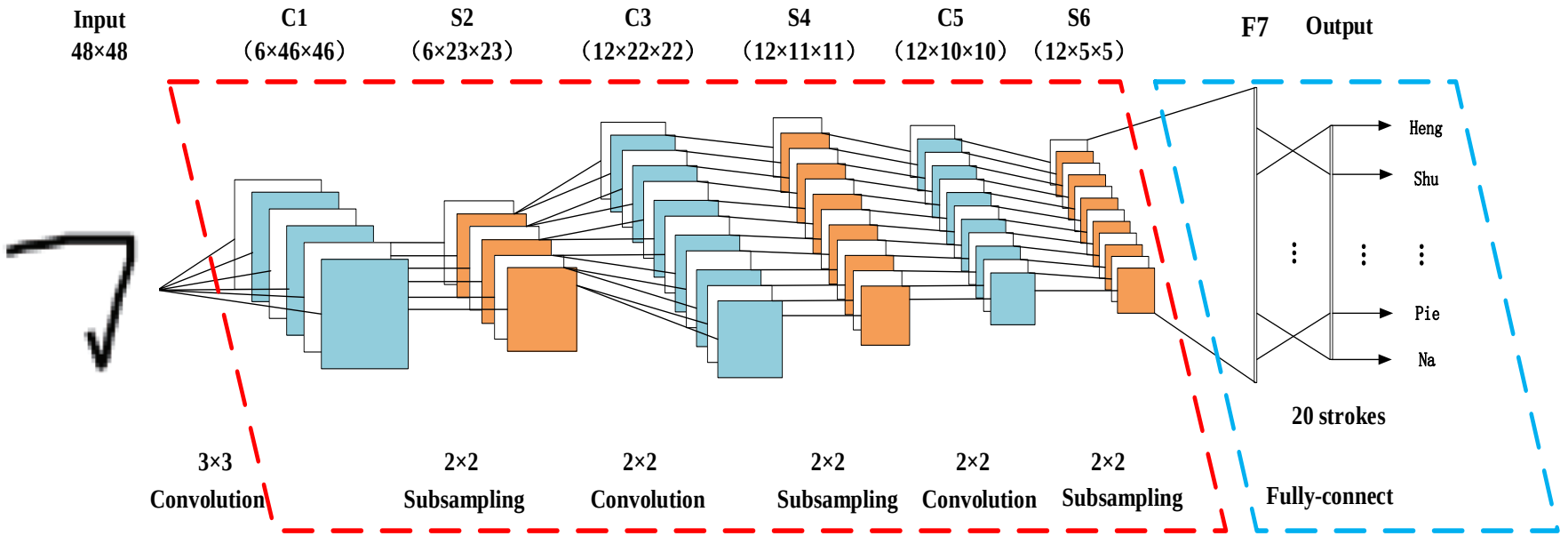
(a) Input from a touch pad. **(b)** writing interface

Stroke recognition with CNN

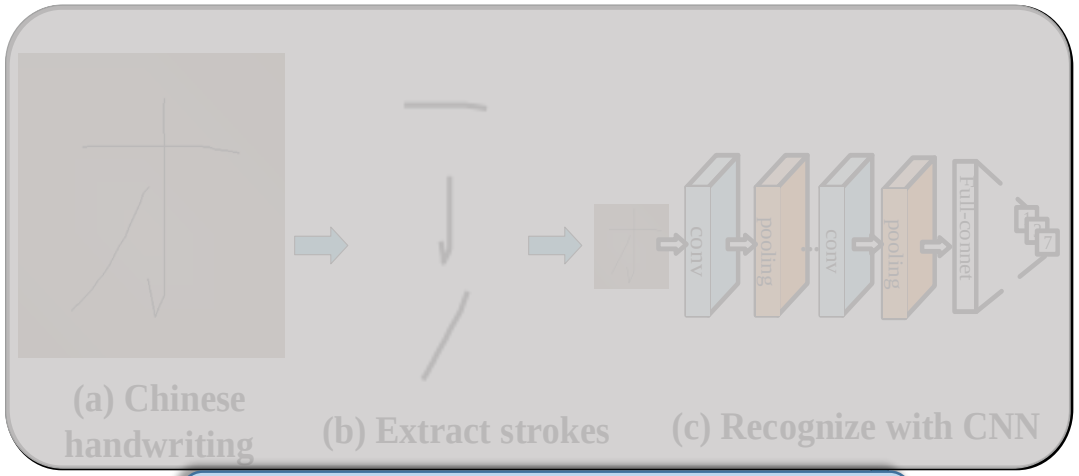
- Convolutional neural networks (CNN)for handwritten characters

  [Gupta et al. 2011], [Syamlan et al. 2015], [Xiao et al. 2017]

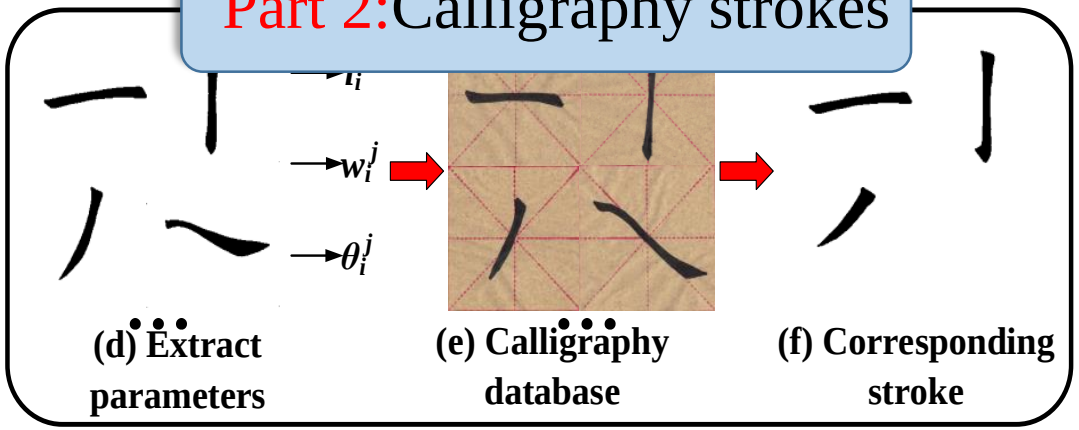
- Our average recognition rate reaches 93%.

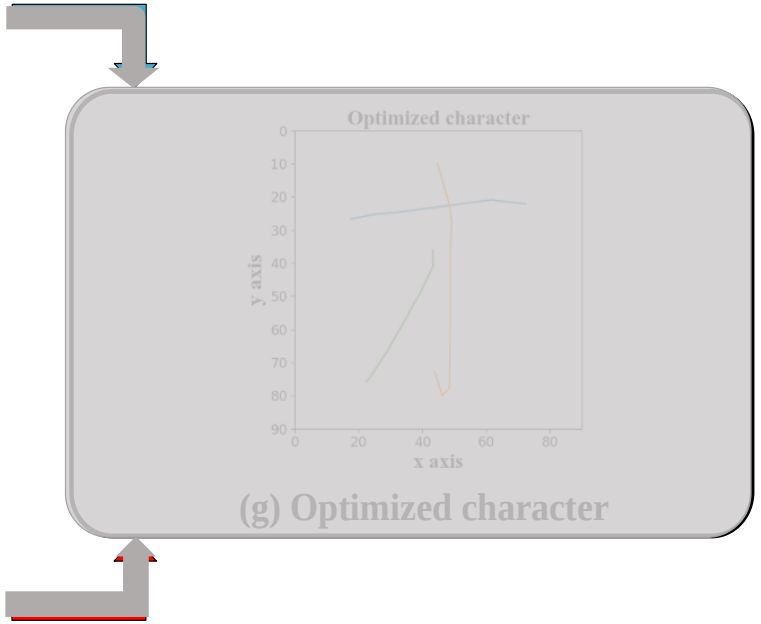


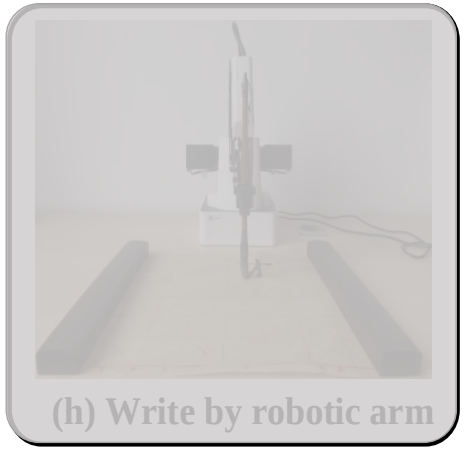
2. Calligraphy stroke database establishment



Part 2:Calligraphy strokes





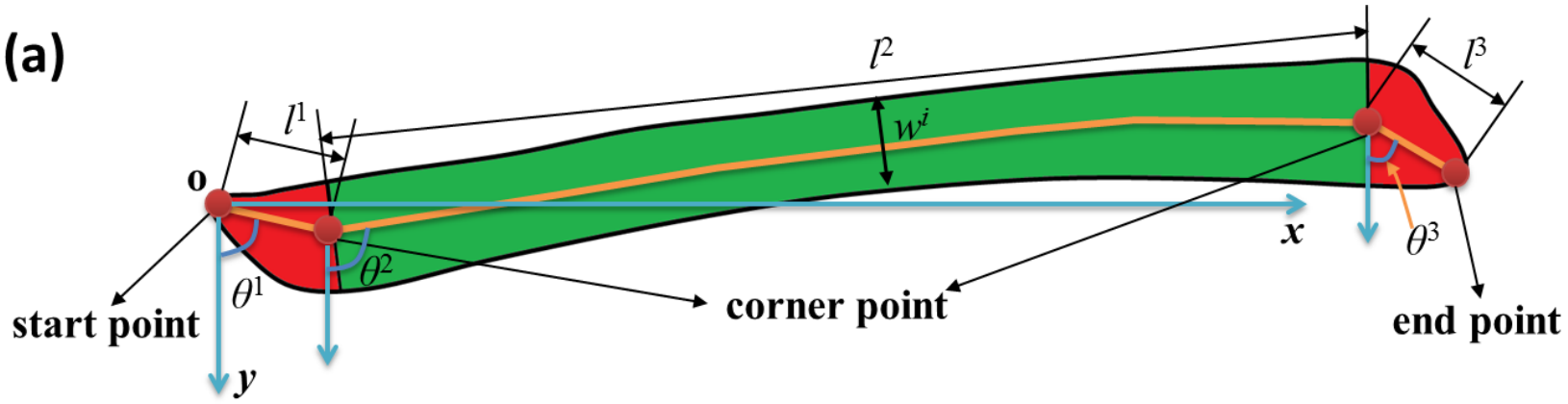


Stroke parameterization

- Extract the skeleton of standard calligraphy stroke

  Tian's book — *The Elaboration of Ancient and Modern Famous Kai Calligraphy*

- Build the parameter model for each stroke



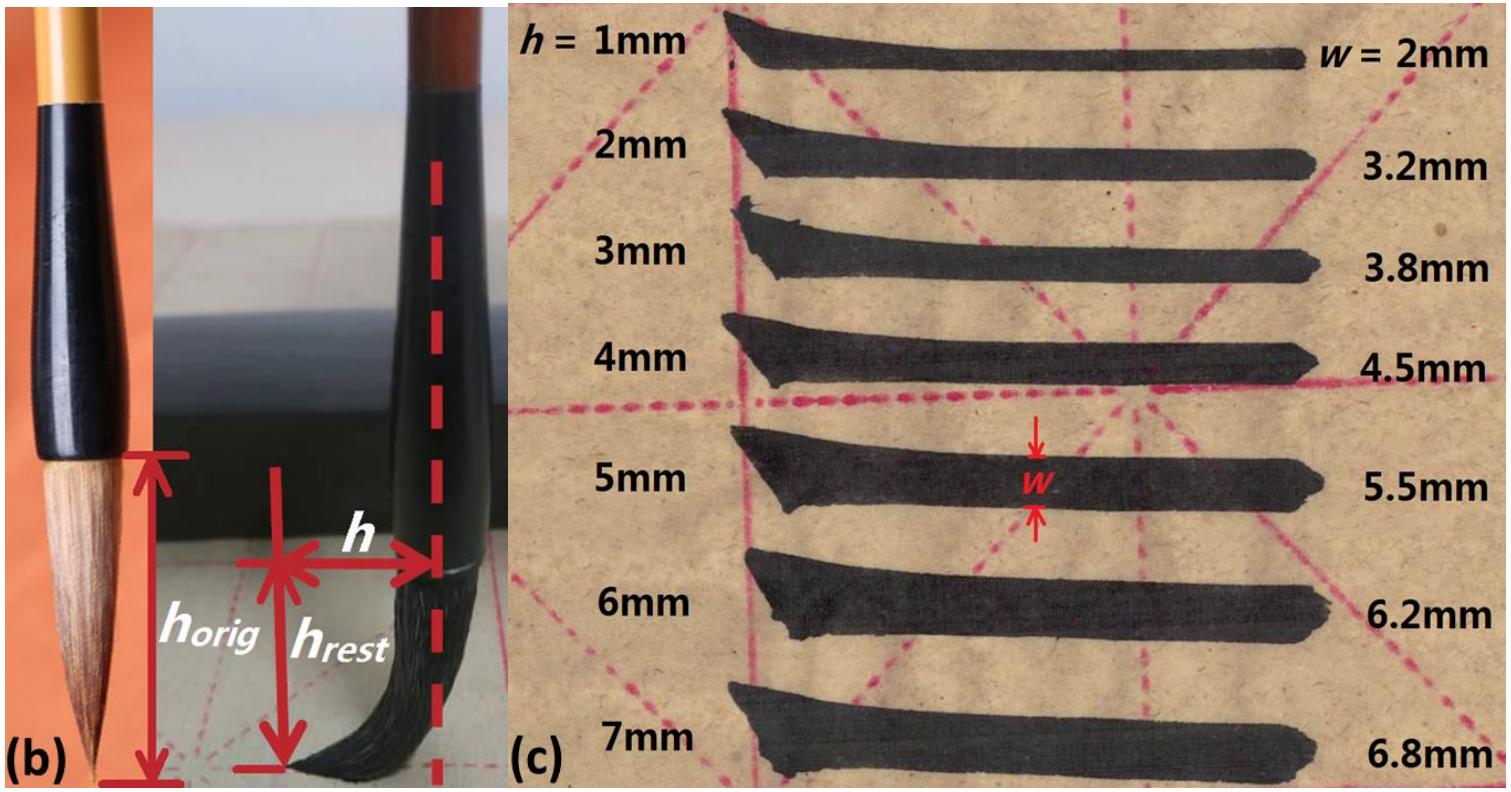
$(l_i^j , \theta_i^j , w_i^j)$

l — length
θ — angle
w — width

Rigid segment (red area) - contains the important features of regular-style calligraphy
Flexible segment (green area) - the transition segment between the rigid segments

Problem & Approach

- Relationship between ***w*** (stroke width) & ***h*** (desent of brush)

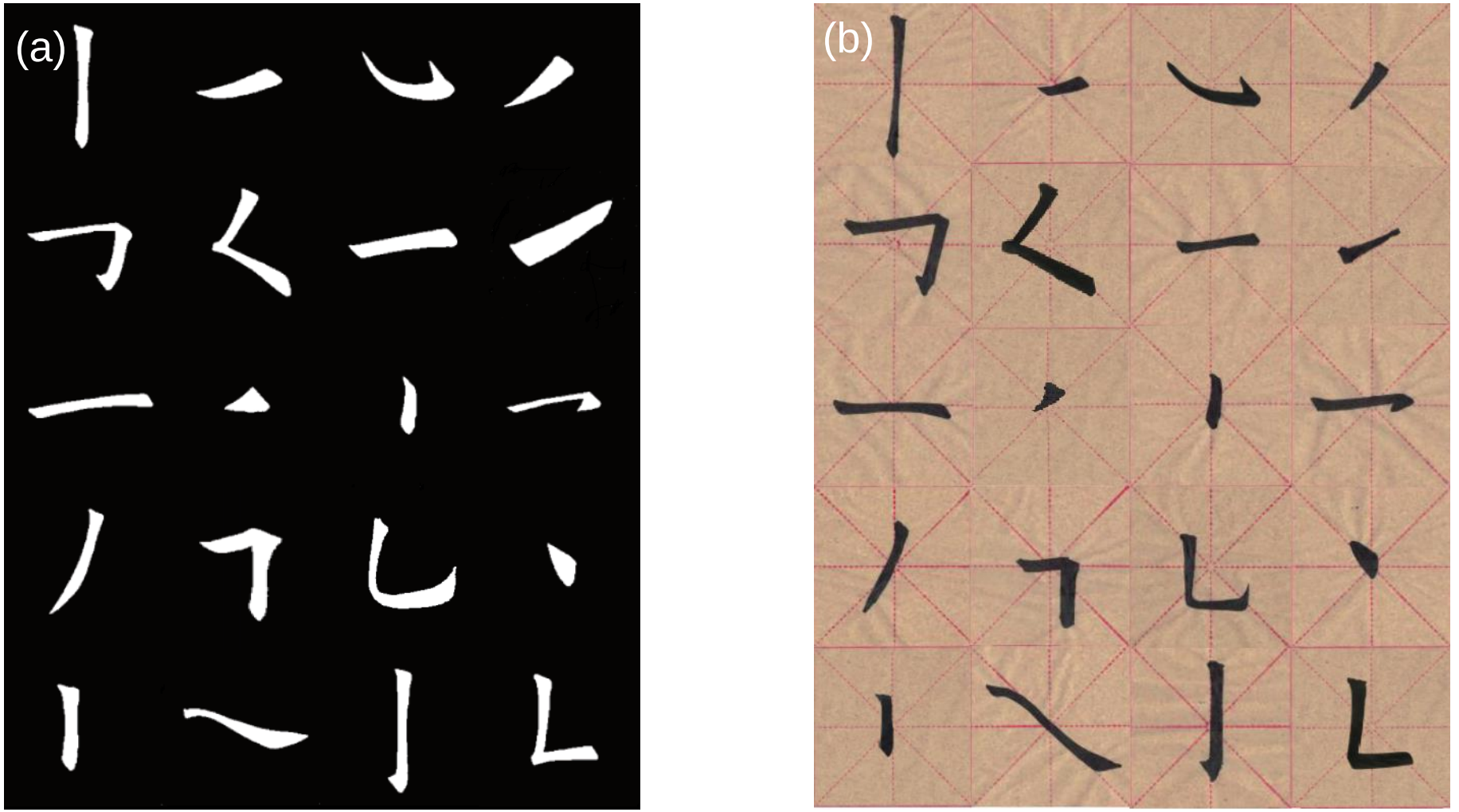


$$h = h_{orig} - h_{rest}$$

$$w = ah + b$$

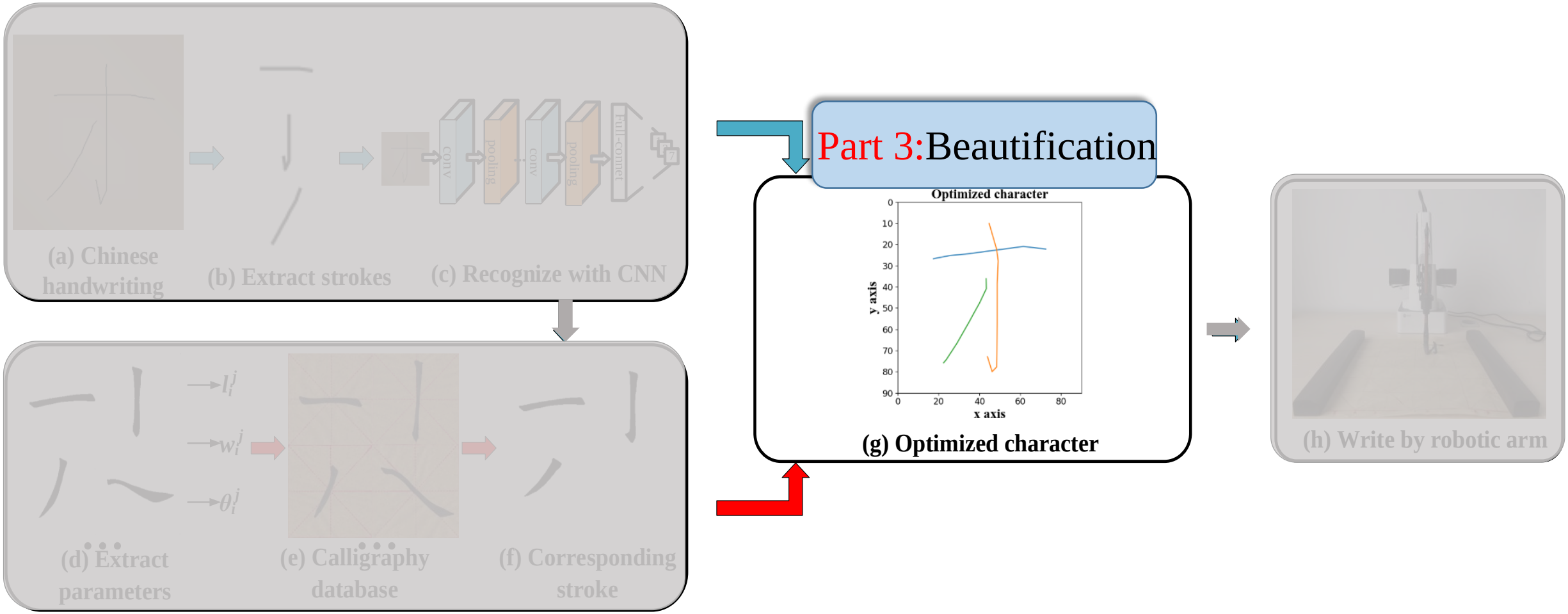
least-squares fitting

Standard stroke database



(a) Tian's 20 Original standard strokes; **(b)** robot-written strokes

3. Calligraphy beautification and writing



Global optimization of the target strokes

- **goal 1: make the target stroke be close to the user's handwriting.**

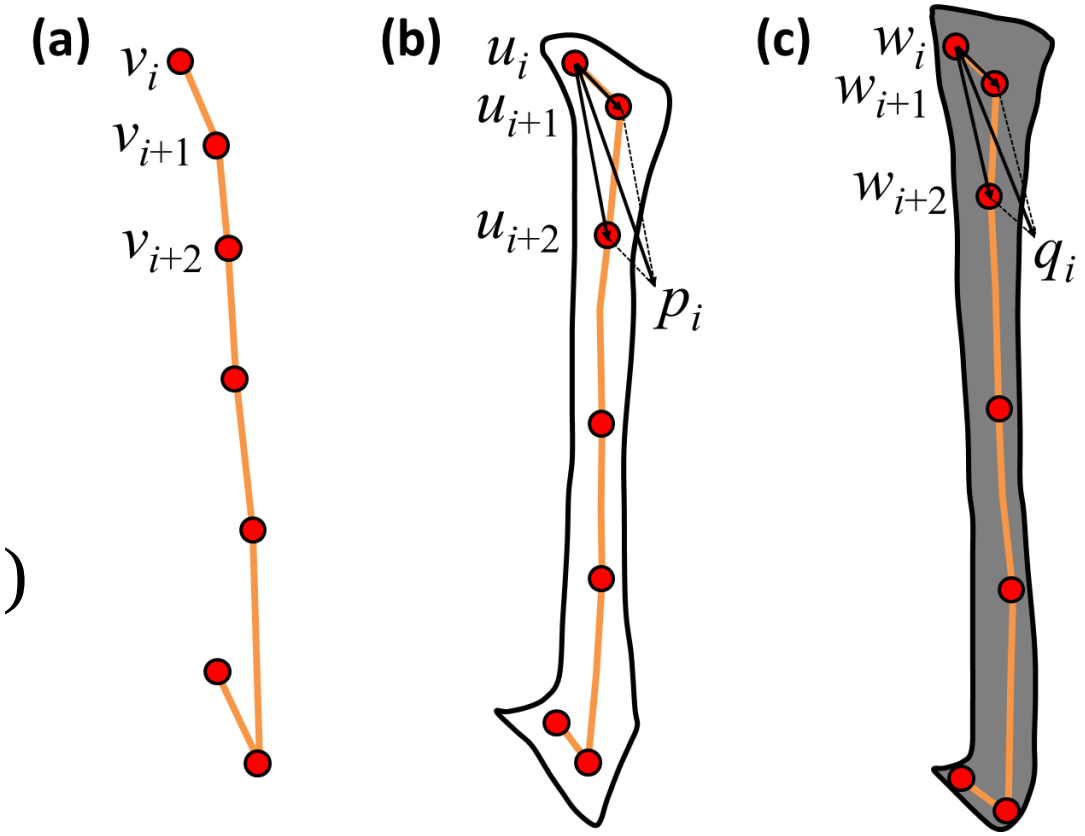
→ Minimize a weighted Euclidean distance between the handwriting and generated points.

→ position similarity function $F(w,v)$:

$$F(w,v) = \sum_i \|w_i - v_i\| = \sum_i (w_i - v_i)^T (w_i - v_i)$$

Generated 2D points

Handwriting 2D points



(a) original handwriting **(b)** skeleton of standard calligraphy **(c)** skeleton of target stroke

Global optimization of the target strokes

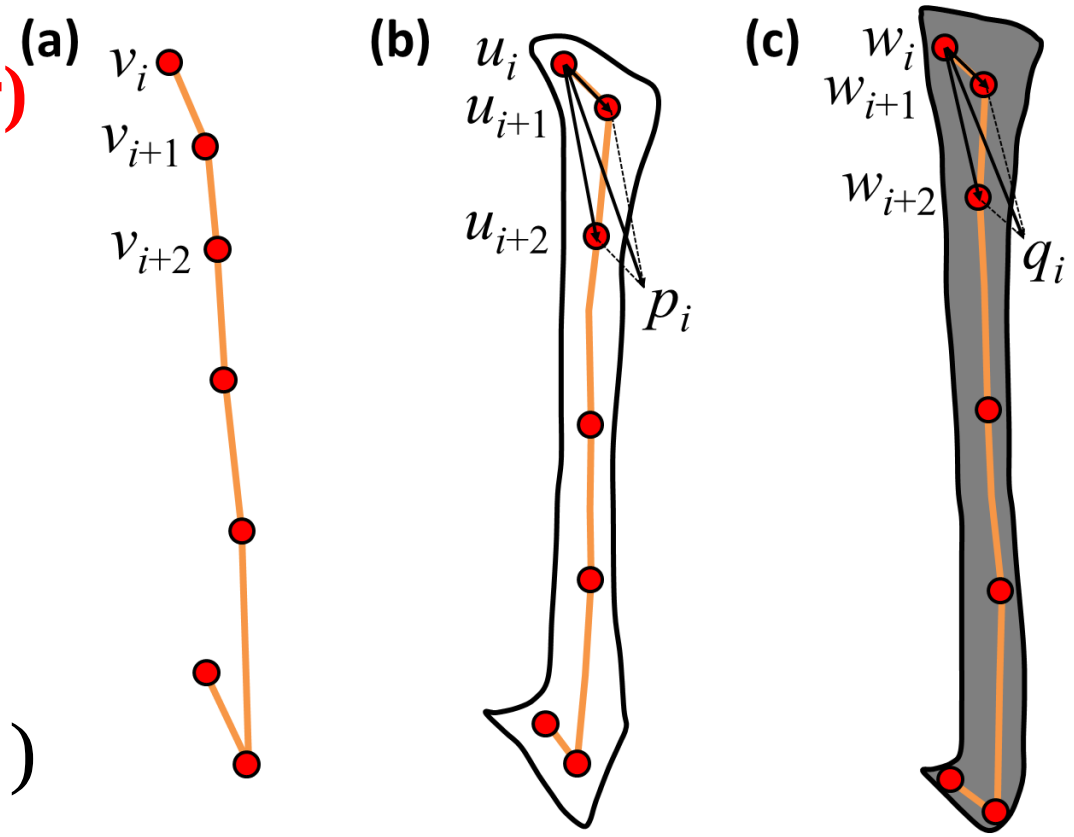
- **goal 2: make the target stroke preserve calligraphy style.**

→ Define an **SCV(**Shape Character Vector**)** to represent the shape of a stroke

$$\text{SCV} \begin{cases} p_i = u_{i+1} + u_{i+2} - 2u_i \\ qi = w_{i+1} + w_{i+2} - 2w_i \end{cases}$$

→ The objective function $G(u,w)$:

$$G(u,w) = \sum_i \|p_i - q_i\|_2 = \sum_i f_{sqrt}(p_i - q_i)$$



(a) original handwriting **(b)** skeleton of standard calligraphy **(c)** skeleton of target stroke

Global optimization of the target strokes

- **goal 3: make the target stroke be smooth as much as possible.**

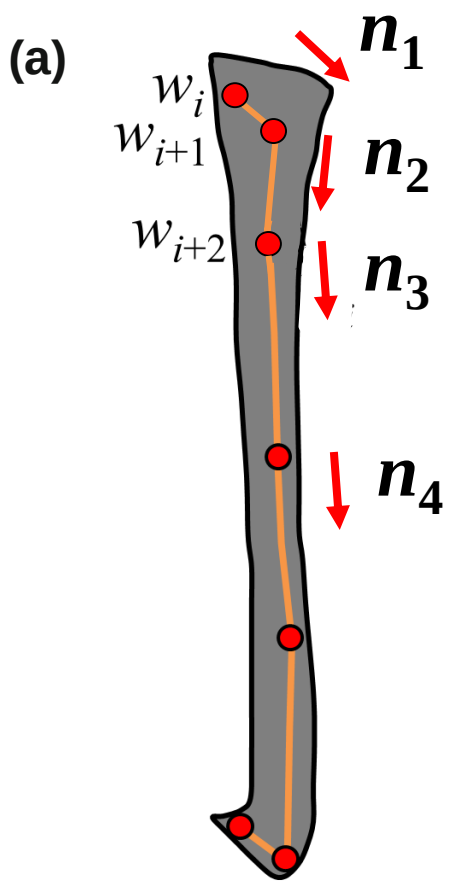
→

$$n_i = \frac{w_{i+1} - w_i}{\|w_{i+1} - w_i\|}$$

normalized direction vector

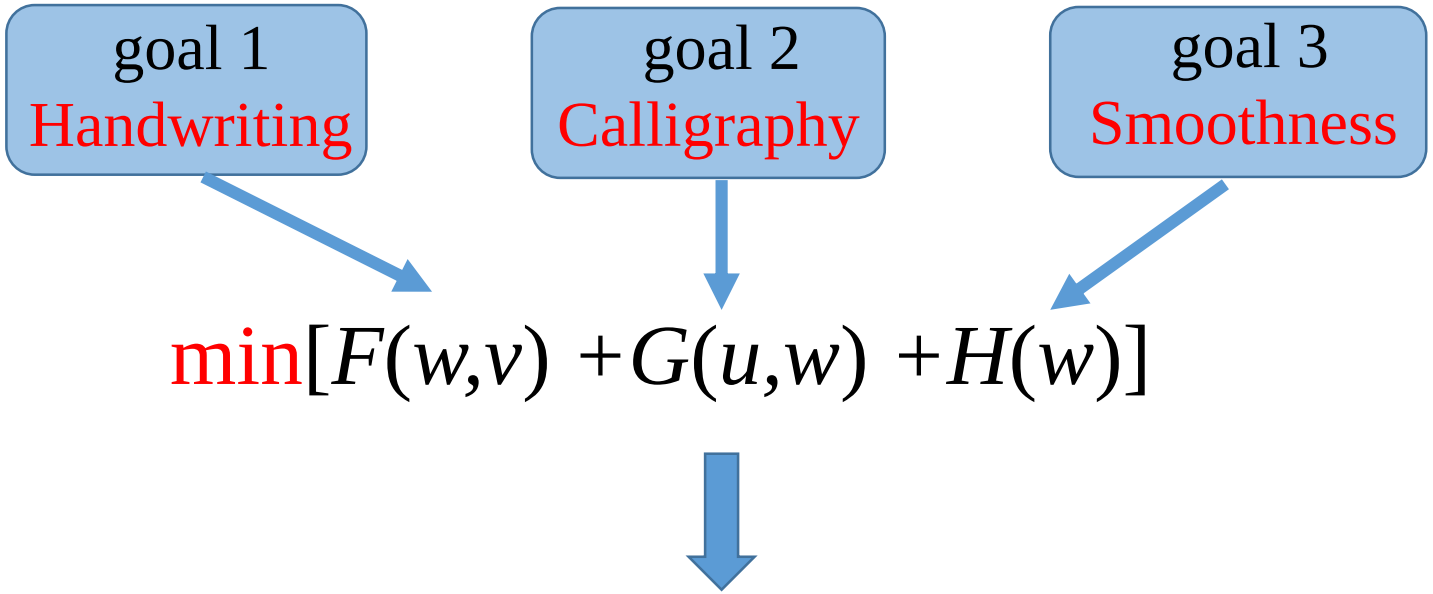
→ The constraint function $H(w)$:

$$H(w) = \frac{n_{i+1} - n_i}{\|n_{i+1} - n_i\|} = \sum_i f_{sqrt}(n_{i+1} - n_i)$$



(a) skeleton of target stroke

Optimization model

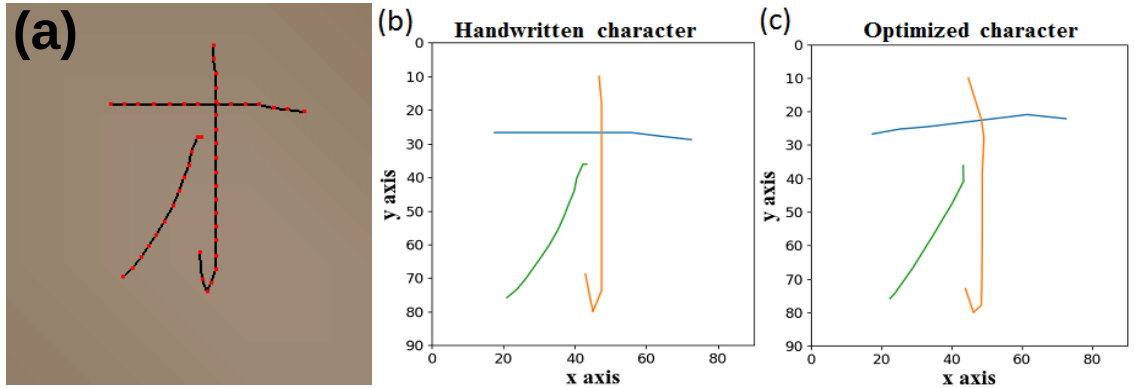


$$\hat{X} = \arg\min_{x}\left[\alpha[\sum_{i}(w_i - v_i)^T(w_i - v_i)] + \beta[\sum_{i} f_{sqrt}(p_i - q_i)] + \gamma[\sum_{i} f_{sqrt}(n_{i+1} - n_i)]\right]$$

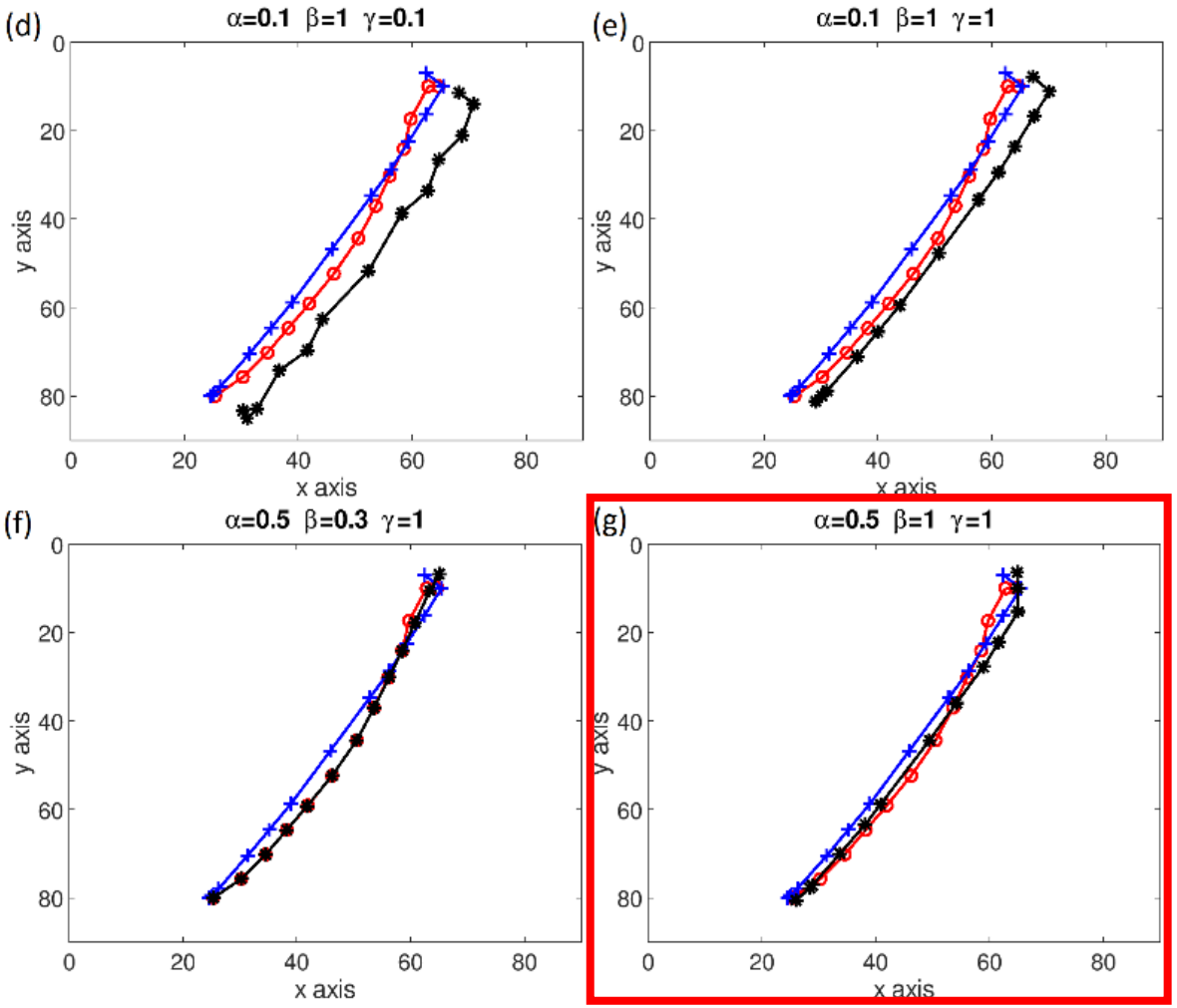
α, β, γ : weight coefficients

Adjust & select parameters

- Set the range of each weight coefficient (α, β, γ) to [0.1,1]



(a) Original handwritten characters;
(b) handwritten characters in a 90 × 90 grid;
(c) optimized character;
(d)-(g) results of different combinations of parameters α, β, γ for the stroke "Pie".

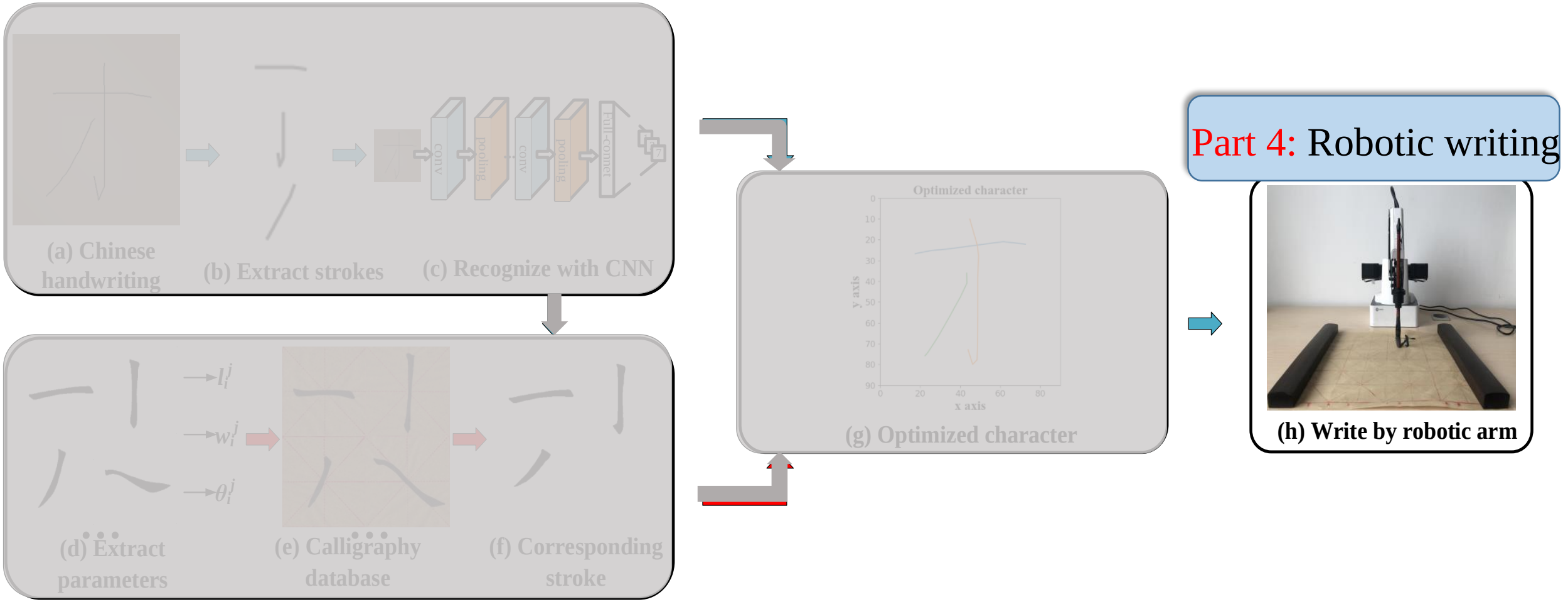


handwritten skeletons

skeletons in standard calligraphy

the optimized result

4. Control of robotic arm writing

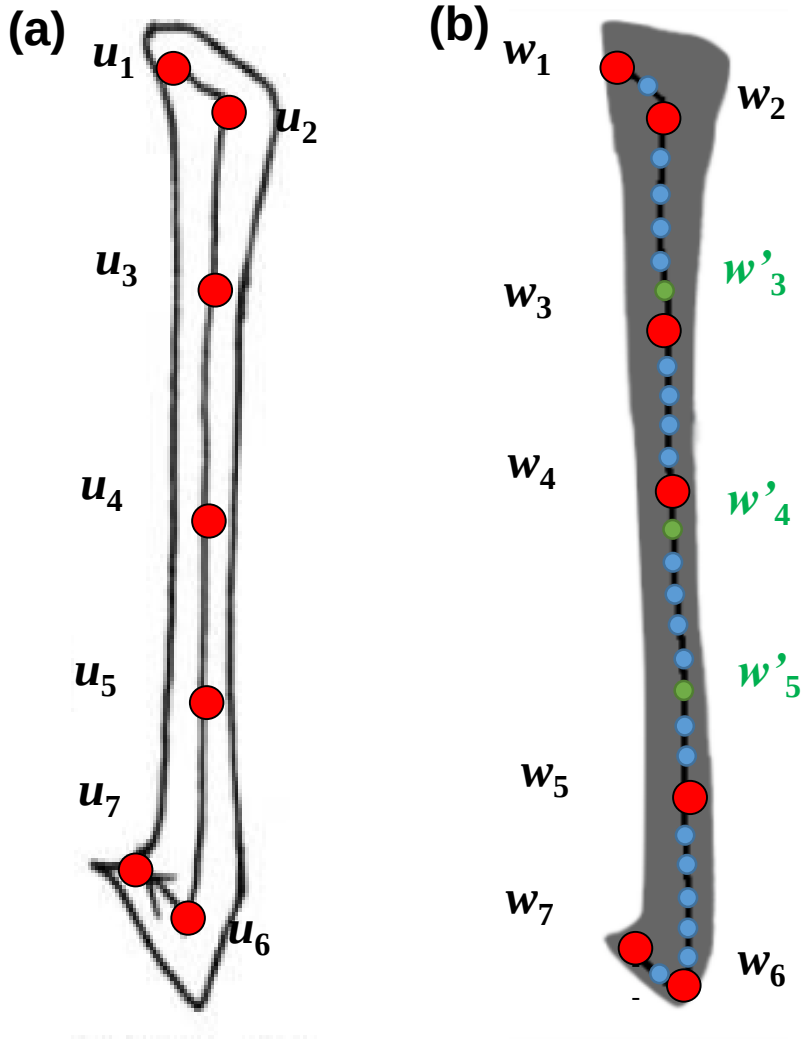


Height values (z) of robot control points

➢ **Problem:** it is inappropriate to directly use the z value of the standard stroke.

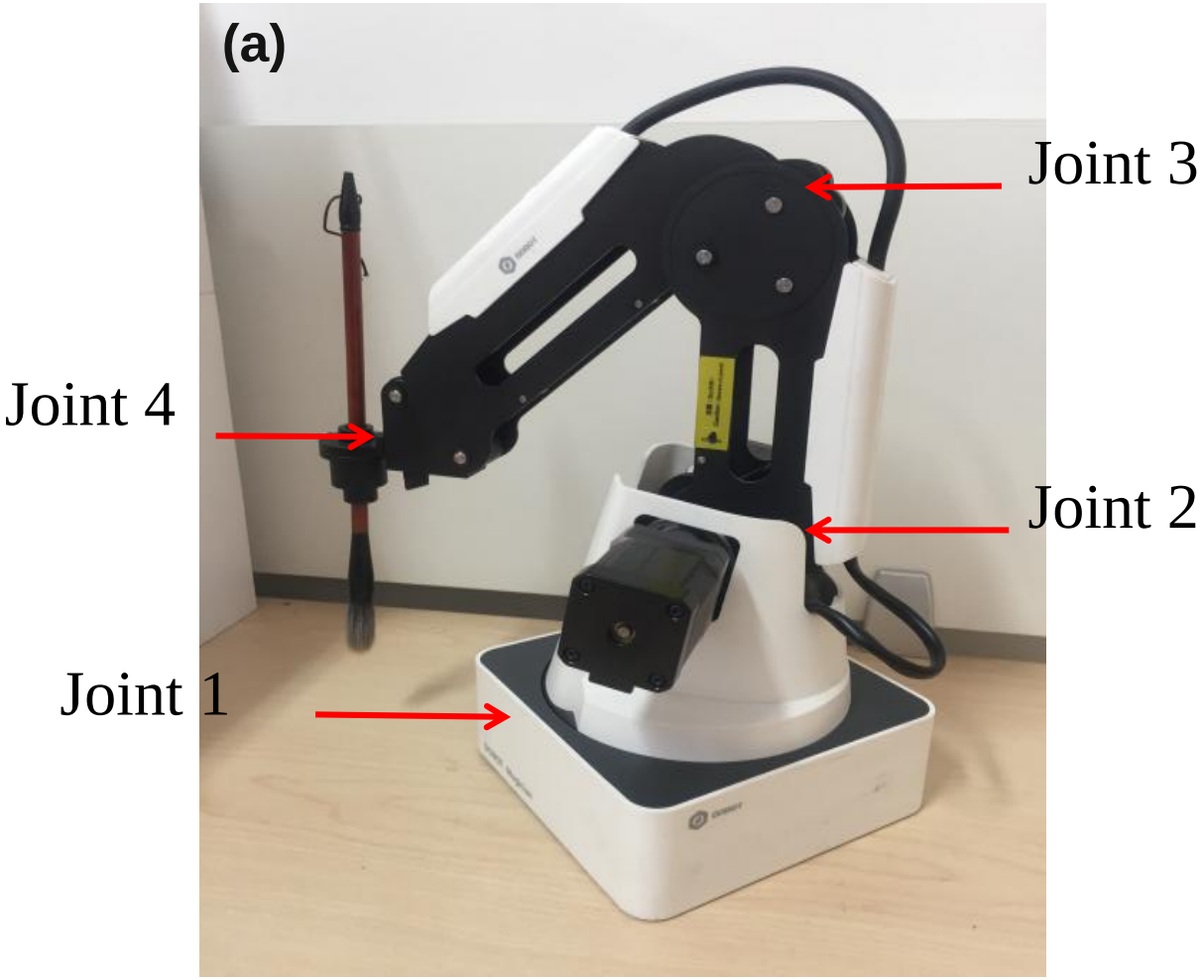
→ **Approach:** find new corresponding points from standard calligraphy stroke, and calculate a reasonable height value.

- Step 1 :expand the points **(blue)** on an optimized stroke
- Step 2 :Look for evenly spaced points w'_i ($|w'_i - w_1| = |u_i - u_1|$)
- Step 3 :the z value of w_i linearly interpolated between w'_i *and* w'_{i+1}



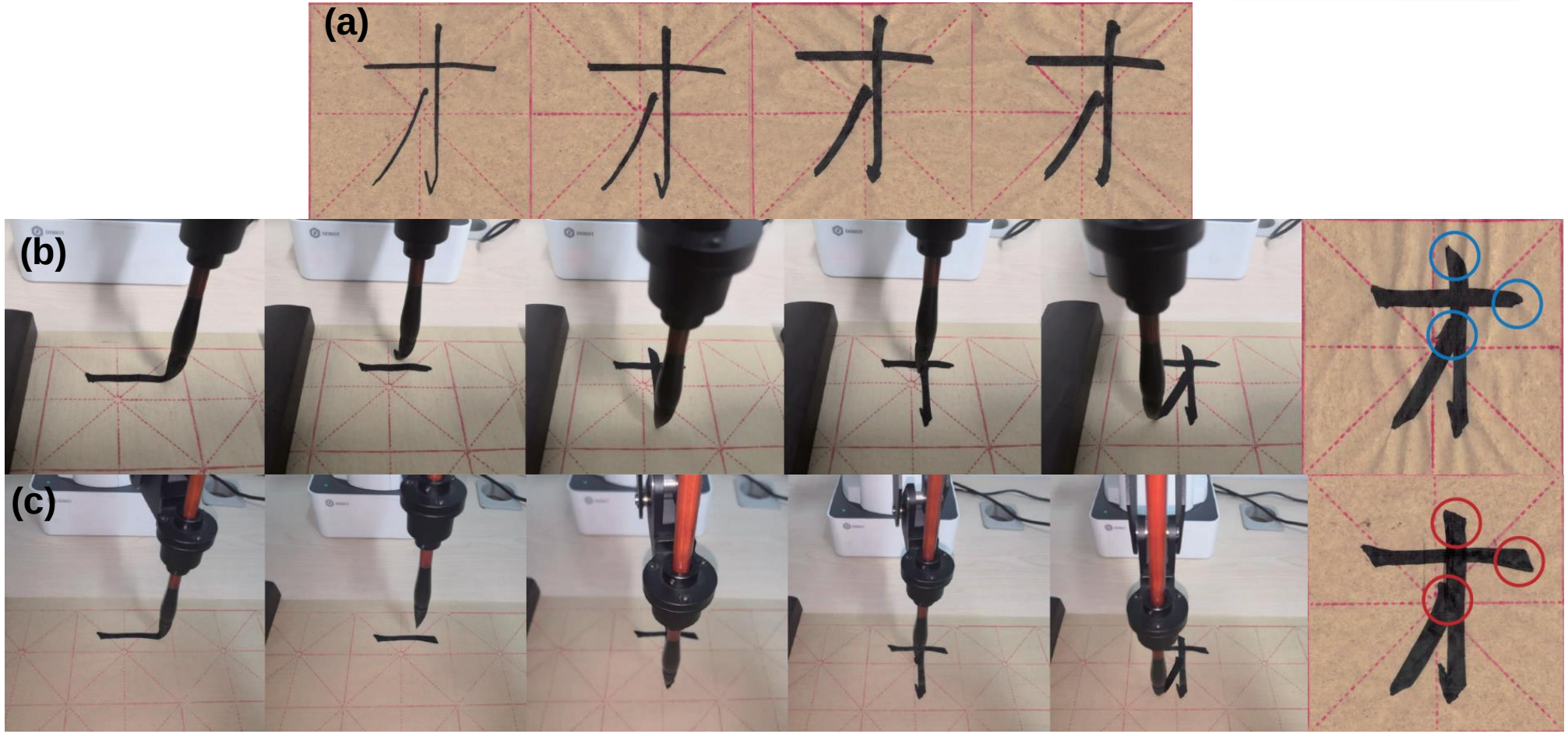
(a) Standard calligraphy stroke **(b)** Optimized stroke

Control of robotic arm writing



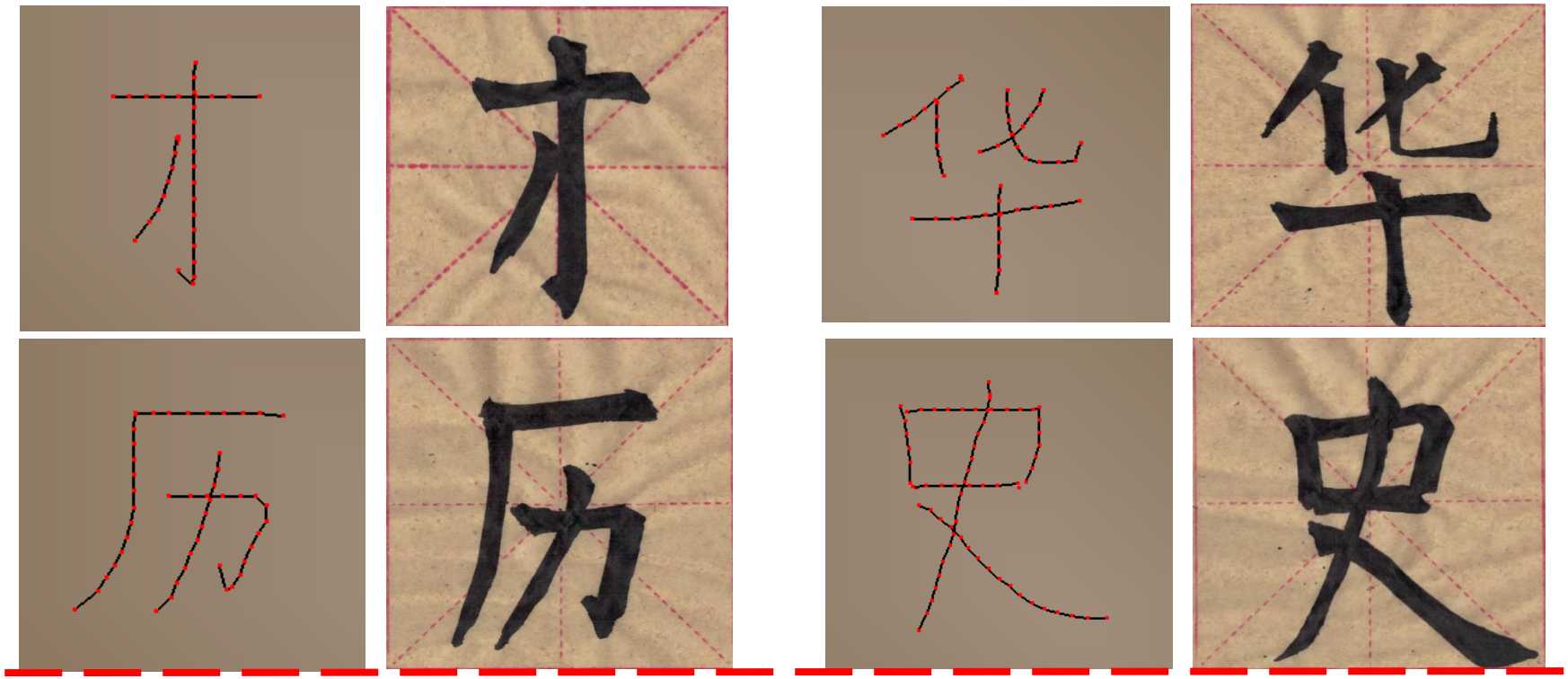
(a) DOBOT robotic arm **(b)** DOBOT Studio interface

Experiments & results

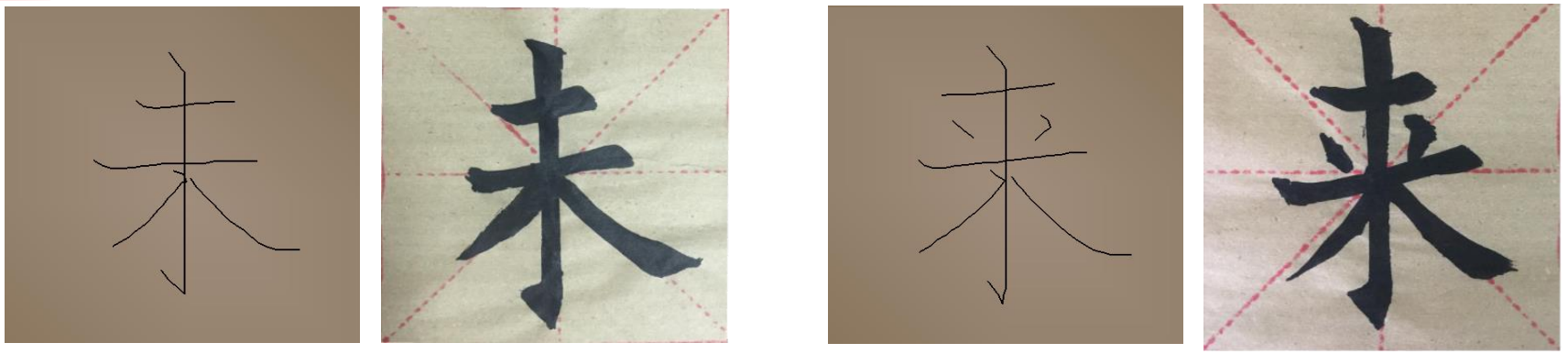


(a) no optimization results as the height of the brush is lowered **(b)** results of calligraphy writing after optimization without rigid segment replacement **(c)** results of calligraphy writing after optimization with rigid segment replacement

Results



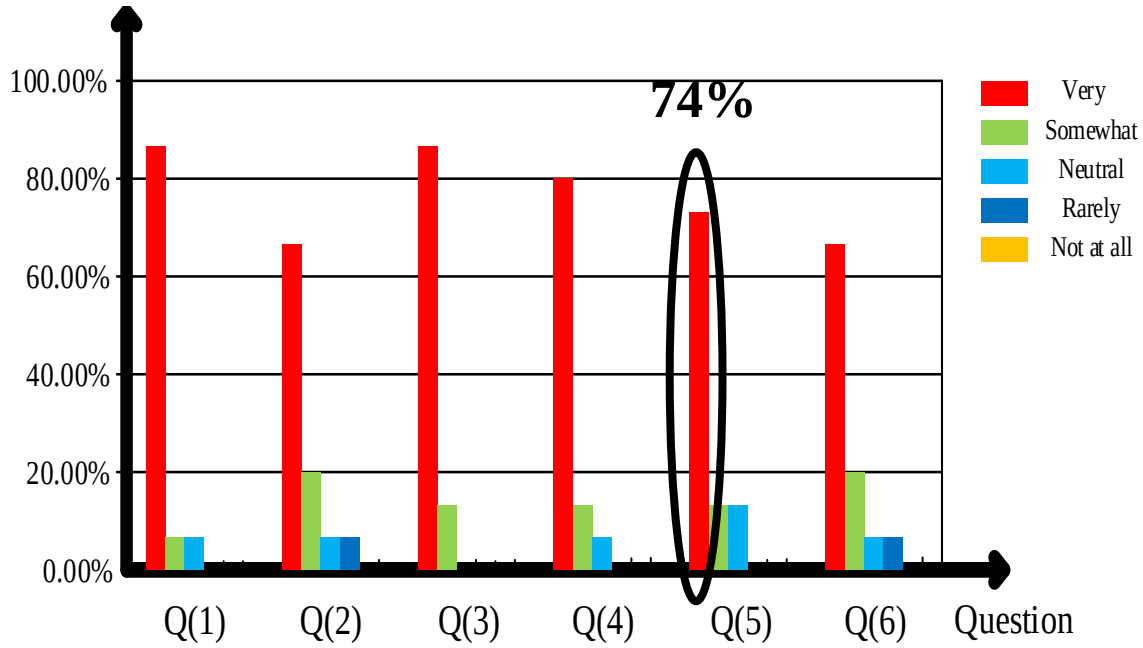
Non-expert users



Expert users

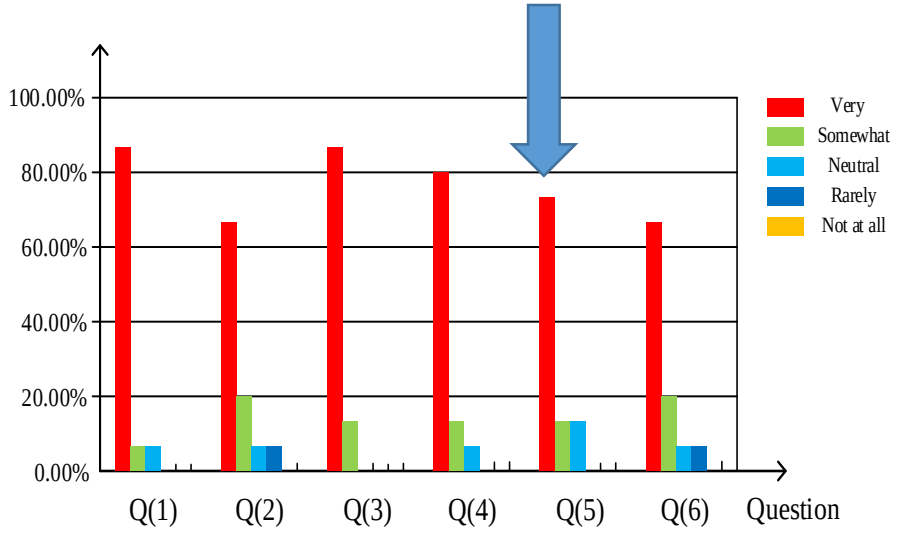
User study

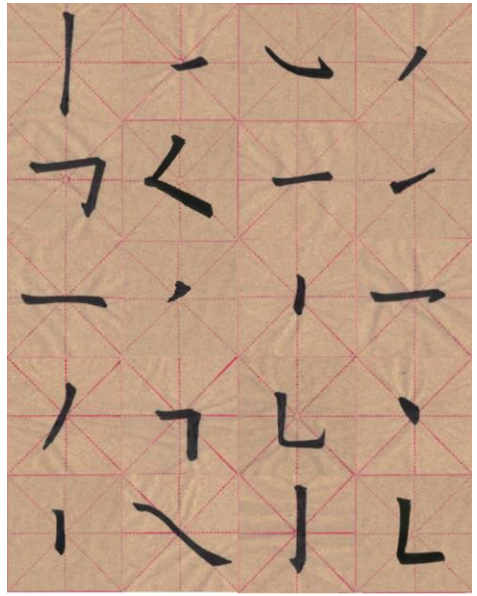
Questions	Choices				
Q(1) The beautification method is usefull	Very	Somew hat	Neutr al	Rarel y	Not at all
Q(2) Calligraphy written by robotic arm has the style of handwriting	Very	Somew hat	Neutr al	Rarel y	Not at all
Q(3) Calligraphy written by robotic arm has the characteristics of regular script	Very	Somew hat	Neutr al	Rarel y	Not at all
Q(4) Calligraphy written by robotic arm is aesthetic	Very	Somew hat	Neutr al	Rarel y	Not at all
Q(5) The overall process is relatively time-consuming	Very	Somew hat	Neutr al	Rarel y	Not at all
Q(6) The system will be recommended to calligraphy amateurs	Very	Somew hat	Neutr al	Rarel y	Not at all



Limitations

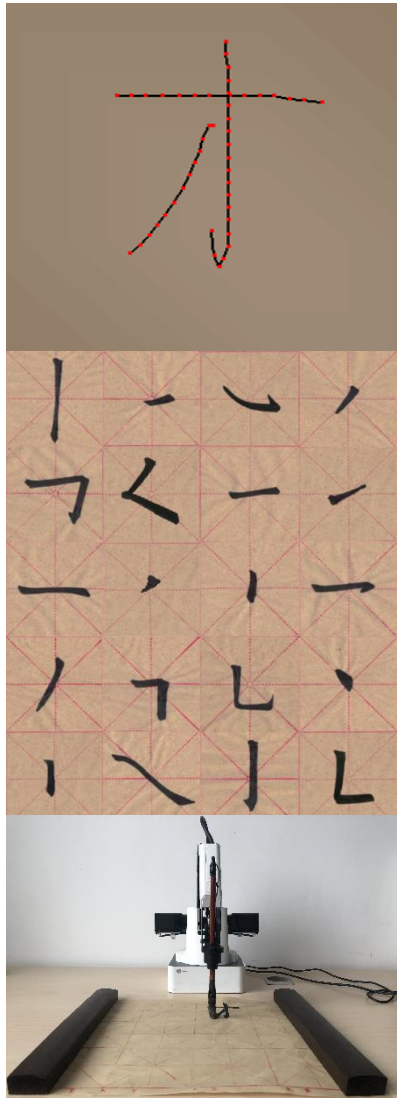
- **Speed of overall process**
- **Incomplete stroke database**
- **The influence of the physical form of a brush.**





Conclusion & future work

- A global optimization approach to generate Chinese calligraphy for robotic calligraphy writing.
- Improve the stroke database for complex Chinese characters.
- Design a control system to automatically detect and adjust the physical state of the brush.



CGI'19

Thank you!

Q&A

hsj@nwafu.edu.cn

xinyue.zhang@nwafu.edu.cn