Assessing Primary and Secondary School Students' Chinese Handwriting Performance Using Digital Handwriting Analysis Tool

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Importance of Chinese Handwriting (1)

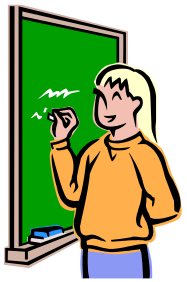
- Background:
  - In 2001/2002, 5-10% school-aged population in Hong Kong have handwriting difficulty
  - They experience difficulties in
    - academic achievement
    - social participation and integration
- It is thus important for students to grasp proper handwriting skills so that they are able to effectively
  - Communicate with other
  - Jot notes in a lesson

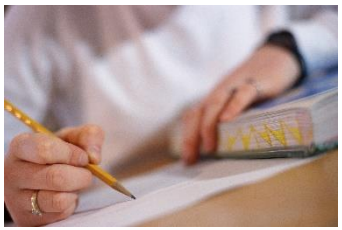
Importance of Chinese Handwriting (2)

- Teaching children handwriting is a very important topic in education
- It is a crucial step towards understanding the language
- Some studies found that there are additional benefits in learning Asian characters
  - Professor Chieh Li, from the department of counseling and applied educational psychology, Northeastern University, found that Chinese American students who read and write in characters also do extraordinarily well on the SAT math test, and have an average score some 200 points higher than non-Chinese, non-character writing students.
  - It is observed that many Asian children educated in their own languages appear to have gained a greater understanding of mathematical concepts than English speaking children. It is believe that this is because these concepts are embedded in their language at a very early stage in the language acquisition

Traditional Chinese Handwriting Education

- Scenario:
  1. Teacher writes a character on the blackboard
  2. Students copy the character on the exercise book or trace the strokes of the character on a copybook
  3. Students write the same character many times as homework exercise
  4. Teacher evaluates the handwritings to check whether the characters are written correctly



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- What is the problem with this approach?

Limitations of Traditional Chinese Handwriting Education

Students need immediate feedback all the time

Time is limited

Limitations of Traditional Chinese Handwriting Education (cont.)

- No immediate feedback from the teacher when a student is doing the handwriting homework
- Too much manual work for the teacher to check all students' handwritings
- Sometimes not easy to spot broken and concatenated strokes
- Temporal information of the strokes is not kept for handwriting on paper, thus teacher is unable to verify the correctness in terms of the stroke order and stroke direction of the student's handwritings

Virtual Assistant for Chinese Handwriting Education (VACHE)

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Our Contribution

- Not only do we highlight the character that has bad shapes, but we also try to detect more challenging errors in missed/extra strokes, stroke order, length and orientation of individual strokes
- In addition to error detection, we also try to identify the exact cause(s) of the error(s) in order to provide useful feedback to the user

Web-based Handwriting Education System

- Practice Chinese handwriting through electronic whiteboard
- Can check multiple kinds of handwriting errors
- Can learn anytime and anywhere
- Pattern recognition techniques are applied:
  - Match strokes of a user's handwriting character with the strokes of a corresponding standard character (Template)

    → the user does not need to write in correct shape / stroke sequence, which relaxes assumptions of some existing works
  - Can check the handwriting errors automatically, with giving appropriate feedbacks
- Enhance the students' learning and reduce teachers' workload

System Flow Diagram

Submit the exercise to teacher

Send comment

Internet

Final version

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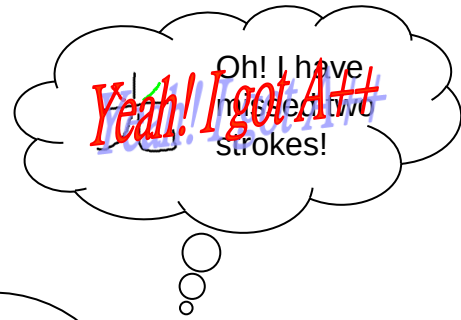

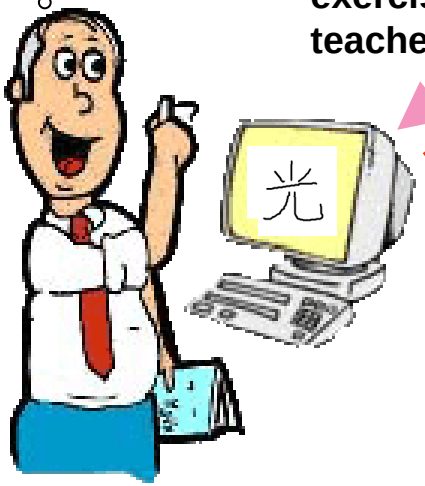

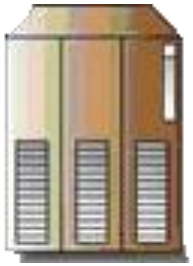

User input character (right) compare with the T e (left)

Analysis Result

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SUN SPARC server hosting the web system, template database, and Automatic Feedback and Analysis (AFA) tool

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Interface Design

Teachers' page

Student's page

Exercise

System from Student's Perspective

Input Devices

USB Writing Pad

Tablet PC

User writes character on the whiteboard

Display feedback on the whiteboard

Front-end web interface

Allow users to practice (input character) using a tablet pen

Input character feeds into AFA for analysis

Receive Feedback from AFA

Back-end Automatic Feedback and Analysis (AFA) tool

Use Pattern Recognition techniques to analyze the input character with reference to a Template character

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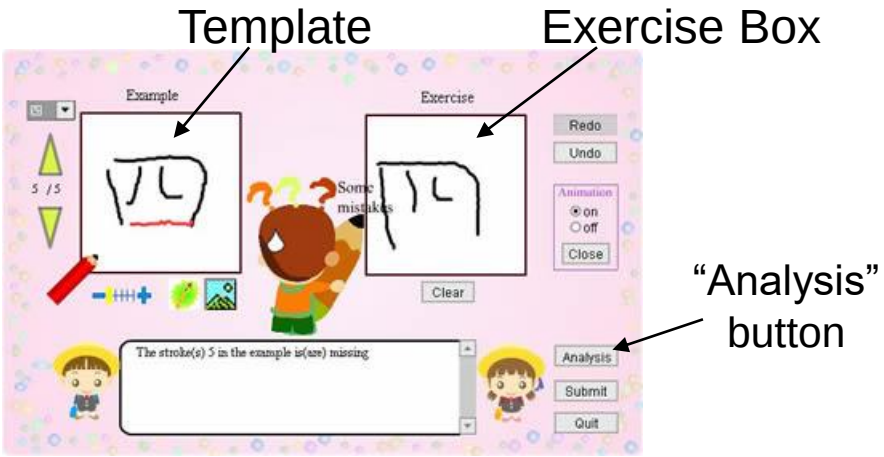
Front-end Web Interface

- Include an interactive whiteboard
- Allow users input character, and receive feedback from back-end Automatic Feedback and Analysis (AFA) tool after analysis.

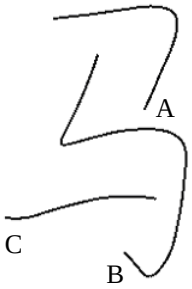


A Flash whiteboard (user follows the Template and practices writing in "Exercise" box)

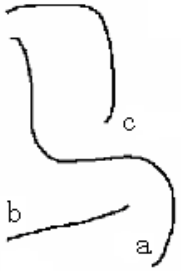
Back-end Automatic Feedback and Analysis (AFA) Tool

- Apply Pattern Recognition techniques to match the strokes of the input character with the strokes of the template character
- Stroke correspondence is found by minimizing the matching costs of the stroke pairs by Hungarian Method.
- The stroke matching result is then used for detecting whether a handwriting error, stroke production error and/or stroke sequence error, has been committed

Stroke Correspondence



Template Character

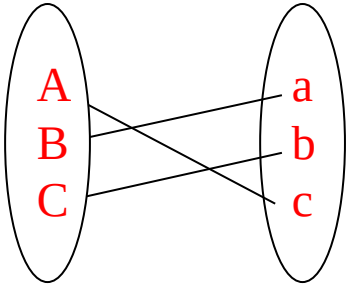


Student's Handwriting

	A	B	C
a	595	108	499
b	793	252	62
c	284	338	1074

Cost matrix

- Given a cost between every stroke pair, the stroke correspondence is determined by a matching function that minimises the total cost



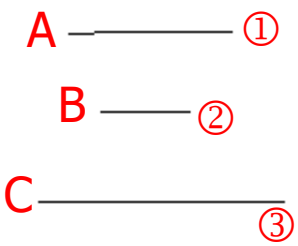
Strokes of template

Strokes of student's handwriting

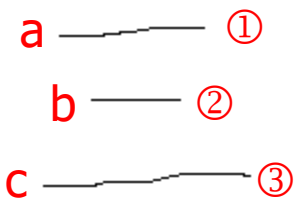
- The matching can be found by the Hungarian Method

Checking Stroke Order

- After determining the stroke correspondence, verify whether the order of the strokes in the user's character also match with those in the template character



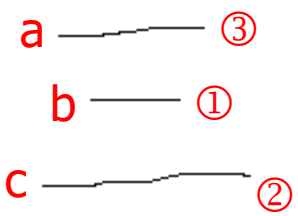
Template Character



Student Character 1

Stroke Correspondence:
A-a, B-b, C-c

Stroke Order:
1 2 3 ✓



Student Character 2

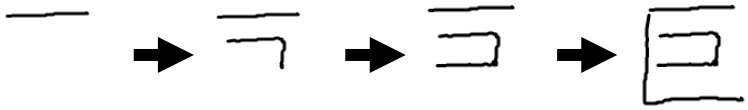
Stroke Correspondence:
A-a, B-b, C-c

Stroke Order:
2 3 1 ✗

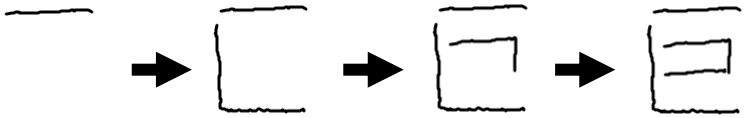
Automatic Feedback on Stroke Sequence Error

- A minimal feedback method (Tsang and Leung 2004) is used to notify user about the stroke sequence error
  - Correct stroke sequence is animated by groups of correct stroke sub-sequences

Template Sequence



Input Sequence (wrong)



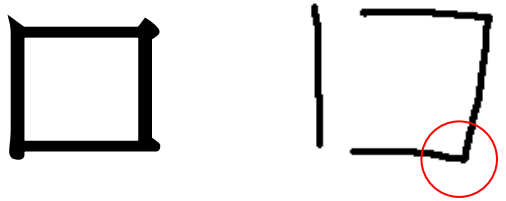
Minimal Feedback on Stroke Sequence

Group 1 (black) **Group 2 (red)** **Group 3 (green)**

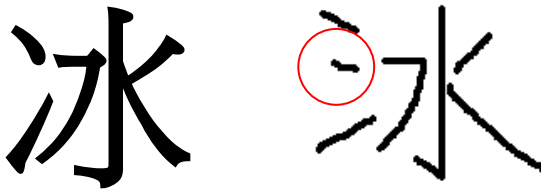
Example Stroke Production Errors

Missing stroke error

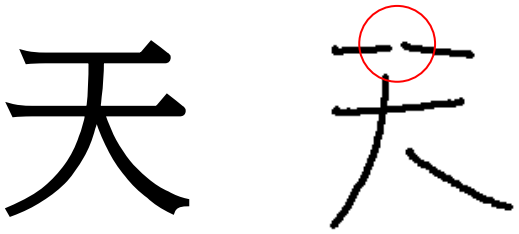
Concatenated stroke error



Extra stroke error

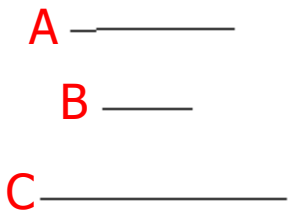


Broken stroke error

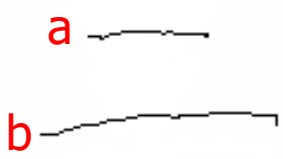


Checking Missing/Extra Strokes

- After determining the stroke correspondence, verify whether there are missed or extra strokes in the student's character



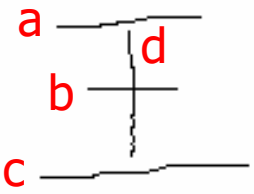
Template Character



Student Character 1

Stroke Correspondence:
B-a, C-b

Missed stroke:
A



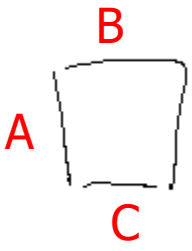
Student Character 2

Stroke Correspondence:
A-a, B-b, C-c

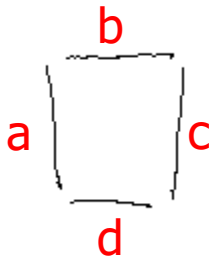
Extra stroke:
d

Checking Broken Strokes

- Form student character instance(s) by merging neighboring problematic strokes who do not have a match or whose matching cost is high, then perform matching to identify the type of error



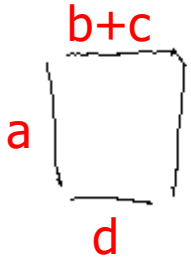
Template Character



Student Character

Stroke Correspondence:
A-a, B-b, C-d

Problematic Strokes:
B, b, c



Since the character matching provides good result, it can be concluded that strokes b and c result from a broken stroke

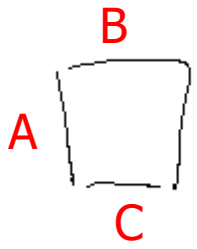
Since problematic strokes b and c are close to each other, form a character instance by merging these two strokes

Checking Concatenated Strokes

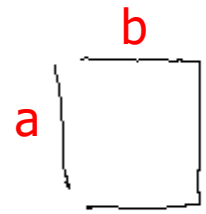
- Form template character instance(s) by merging neighboring problematic strokes who do not have a match or whose matching cost is high, then perform matching to identify the type of error

Stroke Correspondence:
A-a, B-b

Problematic Strokes:
B, C, b

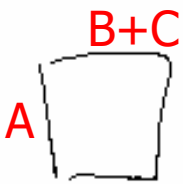


Template Character



Student Character

Since problematic strokes B and C are close to each other, form a character instance by merging these two strokes



Since the character matching provides good result, it can be concluded that stroke b results from concatenating strokes B and C

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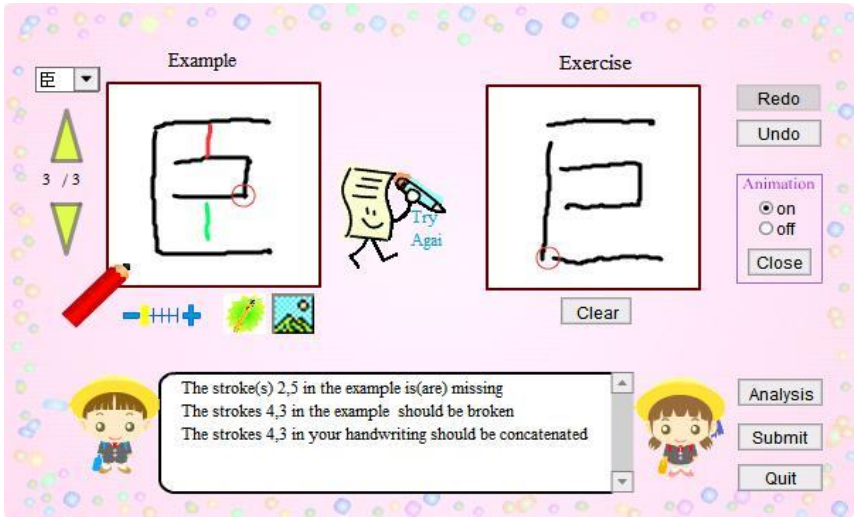
Automatic Feedback on Stroke Production Error

- Stroke production error
  - Missing/extra strokes (highlighted)
  - Concatenated/broken strokes (circled)



Feedback on Stroke Production Error

Paper Award

Lotfi Zadeh Best Paper Award

awarded to

Kai-Tai Tang and Howard Leung

for the paper

Reconstruction Strokes and Writing Sequences from Chinese Character Images

presented by

The Sixth International Conference on Machine Learning and Cybernetics
19-22, August 2007, Hong Kong

Daniel Yeung
President-Elect,
IEEE SMC

Xizhao Wang
Conference Co-Chair,
ICMLC

Michael Smith
Sr. Past President,
IEEE SMC

William Gruver
Jr. Past President,
IEEE SMC

IEEE

Chinese Handwriting Assessment System (CHAS)

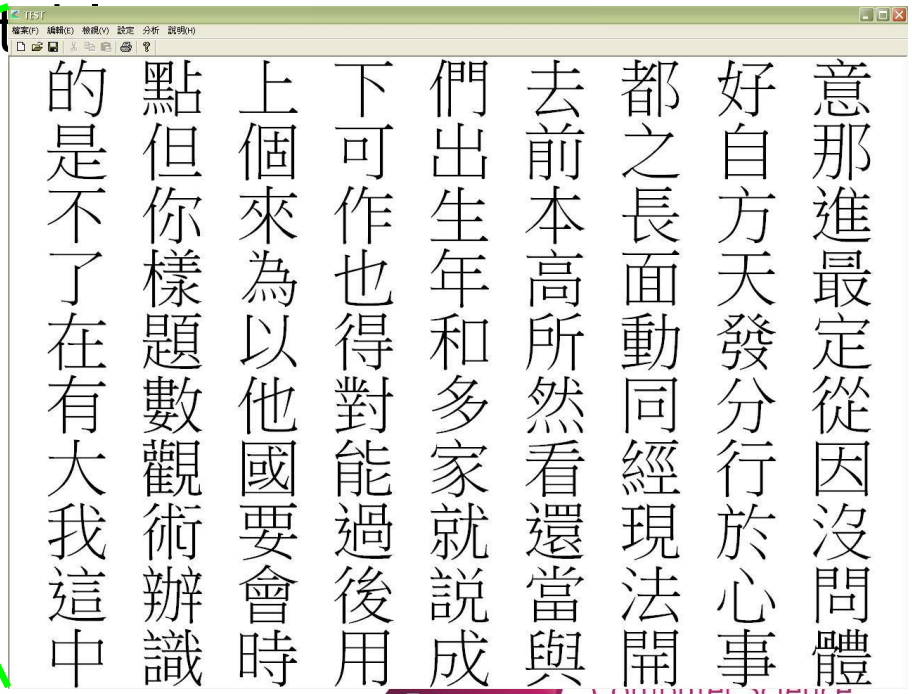
Department of Computer Science
香港城市大學
City University of Hong Kong

CHAS Project

- To standardize the norm of *handwriting construct*, an objective, computerized assessment tool for assessing handwriting legibility is necessary to account for the unique characteristic of Chinese handwriting.
- In August 2008, we have started a project with the PolyU team to develop the Chinese Handwriting Assessment System (CHAS).
- We obtained the Quality Education Fund of HK$2,478,500 for this project

Handwriting Data Collection

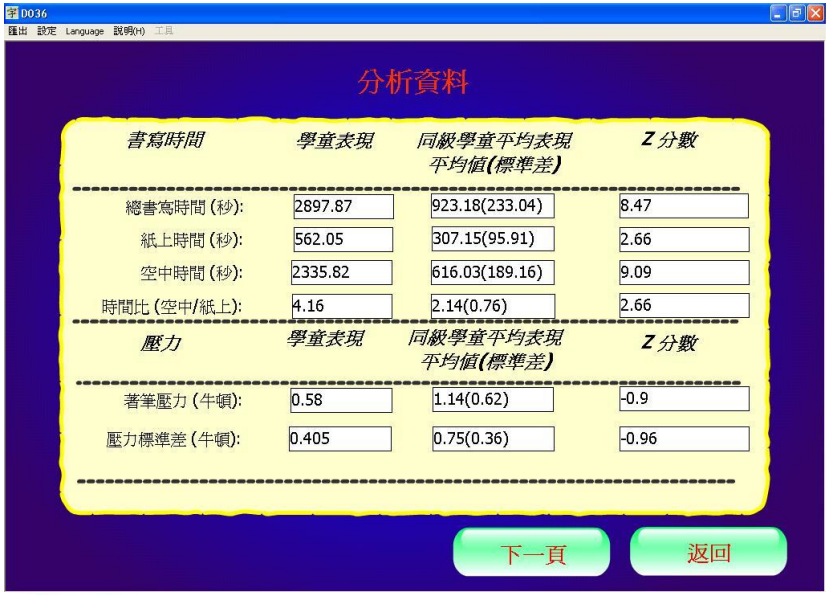
- Some template characters are shown on the screen and we collect handwritings of more than 1000 students from 6 primary schools by asking them to copy the characters on the paper pasted on the t

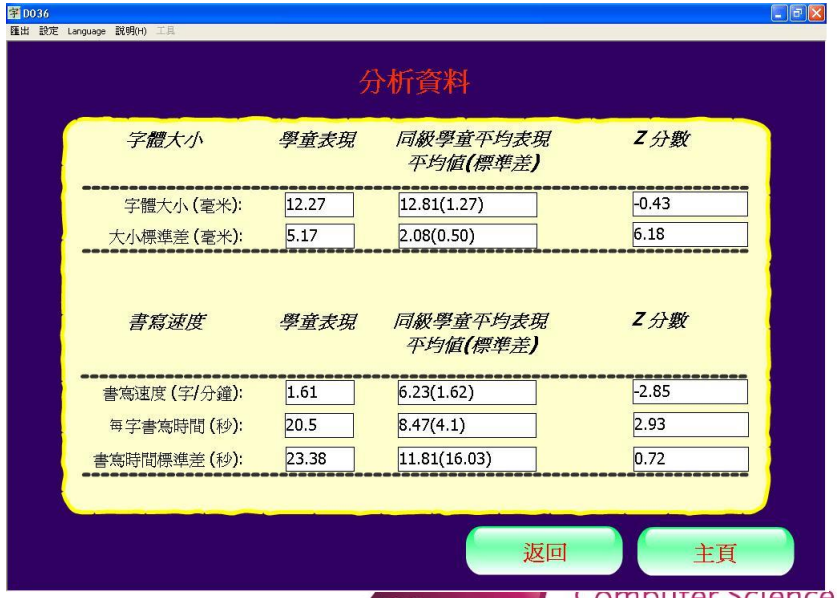


Handwriting Record Loading

Assessment of the Process of Handwriting with CHAS Process

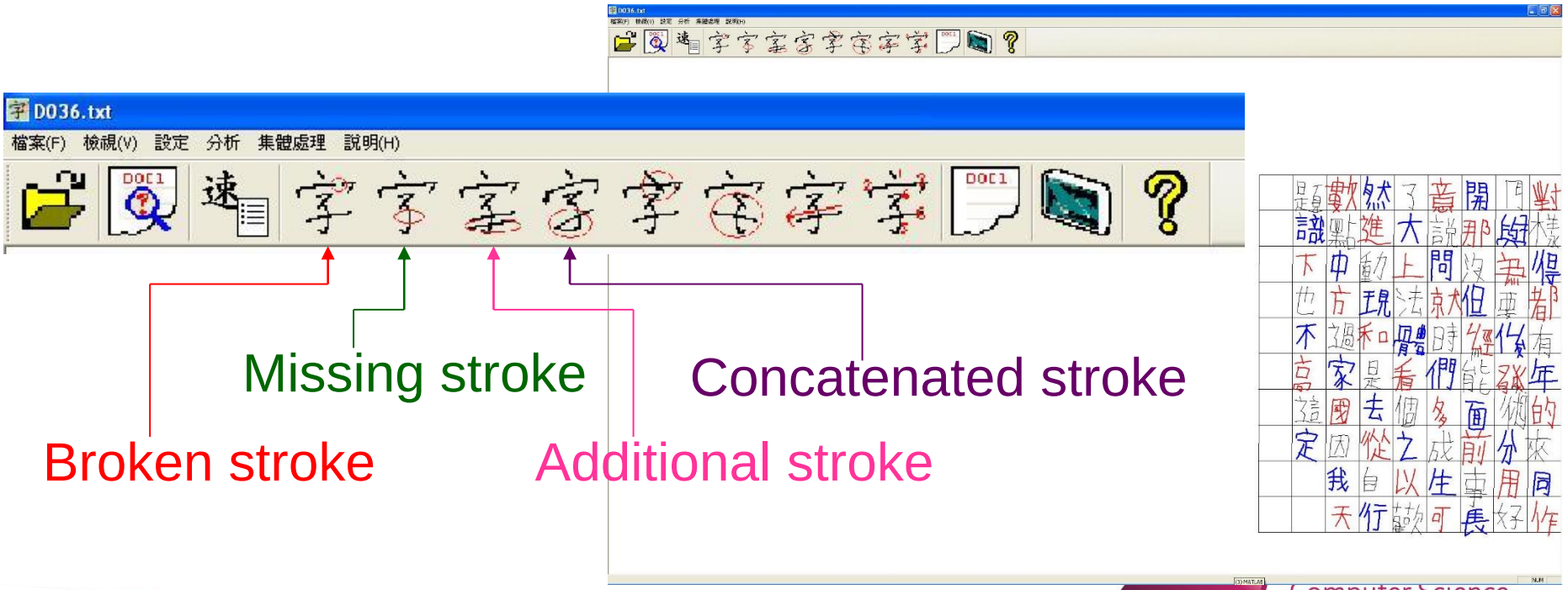
- Quantitative analysis of the handwriting trajectory: the data can be compared with the norm of the same age students to screen their potential handwriting problem



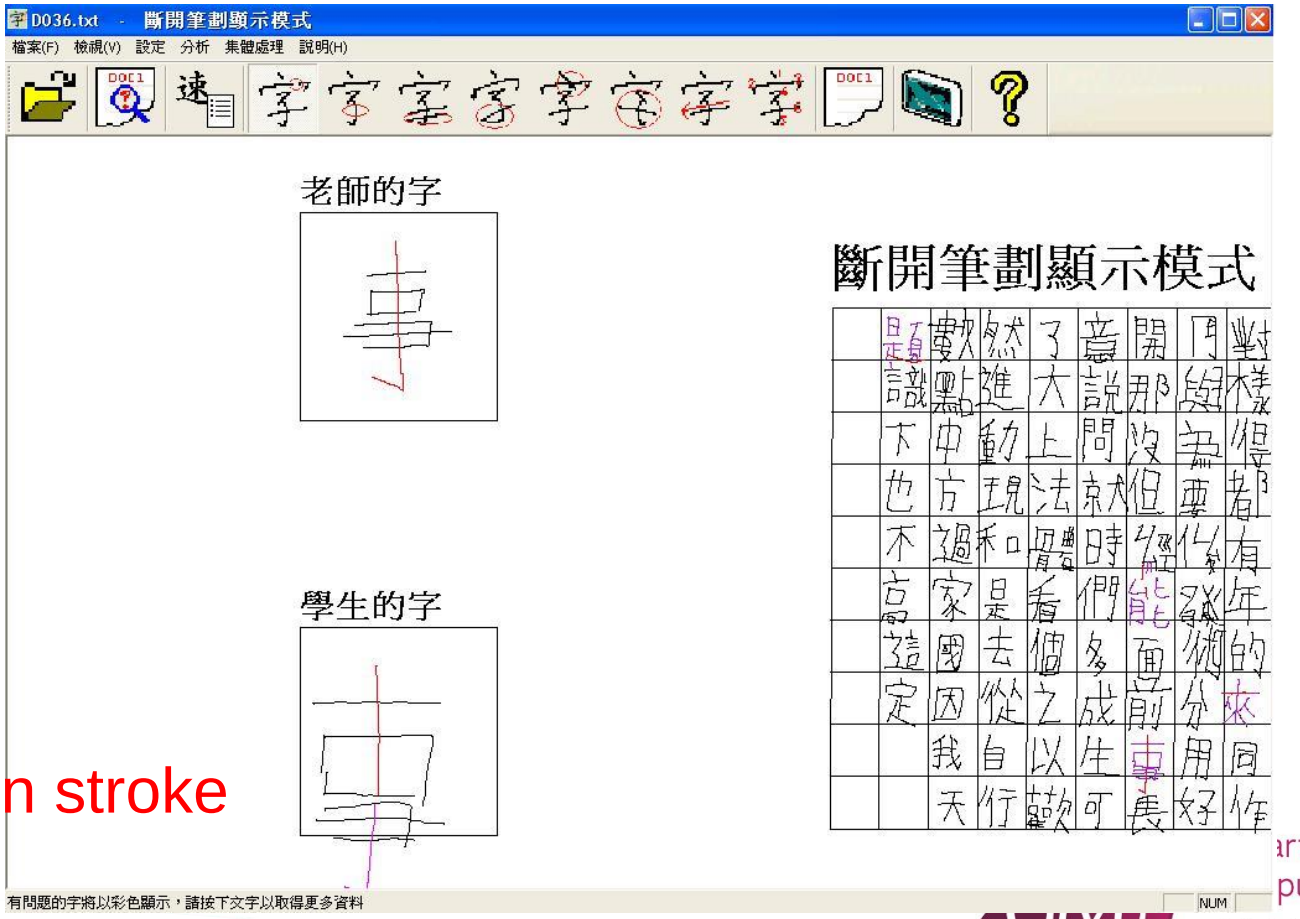


Assessment of the Handwriting Accuracy with CHAS Product (1)

- Aim: to determine the handwriting accuracy by identifying stroke production errors



Assessment of the Handwriting Accuracy with CHAS Product (2)



Broken stroke

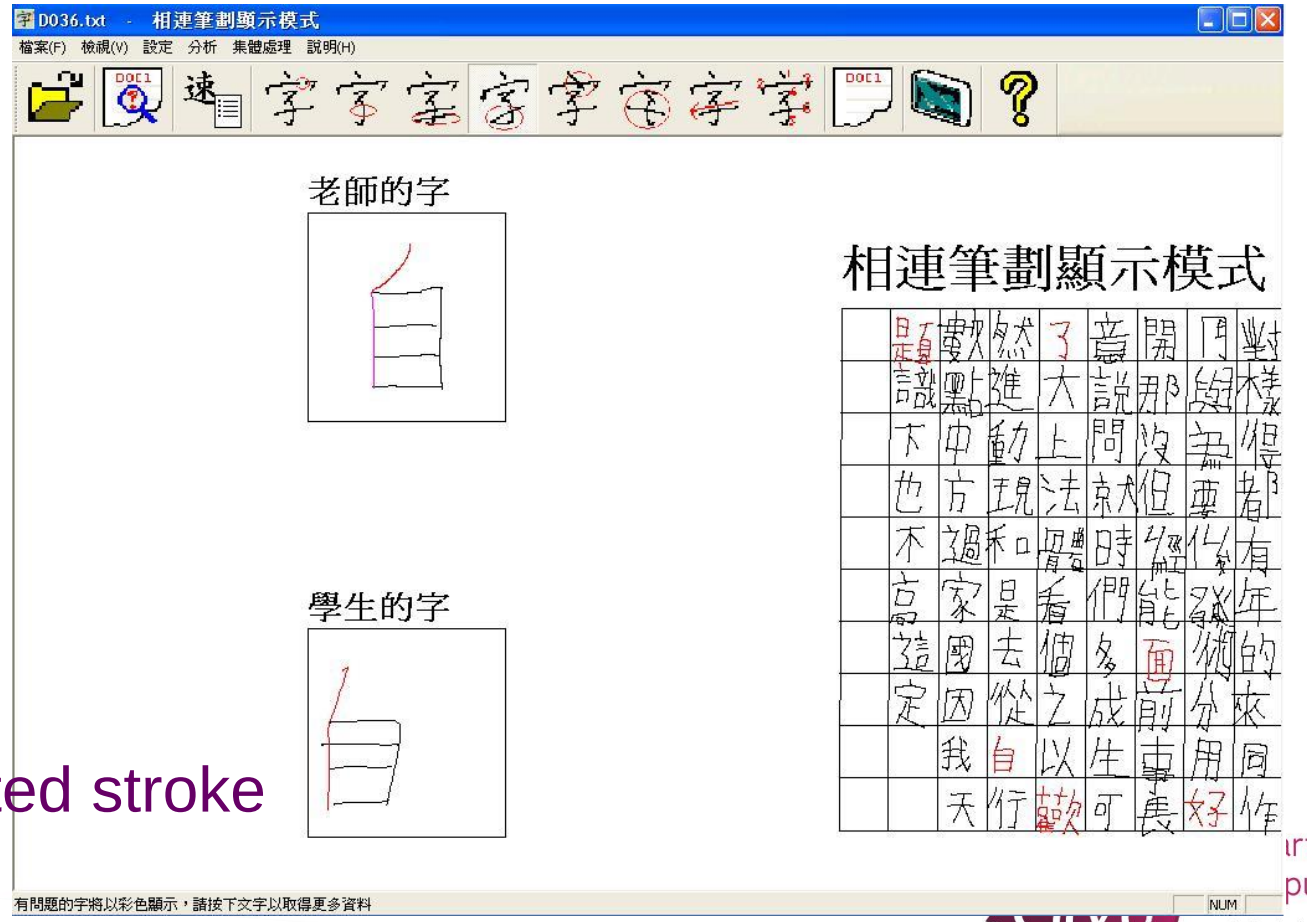
Assessment of the Handwriting Accuracy with CHAS Product (3)

Missing stroke

Assessment of the Handwriting Accuracy with CHAS Product (4)

Additional stroke

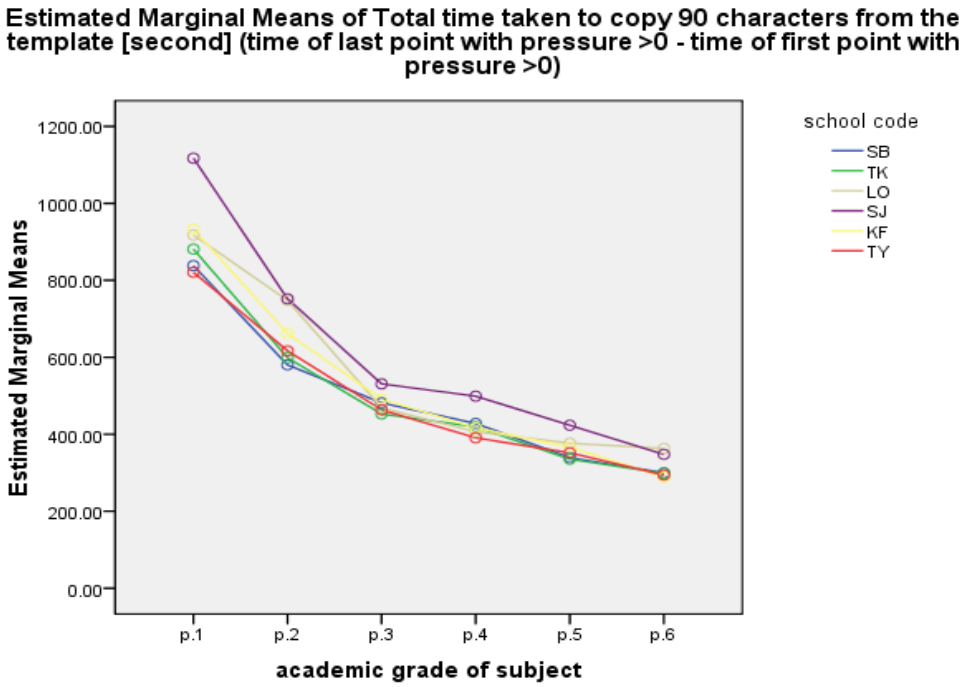
Assessment of the Handwriting Accuracy with CHAS Product (5)



Concatenated stroke

Normative Study

- A local norm of handwriting construct of Hong Kong students has been created



Assessment of the Process of Handwriting with CHAS Process

- Assessment report can be generated as PDF file

學生中文書寫表現綜合評估報告

1. 個人資料：

姓名：	D036	出生日期：	5/7/2002
性別：	M	慣用手：	L
就讀學校：	anonymous		
班別：	1C	評估日期：	19/11/2009

2. 中文書寫表現：

書寫能力數據

項目	學童表現	同級學童平均表現	Z 分數	狀態
書寫速度	1.61 字/分鐘	6.23(1.62) 字/分鐘	-2.85	極需關注
總書寫時間	2897.87 秒	923.18(233.04) 秒	8.47	極需關注
空中/紙上時間比	4.16	2.14(0.76)	2.65	極需關注
書寫時間標準差	23.38 秒	11.81(16.03) 秒	0.72	正常
著筆壓力	0.58 牛頓	1.14(0.62) 牛頓	-0.9	正常
壓力標準差	0.405 牛頓	0.75(0.36) 牛頓	-0.95	正常
字體大小	12.27 毫米	12.81(1.27) 毫米	-0.42	正常
大小標準差	5.17 毫米	2.08(0.50) 毫米	6.18	極需關注

備註：

綠色 --正常

黃色 --需要關注

紅色 --極需關注

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書寫評估備註

項目	Z 分數		
	正常 3 或以上 至 -1	需要關注 -1 至 -2	極需關注 -2 或以下
速度	每分鐘抄寫字數 [字/分鐘]		

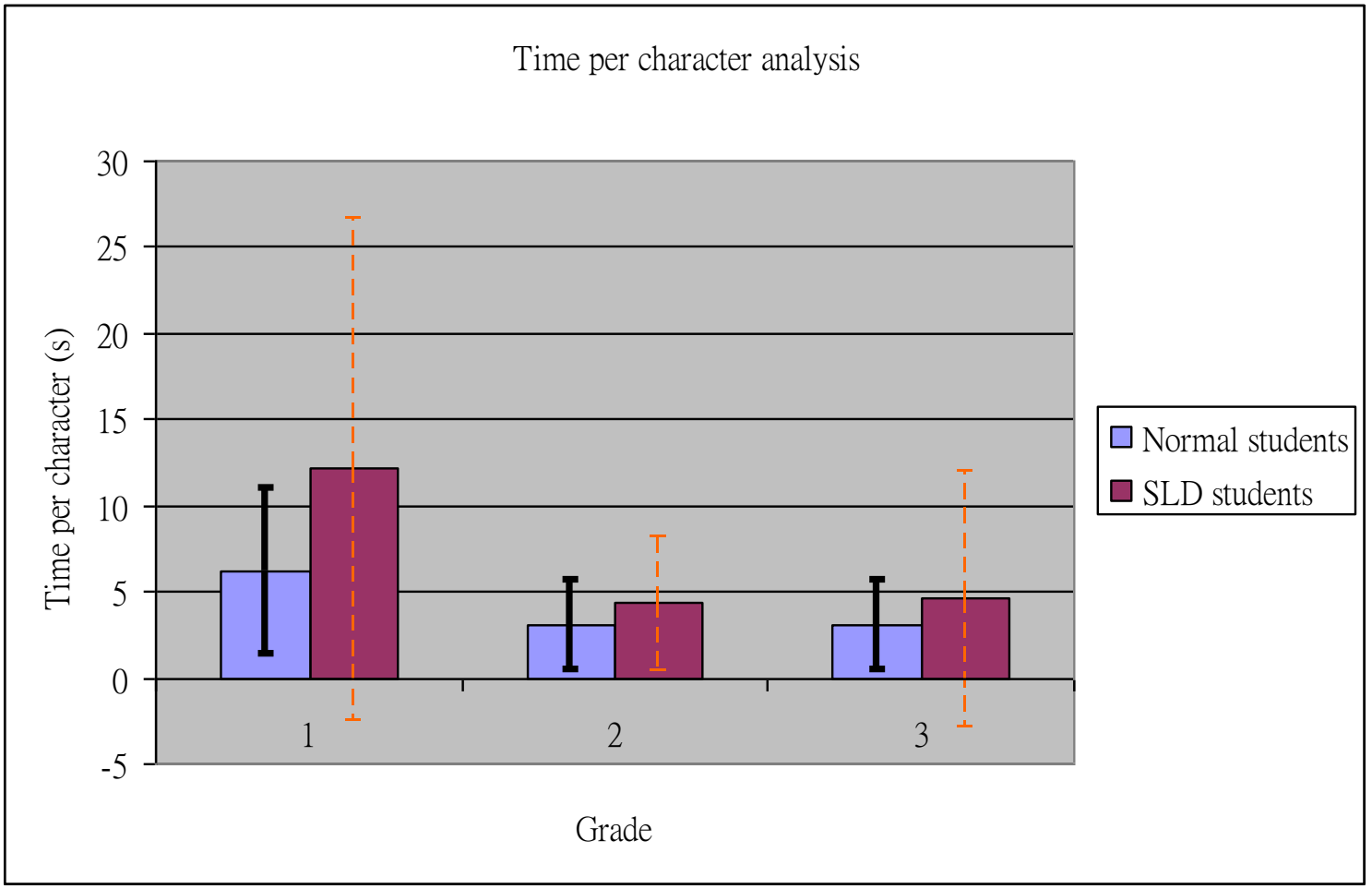
項目	Z 分數		
	正常 1 至 -3 或以下	需要關注 1 至 2	極需關注 2 或以上
總書寫時間	紙上時間及空中時間之總和，以秒為單位。		
空中/紙上時間比	空中時間/紙上時間，比例通常為 1.5。若空中/紙上時間比大於 2 以上，學生書寫時需花較多空中時間，反映學生視覺感知可能較弱或欠注專。		
書寫時間標準差	每字抄寫之速度變化。標準差愈大，表示學生寫字時出現時快時慢的現象愈頻密，書寫速度相對會比較慢。		
著筆壓力	書寫時之著筆壓力，以牛頓(N) 為單位。		
壓力標準差	書寫時之著筆壓力變化。標準差愈大，表示學生寫字時出現輕重壓力不一的現象愈頻密。反映學生力度控制較弱，書寫時容易疲倦。		
字體大小	書寫字體之大小，以毫米為單位。		
大小標準差	書寫字體之大小變化。標準差愈大，表示學生寫字時出現字體大小不一的現象愈頻密。反映學生書寫精確度較差，較易出現字體不工整或寫字時亦較易出格。		

Handwriting Samples

Normal primary student

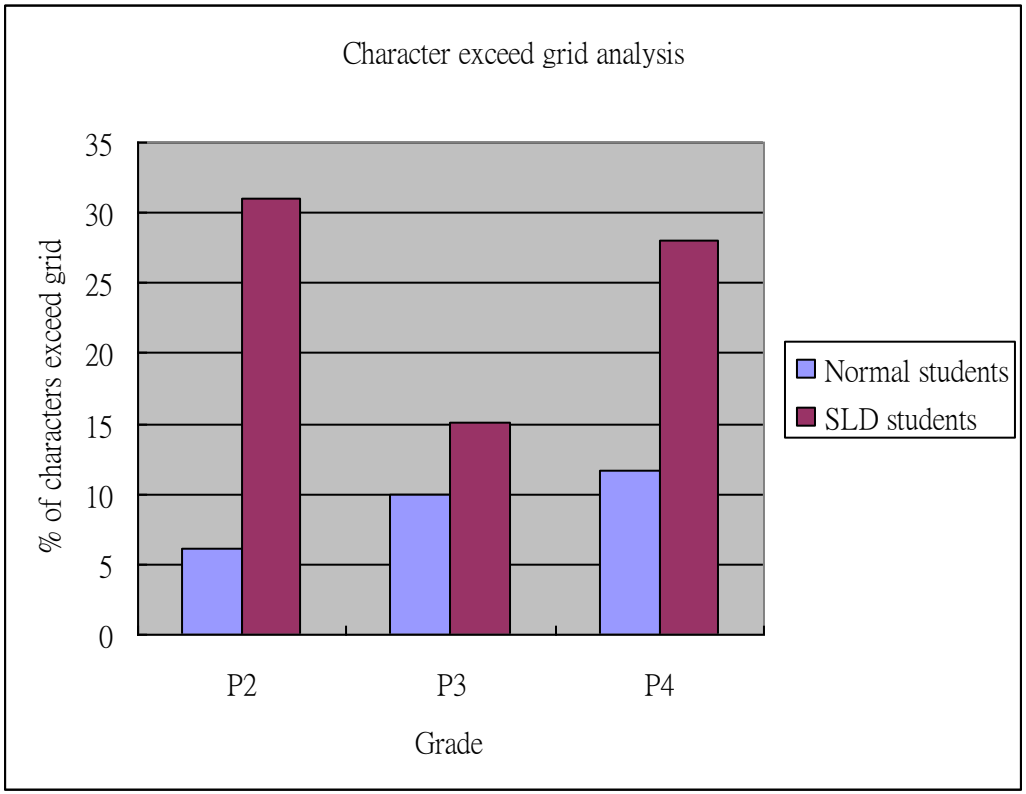
SLD primary student

Data Analysis between Normal and SLD students (1)



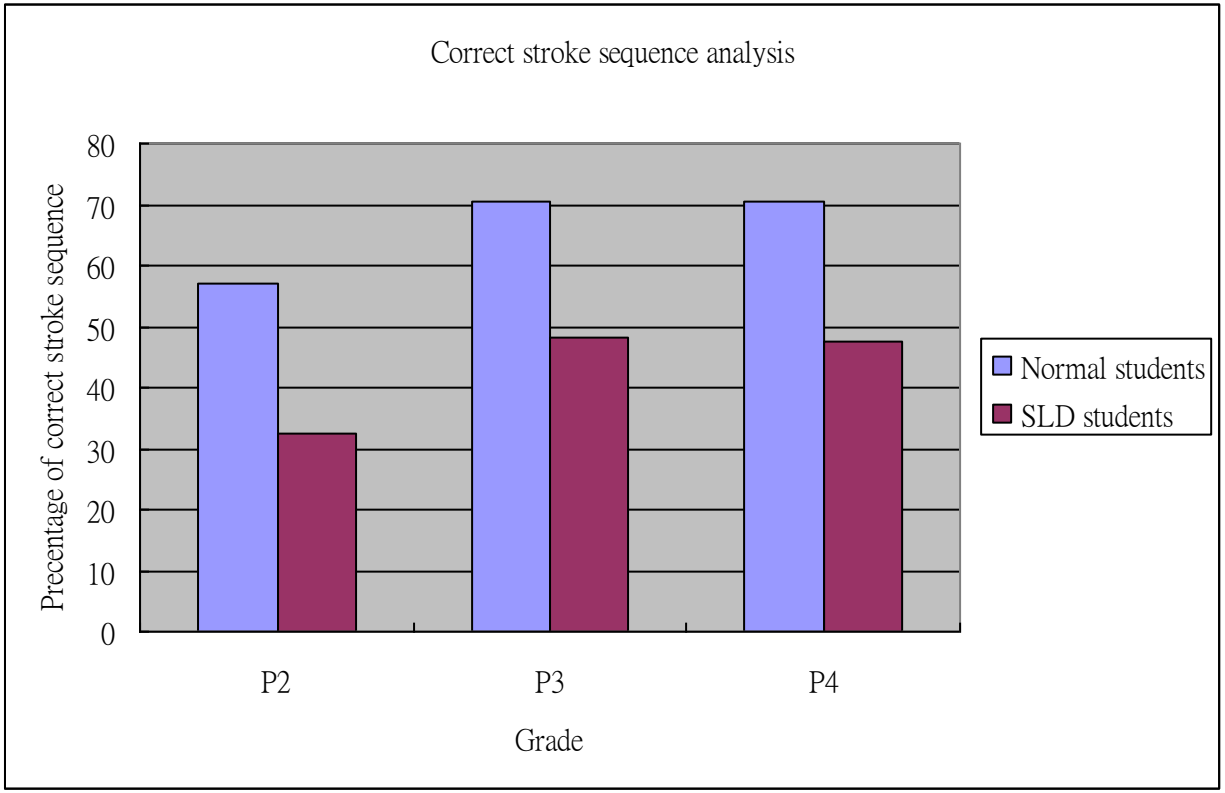
Data Analysis between Normal and SLD students (2)

- Number of characters exceeding the grids



Data Analysis between Normal and SLD students (3)

- Stroke sequence similarity



Computerized Handwriting Speed Test System (CHSTS)

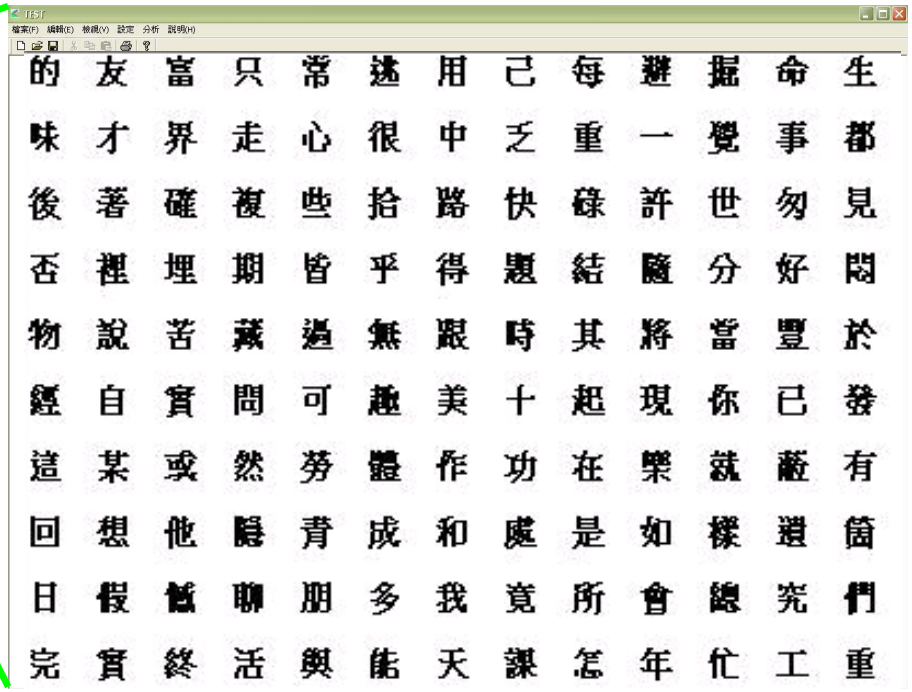
Department of Computer Science
香港城市大學
City University of Hong Kong

CHSTS Project

- To determine the extra time allowance for students with physical disabilities in public exam, a computerized handwriting speed test system (CHSTS) is developed to assist in assessing handwriting performance of secondary school students
- We obtained two grants of HK$470,000 in 2010-2012 and HK$608,012 in 2014-2016 from the Hong Kong Examination Assessment Authority for this project

Handwriting Data Collection

- Some template characters are shown on the screen and we collect handwritings of more than 300 S5 and S6 students from 6 secondary schools by asking them to copy the characters on the paper pasted on the tablet



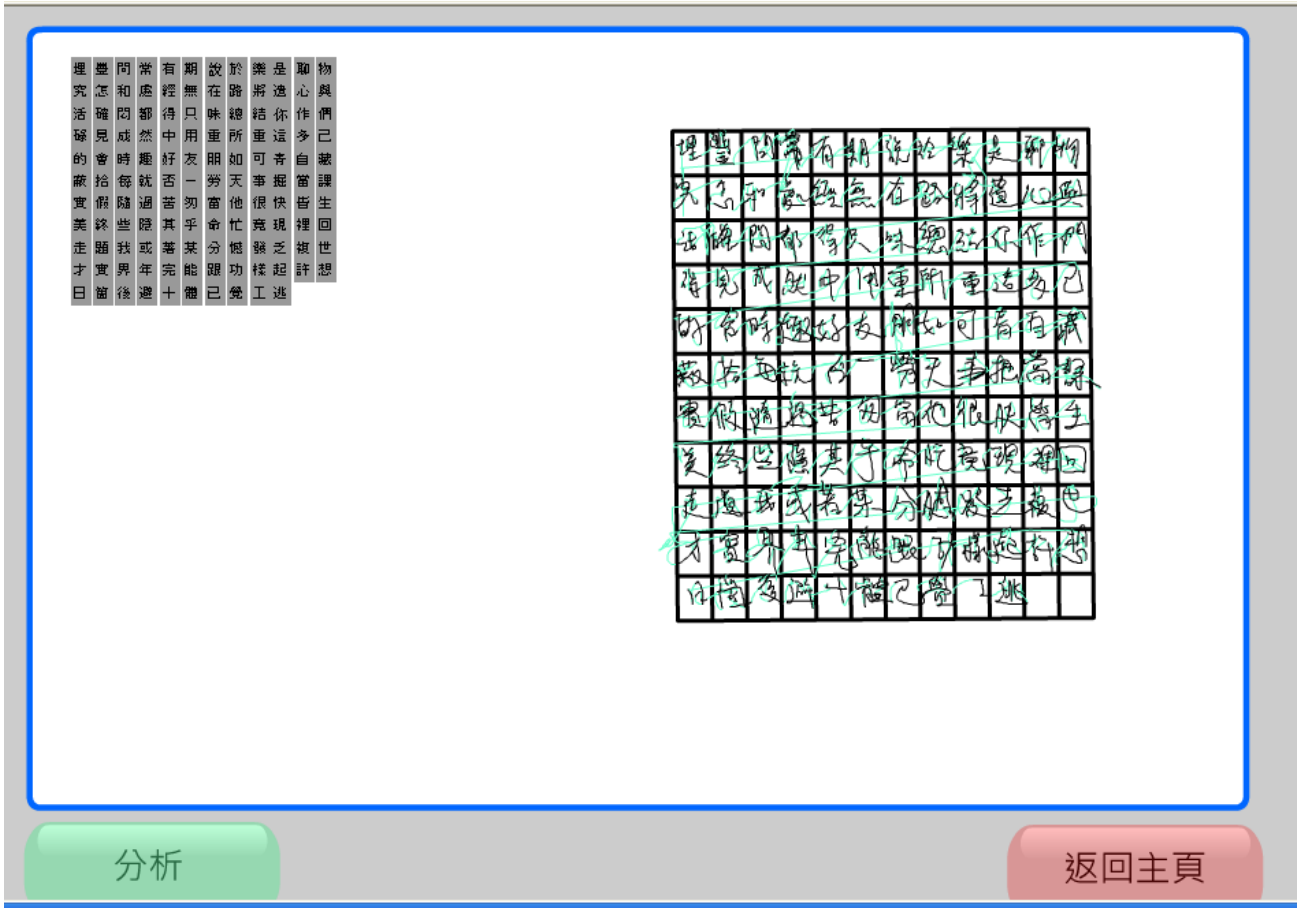
Procedures of Assessment

- All assessments were done with least disturbance to participating schools possible
- After liaison with principal and teachers, dates (5-6 hours, usually separated into 1-3 days) would be set up for project team to complete the assessment
- School was required to provide a quiet and large room, other equipments (ex. Assessment tools, electronic supplies) were brought by project team
- All participation were voluntary, students and parents were all informed and signed written consent before assessment

Procedure of Work

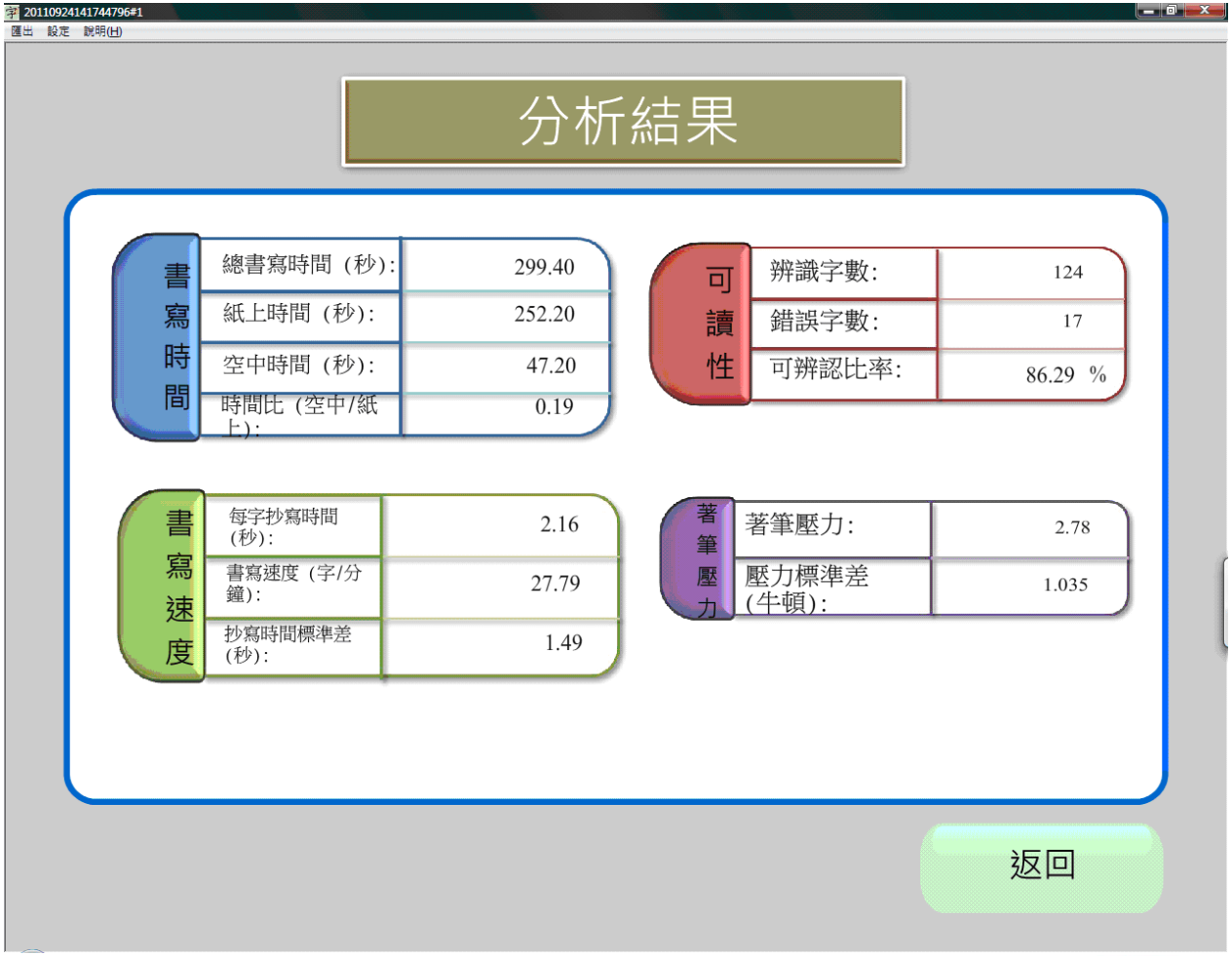
- Each student was asked to copy two templates (one in English & one in Chinese) for three times
- Instruction was to copy as fast as possible with good legibility
- Three trials of copying to measure the variation of handwriting performance due to fatigue or other factors
- No rest time in between each trial, 15 minutes rest between Chinese and English
- The characters/words are randomized to prevent the practice effect
- Usually about 1 hour for a student to complete 3 trials of Chinese and 3 trials of English

Interface of Data Display

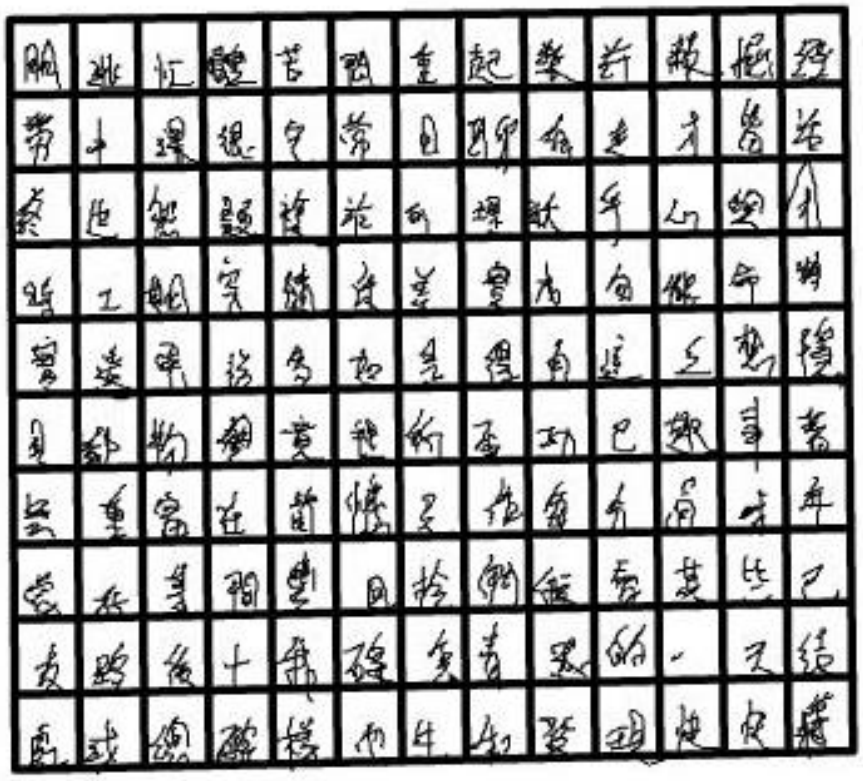


Left: Template
Right: Handwriting image (blue for air pen and black for ground pen)

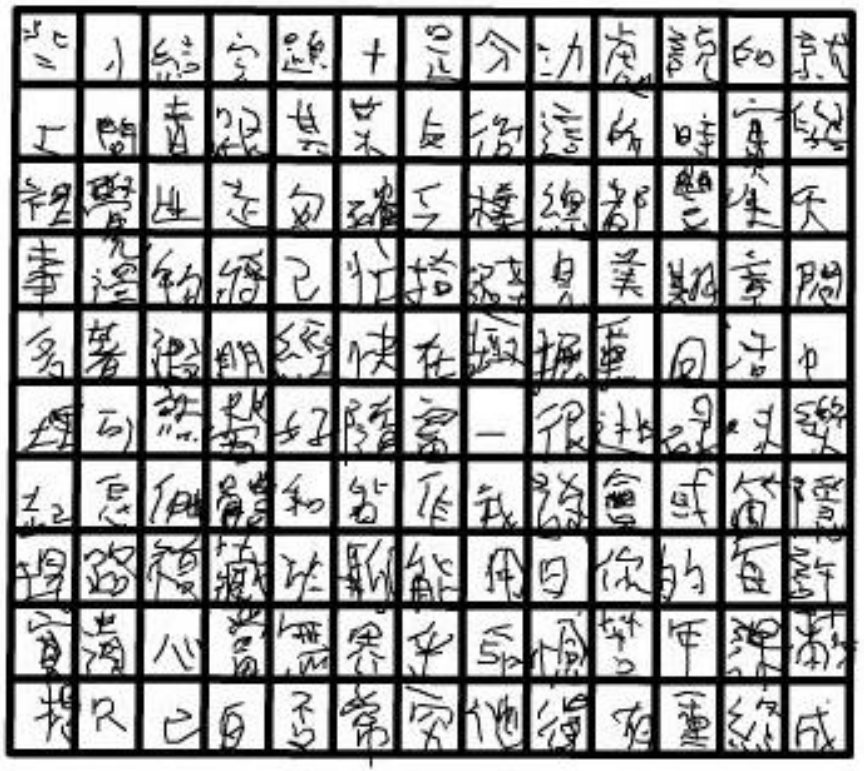
Qualitative Analysis



Handwriting Samples

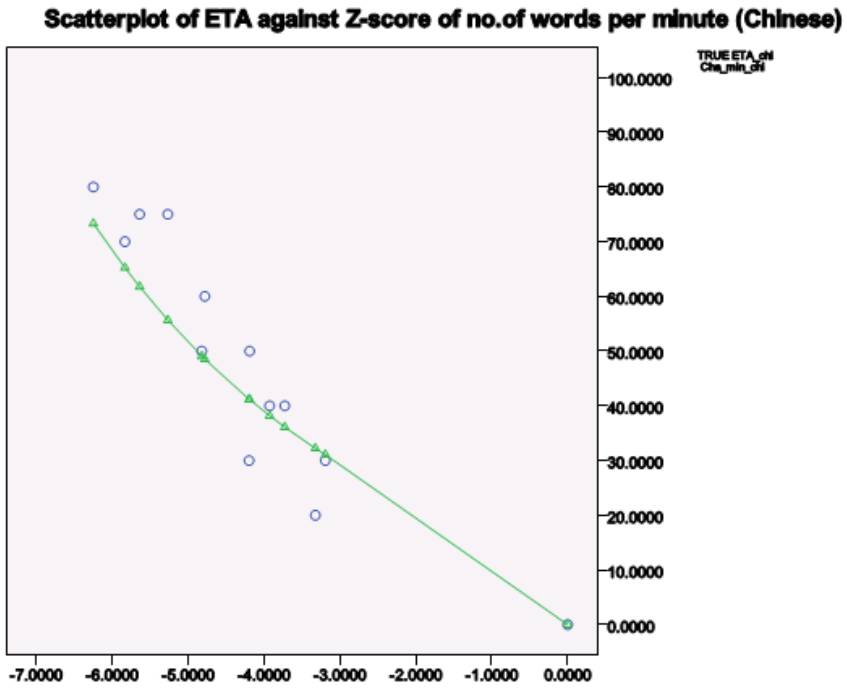


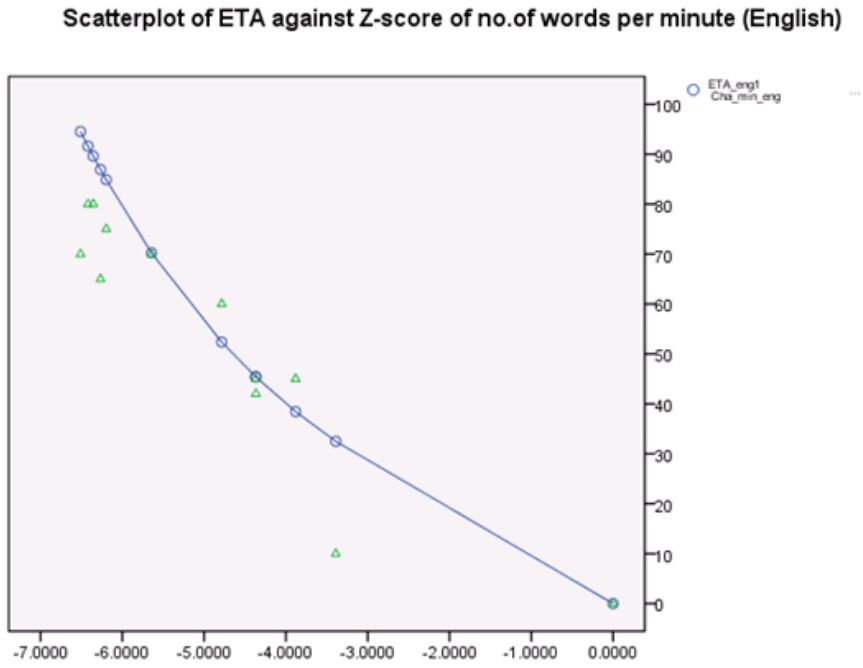
Normal secondary student



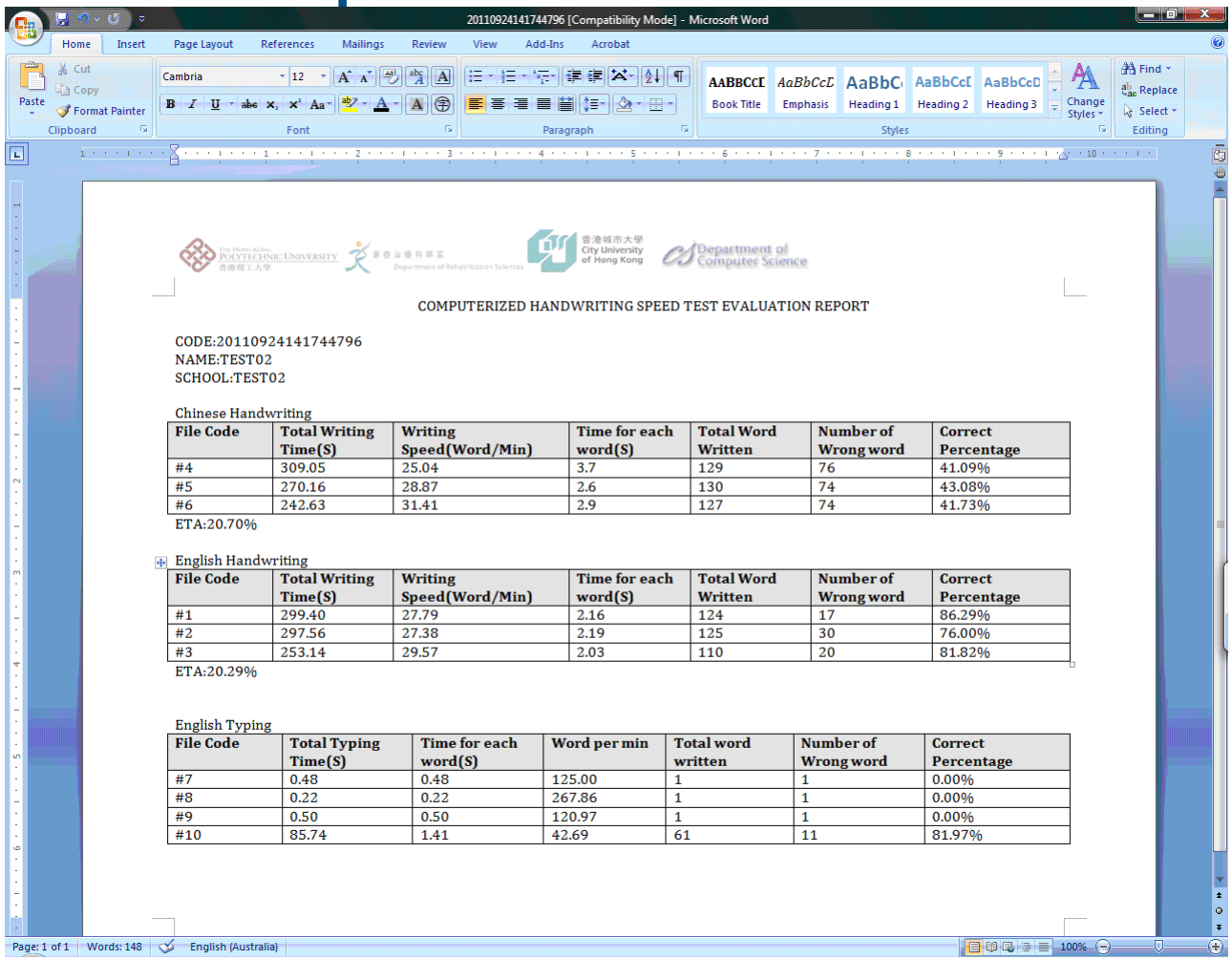
SLD secondary student

Extra Time Allowance Model





Report Generation



COMPUTERIZED HANDWRITING SPEED TEST EVALUATION REPORT

CODE:20110924141744796
NAME:TEST02
SCHOOL:TEST02

Chinese Handwriting

File Code	Total Writing Time(S)	Writing Speed(Word/Min)	Time for each word(S)	Total Word Written	Number of Wrong word	Correct Percentage
#4	309.05	25.04	3.7	129	76	41.09%
#5	270.16	28.87	2.6	130	74	43.08%
#6	242.63	31.41	2.9	127	74	41.73%

ETA:20.70%

English Handwriting

File Code	Total Writing Time(S)	Writing Speed(Word/Min)	Time for each word(S)	Total Word Written	Number of Wrong word	Correct Percentage
#1	299.40	27.79	2.16	124	17	86.29%
#2	297.56	27.38	2.19	125	30	76.00%
#3	253.14	29.57	2.03	110	20	81.82%

ETA:20.29%

English Typing

File Code	Total Typing Time(S)	Time for each word(S)	Word per min	Total word written	Number of Wrong word	Correct Percentage
#7	0.48	0.48	125.00	1	1	0.00%
#8	0.22	0.22	267.86	1	1	0.00%
#9	0.50	0.50	120.97	1	1	0.00%
#10	85.74	1.41	42.69	61	11	81.97%

Smart Handwriting And Recognition Platform (SHARP)

Department of Computer Science
香港城市大學
City University of Hong Kong

SHARP Project

- We obtained two grants of HK$2,910,000 in 2017-2018 and HK$1,453,600 in 2020-2022 from the Innovation and Technology Fund (ITF)

Team

City University of Hong Kong	Howard Leung Associate Professor
The Hong Kong Polytechnic University	Cecilia Li-Tsang Professor
Pendo Technology Limited	Vincent Lo Senior Project Manager
Pendo Technology China Corporation	John Zhu CEO
Wacom Hong Kong Ltd.	Frankie Lo General Manager

Motivation

- According to Chapter 3 Integration Education from the Report No. 70 issued by the HKSAR Audit Commission on April 2018
  - About 42,890 students with special educational needs (SEN) were studying in mainstream primary and secondary schools in 2016/2017
  - About 22% have Attention Deficit/Hyperactivity Disorder (AD/HD)
  - About 18% of them have Autism Spectrum Disorders (ASD)
- It is important to find out if children have specific reading and writing difficulties, such that appropriate training or remedial adaptation could be made to support their learning at school
- Evaluation of handwriting by teachers and parents were found to be too subjective and varied
- We would like to develop an objective handwriting evaluation system, with normative data available for comparison, to assess students who may have handwriting difficulties

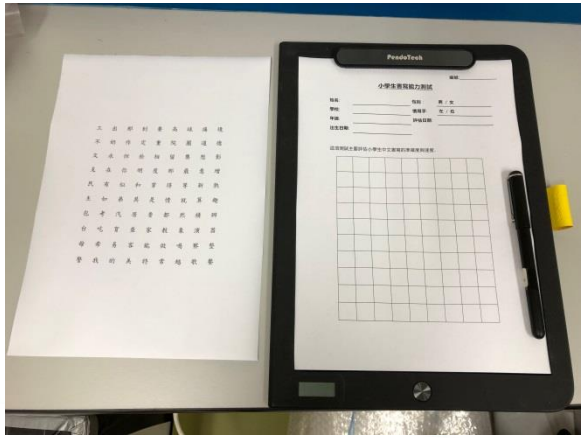
Technical Solution

- SHARP (Smart Handwriting Analysis and Recognition Platform) aims to fulfill our goal by integrating a number of technologies to form the solution:
  - New hardware tablet
  - Deep learning
  - Cloud computing and storage
- SHARP thus offers an effective handwriting screening tool for teachers and helps professionals such as occupational therapists to better understand the underlying handwriting problems of a student with special needs

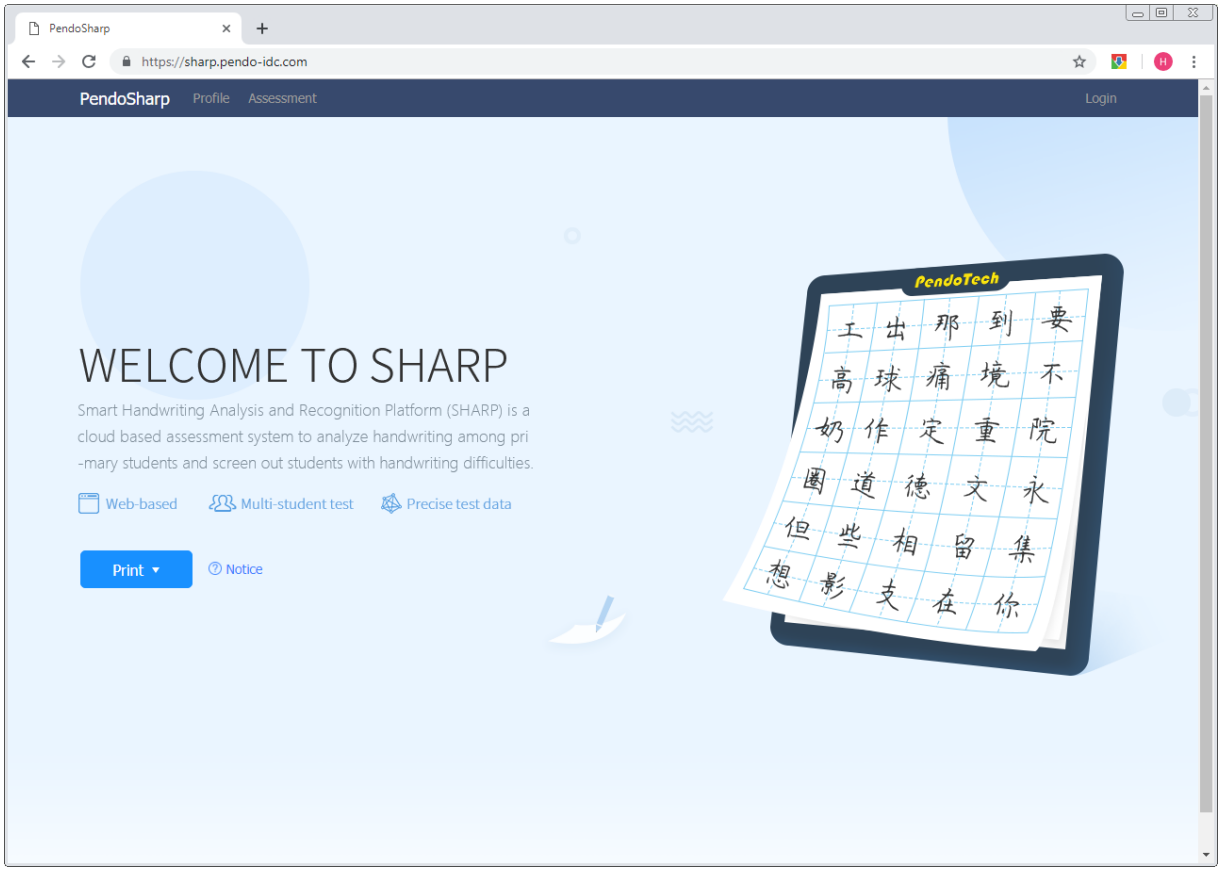
System Description (1) - Equipment

工	出	那	到	要	高	球	痛	境
不	奶	作	定	重	院	圈	道	德
文	永	但	些	相	留	集	想	影
支	在	你	明	度	部	最	意	增
民	有	似	和	穿	得	等	新	熟
主	如	弟	其	是	情	就	算	趣
包	考	汽	居	香	都	然	精	辨
台	吃	育	查	家	教	象	演	器
母	希	易	客	能	做	喝	察	整
警	我	的	美	特	常	越	歌	餐

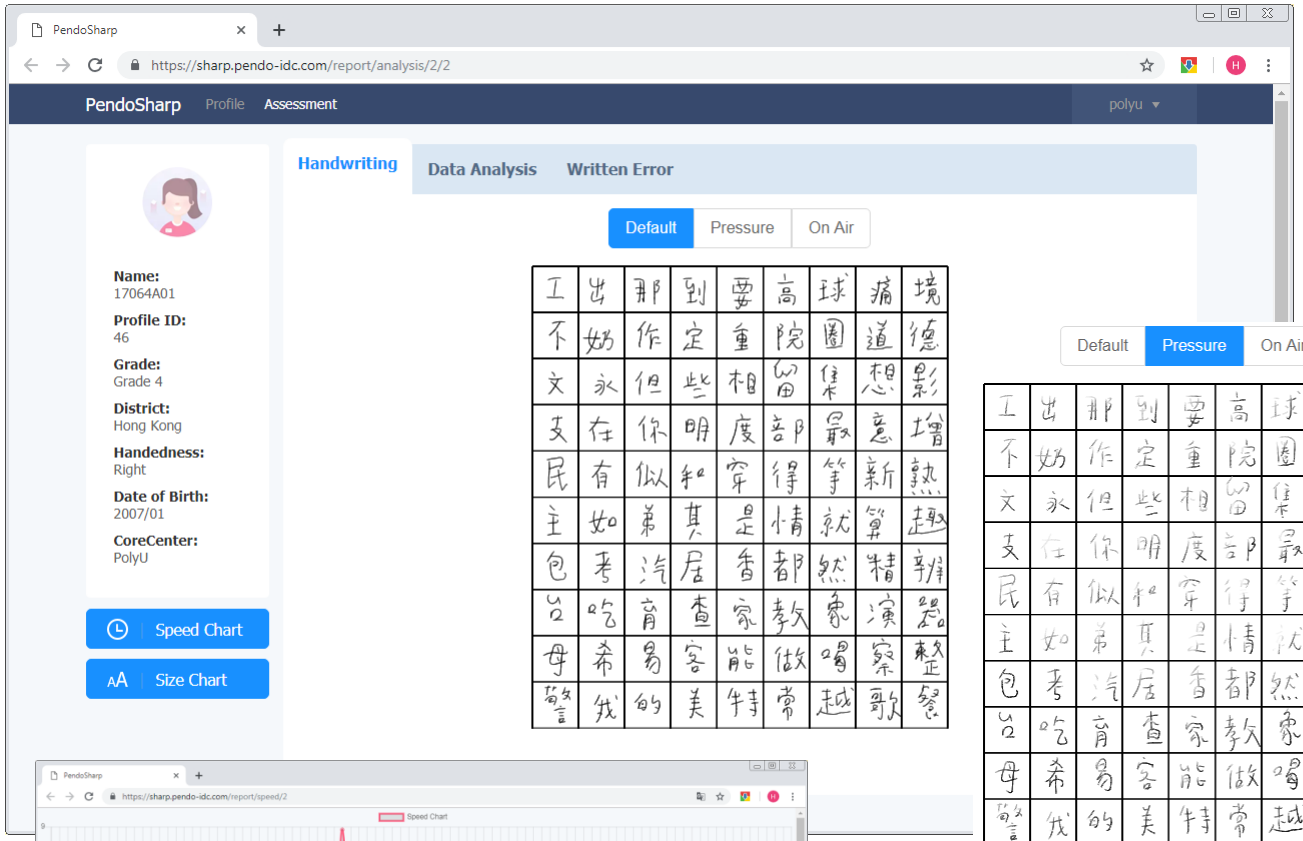
- A4-sized tablet
- Paper template
- Digital ink pen
- Blue-tooth dongle (USB size)
- Notebook or desktop

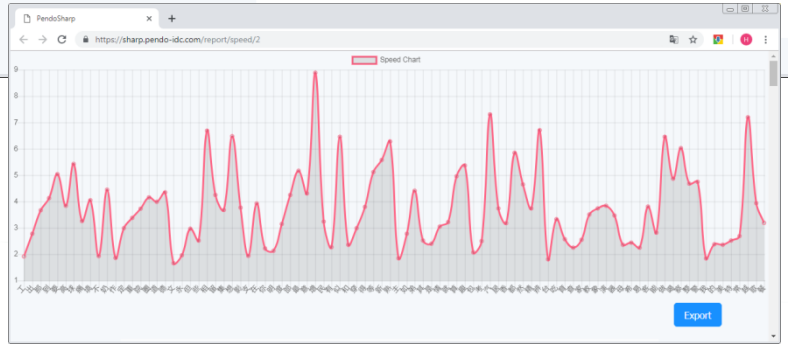


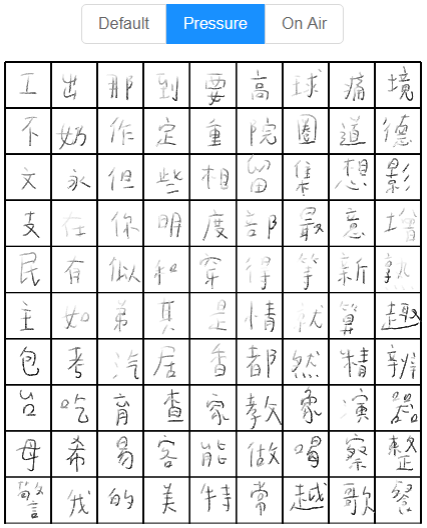
System Description (2) – Cloud Platform



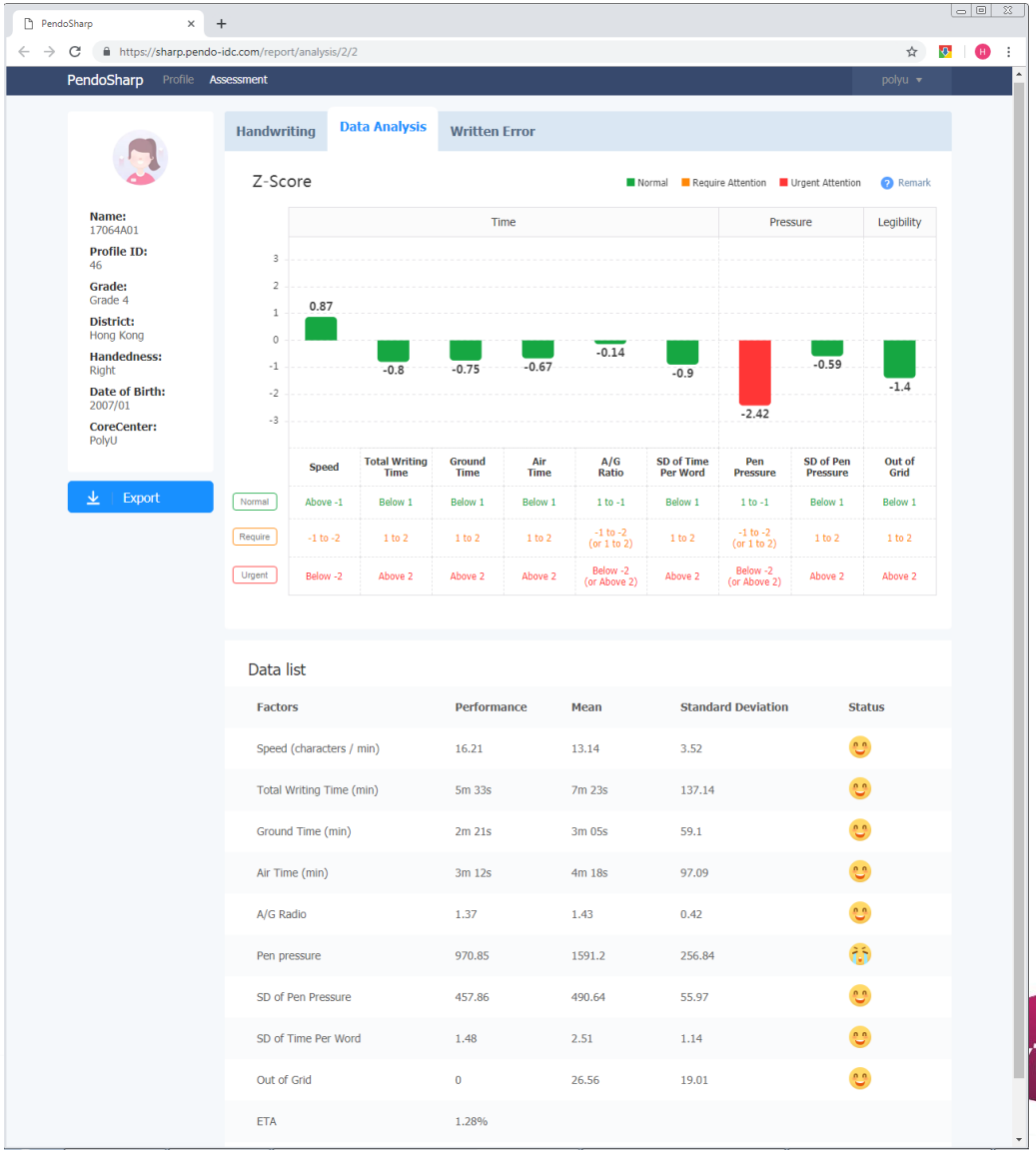
System Description (3) – Handwriting



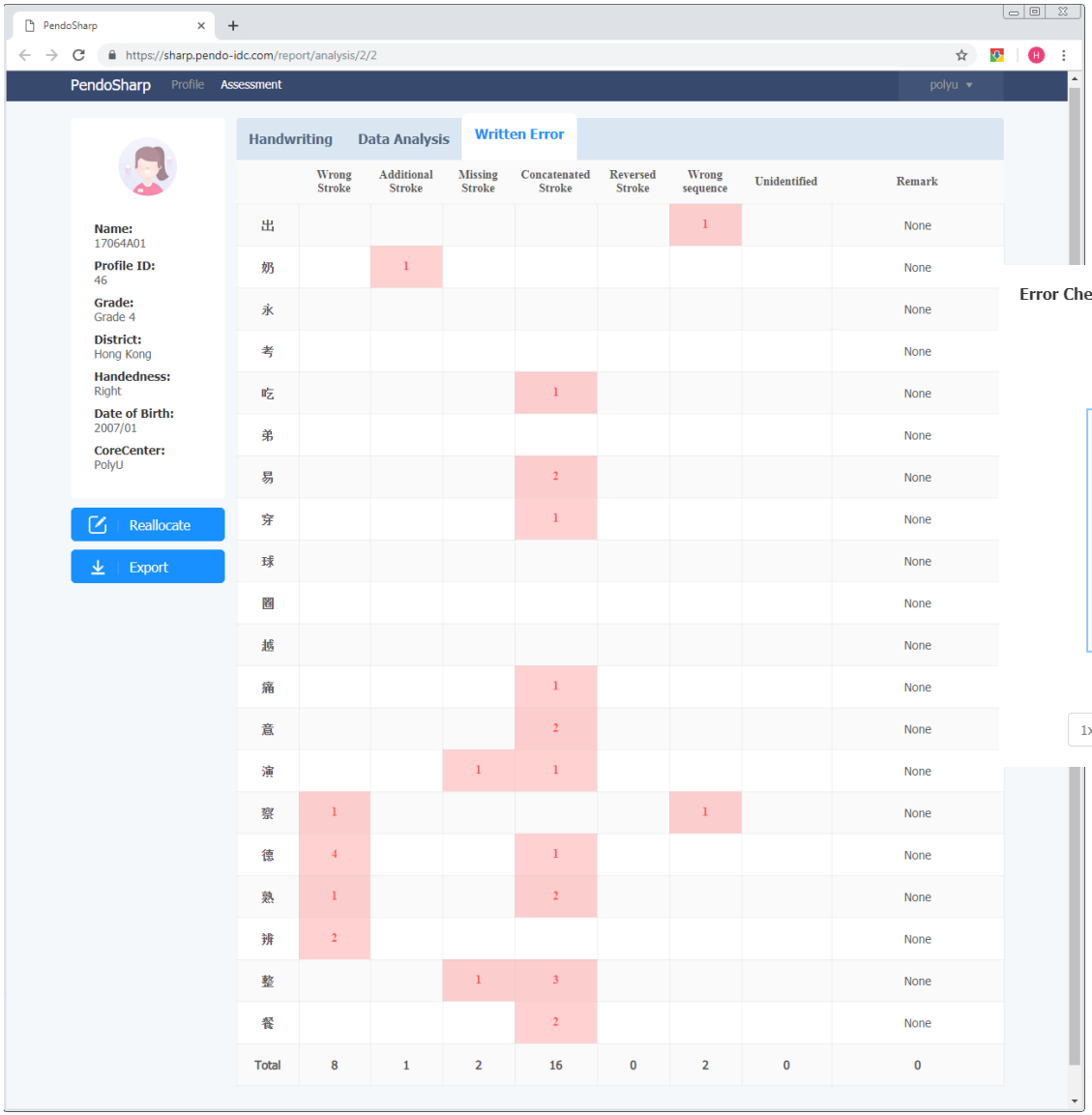




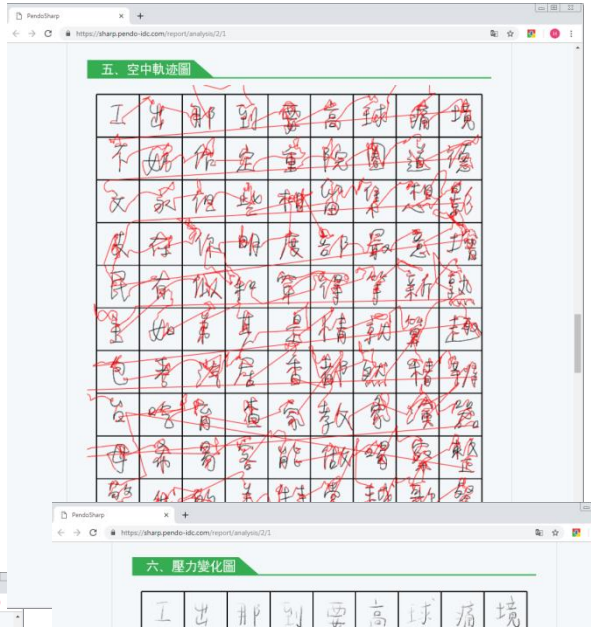
System Description (4) – Data Analysis

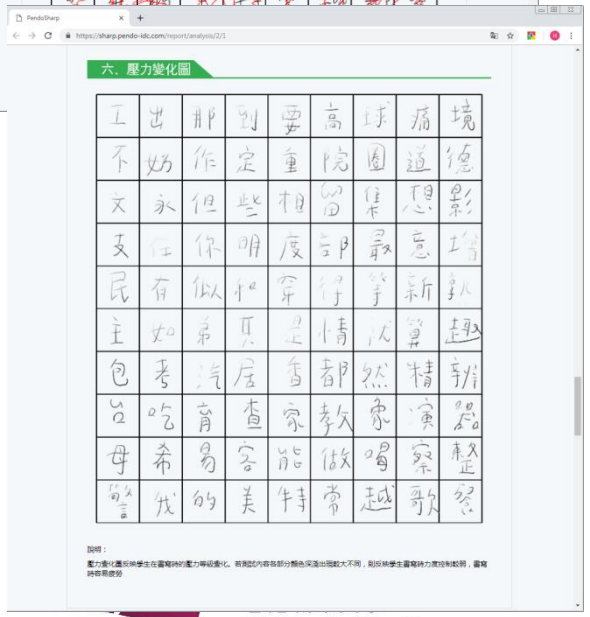


System Description (5) – Written Error



System Description (6) – Report





Data Collection

- Six schools were selected from four major regions in Hong Kong
- A class in each grade was selected and all students in that class were invited to participate the study
- 608 primary school students were recruited:
  - 507 typically developing students
  - 85 students with special educational needs as ASD, ADHD, SpLD, etc.
  - 16 non-Chinese speaking students

Norm Formation

	P.1	P.2	P.3	P.4	P.5	P.6	p	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)		
No. of males	56 (22)	47 (19)	36 (14)	42 (17)	35 (14)	33 (13)	.10	
No. of females	58 (22)	47 (18)	40 (16)	34 (13)	41 (16)	38 (15)	.14	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)		
Age	6.99 (0.44)	8.05 (0.53)	9.13 (0.51)	10.13 (0.58)	11.15 (0.69)	12.11 (0.57)	<.001	***
Handwriting process								
Ground time (min)	5.35 (1.55)	4.92 (1.78)	3.19 (0.86)	2.94 (0.89)	2.45 (0.64)	2.1 (0.48)	<.001	***
Air time (min)						86)	<.001	***
Air/Ground time ratio							<.001	***
Speed (words/sec)						8)	<.001	***
SD of writing time per character	5.79 (2.04)	4.71 (2.44)	2.80 (1.05)	2.30 (0.88)	1.84 (0.61)	1.4 (0.47)	<.001	***
Pen pressure	1598.31 (230.95)	1652.54 (215.03)	1663.61 (196.44)	1560.13 (264.73)	1637.90 (233.86)	1534.77 (289.45)	.003	**
SD of pressure	511.00 (66.03)	497.06 (62.87)	500.17 (56.73)	493.62 (56.18)	476.96 (65.62)	483.91 (65.11)	.006	**
Handwriting product								
Out of grid (no. of words)	32.21 (19.18)	35.84 (21.77)	25.13 (18.42)	24.38 (19.43)	19.14 (18.38)	16.46 (18.06)	<.001	***
Size (mm2)	86.52 (33.62)	74.97 (24.36)	61.40 (22.82)	58.27 (24.54)	52.06 (26.25)	37.47 (15.71)	<.001	***
Identified words (%)	94.12 (14.73)	92.29 (10.41)	97.63 (3.41)	96.91 (4.00)	97.76 (4.50)	98.31 (2.92)	<.001	***
Wrong stroke (%)	33.39 (16.23)	35.96 (18.57)	25.12 (14.43)	24.89 (15.69)	19.78 (12.42)	23.96 (15.09)	<.001	***
Additional stroke (%)	42.13 (17.88)	38.54 (17.42)	25.93 (13.41)	22.91 (15.86)	17.31 (11.07)	16.08 (12.15)	<.001	***
Missing stroke (%)	13.98 (10.87)	15.53 (12.93)	13.79 (11.94)	15.91 (11.73)	13.85 (10.32)	18.59 (14.20)	.10	
Concatenated stroke (%)	26.26 (16.14)	28.56 (18.06)	26.22 (18.96)	31.39 (19.79)	27.66 (19.43)	32.31 (20.49)	.17	
Reverse stroke (%)	3.80 (4.73)	4.54 (5.55)	2.02 (3.80)	3.31 (9.64)	1.93 (3.49)	1.78 (2.96)	.002	**
Wrong stroke sequence (%)	22.68 (11.67)	21.18 (10.89)	20.99 (9.06)	22.19 (11.38)	18.21 (9.86)	17.61 (10.17)	.008	**

Handwriting process improves from P.1 to 6

Deep Learning

- Deep learning technology using long short-term memory (LSTM) under the Recurrent Neural Network (RNN) architecture has been applied to analyze the legibility of the students' handwritings
- The system has been trained on thousands of collected handwriting characters and the parameters have been fine tuned with the aim to boost up the performance

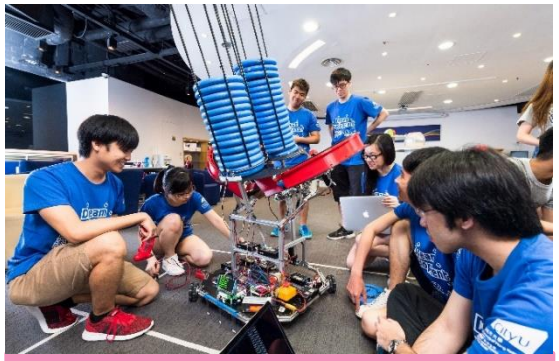
- Aspires to promote engineering education and groom engineering professionals
- Organise a series activities for secondary school teacher, students and their parents

Teachers

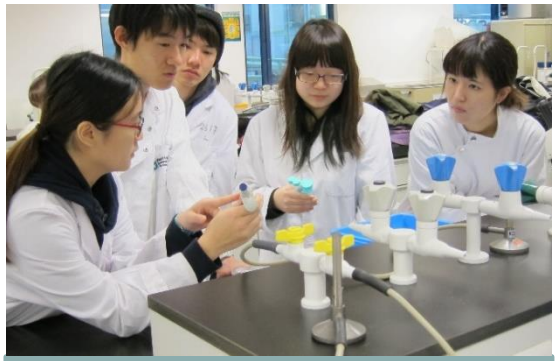
Students

Parents

Bright Future Engineering Talent Hub



STEM Challenge
Mar – Aug 2024



Summer Research Internship
Jul - Aug 2024

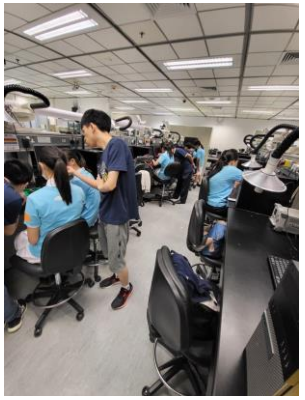
STEM Carnival cum Student Project Exhibition
3-5 Jul 2024

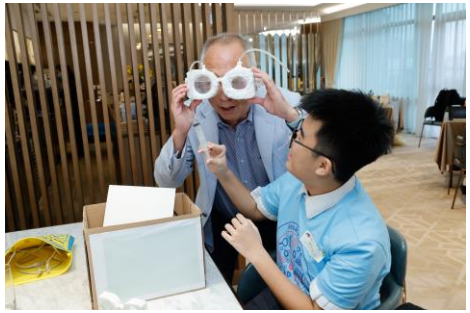
Teachers Update Courses

Engineering = Innovation x Entrepreneurship

Collaborative Activities with Engineering Societies

Photos from Past Events





- STEM Challenge 2024 have rolled out and is currently accepting applications!
- Summer Research Internship 2024 will accept application starting 5 February 2024!