QSC: QuickScan Calculator without Punching Buttons

Haotian Xue*, Lo Yuet Chan*, Ying Zhang*, Hei Yeung Lau*, Sai Hung Yu*, Ka Lok Man, Chi-Un Lei

***Abstract*—QuickScan Calculator (QSC) has been proposed in this paper. QSC is a highlighter shaped electronic calculator equipped with Optical Character Recognition (OCR) technology. It generates results instantaneously when an arithmetic expression is scanned by the QSC. Therefore, people can perform calculations without the process of "punching buttons". This would help the people to reduce the error made when wrong buttons are punched. Technical implementation concerns, societal concerns and possible future developments have been fully addressed in this positioning paper.**

***Index Terms*—common core curriculum, formula recognition, computation**

I. Introduction

THE rapid development of technologies has made a huge change on the way we think. It enables people with creative ideas to make an impact on our lives.

Recently, we have heard complaints from students doing mathematics and accounting. They have difficulties in getting the correct answer when they are doing assignments and tests, not because they were unclear about the concepts or they made careless mistakes, but because they just simply punched the wrong button on their calculators without realizing it.

In ancient times, people performed calculation using their brains and hands. With the development of technology, calculators were invented to help people perform calculations. Those who do not trust their brains may use calculators to check their answers. Nowadays, students complain that even the calculators cannot be trusted because they are so careless in punching the buttons. How to solve such a problem? We have come up with an idea of performing calculations without the process of "punching buttons". Therefore, we have proposed The QuickScan Calculators (QSC). QSC is a highlighter shaped electronic calculator equipped with Optical Character Recognition (OCR) technology. It generates results instantaneously when an arithmetic expression is scanned by the QSC. This would help the people to reduce the error made when wrong buttons are punched.

Different QSCs are designed to satisfy the needs by different types of consumers. The main benefit of using QSC is to improve calculation accuracy by avoiding mistakes due to human action and increase efficiency in study and business. There are mainly two kinds of potential users:

- Students who are loaded with tons of mathematics assignments and works may consider to purchase the calculator in order to increase the working efficiency and accuracy with calculation-orientated works.
- Financial professionals These professional who have to deal with large amount of calculation and data input may consider to purchase the calculator in order to reduce time for calculation and incorrect calculation.

In this positioning paper, Sections II, III IV and V describe main features, technical implementation concerns, flexibility analysis, and societal concerns of using SQC, respectively. Finally, possible future developments are shown in Section VI.

II. Main Features

A. Main Features

1) Efficiency: It greatly differs from the traditional calculators by replacing the keyboards by OCR sensor at the flat end. It requires the user to press the sensor lightly against the text and slide over the arithmetic expression. Time spent on inputting the data into the traditional calculator is greatly reduced.

2) Accuracy: The traditional method of input is by pressing the buttons in the order of the arithmetic expression. The OCR sensor is able to successfully avoid the errors made when a wrong button is pressed and improve the accuracy of calculation.

3) Functions: The calculator can be built into a both-ended highlighter, such that one of the ends is a highlighter while another end is QSC. The QSC end is equipped with most of the features of the traditional scientific calculators including addition, subtraction, multiplication, division, power, square roots, cubic roots, etc.

4) Ergonomics: Traditional calculator has a lot of buttons. While QSC does not require user to press any button (or just a few), it leads to less chance for joint strain and muscle fatigue. A product that keeps you efficient and healthy at the same time

III. Technical Analysis

A. Optical Character Recognition (OCR) Analysis

Since the QSC only targets printed numbers and symbols, no intelligent character recognition technique is required. The most basic OCR which targets printed text will do. An OCR software usually operates in three steps, pre-processing, character recognition and post-processing.

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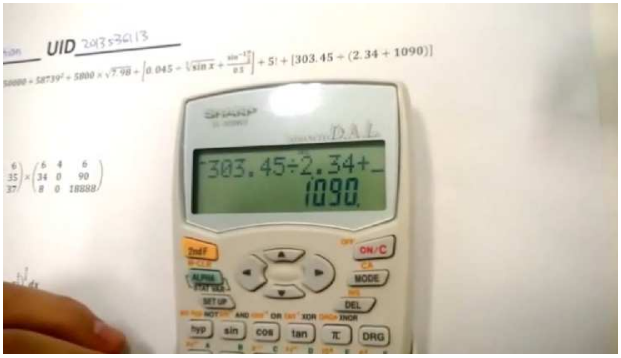

Fig. 1. Calculations without QSC.

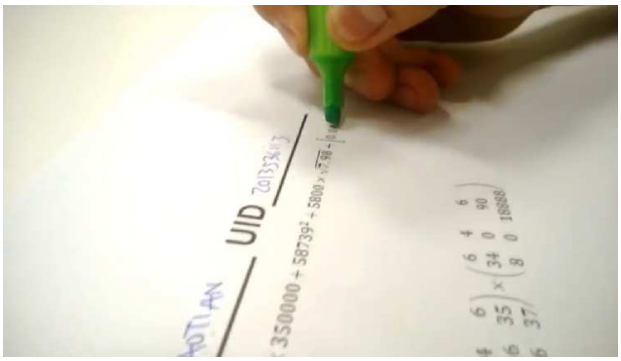

Fig. 2. Calculations with QSC (hypothetical scenario).

1) Pre-processing: The purpose of pre-processing is to improve the chances of success in character recognition. Several methods are used to achieve this goal.

1) De-skewing fine-tiles the scanned image so that the text aligns properly, namely completely horizontal.
2) Line removal removes the non-glyph elements such as lines and boxes.
3) Line and word detection recognize the shapes of the characters.
4) Segmentation separates the connected characters which should have been separated, connect the separated characters which should have been connected.
5) Normalizing adjusts the image to aspect ratio.

2) Character Recognition: In order to recognize these numbers and symbols after pre-processing, matrix matching is then performed to compare the image to the glyph in the storage on a pixel scale. The final results largely depend on the pre-processing step and the comparison step. A better performance is expected with printed text such as textbook or question sheet.

During processing, the images are capture by the image sensor inside QSC. The sensor will detect the frame difference and combine frames to form a whole image of the mathematical equation using the technique of image stitching by slightly overlapping the images captured by the sensor. Once the numbers or symbols are recognized, the data will be sent to the micro-processor for calculation.

The respond of the image sensor inside can detect motion up to 150 inch per second so fast scanning will not be a problem.

3) Post-processing: Usually, the recognized text is checked for accuracy by lexicons and grammars. However, it is not necessary of the QSC because only numbers and symbols are involved. And the recognized text is then passed to calculation.

B. OCR Calibration

It is to note that different individuals may develop different styles of handwriting. Therefore, developing OCR software targeting every individual consumers need may be necessary since personalized OCR service with OCR calibration may greatly increase the accuracy of the character recognition.

This requires the user to calibrate his or her QSC before the first use. The expressions used for calibration are pre-stored in the QSC and are known to the users. The QSC may require the user to scan the hand-write version of these pre-stored expressions. The image obtained is then matched and registered to the pre-stored expression. The differences and similarities between the users hand-writing and the pre-stored version can be generated.

The pre-stored expressions must cover a wide range of numbers and symbols. Some of the pre-stored expression used for calibrations can be as followed.

To further illustrate this, the QSC requires the user to enter number “8”. There is a user who write a single digit “8” in a very fancy way. The normal OCR may not recognize the “8” written by him. However, the personalized OCR can scan the “8” he writes and define the image obtained as number “8”. After several calibrations, the QSC is able to memorize the users habit of writing numbers and symbols. The next time the personalized OCR receives this fancy image, it will automatically recognize it as number “8”. This is likely to increase the scanning accuracy when scanning hand-written mathematical expressions.

C. Calculation Method Analysis

1) Calculation Input Method: The recognition process is shown in Fig. 3. There is a light bean coming out from the scanning head to indicate the range of the scanning. For a short word, users have to put the scanning head closer to the equation. For a long word, users have to put it farther away. The QSC can adjust the focus automatically by detecting the distance from the paper.

Infix notation is us used as the calculation input method in the QSC. It is generally accepted and adopted by many distinguishing instruments producers such as SHARP and Casio. Infix notation as a calculation input method is named as Direct Algebraic Logic (D.A.L.) by SHARP while Visually Perfect Algebraic Method (V.P.A.M) by Casio. This operation method allows the input of the numbers and symbols in the same order as what it is written. Figure 4 shows a few examples to illustrate how the post-processing mathematical expression is interpreted and calculated by the QSC.

The functions used for calculation are pre-installed in the calculator. When the expression is processed from left to right by the QSC, the associated functions will be called in order.

2) Calculation Processing: There are two ways for calculation processing: Whole calculation mode and continuous calculation mode.

For whole calculation mode, user can press the button on the QSC and start to scan the whole equation. Once the scan

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is finished, press the button again and the QSC will process the image and give out the answer.

For continuous calculation mode, user can press the button while scanning the equation. The QSC will process the data simultaneously while scanning so to reduce the input buffer. In this mode, the length of the input equation can be even longer depends on the type of the equation.

This can be done by calculating the equation segments enclosed by plus, minus or bracket. QSC continuously simplifies the equation when it scans from left to right as shown in Fig. 5.

IV. Flexibility Analysis

A. Cost Analysis

1) Cost of Hardware for OCR and Calculation: Hardware is relatively a small portion of the total cost as the production techniques of optical equipment are very mature nowadays. The large scale of optical devices production significantly lowered the cost of the required optical devices. Moreover, the optical devices required for the four different editions of QSC is essentially the same. The projected sale is directly proportional to the cost for hardware assuming that the hardware cost per QSC is constant.

2) Cost of Software for OCR and Calculation: This constitutes a larger portion of the total cost. In order to achieve higher accuracy in calculations, the OCR process must be extremely accurate. This requires the use of sophisticated OCR software, such as Onmipage, Tesseract, ExperVision and ABBYY FineReader. Negotiation with these companies is necessary to set the cost of the software. OCR software with different functions is used for the four different types of QSCs, resulting in different market prices. Furthermore, this cost is expected to be roughly constant through the years assuming this cost does not grow with sales.

V. Societal Concerns of Using QSC

QSC should be used widely for its convenience. The use of QSC in exams is likely to save the candidates time of punching the calculators and worrying whether the correct button is punched. It may largely improve the accuracy of the numerical answers and hence the improving the efficiency in completing the exam papers.

We have interviewed several students from The University of Hong Kong and their responses were positive. *"I think the QSC should be used for examination because it can help to avoid the mistakes made by punching the wrong buttons of the calculator. After all, examination is an assessment of our knowledge of the course rather than calculation skills."* said Li Hanhua, a year one student studying Actuarial Science. Some students also mentioned that it will be particularly useful for accounting courses because large amount of data has to be processed and the calculation can be tedious and lengthy. If careless mistakes can be avoided, the grade may be significantly improved. Overall, most students would like to attempt examinations with QSC and support the use of QSC during examinations.

However, some of the teachers have expressed their objection of QSC during exams. Their main reason is that the pen-shaped QSC might be easily disguised as a normal pen and hence be brought into the examination venue. This provides ease of cheating during exams in which calculators are not permitted. There will probably be an increase in the cost of checking at the entrance of the examinations. More time must be allocated to checking the possession of QSC and the efficiency is therefore reduced. Moreover, some of the teachers doubt whether this will reduce the students incentive to check their own work. Students may over-rely on the QSC and this is likely to affect their abilities to spot the own mistakes during the exams where QSC is not permitted.

Another possible concern would be about the real underlying meaning of learning mathematics. One of our interviewed secondary school teachers has mentioned that learning mathematics is about training our logical thinking, and patience but not just getting the correct answers. She worries about the attitude towards learning if students will be using QSC in the future. In her opinion, such an accuracy-improving device should be used in professional or business aspect in order to speed up work efficiency.

VI. Production Extension and Future Researches

A. User Interface Improvement

Firstly, QSC interface for smartphone platform can be developed. This allows calculations to be done based on photos containing mathematical expressions taken by the phone camera, so users would not have to bring an extra QSC for calculation. Also, an advanced QSC with camera might be developed. With the aid of camera, QSC may be able to analyze more complex mathematical problems involving graphs, charts and geometries. This might attract consumers such as engineers and scientists who work alongside with mathematics. Thirdly, speakers can be installed into QSC to provide voice message of calculation results or instructions. This can enhance the accessibility of QSC for disabled.

B. New Application: QuickScan Musical

Other than the above proposals, we also develop completely new products which are inspired by the QSC. For example, QuickScan Musical (QSM) is a highlighter shaped electronic musical score reader equipped with OCR. It generates sound with pitch and duration as written on the score instantaneously when a musical score is scanned by the QSM. This would help the musicians and performers to reduce the error made and time spent when reading musical scores. Therefore, the targeted consumers are musicians, song-writers, performers and students studying music.

The cost of QSM is expected to be lower than the QSC because no calculation input is required but simply the OCR. For QSM, only MIDI files of each notes on the chromatic scale is needed to be pre-stored in the memory. When the image of the score is detected, the relevant MIDI file will be played accordingly.

C. Calculators Refinement

Not many years ago, nobody has ever thought of using a touch-screen phones and computers. Nowadays, the market of smart phones and tablets are expanding at such an astonishing pace. Apple redefines phones by introducing the touch screen. Our company can redefine calculators by launching QSC.

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What QSC and the first iPhone share in common is that they both abolished the traditional concept of the product and exploring innovative ways to give its user mind-blowing experiences. Some have predicted that in the next five years, the traditional calculator producers would have to be equipped with an OCR component or introducing new figures to in order to compete market shares with the QSC. This is likely to influence other electronic devices and their industries. The use of OCR may become more extensive and the benefit of OCR can be further explored by all.

However, some points out that this type of calculator may not generate the desired social impact. The demand for traditional calculators is very inelastic as people are extremely used to punching buttons, checking their answer by re-punching the buttons. Therefore, the QSC Company may need to consider how to successfully bridge the transitions from using traditional calculator to the QSC. Moreover, the projected social impact may also depends on any new products or technologies introduced at the same time. Therefore, the actual social impact remains undetermined.

VII. Conclusion

A transportation advisory system "QuickScan Calculator" has been proposed in this positioning paper. With "QuickScan Calculator", people can know reduce the error made when wrong buttons are punched. The user interface, technical implementation concerns, and societal concerns have been fully discussed in this paper. Furthermore, feasibility of possible extensions, such as new musical applications as well as development of informative and personalized user interface have been studied.

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