Generating fast automated reports for the Farnsworth-Munsell 100-hue colour vision test

Ray Hidayat
University of Canterbury
Department of Computer Science and
Software Engineering
Private Bag 4800, Christchurch 8140
jrh130@student.canterbury.ac.nz

ABSTRACT
The greatest quality of the Farnsworth-Munsell (FM) 100-hue test is that it is able to indicate the presence of visual defects at early stages, so making it more widely available means more people can be saved from going blind or having their eyesight degenerate due to disease. However, the FM test is not used as often as its merits would warrant because of its main drawback – the extensive amount of time it takes to generate its report. We have developed a system that reduces the amount of time to generate reports for this test from 60 minutes to 4 minutes. The substantial increase in speed means this highly useful diagnostic test can be used more often, allowing for better detection of eye disease at early stages. Additionally the system generates statistical analysis of the results in accordance with Verriest norms, and has been used at Christchurch Hospital for several years.

Categories and Subject Descriptors
J.3 [Computer Applications]: Life and Medical Sciences – health.

General Terms
Measurement, Performance.

Keywords
Colour vision, Farnsworth-Munsell 100-hue, scanning method.

1. INTRODUCTION
Often when someone has a visual defect, colour vision is one of the first parts to be affected. This makes it very important to use a sensitive colour vision test to detect visual defects early. The Farnsworth-Munsell (FM) 100-hue test [1] is one of the most widely used clinical tests for acquired defects in colour vision. The fact that it quantifies a person’s level of vision makes it extremely useful as it can determine statistically whether a person’s colour vision falls within a normal range. This allows it to be used to investigate a wide range of acquired colour vision defects, such as optic nerve disease [2-4], age-related maculopathy [5], diabetic retinopathy [6] and primary open angle glaucoma [7]. Its biggest drawback though is the amount of time it takes to plot its report – often it can take up to 60 minutes. This is an extremely limiting factor in the use of this test, so to enable clinicians to use the test more often, we have developed a program that automates the reporting of the FM 100-hue test, reducing its reporting time from 60 minutes to 4 minutes for both eyes.

1.1 The FM 100-Hue Test
The FM 100-hue test has been widely described in previous literature [1-4] but a brief summary of the test will be provided here. The FM 100-hue test consists of 85 removable coloured caps, each of a different hue. The caps are separated into four boxes, each containing 21 or 22 caps each. In addition to the 21 or 22 caps in each box, at each end of the box there is a fixed cap of a particular hue. What the patient must do is arrange the 21 or 22 removable caps in the box so that they progressively change in hue, starting from the hue of the fixed cap on the left of the box and ending with the hue of the fixed cap on the right of the box.

Once the patient has completed arranging all 85 caps, a report is generated based on how correctly they arranged the caps. To assist with this, each cap has a number 1-85 written on the back, indicating where it should be placed. Calculations are performed on the patient’s chosen position numbers to quantify that patient’s level of colour discrimination, and a polar graph is plotted to allow clinicians to visually identify which hues the patient has the most trouble with discriminating.

2. BACKGROUND
Over the past 30 years, many researchers have developed computer programs to perform the reporting of the FM 100-hue test. Most of these would run under the outdated Microsoft Disk Operating System (MS-DOS). Also, nearly all of these programs required data to be keyed in manually, making them slow and prone to human errors [8-9]. The Huematic system was developed in 1988 [10] and was a prototype for an automated scorer for the FM 100-hue test. It showed great promise but unfortunately the system is based in MS-DOS, which adds an additional level of difficulty for those accustomed to computers using Microsoft Windows.

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3. SOLUTION

We developed a computerised scanning system for the FM 100-hue, designed to address the limitations of existing automated FM 100-hue reporting systems. The computer program was developed in JADE 6.0 and runs on Microsoft Windows. To ensure the program met the needs of its users, the various stages of the program being tested in the Ophthalmology Department in Christchurch Hospital.

3.1 Data Entry

One of the main challenges of developing an effective program for the FM 100-hue test is to have a data entry system that promotes accuracy. As there are 85 numbers to enter, it is easy to miss, transpose, or mistype the numbers. Accurate data entry is necessary so that the program can produce quality results.

The screen that accepts the cap numbers is shown in Figure 1. The system does checks as the user inputs numbers to make sure that the values are correct. First it keeps track of what numbers have been entered already and does not allow the user to input the same number twice. Also, the system is aware that each box can only store numbers within a certain range, for example box 2 consists of only the numbers in the range 22-42, and so the system will not accept numbers outside that range. If at any point the user enters a number that is not acceptable, the system will beep and display a message, preventing the user from continuing until the number is corrected.

It is also easy to determine if the user has mistakenly missed a number, as one of the text boxes in the row will still be empty.

Also to assist with those times when only part of the test has been done, the program has an Auto Fill feature, which will automatically fill in the rest of the test as if it had been done correctly.

Generally when inputting the cap numbers, the user will usually read the numbers into the system using a barcode scanner. Not only is this the fastest way to do this, but it is also much more accurate than typing. To make this possible, barcodes have been...
fixed to the underside of each cap, enabling the cap’s number to be read by a barcode scanner. For the caps to be read quickly, the barcode scanner requires all the caps to generally be aligned. To do this, a magnetic alignment system for the caps has been developed, allowing the box to be scanned in one pass. Figure 2 shows the barcode scanner next to a box of caps which have been turned over, revealing their barcodes.

If the user does not have access to a barcode scanner there are two alternative methods. They can type the numbers in using the keyboard, or use the mouse. The way the mouse input works is the user clicks the buttons 1-85 in the order the caps were positions, and the computer will place each number in the first empty text box in that row. As the cap numbers are entered, the buttons disappear, so that the user can visually see that number has been entered already and cannot be input again.

3.2 Report

Once caps have been entered, the screen will look like the illustration in Figure 1. From here the report, shown in Figure 3, can be generated in a click of a button.

As shown in Figure 3, the report is almost identical to the traditional manual report, giving it a familiar look, and enabling it to be read easily by clinicians. Below the graph is a statement of whether the patient’s colour discrimination lies within the normal range for their age, based on the work of Verriest, Laethem and Uvijls [11] and used with permission from Elsevier Science UK. There is an option to turn this feature off if desired. This report can be saved to disk as a Portable Network Graphics (.png) file, which is ideal for transmission as an email attachment due to its small size (approximately 40 KB), allowing clinicians to be sent patient’s results straight away.

3.3 Database

Not only does this program produce FM test reports in seconds, the software also stores patients and tests in a fully-searchable database using the JADE database. This means the program can keep FM tests for patients organised even when there are several hundred thousand patients to store, making the option of running routine FM tests on every patient a real possibility. This extends the use of the program beyond just an analysis tool.

4. RESULTS AND DISCUSSION

The use of the FM 100-hue test enables defects in colour vision to be detected earlier and more accurately, but its major limitation is the substantial amount of time it takes to generate its report. To reduce the time required and consequently make the test more readily available, we have developed an automated system for generating the reports of this test.

Our work built on that of previous researchers [9, 10], and we have introduced a number of improvements. The system runs...
under Microsoft Windows as opposed to the MS-DOS systems made previously. It also has a built-in database to keep track of tests from all previous patients. The traditional form of the FM 100-hue report was retained to maintain familiarity. Finally, the program performs statistical analysis based on the Verriest et al. norms [11].

The software is easy to use, with a toolbar at the top providing quick access to all the important functions. It is flexible, as demonstrated with the different ways data can be entered – through the use of the mouse or keyboard, or using the preferred method of a barcode scanner. It is also fast, especially when using the barcode scanner. When the cap positions are scanned in, the results can be generated for both eyes within four minutes, which contrasts to the 60 minutes that it takes to produce a report manually.

The use of this new system has proved to be of great assistance both in saving time and in eliminating arithmetic errors in the scoring calculations. This will encourage clinicians to make greater use of this valuable diagnostic tool, enabling the visual defects of more patients to be detected at earlier stages, giving them a better chance at retaining their vision.

This project has won the silver award at the Asian Innovation Awards 2004, Individual Category of the New Zealand Health Innovation Awards 2004, the Supreme Award title of the Canterbury District Health Board (CDHB) Quality & Innovation Awards 2003 and the ComputerWorld Excellence Awards 2005 Highly Commended Certificate.

5. ACKNOWLEDGEMENTS

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6. REFERENCES


