Development of Visual Test Software in Mobile Diagnostic System

Gunars Balodis[1], Ivars Imuns[2], Martins Krasnovs[3], [1-3] *Riga Technical University*

Abstract **— The paper discusses development of visual test software that is used in mobile telemedicine screening complex (MTSC). It is a set of medical devices controlled by a portable computer and means of wirelessly transmitting data to the analysis centre. This complex is used for screening purposes to detect potential problems in the patient's health. Altogether screening complex has 14 measurement modules that measure the status of 12 body subsystems. This paper addresses the development of one of these modules – a visual test.**

Vision test software consists of two parts – visual acuity test and colour test. Visual acuity test is done using a computer screen for displaying test symbols and using remote control for patient response input. Colour vision test is carried out similarly by displaying pictures of coloured numbers on coloured background and requiring a patient to input those numbers using a keyboard or a mouse. The paper focuses on the development of methodology and implementation of both visual tests.

Keywords **— Diagnostics, e-health, screening, vision.**

I. Introduction

The purpose of screening is to detect health problems early before they complications are not developed. An important role here is played by regular preventive examinations. At present, investigations and analysis are usually carried out by health care institutions because only in very rare cases a family doctor has the necessary diagnostic equipment and skills to evaluate the information obtained in the investigations. To organize and facilitate the process of screening at health care institutions and especially at consulting rooms of family doctors, we have developed the Mobile Telemedicine Screening Complex (MTSC) [1], [2]. It consists of a set of 14 physiological parameter measuring modules, interactive questionnaire of subjective symptoms on 12 body subsystems, portable computer with a monitor, wireless data transmission means to the remote analysis and consultancy centre with the database.

One of the subsystems tested by MTSC is human vision. Vision testing evaluates visual quality (visual acuity), and the colour vision. These vision functions with relative ease and interesting to the child [3], [4], [5] can be evaluated by vision screening tests. Results give an indication of the overall vision condition, the ability to operate in increased load conditions and warn about the possible signs of tiredness. Such an assessment is particularly important for school-age children when vision is one of the most important senses in the learning process. If any of the visual functions evaluated by screening tests do not conform to the standards, we recommend a thorough vision examination to assess and prevent vision worsening risks [6], [7].

II. Visual Acuity Test

Visual acuity test verifies the patient's visual acuity, which corresponds to the smallest Landolt C ring size (standard ISO 8596:1994, [8], Fig. 1), that the patient is able to determine the direction of the cut. This symbol has been chosen because it also allows doing tests with very young children or illiterate adults that do not require letter recognition [9].

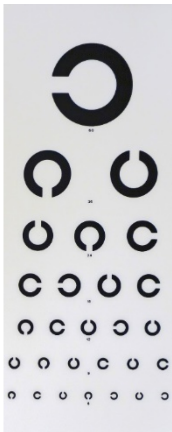

Fig. 1. Landolt C ring table example.

Acuity is evaluated both in distance and nearness. Closeness visual acuity can be affected by person's age, fatigue. Closeness visual acuity is significantly affected by the lighting and quality of the text. If the perfect vision in the distance considers a person's ability to see 1.0 characters of the visual acuity table, the proximity of good vision acuity is assumed to be 0.7-0.8. Usually visual acuity for nearness is evaluated at a distance of 40 centimetres. There are several factors that can affect visual acuity:

– refractive vision defects that can be corrected;

– accommodation disorder;

– the pupil diameter (the wider the pupil is, the more visual acuity is decreased);

– lighting (the worse lighting is, the more rapidly acuity drops);

– contrast (by decreasing contrast, visual acuity decreases);

– object displaying time;

– viewing the target (moving or stationary), and eye movement;

– patient's age (children vision quality reaches a peak at about 6-7 years of age, but after the age of 50 it gets worse);

– a variety of eye diseases (e.g., ocular optical middle opacities, retinal pathology).

The standard of visual acuity for school-age children in visual acuity screening test is 0.8 [10], [11]. If the vision acuity is lower than the one given above, an additional test is needed to determine the cause. The most often causes for school-age children are vision refractive defects, excessive vision tension or fatigue [12].

The serial number of visible lines in the ring table corresponds to patient's visual acuity in format 0.0. The test table has 10 rows, each has rings in different sizes or 'E' capitals. Their dimensions correspond to different visual acuity. The first line corresponds to a visual acuity of 0.1. Each new row number is increased by 0.1. The second row corresponds to a visual acuity of 0.2. The third row corresponds to a visual acuity of 0.3 and so on. The tenth row corresponds to a visual acuity of 1.0, which is the standard. The lowest line, which can be read, corresponds to the patient's visual acuity.

In case of decreased visual acuity, a patient should go to the optometrist to determine the correction glasses or contact lenses. In case of colour vision problems, deeper vision examination must be done by an oculist (if necessary, for example, for acquiring a driver's license, for army soldiers, traffic controllers, etc.).

The visual acuity number determines the size of the letters or cuts in circles from the table that is seen by a person under examination compared to normal eyesight. Usually it is calculated for distance of 6 meters for each eye and expressed as a ratio of two numbers, for example:

6/6.0 – normal vision

6/12 – a two-fold decrease in vision, that is, the person can see only 2 times bigger characters than the norm, or the person sees characters that are seen by a healthy person from the distance of 12 meters. Next, if necessary, the computer can perform the conversion to decimal units (normal vision is 1.0) or logarithmic units (normal vision is 0) [13].

Visual acuity test process. Test begins by showing the largest characters in size. If the test runs without problems, the symbols from next lower row are shown to the patient. The test is finished if a patient makes mistakes in the current row or a patient admits that the characters cannot be seen. In the decimal system, the number of visual acuity is assumed as a code for a line (less than 1) that is seen by a patient without problems. The code for the last smallest character line is 1.0 – normal vision.

Visual acuity test software development. The test mainly consists of displaying rings on a computer screen, outputting the results and storing them in the database. Input from a patient is acquired using a wireless remote control (Fig. 2) with 4 buttons according to the direction of the ring (up, right, down, left).

Fig. 2. Remote control for answer input from a patient.

In addition, the program also includes the setting section for the visual acuity test calibration. Before the test is performed for the first time, a user needs to specify the computer's screen size in centimetres (or inches). This value is used for the calculations in the program so that an appropriate size of the rings can be adjusted to the computer screen (Fig. 3).

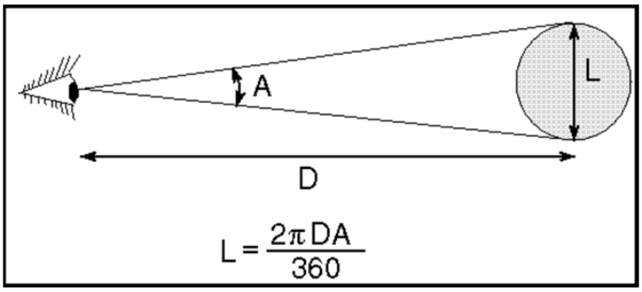

Fig. 3. Object size calculation depending on a distance.

It is required to set which eye will be tested in the current test (by default both eyes are set – the left and right eye), also it is required to determine whether a patient wears glasses during the test and the distance at which patient's vision will be tested. A user can choose a distance from 1 to 6 metres (step of 1 metre). In perfect conditions, the distance should be 6 metres, but the default value is set to 5 metres. The selected distance can significantly affect the progress and outcome of the test [14], i.e., if a user sets a small distance, such as 1 metre, the rings smaller in size will be displayed, because in this case it will be easier to see the displayed symbols from the selected distance. If a user has selected a larger distance, then rings larger in size are also displayed. This means that ring sizes are calibrated and adjusted to the selected distance.

At the beginning of the test, a window gets maximized to a full screen and a message about the eye that must be covered is displayed on the upper part of the window. Moreover, a user is notified that the test will begin as soon as any button is pressed. The button can be pressed on the computer keyboard and also on wireless remote control that is provided for this test. Covering one eye is necessary for proper accomplishing of the vision test, that is, if the right eye is tested, then the left eye must be covered and so on.

The representation of symbols is performed according to the test table – the largest symbols in size are shown in the beginning, if the test runs without any errors, the next lower line of symbols is shown to a patient. The time limit for character recognition is not set. Rings are shown consecutively with cuts in a random direction. This is achieved by Random instruction in the program. This instruction randomly generates one of the four options – left, right, up or down (Fig. 4).

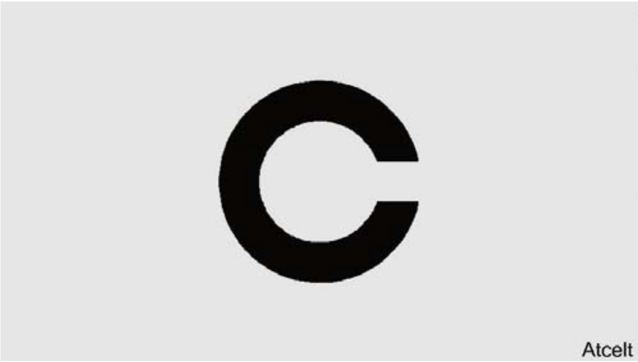

Fig. 4. Test image.

The patient has to press the button on remote control that corresponds to the direction of the cut in the ring while standing at the previously selected distance. For example, if the incomplete part of the ring is located on the right side, patient should press the button that indicates the direction – to the right. Special signals for buttons are used in program for each direction of the ring. The signal from the pressed button is read and compared to the signal that corresponds to the direction of the ring that is displayed. If they match, a new ring is displayed on the computer screen. Otherwise, the error counter is increased by 1. In case the patient has indicated ring directions correctly 4 times, the program moves to the next row in the test table. In this case, the ring size is reduced according to the table and the number of errors is cleared. In case the patient has specified the ring direction incorrectly, the program shows one additional randomly selected ring from the current row in the table. If the patient makes 2 mistakes in the current row, the test is stopped and the result is displayed on the screen, which means that there is only one mistake allowed in each round. The test continues until there are 2 mistakes made or the patient has made not more than one mistake in the very last round or the patient admits that characters cannot be seen. Considering that randomly selected symbols can be repeated, every symbol is displayed with a delay of 0.5 seconds. That is done by a special timer implemented in the program. It prevents patient's confusion if he/she thinks that the output symbol is still the same and the remote control has not worked correctly. If the test is completed successfully, the button "OK" is displayed on the computer screen. After pressing the "OK" button, results are stored in the database. Data: the time when the test was performed, test result – a decimal number for each eye that was tested during the test, the distance in metres at which the patient took the test and also whether the patient wore glasses during the test – are stored in the database. The doctor can also save a comment about a particular test. For example, "Poor lightning conditions in the room", so we can get more information about conditions under which test was taken.

III. Colour Perception Test

The human eye can perceive only a small range of the electromagnetic radiation spectrum – from 380 to 760 nanometers (Fig. 5). This range is called visible light.

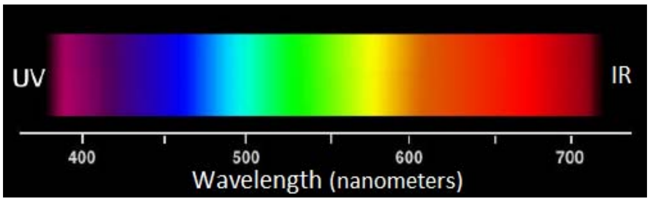

Fig. 5 Visible spectrum of light.

In order to perceive colour, a light pulse from the retina of the eye must reach our brain vision centre. Light can directly shine from an object (the sun, lamp, candle etc.) or even can be reflected from an object that does not emit light. There are two types of photo receptors in the human eye retina – rod cells that are responsible for visual perception in low light and cone cells that perceive colours and work only in good lighting conditions. Three are three types of cone cells – short wave sensitivity cones (earlier known as "blue" cones), average wave sensitivity cones or "green" and long wave sensitivity cones or "red". Thanks to interaction of these three cones, the human eye can distinguish about 10 million colours.

If all three types of cells operate, the colour vision is called trichromacy. For people with impaired colour vision perception, the most common cause is one of a kind cone cell disorder, optic nerve or central nervous system damage.

Unfortunately, about 8% of men and 1% of women have varying degrees of red–green colour vision problems. Yellow–blue colour perception problems are much less common. Total colour vision blindness, when people can differentiate only between black and white colours, is very rarely observed.

For people with colour perception disturbances daily life is not so difficult, but there are professions that require colour perception, such as ship crew members, airplane crew members, certain positions for military personnel, fashion designers, artists etc. If the colour perception from childhood has been good, but some changes appear in a lifetime that may indicate optic nerve or central nervous system damage. In this case, an eye specialist consultation is mandatory.

Testing Colour Perception

Testing task is to see numbers or geometric figures in coloured circles. Colour perception test must be performed from normal distance, if necessary glasses can be used. Person who performs this test must tell what he/she sees in the picture. The main idea of colour test is that different test pictures are shown, where on different colour circle background the patient must see hidden numbers or figures (Fig. 6).

If all answers are correct, the patient dies not have any colour perception problems. If at least one of the answers is wrong, it means the patient has colour perception pathology and it gets recorded. Main task of screening is to determine whether the patient has colour perception pathology. In order to accurately determine what kind of colour vision pathology the patient has, he/she should resort to an ophthalmologist for diagnosis precision.

Colour Perception Test Process

The proposed colour perception test generates 5 random different images out of a set of 25 predefined images. In these images the patient must identify numbers or geometric figures. The numbers may be within the range of 0 to 9 and figures are: triangles, squares, circles, horizontal lines or vertical lines. Patient is given 7 seconds of time to take a look at an image, during this time the patient must identify symbols shown before.

Before starting the colour test, there is another window with short instructions about the test to be carried out. Those instructions are made for patients to inform them about test process. When the patient is familiar with the upcoming test process, he/she can press button “Sākt testu” (“Begin test”) to actually begin the test.

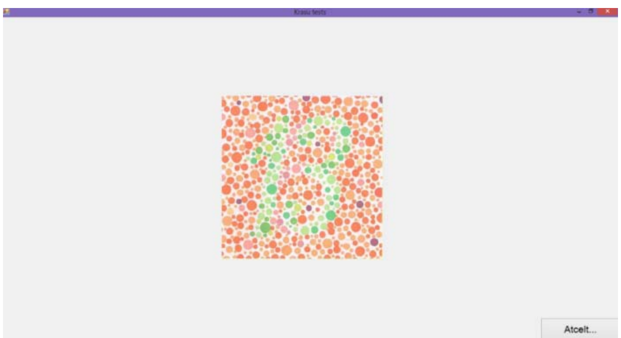

Fig. 6. Test image.

When time is up, test image disappears and a panel with all possible answer buttons shows up. By using memory the patient must enter what he/she saw in test picture one moment ago. To choose an answer the patient needs to press buttons with symbols that he/she saw and confirm the choice by pressing the button “OK”. The chosen answers will become light grey (activated buttons will become inactive).

Fig. 7. Choice confirmation.

It is very important if by mistake the patient has pressed a wrong answer, it can be corrected by pressing the button “Dzēst izvēli” (“Delete choice”), and it will make all buttons active again. It is necessary to enter all the perceived elements that were in the test image, for example, if number “1” and number “3” were shown, both numbers must be given as answers (press both buttons), otherwise the program will make a decision that patient did not recognize all elements (Fig. 7).

In this way the test is continued until all five images are shown and answers are entered.

IV. Results and Conclusions

The proposed system allows for the quick and efficient testing of patient’s vision. It is very flexible and supports different hardware screen sizes and testing distances. It was determined that modern computer display resolution and colour accuracy were good enough for screening purposes [15], [16], [17]. The developed system is a valuable addition to the mobile telemedicine screening complex at a relatively low cost since the system uses the existing computer monitor for displaying test images and no additional hardware is necessary except for the remote control.

The system can be used as a standalone vision test for patient or as part of more complex examination together with other modules of MTSC. The system can be used in medical practices, schools and workplaces for patient’s diagnosis. The complex can also be used by a practitioner to provide additional services to their patients.

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Gunars Balodis has a Master Degree in Computer Science obtained at the University of Latvia, the Faculty of Physics and Mathematics, the Department of Computer Science in 2004. Currently he is a doctoral student at Riga Technical University, the Faculty of Computer Science and Information Technology.
Work experience: Programmer at JSC Amerilat, Programmer at Integris, Ltd, Research Assistant at Riga Technical University. At present he is an Elected Researcher at Riga Technical University, the Faculty of Computer Science and Information Technology.
Address: Meza Str. 1/3, LV-1048, Riga, Latvia
E-mail: gunars.balodis@rtu.lv

Ivars Imuns has a Bachelor Degree in Computer Science obtained at Riga Technical University, the Faculty of Computer Science and Information Technology, the Department of Automation and Computer Engineering in 2012. Currently he is a Master's degree student at Riga Technical University, the Faculty of Computer Science and Information Technology, the Department of Automation and Computer Engineering.
Work experience: Research Assistant at Riga Technical University, the Faculty of Computer Science and Information Technology.
Address: Meza Str. 1/3, LV-1048, Riga, Latvia
E-mail: ivars.imuns@rtu.lv

Martins Krasnovs has a Bachelor Degree in Computer Science obtained at Riga Technical University, the Faculty of Computer Science and Information Technology, the Department of Automation and Computer Engineering in 2012.
Currently he is a Master's degree student at Riga Technical University, the Faculty of Computer Science and Information Technology, the Department of Automation and Computer Engineering.
Work experience: Research Assistant at Riga Technical University, the Faculty of Computer Science and Information Technology.
Address: Meza Str. 1/3, LV-1048, Riga, Latvia
E-mail: martins.krasnovs@rtu.lv

Gunārs Balodis, Ivars Imuns, Mārtiņš Krasnovs. Redzes testa programmatūras izstrāde mobilās diagnostikas sistēmā
Sabiedrības veselības aprūpē nozīmīga loma ir profilaksei un savlaicīgai slimību diagnostikai. Bieži vien diagnostikas iestāžu attālums un cilvēku aizņemtība ir par iemeslu, kāpēc pacienti neapmeklē ārstu veselības pārbaudei. Kā risinājums šai problēmai tiek piedāvāts mobils telemedicīnas skrīninga komplekss (MTSK), kas spētu reģistrēt nozīmīgākos parametrus un sniegt slēdzienu par pacienta veselības stāvokli.
Rakstā apskatīta programmatūras izstrāde redzes pārbaudei, kas ir viens no MTSK moduļiem. Redzes pārbaudei ir divas daļas – redzes asuma tests un krāsu redzes tests. Redzes asuma pārbaude tiek veikta, datora ekrānā parādot testa simbolus, kuri pacientam ir jāatpazīst un jānorāda to orientācijas virziens (uz augšu, uz leju, pa labi, pa kreisi), izmantojot tālvadības pulti atbilžu ievadei. Testa laikā attēli pakāpeniski tiek samazināti, līdz tiek noskaidrots mazākais droši atpazītais attēla lielums. Krāsu redzes pārbaude tiek veikta līdzīgā veidā uz datora ekrāna, parādot krāsainas bildes, kurās ir attēloti krāsaini cipari uz raibi krāsaina fona un pacientam ir jāatpazīst un jāievada šie simboli, izmantojot klaviatūru vai peli. Rakstā tiek apskatīta šo testu veikšanas metodoloģijas un programmatūras izstrāde, kā arī ar datorizēto redzes pārbaudi saistītās problēmas.
Rezultātā ir iegūta sistēma, kas ļauj ātri un efektīvi pārbaudīt pacienta redzi. Sistēma ir elastīga un var darboties uz dažāda izmēra monitoriem un ļauj veikt testus dažādos attālumos no datora ekrāna. Tiek secināts, ka mūsdienu datoru ekrānu izšķirtspēja un krāsu attēlošanas precizitāte ir pietiekami laba skrīningam. Izstrādātā sistēma ir vērtīgs papildinājums citām MTSK iekārtām un var tikt izmantota atsevišķi vai kopā ar citiem moduļiem pacienta vispārējās veselības pārbaudei.

Гунарс Балодис, Иварс Имунс, Мартинъш Краснов. Разработка программного обеспечения для проверки зрения в мобильной диагностической системы.

Профилактика играет важную роль в здравоохранении и ранней диагностике. Часто занятость и расстояния между диагностическими учреждениями является причиной, почему пациенты не посещают врача для проверки здоровья. В качестве решения этой проблемы предлагается разработка нового мобильного комплекса скрининга телемедицины (МКСТ), который способен регистрировать важные параметры организма и сделать из модулей МКСТ. Проверка зрения состоит из двух частей – определение остроты зрения и проверка цветового зрения. Тест на остроту зрения проводится на экране компьютера, показывая тестовые символы, которые пациент должен распознать и указать направление ориентации (вверх, вниз, вправо, влево) с помощью пульта дистанционного управления. Во время испытания изображения тестовые символы постепенно уменьшаются до минимального размера, который и выявляет остроту зрения пачиента. Тест цветового зрения проводится таким же образом, показывая на экран компьютера цветные картинки, отображающие цветные фигуры на пестром цветном фоне, и пациент должен распознавать эти символы и с помощью клавиатуры или мыши ввести ответ. Настоящая работа посвящена методологии тестирования и разработки программного обеспечения, а также рассмотрены проблемы, связанные с компьютеризированной проверкой зрения.

В результате получается система, которая позволяет быстро и эффективно проверить зрение пациента. Система является гибкой и может работать на мониторах различных размеров и проверять зрение на различные расстояниях от компьютерного экрана. Сделан вывод, что разрешения экрана современных компьютеров и точность изображения цветов достаточно хороши для скрининга. Разработанная система является ценным дополнением к другому оборудованию МКСТ и может быть использована отдельно или в комбинации с другими модулями для общей проверки здоровья пациента.