Computer Game Lugram-Version for Blind Children*

Branko Lučić, Nataša Vujnović Sedlar, and Vlado Delić

Abstract — **Computer games have undoubtedly become an integral part of educational activities of children. However, since computer games typically abound with audio and visual effects, most of them are completely useless for children with disabilities. Specifically, computer games dealing with the basics of geometry can contribute to mathematics education, but they require significant modifications in order to be suitable for the visually impaired children. The paper presents the results of research and adaptation of the educational computer game Lugram to the needs of completely blind children, as well as the testing of the prototype, whose results are encouraging to further research and development in the same direction.**

Keywords — **adaptation software, blind children, educational computer games, geometry.**

I. INTRODUCTION

THE number of citizens that use computers increases every day, among them there are more and more blind and visually impaired people. Owing to the development of speech technologies (ST), a computer for this population becomes a voice machine that can read to them, a source of information and one of the main tools in their education. In their education, the visually impaired use various methods and approaches to adjust the educational material to their abilities. Computers together with ST have an important role in this process. The appearance of PC and ST has opened opportunities to develop entirely new applications that can greatly facilitate the education and lives of the visually impaired. In developed countries a lot of attention is devoted to the inclusion of people with disabilities and for that reason many educational and entertainment computer audio games have been developed [1], [2]. Serbia has recently also been trying to do something in this area [3], [4].

The paper presents a proposal for modernization of teaching the visually impaired mathematics, particularly geometry, by using the computer game Lugram [5]. The game was initially developed for sighted pupils, and later adapted for the visually impaired ones [6]. The model of the game for the visually impaired uses tactile and sound presentation of tasks to bring geometry closer to users.

Branko Lučić, Faculty of Technical Sciences, University of Novi Sad, Serbia (phone: +381-21-485-2533; e-mail: bl_lule@hotmail.com).

Nataša Vujnović Sedlar, Faculty of Technical Sciences, University of N. Sad, Serbia (phone: +381-21-485-2519; e-mail: natasav@uns.ac.rs).

Vlado Delić, Faculty of Technical Sciences, University of Novi Sad, Serbia (phone: +381-21-485-2533; e-mail: vdelic@uns.ac.rs).

II. COMPUTER GAME AND VISUALLY IMPAIRED PEOPLE

Computer games for the visually impaired children have an important role in the inclusion process [7], but, on the other hand, computer games industry does not pay sufficient attention to the accessibility of a game. Successful development of the game for the disabled primarily depends on the modification of standard graphical user interfaces (GUIs) according to their ergonomy. For the visually impaired players, non-visual modalities based on tactile and auditory senses are used for presentation of graphical user interfaces (GUIs).

In audio games, sound used for audio interaction with a player could be: causal, semantic and reduced. Auditory events in audio games with casual sound are presented with a characteristic sound of their source. Semantic audio games use auditory messages for interaction with the player. Reduced sound is an adequate auditory stimulus without specific sound features, physical or cognitive that point to a sound event. The Stockholm International Toy Research Center, at KTH, Royal Institute of Technology (SITREC) has designed three audio games within TiM project (Tactile Interactive Multimedia) [8]. TiM audio games show all aspects of audio interactions with a player, but among them Tim's Journey is the only one that uses surround sound and narration elements. Besides several research centers in the world, the visually impaired gaming community also supports and promotes audio games by launching a new one on their site regularly [9].

Besides the auditory sense, touch is another primary sensor for the visually impaired. For that reason tactile computer games have been developed, where the GUI is represented through a specialized panel, keyboards, touch-sensitive tablets or special haptic devices like PHANToM [10] and FEELit Mouse [11]. This concept of GUI presentation provides a tactile/haptic channel of information exchange between humans and computers. Today specialized haptic devices can also support the presentation of 3D objects, not only 2D models and graphs [12]. They can present a shape and/or weight of the object or sometimes even allow virtual manipulation.

A special domain of games for the disabled are educational games with their additional problems related to their educational content and presentation to the visually impaired users. Teaching geometry to the blind has always been most challenging [13], but geometry is most useful to them for the construction of their mental space representation [14]. The awareness of space is crucial for their ability to recognize objects such as circle, triangle, square,

objects at home etc., to perceive relative locations and directions in space such as right, left, up, down, far, or near and to match one space to another.

In papers related to educational games for the visually impaired various applications and modality combinations have been presented, but tactile or haptic devices are mostly used for spatial presentation [15], sometimes in combination with audio interaction as a support [16]. The European project MICOLE (Multimodal Collaboration Environment for Inclusion of Visually Impaired Children) [17] presents several interfaces based on touch and audio for the visually impaired and vision for the sighted because project supports inclusion [18], [19], [20]. From the references mentioned above it can be concluded that the information on the location of objects in a particular space, besides in a tactile/haptic context, could be represented by auditory cues as well. This approach provides greater access to information that the blind user should receive.

The paper will present the computer game Lugram that also uses tactile and audio presentation of GUI to introduce the player with geometric elements and figures to be constructed. For this demo version of Lugram the audio presentation of GUI is completed and tested, but the tactile presentation is still connected with tactile/haptic devices.

III. COMPUTER GAME LUGRAM

Computer game Lugram has been devised with the aim to make, in an interesting and dynamic way, the initial contact of elementary school pupils with geometry more interesting. Lugram is a puzzle game based on composing the given geometric figures. In the basic version of the game, figure tasks are created in a 3x3 matrix of squares.

Elements to be used for assembling are squares of size equal to the unit square of the task matrix and contain geometric figures such as square, rectangle or triangle.
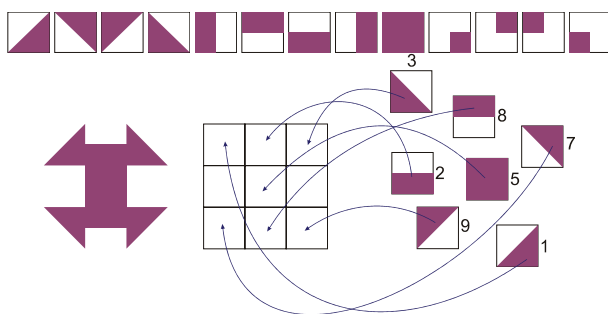

Fig. 1. Composing elements and example of Lugram-task.

Lugram is a modularly organized computer game. It leaves the possibility of adding new modules, improvements and adjustments to the game.

Lugram has three basic modules: the module used to create tasks, the module used to create composing elements and the module for the game itself. The modules for creating tasks and composing elements are implemented in *Borland C++ Builder*. For the implementation of the game module *Macromedia Director* was used (Fig. 2).
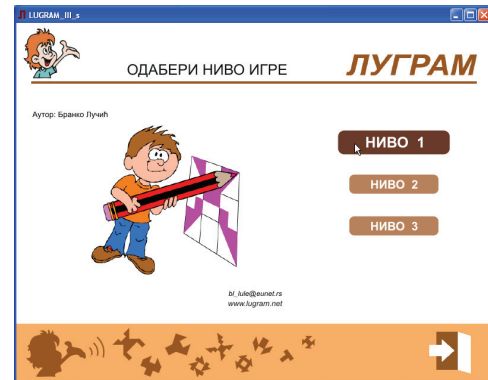

Fig. 2. GUI of module for the game.

IV. ADAPTATION OF COMPUTER GAME LUGRAM FOR BLIND USERS

The first step in the adjustment of the Lugram computer game for the visually impaired was the production of the version for partially sighted children [4]. The adjustment needed many significant modifications in the program. It was also necessary to examine whether it was necessary to coordinate it with additional tactile devices [21], [25].

Interventions in the program are related to the changes in the game module. As a basis for further changes of the program a version of the game module for partially sighted users was used. The method of composing the given elements has remained the same (one at a time) as in a version for partially sighted users. Instead of using a mouse the use of standard PC keyboard (primarily its numeric part) was introduced (Fig. 3).
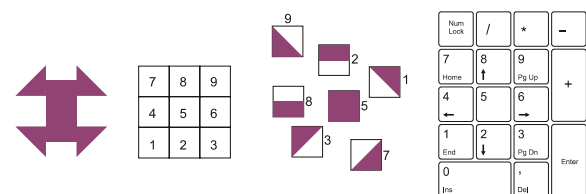

Fig. 3. Numeric keypad and matrix of a Lugram-task.

The modification of the method according to which the composing elements were offered in the version for partially sighted users, has opened the possibility for the adaptation of game control by using only the keyboard, with adequate follow-up gameplay using sound effects, voice messages and interpretations that guide the user through the game. The accompanying soundtrack is not present so as not to disturb the concentration of users [22]. The game status is always visually present on the computer screen.

The positions of the elements in the task matrix are adjusted to the positions of the numeric keys of a separate numeric PC keyboard (Fig. 3). The basic idea of the adaptation to blind users is that the game can be played by using only a standard PC keyboard with sound effects and voice messages, without the need for additional tactile devices.

The changes of the *Lingo* scripts are more significant than those in the version for partially sighted users. For

control and reproduction of sound files and voice messages commands such as *sound()Queue()*, *sound()Play()* and *sound()isBusy()* were used. For the control of player moves, the analysis of the content of system variables *keyPressed* and *keyCode* was used (Fig. 4).

```
on exitFrame me

  if the keypressed <> EMPTY then
    case (the keyCode) of
      24
        if (up1 = 0) then
          if (pamnav = 1) then
            sound(1).queue(member("uput 2a"))
            sound(1).play(member("uput 2a"))
          else
            sound(1).queue(member("uput_2ab"))
            sound(1).play(member("uput_2ab"))
          end if
        end if
      49
        sound(1).stop()
        exit
    end case
    go the frame
  end if

  if sound(1).isBusy() then  go the frame

end exitFrame
```
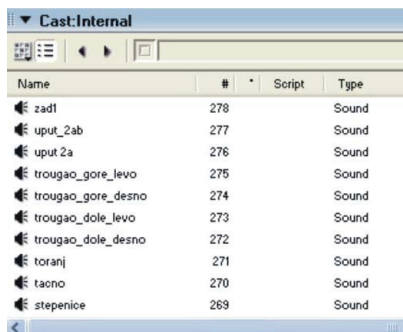
Fig. 4. Example *Lingo* script in Lugram for blind users

A much larger amount of files that contain voice instructions and messages required the use of audio compression, in order to reduce the program size (Fig. 5).

Fig. 5. Example of sound files.

After the recording of voice messages in WAV format, conversion into SWA format was used. For the short sound effects whose carriers are sound files from the library, the format was not changed (MP3, WAV). Flow control precisely matches the application *Sound() Lingo* statements (Fig. 4) with the *TimeLine* of the game module.

V. APPLICATION OF TTS TECHNOLOGY TO THE VERSION OF LUGRAM FOR BLIND USERS

The appearance of TTS technology in the Serbian language has opened a new modality for the production of voice messages and instructions for computer games such as Lugram.

The application of TTS to the versions of the game for blind users was much simpler than recording voice messages with live voice talents. Preparing voice messages no longer required special recording conditions, and the time required for their preparation, that used to be measured in days, has been significantly reduced.

Fig. 6. AlfaNum TTS technology - demonstration [23].

The TTS engine named Snezana, developed by the Faculty of Technical Sciences in cooperation with the company "AlfaNum" from Novi Sad (Fig. 6), used in the Lugram version for the blind, creates voice messages whose quality is close to the natural human speech.

If greater authenticity of the situation is to be achieved, or in order to ensure that the right reaction will be made, synthesised speech can always be replaced by recorded – natural speech [24].

VI. GAMES INTERACTION WITH THE USER

Guided by voice instructions, the users choose how they wish to play Lugram. Selection is done by pressing the appropriate key of the numeric keypad. In order to make it easy to use a standard PC keyboard for the moves in the game and navigate through the game, the player uses almost exclusively keys of the numeric keypad with a very small number of other keys (ESC, Spacebar and arrow keys).

Voice messages that are presented to the player are separated by a sound effect-separator, in order to highlight the guidelines for the player to participate in the game. Voice instructions are of minor importance after the first task of the current level in the game is successfully solved. The player can replay the entire contents of spoken instructions for the current stage of the game.

So far three prototype Lugram versions for the blind have been created: *Lugram – memory game*, *Lugram – arrow navigation game* and *Lugram – three-point navigation game*.

A. Lugram - memory game

This is the main Lugram version for blind users. After the initial instructions for the game, the program describes the contents of the task matrix, by describing the contents and position of each of the nine elements of the task matrix. The program then offers the composing elements, one by one, by using the same descriptions previously used in the task. As in the basic version of the game, the program does not offer blank elements of task matrix. The analysis of moves in the game is accompanied by corresponding voice messages and sound effects. The number of wrong moves is limited. The player can replay the voice message describing the task matrix arbitrarily many times. The player can stop working on a task and return to the task selection of the current game level. The description of the composing elements using voice messages (Fig. 7) was also used in the other two Lugram prototypes.
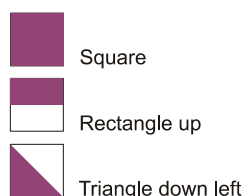
Fig. 7. Description of the composing elements.

Together with the software version an embossed cardboard tactile model of the Lugram figure-tasks was prepared (Fig. 8). The announcer reads: "Task number four: The figure-task: Field 1: Square, Field 2: Square, Field 3: Square, Field 4: Rectangle right, Field 5: Square, Field 6: Rectangle left, Field 7: Empty field, Field 8: Square, Field 9: Empty field".

Fig. 8. Software-auditory model and embossed cardboard tactile model of a task.

B. Lugram – arrow navigation game

In this Lugram version the tasks are presented descriptively. For example: "Letter T", "The plus sign", "The tower", and the elements are again offered one by one. A player positions an element in the task matrix after the navigation using the arrow keys (up, down, left and right). The program sends appropriate messages by voice and sound effects. Information on the analysis of moves in the game is conveyed by using the same sound effects and voice messages in all of three presented prototypes.

C. Lugram - game a three-point navigation

The figure-tasks and the composing elements of the puzzle are presented as in the version presented above. The changes were made in the method of informing the user about the position of the composing element in the matrix of the figure-task. This version uses a "floating" effect as the basic Lugram [5]. Effect is applied only to the element currently offered. The program controls the movements through a reduced model of the matrix of the figure-task. After the arrival at the appropriate position in the matrix, the program reports to the user. On the first level of the game this report contains two voice messages and one sound effect. On the second level it contains one voice message and the same sound effect. Finally, on the third level this information contains only the sound effect.

The player's mission is to learn the position of the nine different sound effects in the matrix of the figure-task during the first two levels of the game, and prepare himself/herself for the third. In the version that was used in testing, the sound effect database is made of sounds of nine music instruments.

VII. TESTING THE LUGRAM VERSION FOR THE BLIND USERS

A. Testing organized with sighted children in a regular primary school

Lugram prototypes for blind users were first tested by 10-year-old sighted children, the 4th grade pupils of the Primary school "20th October" in Sivac, Serbia (2009/10. school year) (Fig. 9).

Fig. 9. Lugram version for the blind - the first tests (monitor obscured for the sighted children).

Owing to the non-compulsory course "From toys to computers", the pupils are introduced to Lugram in the first grade, at the age of 7. Initially they were allowed to play Lugram guided only by voice instructions, without seeing the display monitor and using only a keyboard. The testing was organized in groups of six pupils.

After working with the version for blind children, pupils were asked to describe (in the terms used in the computer program) the task which the teacher drew on the blackboard. This activity was a very important part of the test, because it demonstrates the effectiveness of the auditory modality in presenting the composing elements. The pupils successfully completed this activity, giving useful feedback.

B. Testing organized with two blind children of different ages and intellectual and motor skills

The first child was a blind 12-year-old pupil of the 6th grade of the primary school, with a sound previous knowledge of geometry, also attending a school for elementary music education. The child was able to use a computer unaided, with the help of screen readers and speech synthesis. Owing to the prior knowledge of geo-metry, a short initial assistance by a more experienced user using cardboard embossed Lugram-puzzles was sufficient for him to accept the descriptive terminology of the composing elements of a task. The child has successfully tested all Lugram prototypes for blind users. Our experience shows that a blind child of this age and such intellectual and motor skills can be a successful contributor in the development of prototypes.

The younger child was 8 years old, and attended the 1st grade. He was of slightly weaker motor skills. In the work at school and with parents he used wooden models of different kinds of the toys. The help with the tactile model of the game was of particular importance to him. He was able to test only the *Lugram memory game*. His limited

knowledge of geometry allowed him to solve only carefully selected tasks on the first level of complexity. Work with a blind child in this age group, with limited knowledge of geometry and keyboard use, requires long preparation. The task in this case should have only the composing elements of type square (presented auditorily in Fig. 7). The learning of keyboard use was somewhat alleviated by marking keys with Braille labels.

C. Testing in a specialized primary school for blind children

Testing of the *Lugram memory game* was organized with the help of the pupils of the 4th grade of the primary school for the blind "Veljko Ramadanović" in Zemun, Serbia. The work involved six 10-year-old pupils. The pupils were thus the same age as the sighted children with whom the first tests were made. The blind children participating in the tests did not have any other major disability. A software version of the game was used along with the cardboard tactile model.

The pupils had prior knowledge of geometry required to play Lugram, but they had not used a PC keyboard until then. During the work, the pupils managed to learn and use the keypad layout required to play the game. The testing showed that the pupils were not quite familiar with terms left and right, up and down, and had difficulty in understanding the position/orientation of the composing elements.

Based on the experience gained from these tests we have reached the following conclusions:

- Lugram can be difficult for blind children who have no previous experience in using the keyboard
- The tactile model should have a clear indication of orientation (up/down and left/right)
- Introduction of new elements in the game requests the time for the pupils to get acquainted with them through the tactile model
- The pupils inexperienced in using the keyboard have difficulty in establishing a correlation between the tactile model and the numeric keypad (Fig. 10)
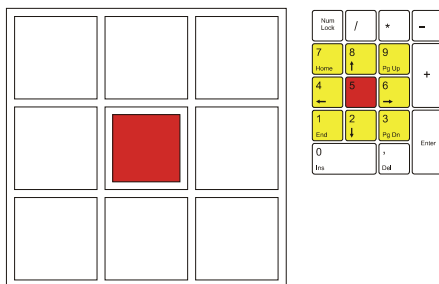

Fig. 10. Correlation: tactile model - numeric keypad.

- A tactile model made of some more robust material such as wood could be more efficient for establishing the described correlation
- The assignment of different composing elements to game levels is adequate and allows the teacher to adjust the complexity of the task to the ability of the pupil, especially in case of children with multiple disabilities

- Individual work is required
- The computer program should allow the repetition of the same task on request
- The motor skills of the pupils are of significant importance to the successful game play, as was expected

Based on this experience the program has been further adapted. An experimental modular wooden tactile model for the game has been made as well (Fig. 11).

Fig. 11. Experimental modular wooden tactile model.

As was the case with the basic versions of computer game Lugram [5] equipped with the task generation modules, the parameterized Lugram version for blind children allows the teacher to prepare Lugram-tasks adequate to the abilities of each individual pupil.

VIII. Discussion

At the first encounter with Lugram, blind children need the help of sighted persons. Individual and multimodal work is required. The teachers and parents who use Lugram in working with blind children, can combine tasks depending on the ability, age and knowledge of children. They can use the tasks individually by selecting them from a different version of the game. For younger children who have no basic knowledge of geometry, introduction of the tactile modality is necessary. A modularly organized tactile wooden model of the game follows the features of parameterized software version of the memory game. In addition to the workbook for cardboard tactile tasks, a modular wooden model offers additional features and further testing in practice will show whether these expectations are justified. With the combined use of tactile and auditory modalities, blind children will have a better chance of success in the further use of the software version of the game.

Because of the simple concept of the game, features of previously developed software modules, using the standard PC keyboard, sound effects and voice message support, the described versions of Lugram are not only modifications of basic software game modules. They are also practically applicable prototypes. In view of the attitudes about the role of basic geometric shapes in the initial teaching of geometry for blind children, a tactile model of the puzzle has been involved in the game testing. This was done with the aim of conceiving a clear mental representation of each element of the game, in order to enable the users to play the game without the help of the tactile model as well.

An important feature of the presented versions is the form of presenting the composing elements of the puzzle. The use of navigation terms opens the possibility to use the game with the focus on the acquisition of mental representation of three-dimensional space.

After the test with only two potential users, tests conducted at the specialized primary school for blind children gave the useful feedback for further improvement of game versions. Further research will provide a more complete picture about the feasibility of such an idea in practice and whether the inclusion of a number of additional software or hardware components will be necessary for the use of Lugram.

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