Towards a User Friendly Rehabilitation Game-A Case Study

Cecilia Sik Lanyi, Balazs Kocsi, and Erika Laszlo

***Abstract*—Stroke is one of the leading death rates all over the world. According to the World Health Organization's data 15 million people suffer stroke worldwide each year. We developed several virtual reality games for stroke rehabilitation. Process optimization raises the efficacy of software technology. We used a model based on "Algorithms and Visualization for difficult optimization problems" (ALVI) project in the developing process of the rehabilitation games. This paper introduces the generic usage model for a games-based rehabilitation. It presents motivations and interdisciplinary solutions for future optimizations.**

***Index Terms*—Software technology, optimization, stroke rehabilitation, virtual reality.**

I. Introduction

A. Virtual Reality and Stroke Rehabilitation

Each year more than 700,000 people suffer stroke in the United States, making it the third most common cause of death [1], especially in the case of elderly people. Incidence in Europe is similar, about 2 million people per year [2]. According to the World Health Organization's data 15 million people suffer stroke worldwide each year. Although survival rate is improving, 5 million people die and another 5 million people remain permanently disabled. In Europe this means about 650,000 stroke deaths every year [3]. Our societies are facing a growing number of people aged at least 75, many of whom will experience impairment or disability due to stroke. This older population will rise from 7.5% of the European population in 2003 to 14.4% in 2040, i.e., almost double [4]. 25% of the EU's population will be over 65 [5] by 2020. It can be clearly seen that the number of stroke patients will be increasing from year to year.

StrokeBack [6] is a newly started project partly funded by the EU. In this project we work to increase the speed of the rehabilitation process of stroke patients, while they are staying at home. This is a very important factor in therapy, because being at home has a good effect on the patient, motivating and moralising them. This method is also advantageous because it is much cheaper than hospital attendance.

Many applications have been developed all over the world for stroke rehabilitation [7] [8] [9]. According to Burke [10], VR games were usable and playable for people with stroke. Further, the games seemed to stimulate a high level of interest and joy for the participants, those may indicate that the games are more engaging to play. Older people and new technologies are important research and development areas [11]. Improving the quality of life for elderly people is an emerging issue within our information society [12]. Most of the stroke patients are in the elder generation. Applications developed for them must be designed to support their needs. User interfaces must be designed with great care. It is not enough if these interfaces are easy to access, they should be useful, usable and most of all enjoyable and a great benefit for people [12].

One of our goals in the StrokeBack project is developing special exercises, with the repetition of many small movements with the fingers, arms and shoulders of the patients, and with practice the damaged psychomotor abilities can be recovered. The aim of this part of the project is to create games, and will help the patient to do these trainings playfully. These games should not only help the patients to take rehabilitating exercises, but they will help to improve their logic and thinking abilities too.

VR based rehabilitation fields are inherent interdisciplinary solutions for domain specific problems. There are some generic subdomains, which are orthogonally as communication technologies, operational researches, software technologies and action research methods, which contribute to the efficiency of the rehabilitation equipment and to the integration of variability for treatment compositions. Model-based development practices enhance the assessment of quality attributes in earlier phases and support involvement of different end-users during the entire life cycle of the product development [13].

B. The Combinatorial Optimization

Combinatorial Optimization is a very important and widely applied area of Mathematical Optimization. There are famous, widely known problems, and algorithms in this area, as well. Many real-life problems need a method, for example one or bigger dimensional bin packing or allocation problems, scheduling of machines (or processors), distribution problems, routing problems, or some combinations of them, etc. [14]. These problems are usually very difficult to solve. In the last few decades many well-working algorithms have been proposed by lots of researchers in these fields. However, new problems always arise which can not be solved efficiently by the known algorithms [15].

Consider the next real-life application. A team (computer science experts) is working on some softwares, and we model the members of the team by "machines". Each machine have some parameters, like working capacity, programming experience, special skills, etc. After we optimize (in some sense) the work, for example the software should be made in a shortest time. We developed several VR games for stroke rehabilitation. In the future we are planning to develop more types of games, for example, a labyrinth, a free-kick game,

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virtual piano game etc. They will form a repository for trainers and for rehabilitation developers, too. The repository process optimization is one of the crucial effects for any interaction efficacy. We follow to integrate results from "Algorithms and Visualization for difficult optimization problems" (ALVI) project. The ALVI methods support the assessment optimization of quantitative and qualitative attributes for training developments with a variability of game processing [16].

II. The Problem Space Correlation with the Solution Space

Nowadays optimization is a very important task for engineers and mathematicians of a company, that wants to produce maximum profit while using minimum resources and spend least money. The time factor is one of the most important aspect of a new product development. Thus, it is in the software development industry as well. ALVI is used to visualize time scheduling on a given set of data. With this software, the users can easily compare the results of a problem solved with multiple algorithms, because instead of calculating these outcomes one-by-one, they just have to give a set of data to the system, run the algorithms, view the results, and then compare the output data.

We have to develop such VR games to imitate the movements of the Wolf Motor Function Test [17]. Two games are finished from the planned 11 VR games. The "Break the bricks" game fit to the horizontal and vertical hand movement exercises. The "Free kick" game fit to reach an object and retrieve it task.

The user can control the games by moving their cell phone, as a remote controller, and these precise arm movements are the rehabilitation exercises, needs concentration. The games are challenging and pleasurable. These attributes combine enjoyment with exercise, enhancing the rehabilitation process. The patient is also motivated by variations of the levels, which can be accessed by reaching a level of the cores. Also an advantage of a game is, it uses the built-in accelerometer of the phone and relies on the patient's balancing ability, so this skill can also be challenged.

The games are developed for Android operating system, because this platform is frequently and widely used on mobile phones and smart phones, making them easy to access. The mobile phone's Android application is written in Java. The PC program is written in Qt, which is a cross-platform framework, as it can be used irrespective of the PC's operating system or configuration.

VR is a very important part of the game, but not in the conventional form. The users will see a 3D environment, for example the corridors of the planned labyrinth game. They can move in virtually, by moving the mobile phone. In this virtual environment, they can do exercises, like grabbing objects, or swinging their wrist, etc., or playing games, such as a free-kicker soccer game, or a logical pairing game. During the game, the patient's movements are detected in 3D by the mobile phone's built in sensors, making movements feel more 'real'. This feeling of reality can also motivate the user to play more, and the more the patient plays, the more exercises are done. The key of rehabilitation is these exercises.

The patient's movement data, scores, the exercises practiced by the patient, the degree of the recovery and other data relevant for the therapists will be stored in a database. The information following from this huge set of data helps the medical attendants and stroke professionals to improve the rehabilitation process of the stroke patients.

A. *The "Break the Bricks" Game*

The Break the Bricks is a classic brick-breaker game. The aim of the game is to break all the bricks with a bouncing ball, while keeping the ball from falling down with a block. The user can control the block by moving the phone. These precise arm movements are the rehabilitation exercises, they need concentration, and the game is funny and enjoyable. The patient is also motivated by the levels of a game, which can be defeated, and by the breaking of his or her own high scores. Also an advantage of a game is that it uses the built-in accelerometer of the phone and based on the patient's balancing ability, this capability can also be trained. First of all, the requirements of the game program had to be identified. The most important ones were the non functional requirements: the application must be easy to use for elderly or disabled people, and it should be available for more platforms. As for the functional requirements, they follow from the use-cases.

The use-case diagram of the Break the Bricks game is shown on Fig. 1. This illustration shows the technology assisted context of the usage model, that supports the patient's inabilities in following the steps and facilities of the game. After the use-cases, the classes and the class hierarchy was designed. The most important classes are responsible for the main functions. For the dynamic menu of the game the *MenuContainer* and the *MenuItem* classes are responsible. These grant that the menu is easily expandable, without writing any source code. The *PhoneStatus* class stores data about the phone's sensors and some calculated values. This information comes from the *Server* class, which is handling the communication of the PC with the mobile phone. The other classes are responsible for the Break the Bricks game's functions, managing the bricks, the ball, etc.

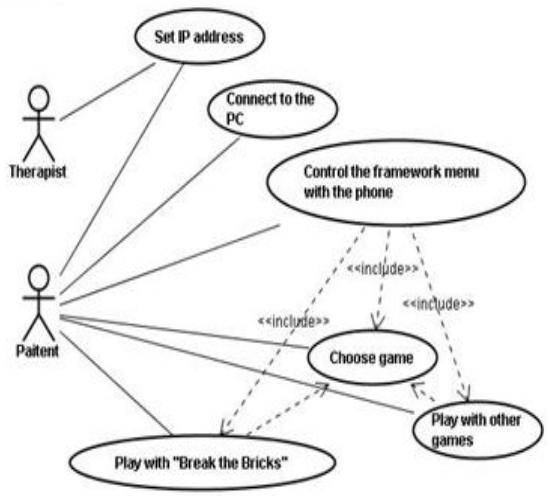

Fig. 1. The use-case diagram of the "Break the Bricks" game.

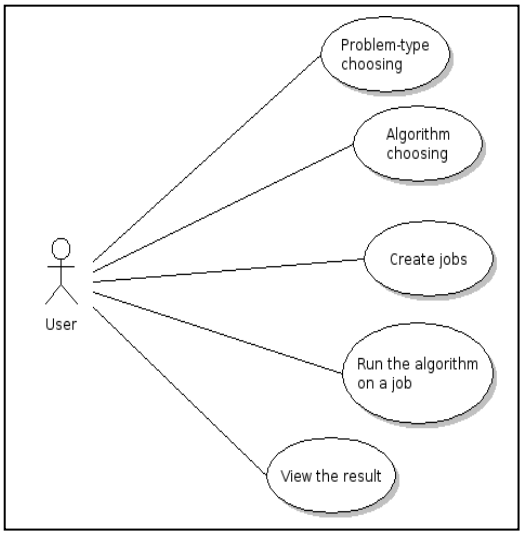

Fig. 2. The use-case diagram of the "ALVI" software.

This game program is using a dummy client, which is connected via Wifi to a Game Server by a TCP port of the hosting PC. The Game Server is running in the background, it only shows up if a phone is connected. The Game Server's menu can be managed by either the PC's devices, or the mobile phone, with flicks. The menu is easy to understand and to use. The Game Server is made with the use of the Qt framework. This is because Qt is for a cross-platform, so it can be used irrespectively of the PC's operating system or configuration. The mobile phone's Android application is written in Java.

B. *The "ALVI" Software*

An expendable software "Algorithms and Visualization for difficult optimization problems" (ALVI) was developed for optimization tasks and algorithms for combined packing and scheduling problems, under certain constrains [18]. The ALVI software and plug-in was made with Qt framework. The created algorithms have been paralleled with the help of OpenCl framework. The results of the algorithms are displayed with visual elements. The use-case diagram of the Break the Bricks game is shown on Fig. 2.

In the window (Fig. 3) the user can set the initial parameters for the algorithm. In the example above, what you see is a problem where products with machines can be processed. The capacity of the machines, the production time and the needed amount of the product are given. With this information, the algorithm creates the optimal scheduling that has the minimal production time. The number of products and machines can be set in the upper two fields. The data for the algorithm can be entered in the table. Afterward, click on the "Done" button to start the algorithm. If the calculation takes too much time, a progress dialog will show up, until it is finished. When the algorithm finishes the result window will be displayed.

Fig. 3 on the right side shows information regarding the products, like color, amount and time. In the left side the scheduling can be seen. The numbers in the left are the machine index, and below them the number in parentheses are the capacity of the machines. The numbers on the top represent the time. The rectangles with red border are the products manufactured with the given machine. The percentage filled in the rectangle is equal to the percentage of the capacity utilized.

Originally "ALVI" software was developed for engineers and mathematicians of a company, which want to produce maximum profit while using minimum resources and spend as little money as possible. The "ALVI" software has been developed to help their work with a program, that is used for visualize the effect of some near optimal algorithms on a given set of data. With the program, the users can easily compare the results of a problem solved with multiple algorithms, because they instead of calculating these outcomes one-by-one just have to give a set of data to the system, run the algorithms, view the results, and then compare the output data. We used the "ALVI" software for time-scheduling in the "Break the Bricks" game programming too. Our future plan is using optimization methods by using the "ALVI" software in the case of the planned games.

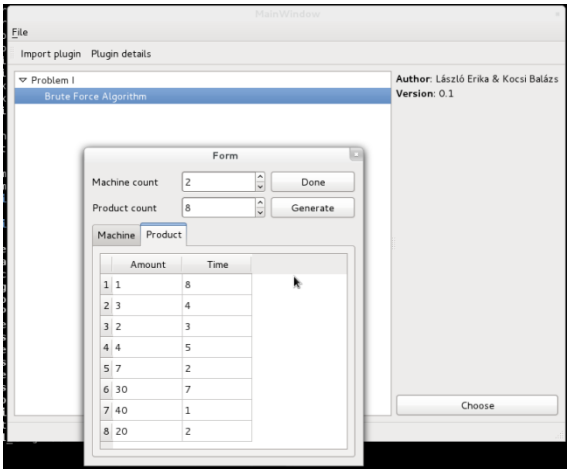

Fig. 3. Setting up the job in the "ALVI" software.

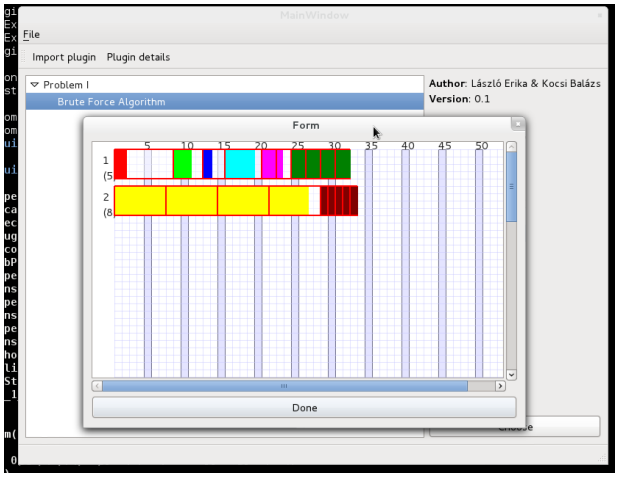

Fig. 4. Showing the results by the "ALVI" software.

III. Conclusion

These games are potentially useful ways to enhance recovery of motor control following stroke, because during playing them, the patients will do small, entertaining, but important exercises. Most people like playing games, so the practice and exercise can be made entertaining and pleasurable. Positive outcomes of the participation of people with disabilities in research and development of VR games have been demonstrated [7]. "ALVI" software was tested in

time-scheduling of the developing process of the rehabilitation games.

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