ABSTRACT
A recent trend in therapy emphasizes the effectiveness of engaging in goal-directed activities, such as playing games, to promote coordination. Patients in rehabilitation for physical, neurological as well as vision related disorders may have difficulty with their basic lifestyle activities whether at home, work or leisure. So in this paper we use the Xilinx Spartan 3AN Series FPGA and propose its use for developing a SoC that eliminates the need of therapists on a daily basis thus providing an opportunity to the patient to be actively involved in the rehabilitation process.

Keywords: FPGA, VGA, SOC, Xilinx Spartan 3AN, RTL View

1. INTRODUCTION
Therapists generally encourage the use of the damaged or impaired organs to carry out an active or passive range-of-exercises. In general therapists emphasize on practicing isolated movements, either carrying out repetitions or repeatedly changing from one movement to another. This System on Chip provides a combination of modules that could aid in vision therapy as well as treatment of nervous disorders. Each module will include the various personalization options so that they could be setup in a manner where they could maximize returns from the activity. The system includes these modules will aggregated to provide a full fledged system which will not only provide innovative therapy methodologies but also do the same at a considerably lower cost.

2. COMPARISON BETWEEN OUR DESIGN AND OTHER POPULAR GAMING SYSTEMS
The following table shows the comparison between the system that we have designed and the popular gaming systems that are currently finding use in therapy.

<table>
<thead>
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<th>Our design</th>
<th>Xbox 360/ Nintendo Wii</th>
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<tbody>
<tr>
<td>Cost</td>
<td>Low</td>
<td>Very High</td>
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<tr>
<td>Adaptability</td>
<td>Very High</td>
<td>Medium</td>
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<td>Complexity</td>
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<td>Effectiveness</td>
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<td>Customizability</td>
<td>Very High</td>
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The game makes use of principles of operant conditioning to motivate the player, positive punishment, positive reinforcement, negative punishment and negative reinforcement [1-2]. The Nintendo Wii has already found a niche with numerous physical therapy and rehabilitation programs worldwide. It has been used for physical fitness and balance training in nursing homes, as well as for stroke rehabilitation and patients with cerebral palsy [3-5]. However, these systems have a few disadvantages in that they are expensive and most of the games that are available are not specifically meant for the rehabilitation purpose.

3. SYSTEM DESCRIPTION
The system has been designed to incorporate five modules that are prototyped on a single SoC which will be mounted on a wheelchair. The modules have been carefully chosen to contain activities that would aid in the treatment or rehabilitation of patients. The following are the modules included in the system:

- Maze follower
- Visual Pursuit and Tracking
- Reflex time analysis
- Color Perception
- Wheel chair movement on predefined path

The system as a whole may be considered as Assistive Technology (AT). The Technology Related Assistance Act for People with Disabilities of 1988 (Public Law 100-407) defined AT as "any item, piece of equipment, or..."
product system, whether acquired commercially off-the-shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities.” These types of durable medical equipment are readily seen as valuable by the medical profession for individuals and their families struggling to cope with disorders. [6]

The modules have been designed to avoid technology failure, maintain overt therapeutic principles within the games, encompass progression to promote continuing physical and cognitive challenge, and to provide feedback that is easily and readily associated with success [7].

4. MODULE APPLICATIONS
The following are the major domains in which the modules in the system may find use.

4.1 Physical Rehabilitation
A large percentage of the population suffers from injuries and neuromuscular disorders which require physical rehabilitation exercises [5]. From the physiotherapist’s point of view, patient participation in rehabilitation is considerable lower than they would desire. Patients shirk from carrying out exercises due to their monotonous nature as a result of which their recovery generally takes longer than it should. Physiotherapists generally end up coaxing patients to come to physiotherapy centers and make them carry out the exercises. Computer-assisted physical rehabilitation is a new and rapidly growing area of research and promising advances have been made in areas such as rehabilitation of the upper limbs, the joints of the legs, or gait and posture after stroke or injury [5-13].

Clinical effectiveness (CE) and evidence-based practice (EBP) is the cornerstone of modern-day healthcare [14], and the weight of published evidence indicating the positive impact of adopting technology is mounting. Occupational therapists and physiotherapists favored the use of gaming technology in rehabilitation as an adjunct to traditional therapy because it is therapeutic, engaging, and may increase patient participation in rehabilitation.

The maze follower module in the system could be used for physical rehabilitation by patients who may be working on regaining proper limb functioning after an injury and are undertaking Musculoskeletal Physiotherapy or Paralysis rehabilitation. The exercise effort would require gradual motion using the affected muscle group. This may first mean linear motion followed by the various directions in which we can move the limb. Since the module offers various levels, it is capable of supporting the entire process.

4.2 Neurological Rehabilitation
Neurological damage may result from strokes or due to disorders such as Multiple Sclerosis, Parkinson’s disease and various others. Nerve damage leads to movement disorders which include tremors, rigidity, slowness of movement and stiffness.

Rehabilitation Medicine (RM) consultants lead and co-ordinate neurological rehabilitation for people with complex needs. RM integrates neurological, musculoskeletal and other physical aspects with the psychological and social dimensions of rehabilitation, alongside the provision of assistive technology. The main focus is on people of working age [15-16]. The maze follower module could be used therefore for rehabilitation. The task also involves ensuring that the hand projection moves within the path boundaries which would test the ability to keep the hand as stable as possible.

Additionally the wheelchair would play a very important role in such a situation because neurological disorders generally leave the body frail and weak. The wheel chair module would allow the user to conveniently move around the house. All that the patient would need to do is tell the wheel chair where to go by pressing a button.

4.3 Visual Rehabilitation
Visual processing disorder refers to a reduced ability to make sense of information taken in through the eyes. This is different from problems involving sight or sharpness of vision. Difficulties with visual processing affect how visual information is interpreted or processed. A person with visual processing problems may have 20/20 vision but may have difficulties discriminating foreground from background, forms, size, and position in space. The person may be unable to synthesize and analyze visually presented information accurately or fast enough.

The primary goal of vision therapy is to improve control of the vergence eye movement system leading to more comfortable and sustainable binocular vision [17].

Conventional rehabilitative vision therapy for the condition is monotonous and dull, leading to low levels of compliance. If the therapy is not performed then improvements in the condition are unlikely [18]. The majority of the eye exercises are tedious and monotonous. As such, most patients do not look forward to their therapy and compliance rates are notoriously low [19]. Researchers have begun to analyze the effects of gaming systems on the visual system. One study found a positive impact on contrast sensitivity with gaming [20]. Another correlated visual attention and processing skills to the use of video games [21].

Important parts of the visual system include the basic skills of saccades, pursuits, and fixations, which function for tracking and scanning. Combined, these skills are better known as oculomotor skills [22].
Three modules can be applied in the field of vision therapy or vision training. The visual pursuit and tracking module would require the patient to identify the changes in the direction of motion of an object on the screen. The reflex time analysis would require speedy spotting the objects blinking on the screen and keeping count, whereas the color perception module will test the ability of the patient to identify changing colors individually and uniquely.

5. MODULE IMPLEMENTATION
5.1 Maze Follower
The module is implemented such that the hand on the screen can be moved along the path using a human interface. A glove that has been fitted with an accelerometer will serve as this interface using which it is possible to control the movement of the hand.

This is intended to be utilized with patients undergoing paralysis rehabilitation and this exercise serves as one of their most rudimentary exercises when starting rehabilitation therapy. As they progress in their therapy sessions the setup has been designed to provide them with further levels that would raise the bar of difficulty by varying the path they would require to trace by hand.

An additional feature for the track is that the user needs to ensure the hand is balanced equally around the centre during its motion on the track. This would prove helpful in situations where the person is looking to control tremors while moving limbs.

![Fig 1: Diagram representing module functionality](image1)

![Fig 2: Block Diagram of System](image2)

The diagram in Fig 1 indicates four situations. The first one indicates the starting position for the patient. Then as the patient moves his/her hand the second and third situations indicate cases when the hand goes off the track and the color changes to red. The fourth diagram indicates a representation of the screen when the patient is carrying out the exercise perfectly.

5.1.1 Block diagram
The block diagram in Fig 2 is a representation of the system that was designed to be used by patients who are en route to recovery and may need to perform certain exercises.

The block diagram includes a VGA monitor on which there is a representation of one of the module’s operation environment. The monitor is further connected to the FPGA board through the VGA connector. The system is then interfaced with a glove with an accelerometer mounted on it. The glove could be worn by the patient and acts as the controller for one of the modules.

5.2 Visual Pursuit and Tracking
Eighty percent of all learning is through the visual system.[23]

This module consists of a box that moves on a maze. The objective for the patient is to track the motion of the box and ultimately be able to count the number of times that the box changes position i.e. the number of left and right turns taken by the box along the path.

![Fig 3: Screenshot of the visual pursuit and tracking module](image3)
5.3 Reflex Time Analysis
This module involves a box changing positions on the screen and the patient is required to identify the number of times the object changes its position as shown in fig 4. The rate at which the box changes position may be varied depending on the requirement and a level selection screen is provided for the same. At the end of the module the numbers of transitions that are actually made are displayed on the screen so that the patient can check his/her response. The tolerable error can be specified by the medical practitioner and the patient can repeat the exercise until the target is achieved.

5.4 Color Perception
This module requires the patient to be able to differentiate between colors. A figure on the screen constantly changes colors and the objective is to be able to view every color change and register it. The order in which the patient registers the colors can then be matched with the original color order. The following is a representation of the color perception module.

5.5 Wheel chair movement on a predefined path
Another module that is included involves a wheelchair guidance system. An electric wheelchair equipped with an interactive TFT screen will be used to implement this module as shown in Fig 7. All that the user needs to do is to select from a list of accessible locations. Then the wheelchair will obtain from its memory the path from the current location to the destination and travel the path automatically.
This TFT screen in Fig 8 is to be mounted will serve as the screen for all the modules and will have a menu driven interface. The user will be able to select the module that needs to be used just by touching the screen. This therefore aids in bringing each of the modules to the comfort of the home of the patient.

6. GENERATED RTL SCHEMATIC

The above figure represents the RTL Schematic for four of the modules that have been included in the design. The following are the pins included in each of the RTL schematics. Some pins may vary
- Clk50_in: 50 MHz Clock Signal
- Blue, Red, Green: Output colors displayed on the screen.
- hs_out: Horizontal sync.
- vs_out: Vertical sync.

Input clock signal Clk50_in is a 50 MHz clock obtained from the clock generating crystal on the FPGA board. It is further divided by a clock divider module to obtain a 25 MHz pixel clock that is utilized in order to sync the VGA screen. We used a 480x640 monitor which needs to be synced at a frequency of 60Hz. The calculations yield a maximum number of horizontal sync lines of 800 and vertical sync lines of 521. The signal from the FPGA board goes to the VGA via the VGA port which has the red, green and blue pins which correspond to the named pins. The hs_out and vs_out are connected to the horizontal sync and vertical sync of the VGA port.

The pins s0, s1, s2, s3 are a part of the simhand and s0, s1 which are part of the hand module that is responsible for the external inputs that need to be given to the system. In the case of the simhand block which pertains to the visual pursuit and tracking module the switches will be used to vary the levels whereas in case of the hand block which pertains to the maze follower module, where an external interface in the form of a glove fitted with an accelerometer.

CONCLUSION

The system has been created on a single chip for an interactive interface wherein patients would enjoy carrying out the exercises. Various modules have been aggregated to develop a system that could be mounted on a wheelchair to provide a complete therapy system. The most effective form of therapy (office-based) is costly since it requires a trained professional in order to administer the therapy to the patient. The computer game based therapy was designed to be performed at home while providing the control and range of exercises typical of office-based therapy. As such it will be much more economical as it only requires the patient to possess or purchase a low cost computer system. In addition, patients will not have to take time away from work or school and can perform their therapy at home at their convenience [19].
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REFERENCES