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SIMULATION OF A BICYCLE TOUR FOR CHILDREN WITH DOWN , USING NON-IMMERSIVE VIRTUAL REALITY.

SIMULATION OF A BICYCLE RIDE FOR CHILDREN WITH DOWN SYNDROME USING NON-IMMERSIVE VIRTUAL REALITY

Julio Alberto González Encinas[1], María Trinidad Serna Encinas[2*], Rafael Armando Galaz Bustamante[3], Rosalía del Carmen Gutiérrez Urquidez[4]

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[1]Mechatronics Engineer. Tecnológico Nacional de México/Instituto Tecnológico de Hermosillo, Graduate and Postgraduate Studies Division.
Research. m22331025@hermosillo.tecnm.mx6625143924, Av. Tecnológico 115, Col. Sahuaro, CP. 83170, Hermosillo, Sonora, México. https://orcid.org/0009-0004-5199-3118
[2]Ph.D. in Computer Science, Tecnológico Nacional de México/Instituto Tecnológico de Hermosillo, División de Estudios de Posgrado e Investigación. *maria.sernae@hermosillo.tecnm.mx , 6622606500, Ext. 136, Av. Tecnológico 115, Col. Sahuaro, CP. 83170, Hermosillo, Sonora, México. https://orcid.org/0000-0002-2020-791X
[3]Master of Science in Computer Science. Tecnológico Nacional de México/Instituto Tecnológico de Hermosillo, Graduate Studies and Research Division. rafael.galazb@hermosillo.tecnm.mx6622606500, Ext. 136, Av. Tecnológico 115, Col. Sahuaro, CP. 83170, Hermosillo, Sonora, México. https://orcid.org/0009-0003-4021-5882
[4]Doctor of Science in Engineering Sciences. Tecnológico Nacional de México/Instituto Tecnológico de Hermosillo, División de Estudios de Posgrado e Investigación. rosalía.gutierrezu@hermosillo.tecnm.mx, 6622606500, Ext. 136, Av. Tecnológico 115, Col. Sahuaro, CP. 83170, Hermosillo, Sonora, México. https://orcid.org/0009-0002-7721-9759

Abstract -- Down syndrome is a genetic condition characterized by the presence of extra material in chromosome 21 in somatic cells. In Mexico, this genetic alteration affects 1 in every 650 births, and causes difficulties in the development motor skills, complicating the performance of daily physical activities. This generates the need to implement strategies based on advanced technologies to support children with this condition in their motor development. The present work proposes a system designed for CRIT (Centro de Rehabilitación e Inclusión Infantil Teletón) Sonora, whose objective is to simulate a bicycle ride for children with Down syndrome, with the purpose of encouraging physical activity in an entertaining way. The system uses non-immersive virtual reality technology, allowing children to experience a virtual ride while using an adapted stationary bicycle. This experience offers visual and sensory stimuli that motivate a more active and fun participation in physical activities. The project covers from conceptualization to implementation of the system, including analysis and design diagrams, system data model and the proposed system architecture. It also details the methodologies and processes used in the realization of the project, integrating both the development of the software and the necessary hardware, as well as the system functionality tests.

Keywords: Virtual reality, Down syndrome, bicycle tour, simulation.

Abstract -- Down syndrome is a genetic condition, characterized by the presence of extra material on chromosome 21 in somatic cells. In Mexico, this genetic alteration affects 1 in every 650 births, and causes difficulties in the development of motor skills, complicating the performance of daily physical activities. This creates a need to implement strategies based on advanced technologies, to support children with this condition in their motor development. This paper proposes a system designed for the CRIT (Centro de Rehabilitación e Inclusión Infantil Teletón) Sonora, aimed at simulating a bicycle ride for children with Down syndrome, with the goal of encouraging physical activity in an engaging way. The system utilizes non-immersive virtual reality technology, allowing children to experience a virtual ride, while using an adapted stationary bicycle. This experience provides visual and sensory stimuli, that motivate more active and enjoyable participation in physical activities. The project encompasses everything from conceptualization to system implementation, including analysis and design diagrams, data model system, and the proposed system architecture. It also details the methodologies and processes used in the project, integrating both software development and the necessary hardware integration, along with functionality tests system.

Key words - Virtual reality, Down syndrome, bicycle ride, simulation.

INTRODUCTION

Disability is a significant challenge that affects a considerable part of the world's population. According to the World Health Organization (WHO), estimated 1.3 billion people have some type of disability, representing approximately 16% of the total population [1]. In Mexico, the 2020 national census of the National Institute of Statistics and Geography (INEGI) reported that 6,179,890 people have difficulties in performing physical activities, such as walking, seeing, hearing or communicating; being more common in women (53%) than in men (47%) [2]. Among the various disabilities, Down syndrome stands out for its impact on orientation and communication. This genetic condition results from the presence of an extra copy of chromosome 21, leading to a total of 47 chromosomes instead of 46 [3]. Among the distinctive physical characteristics of people with Down syndrome are: almond-shaped eyes and smaller head, along with cognitive disabilities and developmental delays; in addition, the importance of addressing their specific needs is emphasized [4]. According to the General Directorate of Health, 689 children with Down syndrome were born in Mexico in 2018. In the state of Sonora, the DIF system reports that 1,678 people currently reside, officially registered with this genetic anomaly [5]. This high prevalence highlights the urgency of developing appropriate solutions that improve the quality of life and social inclusion of these children.

In recent years, the advancement of technologies such as virtual reality (VR) has begun to play a crucial role in therapy and rehabilitation [6]. Although VR has existed for decades in the realm of video games and simulators, its inclusion in the medical field represents a valuable opportunity to help children with Down syndrome interact with virtual environments that simulate everyday situations, facilitating their social adaptation and development.

It has been shown that VR can improve cognitive restoration in people with intellectual disabilities by creating simulated environments that allow patients with Down syndrome to practice motor and social skills in a safe and controlled environment [7] [8].

Disability not only affects these children in their physical and cognitive development, but also makes them vulnerable to diseases and limits their ability to participate in daily activities [9]. Therefore, it is essential to understand the specific needs of these children, in order to integrate them into an environment that favors their social inclusion. This has led to the need to develop a virtual system that facilitates physical activity and the development of motor skills. This leads to the following problem: What functionalities are needed to facilitate physical activity and the development of motor skills? should have a system for a stationary bicycle tour using virtual reality that can be used by children with Down syndrome?

To answer this question, the following general objective was set: to implement a virtual reality system that simulates a bicycle ride for children with Down syndrome, considering factors such as visual discrimination and traffic rules. The specific objectives are:

- To know in depth the concepts related to the subject matter of the project.
- Determine the tools to be used, considering the functional requirements of the end user.
- Analyze and design the operation of the proposed system.
- Implement the virtual reality system of the tour.
- Perform functionality and usability tests.
- Analyze the results obtained.

The creation of a virtual reality system that simulates a bicycle ride not only provides an innovative approach to rehabilitation and motor skills development, but also contributes to the social integration of children with Down syndrome by allowing these children to experience real-life situations in a controlled and safe environment, as well as fostering their autonomy, confidence and social skills. Virtual reality can be a key tool education and therapy, thus improving the quality of life of these children and promoting a more inclusive society.

DEVELOPMENT

Methodology

The system development process begins with an exhaustive research phase on topics related to the project, known as Phase 1. During this stage, a detailed review of the state of the art is carried out, gathering complete and updated information through conference papers, journal articles, theses, as well as previous studies relevant to the topic. This in-depth analysis provides a solid knowledge base that is essential for the following phases of the project.

Phase 2 identifies the components and features necessary for the design and modeling of the proposed system. Diagrams are prepared and design considerations are detailed, thus building the structure of the system.

With the design finalized, we proceed to Phase 3, which consists of the development of the physical prototype. In this stage, all the information gathered is applied and the direct implementation of the system begins.

Phase 4 is devoted to detailed testing of the system to ensure its correct operation. Both the physical structure and the virtual path are verified, making sure that there are no failures and that each component operates as intended. Figure 1 shows the phases of the methodology.

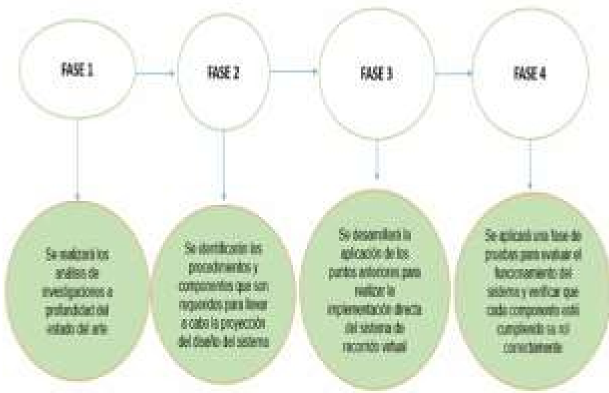

Figure 1. Phases of the methodology
Source. Own elaboration.

Data Flow Diagram (DFD)
This diagram presents the system with a more detailed focus on specific aspects of the project development. Figure 2 illustrates how, initially, the user activates the sensors of the prototype with his presence. These sensors send signals that are processed by an ADC (Analogic-Digital-Convert) converter, which transforms the analog signals from the sensors into digital signals that activate the system.

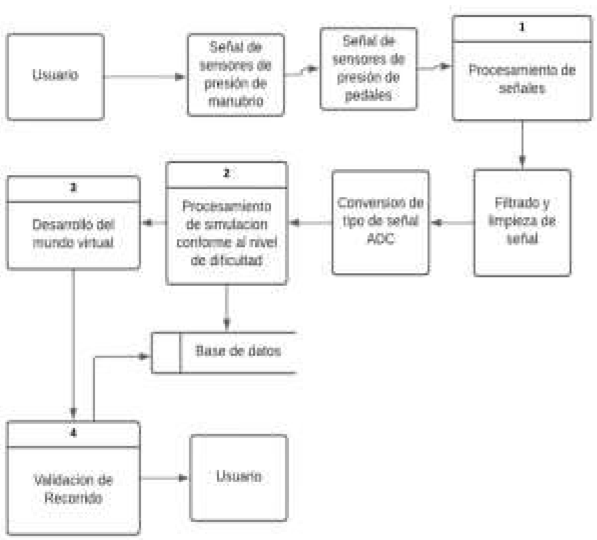

Figure 2. Data flow diagram (Own elaboration).

Use case diagram
The use case diagram provides a detailed representation of the interactions between the different actors and the system [10]. In this case, three main actors are identified: the physical therapist, the user and the system itself. The system is responsible for generating the game levels, but it must first validate the access of the physical therapist; in addition, it must log in to access the main menu. In this menu, several functions can be performed, the most relevant being the registration of the user's name or the deletion of an existing user. Finally, the third actor is the end user, who is the person who interacts directly with the stationary bicycle. The use case diagram is presented in Figure 3.

Figure 3. Diagram of use cases Source.
Own elaboration.

Sequence diagram
A sequence diagram is a visual representation that belongs to the unified modeling language (UML), and is used to illustrate the interactions between objects in a system over time [11]. Figure 4 shows the process in which the physical therapist performs the initial configurations of the system, including the interaction with the user-designed walkthrough guide. Once these configurations have been completed, the user can start the chosen level, while the virtual system is responsible for processing and recording the results obtained during the game.

Class diagram
A class diagram is a static representation used in software engineering and object-oriented systems development. This type of diagram illustrates the structure of the system by showing its classes, attributes, operations and the relationships that exist between the different objects. The four classes identified are: ***User*****,** ***VirtualSystem*****,** ***Sensor*****, and** ***PathData*** [12].

Figure 5 shows the classes that make up the system.

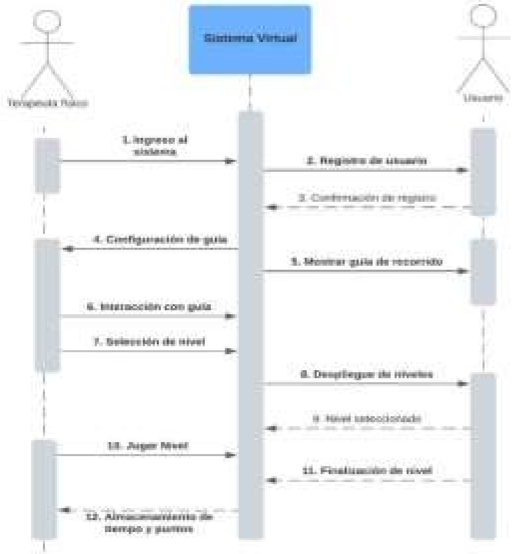

Figure 4. Sequence diagram.
Source. Own elaboration.

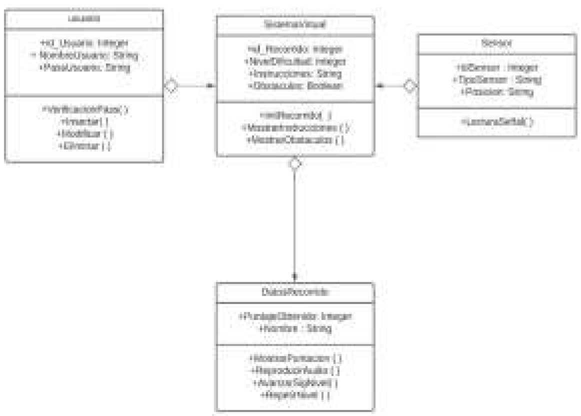

Figure 5. Class diagram. Source.
Own elaboration.

Software Architecture

The system architecture for the virtual bicycle tour is composed of several essential modules. The Input Module captures signals from the bicycle through sensors that monitor speed and position. These signals are processed by the Signal Processing Module, which filters out noise and converts the data into a digital format and stores it in a database. The System Development Module uses this data to define the structure of the virtual course, setting difficulty levels and creating visual elements and obstacles in C#. This module integrates with the database to adjust the game's behavior according to sensor signals. Finally, the Game Execution Module, based on Unity, renders the virtual environment and manages user interaction, providing an immersive experience. The structure of this architecture is shown in Figure 6.

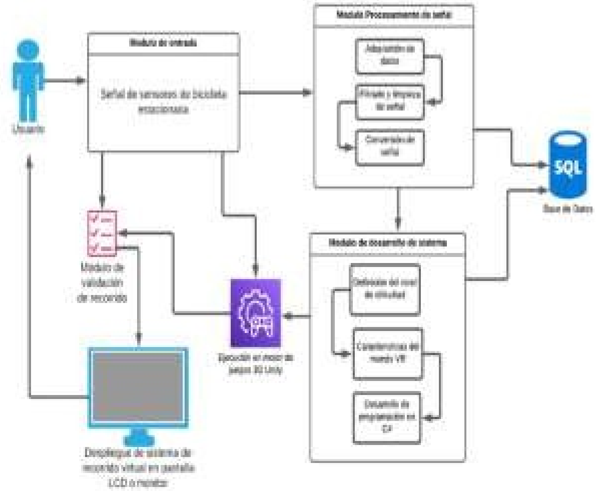

Figure 6. Proposed Software Architecture.
Source. Own elaboration.

Acquisition of resources for the development of the virtual map

The main elements of the map were acquired from Unity's official store, known as Unity Asset Store, a platform dedicated to obtaining resources for video game development. The collection of these elements was aimed at recreating a generic city map. Buildings, streets, trees, vehicles and characters were included to enrich the visual and interactive experience. In addition, other websites such as Pixabay and FreeSound [13] were used.

Some prefabricated objects, such as the diamond-shaped dots and a ramp-shaped obstacle, were not obtained from online platforms due to their lack of availability. Therefore, it was decided to design them directly in the Unity interface or using external applications. For example, Blender [14] was used. These objects are visualized in Figures 7 and 8 respectively.

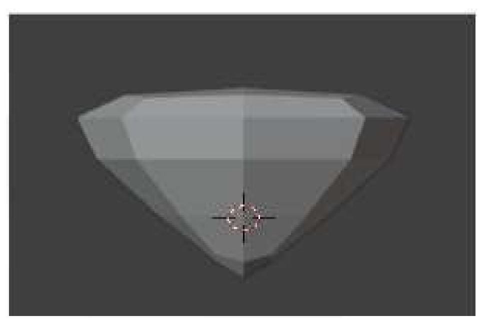

Figure 7. Diamond-shaped point.
Source. Own elaboration.

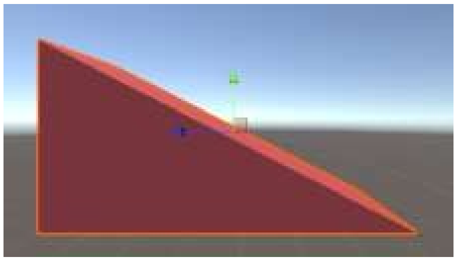

Figure 8. Ramp obstacle. Source. Own elaboration.

Level 1 (Beginner)

The first level of the game introduces children with Down syndrome to the virtual world in a simple way. It features a straight path to familiarize them with bicycle movements and to recognize obstacles and traffic signs such as stops, crosswalks, directional signs, cars and pedestrians. The user starts on a completely straight bike path, and must collect blue diamonds to increase their score. Figure 9 shows the player's animation as points are collected, and a celebratory confetti shower is included, which is expected to motivate the user to follow the rules.

Figure 9. Animation when obtaining points. Source. Own elaboration.

Along this route, players must navigate various obstacles and traffic signs. In Figure 10, the character encounters a stop sign and a crosswalk, where the user must stop and check for cars and pedestrians before proceeding.

Figure 10. Zebra crossing and stop sign. Source. Own elaboration.

If the player ignores the stop sign, there is a possibility that the character will collide with a car or pedestrians crossing the street. This type of incident triggers an explosion animation to represent the impact, as shown in Figure 11.

Figure 11. Collision with a car. Source. Own elaboration.

Level 2 (Intermediate)

In the second level, the course features 90-degree turns that require greater control of the handlebars, as shown in Figure 12. This level maintains the signs and obstacles of the previous level, but adds new challenges.

Figure 12. 90 degree turns. Source. Own elaboration.

During the course of the level, the user encounters traffic lights at various intersections. These work as in life: if the green light is on, the player can move forward. If the yellow light is active, he must proceed with caution, as it will change to red soon; in that case, he must stop and wait for the traffic light to change. Figure 13 shows the red light.

Figure 13. Red traffic light. Source. Own elaboration.

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A notable obstacle in this level is the ramp with the speed multiplier. These ramps appear after completing turns or passing through a stop sign. To traverse them, the player must first pass through an acceleration arrow located a few meters away. This arrow increases the base speed of the bicycle by 2.5 times, allowing the user to cross the ramp with ease. Figure 14 illustrates the ramp next to the arrow that multiplies the speed.

Figure 14. Acceleration ramp and arrow.
Source. Own elaboration.

Level 3 (Advanced)
The third level retains all the features of the previous levels, but also features a track specifically designed to take advantage of curves, combinations of tight turns and changes of direction; which increases the complexity and skills required to navigate it.

This circuit is inspired by Formula 1 tracks, known for their technical challenge. S-curves and U-turns were incorporated to test the player's ability to change direction quickly. In addition, special attention was paid to the flow of the course, ensuring smooth transitions between the different sections of the track. Figure 15 provides an aerial view of the track in its entirety.

Figure 15. Aerial view of the circuit.
Source. Own elaboration.

Serial Communication
To facilitate communication between the bicycle and the virtual environment, serial communication was implemented through the Arduino. As shown in Figure 16, the connection between the Arduino and the virtual system was configured at a speed of 9600 baud, which is a common standard for serial communication devices. This speed is adequate to handle control signals, necessary for the operation of the simulator. Data was set to be sent every 100 milliseconds, which is equivalent to an update rate of 10 times per second. This interval was chosen to ensure real-time response without overloading the processing system.

```
void setup() {
  pinMode(potPin, INPUT);
  pinMode(reedSwitchPin, INPUT_PULLUP);
  pinMode(limitSwitch, INPUT_PULLUP);
  pinMode(limitSwitch2, INPUT_PULLUP);
  // Velocidad serial a 9600 bps
  Serial.begin(9600);

}
```

Figure 16. Data transmission speed.
Source. Own elaboration.

Functional tests
At the first level, three key aspects of the system were evaluated: signal detection, point and collision avoidance. Twenty tests were performed each category, and the results were generally satisfactory. Signal detection achieved 95% success rate, demonstrating that the system was able to recognize most traffic signs and obstacles in the game environment. As for point collection, 90% effectiveness was achieved, although some points were identified that were not collected due to inconsistencies in proximity detection. Collision avoidance also showed a 90% success rate, although some minor collisions were recorded, which were not properly captured by the system. These tests can be visualized in Table 1.

After analyzing these results, improvements to the detection algorithm and scoring system were implemented to increase the reliability and accuracy of the game. As a result of these improvements, 100% effectiveness was achieved in all areas evaluated in subsequent tests. These results demonstrate the positive impact of the optimizations made at level 1, details of which are presented in Table 2.

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Table 1. Level 1 functional tests

Description	Number of Tests	Results	Identified Problems
Signal .	20	95% recognition.	Minor collisions no registered.
Collection of blue dots.	20	90% of points recorded.	Inconsistent collection of points.
Collisions with vehicles and pedestrians.	20	90% of collisions detected.	Minor collisions not always recorded.

Table 2. Tests with optimized level 1 improvements.

Description	Number of Tests	Results	Optimized improvement s
Signal .	20	100% recognition.	Refined detection algorithm.
Collection of blue dots.	20	100% of points recorded.	Adjustment in the scoring.
Collisions with vehicles and pedestrians.	20	100% of collisions detected.	Expansion of collision zones.

Source. Own elaboration.

At the intermediate level, tests focused on 90-degree turns, synchronization with traffic lights and ramps with accelerators. In each category, 20 tests were performed. Navigation in turns had an 85% success rate, although connection response problems were encountered between the handlebars and the system. Synchronization with traffic lights showed 80% effectiveness, facing difficulties in stopping in time and accelerating properly. The use of ramps also reached 80%, with challenges in control behind the throttles. Adjustments were made to handlebar response and throttle smoothness. Level 2 functionality tests are presented in Table 3.

In response to the identified issues, adjustments were made to handlebar response and throttle smoothness to address the identified issues. Level 2 functionality tests are presented in Table 4.

Table 3. Level 2 functional tests.

Description	Number of Tests	Results	Problems Identified
Navigation in 90-degree turns.	20	85% success rate.	Handlebar connection response problems.
Synchronization with traffic lights.	20	80% effectiveness.	Difficulty in stopping on .
Use of ramps with accelerators	20	80% success rate	Control challenges behind the accelerators.

Source. Own elaboration.

Table 4. Tests with optimized level 2 improvements.

Description	Number of Tests	Results	Optimized improvement s
Navigation in 90-degree turns.	20	100% success rate.	Handlebar response adjustment.
Synchronization with traffic lights.	20	100% effective.	Adjustment in the response of the system.
Use of ramps with accelerators	20	100% success rate	Smoothness in the effects of accelerators.

Source. Own elaboration.

The third level, the most complex, integrated elements of the previous levels in a multi-turn circuit. The following were evaluated: navigation in tight curves and fast changes, stability under high load, and signaling integration. Out of 35 tests, navigation in sharp turns and quick changes had an 80% success rate, affected by the sensitivity of the handlebars. Stability under load was 90%, due to latency problems in complex sections. These tests are shown in Table 5.

To correct handlebar sensitivity, optimizations were applied to stabilize cornering response and quick shifting, as well as load management to optimize system performance. These changes were crucial to achieve greater stability and control. The results of level 3 with the optimized improvements are shown in Table 6.

Table 5. Tests with optimized level improvements.

Description	Number of Tests	Results	Problems Identified
Navigation in tight curves and changes fast.	35	80% success rate.	Excessive handlebar sensitivity.
Stability under high load.	35	90% effectiveness.	Latency problems in sections complex.

Table 6. Level 3 functional tests.

Description	Number of Tests	Results	Optimized improvements
Navigation in tight curves and fast changes.	35	100% success rate.	Excessive handlebar sensitivity.
Stability under high load.	35	98% effectivenes s.	Load management optimization.

Source. Own elaboration.

DISCUSSION AND ANALYSIS OF RESULTS

The results obtained and improvements implemented demonstrate significant progress in the project, underscoring the commitment to creating an effective and accessible educational tool. The high success rate in identifying landmarks and navigating through sharp curves and quick changes indicates a solid understanding of the fundamental concepts. These aspects are crucial to ensure that children with Down syndrome have a realistic and educational experience, enhancing their learning about traffic rules and road safety.

Several studies have supported the effectiveness of virtual reality (VR) and simulators in practical and adaptive skills education. Larson et al [15] highlight that VR is beneficial in cognitive rehabilitation, as it allows patients to practice skills in a controlled and safe environment, which is central to our application, which simulates traffic situations to help children with Down syndrome improve their understanding of road rules.

Parsons et al. [16] investigated the use of virtual reality for teaching social and cognitive skills in

The results of these studies show that virtual simulators offer an effective way to train skills in practical situations. These studies provide a solid basis for the use of simulated environments in the development of functional skills and in improving interaction with complex environments, which is relevant to the objective of our system, which seeks not only to teach traffic rules, but also to promote road safety through the use of the developed system, since it contains traffic signs and road rules.

Finally, Pedroli et al [17] have also evidenced the positive impact VR cognitive rehabilitation, suggesting that VR environments can improve concentration, attention and response to visual stimuli in users with intellectual disabilities. This research highlights the usefulness of virtual environments as therapeutic tools, because it also uses a stationary bicycle to make a virtual tour, oriented to elderly people living with a disability. This project is the most similar to ours; however, the big difference is that it is oriented to children with Down syndrome. The success rate in navigation increased from 80% to 100% after making adjustments to the sensitivity of the handlebars, improving precision in turns and changes of direction, which allowed the children to feel more confident when interacting with the environment. The implementation of the virtual reality system effectively integrated concepts of visual discrimination and road rules.

During testing, it was confirmed that the system responded appropriately to user interactions while maintaining a high degree of realism. This aspect is crucial for children with Down syndrome, who can benefit from an environment that simulates real-life situations. Functionality tests, carried out by the development team, were performed at each level, allowing to identify areas of improvement and make necessary adjustments to optimize the user experience. The overall results were satisfactory, showing a significant increase in the success of the tests after implementing the improvements. See figure 17.

Figure 17. Comparison of before and after improvements. Source. Own elaboration.

The overall results were satisfactory, showing a significant increase in the success of the tests after implementing the improvements. The functional tests applied to the eight indicators contained in the figure show a 100% increase in most of them.
The percentage achieved, after the functionality tests in three of the indicators that presented the greatest conflicts, reflects 100% as shown in Figure 18.

Figure 18. Indicators with greater conflict.
Source. Own elaboration.

The figure shows a 100% optimization for navigation, point collection and collision detection, the latter highlighting the effectiveness of the modifications made. These findings demonstrate that the project is consolidating as a valuable tool for road safety education for children with Down syndrome, providing not only an immersive and safe experience, but also an educational platform that can be adapted to the individual needs of each user.
Finally, the only indicator that did not reach 100% after the improvements was stability, as shown in Figure 19.

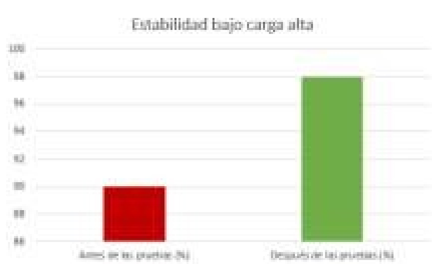

Figure 19. Stability under high load.
Source. Own elaboration.

System stability under high load conditions showed a marked improvement from 90% to 98% after optimizing load management.

CONCLUSIONS

The road simulation system developed for CRIT Sonora has proven to be an innovative and effective tool for child rehabilitation and personalized road safety education. During the functional tests, which were carried out in the three levels of difficulty, it was

The system's ability to adapt to the ' skills, improving its performance in the following areas

a controlled and safe environment. From the initial evaluation phase to the most advanced levels, the system showed consistency in accurate signal and obstacle detection, as well as in point collection and collision avoidance. Despite these achievements, it is important to note the limitations encountered during testing. There were communication problems using Arduino and difficulties in managing the COM port, as well as permission restrictions on Android devices. These difficulties represented significant challenges that required continuous adjustments during the implementation process. These obstacles underscore the need for future technological and collaborative improvements to strengthen the effectiveness and accessibility of the system in clinical and educational settings.

In order to optimize the system and expand its impact, the following two improvements are proposed to be implemented. Integrate advanced virtual and augmented reality tools and expand the system to occupational and physical therapy. Implementing these improvements will not only enhance the road simulation system, but also expand its scope and effectiveness in the field of children's rehabilitation. In this way, it will be able to benefit a greater number of users, optimizing their rehabilitation and learning experience, and contributing to a more inclusive and accessible environment.

Finally, we wish to highlight the proposal to explore the adaptation of the developed system for use with various disabilities. This can be achieved by integrating advanced virtual and augmented reality tools to enrich the learning and rehabilitation experience, offering interactive and personalized environments that improve motor skills, spatial cognition and navigation of users.

BIBLIOGRAPHY .

[1] World Health Organization. Disability [Internet]. Geneva: World Health Organization; 2023 Mar [cited 2023 Mar]. Available from: https://www.who.int/es/news-room/fact-sheets/detail/disability-and-health.
[2] National Institute of Statistics and Geography. Population. disability [Internet]. INEGI; 2023 [cited 2023 Apr 03]. Available at: https://cuentame.inegi.org.mx/poblacion/discapacidad.aspx.
[3] National Council for the Prevention of Discrimination and Inclusion of Persons with Disabilities. World Down Syndrome Day [Internet]. gob.mx; 2017 Mar 21 [cited 2023 Mar 29]. Available from: https://www.gob.mx/conadis/articulos/dia-mundial-del- sindrome-de-down-100498?idiom=en.

[4] Powell-Hamilton NN. Down syndrome (trisomy 21) [Internet]. MSD General Public Handbook; 2023 Jun 05 [cited 2023 Jun 29]. Available from: https://www.msdmanuals.com/es-mx/hogar/salud-children/anomalous%C3%ADas-chromos%C3%B3micas-and-gene%C3%A9ticas/s%C3%ADndrome-de-down-trisom%C3%ADa-21.

[5] Government of Sonora. DIF Sonora commemorates World Down Syndrome Day [Internet]. Gobierno De Sonora; 2023 Mar 22 [cited 2023 Apr 09]. Available from: https://www.sonora.gob.mx/gobierno/acciones/dependencias/conmemora-dif-sonora-el-dia-mundial-del-sindrome-de-down.

[6] Torres Samperio, Franco Arcega, Gutiérrez Sánchez, Suarez Navarrete. Methodology for modeling virtual reality systems for learning on mobile devices. Pistas Educativas [Internet]. 2017 Dec [cited 2024 Apr 19];39. Available from: https://pistaseducativas.celaya.tecnm.mx.

[7] Salorio P, Sánchez R, Morales Moreno I, Torres-Ortuño A, Cuenca A, Capel A. Virtual reality: a new therapeutic tool for the treatment of body image in eating disorders. Enferm Global [Internet]. 2004;5 [cited 2024 Aug 05]. Available from: ISSN 1695-6141.

[8] Campuseducacion.com. Virtual, augmented and mixed reality in the classroom [Internet]. Campuseducacion.com; 2019 Sep 10 [cited 2023 Apr 23]. Available from: https://www.campuseducacion.com/blog/recursos/realidad-virtual-augmented-and-mixed/.

[9] SINC. Why people with Down syndrome have spatial orientation problems [Internet]. Agencia SINC; [cited 2024 Mar 01]. Available from: https://www.agenciasinc.es/Noticias/Por-que-las-personas-con-sindrome-de-Down-tienen-problemas-de-orientacion-espacial.

[10] Microsoft. Creating a UML use case diagram [Internet]. Microsoft Support; [cited 2024 Jun 10]. Available At: https://support.microsoft.com/es-es/topic/crear-un-diagrama-de-casos-de-uso-uml-92cc948d-fc74-466c-9457-e82d62ee1298.

[11] Miro. UML sequence diagram: What it is and how to do it successfully [Internet]. Miro; [cited 2024 Jun 10]. Available from: https://miro.com/es/diagrama/que-es- sequence-uml-diagram/.

[12] Miro. Class diagram: What it is, how to do it and examples [Internet]. Miro; [cited 2024 Jun 12]. Available from: https://miro.com/es/diagrama/que-es-diagrama-clases-uml/.

[13] LittleRobotSoundFactory. Sound 270302 [Internet]. Freesound; [cited 2024 Apr 05]. Available from: https://freesound.org/people/LittleRobotSoundFactory/sounds/270302/.

[14] Blender. Blender: Free and open source 3D authoring software [Internet]. Blender; [cited 2024 Apr 05]. Available from: https://www.blender.org.

[15] Larson EB, Feigon M, Gagliardo P, Dvorkin AY. Virtual reality and cognitive rehabilitation: a review of current outcome research. NeuroRehabilitation. 2014;34(4):759-72. doi: 10.3233/NRE-141078. PMID: 24820166.

[16] Parsons S, Cobb S. State-of-the-art of virtual reality technologies for children on the autism spectrum. Eur J Spec Needs Educ. 2011;26(3):355-66. Available at: https://doi.org/10.1080/08856257.2011.593831.

[17] Pedroli E, Greci L, Colombo D, Serino S, Cipresso P, Arlati S, Mondellini M, Boilini L, Giussani V, Goulene K, et al. Characteristics, usability, and user experience of a system combining cognitive and physical therapy in a virtual environment: Positive Bike. Sensors (Basel) [Internet]. 2018 [cited 2024 Aug 07];18(7):2343. Available from: https://doi.org/10.3390/s18072343.

CONTRIBUTION ROLES

Role	Author(s)
Conceptualization	Julio Alberto Gonzalez Encinas
Data Curation	Julio Alberto Gonzalez Encinas
Methodology	María Trinidad Serna Encinas
Project Management	Julio Alberto González Encinas (same) - María Trinidad Serna Encinas (same).
Resources	Rafael Armando Galaz Bustamante (same) - Rosalía del Carmen Gutiérrez Urquidez (same).
Software	Julio Alberto Gonzalez Encinas
Supervision	María Trinidad Serna Encinas
Validation	Rosalía del Carmen Gutiérrez Urquidez
Visualization	Julio Alberto González Encinas (same) - María Trinidad Serna Encinas (same).
Drafting, original draft.	Julio Alberto González Encinas (same) - María Trinidad Serna Encinas (same).
Writing, proofreading and editing.	Julio Alberto González Encinas (same) - María Trinidad Serna Encinas (same) - Rafael Armando Galaz Bustamante (same).