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Assistive Technology Innovation Based on Visual Feedback and Computer Vision to Improve Fine Motor Skills in Children with Cerebral Palsy

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Abstract: Cerebral Palsy (CP) affects fine motor development, causing obstacles in daily activities. Existing assistive technologies are often not interactive or adaptive enough, hindering independent learning in children with CP. Fine motor issues in learning are also related to a lack of engaging exercise methods. This research develops assistive technology based on visual feedback and computer vision as an innovative solution to improve fine motor skills in children with CP. This technology utilizes motion sensors for real-time visual feedback, helping children understand and correct movements effectively. The Research and Development (R&D) method was employed, focusing on needs analysis, design, and prototype development using the ADDIE model. Validation results demonstrated the system's feasibility and effectiveness. Subject matter experts scored an average of 3.75, media experts 3.5, and education practitioners 3.67. Trials at SLB ACD Pertiwi Mojokerto showed increased motivation and engagement among children during exercises. This technology is expected to become an effective solution for motor and coordination exercises at school and at home, motivating children with CP to practice and develop their motor skills.

Keywords: ***cerebral palsy, assistive technology, fine motor, motion sensor***

I. Introduction

Assistive technology has become one of the main solutions in supporting children with special needs, including cerebral palsy (CP). This technology includes various devices and systems specifically designed to help individuals with physical, sensory, and cognitive limitations. Rosita et. (2020) explain that assistive technology not only enhances functional abilities but also improves quality of life by providing greater access to education, communication, and daily activities. Current technological advancements continue to address these evolving needs effectively.

Children with CP face complex challenges in developing fine motor skills, which are essential for daily activities such as writing, grasping objects, or independent eating (Dewantoro et al., 2018). This neuromotor condition specifically affects fine motor development, causing significant barriers to these crucial daily tasks (Balf & Ingram, 1955). Although these impairments are permanent and incurable, appropriate interventions can significantly improve the abilities of children with CP to lead more independent and productive lives (Clark, 2020).

Innovative and effective approaches are required to help these children overcome such challenges. Previous studies have demonstrated the efficacy of visual feedback, in correcting complex motor skills, particularly in individuals with neuromotor limitations (Gelkop et al., 2015). Hsiao & Chen (2016) found that interactive game-based therapy enhances children's motivation and engagement, ultimately accelerating the learning process in motor skill acquisition.

Systems based on visual feedback and computer vision offer significant potential in supporting the development of fine motor skills in children with CP. Visual feedback is a method that provides immediate visual information to users about how they perform a movement. This mechanism helps children with CP perceive and understand the discrepancies between correct and incorrect movements, thereby enabling them to learn independently (Saunders & Knill, 2004). This feedback leverages the brain's capacity to correct errors through visual information, progressively enhancing proprioceptive awareness and movement coordination.

Computer vision constitutes a technology that enables computers to recognize, analyze, and process images or videos in real-time. Aarts et al. (2012) reveal In the context of motor training,

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computer vision can detect a child's hand movements, analyze the accuracy of these movements, and provide appropriate feedback. Bhatt et al. (2021) support that computer vision can improve the effectiveness of training by providing consistent objective evaluations, which are often difficult to achieve with conventional methods. The integration of these technologies allows for personalized motor exercises tailored to each child's abilities and needs, fostering an interactive and adaptive learning environment.

II. Method

This study uses the Research and Development (R&D) method, which aims to develop visual feedback-based assistive technology using computer vision to improve the fine motor skills of children with CP. R&D is a systematic approach that encompasses the process of developing new products and testing their effectiveness. In this study, the development model used is ADDIE, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Spatioti et al., 2022). However, this study focuses only on the first three stages: needs analysis, design, and prototype development.

Pre-tests and post-tests using observation instruments to assess the fine motor skills of children with CP were used to test the effectiveness of the developed visual feedback and computer vision-based assistive technology. Pre-tests were conducted before the children used the product, while post-tests were conducted after the children had participated in several training sessions using the technology. The fine motor skills measured include hand-eye coordination, finger flexibility, movement control, and movement accuracy. Data were analyzed using quantitative descriptive techniques, including calculating average scores and the percentage increase in children's motor skills before and after the intervention.

The selection of the research location at one of the Special Schools in Mojokerto was based on several strategic considerations relevant to the research objectives. This school is one of the special education institutions that actively provides fine motor therapy services for children with CP. Additionally, the school has a sufficient number of CP students, enabling the implementation of assistive technology product trials in a representative and needs-based manner. The presence of competent therapists and special education teachers specializing in special needs education is a crucial factor in supporting the implementation, validation, and evaluation of the developed technology prototypes.

SLB Pertiwi Mojokerto was chosen as the research location because of its inclusive environment, commitment to improving educational services for children with special needs, and enthusiasm for developing technology-based innovations to support motor therapy for children with CP, making it an ideal and supportive setting for the development, testing, and refinement of assistive technology based on visual feedback and computer vision to enhance their fine motor skills. The research was conducted in several stages, as detailed in table 1.

Table 1. Time of Implementation and Results of Data Collection Techniques

No	Data Collection Techniques	Time of Implementation	Research	Analysis
1.	Observation	February 202	Children with CP experience hand-eye coordination and finger flexibility issues during manual exercises.	This became the basis for the design of a system with real-time visualization of the child's movements.
2.	Interview	February 2025	Teachers and therapists conveyed the limitations of conventional training media and the need for adaptive and engaging media.	Determining specifications for features that are easy to operate and appealing to children.
3.	Questionnaire (product	March 2025	Subject matter experts, media, and practitioners gave an	The product is suitable for implementation with minor revisions

	validation survey)		average rating of above 3.5 with notes for improvement on technical aspects.	to the user manual and software stability.
4.	Pre-test	March 2025	The average fine motor skills of children are in the low category.	This serves as a baseline for measuring the effectiveness of the system after intervention.
5.	Post-test	April 2025	There was an increase in the average fine motor skills of children in terms of coordination and movement control	This proves the effectiveness of the system in improving the fine motor skills of children with CP.

Through the sequential and structured implementation of these data collection techniques, an accurate picture of the needs, development design, and effectiveness of the product was obtained to support fine motor therapy interventions for children with CP. Each data collection stage complements the others, where observations provide initial data on real-world conditions, interviews delve into detailed information regarding needs and challenges faced, while questionnaires offer objective assessments from experts and practitioners on the product's feasibility. The results of the analysis from these three techniques then form a strong foundation for the design of features, system development, and product effectiveness testing, ensuring that the resulting product is truly aligned with the specific needs of children with Cerebral Palsy and implementable in special education settings.

III. Results and Discussion

This study successfully developed an assistive technology based on visual feedback and computer vision to improve the fine motor skills of children with CP. The resulting prototype has undergone validation by subject matter experts, media experts, and education practitioners, as well as direct effectiveness testing on CP students at SLB Pertiwi Mojokerto.

A. Student Profile of Trial Participants

During the trial phase, the technology prototype was used by six children with cerebral palsy at SLB ACD Pertiwi Mojokerto who met the inclusion criteria. The inclusion criteria used were children with mild to moderate spastic cerebral palsy who were still able to follow visual instructions, had limited basic fine motor skills, and were accompanied by teachers and parents during the training process. The students' age range was 7 to 12 years old, consisting of 3 boys and 3 girls. The students' fine motor skills varied, ranging from difficulty in grasping objects, weak hand-eye coordination, to challenges with finger flexibility.

B. Expert Validation Results

The results of the validation of this assistive technology show that the product is considered suitable for use in fine motor therapy interventions for children with CP, with some minor improvements needed to increase its effectiveness and ease of use. The validation process was conducted by three parties: a content expert who assessed the alignment of content and activities with the principles of fine motor skill development, a media expert who evaluated the technical, visual, and interactive aspects of the system, and an education practitioner who assessed the usability of the product in a special education school environment. Input from these three parties served as the basis for refining the system prior to conducting field trials to test its effectiveness.

Subject matter experts assess the suitability of technological content with fine motor principles. They ensure that the activities provided in this system are relevant to the needs of children with CP and can support the development of their motor skills. The validation results show that this

systemis capable of providing appropriate stimulation to train hand-eye coordination, finger flexibility, and fine motor control. Activities involving simple to complex movements are considered effective in improving children's motor skills. According to experts, the visual feedback feature is very helpful for children to understand movement errors and correct them independently. The results of the content expert validation are presented in table 2.

Table 2. Subject Matter Expert Validation

No	Indicator	Value
1.	Content Relevance	3.5
2.	Content Organization	4
3.	Evaluation	3.5
4.	Effect on Learning Strategy	4

Media experts evaluated the technical aspects, visual design, and interactivity of the system. They highlighted that a user-friendly interface and attractive graphics can increase children's motivation to practice. This technology is considered easy to operate by children and teachers, with clear instructions and intuitive features. The real-time visual feedback is deemed effective in providing children with immediate information about correct and incorrect movements. Media experts also note that this system has great potential for application in special schools. The results of media expert validation are shown in table 3.

Table 3. Media Expert Validation

No	Indicator	Value
1.	Language	3.5
2.	Effects on Learning Strategies	4
3.	Software Engineering	3
4.	Visual Skills	3.5

Teachers and special education therapists assessed that the system is effective in increasing children's motivation and engagement during training, with the caveat that the system's user guide should be simplified. Teachers and therapists reported that children were more enthusiastic and engaged during training sessions using this technology compared to conventional methods. The visualization of movements and feedback provided helped children understand the improvements they needed to make, making the learning process more effective and enjoyable. The results of practitioner validation are shown in table 4.

Table 4. Practitioner Validation

No	Indicator	Value
1.	Content Relevance	3.5

2.	Content Organization	4
3.	Evaluation	3
4.	Language	3
5.	Visual Appearance	3.5
6.	Software Engineering	4

As a direct implementation of the research objectives, an effectiveness test was conducted on six children with CP who participated in the trial. This test was conducted through pre- and post-tests using a fine motor skills observation sheet that included four indicators: hand-eye coordination, finger flexibility, movement control, and movement accuracy. The results of the content expert validation are presented in table 5.

Table 4. Practitioner Validation

No	Gender	Pre-test Score	Post-test Score	Description
1.	Male	50	72	Increase
2.	Female	55	76	Increase
3.	Male	52	74	Increase
4.	Male	48	70	Increase
5.	Female	54	75	Increase
6.	Female	53	73	Increase

The results of the effectiveness test showed a significant increase in scores after the use of assistive technology in several training sessions. The following is a summary of the pre-test and post-test scores. The average pre-test score for all students was 52, while the average post-test score increased to 73.3. This increase in scores was observed in all fine motor skill indicators, especially in movement control and hand-eye coordination.

Research findings demonstrate that the application of visual feedback technology significantly contributes to improving the fine motor skills of children with cerebral palsy (CP). Direct visualization of movements on a screen helps children recognize errors and correct their movements independently. In line with the theory proposed by Yu et al. (2004), visual feedback enhances proprioceptive awareness, which is the body's ability to sense its position and movement without direct visual input. This improvement in proprioceptive awareness is crucial for developing fine motor skills, as it enhances hand-eye coordination, finger flexibility, and control over precise movements.

Research by Elnaggar (2022) demonstrates the effectiveness of visual feedback in improving complex motor skills, particularly in individuals with neuromotor limitations. The results of the trials in this study reinforce these findings. Children with CP showed significant improvement in movement control after using the visual feedback system, as evidenced by higher post-test scores compared to pre-test scores. This system helps children understand the difference between correct and incorrect movements more quickly and intuitively.

The computer vision technology integrated into this system plays an important role in detecting hand movements in real time and providing automatic feedback. The system is able to compare the position and movement of the child's hands with the desired movement standards, then display the evaluation results on the screen. Bhatt et al. (2021) explain that computer vision is effective in providing objective and consistent evaluations, which are difficult to achieve with manual methods.

Personalization of exercises becomes more optimal because the difficulty level can be adjusted according to the child's ability and response during therapy sessions. As a result, children with CP can practice without feeling overwhelmed, while the system maintains the necessary challenges for motor development.

Children's motivation and engagement during the training process increased. Teachers and therapists at SLB Pertiwi Mojokerto stated that children appeared more focused, enthusiastic, and excited when participating in technology-based training compared to conventional methods. The visualization of movements and interactive displays of the system were effective attractions for children with motor limitations. Lee Kyeongbong et al. (2022) demonstrated that game-based and interactive technology can enhance the motivation of children with cerebral palsy while accelerating the learning process of motor skills.

The application of this technology also contributes to the development of children's independence. Children who were initially completely dependent on teachers or therapists began to show independent learning abilities in improving their movements, thanks to easy-to-understand visual feedback. This increase in independence is an important aspect of occupational therapy, which, according to Eliasson et al. (2014), requires repetitive practice in a supportive, flexible, and enjoyable environment to optimally develop children's motor function independence.

This technology also has great potential for application in inclusive educational settings, particularly through integration into the curriculum for children with special needs. Data on children's development recorded automatically through the system can be utilized by teachers and therapists in compiling individual progress reports. Such technology-based reporting systems are crucial for supporting differentiated learning models, as suggested by Rhoads et al. (2024), who emphasizes that computer-based sensory and visual feedback technologies offer significant benefits in monitoring therapy progress and adjusting interventions according to a child's ability profile.

The validation results from subject matter experts, media experts, and education practitioners indicate high feasibility, coupled with significant effectiveness testing, reinforcing the position of this technology as an alternative solution for fine motor therapy for children with CP both at school and at home. Expert validation scores above 3.5 and post-test score improvements demonstrate that this system is effective in improving hand-eye coordination, movement control, and finger flexibility. Recommendations from the research by Sujarwanto et al. (2023) also mention that the development of virtual and interactive therapy media has a positive impact on improving motivation, fine motor skills, and independence in children with special needs. This innovation not only impacts motor skills but also enhances motivation and readiness in children with CP to actively participate in an inclusive educational environment.

IV. Conclusion and Suggestion

This study successfully developed assistive technology based on visual feedback and computer vision that effectively improves the fine motor skills of children with cerebral palsy (CP). Validation by subject matter experts, media experts, and education practitioners showed that this product is suitable for use, with visual feedback features that help children understand and correct their movements independently, as well as an accurate movement monitoring system. A trial involving 6 children with CP at SLB Pertiwi Mojokerto showed significant improvements in hand-eye coordination and grasping ability. The children were also more motivated to practice because the system offers an interactive and enjoyable learning environment. These findings reinforce that this technology has the potential to become an innovative therapeutic solution in special schools and therapy centers for children with special needs.

Researchers recommend implementing this technology in special schools and therapy centers, supported by training for teachers, therapists, and parents. Further development is needed to improve system responsiveness and exercise result reporting. Future studies should involve more diverse participants, including children with severe CP, and assess long-term effectiveness. Integrating interactive games and VR is also suggested to boost motivation and therapy variety for children with CP.

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