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Development of Computer Vision-based Visual Feedback Assistive Technology for Fine Motor Improvement in Children with Cerebral Palsy

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Abstract: Cerebral Palsy (CP) is a neuromotor condition that affects fine motor development, causing barriers to daily activities such as writing and grasping. This research develops an assistive technology that utilizes motion sensors to provide real-time visual feedback, which helps children understand and correct movements more effectively. The technology improves movement precision and coordination in motor skills, learner engagement, and structured monitoring of skill improvement. The uniqueness of this research lies in integrating computer vision technology with an interactive design that allows CP children to perform motor exercises and engage them in a more personalized and adaptive learning process. The Research and Development (R&D) method was used in the development, involving validating material experts, media experts, and educational practitioners. The results of media development show that assistive technology is feasible to use in improving the fine motor skills of children with cerebral palsy. Material experts stated an average value of 3.92, which was accumulated in percentage to 98.21%; media experts obtained results of 3.71, which was collected in percentage to 92.85%; and expert practitioners stated an average value of 3.93, which was accumulated in percentage to 98.43%. The assistive technology developed is worth testing in improving the fine motor skills of cerebral palsy children. This technology is expected to solve motor and coordination training issues at school and home. With a more interactive and fun approach, CP children can be more motivated to practice so that their motor skills can develop better.

Keywords: Assistive Technology; Cerebral Palsy; Fine Motor.

Introduction

Cerebral Palsy (CP) is a neurodevelopmental disorder caused during pregnancy, birth, or early childhood. It results in impairments in muscle control, movement coordination, and posture, especially in fine motor skills that are important for daily activities such as writing, grasping objects, or eating independently [1,2]. These impairments are permanent and incurable, but with the proper intervention, children with CP can improve their ability to lead more independent and productive lives [3]. Therefore, innovative and practical approaches are needed to help them overcome these challenges.

Assistive technology has become one of the leading solutions in supporting special needs children, including CP. These technologies include various devices and systems to assist individuals with physical, sensory, and cognitive limitations. Assistive technology improves functional abilities and quality of life by providing greater access to education, communication, and daily activities [4]. Among the various types of assistive technology, visual feedback, and computer vision-based systems offer great potential in supporting fine motor development in CP children [5].

Visual feedback is a method that provides immediate feedback in visual form to the user on how they perform a movement. This helps children with CP see and understand the difference between correct movements and movements that need to be corrected so they can learn independently [6,7]. This feedback utilizes the brain's ability to correct errors through visual information, thus improving proprioceptive awareness and movement coordination gradually [8]. For example, when a child sees a visual representation of his hand movement on the screen, he can immediately recognize and correct the error.

Meanwhile, computer vision is a technology that enables computers to recognize, analyze, and process images or videos in real time [9,10,11]. In the context of motor training, computer vision can detect a child's hand movements, analyze the accuracy of the movements, and provide appropriate feedback. This technology can create an interactive and adaptive learning environment where fine motor training can be tailored to each child's abilities and needs [12]. In this way, children practice physically and develop cognitive skills such as problem-solving and decision-making.

The incorporation of this technology in fine motor training provides significant benefits compared to using conventional training or the use of toy aids without technology. First, the system provides real-time feedback, allowing the child to correct their movements immediately after making a mistake. This accelerates the learning process and increases the effectiveness of the exercise. Secondly, the interactive environment created by this technology makes motor improvement exercises more engaging and fun. Research shows that children are more motivated to practice if they engage in activities that are game or challenge-based [13]. Third, the media developed

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in this study aims to create a more engaging and fun practice environment, thereby increasing children's motivation to practice consistently. The media can be accessed in various locations, both at home and at school, thus providing greater flexibility for children and their families. The urgency of this research is to provide an exercise solution that effectively improves the motor skills of children with cerebral palsy and is also practical and accessible, thereby supporting their development in a more optimal manner for daily activities.

Research Methods

This research uses the Research and Development (R&D) method, which aims to develop assistive technology based on visual feedback with computer vision to improve children's fine motor skills with Cerebral Palsy (CP). R&D is a systematic approach that includes developing new products and testing their effectiveness. In this research, the development model used is ADDIE, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation [14,15,16]. However, this study only focuses on the first three stages: needs analysis, design, and prototype development.

In the analysis stage, researchers identified the needs of CP children in developing fine motor skills through observations and interviews. The results of this analysis were used to design a system that provides real-time visual feedback. At the design stage, a storyboard and system flow were created to detect the child's hand movements and display the results in the form of interactive visuals, adjusted to the child's ability and the difficulty level of the exercise. At the development stage, a prototype was developed, validated by material and media experts, and tested by educational practitioners to ensure the effectiveness and suitability of the technology to the needs of CP children.

Data collection techniques involve observation, interviews, and questionnaires. The instrument used is a validation sheet that is assessed directly by 1 Media Expert, namely a S3 lecturer in Education Science, 1 Material Expert, namely an S1 lecturer in Special Education, and 2 Practitioner Experts, namely Teachers who deal directly with Cerebral Palsy children in SLB ACD Pertiwi Mojokerto. Feasibility in the aspect of validity is reviewed technically, as well as content feasibility, interactivity, usability, security, content relevance, organization, evaluation, language, visual, software engineering, and effects for learning strategies. Validation was analyzed using quantitative descriptive using Likert scale calculation as follows:

Table 1. Scoring Criteria

Category	Score
Strongly Agree	4
Agree	3
Disagree	2
Strongly Disagree	1

[17]

In this study, a modification was made by eliminating the "Disagree" option in the scoring criteria so that only 4 alternative answers were available. This is done because the data obtained is empirical and avoids safe answers to the "Disagree" criteria. Then, the average obtained for each indicator is using the following formula:

$$\bar{X} = \frac{\sum X}{N} \quad [17]$$

Description:
$\bar{X}$ = Average score
Σx = Total score
N = Number of trial subjects

Then, the data is interpreted qualitatively on the average Number of scores on each aspect by applying the scoring criteria as follows:

Table 2. Conversion Formula for Average Number of Scores

Criteria	Score	Value
Not Very Good	x ≥ *Mi* + 1.5 *Sdi*	4
Not Good	*Mi* + 1.5 *Sdi* > x ≥ *Mi*	3
Good	*Mi* > x ≥ *Mi* – 1.5 *Sdi*	2
Very Good	x ≤ *Mi* – 1.5 *Sdi*	1

[18]

Description:
Mi (Average ideal score) = ½ (maximum ideal score + minimum ideal score)
Sdi (Ideal standard deviation) = 1/6 (maximum ideal score – minimum ideal score)
x (Actual score) = Score obtained

The eligibility criteria of the product or media developed can also be determined by multiplying the assessment score by the number of indicators measured in each aspect assessed. For further analysis purposes in the form of comparing the assessment results on each element with the expected level of feasibility, it can use the percentage technique in data analysis with the following formula:

$$\text{Percentage of feasibility of each aspect (\%)} = \frac{\sum \text{average score obtained}}{\sum \text{average ideal score}} \, x \, 100\%$$

[18]

Furthermore, analyzing the data that has been collected using quantitative descriptive analysis presented in the distribution of scores and percentages on a rating scale determined as follows:

Table 3. Feasibility Assessment

Percentage	Assessment Interpretation
76 - 100%	Very Feasible
50 - 75%	Feasible
26 - 50%	Fair
<26%	Less Feasible

To determine the feasibility of the media development, the researchers set the minimum criteria in the "Good" category. If the assessment of the developed media gets a value of "Good," it can be concluded that the developed media is feasible to be applied as a learning media.

Results and Discussion

The results of this study show that the development of Computer Vision-based Virtual Feedback assistive technology aims to improve the fine motor skills of children with cerebral palsy. This development process follows the ADDIE model, which begins with the analysis stage (Analyze). At this stage, direct observations were made at special schools, and interviews with teachers were conducted to identify the fine motor needs of cerebral palsy learners. The collected data was used to design appropriate strategies and assistive technologies, including real-time feedback, difficulty level adjustment, and objects that can be selected according to the learners' interests.

Next, the media was developed at the design stage by considering the design features, technology, and programming language used. The development was done using Python, which allows for more effortless operation and minimal problems. The media design includes the creation of a storyboard as a guide, selecting relevant visual and interactive content, and preparing a usage module that guides how the media works. The fonts, images, and objects were matched with colors and elements that appeal to learners to support their engagement in the exercises.

At the development stage, the media was built using supporting hardware and Python-based software for computer or laptop devices with Windows operating systems. The development includes setting up the main page, selecting the difficulty level of the exercise, and selecting objects that children like candies, balls, and cars favor. The main page also provides the option to choose the camera and provides instructions and video tutorials to facilitate children's use of this technology. The development process focused on creating an environment that was adaptive, engaging, and suited to the individual abilities of children with cerebral palsy.

A validity test was conducted on material experts, media experts, and one practitioner to determine the feasibility of the media or product. The following are the results of the validation of each expert to assess whether Computer Vision-based Virtual Feedback assistive technology is feasible to use in improving the fine motor skills of children with cerebral palsy:

Material Expert Validation Results

Material experts assessed the appropriateness of the technology content to the principles of fine motor. They ensured that the activities provided in the system were relevant to the needs of CP children and could support their motor skill development. The validation results show that the system can provide appropriate stimulation to train hand-eye coordination, finger flexibility, and fine movement control. Activities involving simple to complex movements effectively improve children's motor skills. According to the expert, the visual feedback feature greatly helps children understand and correct movement errors independently. The results of the material expert validation are shown in Table 4.

Based on the table above, the material expert validation consisting of 4 assessment indicators obtained an accumulated score of 15.75, which is included in the perfect criteria. If it is percented, the accumulated assessment gets 98,21%, which is included in the feasible criteria.

Table 4. Material Expert Validation

No	Indicator	Value
1.	Content Relevance	3.75
2.	Content Organization	4
3.	Evaluation	4
4.	Effect of Learning Strategy	4
	Total	15.75
	Average	3.92
	Percentage	98.21%

Media Expert Validation Results

Media experts assessed the system's technical aspects, visual design, and interactivity. Media experts highlighted that the user-friendly interface and attractive graphics can increase children's motivation to practice. Both children and teachers rated The technology as easy to operate, with clear instructions and intuitive features. The visual feedback displayed in real-time was considered effective in providing immediate information to the child about correct and incorrect movements. The media expert also noted that the system can be implemented in special schools. The results of the media expert validation are shown in Table 5.

Table 5. Media Expert Validation

No	Indicator	Value
1.	Technical	3.25
2.	Feasibility of Content	3.66
3.	Interactivity	3.66
4.	Usability	4
5.	Safety	4
	Total	18.57
	Average	3.71
	Percentage	92.85%

Based on the table above, the media expert validation consisting of 5 assessment indicators obtained an accumulated score of 18.57, which is included in the very good criteria. If it is percented, the accumulated assessment gets 92.85% which is included in the very feasible criteria.

Trial by Educational Practitioners

The field trial at SLB ACD Pertiwi Mojokerto involved teachers and therapists who work directly with CP children. Practitioners provided positive feedback on the system's effectiveness in improving learners' fine motor skills. They reported that children were more enthusiastic and engaged during practice sessions using this technology than conventional methods[13]. The expert practitioner's opinion is reinforced by other research, which states that an attractive appearance is a factor in the development of assistive technology [19], and a design that considers user characteristics, including the selection of appearance or level, can increase attractiveness and effectiveness in the use of media [20]. The visualization of movements and the feedback provided helped children understand the improvements that needed to be made, making the learning process more effective and enjoyable. After several use sessions, teachers also noted improvements in hand-eye coordination and fine motor control. The results of the practitioner validation are shown in Table 6.

Table 6. Expert Practitioner Validation

No	Indicator	Value
1.	Content Relevance	4
2.	Content Organization	4
3.	Evaluation	4
4.	Language	4
5.	Visual Display	3.625
6.	Software Engineering	4
	Total	23.625
	Average	3.93
	Percentage	98.43%

Based on the table above, the practitioner expert validation consisting of 6 assessment indicators obtained an accumulated score of 23.625, included in the very good criteria. If present, the accumulated assessment obtained 98.43%, which is feasible in the requirements.

A simple average calculation (Mean) was used to analyze the scores of the validation results, and a simple average calculation (Mean) was used, which showed that this product was feasible to implement and required minor revisions to make it more optimal. Considering the input from the experts, this technology is expected to significantly contribute to supporting the fine motor development of CP children in the school and home environment.

This study shows that assistive technology based on visual feedback and computer vision has a positive impact in supporting the development of fine motor skills in children with Cerebral Palsy (CP). Support from experts, including material, media, and educational practitioners, reinforced these findings, suggesting that this technology is relevant and effective for therapy and learning.

The Role of Visual Feedback in the Process of Improving Motor Skills

Visual feedback technology provides immediate feedback in the form of visualization of the movements children perform so that they can understand how to correct movement errors independently. Visual feedback increases proprioceptive awareness, which is the body's ability to feel the position and movement of muscles without seeing them directly [6]. This awareness is important in training fine motor skills as it helps children develop better coordination and control over movements. In motor enhancement training for CP children, the visualization of movements displayed through this system makes it easier for them to recognize the difference between correct and incorrect movements. When the child sees their hand movements displayed on the screen, they more easily understand the corrections that need to be made. Several studies have shown that visual feedback improves complex motor skills, especially in individuals with neuromotor limitations [21].

Computer Vision Integration for Accurate Monitoring

Computer vision systems enable real-time detection of movements, which are then analyzed to provide accurate feedback [21,22]. This technology works by monitoring the position and movement of the child's hand and then comparing it to the desired movement. This process provides information on the movement's success and helps the child identify and correct errors in real-time [23]. Computer vision can improve the effectiveness of training as it can provide consistent objective evaluation, which is difficult to achieve with conventional methods [12]. In addition, this technology allows the personalization of exercises according to each child's abilities and needs. The difficulty level can be adjusted based on the child's response so they do not feel overwhelmed or bored during the exercise session. This supports the concept of occupational therapy, which emphasizes the importance of repetitive and consistent practice in a supportive environment.

Children's Motivation and Engagement in Motor Enhancement Exercises

One of the advantages of this technology is its ability to create an interactive and engaging learning environment. Teachers and therapists at SLB ACD Pertiwi Mojokerto reported that children were more enthusiastic and focused when using this system than when using conventional methods. This is supported by Lee Kyeongbong's research, which found that interactive game-based therapy increases children's motivation and engagement, ultimately accelerating the learning process [13]. This technology also reduces the child's dependence on help from the therapist or teacher. Children can learn independently with visual feedback and are more confident in trying new movements. Teachers noted that children who initially required a lot of assistance began to show increased independence after a few practice sessions using this technology.

Implications in Inclusive Education

The use of assistive technology is not only limited to the therapy environment but also has excellent potential to be applied in inclusive education. These systems can be integrated into the school curriculum to support students with special needs learning. Assistive technology is essential in creating an inclusive learning environment where every child, including those with physical disabilities, can learn according to their needs and abilities [24,25]. In addition, the system allows teachers and therapists to monitor students' progress more systematically. The data collected by the system can be used to create individual progress reports, which will help design more effective interventions in the future. With the automatic reporting feature, teachers can quickly identify areas that need improvement and adjust teaching approaches accordingly.

Conclusion

Main This research successfully developed computer vision-based visual feedback assistive technology to improve fine motor skills in children with cerebral palsy (CP). The validation results by material experts, media experts, and educational practitioners show that this product is feasible and effective in supporting motor training. Visual feedback provides immediate feedback that helps children understand and correct movements independently, while computer vision ensures accurate and consistent movement monitoring. Children were more motivated to practice as the system provided an engaging, interactive environment. Teachers and therapists noted that the technology helps children develop independence and increases the effectiveness of the therapy process compared to conventional methods. With expert support and satisfactory validation results, this technology is expected to be an innovative tool applied in special schools, therapy centers, or home practice. It not only improves the motor skills of CP children but also makes a positive contribution to inclusive education.

Author's Contributions

Tarisya Mawaddah: Contributed as a researcher and article writer. Endang Pudjiastuti Sartinah: A supervisor of research ideas and article writing; Wagino contributed as a supervisor in research data processing. All authors have read and approved the published version of the manuscript.

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