

**UNIVERSITI TEKNOLOGI MARA**

**HYBRID HEAD POSE ESTIMATION  
FRAMEWORK FOR ASSESSING  
VISUAL ATTENTION IN  
ROBOT-ASSISTED THERAPY**

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## ABSTRACT

Visual attention plays a crucial role in learning and therapeutic engagement; however, its assessment among children with special needs remains a challenge due to dynamic, non-verbal behaviours. Existing robot-assisted therapy systems do not offer an automated, reliable mechanism for quantifying attention in real time. To address this gap, this study developed a hybrid Head Pose Estimation (HPE) framework that integrates MediaPipe and Dlib, optimised for mobile robotic platforms to facilitate real-time visual attention monitoring. The study aimed to develop and evaluate a robust, real-time HPE algorithm designed to quantify visual attention in children with special needs during robot-assisted sessions. This algorithm incorporated hybrid facial landmark detection techniques by integrating MediaPipe and Dlib, thereby enhancing accuracy across various head orientations and occlusions. Validation was conducted with 90 participants: 30 adults, 30 typically developing children, and 30 children with special needs. Head orientation parameters (yaw, pitch, and roll) and visual orientation (left, right, forward) were derived from video frames. System performance was assessed using metrics such as frames per second (FPS), latency, frame drops, and concordance with manual annotations. For children with special needs, the system achieved 81.5% attention detection accuracy, 96.5% precision, 66.7% recall, and an F1-score of 78.9%. The system demonstrated substantial agreement with the ground truth, as evidenced by a Cohen's Kappa of 0.739. The average attention score recorded was 63.6%, with elevated engagement levels correlating with age and previous screen time. Conversely, male gender and diagnoses such as Autism Spectrum Disorder (ASD) or Speech Disability (SD) were associated with decreased attention levels. The duration of therapy did not show any significant effect. In conclusion, the HPE-based system developed provides a reliable, non-intrusive, and cost-effective solution for real-time estimation of visual attention. Its integration with a social robot platform enables therapists and educators to monitor engagement levels and to customise interventions based on individual attention patterns, thereby enhancing the effectiveness of robot-assisted therapy for children with special needs.

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# CHAPTER 1

## INTRODUCTION

### 1.1 Research Background

The increasing global population of children with special needs, including in Malaysia, highlights the need for effective intervention systems. According to a recent World Health Organisation (WHO) and United Nations International Children's Emergency Fund (UNICEF) report, approximately 317 million children worldwide were affected by health conditions contributing to a developmental disability[1]. According to UNICEF Malaysia's Country Office Annual Report 2023, Malaysia has an estimated 9.13 million children, and approximately 1 in 20 of these children have disabilities[2]. Despite the development of various intervention systems, it remains challenging to meet the unique needs of each child, particularly those with complex or rare conditions requiring specialised interventions. Consistent and effective therapy is crucial for these children, as it helps them develop new skills, overcome challenges, and enhance their overall quality of life[3].

Children with special needs are a diverse group of individuals who require assistance due to physical, mental, emotional, or developmental disabilities. They may have conditions such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), intellectual disability (ID), learning disability (LD), speech and language disorders (SLD), physical disabilities, sensory processing disorder, or emotional and behavioural disorder. Understanding and addressing these differences is crucial for providing effective interventions and improving outcomes for children with special needs[4], [5].

Intervention systems for children with special needs include early intervention services, special education, inclusive education, assistive technology, therapy, and support services. The primary objective of these interventions is to provide comprehensive support, enabling children to maximise their potential and actively engage in their communities[6]. Innovative robot-based intervention systems offer a distinctive and practical approach to assisting children with special needs in socialisation, motivation, repetition, and customisation. Robots can be programmed with facial expressions, gestures, and body language, enabling children to practice their