Technical Report on Generative AI for Automated FRT (Functional Reach Test)

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Contents

1 Introduction

1.1 Background

As the global population ages, the prevalence of cognitive disorders and balance issues among the elderly has become a significant public health concern. Cognitive disorders such as dementia and Alzheimer's disease can impact memory, attention, language, and other cognitive functions, leading to increased fall risk and diminished quality of life. Balance issues are a major cause of falls, which are the leading cause of injury and death among older adults.

Falls often result in serious injuries such as fractures and head traumas, which can lead to prolonged hospital stays, disability, and a decrease in the overall quality of life. In addition to physical injuries, falls can cause psychological impacts, including fear of falling again, which can lead to reduced mobility and social isolation. The Functional Reach Test (FRT) has emerged as a crucial test for assessing fall risk and balance in older adults. This simple and quick assessment involves measuring how far a person can reach forward while keeping their feet stationary. It is a reliable indicator of balance and fall risk.

Traditionally, the FRT and other cognitive health assessments require the presence of trained professionals and specialized equipment, limiting their accessibility and usability in various settings. With advancements in technology, there is a growing interest in developing automated and accessible solutions to conduct these assessments efficiently and accurately.

1.2 Problem Statement

The traditional methods of assessing cognitive health and fall risk often require specialized equipment and clinical expertise, which may not be readily available in all settings, particularly in remote or underserved areas. The lack of accessibility to these assessments can delay the identification and intervention of cognitive decline and balance issues, potentially leading to adverse health outcomes. There is a need for an accessible, efficient, and reliable system that can perform these assessments using widely available technology such as smartphones, tablets, and computers.

This project aims to address this gap by leveraging Generative AI to develop a system capable of conducting cognitive health assessments and the Functional Reach Test (FRT) in a user-friendly and accessible manner.

1.3 Objectives

The primary objective of this project is to develop a Generative AI system that can:

- Assess cognitive health through a user-friendly interface.
- Determine the need for the Functional Reach Test (FRT) based on initial evaluations.
- Provide options for performing the FRT either via video upload or live using a device camera.
- Offer recommendations based on FRT results to guide users on whether they should seek medical consultation.

Secondary objectives include:

- Enhancing the accuracy and reliability of cognitive health assessments through the integration of advanced AI models.
- Improving the accessibility of cognitive health assessments for individuals in remote or underserved areas.
- Reducing the need for specialized equipment and clinical expertise in conducting cognitive health assessments and the FRT.

1.4 Scope and Limitations

This project focuses on the development of a Generative AI system for cognitive health assessment using the FRT. The system is designed to be used in a variety of settings, including home environments, clinics, and community centers. It aims to provide an accessible and efficient solution for assessing cognitive health and fall risk.

However, the system's effectiveness is limited by several factors, including the accuracy of the input data, the quality of video capture, and the user's adherence to the test instructions. Additionally, while the system aims to provide valuable insights and recommendations, it is not a substitute for professional medical advice and should be used as a supplementary tool for cognitive health assessment.

1.5 Overview of the Functional Reach Test (FRT)

The Functional Reach Test (FRT) is a clinical assessment tool used to measure balance and fall risk in elderly individuals. Developed in 1990 by Pamela Duncan and colleagues, the FRT involves measuring the distance a person can reach forward while maintaining a fixed base of support. The test is performed by having the individual stand next to a wall with their feet shoulder-width apart and reach forward as far as possible without losing their balance or taking a step. The distance reached is measured in centimeters and provides an indication of the individual's balance and stability.

Research has shown that the FRT is a reliable and valid measure of balance and fall risk. Individuals who score lower on the FRT are at a higher risk of falls, and the test can be used to identify those who may benefit from interventions to improve balance and reduce fall risk.

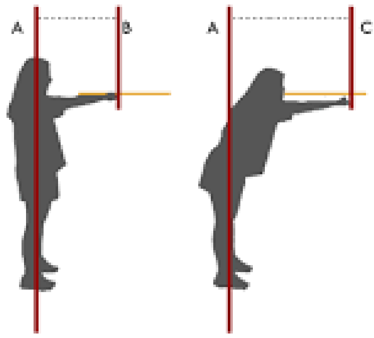

Figure 1: Functional Reach Test (FRT)

1.6 Significance of Cognitive Health Assessment

Accurate and timely assessment of cognitive health is essential for early intervention and management of cognitive disorders. Cognitive health assessments can help identify early signs of cognitive decline, allowing for timely interventions that can slow the progression of cognitive disorders and improve the quality of life for affected individuals.

By integrating AI technology into the cognitive health assessment process, we aim to enhance the accessibility and efficiency of these evaluations. AI-driven assessments can provide consistent and objective results, reduce the burden on healthcare professionals, and make cognitive health evaluations more widely available. Ultimately, improving cognitive health assessment through AI technology can lead to better patient outcomes and contribute to the overall well-being of the aging population.

2 Methodology

2.1 Overview

The development of the Generative AI system for cognitive health assessment involves a structured methodology to ensure that the system is accurate, reliable, and user-friendly. The methodology encompasses several phases, including data collection, system design, implementation, and evaluation. Each phase is essential for achieving the project's objectives and ensuring the system's effectiveness in assessing cognitive health and fall risk.

2.2 Data Collection

2.2.1 Objective

The objective of the data collection phase is to get insights into how the test will be considered to be performed correctly, and what the measurements ensure the validity of the test. This data is critical for training the AI models and ensuring accurate predictions and recommendations.

2.2.2 Data Sources

Data is collected from various sources, including:

- **User Registration:** Users provide basic information such as age, gender, and contact details.
- **Cognitive Health Complaints:** Users report any symptoms or complaints related to cognitive health, such as memory loss, confusion, or difficulty concentrating.
- **Standardized Questionnaires:** Users complete standardized cognitive assessments to provide additional data on their cognitive function.

2.3 System Design and Architecture

2.3.1 Design Objectives

The design of the system focuses on creating a user-friendly interface and robust functionality to ensure that users can easily navigate the system and perform the necessary assessments.

2.3.2 System Components

The system is composed of several key components:

- **User Interface:** A graphical user interface (GUI) designed to be intuitive and accessible. The interface includes a chat room and based on the need for FRT the pop-up of two buttons appears to upload the video or to perform the live FRT.
- **Evaluation Criterian:** The in-context learning of the chatbot is done, and it will ask the questions to the user and based on the user input it will validate the seriousness of the FRT to be performed,

- **FRT Mechanism:** A mechanism for conducting the FRT. Users can either upload a video or perform a live test using their device camera. The system provides real-time guidance and feedback during the test.
- **AI Models:** The core of the system's functionality, these models analyze the data collected during cognitive assessments and the FRT.
- **Recommendation Engine:** A component that generates recommendations based on the results of the FRT and other assessments. The engine guides whether users can have a fall risk or cognition issue or not.

2.3.3 System Architecture Diagram

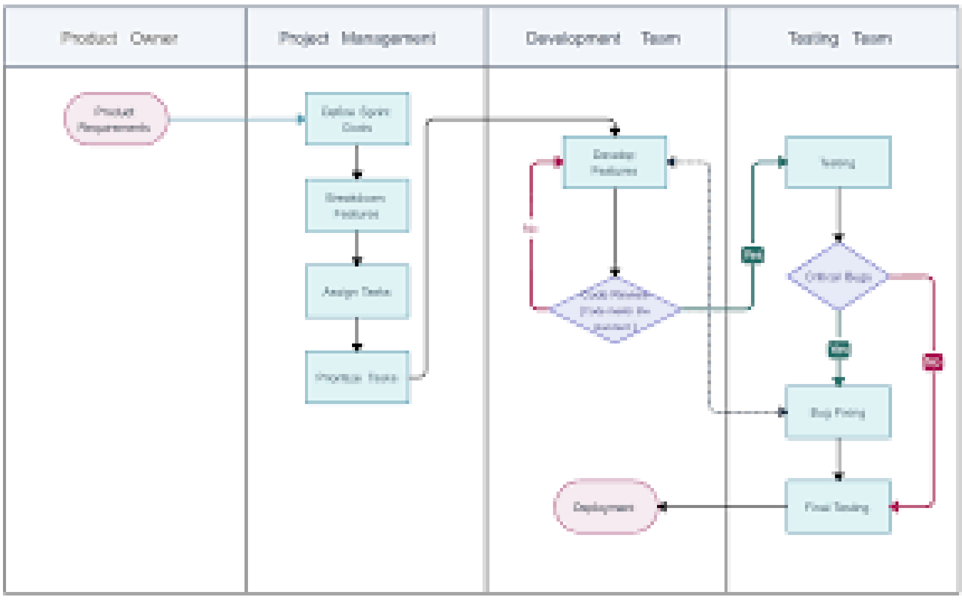

Figure 2: System Architecture Diagram

2.4 Implementation Details

2.4.1 Software Development

The implementation phase involves the development of the software components required for the system:

- **Backend Development:** Includes the development of server-side logic, which includes the in-context of learning of the chatbot before the initialization of the chat.
- **Frontend Development:** Focuses on creating the user interface and ensuring a seamless user experience. This involves designing and coding the GUI elements.
- **Integration:** Ensures that all components of the system work together seamlessly. This includes integrating the chatbot with the user interface and the FRT mechanism which involves the Computer vision script.

2.4.2 Testing and Quality Assurance

Testing is conducted to ensure that the system functions correctly and meets the desired performance criteria:

- **Unit Testing:** Individual components of the system are tested to ensure they work as intended.
- **Integration Testing:** Ensures that different components of the system interact correctly and data flows seamlessly between them.
- **User Testing:** Involves real users testing the system to provide feedback on usability and functionality.
- **Live Testing:** Because there is no data available on the internet where the person is performing the FRT, we did it ourselves on multiple videos of our team.

2.5 Evaluation and Validation

2.5.1 Performance Metrics

The performance of the system is evaluated based on several metrics:

- **Accuracy:** The accuracy of the AI models in predicting the need for the FRT and analyzing test results.
- **Usability:** User feedback on the ease of use and overall experience with the system.
- **Reliability:** The consistency of the system's performance across different users and testing conditions.

2.6 Challenges and Solutions

2.6.1 Challenges

Several challenges were encountered during the development process:

- **Data Quality:** Ensuring that the very informative and to-the-point prompt is to be made for the in-context learning of the model.
- **Real time Distance Measurement:** It is very hard to exactly measure the real-time distance from the camera.
- **User Privacy:** Protecting user data and maintaining privacy while providing accurate assessments.

2.6.2 Solutions

Solutions to these challenges include:

- **In-context learning:** Did thorough research and made multiple prompts for the in-context learning and chose the one that provides the great results.

- **Real time Distance Measurement:** To measure the distance we have used the hard-coded value of 100, which worked pretty well in measuring the distance. where we added this value in the monitored points value to get the estimated value in "cm" which was pretty accurate.
- **Privacy Protection:** Adopting strict data security measures and privacy policies to safeguard user information.

2.7 Future Enhancements

Future enhancements to the system may include:

- **Integration of Additional Assessments:** Adding more cognitive and physical assessments to provide a comprehensive evaluation.
- **Enhanced Computer Vision Models:** Incorporating advanced techniques to improve accuracy and performance while performing the test.
- **User Personalization:** Customizing the system based on individual user profiles and preferences to enhance the user experience.

3 Tools Used

3.1 Software and Libraries

The following software and libraries were used in the development of the project:

- **Python:** The primary programming language used for developing the AI models and system components.
- **TensorFlow and PyTorch:** Deep learning frameworks used for building and training the AI models.
- **OpenCV:** A computer vision library used for video processing and analysis.
- **Flask:** A web framework used for developing the user interface and backend services.
- **MediaPipe:** An open-source framework for building and deploying machine-learning pipelines.

3.2 Hardware

The project required specific hardware to ensure optimal performance and efficiency:

- Devices with camera capabilities for performing the Functional Reach Test (FRT).
- Secure servers for data storage and processing.

3.3 Experimental Setup

The experimental setup involves the following components:

- **Data Collection:** Collecting user data through the system interface, including personal details, cognitive health complaints, and initial assessments.
- **AI Model Training:** Training AI model on in-context learning mechanism. The models are trained to predict the need for the FRT and analyze FRT performance.
- **Evaluation and Testing:** Conducting thorough testing and evaluation to assess the system's performance, usability, and accuracy.

4 Experimental Setup

4.1 Overview

The experimental setup for the Generative AI system involves configuring the environment where the system will be tested and validated. This includes setting up the hardware and software, defining experimental protocols, and conducting experiments to assess system performance and reliability. The goal is to ensure that the system performs accurately and efficiently in real-world scenarios.

4.2 Equipment and Software Requirements

4.2.1 Hardware Requirements

- **User Devices:**
  - **Smartphones/Tablets:** Equipped with high-resolution cameras and recent versions of operating systems (iOS or Android)
  - **Computers:** Desktop or laptop computers with modern processors and sufficient RAM (8 GB or more)
- **External Devices:**
  - **Webcams:** High-definition webcams for live FRT

4.2.2 Software Requirements

- **Development Tools:**
  - **Programming Languages:** Python, JavaScript, etc.
  - **Frameworks and Libraries:** TensorFlow, PyTorch, OpenCV, etc.
  - **Development Environment:** Integrated Development Environment (IDE) such as PyCharm or Visual Studio Code
- **System Software:**
  - **Operating System:** Linux or Windows Server for backend systems

4.3 Experimental Procedures

4.3.1 Preparation Phase

- **System Installation:**
  - Install and configure the backend server and database.
  - Deploy the frontend application and ensure proper integration with the backend.
  - Set up and calibrate external devices (webcams, microphones) as needed.
- **User Preparation:**
  - Recruit participants for user testing and obtain informed consent.
  - Provide instructions to users on how to use the system and perform the FRT.

4.3.2 Experimental Execution

- **Functional Testing:**
  - Conduct tests to ensure that each component of the system (user interface, AI models, FRT mechanism) functions correctly.
  - Verify that the system can handle various types of user input and scenarios.
- **Performance Testing:**
  - Measure the system's response time and throughput under different load conditions.
  - Assess the system's ability to handle concurrent users and large datasets.
- **User Testing:**
  - Have users perform cognitive assessments and FRT using the system.
  - Collect feedback on the user experience, ease of use, and system performance.
- **Accuracy Evaluation:**
  - Compare the system's predictions and recommendations with clinical assessments and expert evaluations.
  - Use statistical methods to calculate accuracy.

4.3.3 Post-Experiment Phase

- **Data Analysis:**
  - Analyze collected data to identify trends, performance metrics, and areas for improvement.
  - Review user feedback and system logs to evaluate user experience and identify issues.
- **System Optimization:**
  - Based on experimental results, make adjustments to the AI models, user interface, or system components to enhance performance and accuracy.
  - Update the system with improvements and new features based on user feedback.
- **Documentation and Reporting:**
  - Document experimental procedures, results, and any issues encountered.
  - Prepare a comprehensive report detailing the experimental setup, findings, and recommendations for further development.

4.4 Evaluation Methods

4.4.1 Performance Metrics

- **System Accuracy:**
  - Measure the accuracy of AI models in predicting the need for FRT and analyzing test results.
- **Usability Metrics:**
  - Assess user satisfaction through surveys and feedback forms.
  - Evaluate ease of use, user interface design, and overall user experience.
- **Reliability Metrics:**
  - Monitor system stability and performance over time.
  - Track error rates, system crashes, and other reliability indicators.

4.4.2 Validation Methods

- **Clinical Validation:**
  - Compare the system's outputs with clinical assessments conducted by healthcare professionals.
  - Ensure that the system's recommendations align with expert evaluations.
- **Cross-Validation:**
  - Use cross-validation techniques to evaluate the performance of AI models and prevent overfitting.
  - Divide data into training and validation sets to assess model generalization.
- **User Feedback:**
  - Collect and analyze user feedback to identify areas for improvement.
  - Incorporate user suggestions into system updates and enhancements.

5 Conclusion

This project demonstrates the potential of Generative AI and Computer Vision in enhancing cognitive health assessments and balance evaluations through the Functional Reach Test (FRT). By leveraging AI technology, we have developed a system that provides accessible, efficient, and reliable cognitive health assessments, particularly in remote and underserved areas.

The system's ability to conduct assessments using widely available technology such as smartphones and tablets makes it a valuable tool for early detection and intervention of cognitive decline and balance issues. The integration of advanced AI models ensures accurate and objective assessments, reducing the burden on healthcare professionals and improving patient outcomes.

Future work will focus on further refining the AI models, expanding the dataset to enhance model performance, and exploring additional assessment tools to provide a comprehensive cognitive health evaluation system. The ultimate goal is to improve the quality of life for individuals at risk of cognitive decline and balance issues by providing timely and accurate assessments and interventions.

References

[1] Duncan, P. W., Weiner, D. K., Chandler, J., Studenski, S. (1990). Functional reach: a new clinical measure of balance. *J Gerontol*, 45(6), M192-M197.

[2] Rubenstein, L. Z. (2006). Falls in older people: epidemiology, risk factors, and strategies for prevention. *Age Ageing*, 35(suppl$_2$), $ii37 - ii41$.

[3] Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., DePristo, M., Chou, K., ... Dean, J. (2019). A guide to deep learning in healthcare. *Nat Med*, 25(1), 24-29.

[4] Inouye, S. K., Studenski, S., Tinetti, M. E., Kuchel, G. A. (2007). Geriatric syndromes: clinical, research, and policy implications of a core geriatric concept. *J Am Geriatr Soc*, 55(5), 780-791.

[5] Topol, E. J. (2019). High-performance medicine: the convergence of human and artificial intelligence. *Nat Med*, 25(1), 44-56.