QuAlz: Quantum Alzheimer Detection

INNOVATIVE QUANTUM METHODS FOR EARLY DISEASE DIAGNOSIS

INTRODUCTION

QuAlz: Quantum Alzheimer Detection

Project Motivation

QuAlz aims to tackle the challenge of delayed Alzheimer's diagnosis through innovative quantum computing methods.

Quantum Image Processing

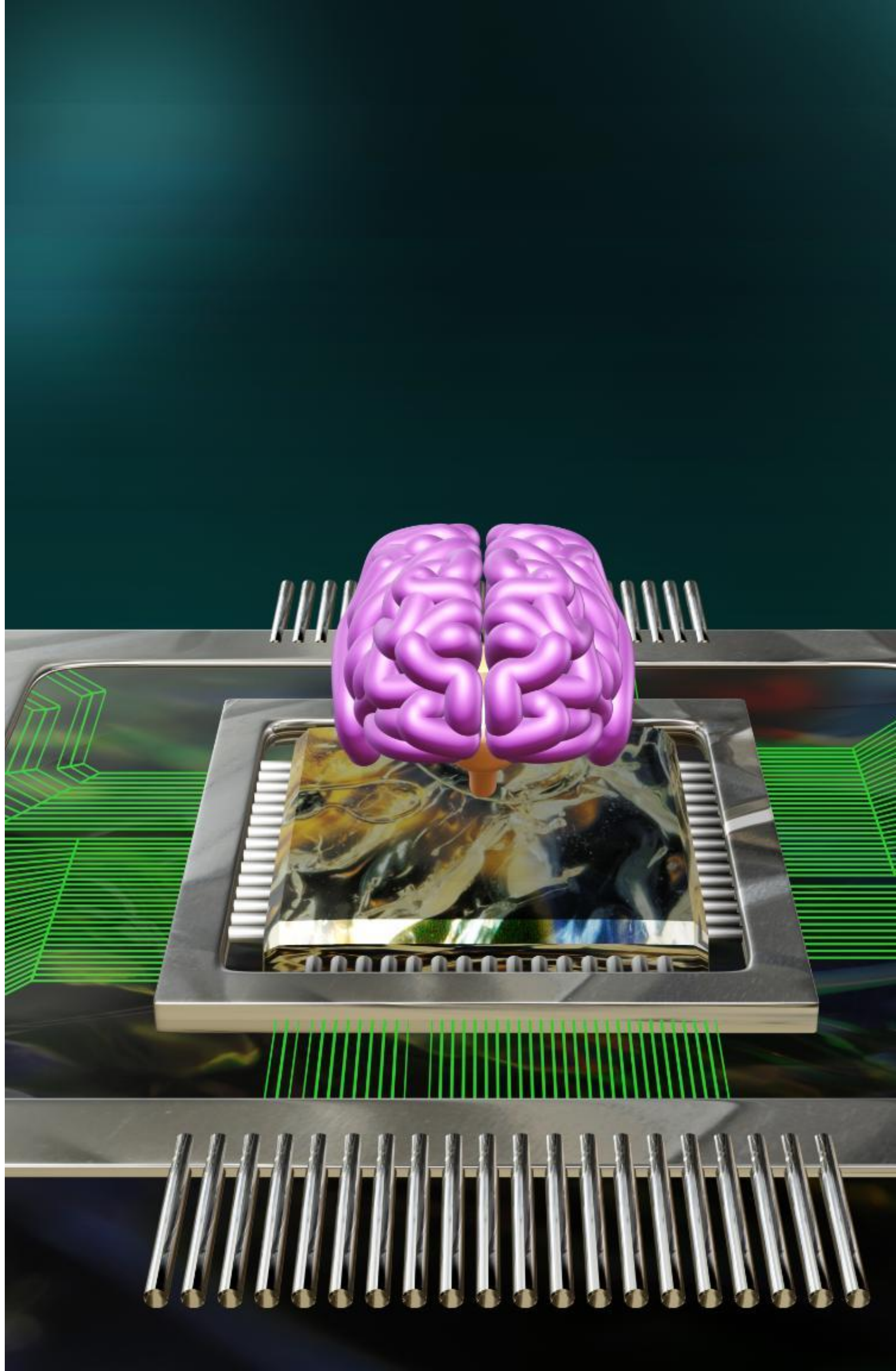
The project utilizes advanced quantum image processing techniques combined with medical imaging to enhance early detection.

Interdisciplinary Collaboration

A diverse team of students and mentors integrates quantum technology and healthcare expertise to develop QuAlz.

Impact on Healthcare and Quantum Computing

QuAlz represents a significant step in applying quantum technologies to real-world medical challenges like Alzheimer's disease.



PROBLEM AND SOLUTION

Problem Statement

Rising Alzheimer's Cases

Global Alzheimer's cases have increased by over 600%, creating urgent healthcare challenges.

Diagnosis Delays

MRI scan analysis delays exceed eight weeks, hindering timely Alzheimer's diagnosis and treatment.

Data Processing Challenges

Large MRI data volumes strain healthcare systems, complicating efficient storage and analysis.

Need for Efficient Tools

There is an urgent need for fast, scalable diagnostic tools that integrate with existing healthcare systems.

Solution Overview

Quantum-Enhanced MRI Processing

MRI scans are preprocessed and converted into quantum-compatible formats using theta encoding for advanced analysis.

Flexible Quantum Image Representation

The Flexible Representation of Quantum Images (FRQI) builds quantum circuits to represent MRI data effectively.

Fidelity-Based Classification

Quantum circuits are analyzed with fidelity-based classifiers to detect Alzheimer's presence efficiently.

Efficient and Scalable Diagnosis

This quantum approach reduces diagnosis time and storage needs, ensuring compatibility with current MRI systems.

TECHNICAL WORKFLOW

Workflow

MRI Scan Acquisition and Preprocessing

The workflow starts with MRI scan acquisition and preprocessing including resizing, cropping, and enhancement of images.

Theta Encoding for Quantum Representation

Pixel intensities are converted into theta values between 0 and $\pi/2$ for quantum encoding of images.

FRQI Quantum Circuit Construction

Theta-encoded vectors form FRQI quantum circuits representing images as quantum states.

Fidelity-Based Nearest Centroid Classifier

A fidelity-based nearest centroid classifier compares test images to reference states for Alzheimer detection.

Preprocessing Details

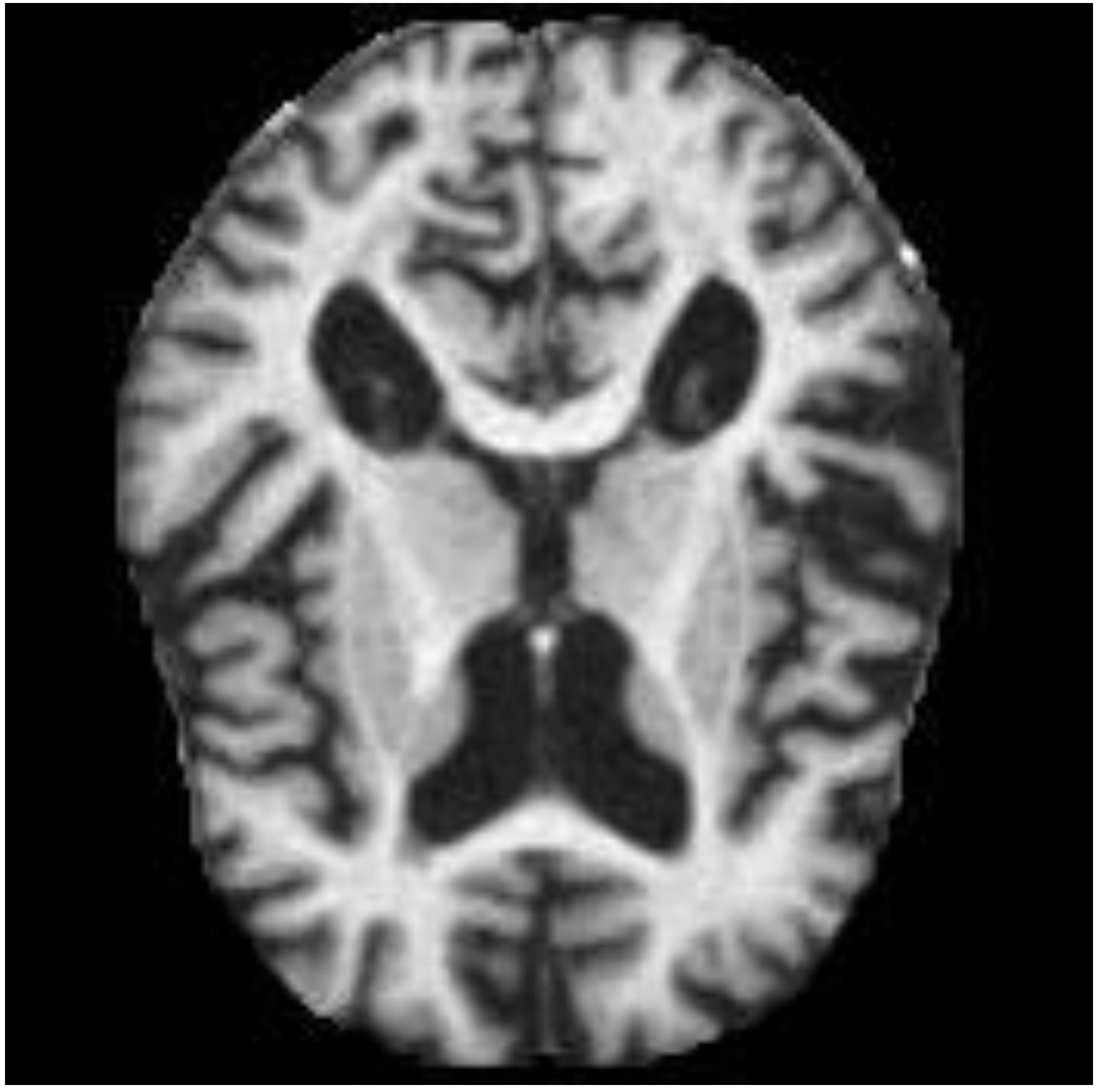


Image Conversion and Classification

The dataset of 6,400 MRI images is converted into a binary classification problem: Non-Demented vs Demented.

Image Enhancement Techniques

Resizing, contrast enhancement, and histogram equalization are applied to improve image quality.

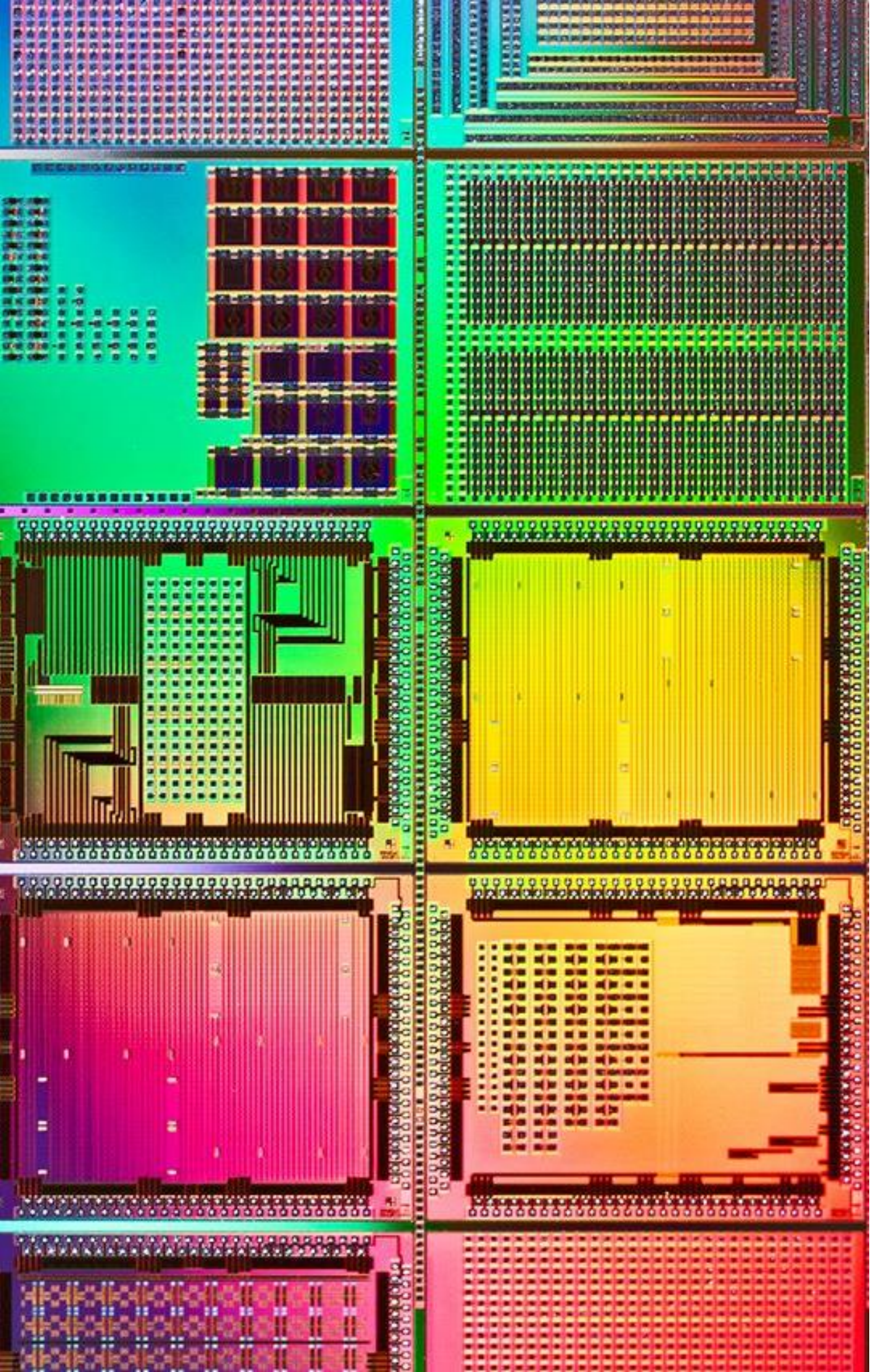
Focusing on Brain Regions

Center cropping is used to focus on relevant brain regions critical for diagnosis.

Quantum Data Encoding

Pixel values are normalized and converted into theta angles for quantum encoding and analysis.

QUANTUM PROCESSING



Quantum Encoding (FRQI)

Quantum Image Representation

FRQI encodes 16×16 image patches as quantum states using 8 qubits for pixel addresses.

Pixel Intensity Encoding

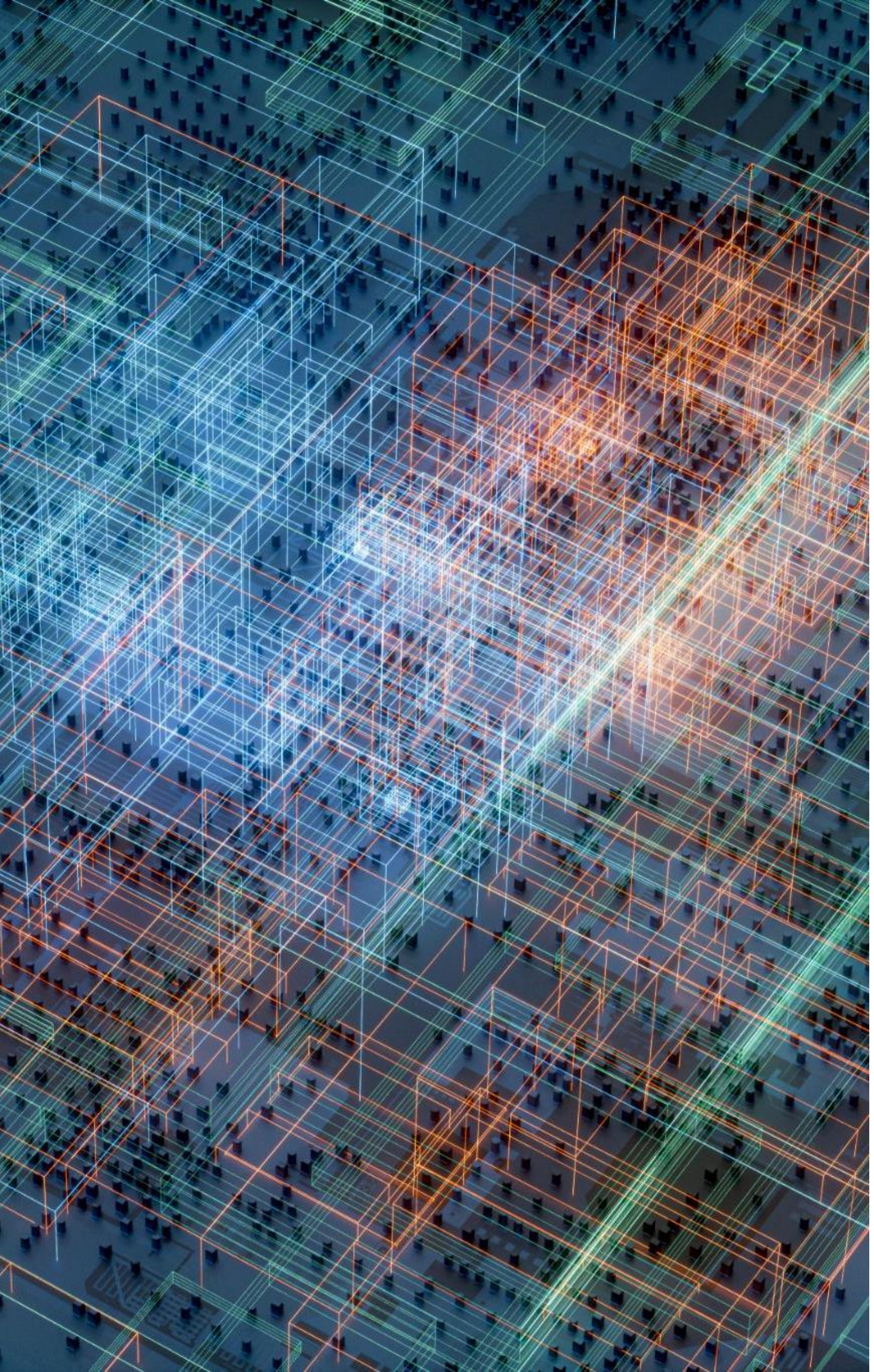
An ancillary qubit encodes pixel intensity through controlled RY rotations in the quantum circuit.

Efficient Quantum Analysis

FRQI enables complex image analysis by compactly representing data for quantum algorithm processing.

Application in MRI Classification

The encoding method is suitable for MRI scan classification through quantum circuit transformations.



Classifier & Metrics

Fidelity-Based Classifier

QuAlz uses a nearest centroid classifier based on fidelity to measure similarity between test and reference quantum states.

Types of Fidelity Metrics

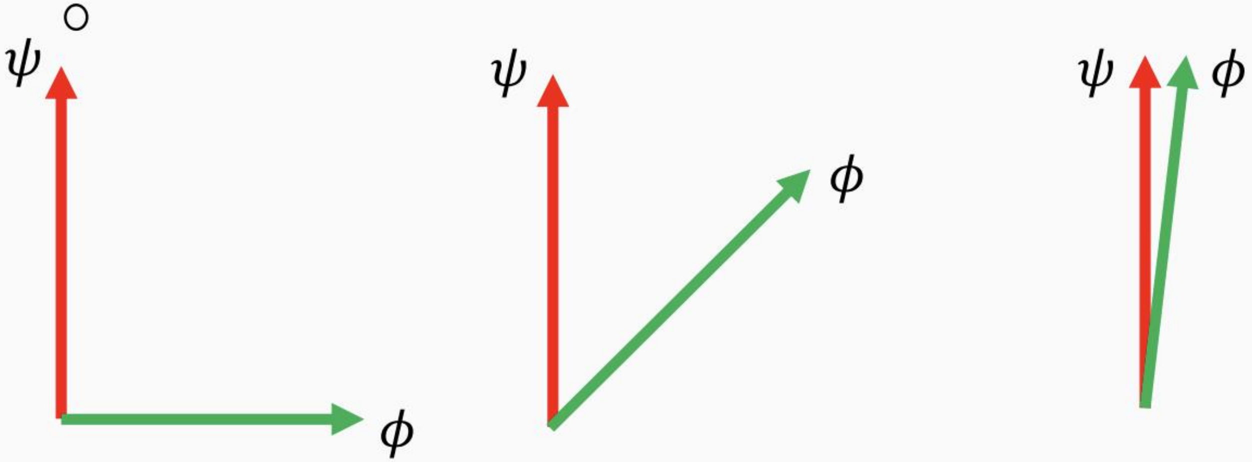
Statevector fidelity provides exact simulation, while shot-noise fidelity models real quantum hardware noise effects.

Classification Process

The classifier calculates inner products and applies a threshold to classify images as Non-Demented or Demented.

Robustness and Accuracy

This method is robust against noise, offering high accuracy and enhancing scalability with quantum fidelity metrics.



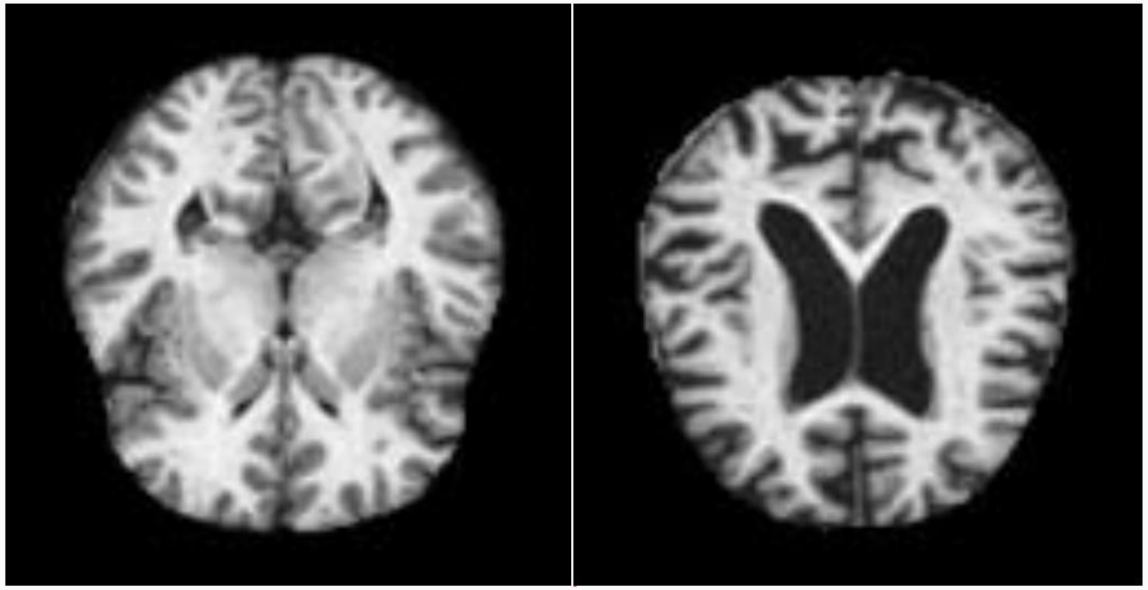
Not At All Similar
Score: 0

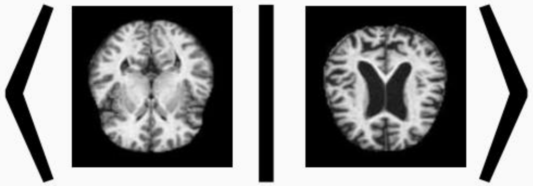
Somewhat Similar
Score: 0.5

Very Similar
Score: 0.9

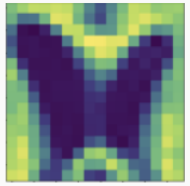
$$\langle \psi | \phi \rangle$$

Non-Demented **Demented**

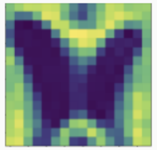
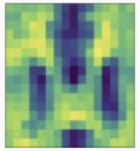




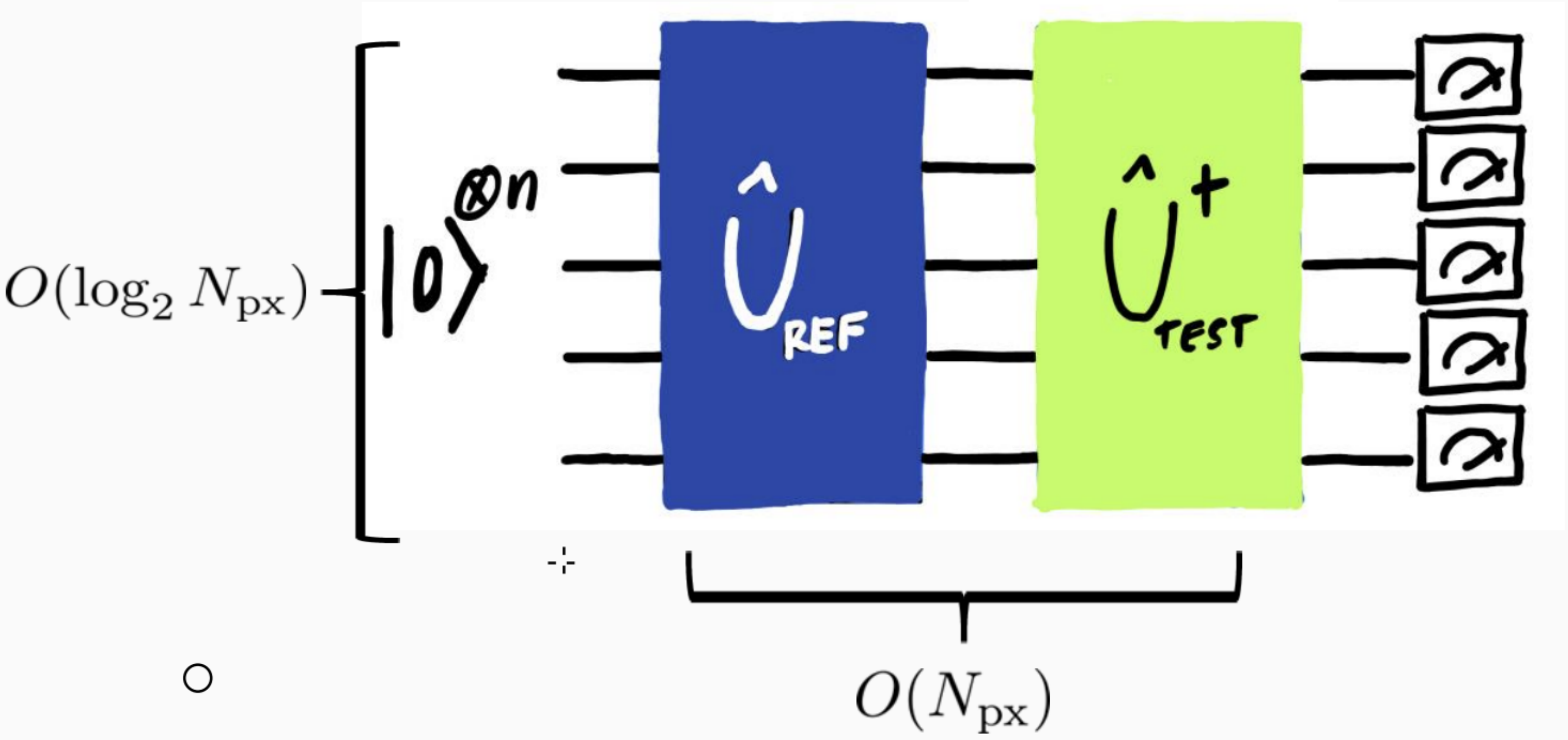
FRQI and Fidelity Estimation

 → $|\psi\rangle$

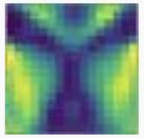
$\theta_0, \|0000\rangle$	$\theta_1, \|0001\rangle$	$\theta_2, \|0010\rangle$	$\theta_3, \|0011\rangle$
$\theta_4, \|0100\rangle$	$\theta_5, \|0101\rangle$	$\theta_6, \|0110\rangle$	$\theta_7, \|0111\rangle$
$\theta_8, \|1000\rangle$	$\theta_9, \|1001\rangle$	$\theta_{10}, \|1010\rangle$	$\theta_{11}, \|1011\rangle$
$\theta_{12}, \|1100\rangle$	$\theta_{13}, \|1101\rangle$	$\theta_{14}, \|1110\rangle$	$\theta_{15}, \|1111\rangle$

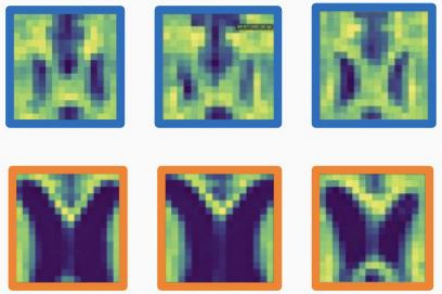
$|\psi_{ref}\rangle =$  $|\psi_{test}\rangle =$ 

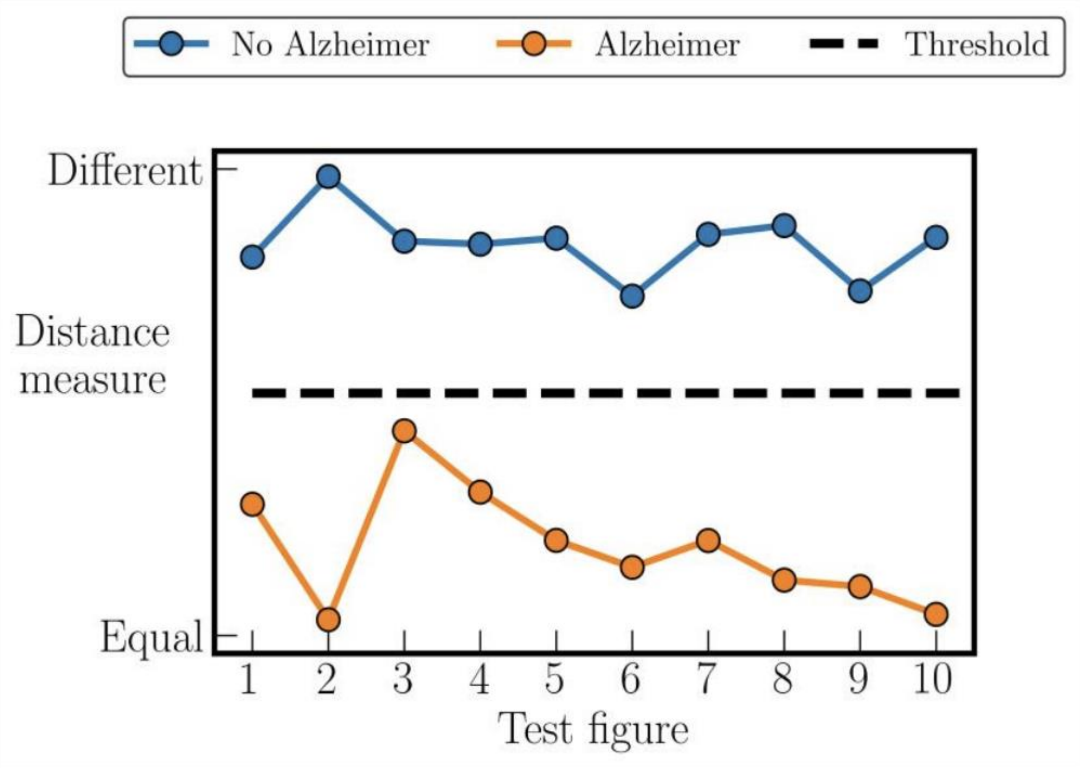
$$\text{Fidelity} = |\langle\psi_{ref}|\psi_{test}\rangle|^2$$



Results

$|\psi_{ref}\rangle =$ 

$|\psi_{test}\rangle = \{$  $, \ldots \}$



EVALUATION AND IMPACT

Results

Effectiveness in MRI Classification

QuAlz effectively distinguishes Non-Demented from Demented MRI scans through high fidelity scoring.

Quantum Classifier Performance

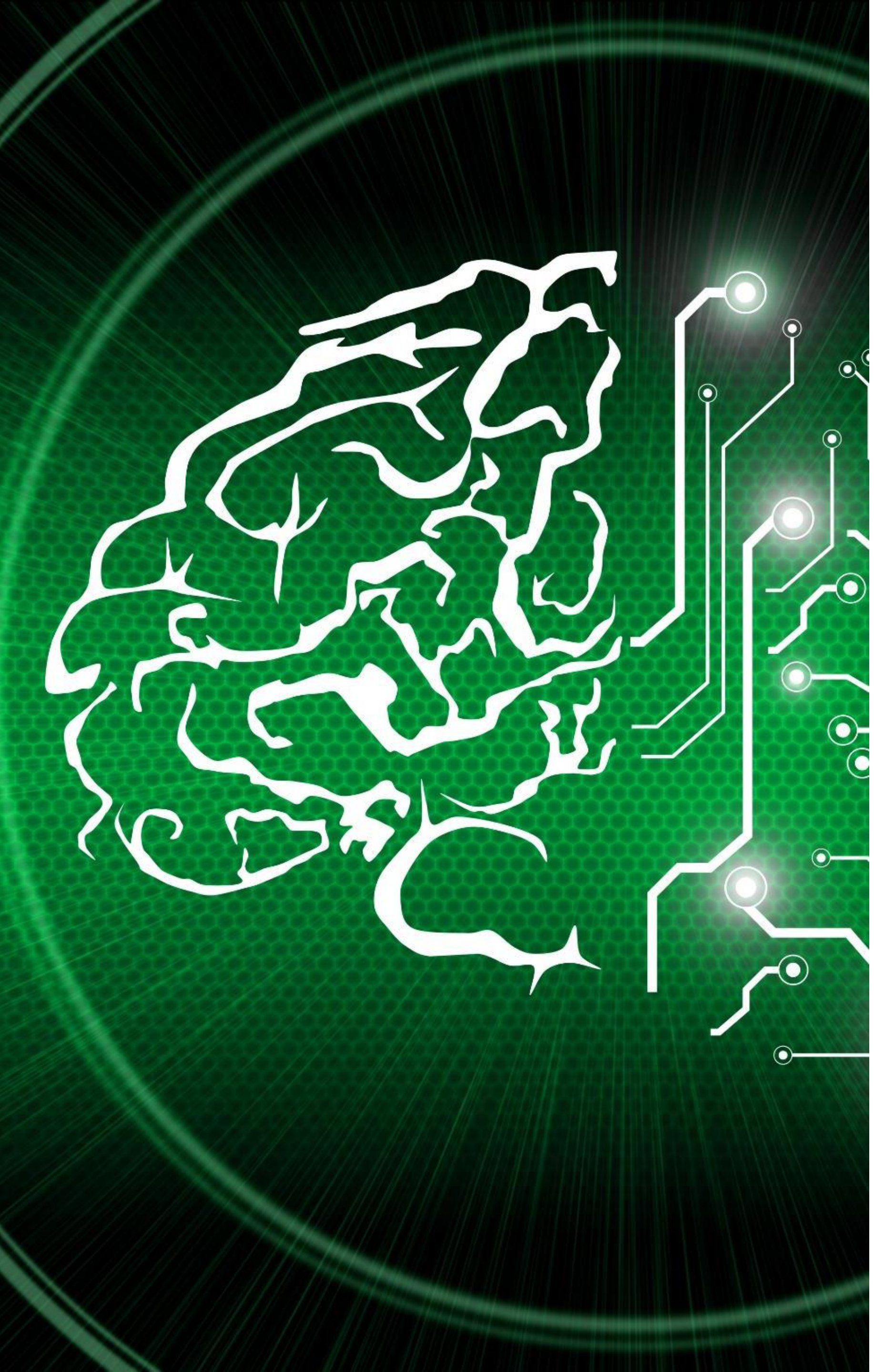
The quantum classifier demonstrated superior accuracy and speed compared to classical methods in some cases.

Validation Metrics

L2 distance and closeness metrics were used to validate the model's performance and reliability.

Quantum Healthcare Potential

These results highlight quantum computing's promise in medical diagnostics and future healthcare applications.



Advantages

Reduced Diagnosis Time

QuAlz leverages quantum processing to significantly speed up Alzheimer diagnosis compared to traditional methods.

Efficient Storage Usage

Efficient encoding and preprocessing techniques reduce storage space requirements for diagnostic data.

Compatibility with MRI

QuAlz integrates easily with existing MRI infrastructure, supporting seamless adoption in medical workflows.

Scalability for Future

The quantum classifier is scalable, allowing for future improvements as quantum hardware advances.

COMMUNITY AND BUSINESS IMPACT

Business & Community Impact

Open-Source Collaboration

QuAlz promotes innovation by contributing quantum tools to open-source communities focused on healthcare.

Partnerships and Development

The project fosters partnerships with NGOs, governments, and research institutions for advancing quantum healthcare.

Educational Advancement

QuAlz enhances learning by promoting quantum computing education for students and professionals.

Improving Patient Outcomes

By driving adoption of quantum technologies in diagnostics, QuAlz aims to improve healthcare results.

Thank You

Team:
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