Neurosymbolic AI for ADRD Classification:

Comparing Pure LLM vs. Hybrid Approaches

A Comprehensive Paper Outline and Pipeline Code Review

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PART I: PAPER OUTLINE

Abstract

Background: Alzheimer's Disease and Related Dementias (ADRD) classification from clinical notes remains challenging due to complex diagnostic criteria requiring integration of cognitive assessments, functional status, and differential diagnosis.

Objective: To compare the performance of pure LLM-based classification versus a neurosymbolic AI approach that integrates LLM reasoning with deterministic symbolic computation and knowledge retrieval for ADRD classification using NIA-AA criteria.

Methods: We developed ClinOrchestra, a neurosymbolic orchestration platform that combines: (1) LLM reasoning for natural language understanding, (2) symbolic functions for deterministic clinical score interpretation (MoCA, MMSE, CDR), (3) RAG-based retrieval from clinical guidelines, and (4) domain-specific hints.

1. Introduction

Research Questions:

RQ1: How does pure LLM classification compare to neurosymbolic hybrid approaches?
RQ2: Does integrating symbolic functions improve classification accuracy?
RQ3: What role does RAG-based guideline retrieval play in performance?
RQ4: Can neurosymbolic approaches provide more interpretable reasoning chains?

2. Methods

2.1 Study Design

Comparison Arms:

- Arm 1 (Control): Pure LLM classification with NIA-AA prompt only
- Arm 2 (Treatment): Neurosymbolic approach (LLM + Functions + RAG + Extras)

2.2 Neurosymbolic Architecture

The ClinOrchestra platform implements a 4-stage pipeline:

Stage 1: Task Analysis - LLM analyzes clinical text and determines required tools
Stage 2: Tool Execution - Functions, RAG, and Extras execute in parallel
Stage 3: Synthesis - LLM combines all tool outputs into structured JSON
Stage 4: RAG Refinement - Optional evidence-based verification

2.3 Symbolic Functions for ADRD

Function	Purpose	Output
interpret_moca	MoCA score interpretation	impairment_level
interpret_mmse	MMSE score interpretation	severity
calculate_cdr_severity	CDR global score	category
count_domains	NIA-AA domain count	meets_criteria
check_dementia_criteria	Full criteria check	classification

3. Expected Results

Hypotheses:

H1: Neurosymbolic approach will achieve higher accuracy than pure LLM
H2: Symbolic function integration will reduce score interpretation errors
H3: RAG retrieval will improve guideline adherence
H4: Neurosymbolic reasoning will be more interpretable

PART II: PIPELINE CODE REVIEW

1. ClinOrchestra Architecture Overview

ClinOrchestra is a task-agnostic neurosymbolic AI orchestration platform that combines:

- Neural reasoning (LLMs) for natural language understanding
- Symbolic computation (deterministic functions) for grounded calculations
- Knowledge retrieval (RAG) for guideline-based evidence
- Domain hints (Extras) for contextual knowledge injection

Key Files:

- core/agent_system.py: STRUCTURED 4-stage extraction pipeline
- core/function_registry.py: Manages deterministic Python functions
- core/regex_preprocessor.py: Text normalization patterns
- core/rag_engine.py: FAISS-based retrieval from guidelines
- core/extras_manager.py: Domain-specific knowledge hints

2. Strengths of Current Implementation

Clinical Accuracy:

- Functions correctly implement NIA-AA and DSM-5 guidelines
- Education-adjusted scoring (MoCA, SLUMS)
- CDR 0.5 ambiguity correctly handled (critical MCI vs dementia distinction)

Architecture Quality:

- Clean separation of neural vs. symbolic concerns
- Task-agnostic design (reusable for other clinical tasks)
- Parallel tool execution for performance
- Adaptive retry with metrics tracking

Appendix: NIA-AA Criteria Summary

Dementia Criteria (Table 1)

Cognitive or behavioral symptoms that:

1. Interfere with ability to function at work or usual activities
2. Represent decline from previous levels of functioning
3. Not explained by delirium or major psychiatric disorder

AND cognitive impairment in minimum TWO domains:

- Memory: repetitive questions, misplacing items, forgetting events, getting lost
- Executive: poor safety understanding, cannot manage finances, poor decisions
- Visuospatial: cannot recognize faces/objects, cannot find objects
- Language: word-finding difficulty, hesitations, speech/writing errors
- Behavior: mood fluctuations, agitation, apathy, loss of drive, withdrawal

MCI Criteria (Table 1)

- Cognitive concern reflecting change, reported by patient/informant/clinician
- Objective evidence of impairment in >= 1 cognitive domain
- PRESERVATION OF INDEPENDENCE in functional abilities
- Not demented

KEY DISTINCTION: MCI vs. Dementia = Functional Independence

- MCI: Cognitive impairment WITH preserved independence
- Dementia: Cognitive impairment WITH functional decline