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Healthcare Assistance Challenges-Driven Neurosymbolic AI

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ABSTRACT

Although Artificial Intelligence technology has proven effective in providing healthcare assistance by analyzing health data, it still falls short in supporting decision-making. This deficiency largely stems from the predominance of opaque neural networks, particularly in mental health care AI applications, which raise concerns about their unpredictable and unverifiable nature. This skepticism hinders the transition from information support to decision support. This presentation will explore neurosymbolic approaches that combine neural networks with symbolic control and verification mechanisms. These approaches aim to unlock AI's full potential by enhancing information analysis and decision-making support for healthcare assistance.

A Domain Agnostic Technical Primer

Consider the dataset $X = \{(1,1),(2,4),(3,9)\}$, in- dexed by $\chi_i, i \in \{1,2,3\}$ generated from the ground truth function $f:\chi \to \chi^2$ .Symbolic AI approaches would involve first gathering domain expertise regarding reconstructing the ground truth function, for example, by starting with the set of mappings $\hat{f}:\chi \to \chi, \hat{f}:\chi \to \chi^2$,and $\hat{f}:\chi \to \chi^3$, and then letting an expert human map each point in $\chi_i \in X$. The expert human might map $\chi_1 = (1,1)$ to the mapping $\hat{f}:\chi \to \chi, \chi_2 = (2,4)$ to the mapping $\hat{f}:\chi \to \chi^2$, and $\chi_3 = (3,9)$ to the mapping $\hat{f}:\chi \to \chi^2$. Subsequently, this mapping can be consolidated to obtain the symbolic approximation as follows:

$$f = \begin{cases} \hat{f}: x \to x, x = 1, \\ \hat{f}: x \to \hat{x}^2, x \neq 1. \end{cases} \quad (1)$$

It is clear from Equation 1 that symbolic AI can lead to wrong approximations due to legitimate human errors (e.g., mapping $x_1 = (1,1)$ to $\hat{f}:\chi \to \chi$ instead of $\hat{f}:\chi \to \chi^2$). Note that although this approximation is inaccurate, it still generalizes well to all cases of $f:\chi \to \chi^2$; Generalization is a powerful benefit of symbolic AI.

Neural AI approaches would involve learning a parameterized neural network $\hat{f}_{\theta*}:(\chi,\theta^*) \to \chi^2$ to approximate the ground truth function $f:\chi \to \chi^2$. This is done by finding the parameters that minimize the expected value of a loss with respect to the data, i.e.,

$$\hat{\theta} = \arg\min_{\theta} E_{xi} \in X\left[loss(f - \hat{f}_{\theta})\right]$$

Such a function is expected to do well on the training data but generalize poorly too far outside of the training distribution [1]. Furthermore, a significant disadvantage of Neural AI is its black-box nature makes it challenging to interpret and analyze the mappings from inputs to outputs.

Neurosymbolic AI involves using a neural network to first map the data in X to one of the mappings among $\hat{f}:\chi \to \chi, \hat{f}:\chi \to \chi^2$, and $\hat{f}:\chi \to \chi^3$. A neural network will not make the error that the hu- man did in the symbolic AI case, and correctly map $(1,1)$ to $f:\chi \to \chi^2$ in relation to the other data points in X (by minimizing the loss mentioned in the neural AI subsection). Consequently, when such a mapping is consolidated, we obtain an approximation $\hat{f}:\chi \to \chi^2$,which exactly matches the ground truth. This approximation is accurate, does well onthe training data, and generalizes to all $\chi \in \mathbb{R}^1$. In this way, neurosymbolic AI combines the benefits of both neural and symbolic AI.

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Challenges in AI for Health- care

Individual Centric Challenges

These challenges are related to the assistance provided by an AI system in individual-specific assessments (e.g., diagnostic or symptom assessments) and recommendations (e.g., treatment methods). The core challenges lie in adequately capturing the individual's context and adhering to decision-making processes followed by human experts. An Example of Contextualized and Expert Procedure Compliant Decision-Making A person suffering from the most severe form of depressive dis- order must be determined by a PHQ-9 questionnaire-based assessment (specifically, must score in the range of 10-14 on the PHQ-9 assessment scale) (adherence to process followed by expert). Furthermore, the recommended treatment route is pharmacotherapy; however, if the person is found to be exhibiting symptoms of pregnancy, pharmacotherapy is undesirable (contextualized compliance with expert processes).

Overall Infrastructure-Centric Challenges

In the United States, infrastructure issues are one major obstacle to accessing healthcare and implementing AI-driven healthcare support. These include challenges such as healthcare providers struggling to access essential information and protocols within the health- care system. A significant hurdle is creating an AI system that can efficiently navigate the intricate layers of information within the system, helping healthcare professionals streamline care delivery for patients in need. Figure 1 illustrates a concept of AI for tackling infrastructure issues.

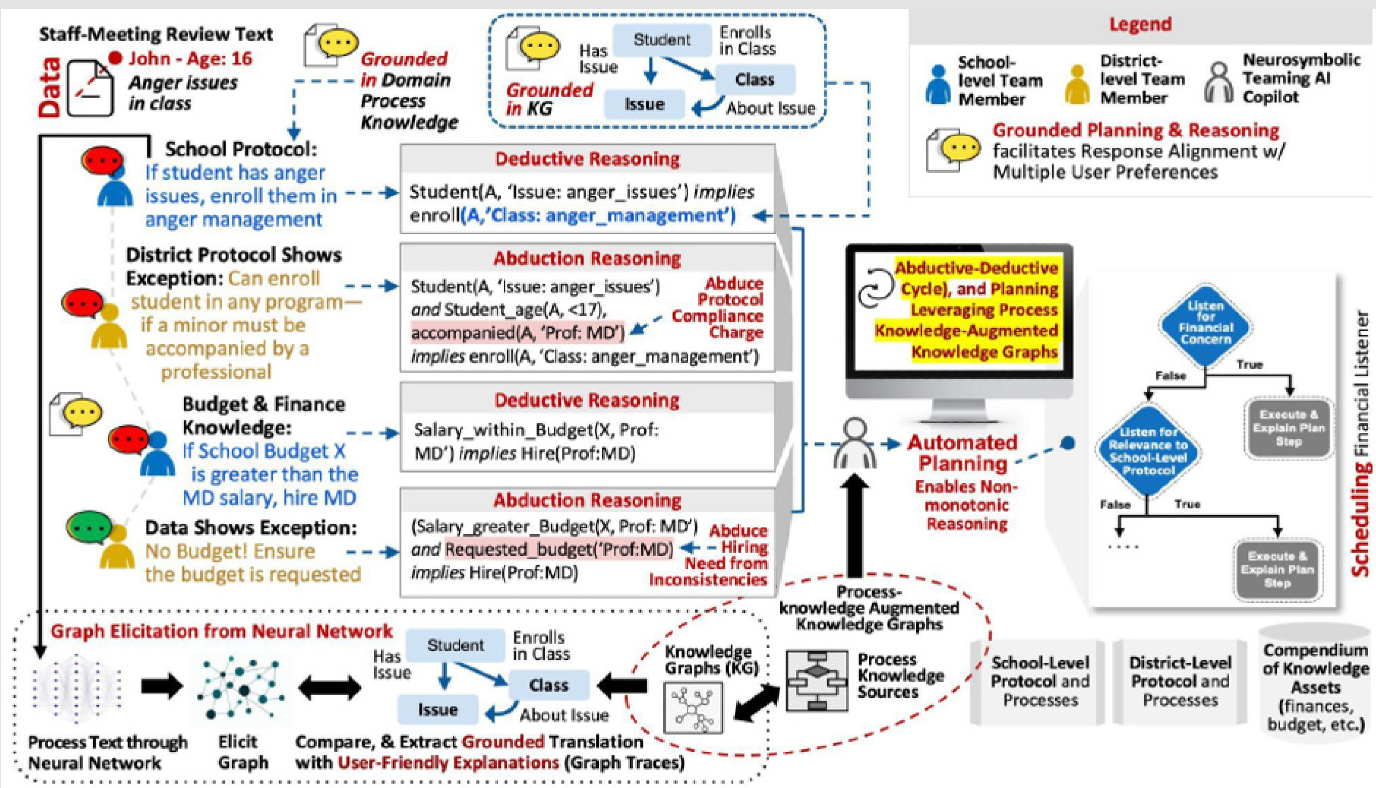

Figure 1: A Vision for a neurosymbolic planning and reasoning-based AI system for facilitating discussions between healthcare professionals by navigating intricate information layers at school and district administration Levels in a healthcare system (This example is from the MTSS system).

Systemic Challenges

For brevity, we refer to the caption in Figure 2 for an explanation of systemic issues such as regulatory compliance, ethical standards, privacy issues, etc.

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Figure 2: An illustration from the talk recording showing how various interdisciplinary efforts must come together to tackle systemic challenges related to AI based assistance for healthcare.

Conclusion

The talk discusses approaches neuro symbolic AI approaches for handling various challenges in implementing AI-based assistance for improving outcomes. It specifically outlines three levels of challenges at the individual-centric level, the infrastructure- centric level, and the systemic level. I hope this talk will foster innovation at the frontiers of human-AI collaboration for healthcare assistance.

Author Bio

Kaushik Roy is currently pursuing his fourth year as a doctoral student at the AI Institute of the University of South Carolina. His research focuses on developing algorithms that merge statistical data-driven learning techniques with domain-specific information from external sources, with a particular emphasis on ap- plications for social good. He has a track record of publishing numerous papers and presenting talks at prestigious conferences, showcasing his work in areas such as AI for mental health assessment support and other socially impactful applications. The publications venues include IEEE [2–13], NeurIPS [14], NAACL [15, 16], AAAI [17–27], Frontiers [28], KR [29], ECML [30], KDD [31–33], ICAPS [34], KGC [35, 36], ACM [37–40], ICLR [41], SPIE [42], IJCAI [43], PyData [44], etc. [45–49].

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