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Fall 10-15-2022

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Publication Info

Preprint version *ACM Proceedings of AIML Systems Conference*, Fall 2022.

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Tutorial: Neuro-symbolic AI for Mental Healthcare

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ABSTRACT

Artificial Intelligence (AI) systems for mental healthcare (MHCare) have been ever-growing after realizing the importance of early interventions for patients with chronic mental health (MH) conditions. Social media (SocMedia) emerged as the go-to platform for supporting patients seeking MHCare. The creation of peer-support groups without social stigma has resulted in patients transitioning from clinical settings to SocMedia supported interactions for quick help. Researchers started exploring SocMedia content in search of cues that showcase correlation or causation between different MH conditions to design better interventional strategies. User-level Classification-based AI systems were designed to leverage diverse SocMedia data from various MH conditions, to predict MH conditions. Subsequently, researchers created classification schemes to measure the severity of each MH condition. Such ad-hoc schemes, engineered features, and models not only require a large amount of data but fail to allow clinically acceptable and explainable reasoning over the outcomes. To improve Neural-AI for MHCare, infusion of clinical **symbolic** knowledge that clinicians use in decision making is required. An impactful use case of Neural-AI systems in MH is conversational systems. These systems require coordination between classification and generation to facilitate humanistic conversation in conversational agents (CA). Current CAs with deep language models lack factual correctness, medical relevance, and safety in their generations, which intertwine with unexplainable statistical classification techniques. This **lecture-style** tutorial will demonstrate our investigations into **Neuro-symbolic** methods of infusing clinical knowledge to improve the outcomes of Neural-AI systems to improve interventions for MHCare: (a) We will discuss the use of diverse clinical knowledge in creating specialized datasets to train Neural-AI systems effectively. (b) Patients with cardiovascular disease express MH symptoms differently based on gender differences. We will show that knowledge-infused Neural-AI systems can identify gender-specific MH symptoms in such patients. (c) We will describe strategies for infusing clinical process knowledge as heuristics and constraints to improve language models in generating relevant questions and responses.

ACM Reference Format:

Kaushik Roy, Usha Lokala, Manas Gaur, and Amit Sheth. 2022. Tutorial: Neuro-symbolic AI for Mental Healthcare. In *Proceedings of 2nd International*

Conference on AI-ML Systems (AIML Systems'22). ACM, New York, NY, USA, 3 pages. <https://doi.org/10.1145/nnnnnnnn.nnnnnnnn>

1 TUTORIAL SCHEDULE AND ACTIVITIES

The tutorial will cover methodologies for classification, generation, and multi-task learning. Although we use MH as the use case, other application domains where domain and process knowledge are critical in decision making will benefit from the methods we will discuss. **Six** modules of the tutorial are:

- (15 mins) Introduction with Use Cases:** We will begin the session motivating the need for Knowledge-infusion based neuro-symbolic AI techniques for use in MHCare. Real-world examples will be used to demonstrate limitations in current statistical and data-driven AI Systems. This will highlight the necessity of duality between data and knowledge for developing explainable AI systems [16], as opposed to the contemporary statistical AI and data driven approaches.
- (30 mins) Explainable Data Creation:** Explainable data refers to resources that leverage guidelines created by subject matter experts (SMEs) in labeling samples of the datasets. For instance, “Reddit C-SSRS Dataset” uses SME-created Columbia Suicide Severity Rating Scale as the scheme to annotate posts from users writing on r/SuicideWatch subreddit [2, 6, 9]. We will discuss **four** such datasets.
- (30 mins) Knowledge-infusion for Classification:** Classification problems in MHCare require end-user clinician to retrospect on the models’ outcomes and reason on it for explanations, followed by documenting the basis of decision (diagnosis, treatment plan) made by the clinician. If the classification scheme is not grounded in clinical knowledge, it would subject to varied interpretations and wrongful conclusions. In this module, we will discuss the use of expert curated ontologies as the source of knowledge to be infused in machine learning classifiers. Further, we will introduce novel evaluation metrics for assessing the effectiveness of the classifiers [2, 3, 13].
- (25 mins) Knowledge-infusion for Language Generation in Conversational Systems:** Drawing on the findings from the infusion in classification-based AI systems, we will investigate parallel methods in generation-based AI systems for conversational AI. In MHCare, question and response generation are not simply conditional on the user query or posts but rather retrieval of knowledge passages, context in previous generated question or response, knowledge context

disambiguation, and logical coherence is equally important for consistent and conceptual-flow-based conversations. We will discuss methods to achieve conceptual flow on MHCare datasets [1, 5]. We will discuss the benefit evaluation metrics based on pre-trained language models to assess AI systems for generation.

(25 mins) Process Knowledge-infused Learning: While covering “knowledge-infusion for generation” we will be focusing on making deep language models capable of generating questions and responses by designing new constraint-based optimization functions [14]. Whereas, in this module, we will enforce logical coherence constraints in deep language models using (a) process knowledge-guided dataset [8], and (b) constraint-based optimization function [12]. We introduce novel evaluation metrics to better judge the performance of AI System.

(30 mins) Knowledge-aware Multi-task Learning: We design a multi-task learning framework for identifying MH symptoms that consider gender language infused in user social media posts using (a) how we built a massive data set for task adaptation, (b) how knowledge aware task adaptive models can help decision making process for clinicians, (c) how to formulate a knowledge aware transformer model and the sources of knowledge used in the design, and (d) how our model provides the clinically relevant outcome [11].

Some of the previous and related tutorials: (a) Knowledge-infused Reinforcement Learning, (b) Explainable AI using Knowledge Graphs [4], (c) Knowledge In-Wisdom Out-Explainable Data for AI [15], (d) Knowledge-infused Deep Learning [7], and (e) Knowledge-infused Learning for Autonomous Driving

2 TUTORIAL ORGANIZER BIOS

Kaushik Roy: He is a Ph.D. student at Artificial Intelligence Institute at the University of South Carolina (AIISC). He completed his master’s in computer science at Indiana University Bloomington and has worked at UT Dallas’s sterling lab. His research interests include statistical relational artificial intelligence, sequential decision making, knowledge graphs, and reinforcement Learning. His work is published in reputed conferences in IEEE, KR, AAAI, and ECML-PKDD. For more details, please visit his webpage.

Usha Lokala: She is a Ph.D. student at AIISC. Her research interests include ontology engineering, knowledge graphs and natural language processing. Her interdisciplinary research funded by NIH, NIDA, and NSF applies ontology, deep learning, and natural language processing in the domain of Public Health, Addiction, Social Media Analysis and Age related Cognition. Her work has been published in reputed conferences and Journals (IEEE, Drug and Alcohol Dependence, WWW, CPDD, AAAI ICWSM, JMIR, PLOS One). [10]’s work on public health addictions won second prize in Opioid Challenge at SBP BRiMS 2018, a computational social science conference. For more details, please visit her webpage.

Manas Gaur: He is an Assistant Professor at the University of Maryland Baltimore County (UMBC) Department of Computer

Science. His research expertise uses knowledge graphs, artificial intelligence, and natural language processing methods for knowledge-intensive language understanding applications such as conversational AI, summarization, and recommender systems. Before UMBC, I was a senior research scientist in the AI Center in Samsung Research America, a visiting researcher at Alan Turing Institute, and a Ph.D. student with Dr. Amit Sheth in the AIISC. His work has been covered through media articles, podcast interviews, and invited keynotes. For more details, please visit his webpage

Amit Sheth: He is an Educator, Researcher, and Entrepreneur. He is the founding director of AIISC and NCR Chair at The University of South Carolina. Previously, he was the Lexis-Nexis Ohio Eminent Scholar and the executive director of Ohio Center of Excellence in Knowledge-enabled Computing. He is a Fellow of IEEE, AAAI, ACM, and AAAS. He has organized >100 international events (general/program chair, organization committee chair), >70 keynotes, given >45 many well-attended tutorials and is among the well-cited computer scientists. He has founded three companies by licensing his university research outcomes, including the first Semantic Web company in 1999 that pioneered technology similar to what is found today in Google Semantic Search and Knowledge Graph. Several commercial products and deployed systems have resulted from his research. For more details, please visit his webpage.

3 TUTORIAL AUDIENCE AND PREREQUISITES

This tutorial will bring researchers in academic, industry, and healthcare practitioners at the confluence of knowledge representation, reasoning, semantic linking, NLP, and deep learning. Since it is a lecture style tutorial, basic understanding of AI machinery, machine learning (ML), and deep learning, and natural language processing (NLP) is assumed. This will allow the audience to appreciate the limitations in statistical AI in MHCare and follow through the advancement in AI, reaching towards Neuro-symbolic AI in general and for MHCare in particular. The tutorial will cover basics and advanced methodologies in machine learning, deep learning, and NLP/NLU/NLG with sufficient examples. Newcomers interested in AI/ML systems for healthcare, will learn the current state of AI/ML systems for MHCare. Expert attendees will appreciate methodologies and datasets presented in tutorial as promising, reliable, and practical approaches to overcoming familiar technical obstacles in social good domains. We encourage other researchers to use our datasets and approach to provide additional analysis, to further our understanding of knowledge-infused AI systems for MHCare and other domains.

4 ACKNOWLEDGEMENT

We acknowledge partial support from National Science Foundation (NSF) awards #1761931 and #2133842.

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