Artificial Intelligence Institute

Knowledge-infused AI for Healthcare:

Role of Conceptual Medical Knowledge in Improving Machine Understanding

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Outline

- State of AI in Healthcare
- Knowledge & Machine Learning - Knowledge Infusion
  - Contribution of knowledge to ML
  - Incremental Infusion of Knowledge
- Challenges
  - Abstraction, Contextualization, Personalization
- Case Study: Classification of social media data on Mental Heatlh using Knowledge
  - Dataset, Approach, Results

Probably Approximately Correct Learning

$$\mathbf{Prob}(Test_{err} > \epsilon \,|Train_{err} \approx 0) < |H|e^{-\epsilon m}$$

$$|H|e^{-\epsilon m} < \delta$$

$|H|$: All possible hypothesis for classification

ϵ : Minimal mis-classification error

δ : Empirical threshold (e.g. Human Annotation Error)

Valiant, Leslie G. "Robust logics." *Artificial Intelligence* 117.2 (2000): 231-253.

Probably Approximately Correct Learning

$$\mathbf{Prob}(Test_{err} > \epsilon \,|Train_{err} \approx 0) < |H|e^{-\epsilon m}$$

$$|H|e^{-\epsilon m} < \delta$$

How do you know that a training set has a good domain coverage?

Robust Classifier → Low Generalizability Error

Consistent Classifier → Low Training Error

Confidence: More Certainty (**lower δ**) means more number of samples.

Complexity: More complicated hypothesis (**|H|**) means more number of samples

PAC Learning to Knowledge Infusion

True Data Distribution D $\Longleftrightarrow$ $\mathcal{D}$ Hypothesis Data Distribution

Existing ML Models:

$$\mathcal{M}(D_X, \{0,1\}) \equiv \mathcal{D}_X$$

$$\min||D_X - \mathcal{D}_X||_F^2$$

Challenge:

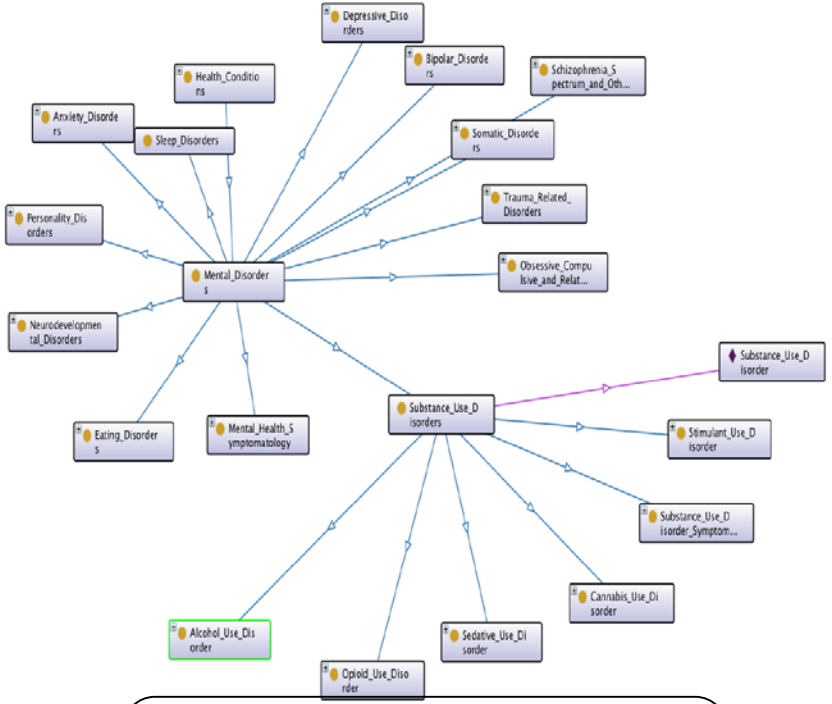
$$\mathcal{M}(D_X, C_X) \equiv \mathcal{F}(\mathcal{D}_X, \mathcal{C}_X)$$

Infusion:

$$\mathcal{M}(\mathcal{K}(D_X, C_X), \{0,1\}) \equiv \mathcal{D}_X$$

Algorithmic possibilities and limitations of AI Systems

Knowledge Resources
- Ontology
- Knowledge Graph
- Knowledge Base
- Lexicons

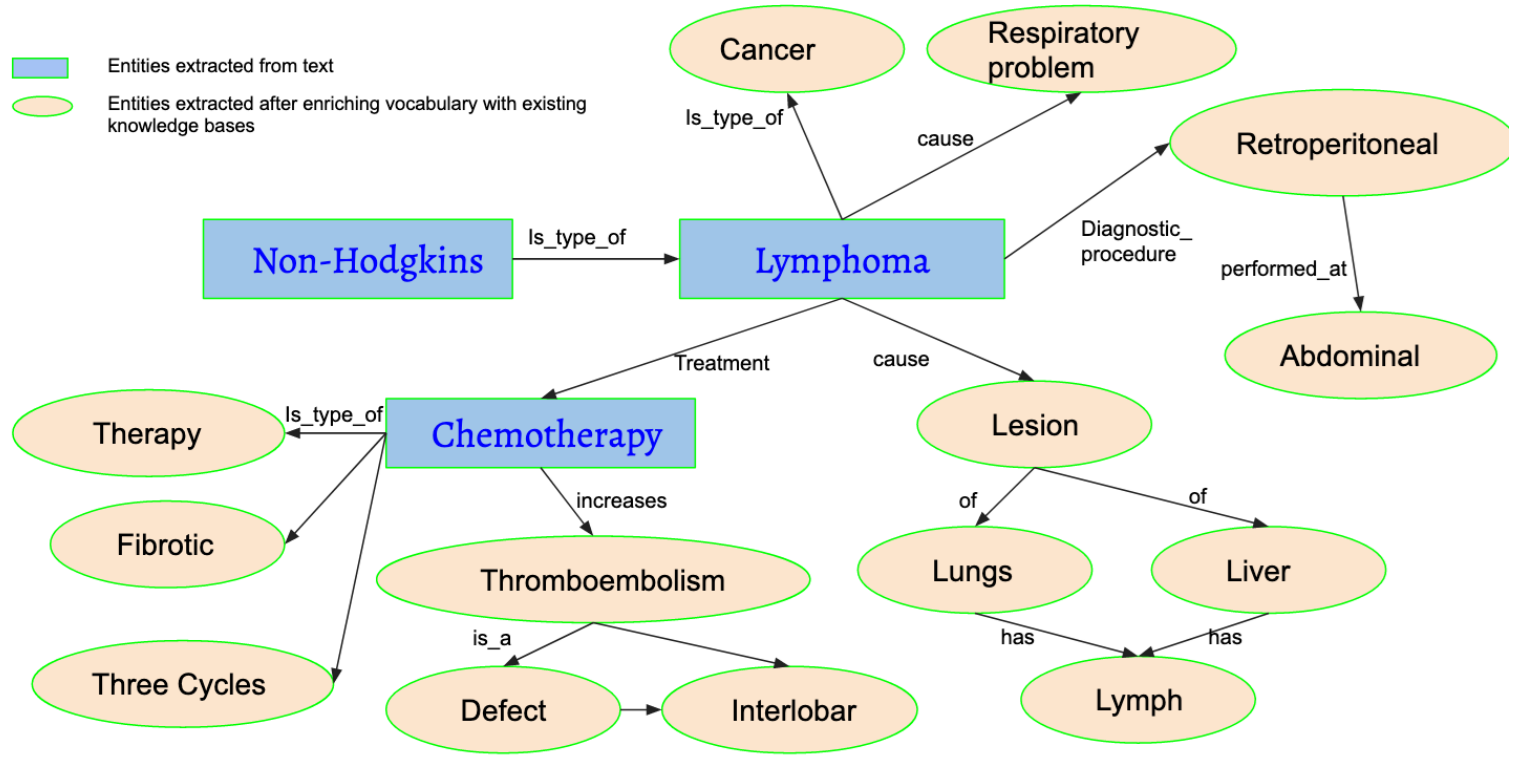


Drug Abuse Ontology
- Concepts (315)
- Relations (31)
- Instances (814)

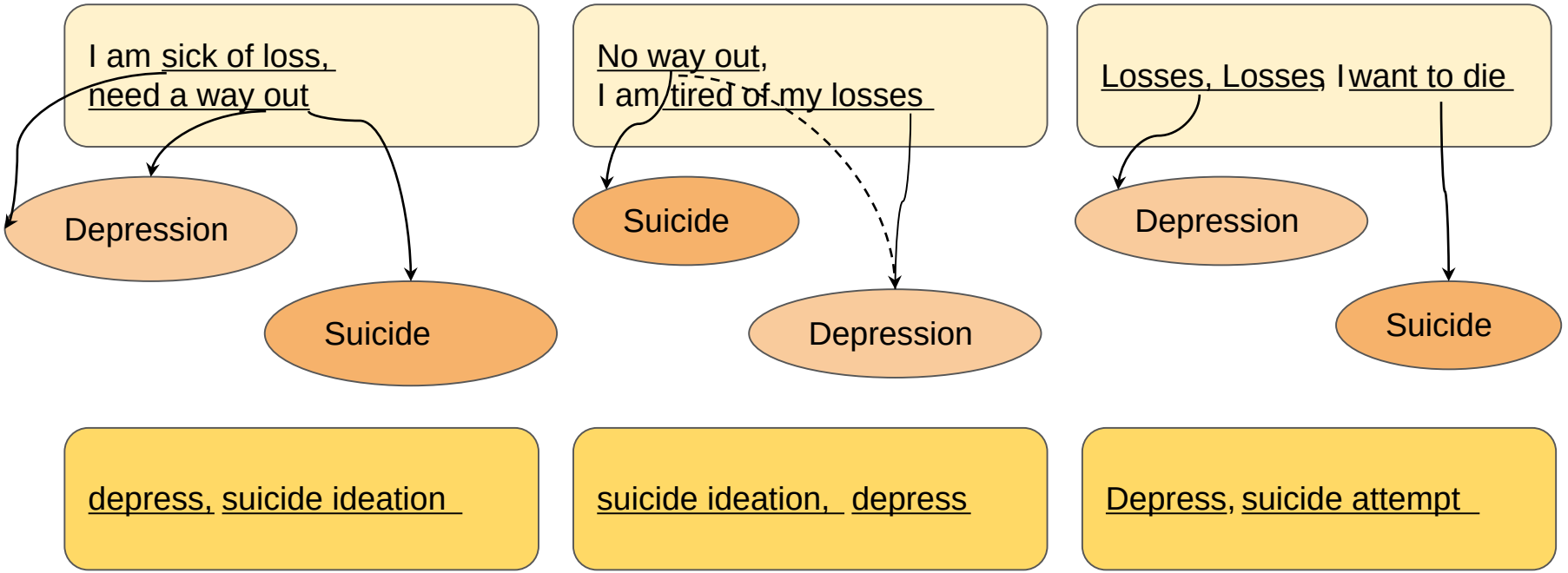
- Forms a ***conceptual*** framework of interconnecting sets of ***domain-focused*** concepts and relationships
- Remove ***ambiguity*** and ***sparsity***.
- Reduce ***false alarm***.

Context

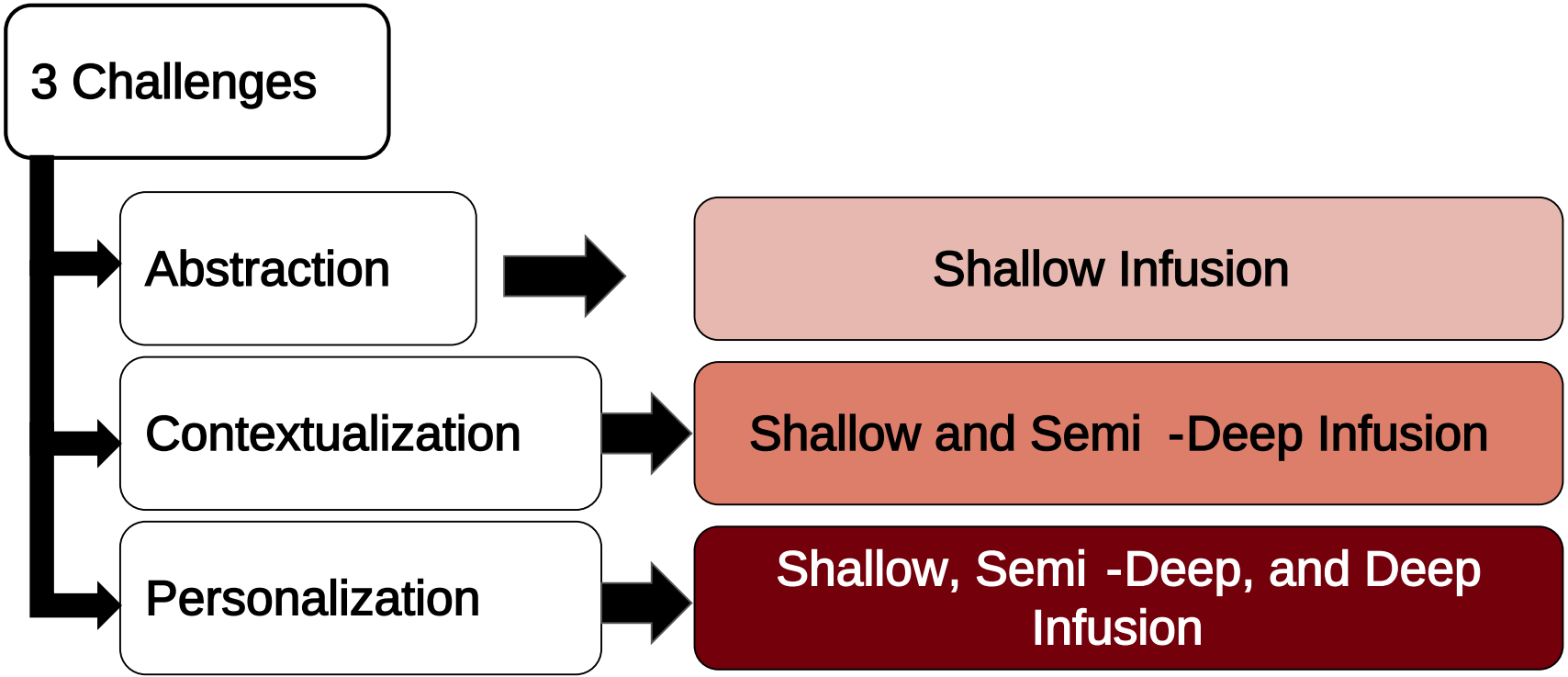
Patient is a known case of non-Hodgkin's lymphoma and undergone three cycles of chemotherapy.



Example: Depression



Challenges


3 Challenges
Abstraction
Shallow Infusion
Contextualization
Shallow and Semi -Deep Infusion
Personalization
Shallow, Semi -Deep, and Deep Infusion

Knowledge Infusion -Existing Work

A Unified Framework for Knowledge Intensive Gradient Boosting: Leveraging Human Experts for Noisy Sparse Domains

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Knowledge-aware Assessment of Severity of Suicide Risk for Early Intervention

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Infusing Knowledge into the Textual Entailment Task Using Graph Convolutional Networks

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Using a Knowledge Graph of Scenes to Enable Search of Autonomous Driving Data

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Knowledge Infused Learning (K-IL): Towards Deep Incorporation of Knowledge in Deep Learning

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Summarization: Hybrid Approach

Summary using Pretrained Model
< *unk* > depends on what it is
< *unk* > told to give me a example
< *unk* > calls for
< *unk* > yes says
< *unk* > with depression
< *unk* > we had been
< *unk* > told to seek help

Summary using AS
Participant was asked: what do they do when they are annoying until they stop **Participant said:** that they stop talking **Participant was asked:** when was the last time they felt really happy **Participant said:** a year while ago **Participant was asked:** How long ago were they diagnosed depression **Participant said:** they are still depressed.

Summary using PHQxAS
Participant was asked: What do you do when they are annoying **Participant said:** She stop talking **Participant was asked:** can you explain with example **Participant said:** Yeah **Participant was asked:** When was the last time they felt happy **Participant said:** awhile ago **Participant was asked:** what got them to seek help **Participant said:** they are still depressed **Participant was asked:** Tell me more about that **Participant said:** yeah **Participant was asked:** do they feel like therapy useful **Participant said:** oh yeah definitely **Participant was asked:** how long ago were they diagnosed depression **Participant said:** a year ago

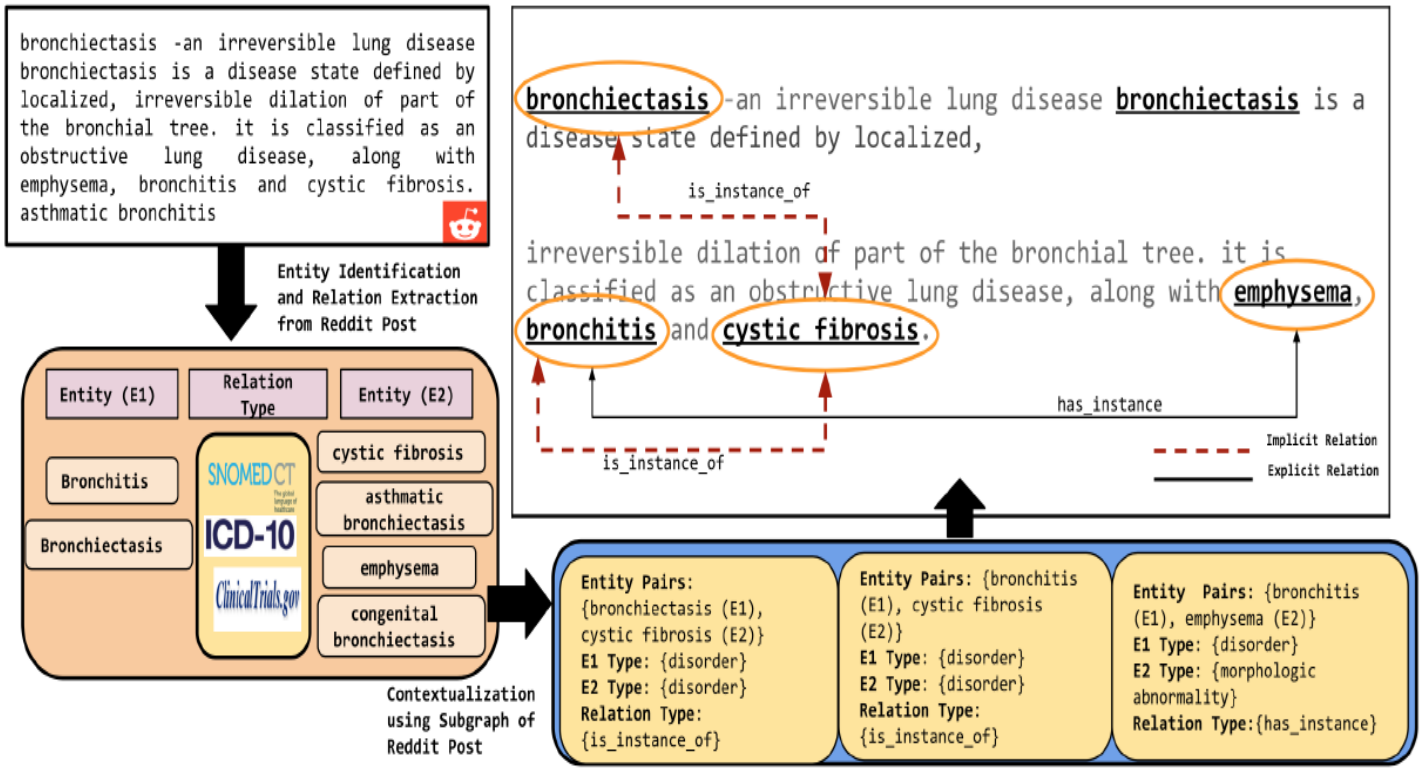
BERT

Abstractive Summarization using Integer Linear Programming (ILP)

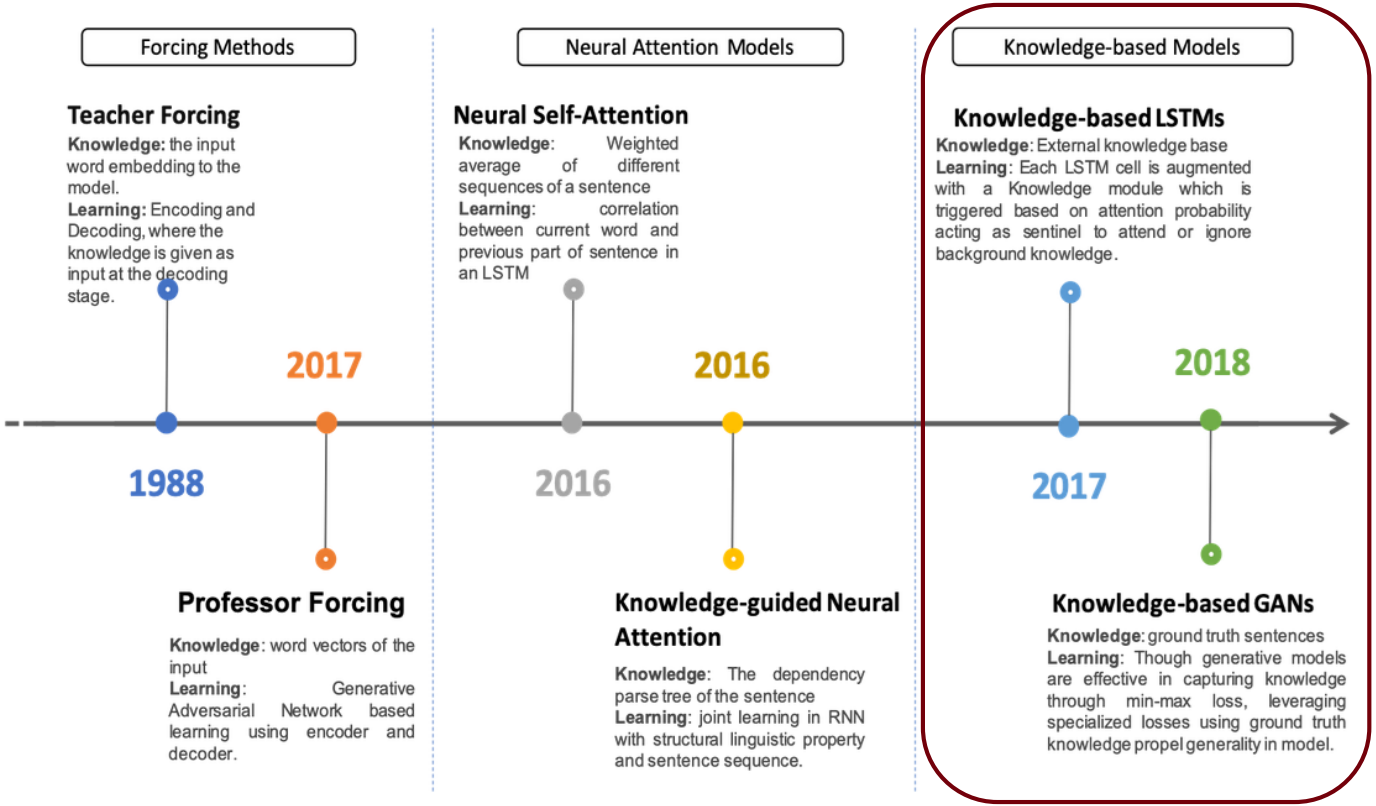
Abstractive Summarization using ILP and PHQ-9

Statistical → Statistical + Constraints → Statistical + Constraints + Knowledge

Personalized Health Knowledge Graph

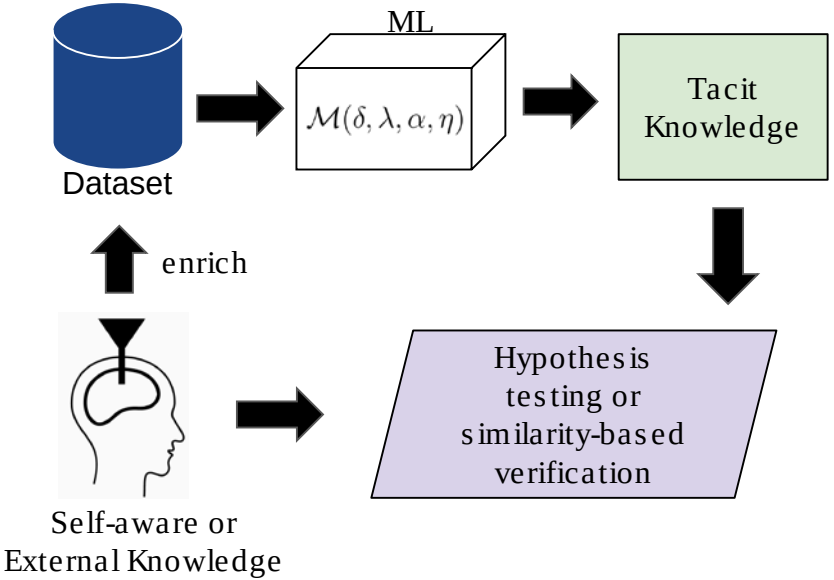


Knowledge Incorporation in ML

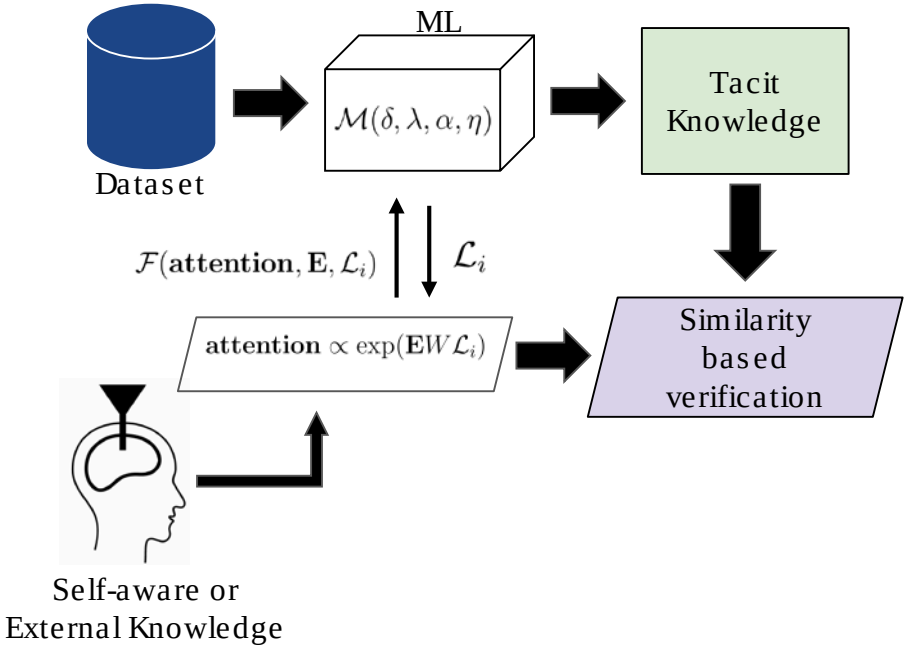


Hu, Zhiting, et al. "Deep generative models with learnable knowledge constraints." *Advances in Neural Information Processing Systems* 2018.

Knowledge Incorporation in ML



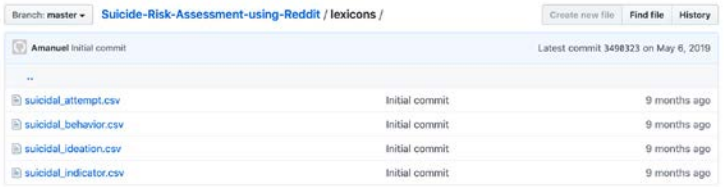
Shallow Infusion



Semi-Deep Infusion

Knowledge: Suicide Severity Lexicon

Suicide Risk Class	Number of Entities	Sample Medical Phrases
Suicide Indicator	1472	Severe mood disorder with psychotic feature; Severe major depression; Family history of suicide; Sedative
Suicide Ideation	409	Bipolar affective disorder; Borderline Personality; Depressive conduct disorder; Sexual maturation disorder
Suicide Behavior	145	Suicidal behavior; Intentional self - harm; Incomplete attempt; Threatening suicide
Suicide Attempt	123	Attempt actual suicide; Attempt physical damage; Intensive care; Second-degree burns



http://bit.ly/lexicons_suicide_severity

Suicide by Hanging [SNOMED ID: 287190007]

- **<child of>** Suicide [SNOMED ID:44301001]
- **<sibling of>** Drug Overdose [SNOMED ID:274228002]
- **<sibling of>** Personal history of self-harm [ICD-10 ID: Z91.5]
- **<sibling of>** Severe depressive episode psychotic symptoms [ICD-10 ID: F32.3]

Contextualization

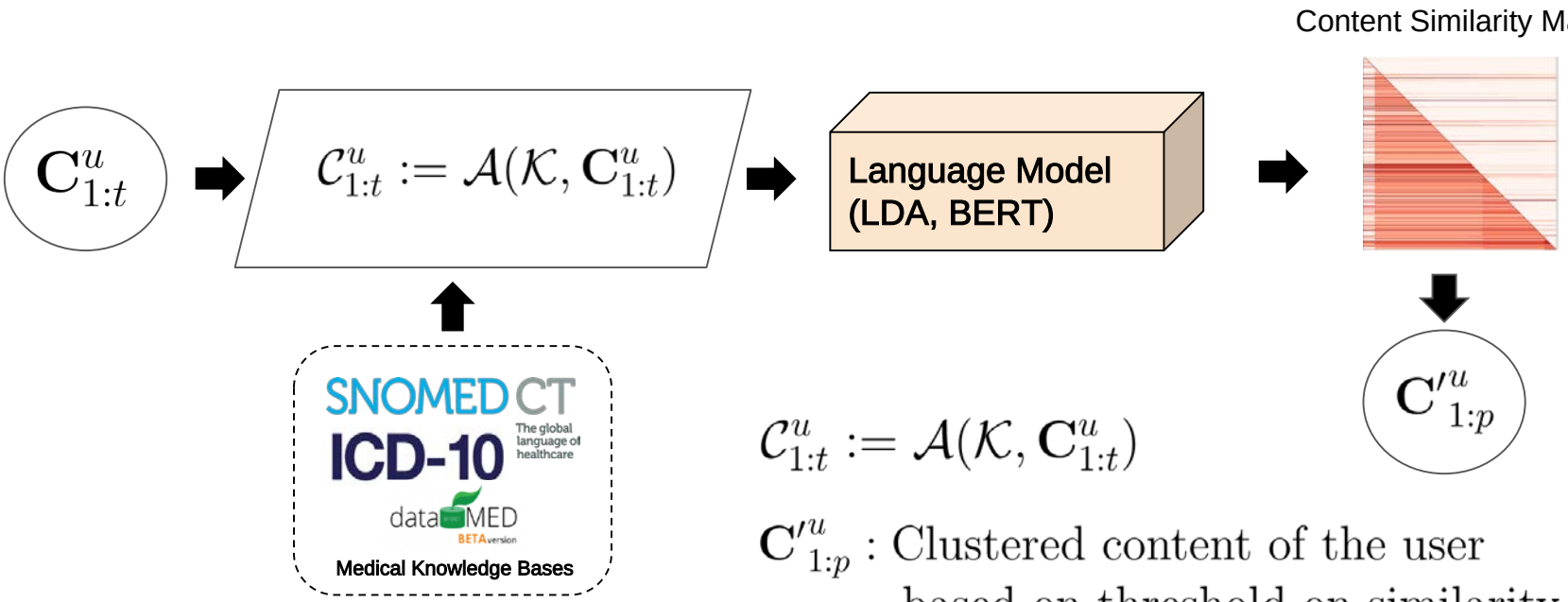
I dont think Ive thought about it every day of my entire life. I have for a good portion of it, however, my boyfriend may be able to determine whether I'm worth his time

Outcome : Suicide Indication

Having a plan for my own suicide has been a long time relief for me as well. I more often than not wish I were dead.
I dont think Ive thought about it every day of my entire life. I have for a good portion of it, however, my boyfriend may be able to determine whether I'm worth his time

Outcome : Suicidal Ideation

Contextualization & Abstraction



$\mathcal{C}^u_{1:t} := \mathcal{A}(\mathcal{K}, \mathbf{C}^u_{1:t})$

$\mathbf{C}'^u_{1:p}$: Clustered content of the user based on threshold on similarity

$\mathbf{C}^u_{1:t}$: Content of a user "u" from timestamp 1 to t

$\mathcal{K}$: Knowledge Base/Graph

$\mathcal{A}$: Content Abstraction Module

Personalization

… refers to future course of action by taking into account the contextual factors such as user's *health history, physical characteristics, environmental factors, activity, and lifestyle.*

Cognitive Services and Intelligent Chatbots: Current Perspectives and Special Issue Introduction

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Wright State University

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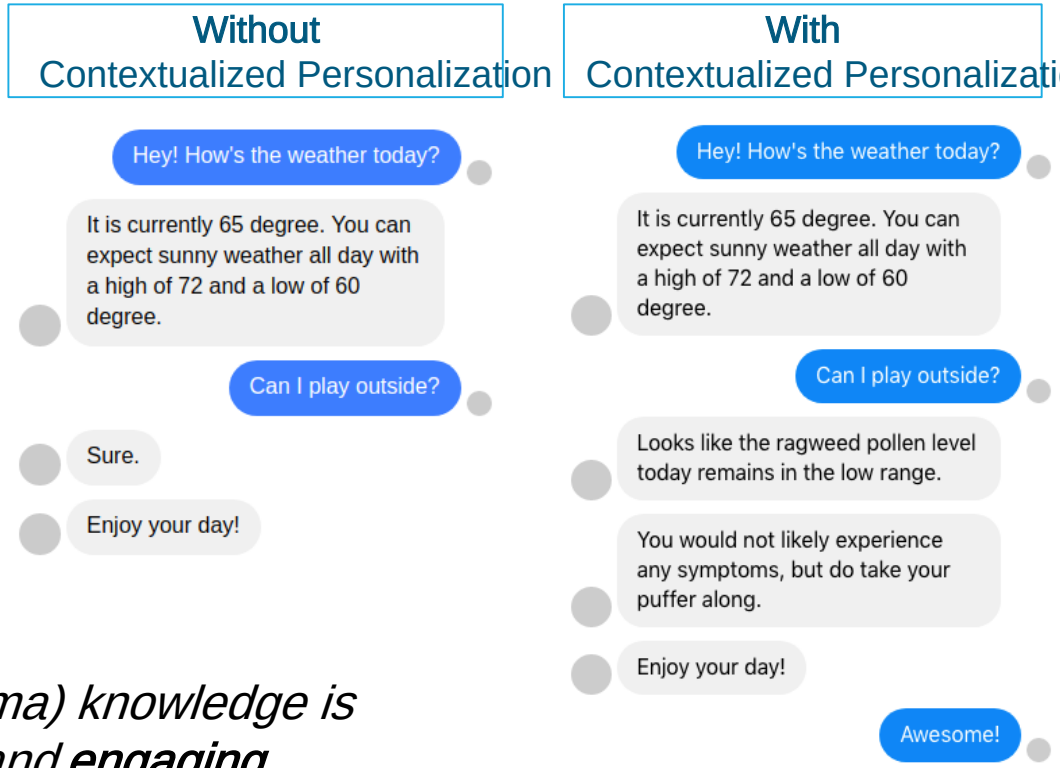
IBM TJ Watson

Paul Tepper
Nuance Communications



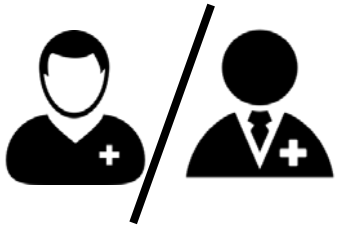
*Chatbot with contextualized (asthma) knowledge is potentially **more personalized** and **engaging.***

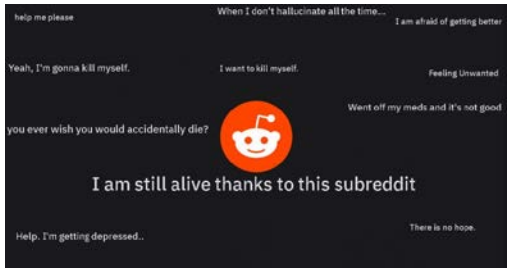
Case Study - Mental Health

Let Me Tell You About Your Mental Health! : Contextualized Classification of Reddit Posts to DSM-5

Gaur, Manas, Ugur Kursuncu, Amanuel Alambo, Amit Sheth, Raminta Daniulaityte, Krishnaprasad Thirunarayan, and Jyotishman Pathak. "Let me tell you about your mental health!: Contextualized classification of reddit posts to dsm-5 for web-based intervention." In *Proceedings of the 27th ACM International Conference on Information and Knowledge Management*, pp. 753-762. ACM, 2018.

Problem





Social Anxiety and Therapeutic Pessimism

Patient: Poor Recall Rate

Clinician: Poor understanding of patient behavior

Poor long lasting patient-doctor relationship

Clinical data is time-limited

Data is short and not categorized

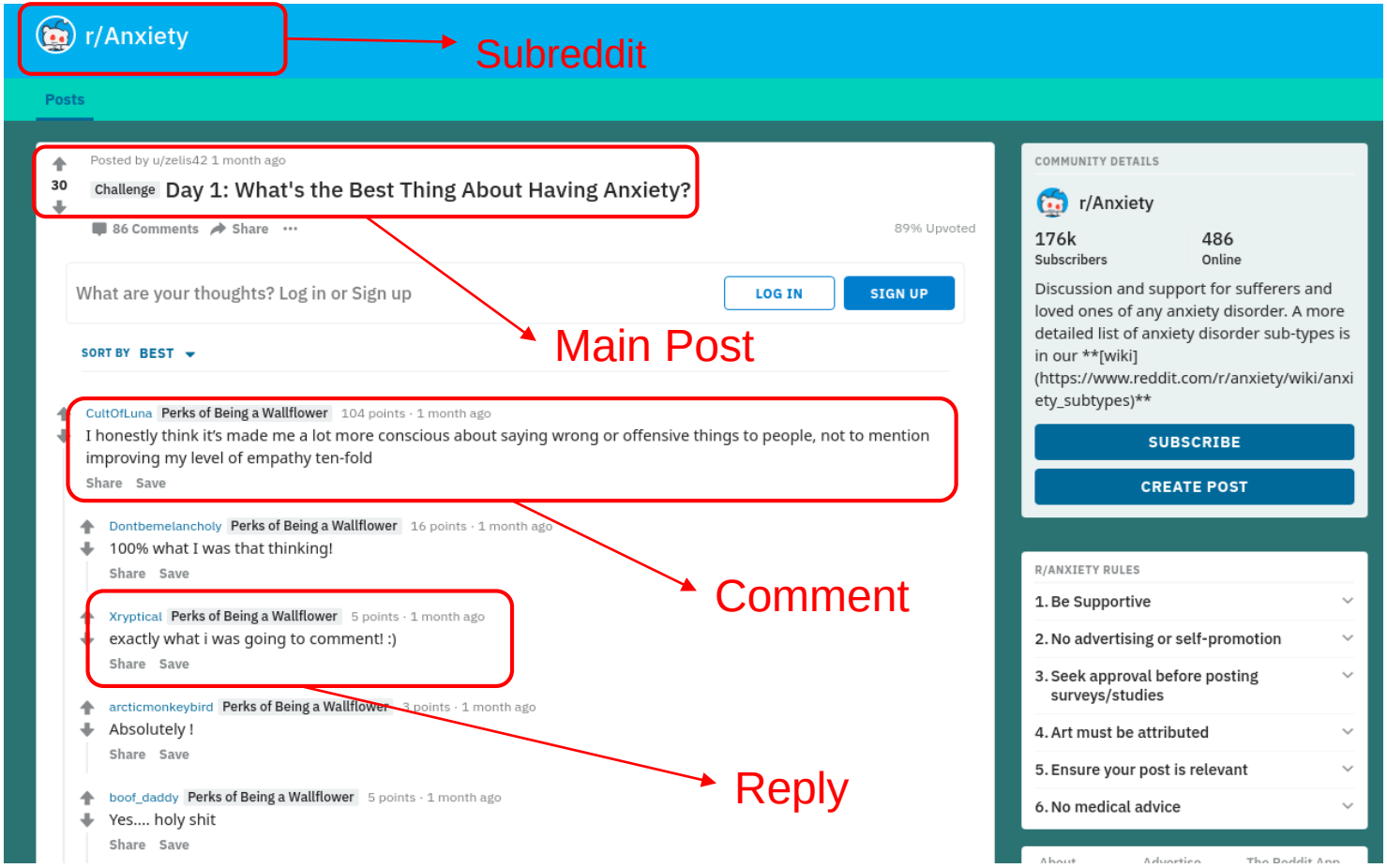
Data is long and categorized

Reddit categorization does not overlap with Clinician

Problem

- Can social media data assist Mental Health Professionals in psychiatric diagnosis, prevention and early intervention ?
- Map Subreddits to Diagnostic Statistical Manual for Mental Health (DSM-5) ?

Problem


r/Anxiety
Subreddit
Posts
Posted by u/zelis42 1 month ago
30
Challenge Day 1: What's the Best Thing About Having Anxiety?
86 Comments Share
89% Upvoted
What are your thoughts? Log in or Sign up
LOG IN
SIGN UP
SORT BY BEST
Main Post
CultOfLuna Perks of Being a Wallflower 104 points · 1 month ago
I honestly think it's made me a lot more conscious about saying wrong or offensive things to people, not to mention improving my level of empathy ten-fold
Share Save
Dontbemelancholy Perks of Being a Wallflower 16 points · 1 month ago
100% what I was that thinking!
Share Save
Comment
Xryptical Perks of Being a Wallflower 5 points · 1 month ago
exactly what i was going to comment! :)
Share Save
arcticmonkeybird Perks of Being a Wallflower 3 points · 1 month ago
Absolutely !
Share Save
Reply
boof_daddy Perks of Being a Wallflower 5 points · 1 month ago
Yes.... holy shit
Share Save
COMMUNITY DETAILS
r/Anxiety
176k
Subscribers
486
Online
Discussion and support for sufferers and loved ones of any anxiety disorder. A more detailed list of anxiety disorder sub-types is in our **[wiki](https://www.reddit.com/r/anxiety/wiki/anxiety_subtypes)**
SUBSCRIBE
CREATE POST
R/ANXIETY RULES
1. Be Supportive
2. No advertising or self-promotion
3. Seek approval before posting surveys/studies
4. Art must be attributed
5. Ensure your post is relevant
6. No medical advice

Examples

*Post from **Bipolar** Subreddit:*

I know you want me to say no and that it is a part of me blah blah blah. But I can't. Honestly, not having bipolar disorder would be a huge blessing. I would be so much happier and could control my life better. I wouldn't have frantic, scattered thoughts and depression. I would be normal, happy, and less dramatic.

DSM-5 Chapter:

Depressive Disorders

*Post from **Suicidewatch** Subreddit:*

Upon additional research, zolpidem (ambien) has a half-life of 2-3 hours, and so if he's still awake, he's either got a massive tolerance for this stuff or he's really trolling.

DSM-5 Chapter:

Suicidal Behavior/Ideation Disorders

Dataset

2005 - 2016

550K Users

8 Million Conversations

15 Mental Health Subreddits

2005 - 2016

270K Users (Only Authors of Main Posts)

3 Million Conversations (Main Posts Only)

15 Mental Health Subreddits

Dataset

May 4, 2019

Conference paper | Open Access

Reddit C-SSRS Suicide Dataset

Gaur, Manas; Alambo, Amanuel; Sain, Joy Prakash; Kurscuncu, Ugur; Thirunarayan, Krishnaprasad; Kavuluru, Ramakanth; Sheth, Amit; Welton, Randon; Pathak, Jyotishman

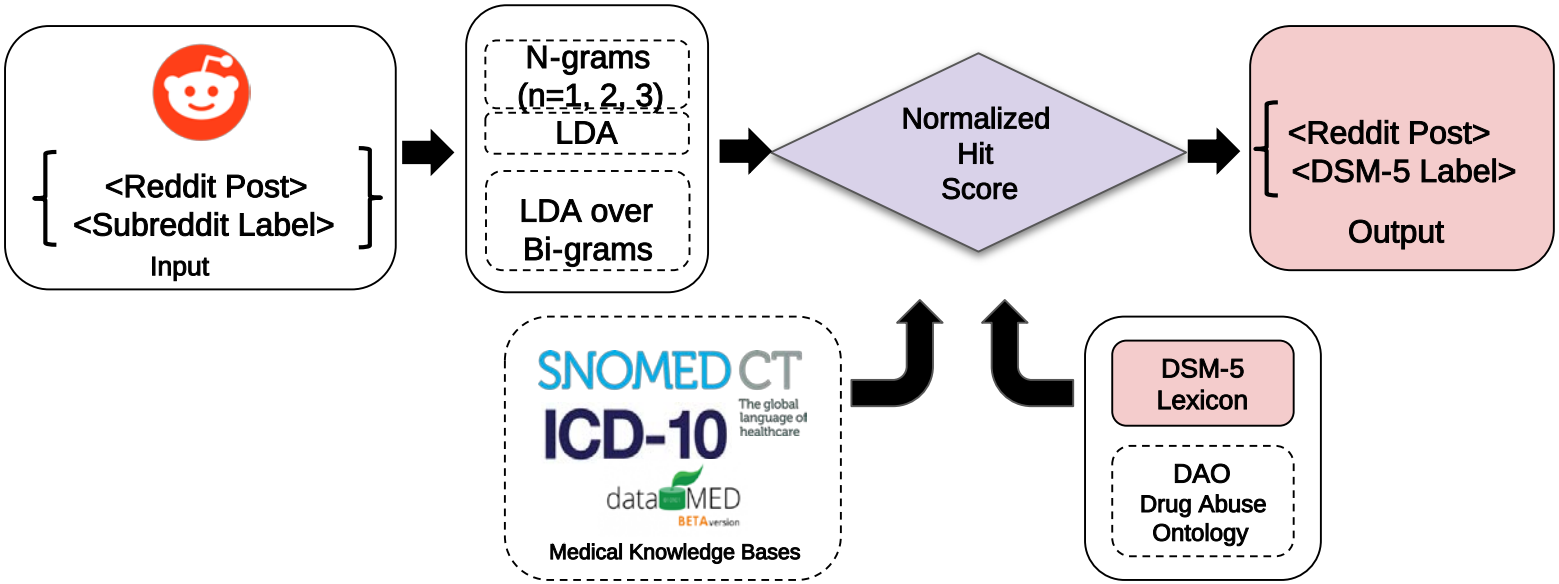
Knowledge-aware Assessment of Severity of Suicide Risk for Early Intervention

Mental health illness such as depression is a significant risk factor for suicide ideation, behaviors, and attempts. A report by Substance Abuse and Mental Health Services Administration (SAMHSA) shows that 80% of the patients suffering from Borderline Personality Disorder (BPD) have suicidal behavior, 5-10% of whom commit suicide. While multiple initiatives have been developed and implemented for suicide prevention, a key challenge has been the social stigma associated with mental disorders, which deters patients from seeking help or sharing their experiences directly with others including clinicians. This is particularly true for teenagers and younger adults where suicide is the second highest cause of death in the US Prior research involving surveys and questionnaires (e.g. PHQ-9) for suicide risk prediction failed to provide a quantitative assessment of risk that informed timely clinical decision-making for intervention. Our interdisciplinary study concerns the use of Reddit as an unobtrusive data source for gleaning information about suicidal tendencies and other related mental health conditions afflicting depressed users. We provide details of our learning framework that incorporates domain-specific knowledge to predict the severity of suicide risk for an individual. Our approach involves developing a suicide risk severity lexicon using medical knowledge bases and suicide ontology to detect cues relevant to suicidal thoughts and actions. We also use language modeling, medical entity recognition, and normalization and negation detection to create a dataset of 2181 redditors that have discussed or implied suicidal ideation, behavior, or attempt. Given the importance of clinical knowledge, our gold standard dataset of 500 redditors (out of 2181) was developed by four practicing psychiatrists following the guidelines outlined in Columbia.Suicide Severity Rating Scale (C-SSRS), with the pairwise annotator agreement of 0.79 and group-wise agreement of 0.73. Compared to the existing four-label classification scheme (no risk, low risk, moderate risk, and high risk), our proposed C-SSRS-based 5-label classification scheme distinguishes people who are supportive, from those who show different severity of suicidal tendency. Our 5-label classification scheme outperforms the state-of-the-art schemes by improving the graded recall by 4.2% and reducing the perceived risk measure by 12.5%. Convolutional neural network (CNN) provided the best performance in our scheme due to the discriminative features and use of domain-specific knowledge resources, in comparison to SVM-L that has been used in the state-of-the-art tools over similar dataset

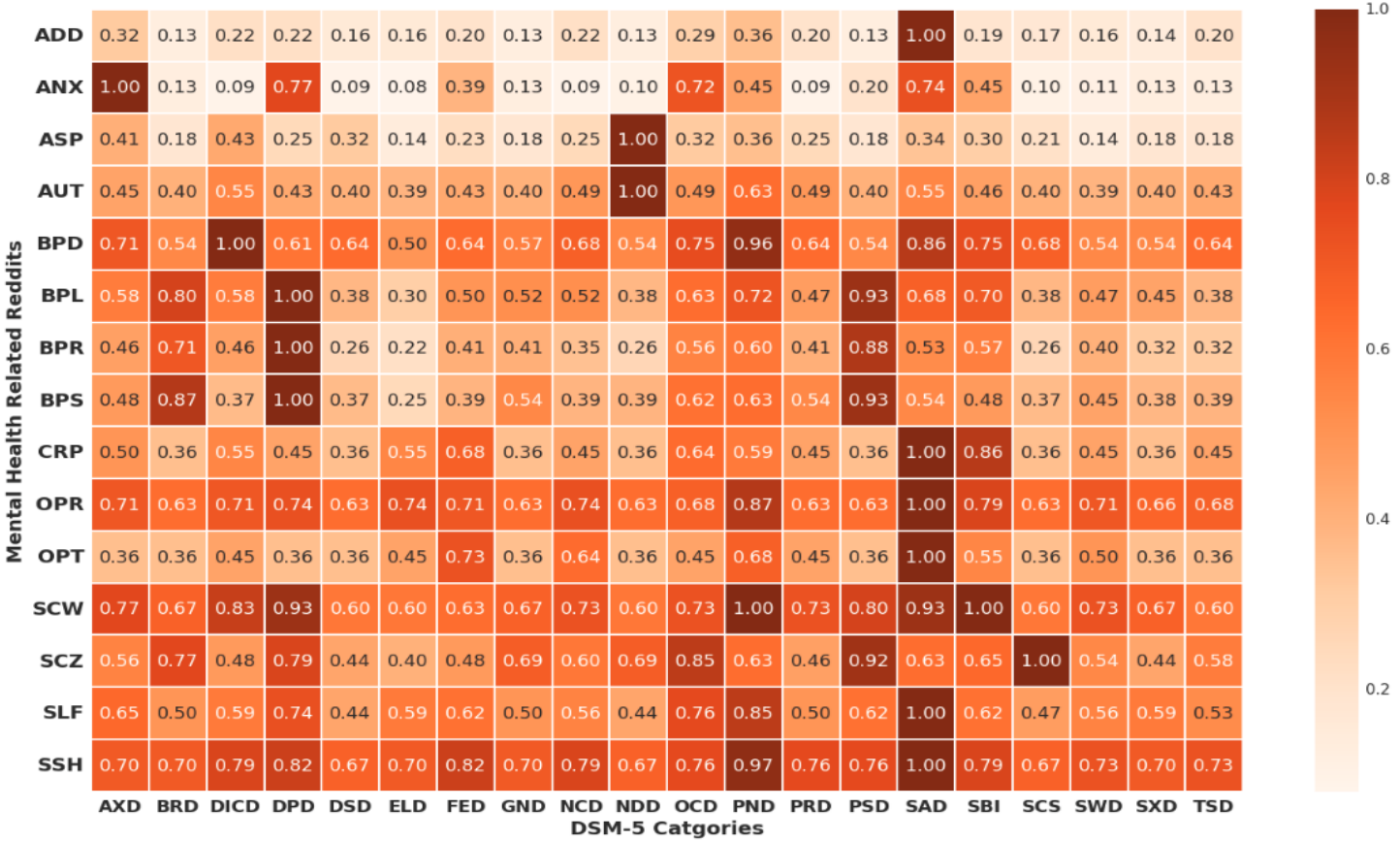
Preview

Publication date:
May 4, 2019
DOI:
DOI 10.5281/zenodo.2667859
Keyword(s):
Surveillance and Behavior Monitoring; Reddit; Mental Health; Suicide Risk Assessment; C-SSRS; Medical Knowledge Bases; Perceived Risk Measure; Semantic Social Computing
Meeting:
The World Wide Web Conference

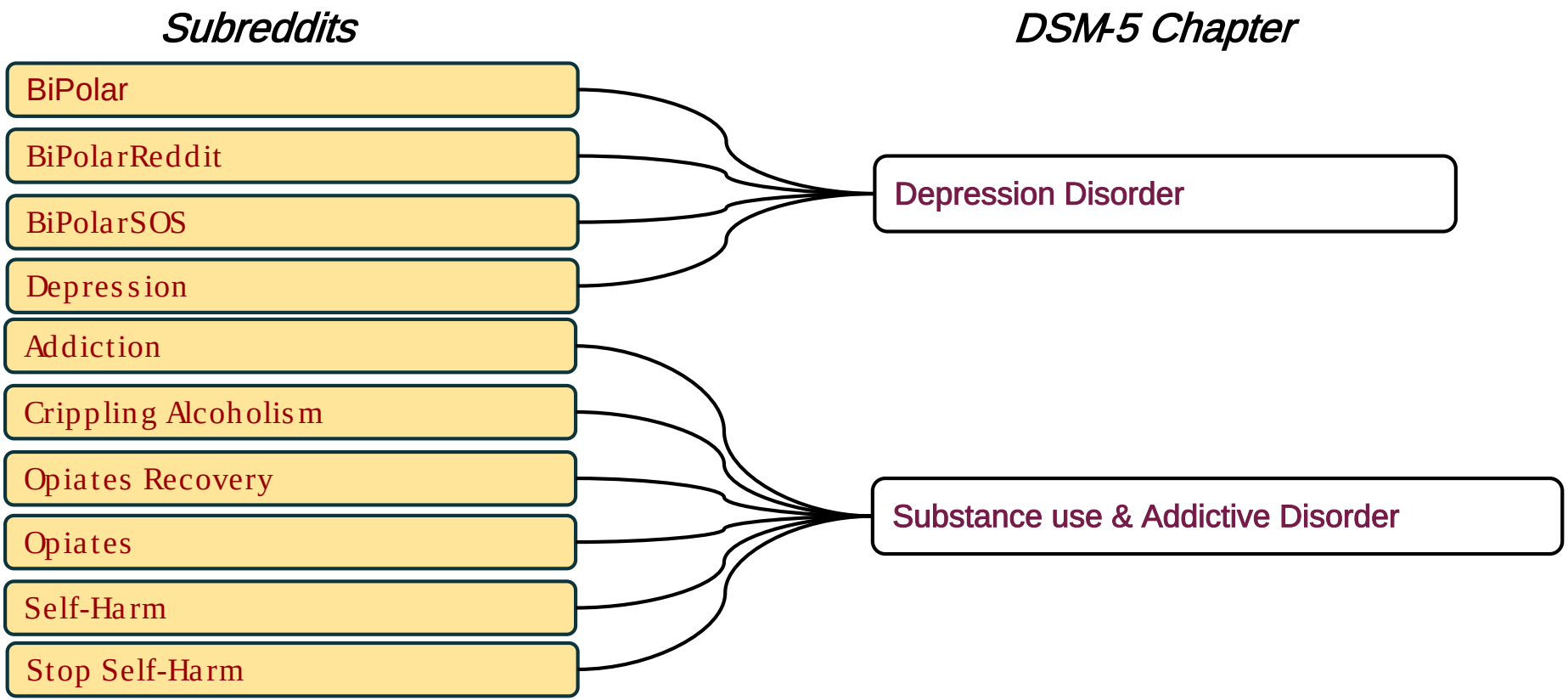
Reddit to DSM-5 Mapping



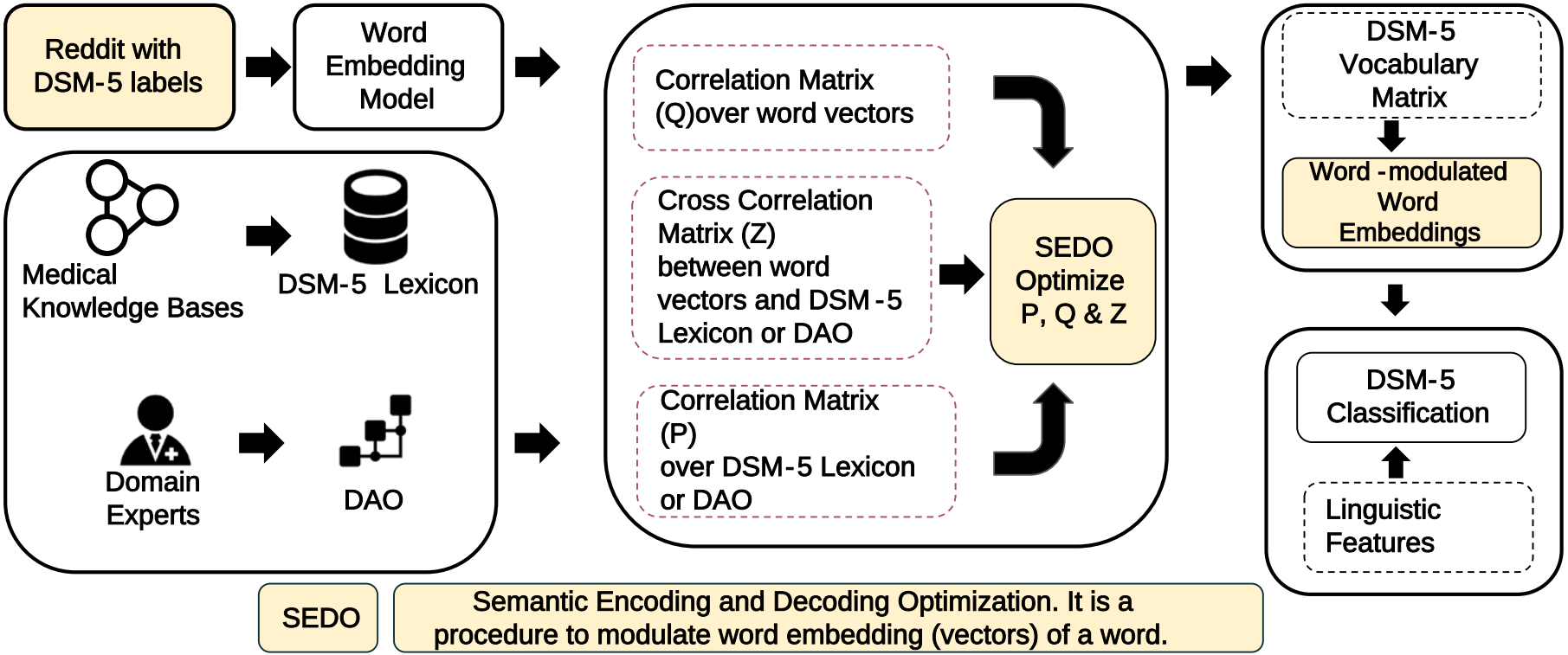
Reddit to DSM-5 Mapping



Mapping Example



Architecture



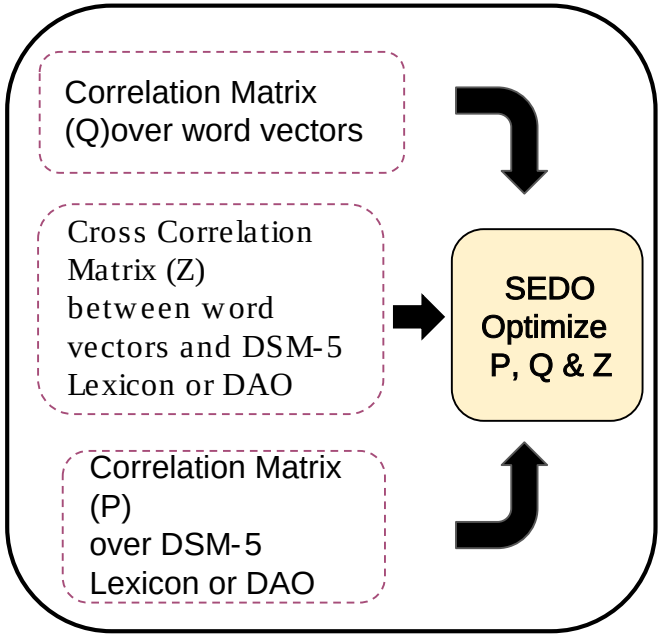
SEDO — Semantic Encoding and Decoding Optimization. It is a procedure to modulate word embedding (vectors) of a word.

Semantic Encoding and Decoding Optimization

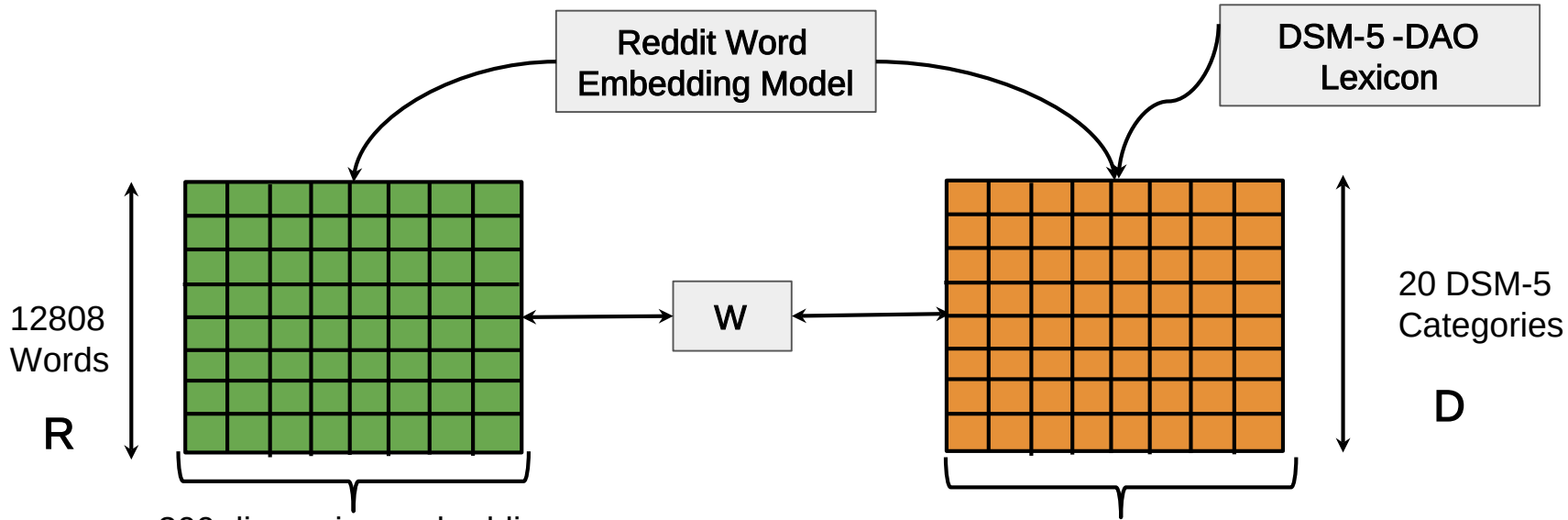
We introduce SEDO as an approach for obtaining a **discriminative weight matrix** between the **DSM-5 lexicon and Reddit embedding space**

Infused knowledge in DSM-5-DAO to the classification process utilizing SEDO.

SEDO modulates the embeddings of each word in the Reddit content of the user **based on proximity of the word to DSM-5 category**.



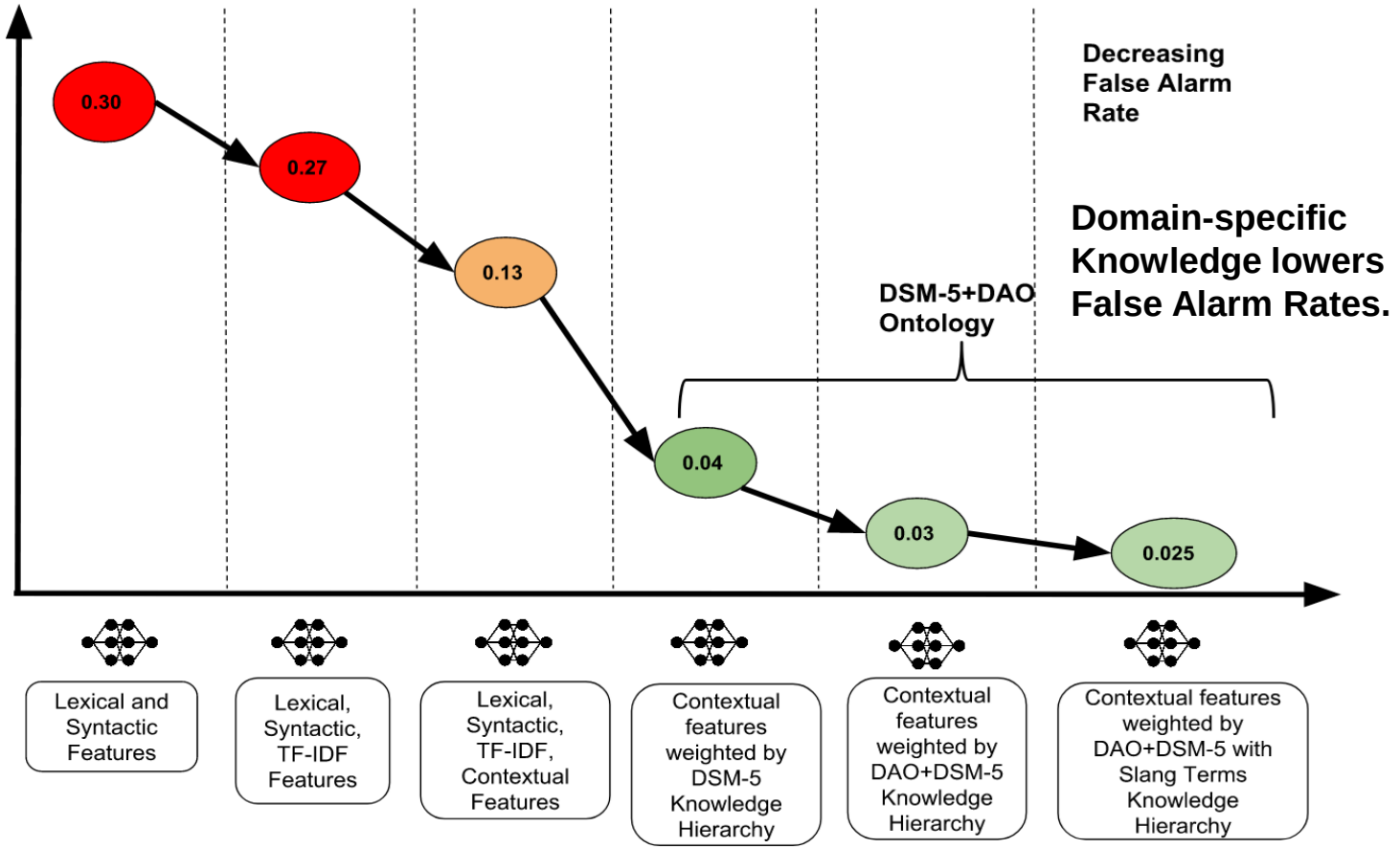
Semantic Encoding and Decoding Optimization



$$E(R,D) = min_W\{||R - W^T D||_F^2 + \delta||WR - D||_F^2\} \xrightarrow{\frac{d(E(R,D))}{d(W)}} (DD^T)W + W(\delta RR^T) = (1+\delta)DR^T; 0 < \delta < 1$$

Solvable Sylvester Equation

Reduction in False Alarm



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Amanuel Alambo


Vamsi Aribandi


Vedant Khandelwal

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