Deep RDNs: A Neurosybolic Framework for Reasoning about Structured and Unstructured Data

Under Review for NeSy 2025

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Abstract

We might want to model a joint distribution over a set that is subject to some relations. Neural networks may work, but they lack interpretability.

Traditional methods (for example, Bayesian networks or Markov Networks) for this task require data in structured forms (for example, relational databases.)

The present paper aims to augment a traditional model (Relational Dependency Networks, RDN) with NN to make use of unstructured modalities (for example, images and text.)

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Relational Dependency Networks
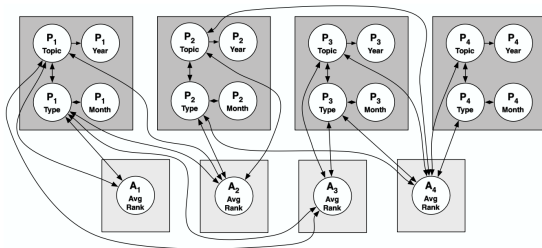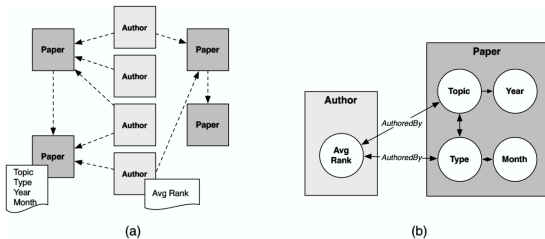
Formalization

A dataset $\mathcal{D}$ with labeled

- Structured Data $\mathcal{A}$ containing predicates.
- Unstructured Data $Z = \{z^{(i)}\}_{i=1}^{N}$.

Predicates $X \in \mathbf{X}$.

Use

$$f(x, \mathcal{A}, z) = \sigma(f_{\text{Tree}}(x, \mathcal{A}, z) + f_{\text{DNN}}(x, \mathcal{A}, z))$$
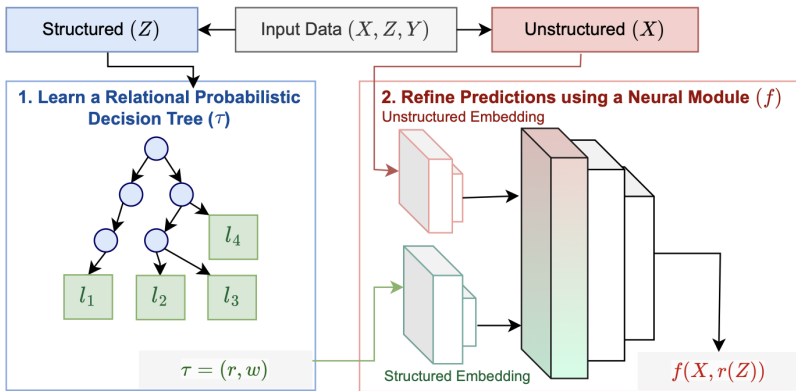
to model

$$P_X(x | \mathcal{A} \setminus x, z)$$

Learning Procedure
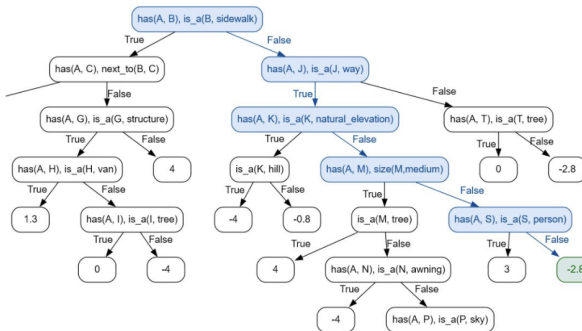
- Create a predicate based decision tree according to $\mathcal{A}$, or the RDN learnt.

- Learn DNN over the sturctured & unstructured data.

- Embedding: One-hot vector encoding the leave index of x, concatenated with the embedding of some unstructured data.

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Overview

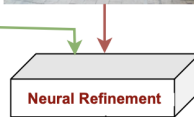$$P(Y|X, Z; \tau, f) = \sigma(w(r(Z)) + f(x, r(Z)))$$

Qualitative Illustration

Learned Relational Probability Tree (RPT) outputs a potential of -2.8

Final Refined Prediction: $P(Y = street | X, Z; \tau, f) = \sigma(\;-2.8 + 4.5\;) = 0.85$

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Settings & Results

Baselines:

- A Neural Network that only uses unstructured modality.

- A RDN that only uses the structured modality.

Model	RelKP		ADE20k-Highway		ADE20k-Street	
	AUC-PR	AUC-ROC	AUC-PR	AUC-ROC	AUC-PR	AUC-ROC
NN	0.86 ± 0.09	0.81 ± 0.11	0.88 ± 0.04	0.94 ± 0.04	0.85 ± 0.08	0.66 ± 0.19
RDN	0.85 ± 0.12	0.88 ± 0.09	0.73 ± 0.14	0.93 ± 0.06	0.91 ± 0.03	0.77 ± 0.05
DRDN (Ours)	$\mathbf{0.91 \pm 0.10}$	$\mathbf{0.88 \pm 0.12}$	$\mathbf{0.91 \pm 0.07}$	$\mathbf{0.96 \pm 0.05}$	$\mathbf{0.92 \pm 0.04}$	$\mathbf{0.78 \pm 0.13}$

Model	Cough		Pain		Fever	
	AUC-PR	AUC-ROC	AUC-PR	AUC-ROC	AUC-PR	AUC-ROC
NN	$\mathbf{0.83 \pm 0.01}$	$\mathbf{0.92 \pm 0.01}$	$\mathbf{0.69 \pm 0.02}$	$\mathbf{0.89 \pm 0.00}$	$\mathbf{0.80 \pm 0.00}$	$\mathbf{0.90 \pm 0.00}$
RDN	0.62 ± 0.02	0.71 ± 0.03	0.27 ± 0.03	0.70 ± 0.02	0.45 ± 0.00	0.69 ± 0.01
DRDN (Ours)	0.76 ± 0.01	0.87 ± 0.01	0.64 ± 0.03	0.83 ± 0.00	0.77 ± 0.01	0.89 ± 0.00

Weaknesses from a Personal Perspective

- Writing.

- The background part is not sufficiently informative for me.

- Formalization, including that of the task and the method, is not crystal clear (or chaotic, if I may).

- The experimental part is weak.

- The approach does not seem very innovative.

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Q&A

Questions?