

Report for CSE 505 - Phase 3

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Abstract—My abstract

Keywords—Multi-valued Real Logic, Tensor Network, Reasoning.

2) *Function*: For each function f/m on m parameters, LTN define it as a mapping on vector space, which means:

$$\mathcal{G}(f(t_1, t_2, \dots, t_m)) \in \mathbb{R}^{mn} \rightarrow \mathbb{R}^n \quad (2)$$

I. PAPER OVERVIEW

A. Basic Information

Here is some basic information about the paper I selected:

- Title: Logic Tensor Networks: Deep Learning and Logical Reasoning from Data and Knowledge[1].
- Author: Luciano Serafini and Artur dAvila Garcez
- From: ArXiv.2016
- Abstract: This paper proposes Logic Tensor Networks (LTN) to integrate **learning** and **reasoning** together based on vector representation. The proposed model LTN represent each object with a vector and then converts each function on multiple objects into a manipulate on their vector representations. Then it also uses a s-norm operator to transform a predicate to a real number in $[0, 1]$, which means the confidence of this predicate. Finally, it defines a lose function for all predicates, which means it transfers the reasoning process into a learning and optimization problem.

Note that here we specify the parameter of f is t_i instead of c_i because function f can be recursive like $f(f_1(c1, c2), f_2(c1, c3))$.

$$\mathcal{G}(f(t_1, t_2, \dots, t_m)) = \mathcal{G}(f)\mathcal{G}(t_1), \mathcal{G}(t_2), \dots, \mathcal{G}(t_m) \quad (3)$$

More specifically, $\mathcal{G}(f(t_1, t_2, \dots, t_m))$ is fitted by a linear function, which can be implemented with tensor network:

$$\begin{aligned} \mathcal{G}(f(t_1, t_2, \dots, t_m)) &= \mathcal{G}(f)(v_1, v_2, \dots, v_m) \\ &= \mathcal{G}(f)(v) \\ &= M_f v + N_f \end{aligned} \quad (4)$$

where $v = \langle v_1, v_2, \dots, v_m \rangle$, $M_f \in \mathbb{R}^{n \times mn}$, and $N_f \in \mathbb{R}^n$

3) *Predicate*: Like the grounding of a function,

$$\mathcal{G}(P(t_1, t_2, \dots, t_m)) \in \mathbb{R}^{mn} \rightarrow [0, 1] \quad (5)$$

B. Definitions

Recall that a first-order language L is composed by three parts:

- $\mathcal{C} = \{c_1, c_2, \dots\}$, the set of constant symbols;
- $\mathcal{F} = \{f_1, f_2, \dots\}$, the set of functional symbols;
- $\mathcal{P} = \{p_1, p_2, \dots\}$ the set of predicate symbols.

Again, as t_i has been mapped to a vector, then:

$$\mathcal{G}(P(t_1, t_2, \dots, t_m)) = \mathcal{G}(P)\mathcal{G}(t_1), \mathcal{G}(t_2), \dots, \mathcal{G}(t_m) \quad (6)$$

Therefore we transfer a predicate into a series of manipulation on tensor space:

$$\begin{aligned} \mathcal{G}(P(t_1, t_2, \dots, t_m)) &= \mathcal{G}(f)(v_1, v_2, \dots, v_m) \\ &= \mathcal{G}(f)(v) \\ &= \sigma(u_p^T \tanh(v^T W_P v + V_P v + B_P)) \end{aligned} \quad (7)$$

C. Groundings

LTN defines a term \mathcal{G} , called **grounding**, which contains $\mathcal{G}(c)$, $\mathcal{G}(f)$, $\mathcal{G}(P)$ respect to $c \in \mathcal{C}$, $f \in \mathcal{F}$, $P \in \mathcal{P}$:

Also, LTN define the manipulate of each clause ϕ .

1) *Constant*: For each constant, LTN allocate a n -dimension vector to it:

$$\mathcal{G}(c) \in \mathbb{R}^n \quad (1)$$

where $v = \langle v_1, v_2, \dots, v_m \rangle \in \mathbb{R}^{mn}$, $W_P \in \mathbb{R}^{mn \times mn \times k}$, $V_P \in \mathbb{R}^{mn \times k}$, $B_P \in \mathbb{R}^k$, $u_P \in \mathbb{R}^k$, and σ is the sigmoid function.

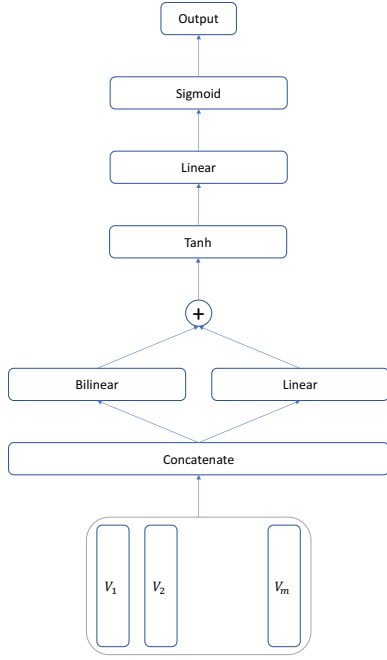


Figure 1: Model for Predicate

4) *Clause*: In this project, we assume each clause is disjunctive normal form. So it's easy to get that

$$\mathcal{G}(\phi_1, \phi_2, \dots, \phi_k) = \mu(\mathcal{G}(\phi_1), \mathcal{G}(\phi_2), \dots, \mathcal{G}(\phi_k)) \quad (8)$$

where μ is the max function.

D. Optimization

So now we get the definition of all components of multi-valued first-order language in tensor networks. The next step is to define a proper lose function.

Saying we know the value of $\phi(x)$ in our dataset, where x is a constant. Intuitively, an optimal groudng should make $\mathcal{G}(\phi(t))$ as close as to $\phi(x)$.

II. MODELS

A. *Logic Tensor Network (LTN)*

B. *Weight Logic Tensor Network (WLTN)*

C. *Convolutional Logic Tensor Network (CLTN)*

III. EXPERIMENTS

A. *Fit Knowledge Base*

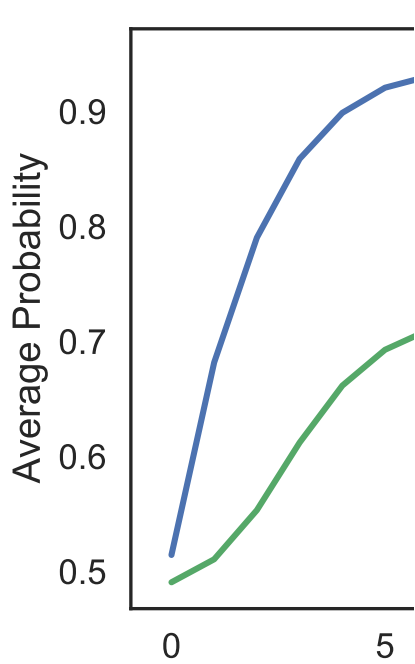
B. *Learn From Rule*

C. *Parameter Sensitive*

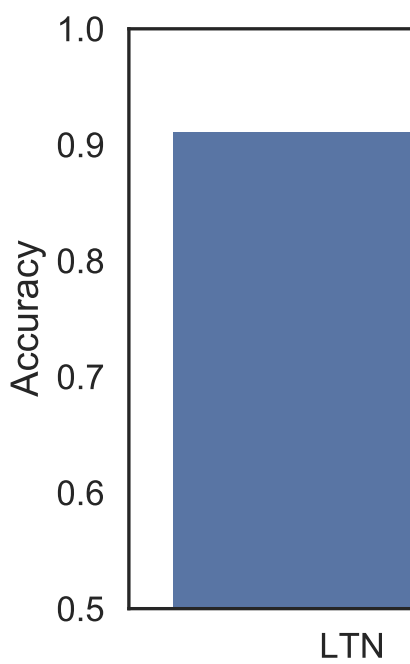
IV. DETAILS AND DISCUSSION

REFERENCES

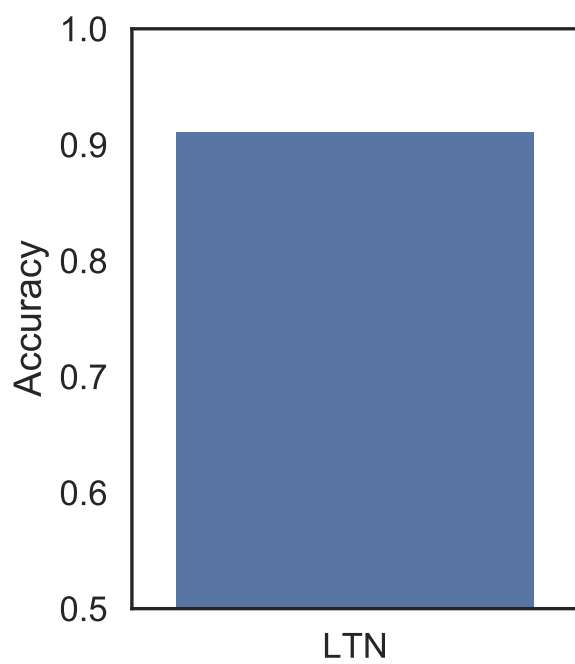
- [1] L. Serafini and A. d. Garcez, "Logic tensor networks: Deep learning and logical reasoning from data and knowledge," *arXiv preprint arXiv:1606.04422*, 2016.



(a) A gull



(b) A tiger



(c) A mouse

Figure 2: Pictures of animals