Consistency text similarity on the example of the task of recognizing hallucinations of language models

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Introduction

Explanation

Hallucination of the language model is a grammatically correctly generated response, which, however, contains incorrect information.

Examples

Paraphrase generation & Machine translation – different meaning.
Definition modeling – deviation from the database.

Problem statement

Language model is a function

$$\mathbf{f} : \mathcal{P}(\mathbf{T_s}^{L_s}) \to \mathcal{P}(\mathbf{T_h}^{L_h}),$$

$\mathbf{s}_i$ is called *source sentence* and $\mathbf{h}_i$ is called *model hypothesis*. We can define function

$$\mathbf{f}^{-1} : \mathcal{P}(\mathbf{T_h}^{L_h}) \to \mathcal{P}(\mathbf{T_s}^{L_s})$$

Then it is said that $\mathbf{h} = \mathbf{f}(\mathbf{s})$ is a *hallucination* of the language model $\mathbf{f}$ with the input $\mathbf{s}$ if

$$p(\mathbf{f}^{-1}(\mathbf{f}(\mathbf{s})) = \mathbf{s}) = 0.$$

Problem statement

The task of recognizing hallucinations is to find a function $sim : \mathbf{T_s}^{L_s} \times \mathbf{T_h}^{L_h} \to [0, 1]$, such that

$$\mathbb{E}_{\mathbf{s}_i \sim \mathbf{T_s}^{L_s}, \mathbf{h}_i \sim f(\mathbf{s}_i)} \{\mathbb{I}[sim(\mathbf{s}_i, \mathbf{h}_i) \geq \text{thr}] = y_i\} \to \max_{sim, \text{thr}},$$

where y_i denotes the presence of a hallucination.

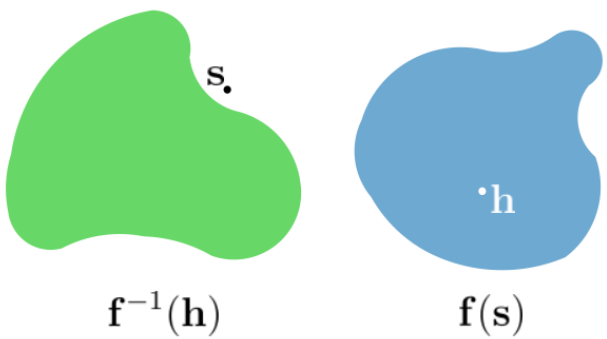

Figure: An illustration of a model's hallucination. **s** does not belong to the set of possible outputs of $\mathbf{f}^{-1}(\mathbf{h})$

Existing solutions

1. **Words or characters n-grams**

$$sim_{\text{BLEU}}(\mathbf{s}, \mathbf{h}) = \frac{|N_s \cap N_h|}{|N_h|}$$

2. **Similarity between static embeddings**

$$sim_{\cos}(\mathbf{s}, \mathbf{h}) = \cos(\mathbf{v_s}, \mathbf{v_h})$$

3. **Similarity between contextualized embeddings**

$$R = \frac{1}{L_s} \sum_{v_i \in \mathbf{v_s}} \max_{\hat{v}_j \in \mathbf{v_h}} v_i^T \hat{v}_j \; P = \frac{1}{L_h} \sum_{\hat{v}_j \in \mathbf{v_h}} \max_{v_i \in \mathbf{v_s}} v_i^T \hat{v}_j$$

$$\text{BERTScore} = 2\frac{PR}{P + R}$$

Existing solutions

4. **Similarity between embeddings from bi-encoders**

$$sim_{\text{bi-enc}}(\mathbf{s}, \mathbf{h}) = \cos(\mathbf{enc_s}(\mathbf{s}), \mathbf{enc_h}(\mathbf{h}))$$

5. **Symmetric and asymmetric cross-encoders**

$$sim_{\text{cross-enc}}(\mathbf{s}, \mathbf{h}) = \mathbf{clf}(\mathbf{enc}(\mathbf{s}, \mathbf{h}))$$

In the general case, the similarity function should be defined for objects from different spaces $\mathbf{T_s}^{L_s}$ and $\mathbf{T_h}^{L_h}$.
The existing methods do not investigate whether there is enough information in $\mathbf{h}$ to restore $\mathbf{s}$.

Computational experiment

We are given the dataset

$$\mathcal{D} = \{(\mathbf{s}_i, \mathbf{h}_i, y_i)\}_{i=1}^{N}, \quad \mathbf{h}_i \in \mathbf{f}(\mathbf{s}_i), \quad y_i \in \{0, 1\}$$

The target variable y_i indicates the occurrence of a hallucination in the $\mathbf{f}$ model at the input of $\mathbf{s}_i$ and the output of $\mathbf{h}_i$.

1. The proportion of correct predictions:

$$\text{Accuracy} = \frac{1}{N} \sum_{i=1}^{N} \mathbb{I}[\hat{y}_i \geq \text{thr}] = y_i$$

2. Spearman's rank correlation coefficient:

$$r_s = \rho_{R(Y),R(\hat{Y})} = \frac{\text{cov}(R(Y), R(\hat{Y}))}{\sigma_{R(Y)} \sigma_{R(\hat{Y})}}$$

Results

- Paraphrase generation task

Method	Accuracy ↑	r_s ↑
$sim_{\text{bi-enc}}$	0.808	0.153
sim_{C}	**0.824**	**0.186**

Table: Hallucination recognition results in the PG task

- Machine translation task

Method	Accuracy ↑	r_s ↑
sim_{LaBSE}	0.786	0.592
$sim_{\text{BLASER-QE}}$	**0.802**	**0.605**

Table: Hallucination recognition results in the MT task

Conclusion

- Analysis of the existing measures of textual similarity.
- New method that corrects the disadvantages of the previous ones.
- Hypotheses about properties of the *consistency similarity measure*.
- Computational experiments with different measures.

Future work:

- Theoretical justification of hypotheses.
- Extend the method to work with an external database
- Conduct comprehensive ablation study.

Literature

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