Privacy-Preserving Inference on Neural Networks with FHE/PHE Schemes

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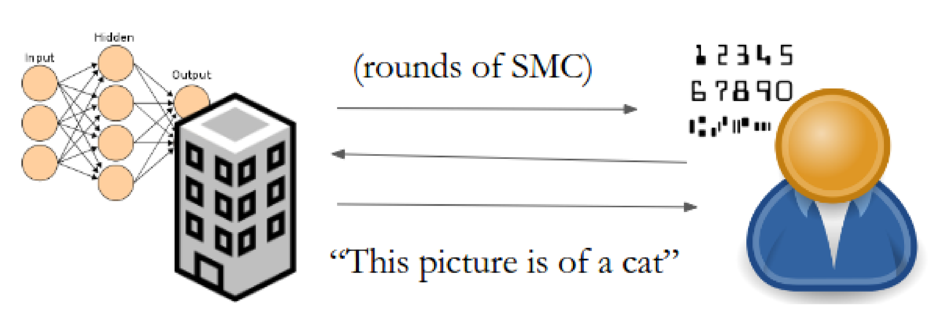
Problem Overview

In the past decade, neural networks have achieved state-of-art results on many inference benchmarks. In practice, many reasons to perform inference on encrypted data using neural networks:

- Hospital sending private patient data to cloud engine to predict a diagnosis
- Prediction over patentable drug candidates, voice biometric classification, etc.

We provide an overview of existing literature on neural network inference over encrypted data using SHE schemes [1, 2, 3]. We implement one such scheme using Simple Encrypted Arithmetic Library, and propose 2PC-based extensions on existing schemes.

The Multi-Party Game



Preliminaries

Neural Networks
State-of-art networks use a few key operations:

- Matrix-multiplication ($Ax + b$) for FCN layers
- Non-linear activations between linear layers:
  - Sigmoid: $\frac{1}{1+e^{-x}}$
  - Max-Pool/Max-Out: $\max(x_1, \ldots, x_n)$
  - ReLU: $\max(0, x)$
  - Softmax: $\frac{e^{z_j}}{\Sigma_{i=1}^{N} e^{z_i}}$

Parameters fixed after training. State-of-art speech networks have known multiplicative depth of 5-8.

R-LWE Assumption

$\nexists$ PPT A that can non-negligibly distinguish independent samples of $(a_i, a_i s + e_i)$ from (a_i, b_i), drawn uniform from $R_q \times R_q$. Generalizes to vectors/polynomials with components a_i.

Preliminaries Cont'd

YASHE
Fan-Ver **Pallier** Damgard-Jurik is a generalization that allows for arbitrary-long plaintexts ($\mod n^s$) used in practice.
The following materials were required to complete the research:

- Curabitur pellentesque dignissim
- Eu facilisis est tempus quis
- Duis porta consequat lorem
- Eu facilisis est tempus quis

The materials were prepared according to the steps outlined below:

1. Curabitur pellentesque dignissim
2. Eu facilisis est tempus quis
3. Duis porta consequat lorem
4. Curabitur pellentesque dignissim

Methods

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Important Result

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Mathematical Section

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$$E = mc^2 \tag{1}$$

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$$\cos^3\theta = \frac{1}{4}\cos\theta + \frac{3}{4}\cos 3\theta \tag{2}$$

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Results

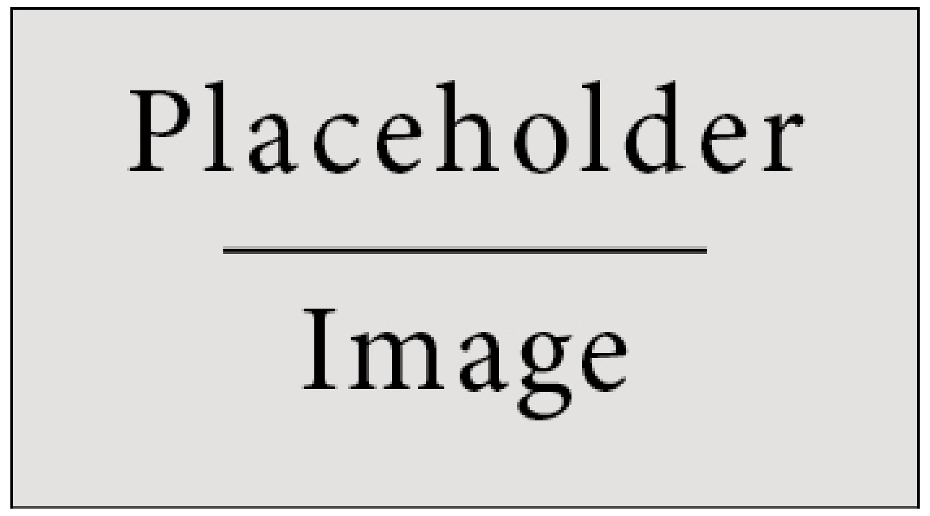

Figure 1: Figure caption

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Treatments	Response 1	Response 2
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910

Conclusion

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Additional Information

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- Curabitur pellentesque dignissim
- Eu facilisis est tempus quis
- Duis porta consequat lorem

References

[1] Ran Gilad-Bachrach, Nathan Dowlin, Kim Laine, Kristin Lauter, Michael Naehrig, and John Wernsing. Cryptonets: Applying neural networks to encrypted data with high throughput and accuracy. 2016.

[2] Pengtao Xie, Misha Bilenko, Tom Finley, Ran Gilad-Bachrach, Kristin Lauter, and Michael Naehrig. Crypto-nets: Neural networks over encrypted data. 2014.

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[5] Yan Huang, David Evans, Jonathan Katz, and Lior Malka. Faster secure two-party computation using garbled circuits. In *USENIX Security Symposium*, 2011.