Machine
Learning
Laboratory

Gradient Inversion with Generative Image Prior

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[*]contributed equally

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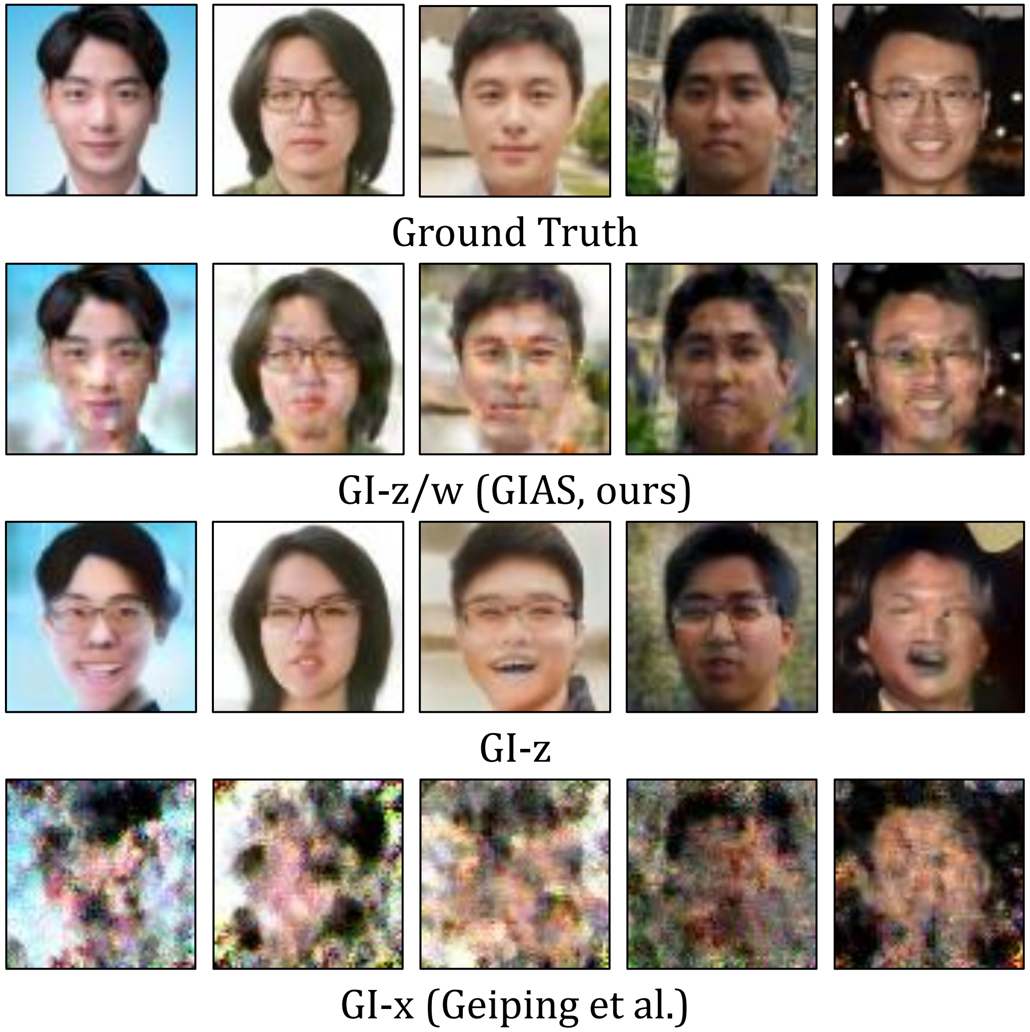
Advantages of Federated Learning

Privacy Concern in Federated Learning

Advantage in privacy is debatable

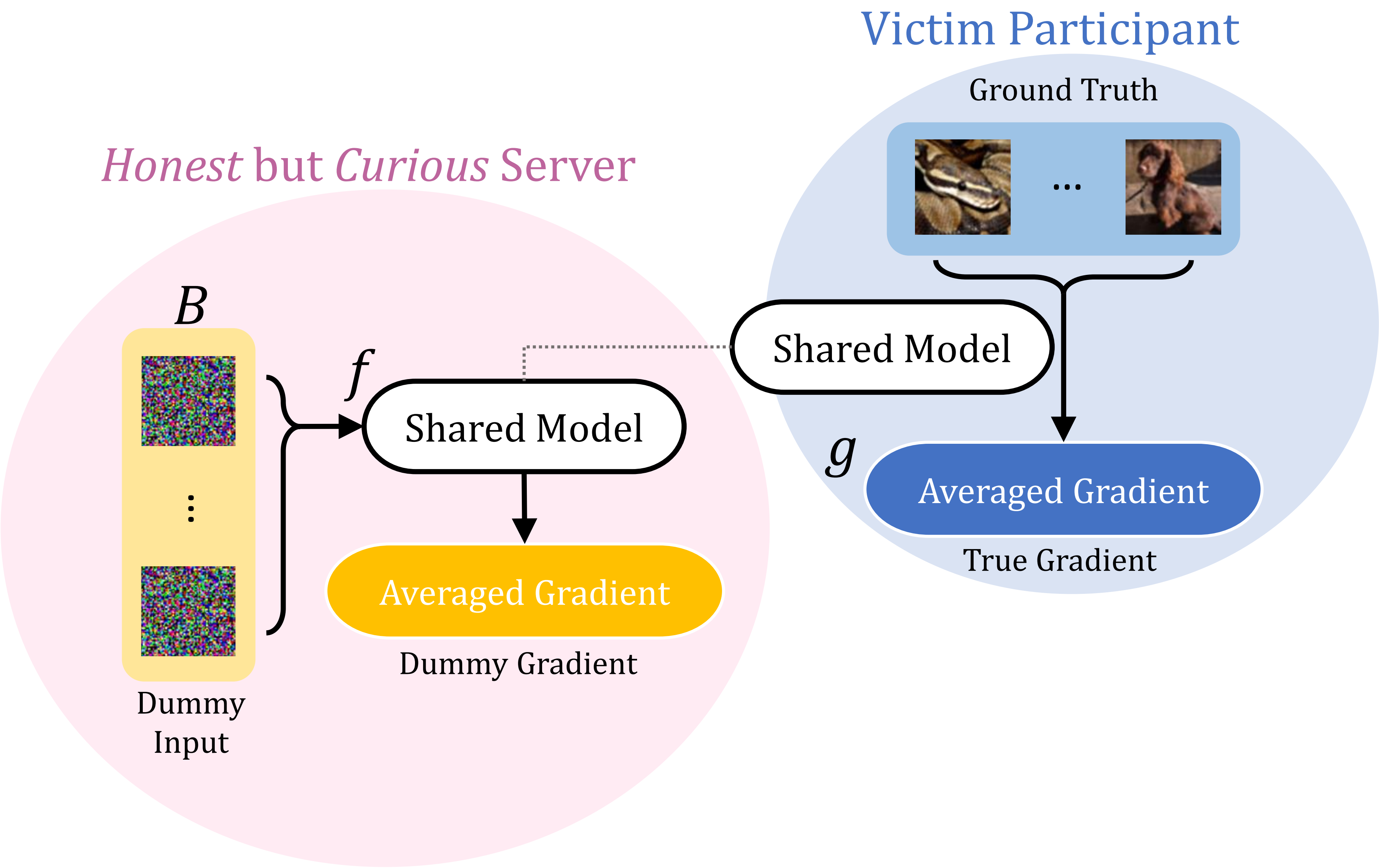
Gradient Inversion with Generative Image Prior

Gradient Inversion Attack using Prior



Learning Prior via Gradient Inversion

What is Gradient Inversion?



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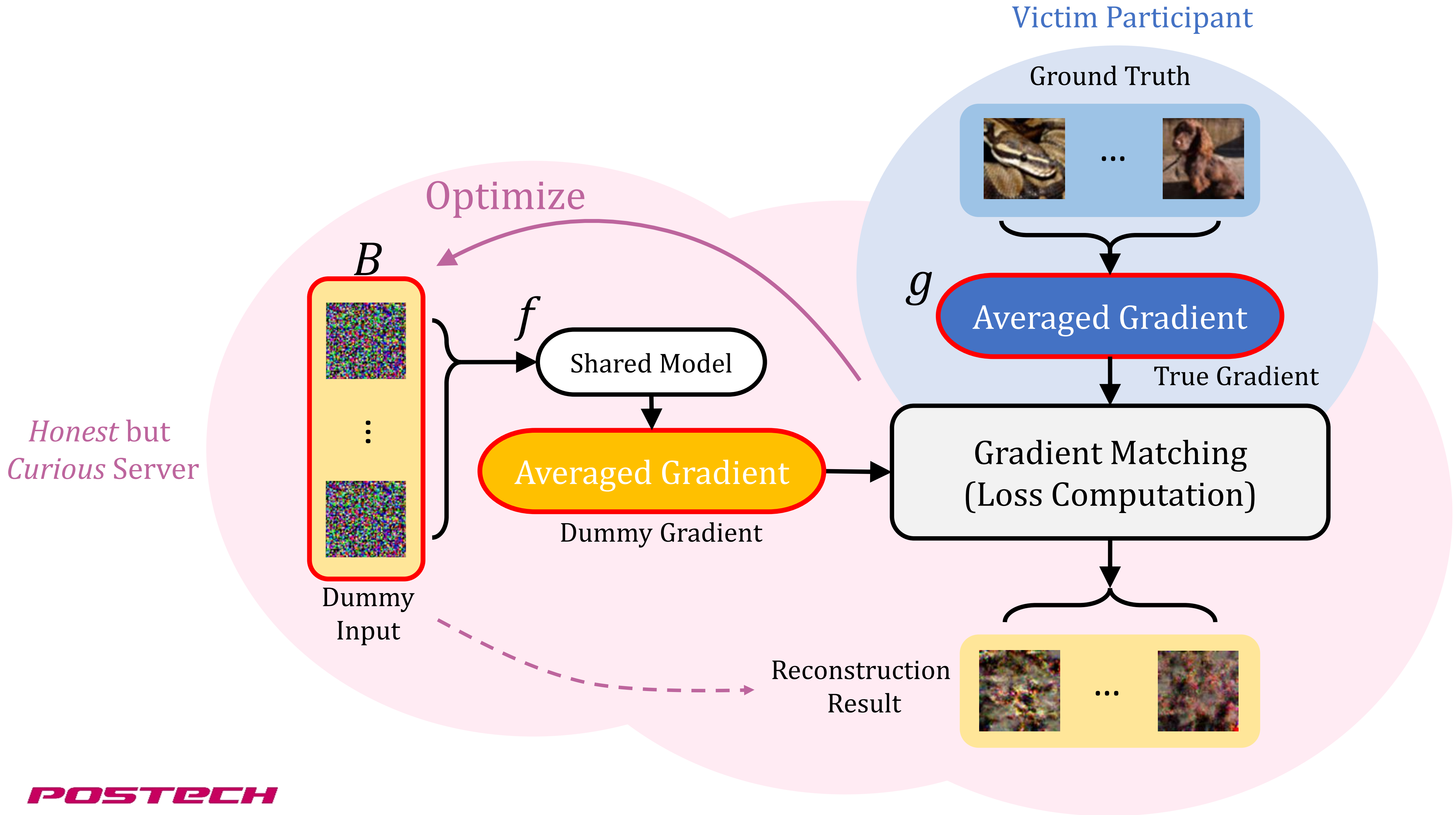
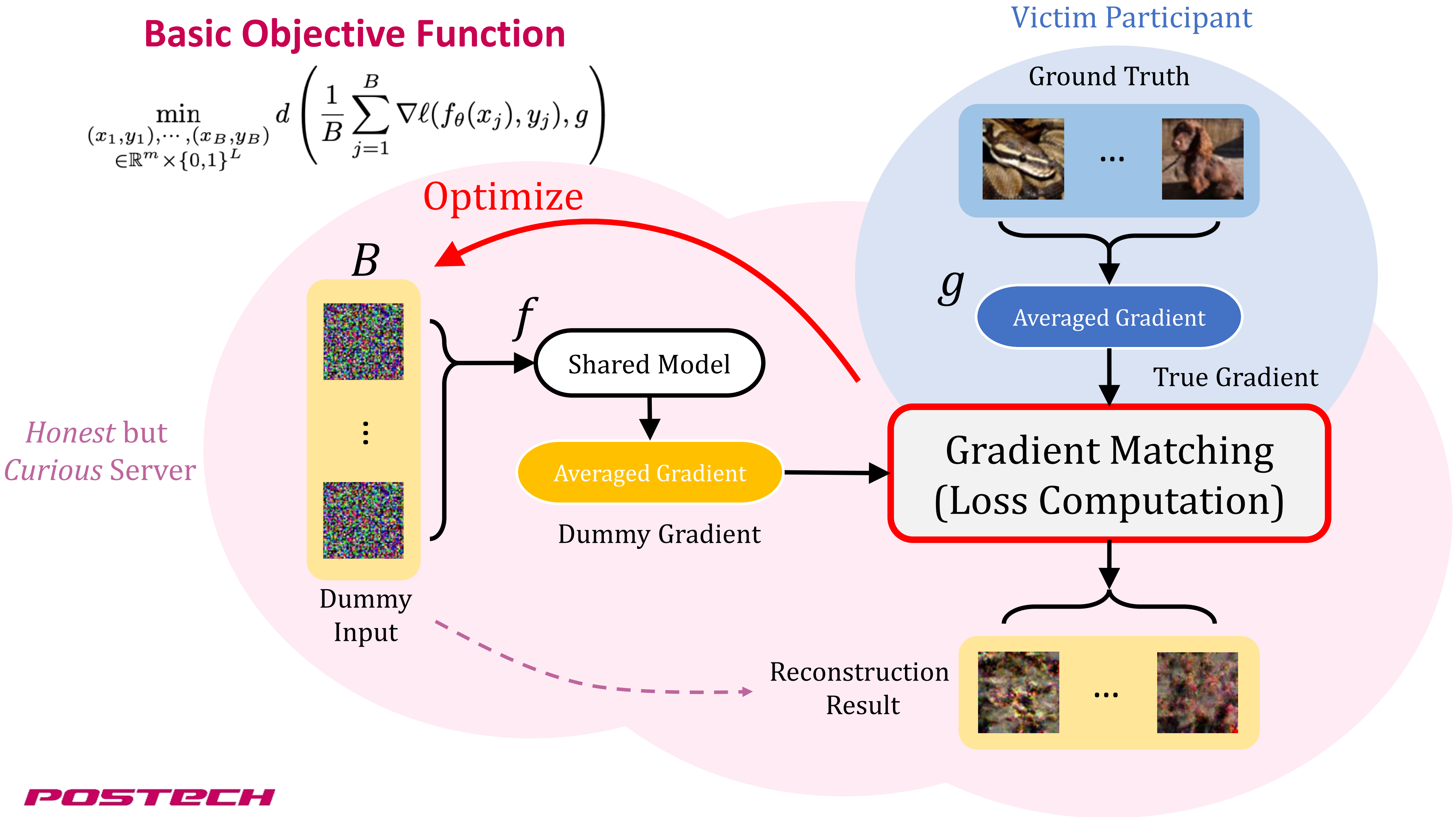


What is Gradient Inversion?

Basic Objective Function

$$\min_{\substack{(x_1,y_1),\cdots,(x_B,y_B)\\ \in\mathbb{R}^m\times\{0,1\}^L}} d\left(\frac{1}{B}\sum_{j=1}^{B}\nabla\ell(f_\theta(x_j),y_j),\, g\right)$$



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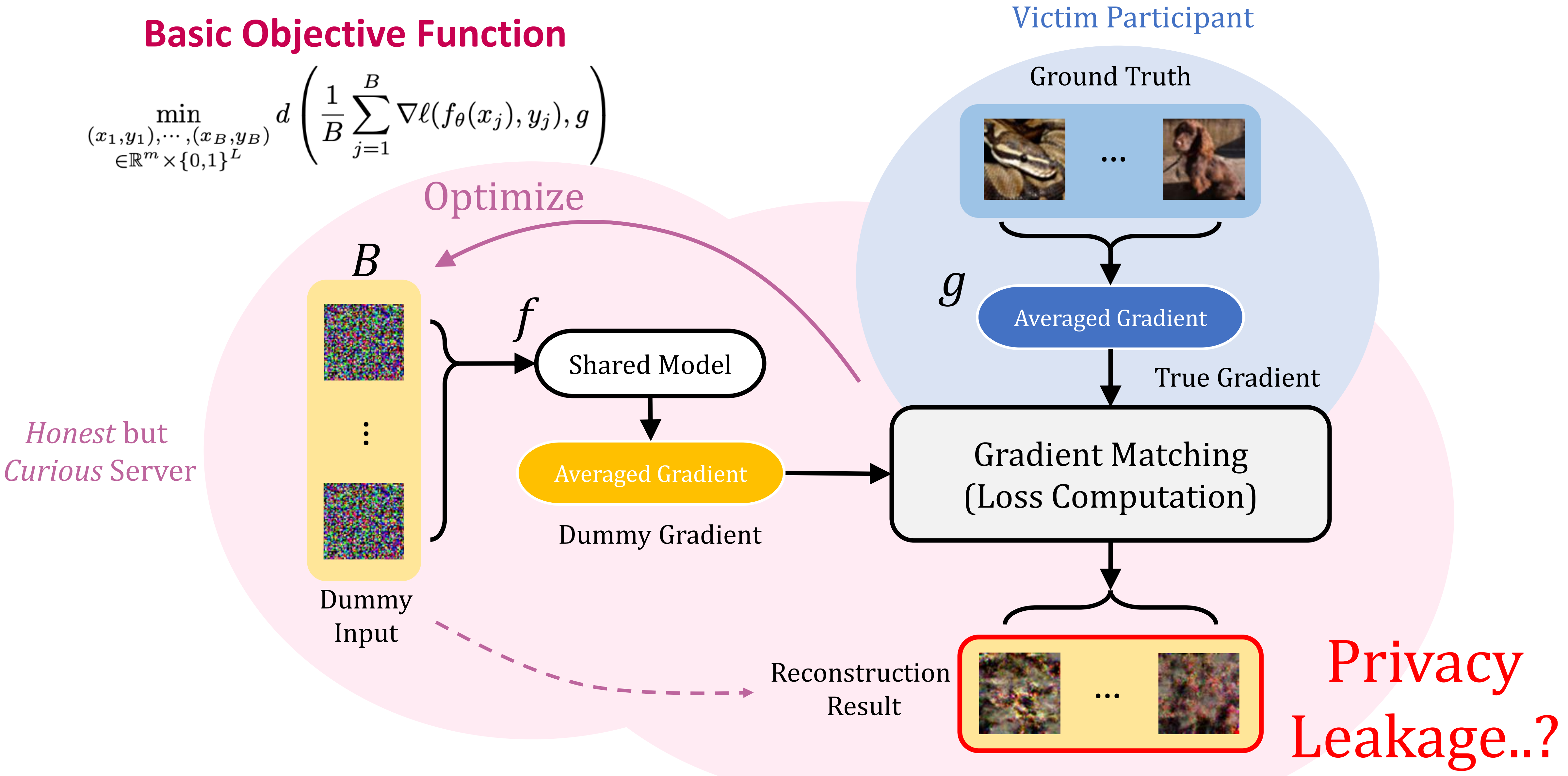
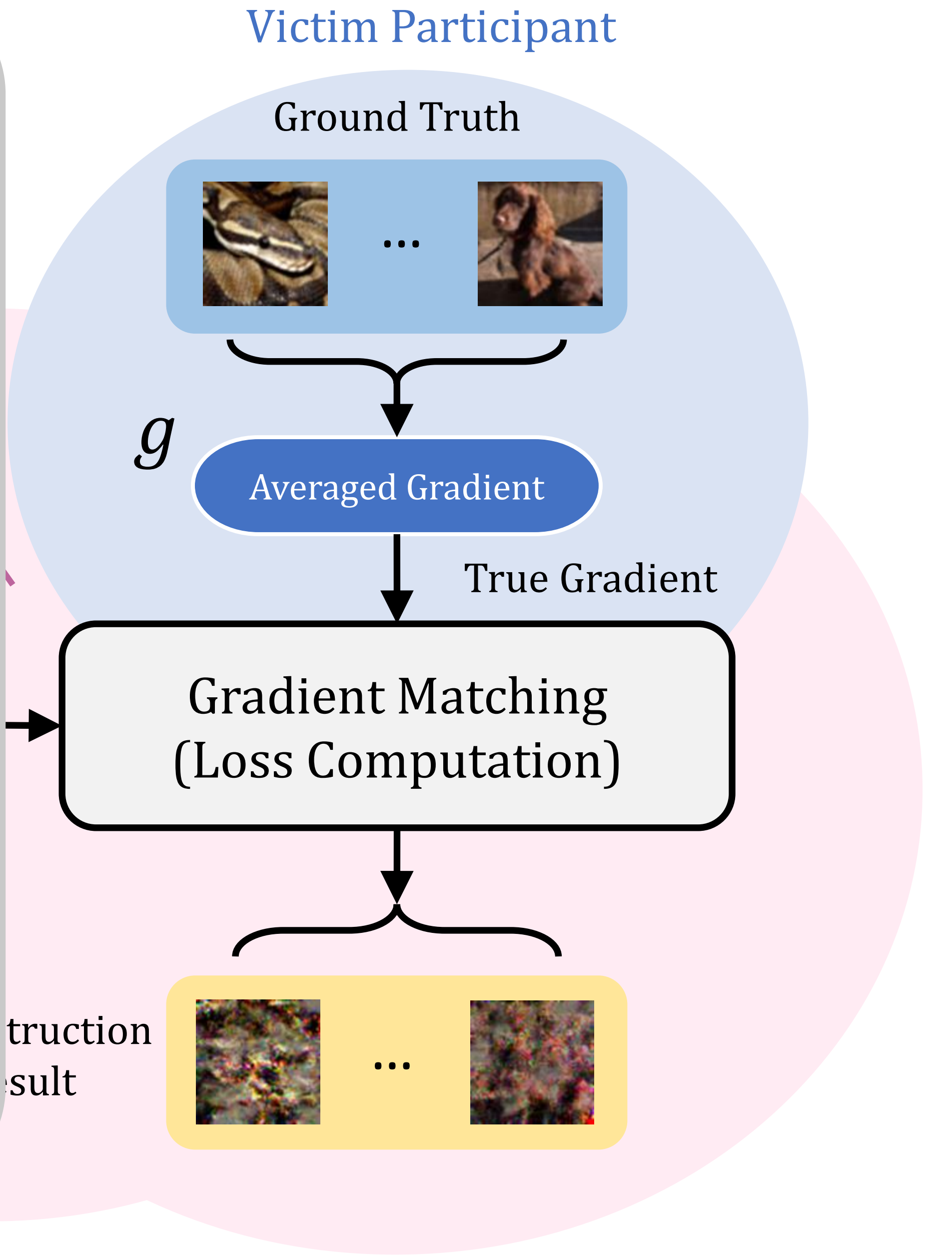


What is Gradient Inversion?

Why Gradient Inversion is hard?

$$\min_{\substack{(x_1,y_1),\cdots,(x_B,y_B)\\ \in\mathbb{R}^m\times\{0,1\}^L}} d\left(\frac{1}{B}\sum_{j=1}^{B}\nabla\ell(f_\theta(x_j),y_j),g\right)$$



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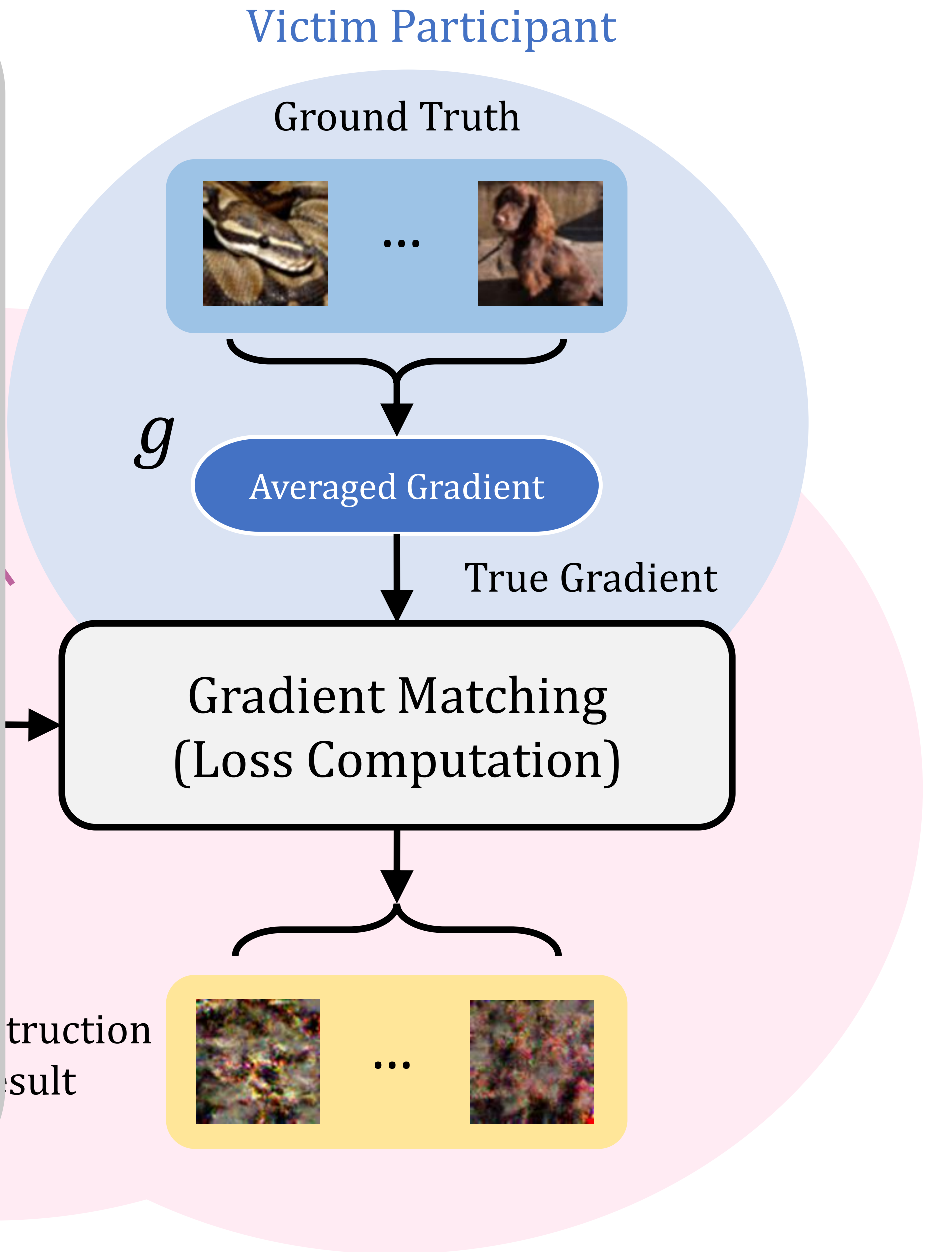
Source Separation + **Compressed Sensing**

→ Under-determined Problem!



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Source Separation

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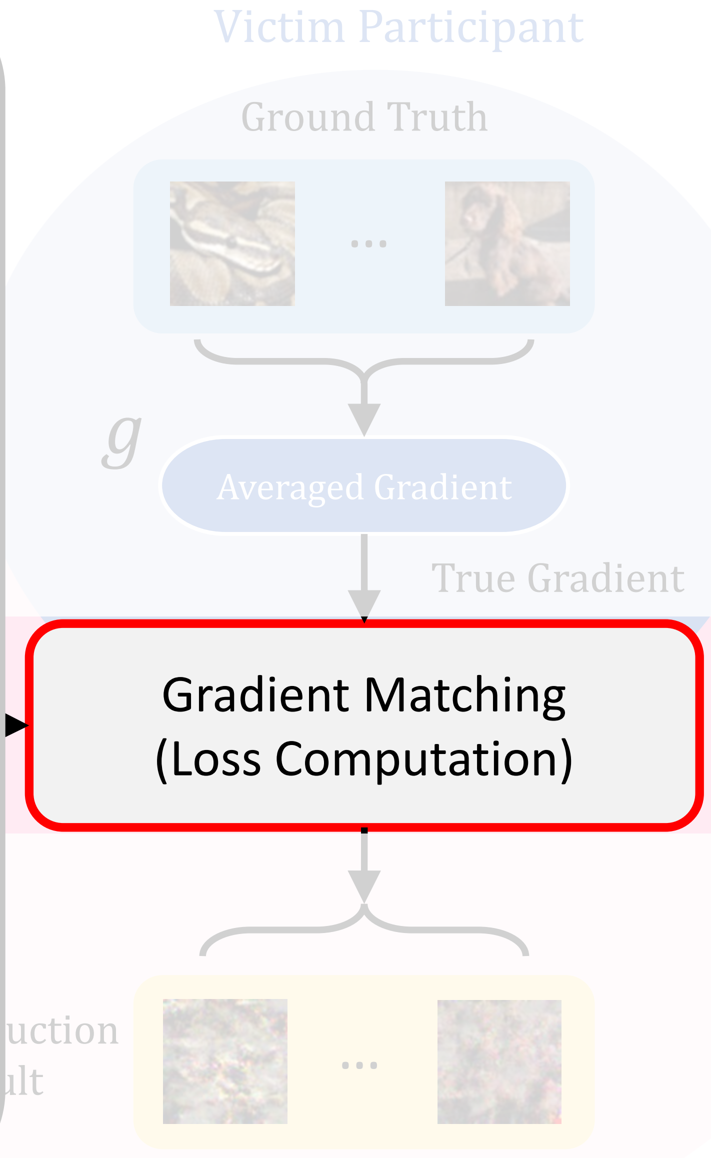


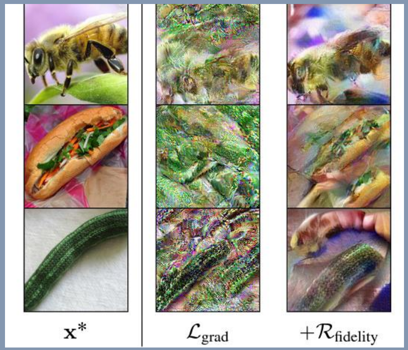
Priors can help attacks

Total Variation (Geiping et al.)

$$R_{\mathrm{TV}}(x) := \sum_{(i,j)} \sum_{(i',j') \in \partial(i,j)} \|x(i,j) - x(i',j')\|^2$$

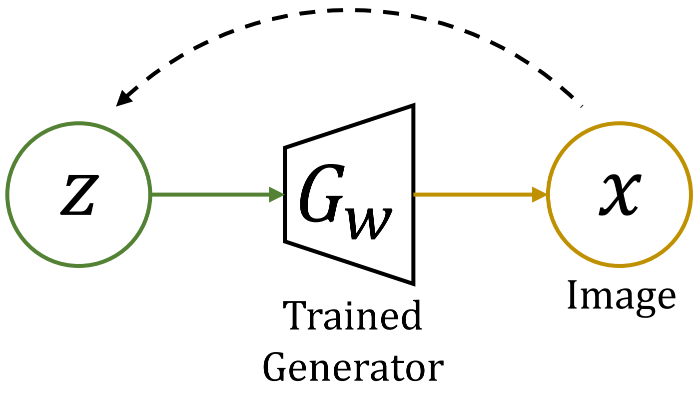
BN statistics (Yin et al.)

$$R_{\mathrm{BN}}(x_1, \ldots, x_B; \theta) := \sum_l \|\mu_l - \mu_{l,\mathrm{exact}}\|_2 + \|\sigma_l^2 - \sigma_{l,\mathrm{exact}}^2\|_2$$

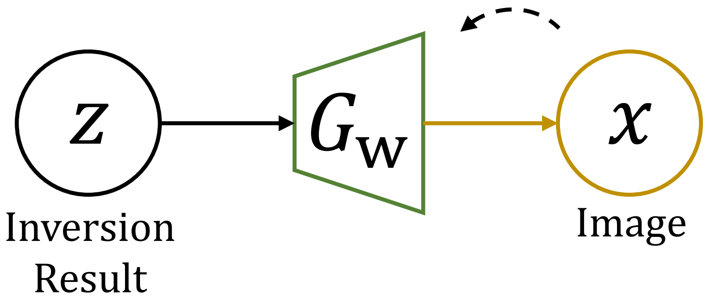


Gradient Inversion on Alternative Space

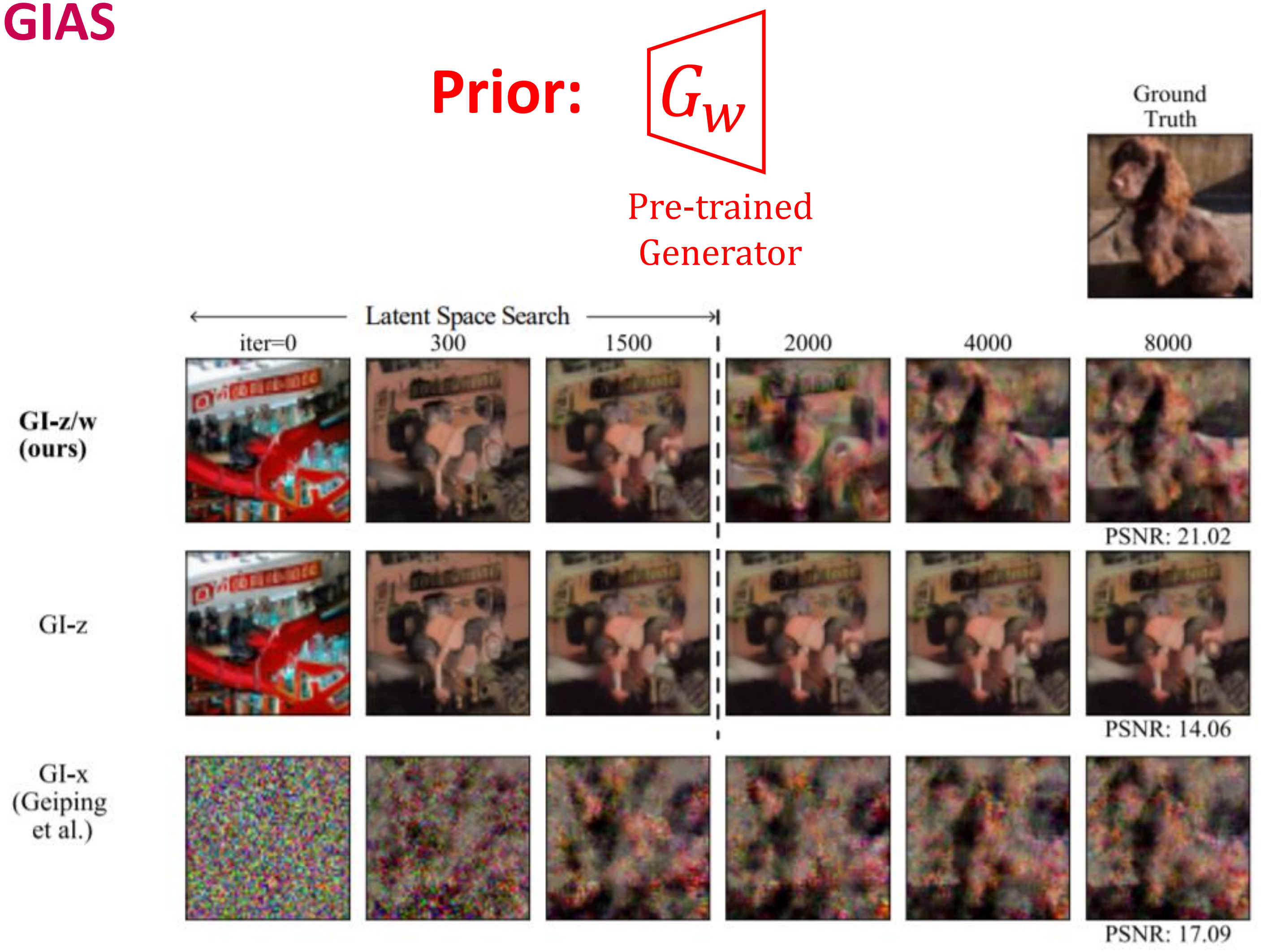
GAN Inversion



Generative Prior



GIAS



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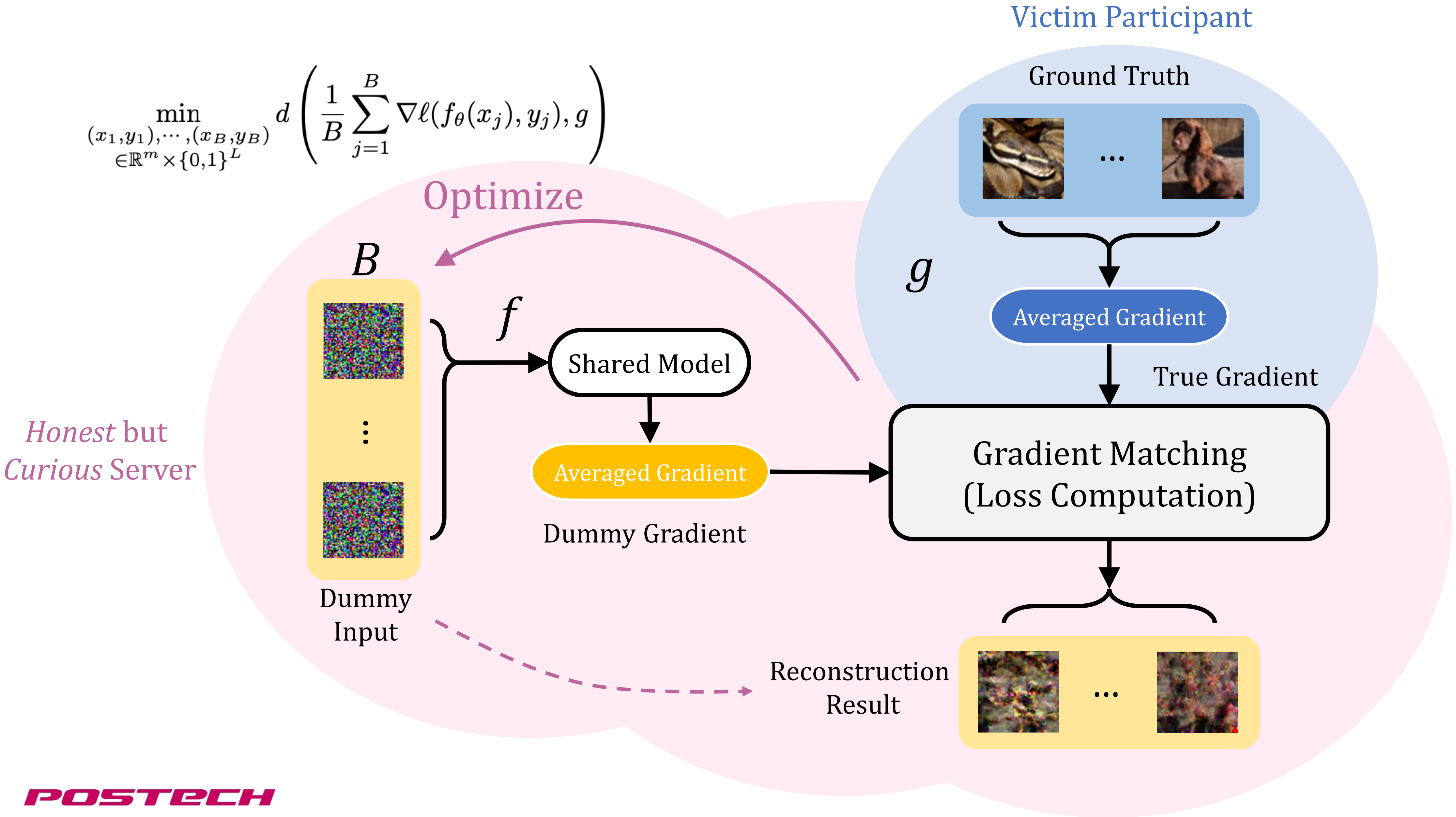
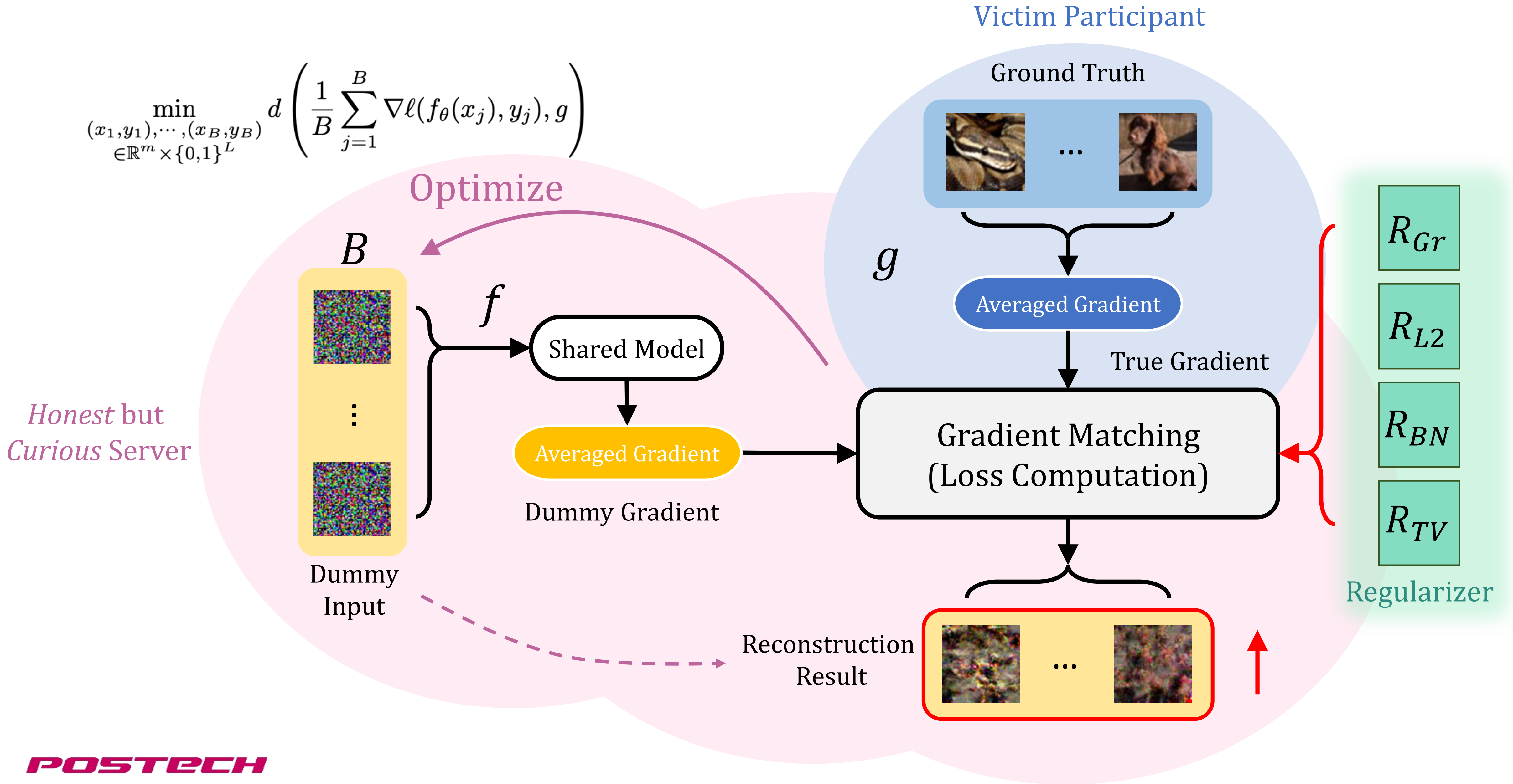
Basic Gradient Inversion

$$\min_{\substack{(x_1,y_1),\cdots,(x_B,y_B) \\ \in \mathbb{R}^m \times \{0,1\}^L}} d\left(\frac{1}{B}\sum_{j=1}^{B} \nabla \ell(f_\theta(x_j), y_j), g\right)$$



Gradient Inversion with Regularizers

$$\min_{\substack{(x_1,y_1),\cdots,(x_B,y_B)\\ \in \mathbb{R}^m \times \{0,1\}^L}} d\left(\frac{1}{B}\sum_{j=1}^{B} \nabla \ell(f_\theta(x_j), y_j), g\right)$$



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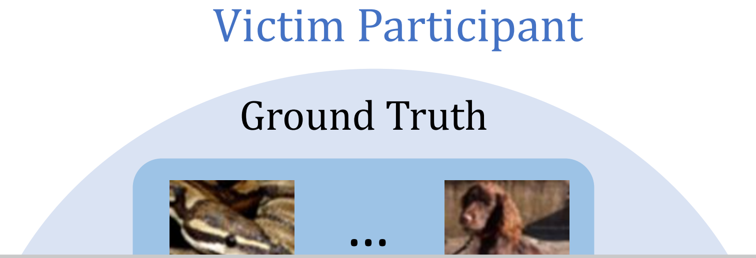
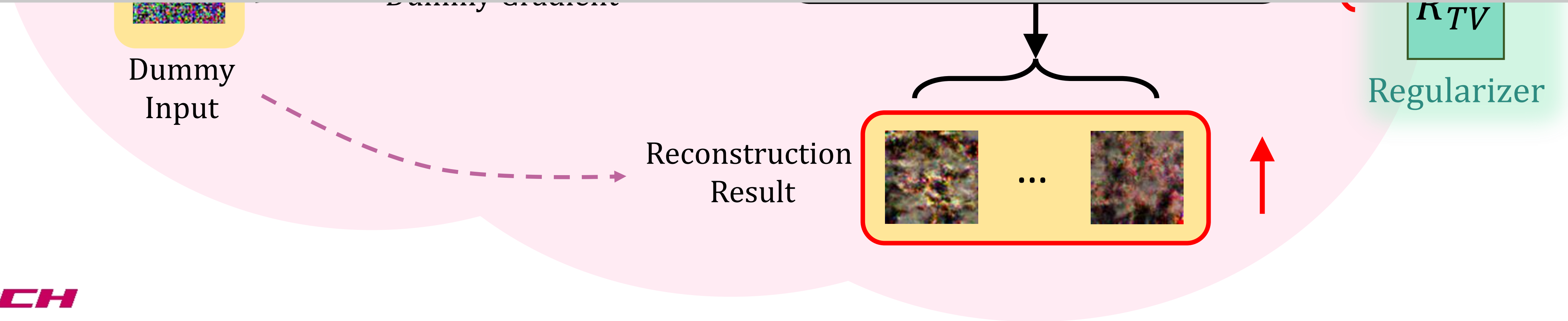
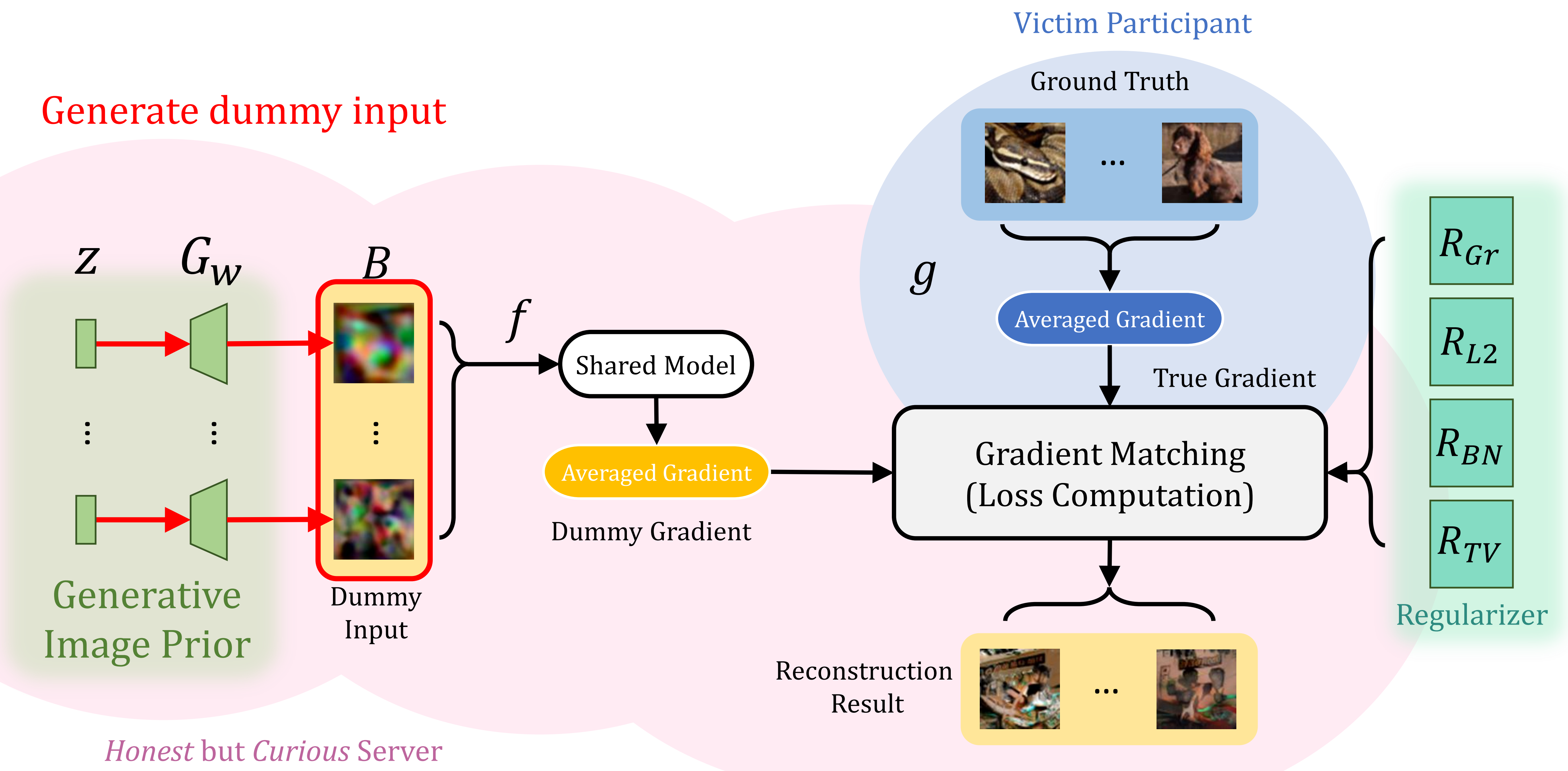


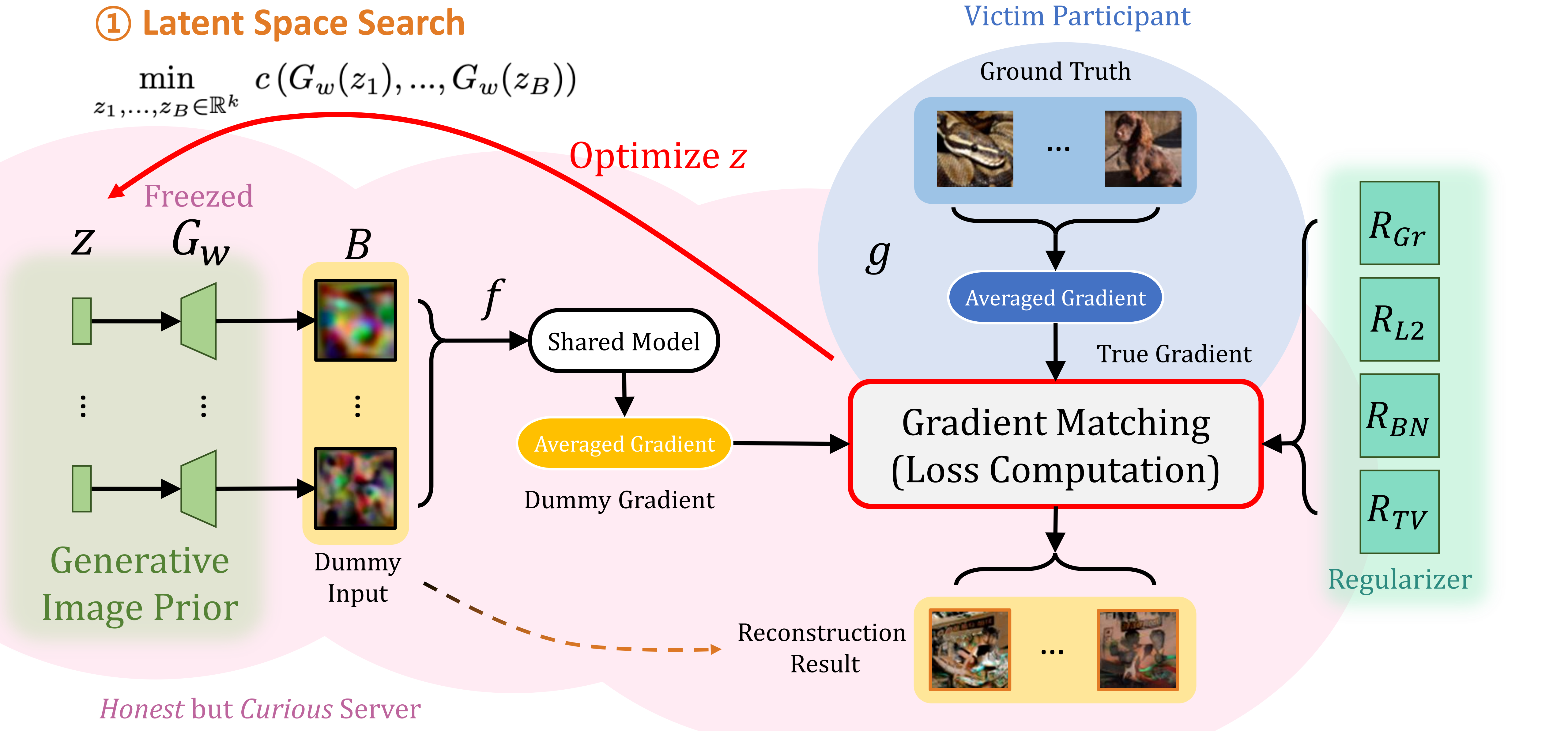
*What if we make the algorithm **only** explore among the **natural images**?*



Gradient Inversion on Alternative Space



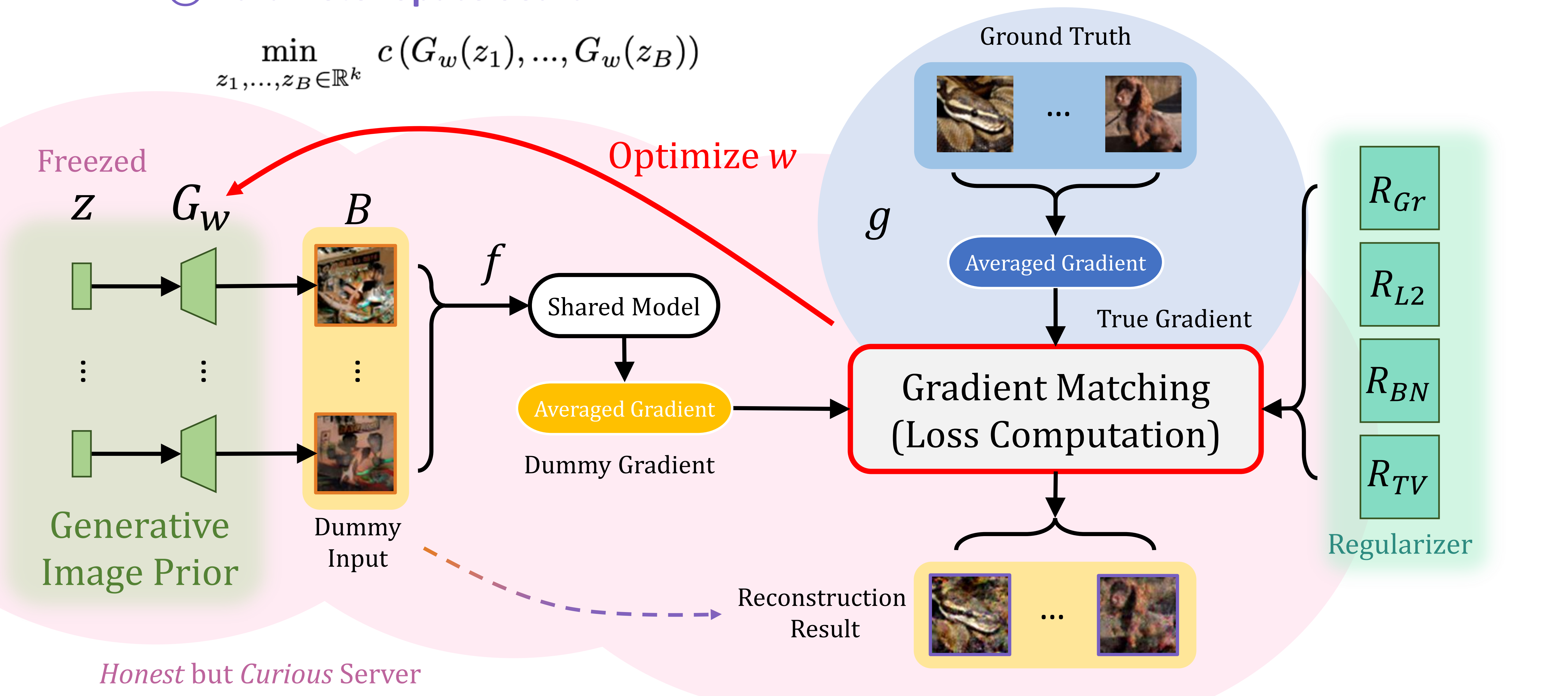
Gradient Inversion on Alternative Space



Gradient Inversion on Alternative Space

② Parameter Space Search

$$\min_{z_1,\dots,z_B \in \mathbb{R}^k} c\left(G_w(z_1), \dots, G_w(z_B)\right)$$



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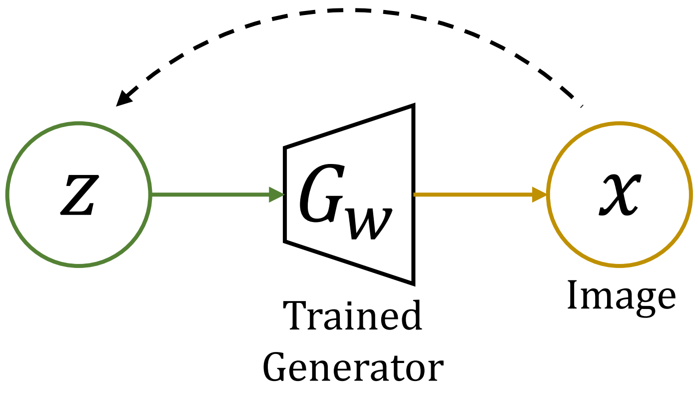
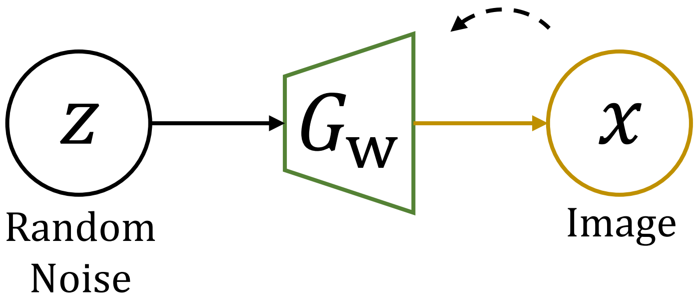
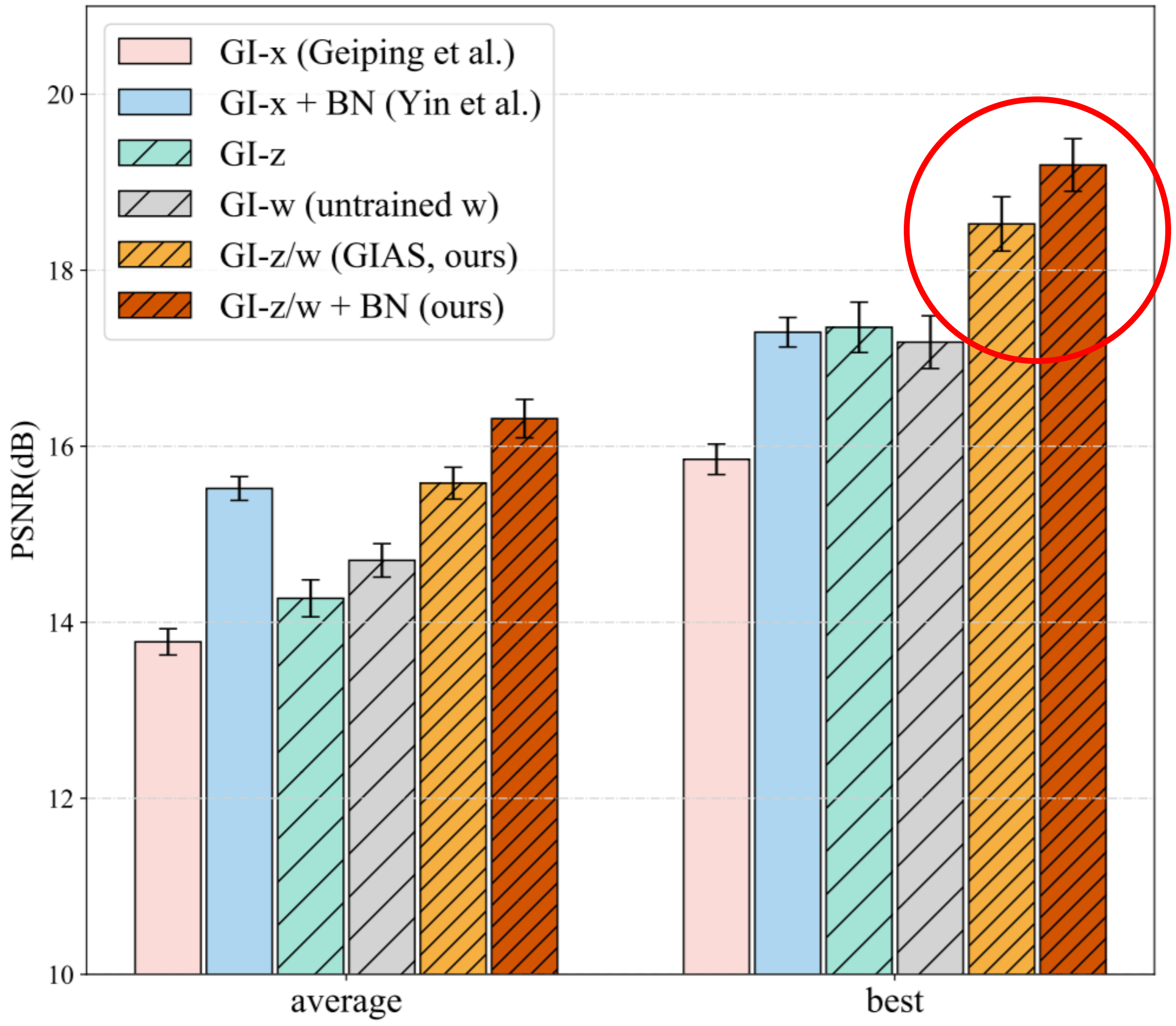
GAN Inversion



Deep Image Prior



GIAS



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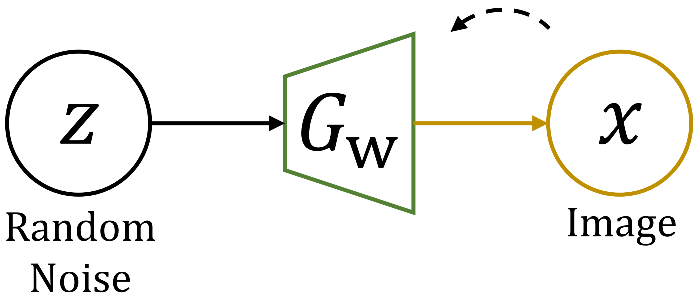
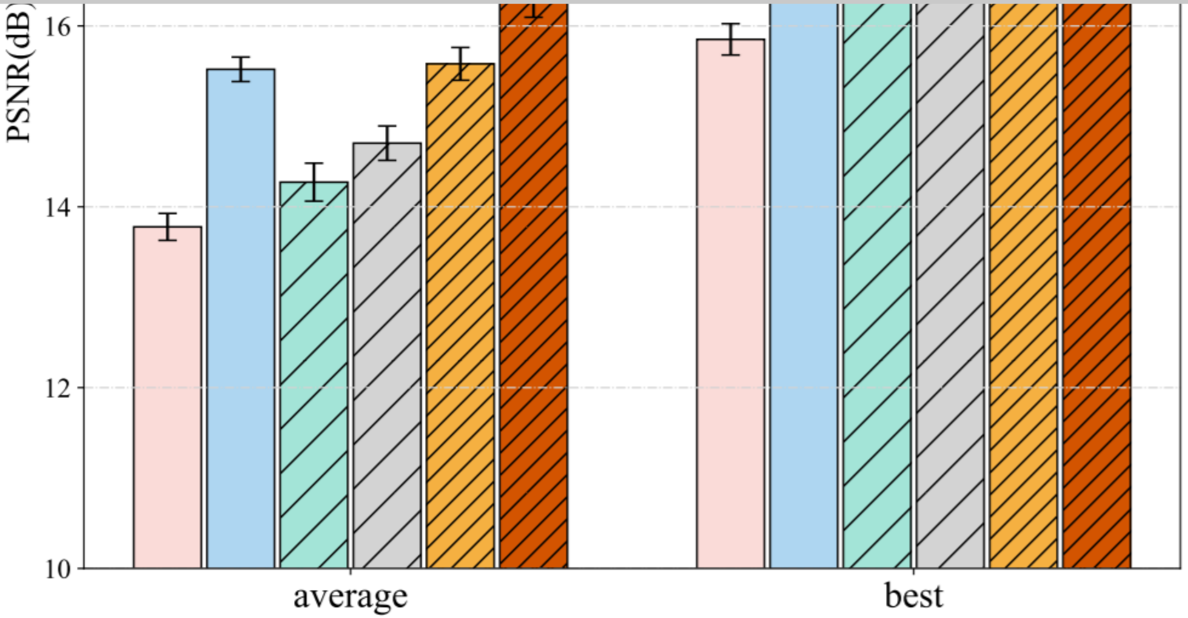
Gradient Inversion with Generative Image Prior

*How to **get a pre-trained model** with **unknown dataset**?*

Deep Image Prior





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Gradient Inversion with Generative Image Prior

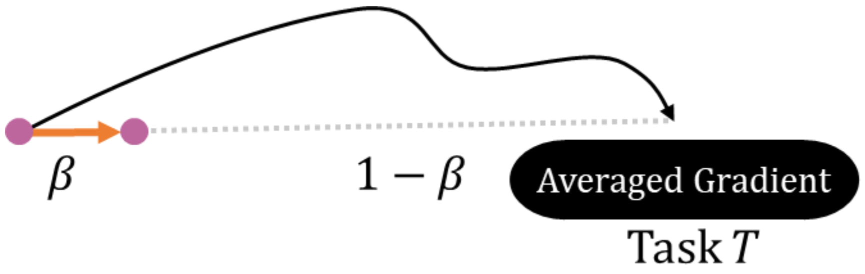
*How to **get a pre-trained model** with **unknown dataset**?*

*Is there any **advantage** of doing **a series of Gradient Inversions**?*

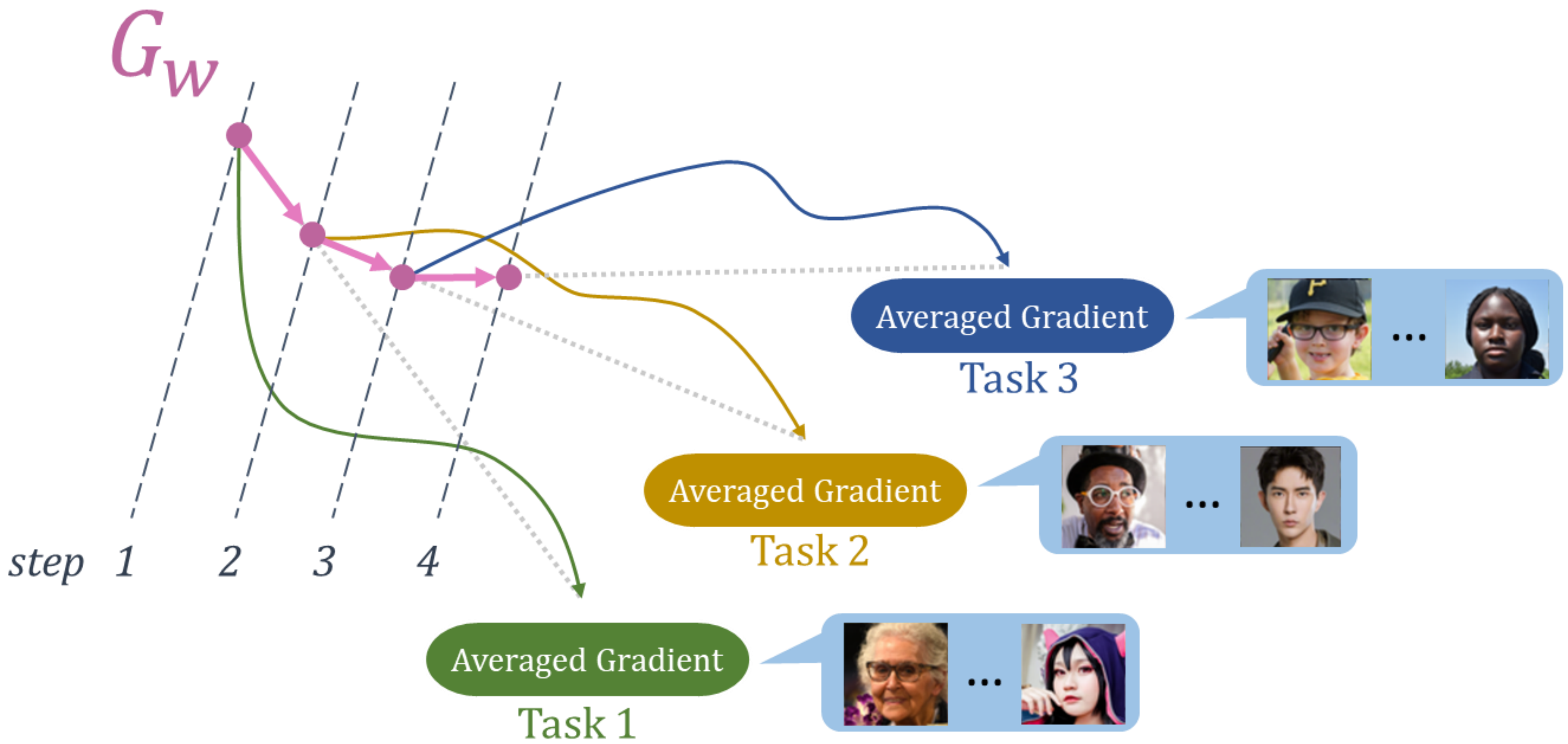
Gradient Inversion to Meta-Learn

First-Order Meta-Learning: Reptile

(A. Nichol et al.)



GIML



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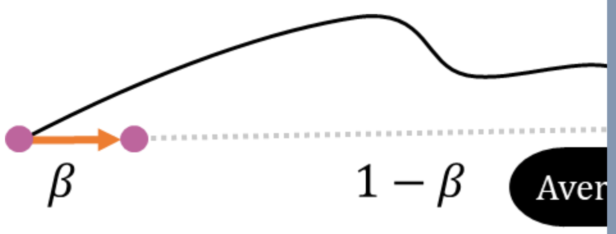

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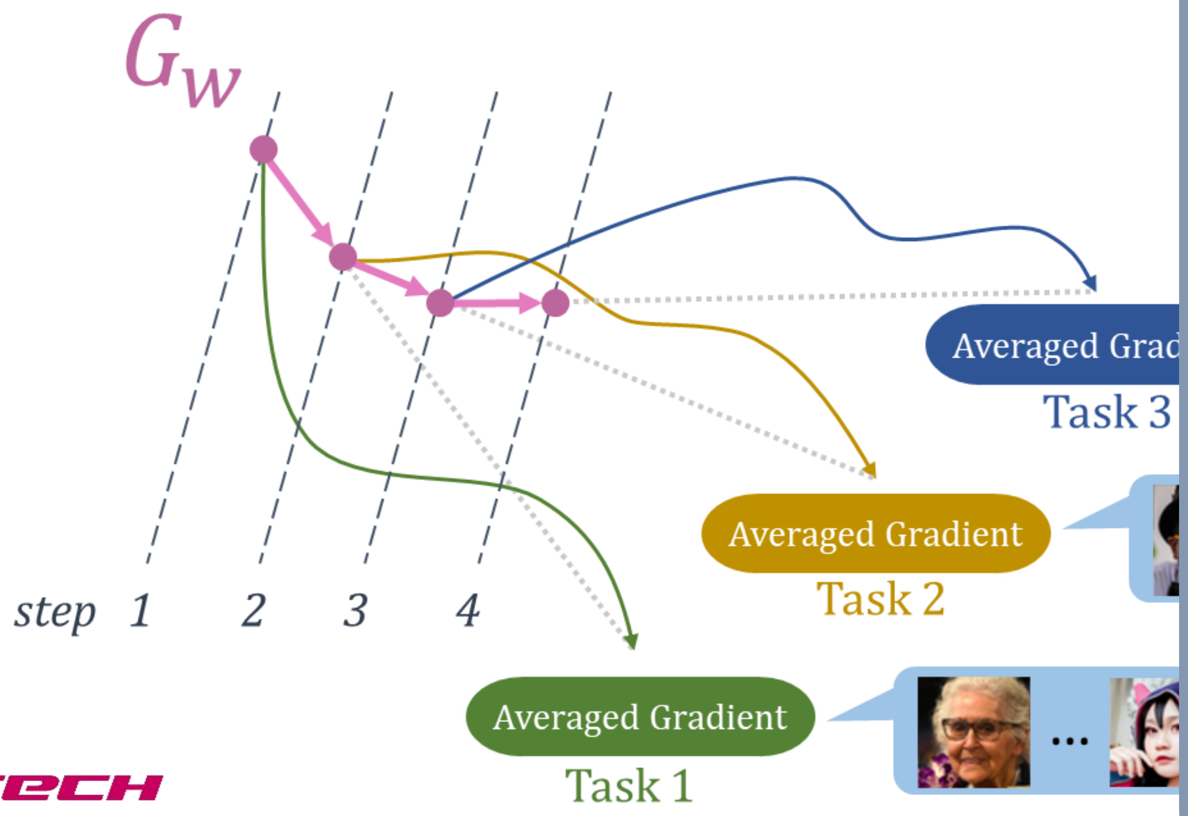
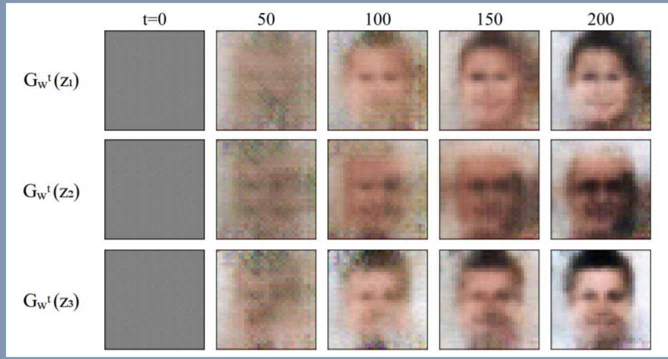


GIAS using GIML

Prior:



Meta-Learned Generator

Gradient Inversion to Meta-Learn

First-Order Meta-Learning: Reptile

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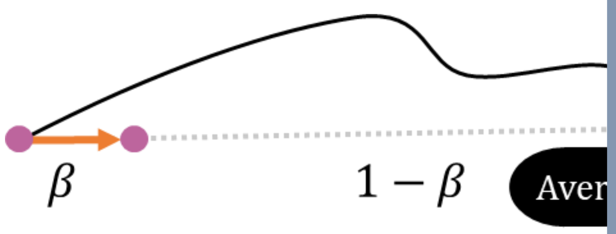

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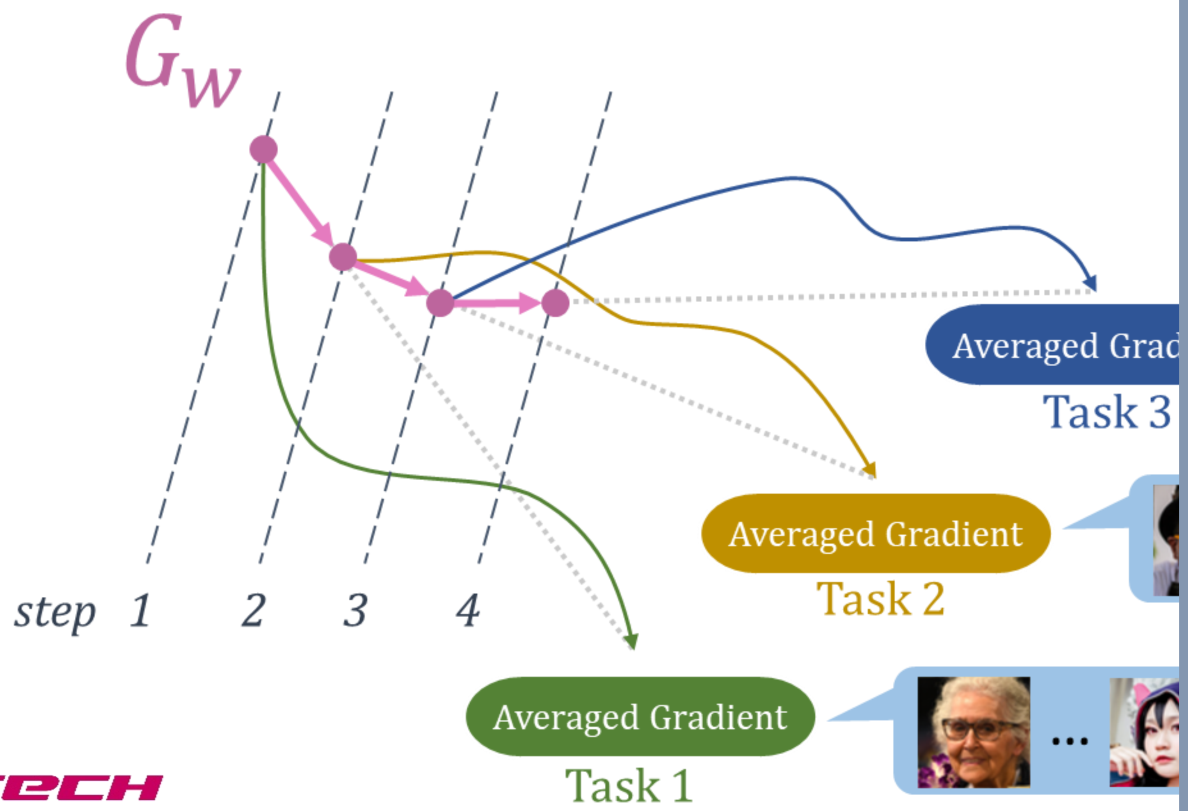

GIAS using GIML

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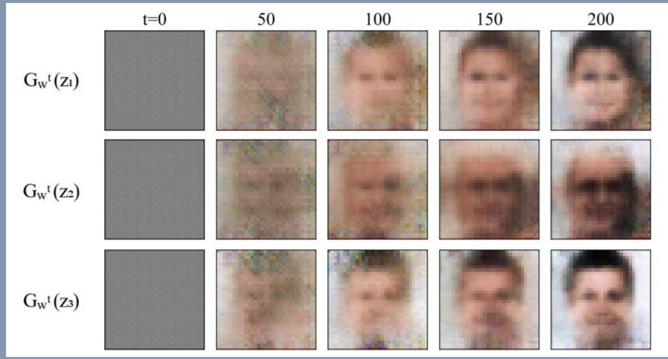


Meta-Learned Generator

Task T

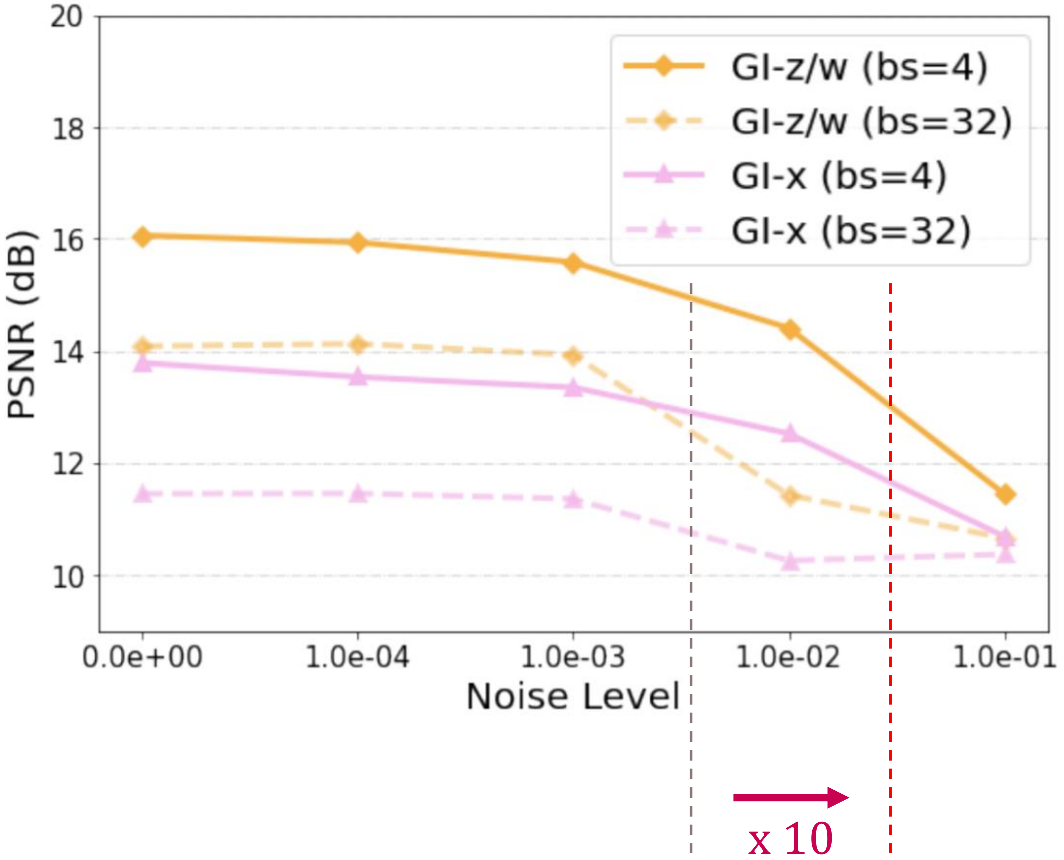
Not Trained

Well Trained

Wrong Prior

How to Protect Gradient Inversion Attacks?

Differential Privacy – Noisy Gradient



How to Protect Gradient Inversion Attacks?

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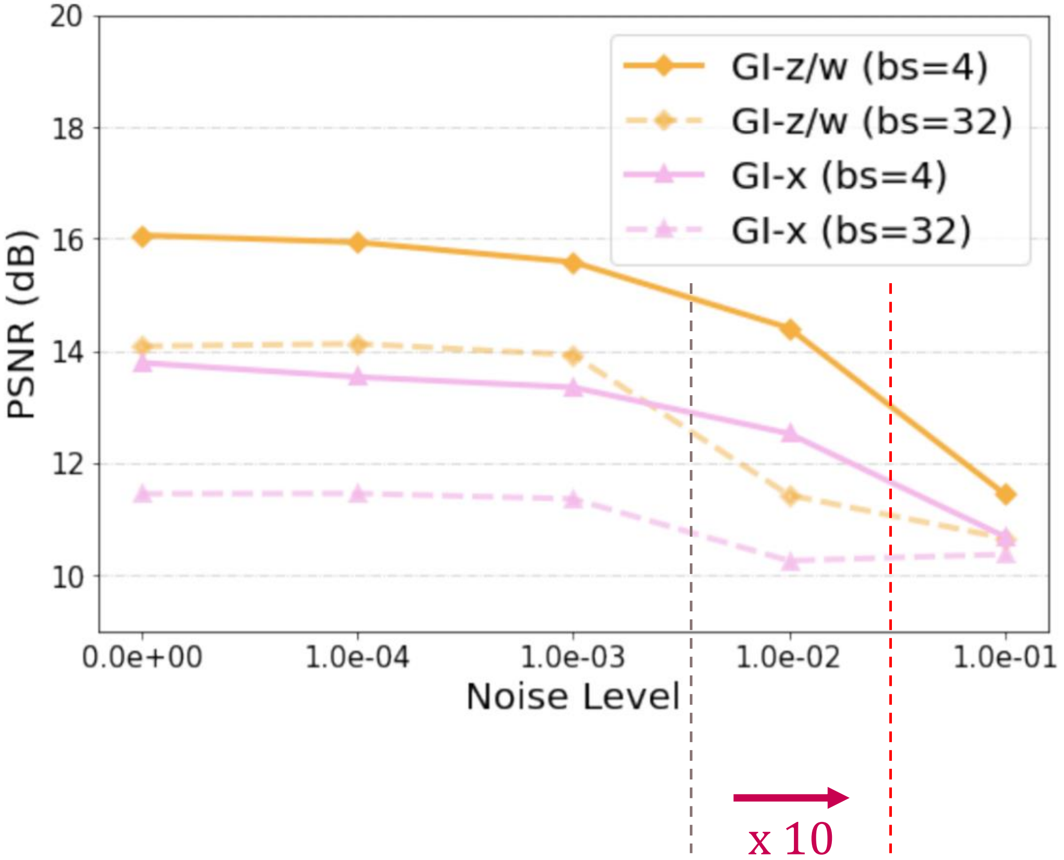
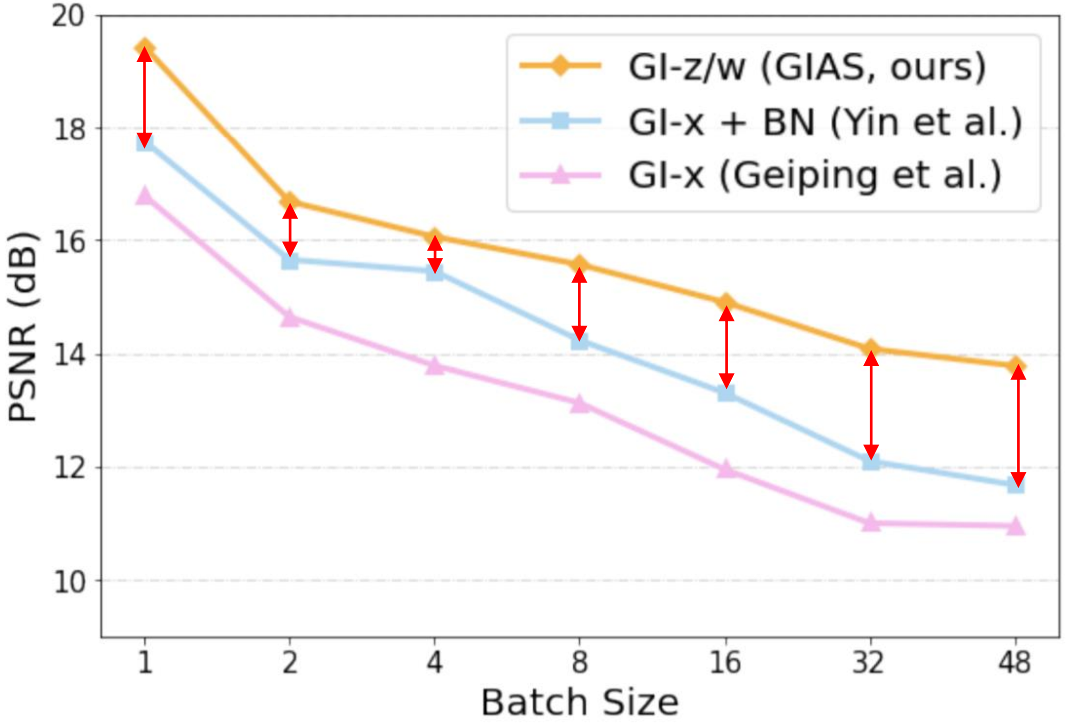


Large batch size



How to Protect Gradient Inversion Attacks?

Takeaways

Conclusion

- Priors help to solve under-determined problems like Gradient Inversion
- Utilizing priors gives us significant benefits to accomplish our goal
- Learning prior of the data via Gradient Inversion is possible

Our Contribution

- Propose the necessity of a higher standard on privacy
- Warn FL practitioners to choose more conservative choice of defense mechanisms

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Thank You :)

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