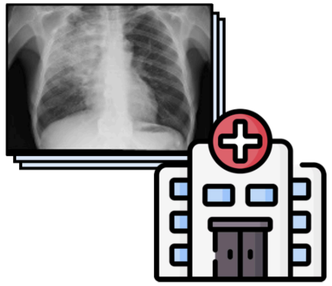
DLBox: New Model Training Framework for Protecting Training Data

Jaewon Hur, Juheon Yi, Cheolwoo Myung, Sangyun Kim, Youngki Lee, and Byoungyoung Lee

서 울 대 학 교
SEOUL NATIONAL UNIVERSITY

Sharing Training Data can be Dangerous



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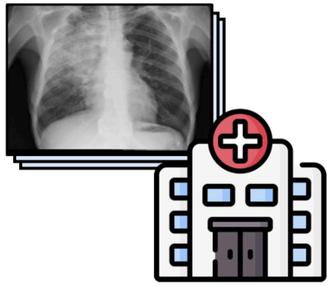

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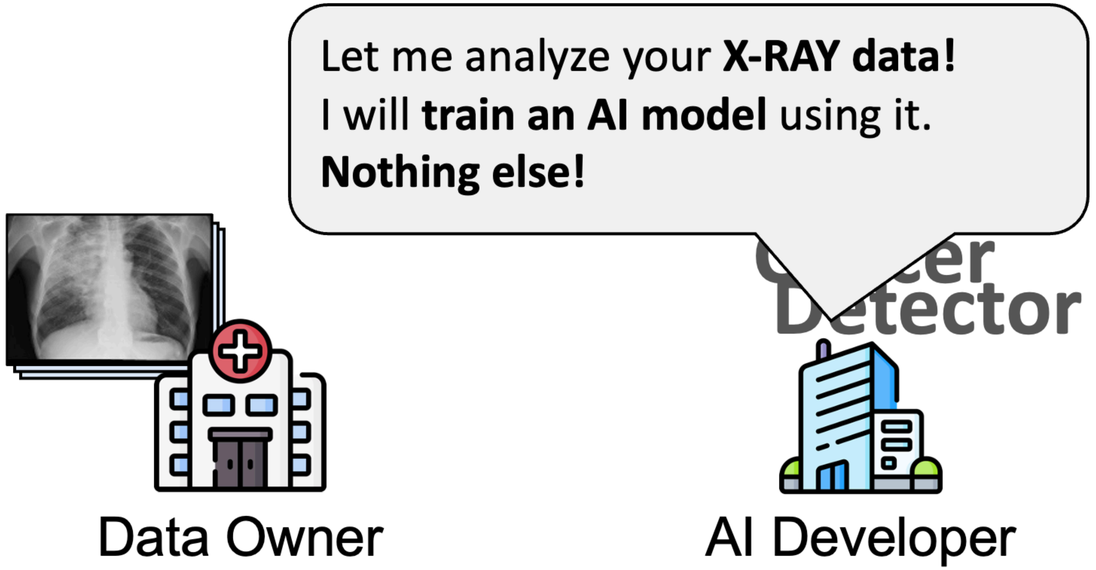

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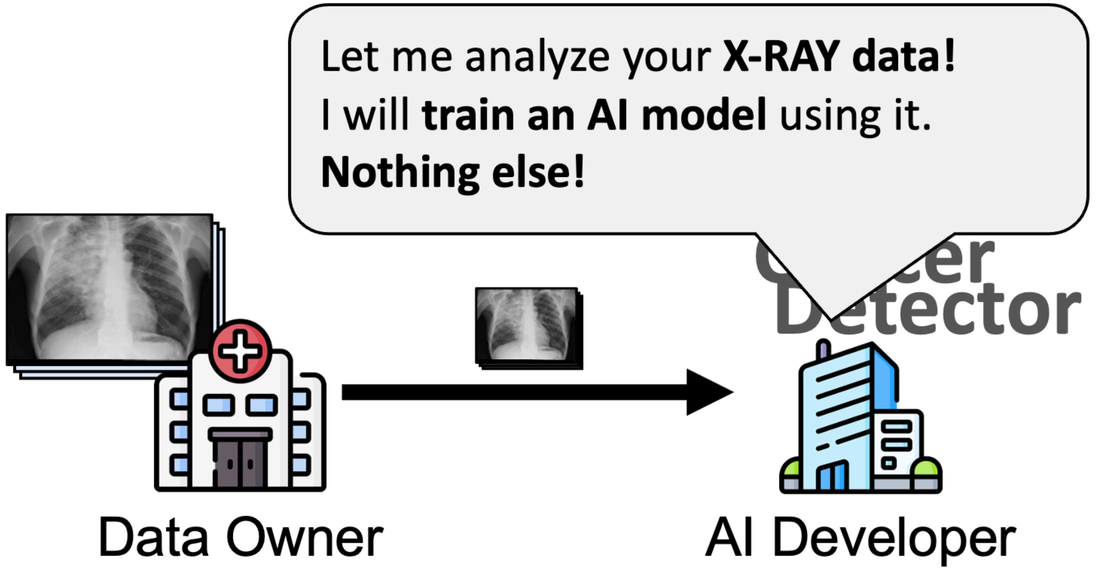

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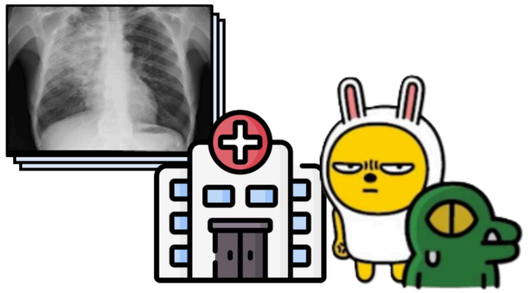

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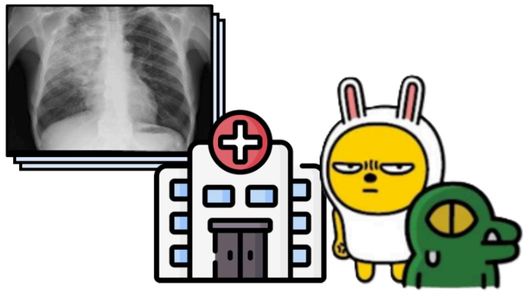

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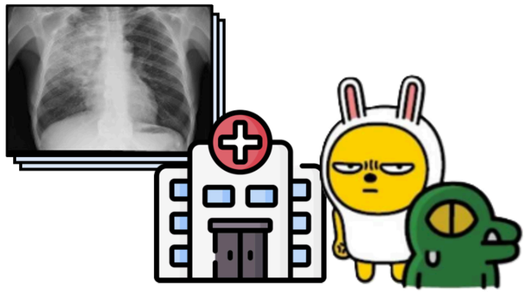

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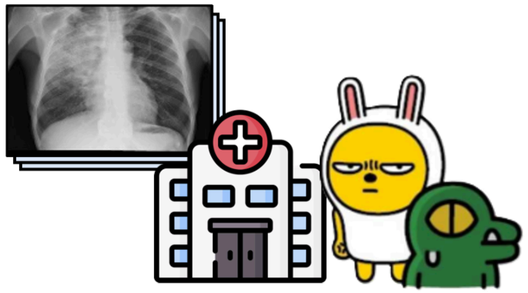

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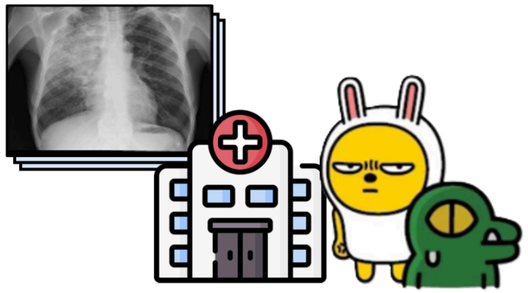

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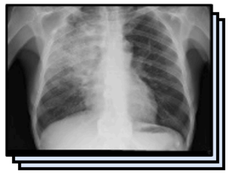

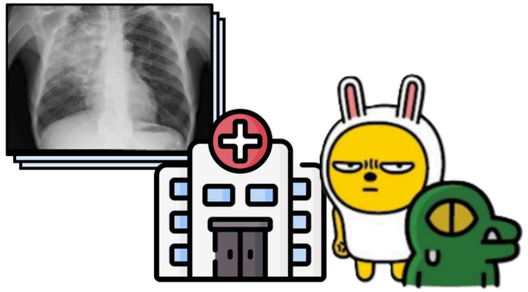

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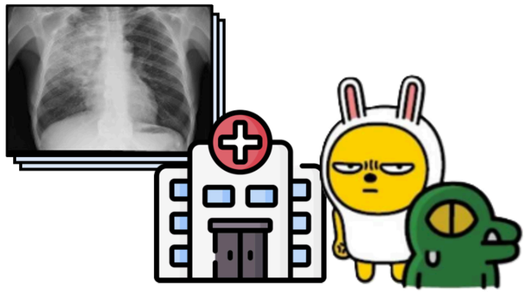

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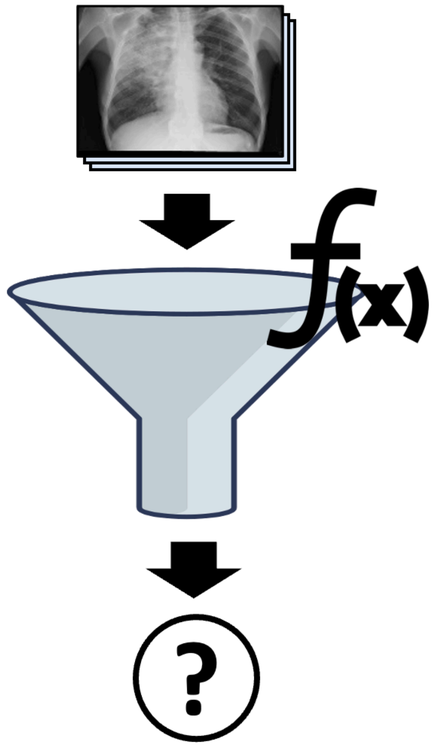

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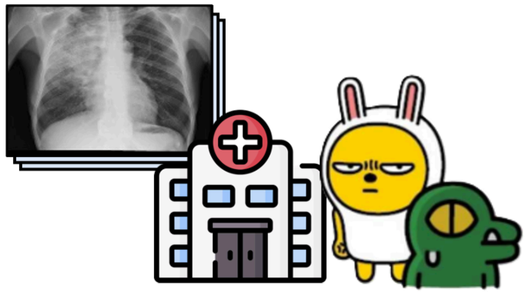

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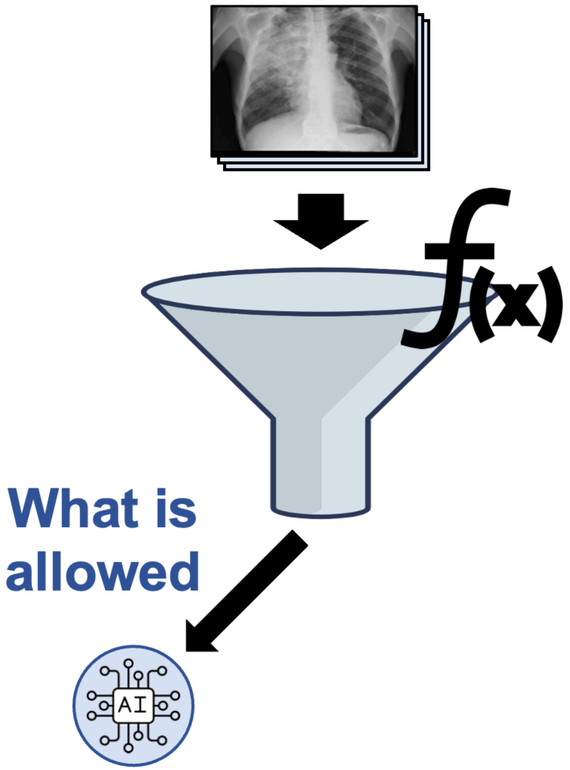

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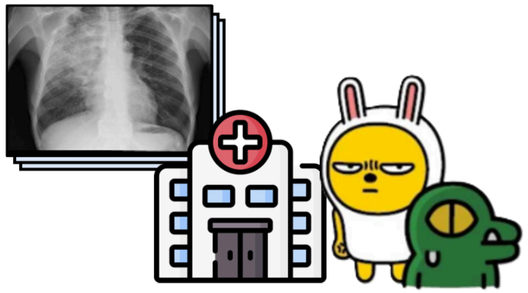

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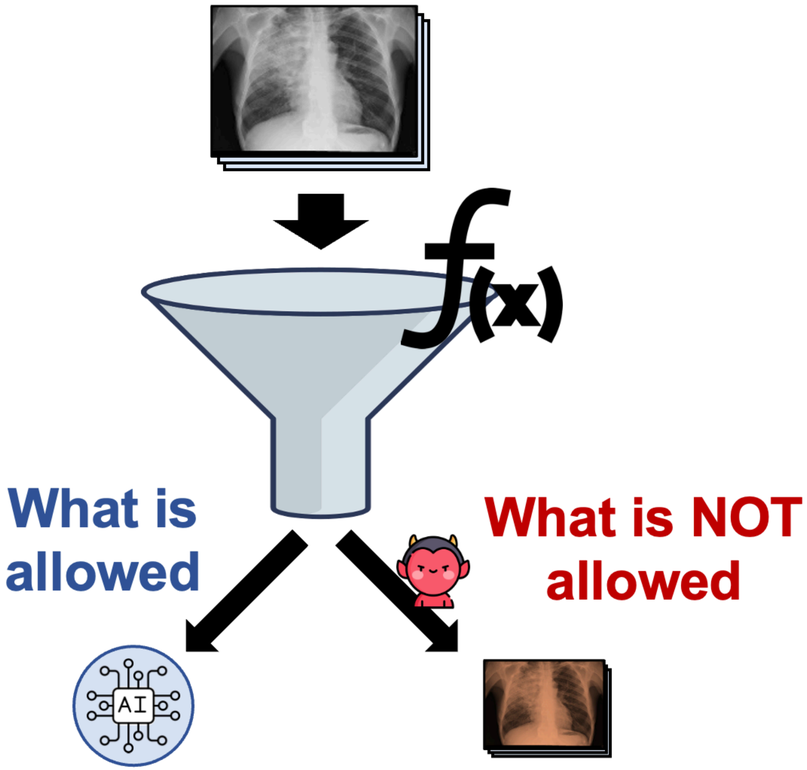

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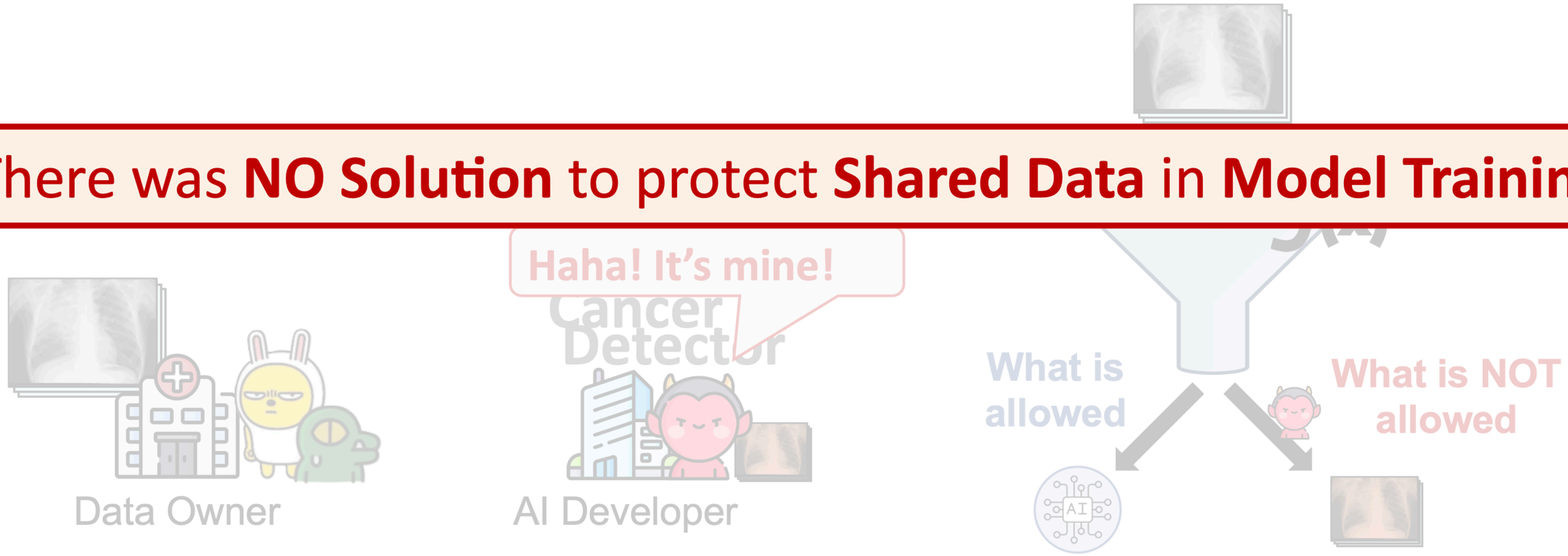

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Big Hurdle in Deep Learning Industry

Possible Attacks to Leak the Data

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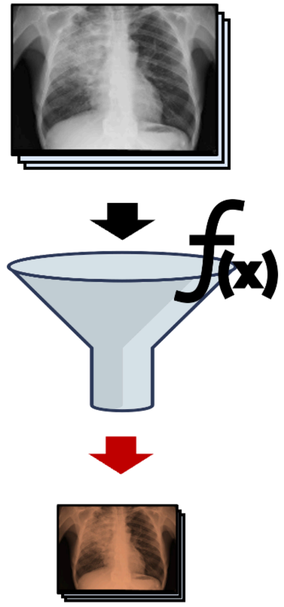
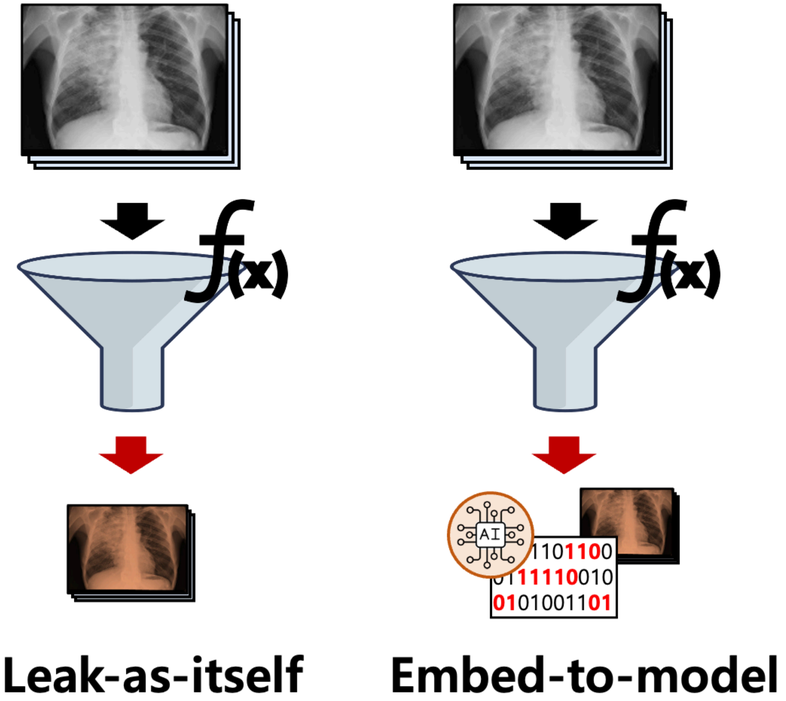


Leak-as-itself

Possible Attacks to Leak the Data



Leak-as-itself **Embed-to-model**

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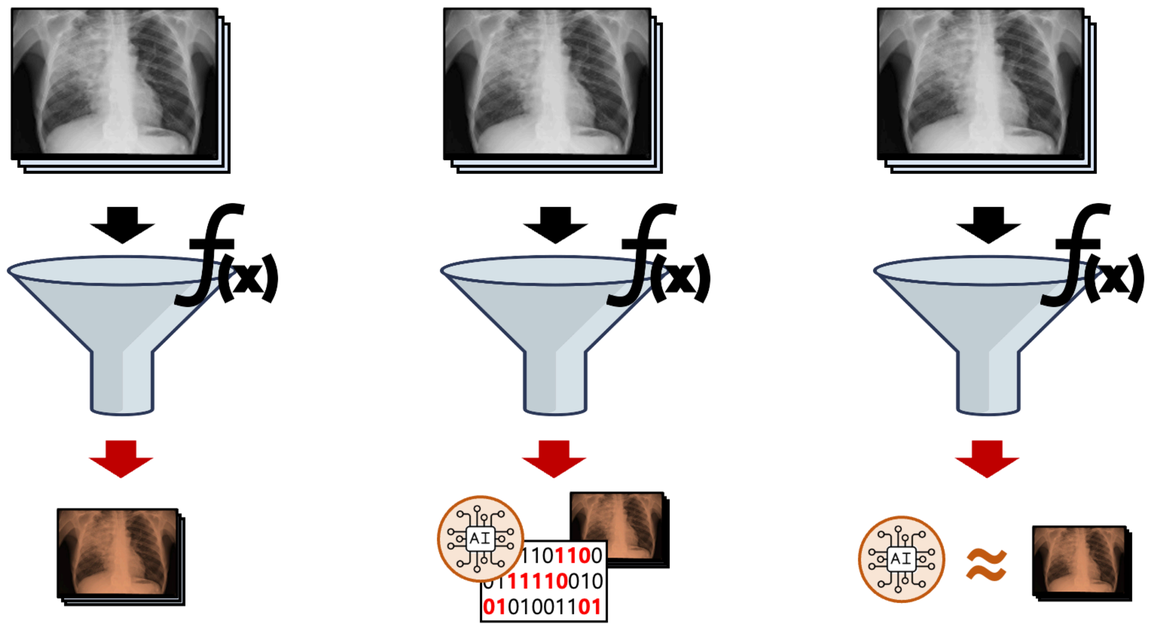

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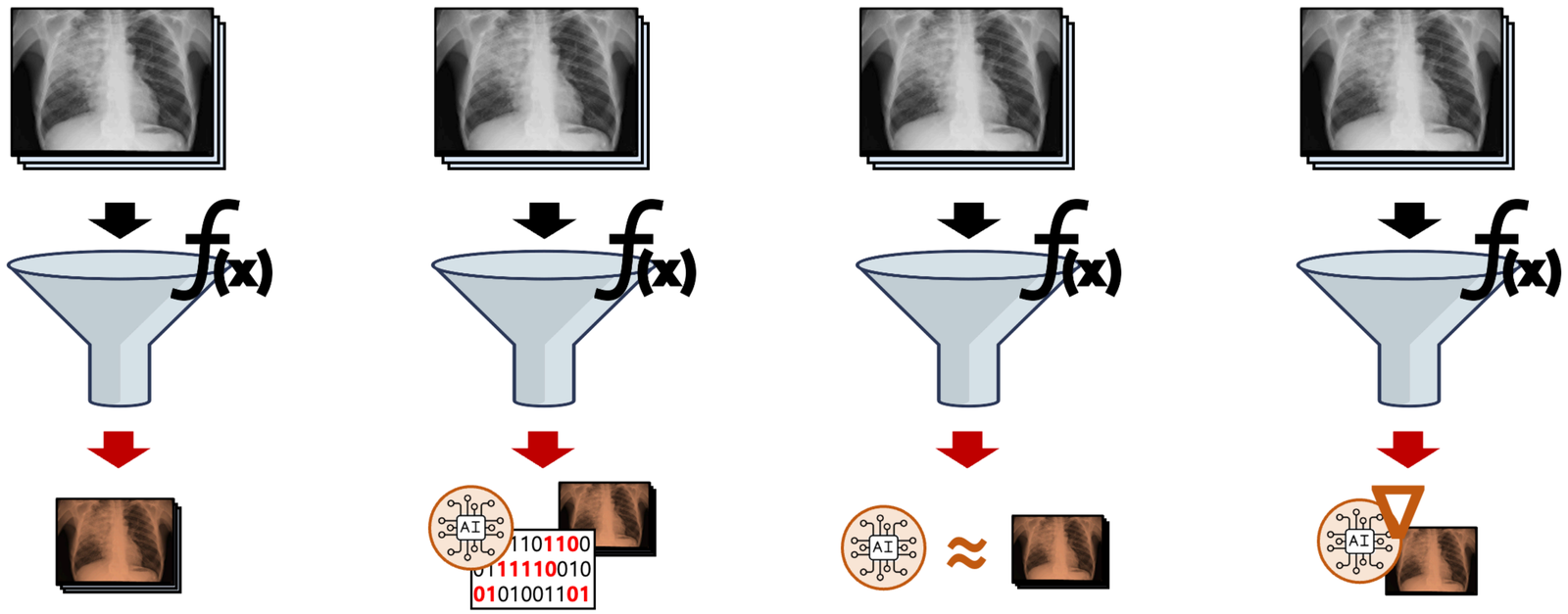

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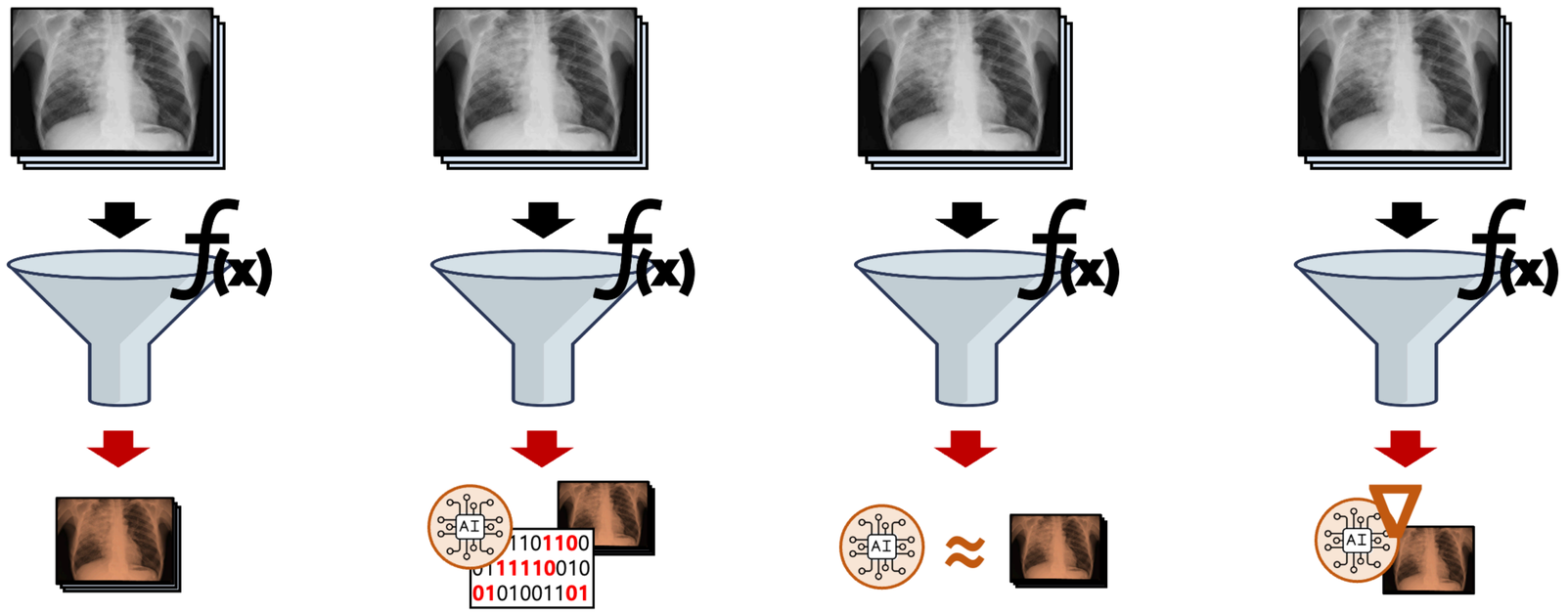

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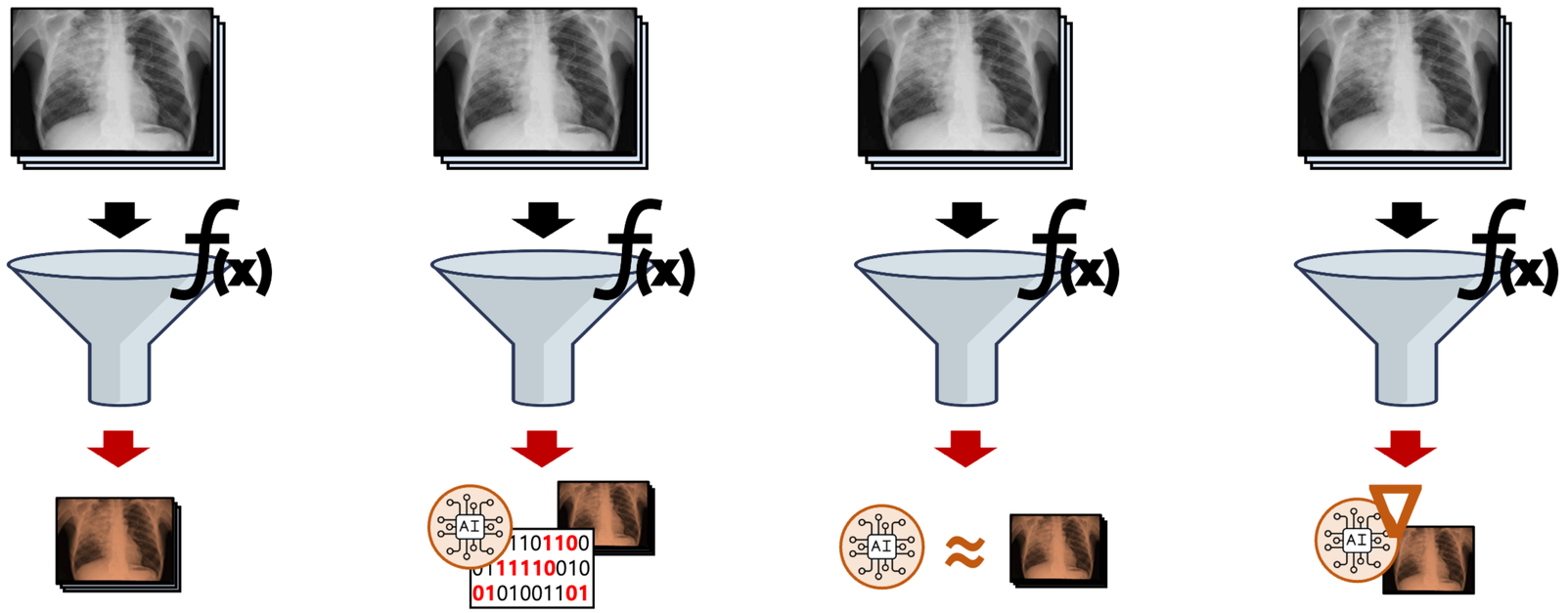

Leak-as-itself | Embed-to-model | Bias-to-be-data | Invert-gradients

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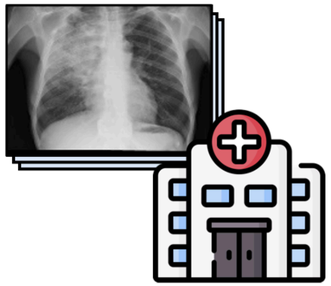
No one knows **"How to prevent data leaks"**

DLBox: Protecting Data in Model Training



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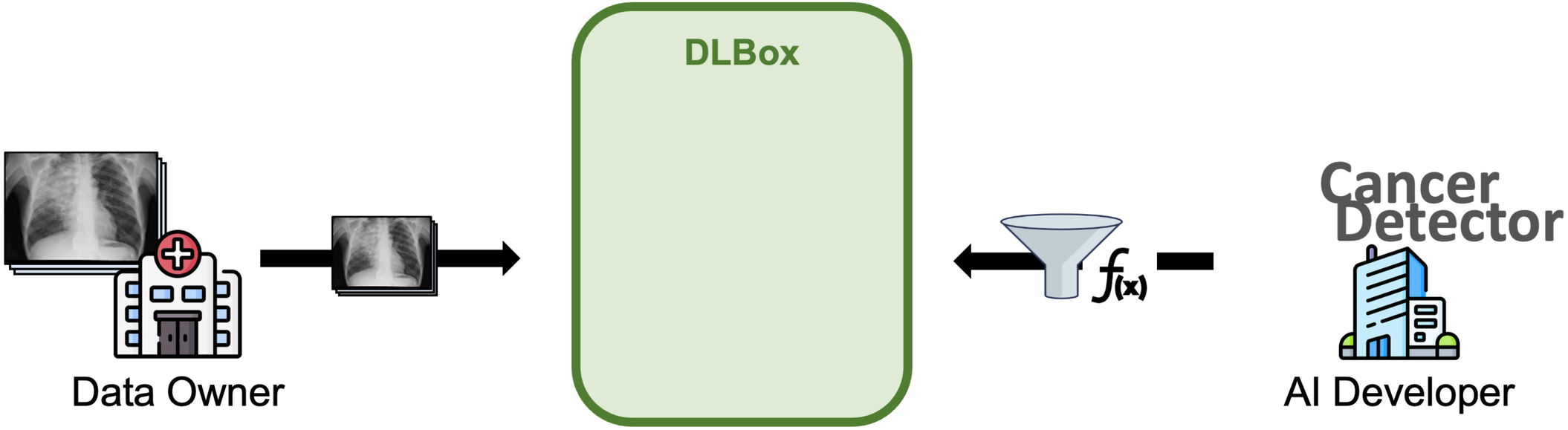

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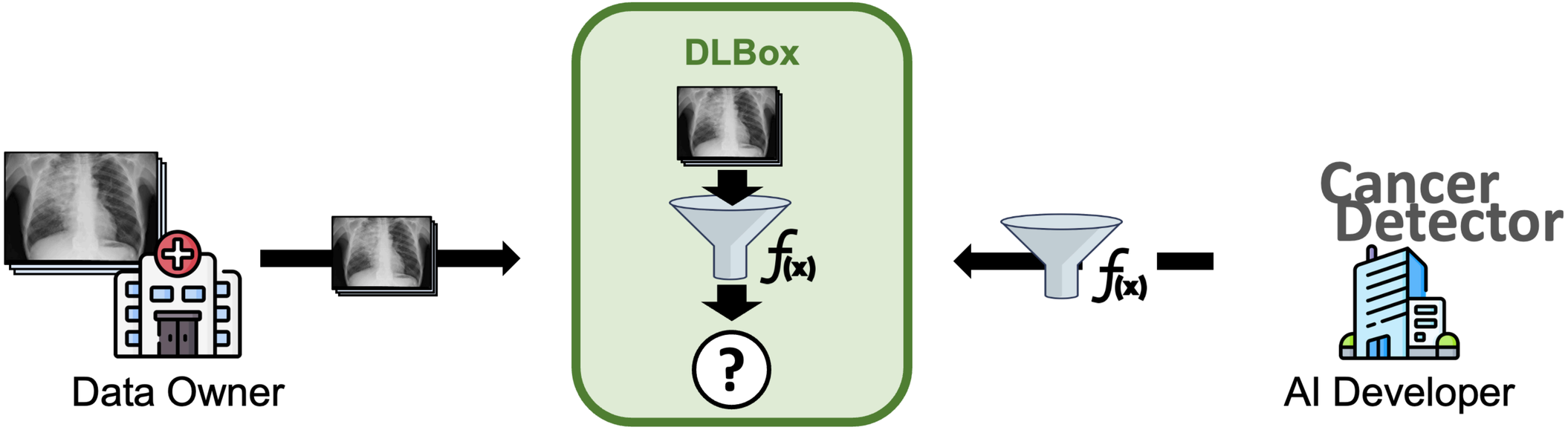

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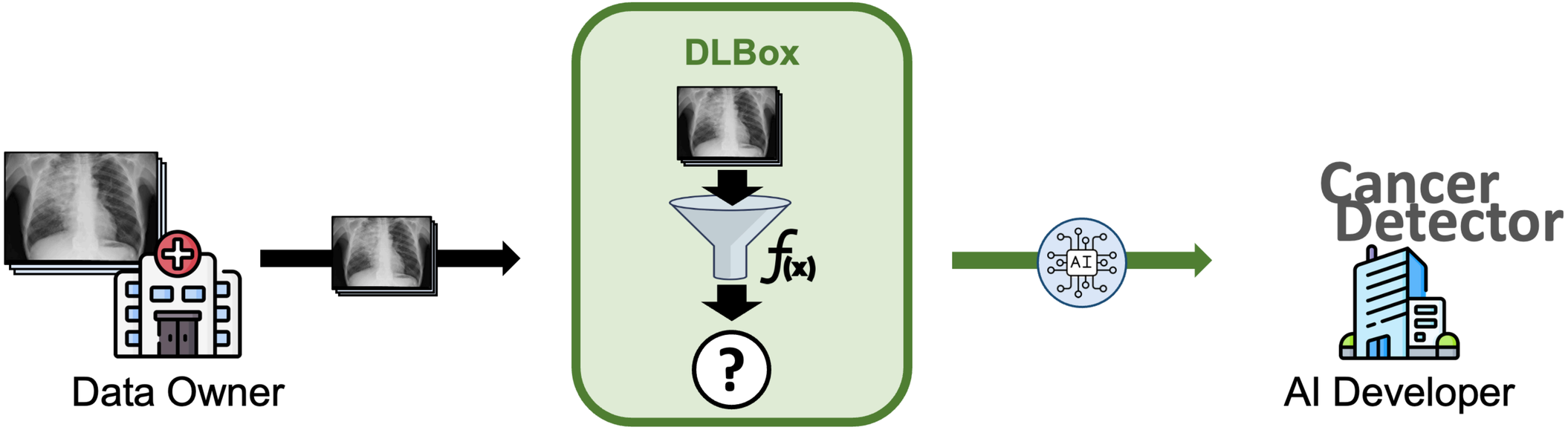

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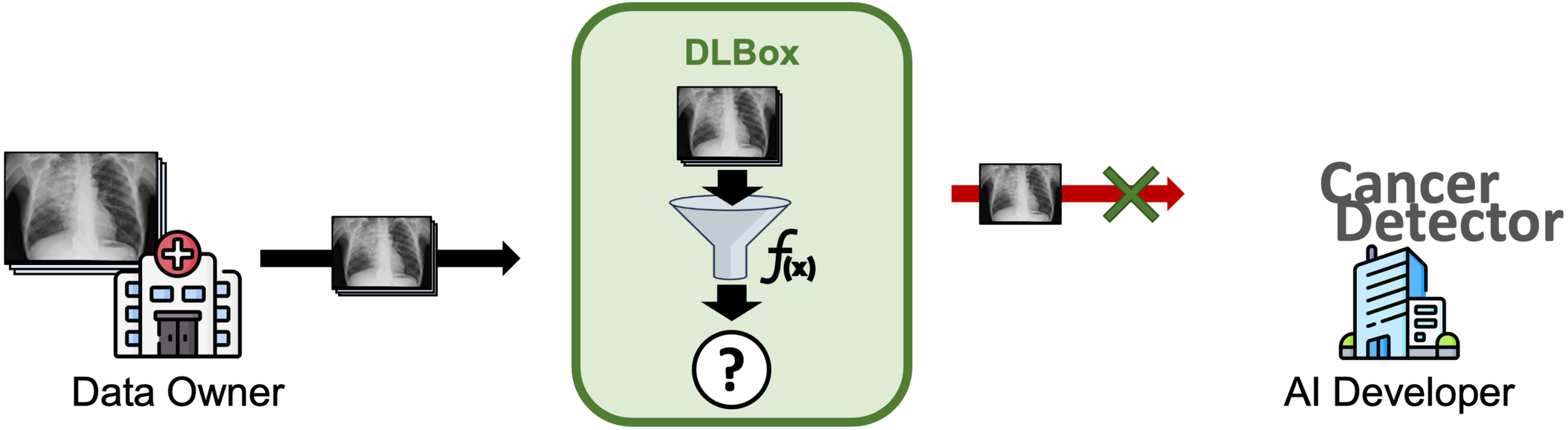

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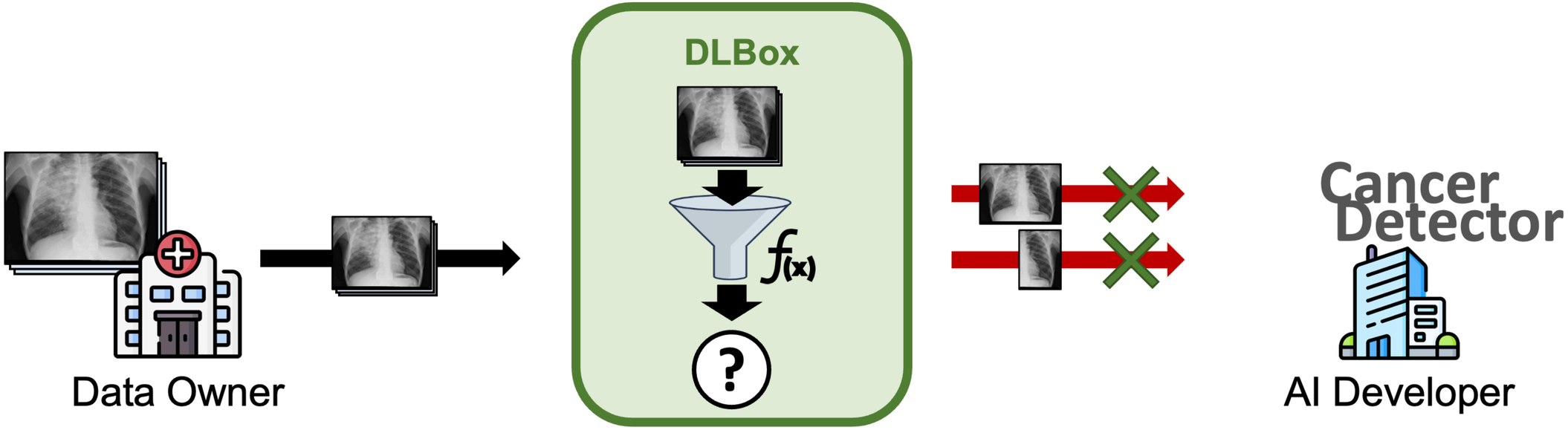

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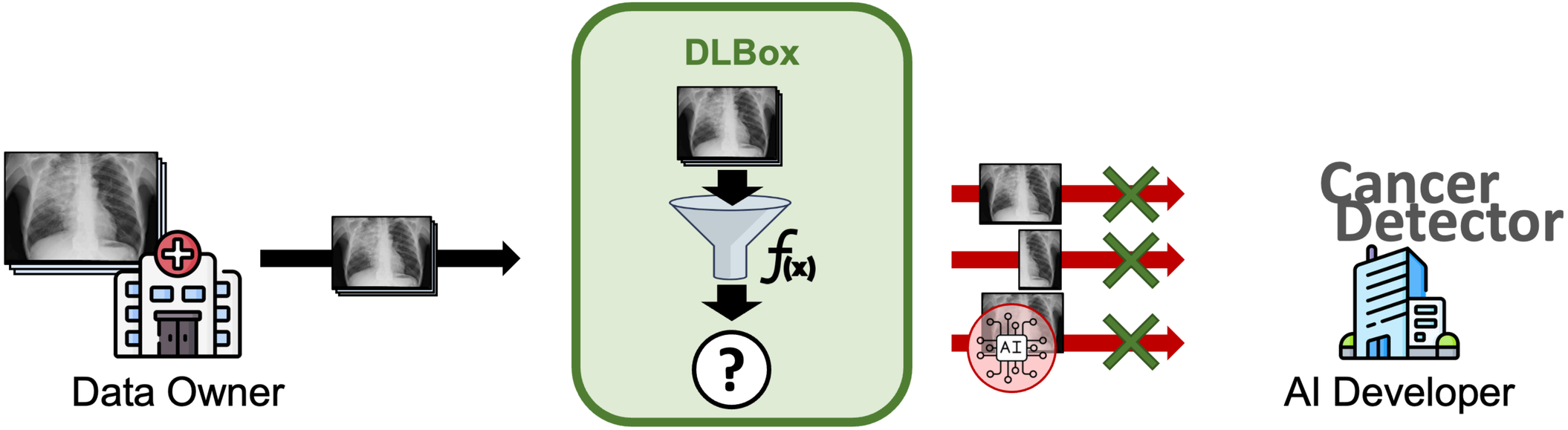

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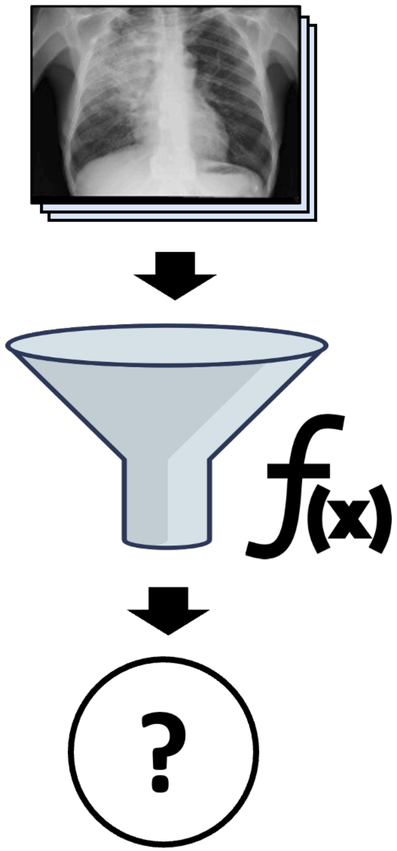

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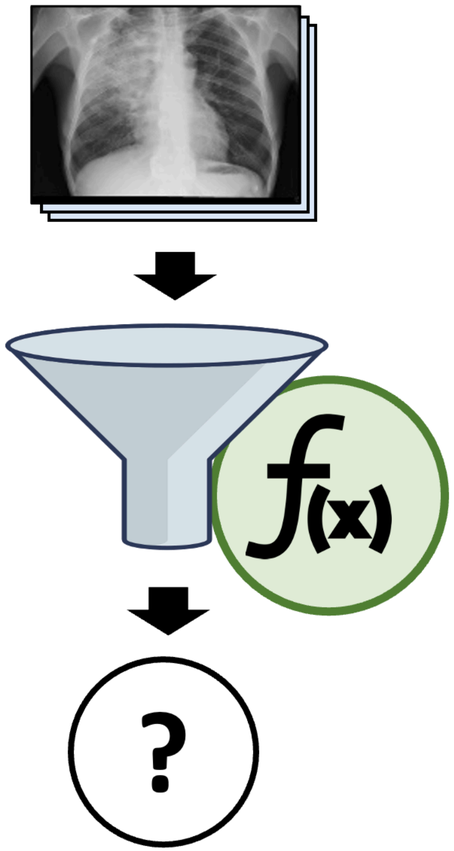

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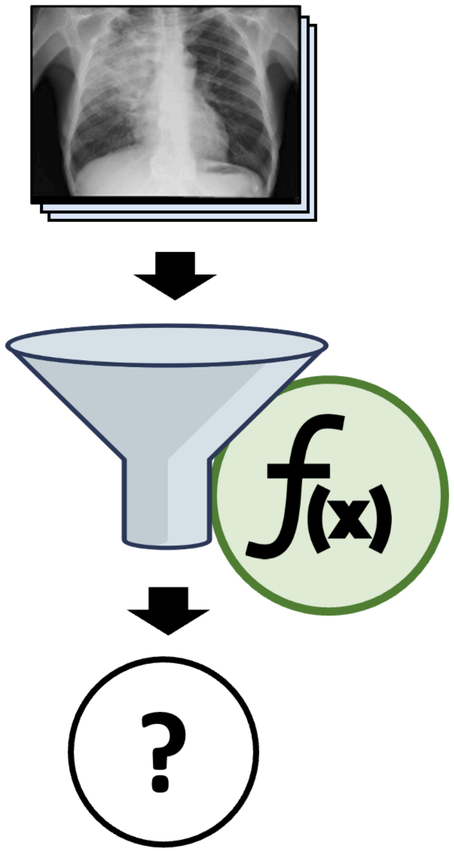

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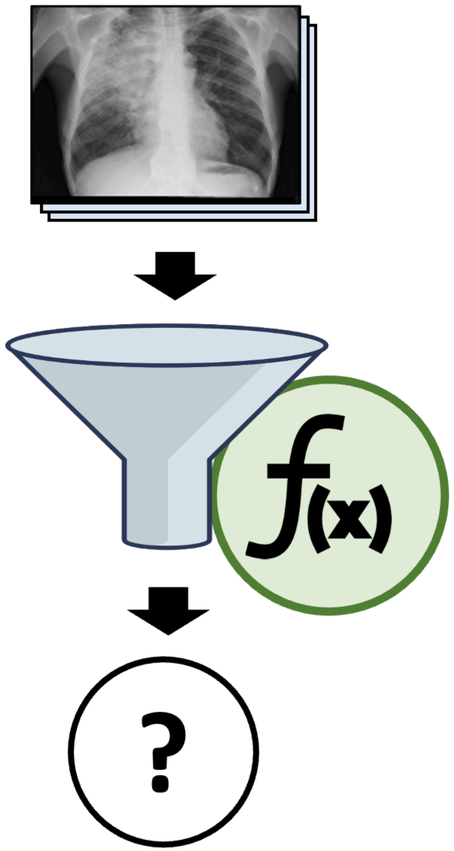

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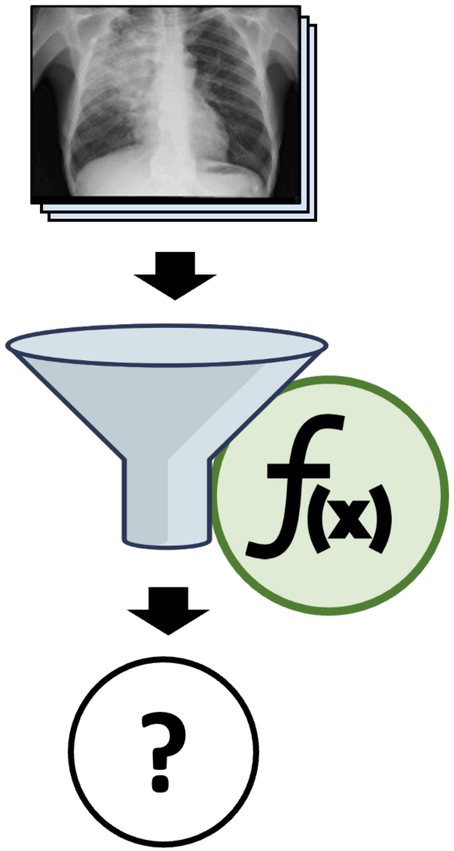

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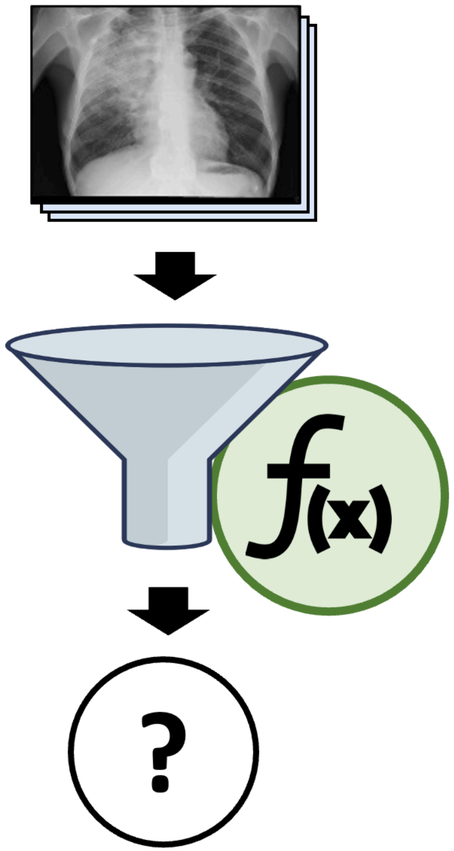

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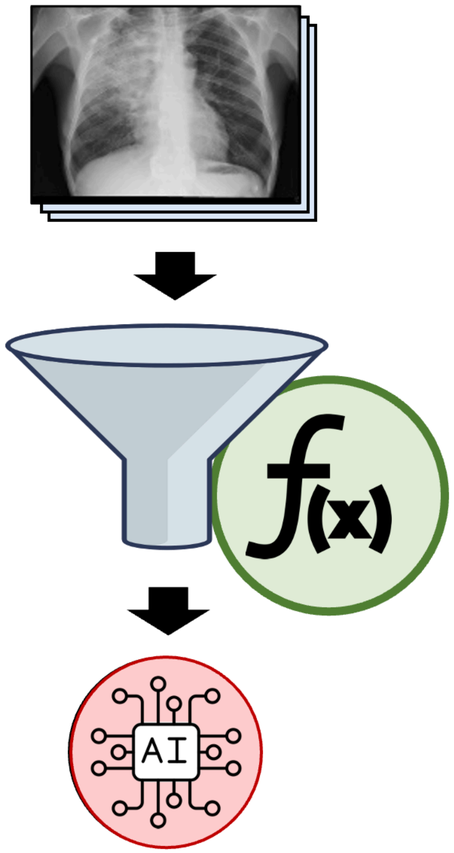

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Trained model always accompanies some sort of data leakage

Infeasibility of Complete Data Protection

- DLBox checks $f(x)$ provided by an AI developer
- Properties of allowed functions

It is impossible to completely prevent data leak

1. Allowed functions **can train an AI model**

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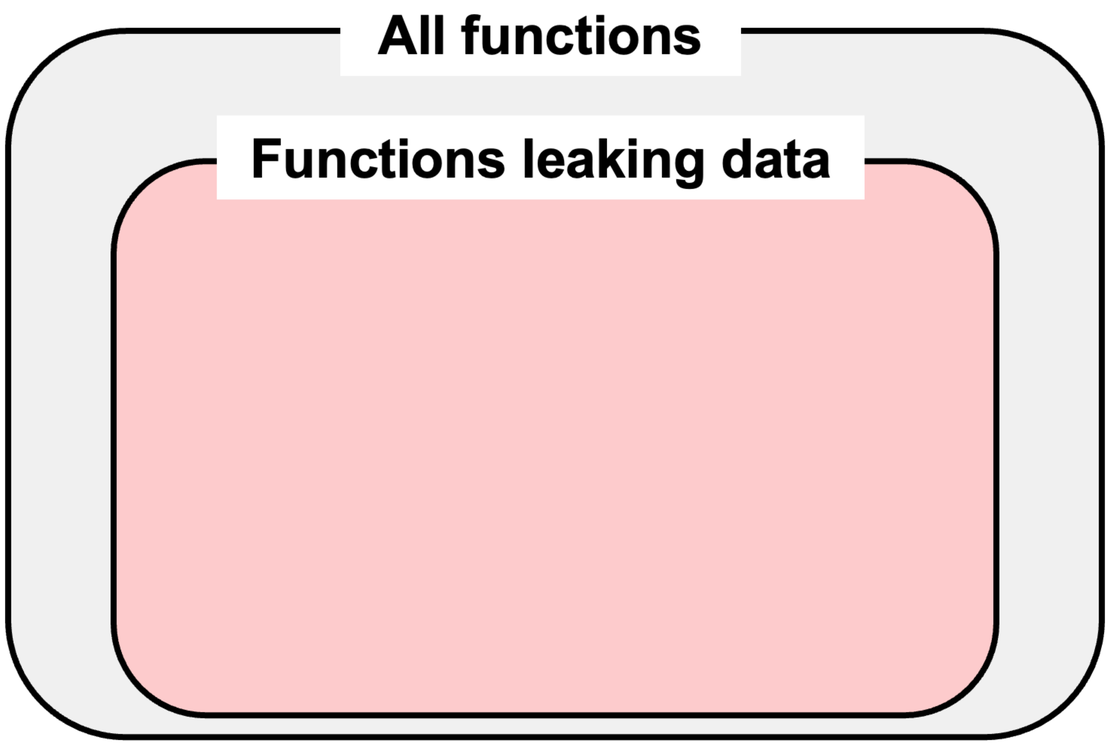

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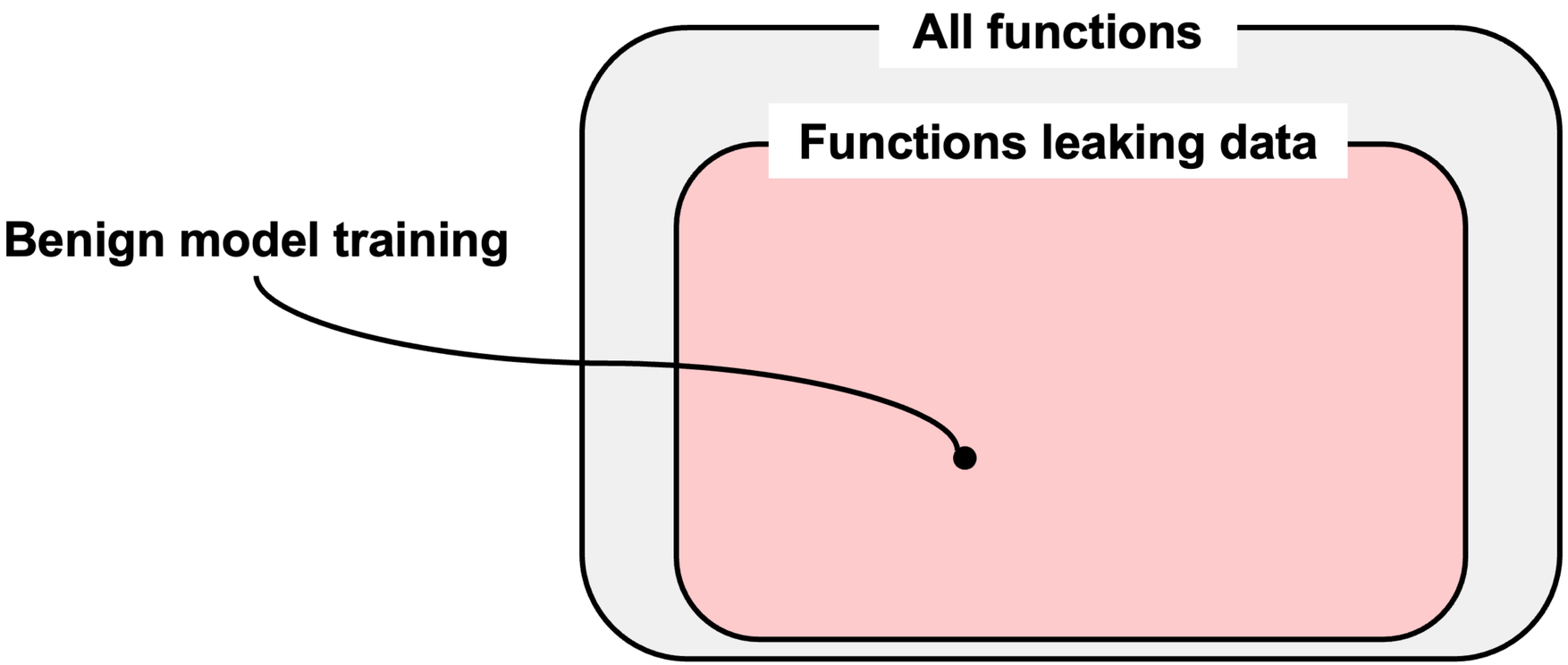

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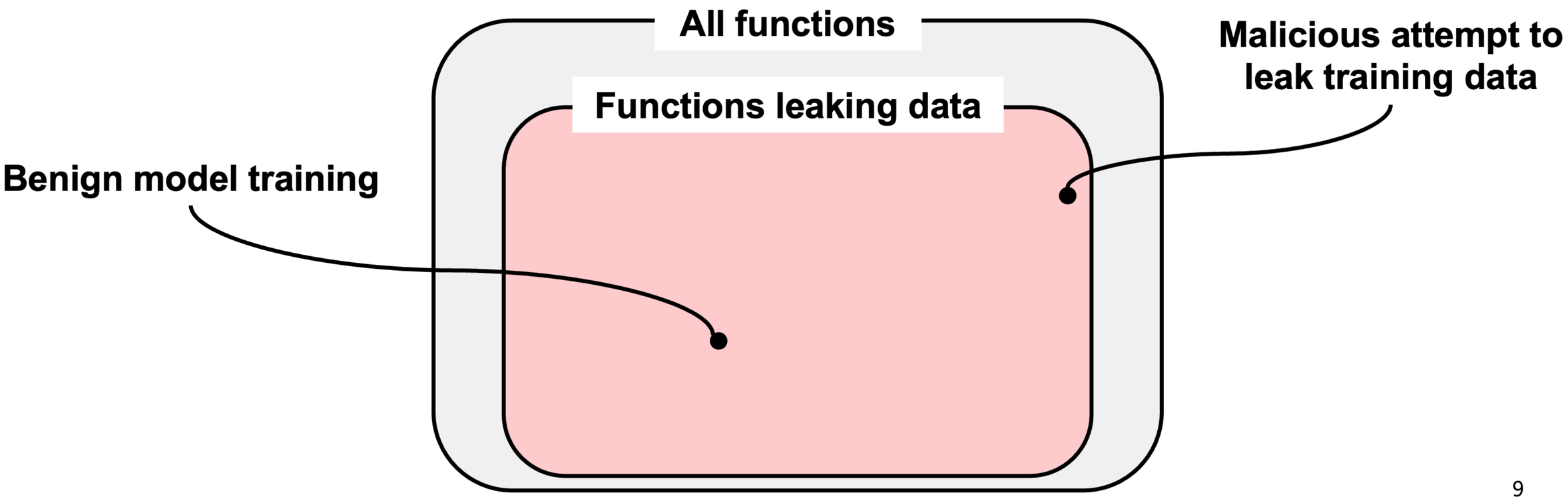

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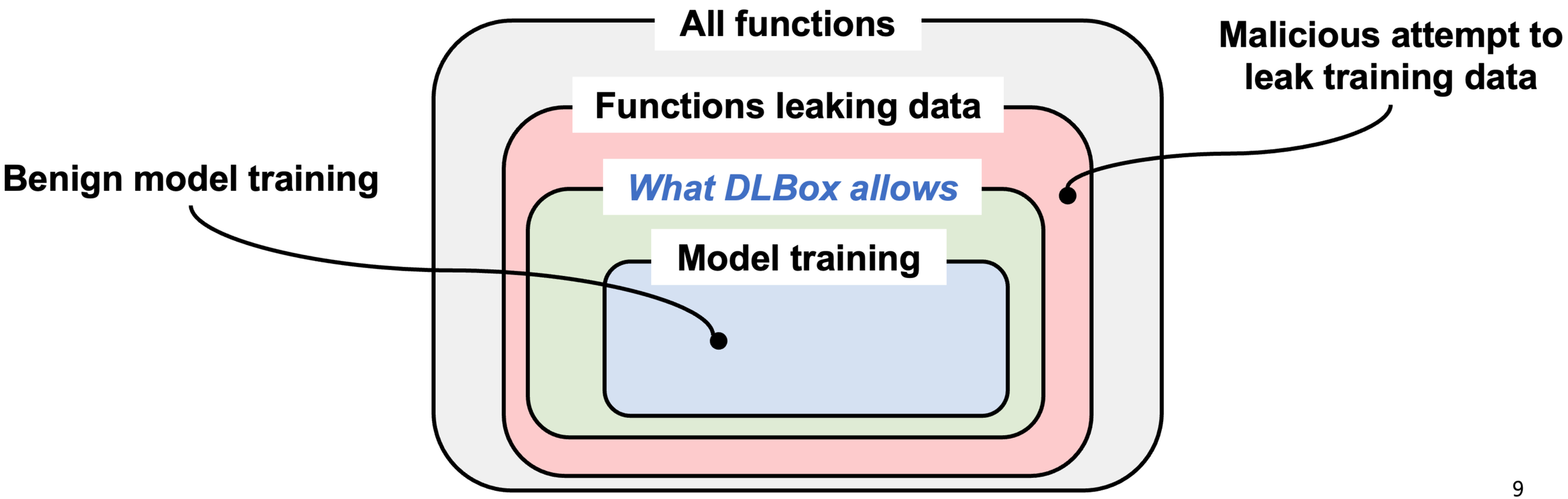

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- Allow **Benign Model Training**
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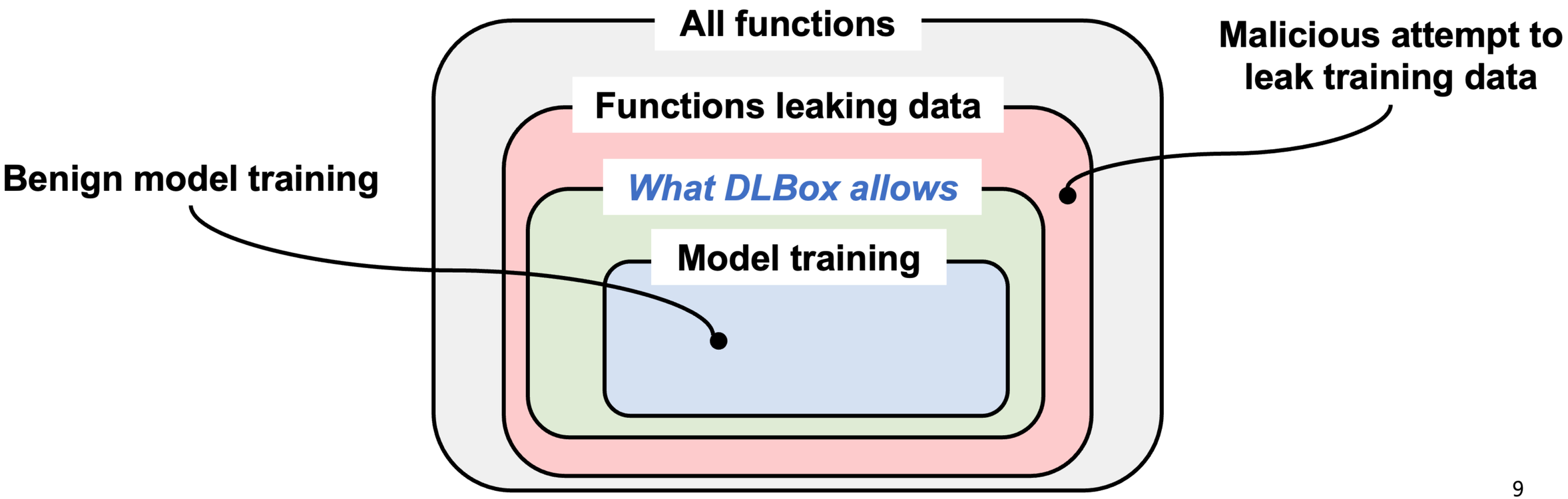

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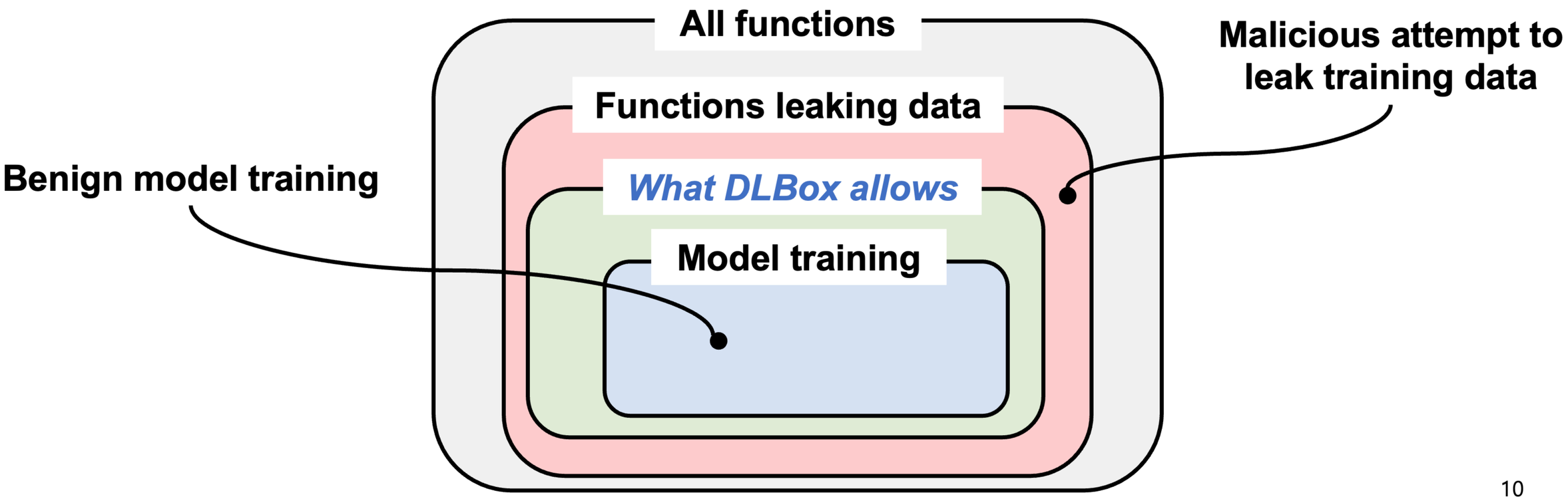
Question What is the Benign Model Training?

- Prevent **Malicious Attempts**



What DLBox Wants to Do

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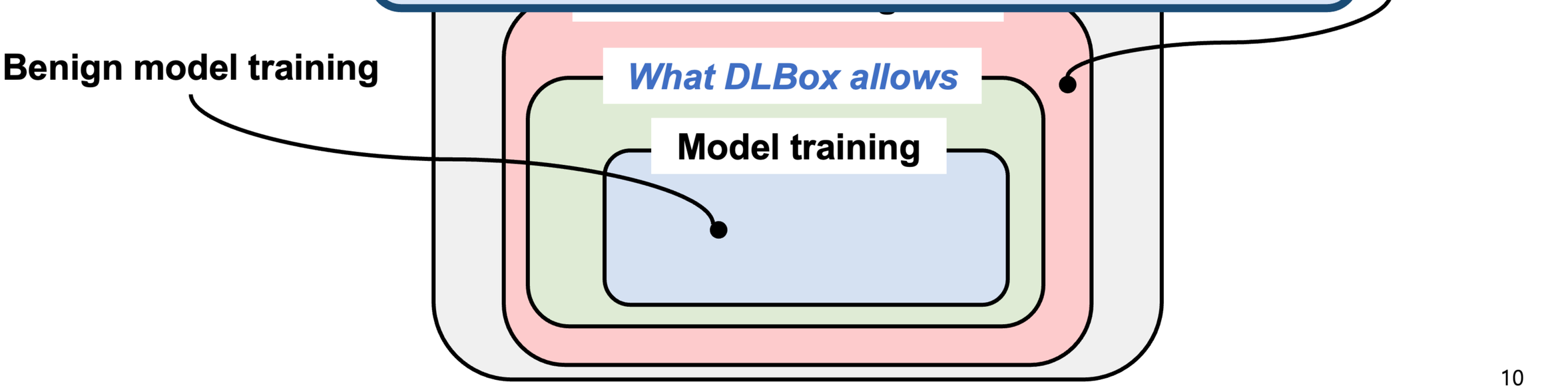
What is the Benign Model Training?

- Prevent Malicious Attempts

Observation

It is a statistical process of learning common patterns from a dataset



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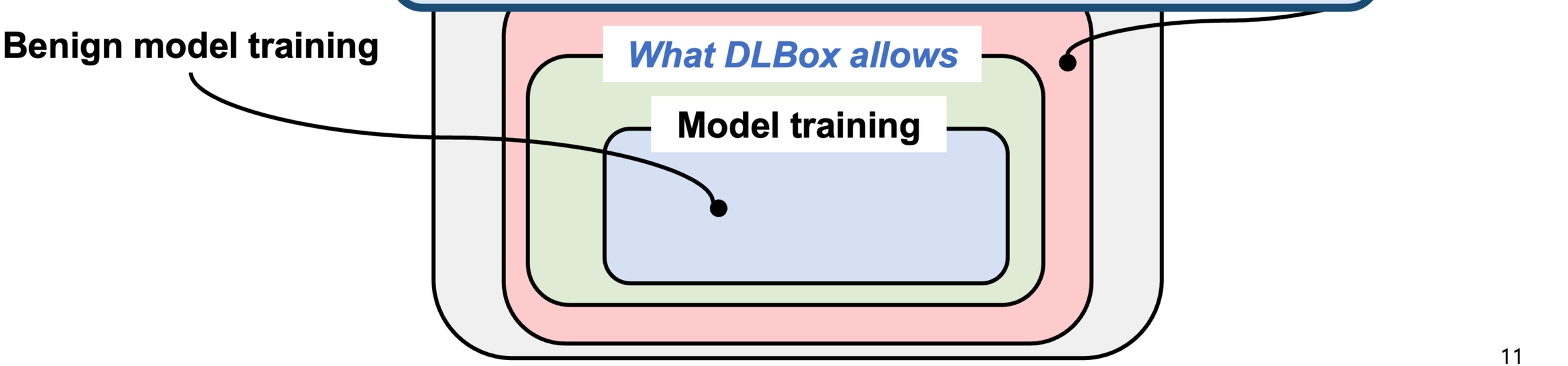
There is no need to prioritize or discriminate a specific sample



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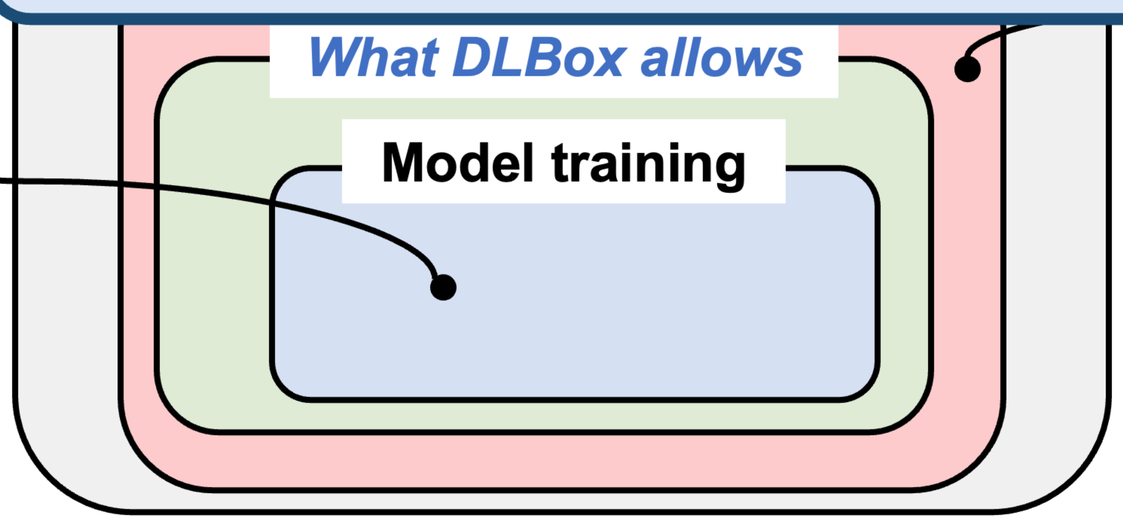

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Benign model training

DGM-Rules

D ata samples receiving the same augmentation
G radients back propagated from loss value
M odel updated by adjusting all gradients

DGM-Rules: Rules for Benign Model Training

Sample 1

Sample 2

…

Sample **N**

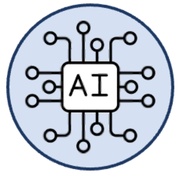
DGM-Rules: Rules for Benign Model Training

Sample 1

Sample 2

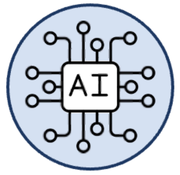
...

Sample **N**

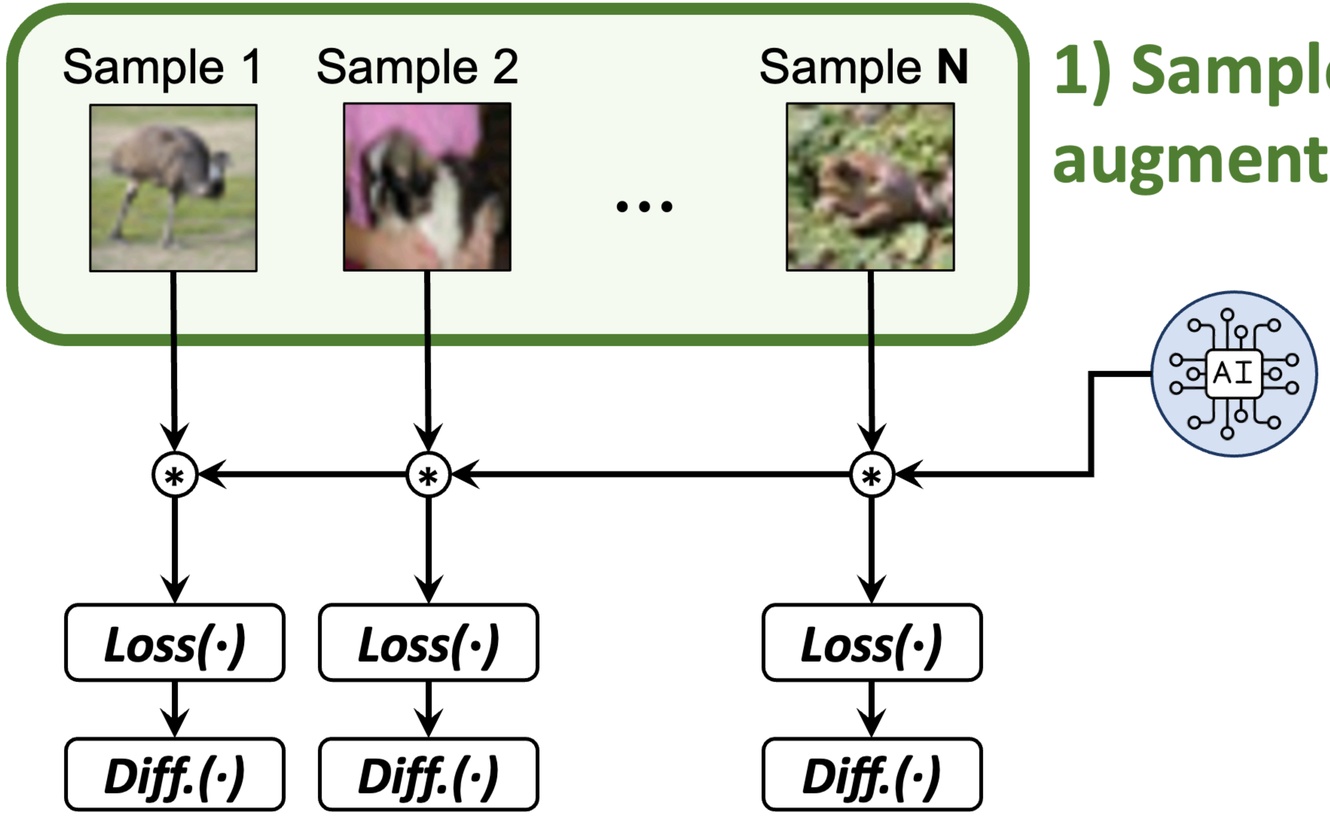


DGM-Rules: Rules for Benign Model Training

1) Samples augmented.



DGM-Rules: Rules for Benign Model Training



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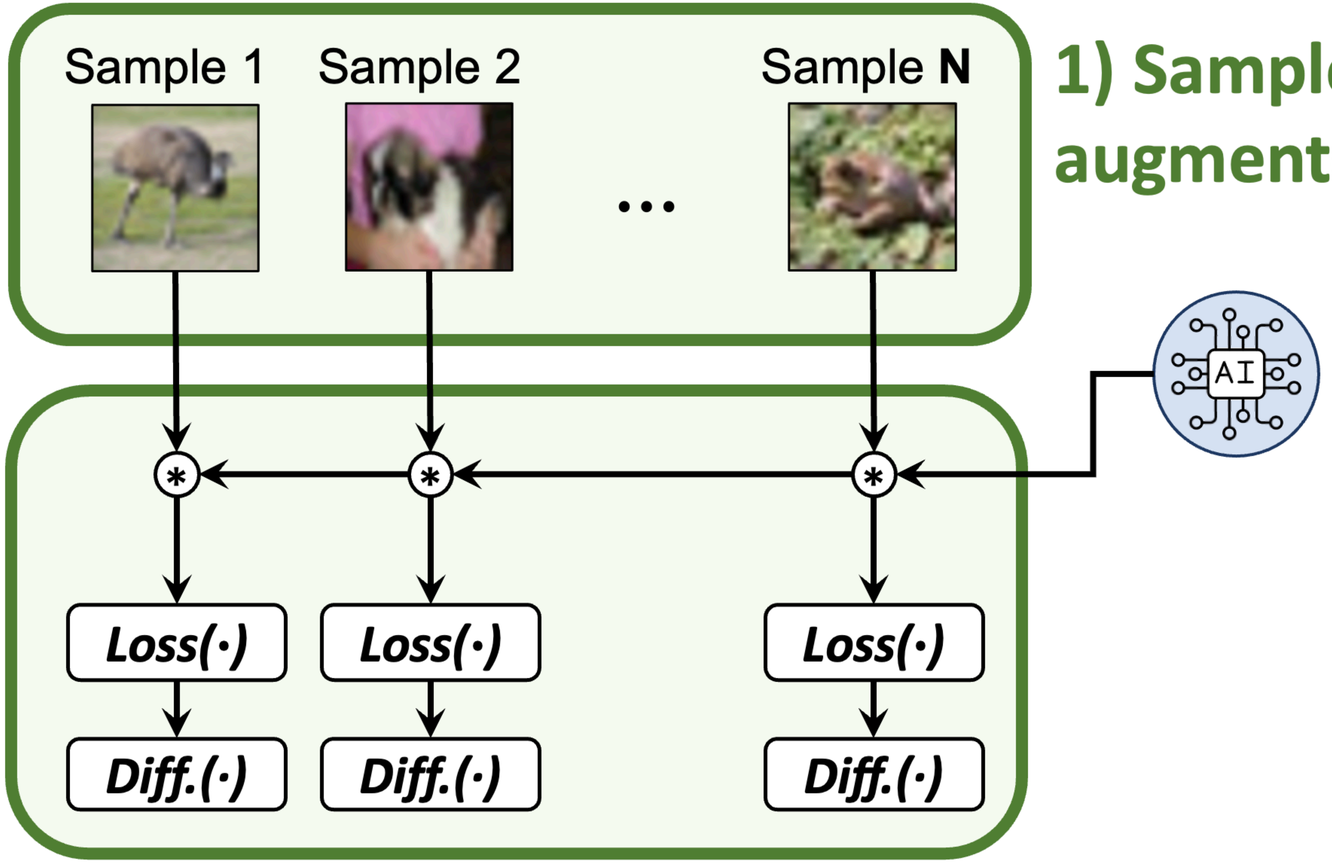
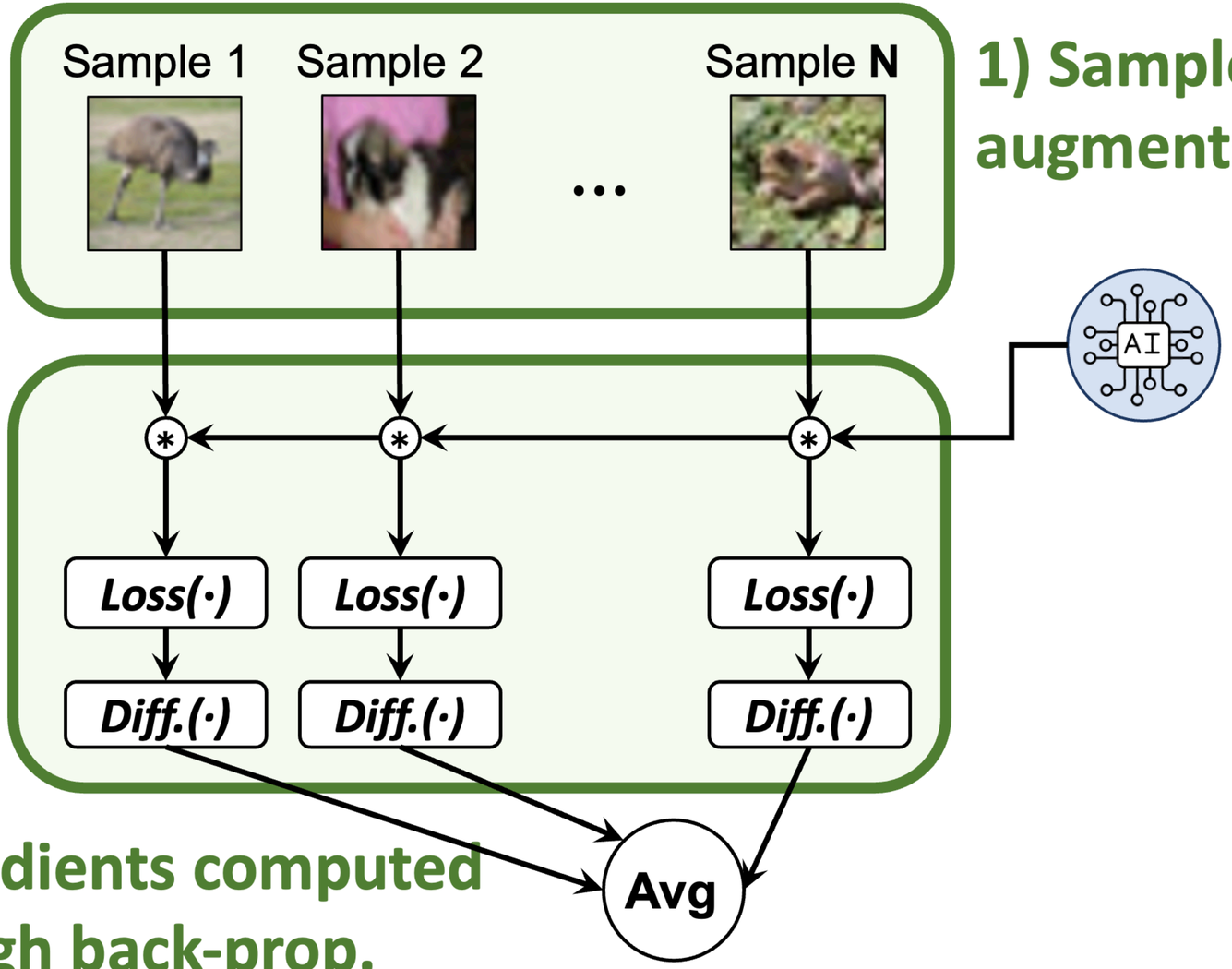
DGM-Rules: Rules for Benign Model Training



1) Samples augmented.

2) Gradients computed through back-prop.

DGM-Rules: Rules for Benign Model Training



1) Samples augmented.

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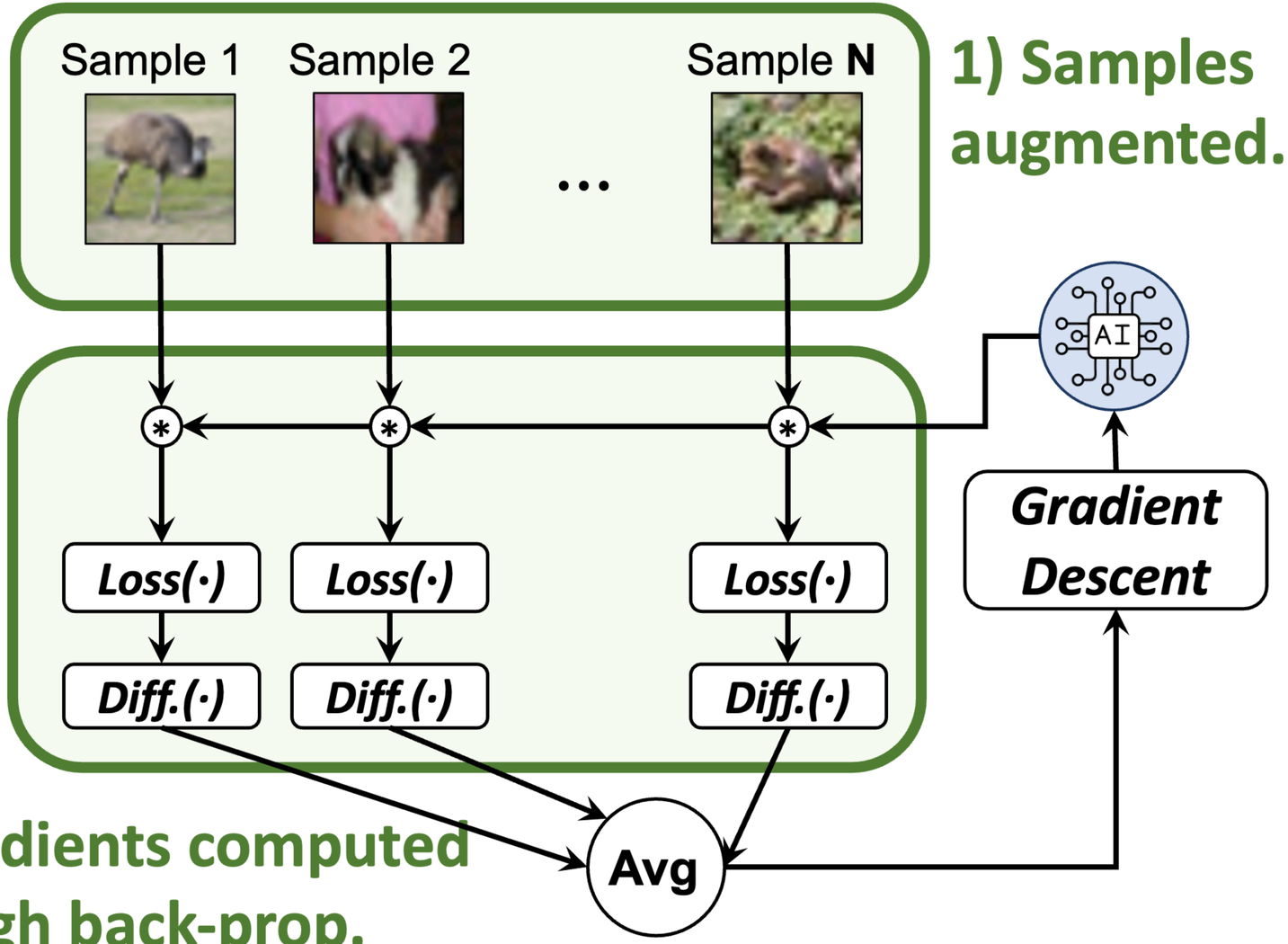
DGM-Rules: Rules for Benign Model Training



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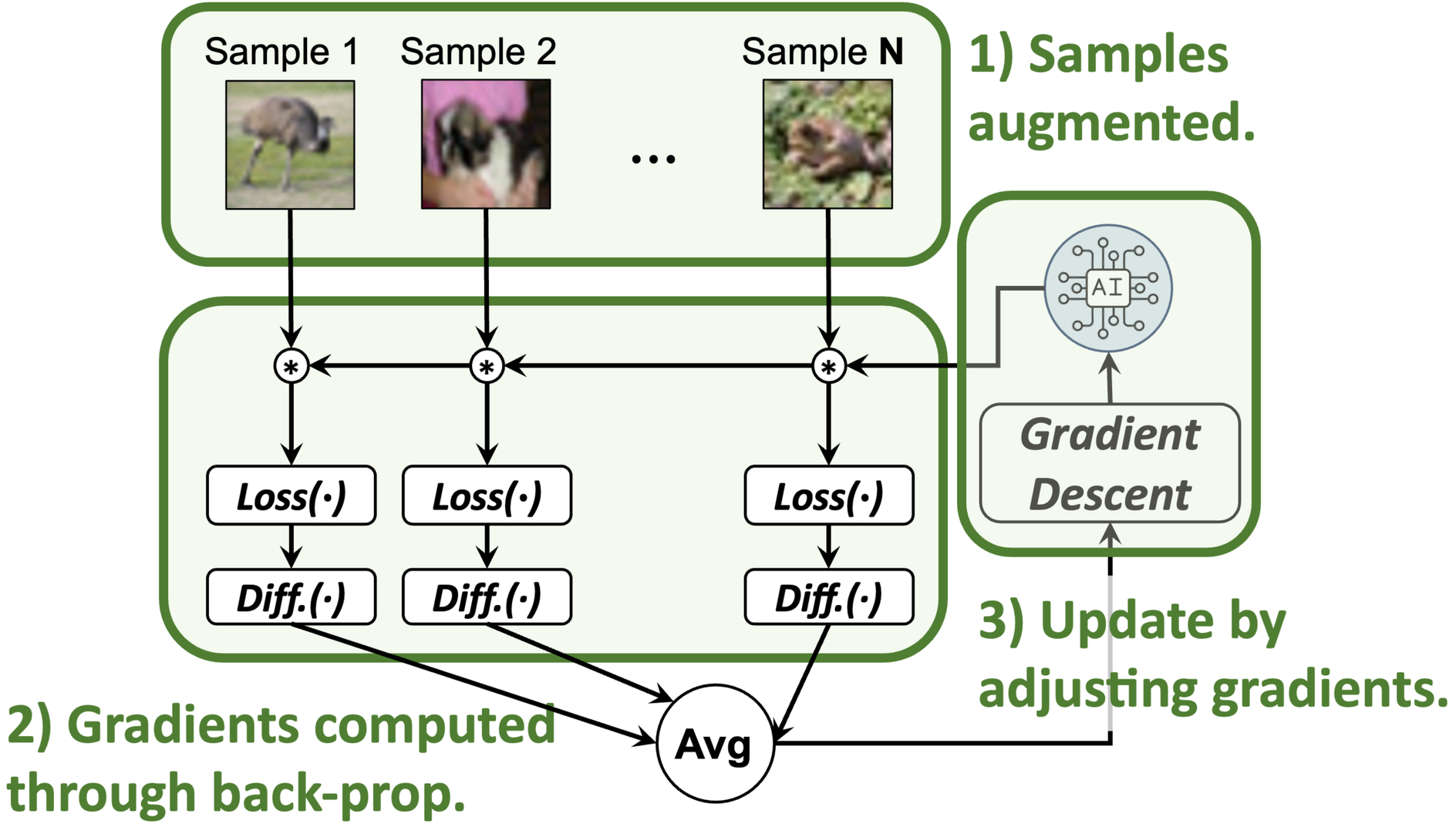
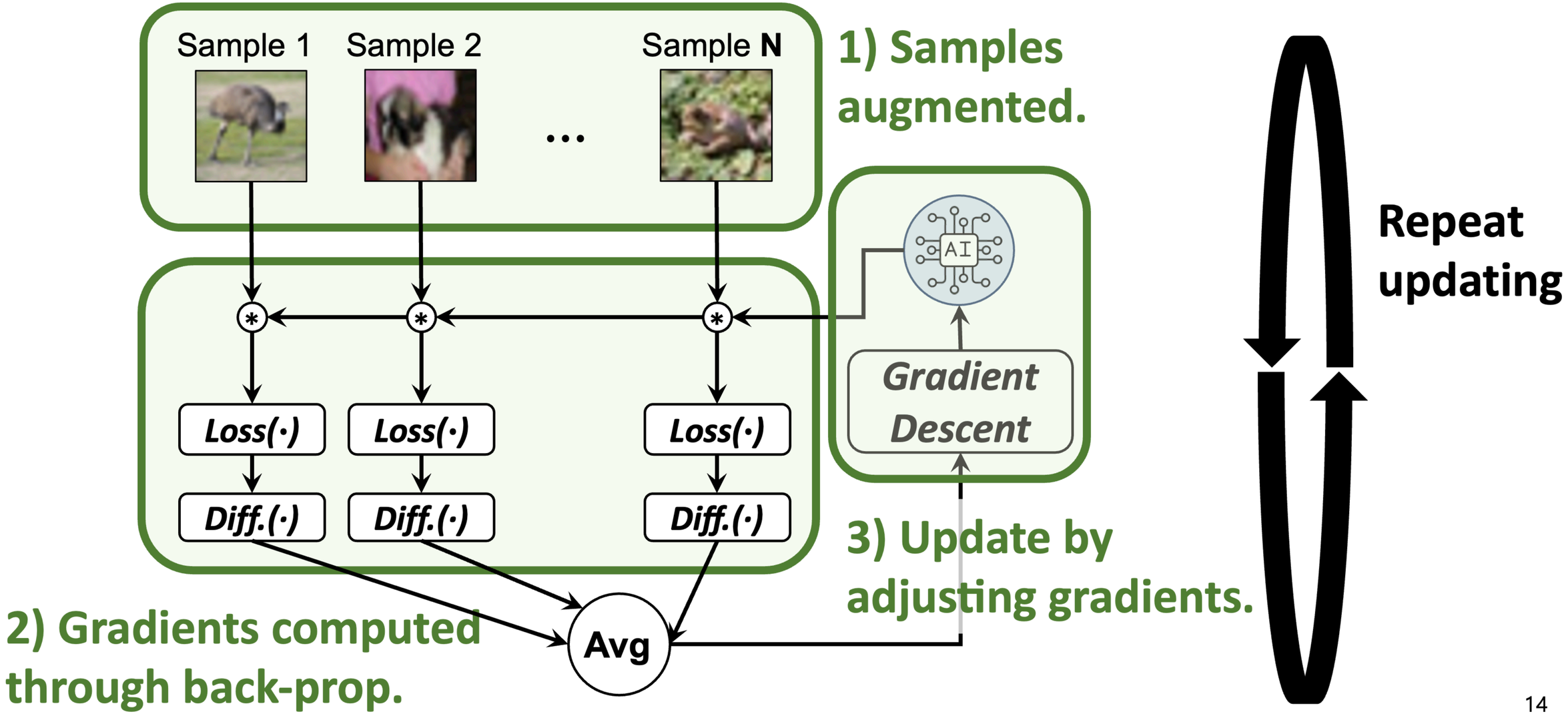
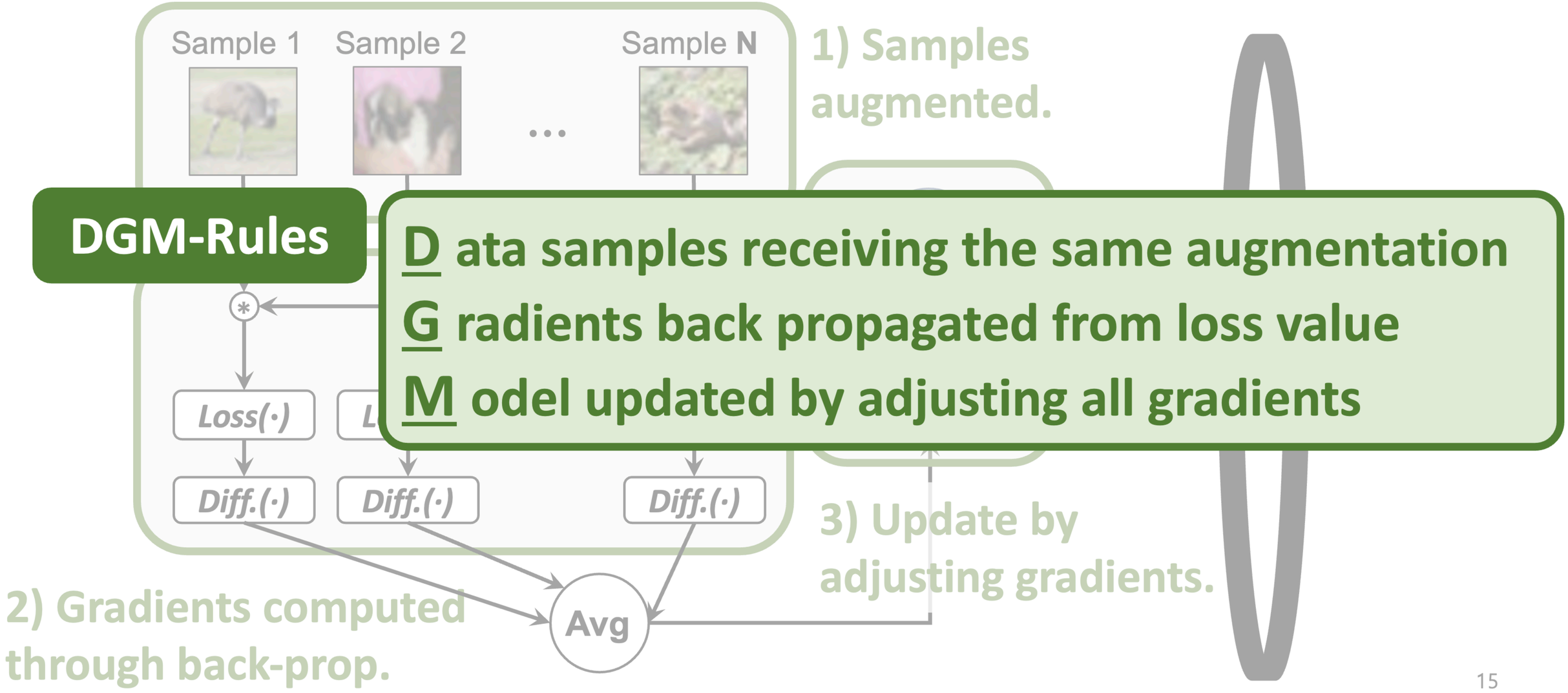


DGM-Rules: Rules for Benign Model Training



DGM-Rules: Rules for Benign Model Training



DLBox: Enforcing DGM-Rules

DLBox: Enforcing DGM-Rules

DL-Sandbox

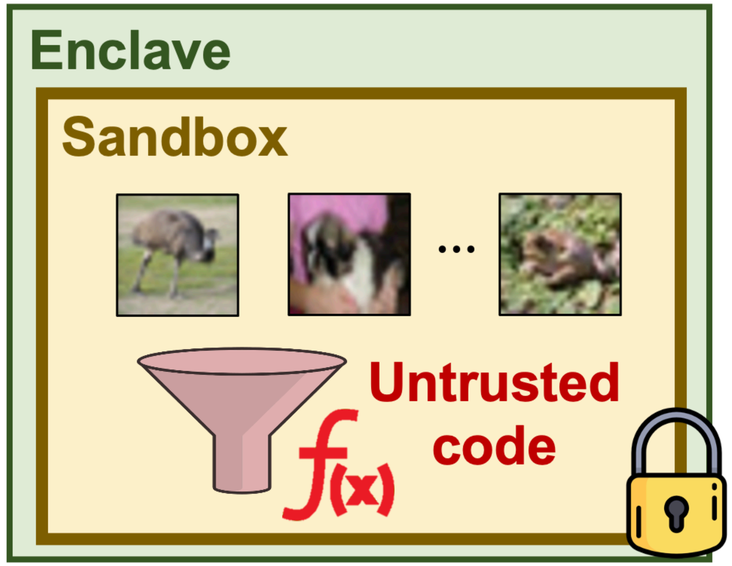
DL-Oracle

DLBox: Enforcing DGM-Rules

DL-Sandbox

Sandbox AI developer's code

- Sanitizing all outgoing data flows of training data



Cannot pull the data without approval

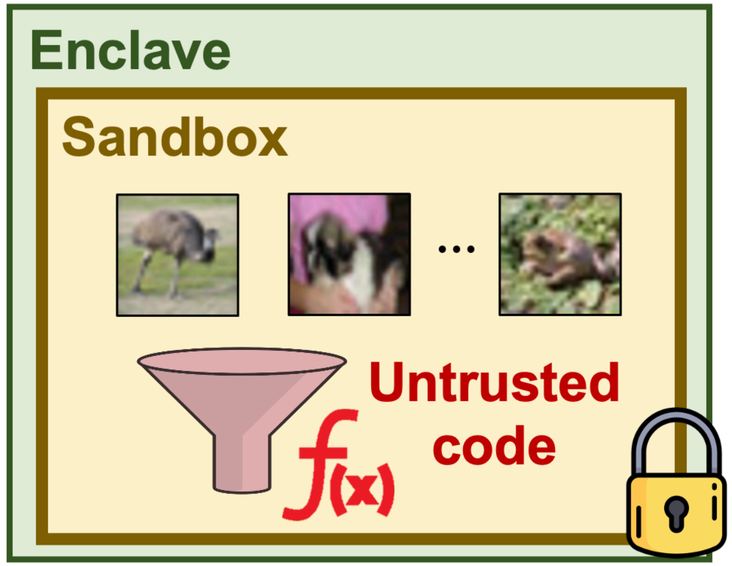
DL-Oracle

DLBox: Enforcing DGM-Rules

DL-Sandbox

Sandbox AI developer's code

- Sanitizing all outgoing data flows of training data

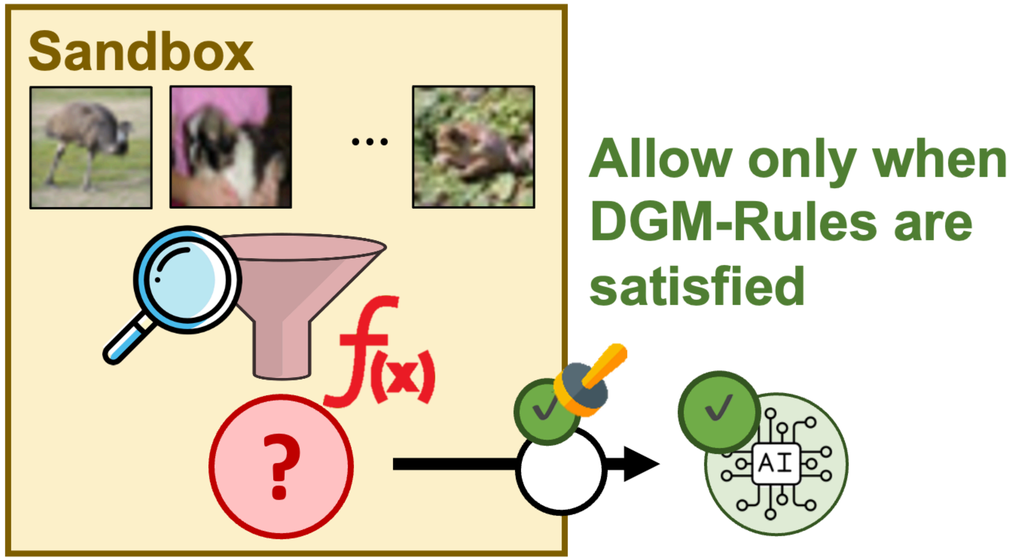


Cannot pull the data without approval

DL-Oracle

Taint analyze computations on data

- Checking the data flows satisfy **DGM-Rules**



Allow only when DGM-Rules are satisfied

DL-Sandbox: Sandboxing AI Developer's Code

```
samples, labels = sample_init()

print("[mnist] start running...")

DATA_MEAN = (samples / 255.0).mean(axis=(0, 1, 2))
DATA_STD  = (samples / 255.0).std(axis=(0, 1, 2))

print(f"[mnist] data_mean: {DATA_MEAN}, data_std: {DATA_STD}")

transforms = Compose([
  Tensor.numpy,
  Image.fromarray,
  ToTensor(),
  Normalize(DATA_MEAN, DATA_STD)
])

print("[mnist] fit model...")

dataset = TensorDataset(samples, labels, transforms=transforms)
loader = DataLoader(dataset, batch_size=32, shuffle=True)

trainer = pytorch_lightning.Trainer(gpus=1, max_epochs=10)
model = LitClassifier()

trainer.fit(model, train_dataloaders=loader)

print("[mnist] done")
```

DL-Sandbox: Sandboxing AI Developer's Code

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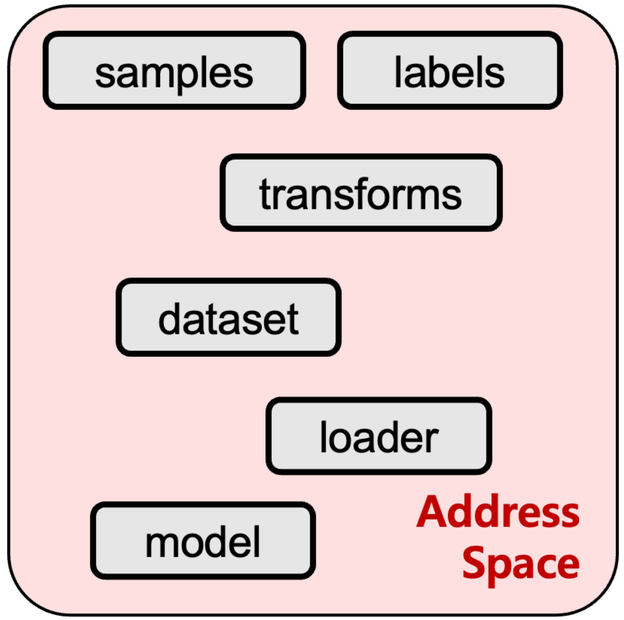

Address Space w/o DL-Sandbox (**UNSAFE**)

DL-Sandbox: Sandboxing AI Developer's Code

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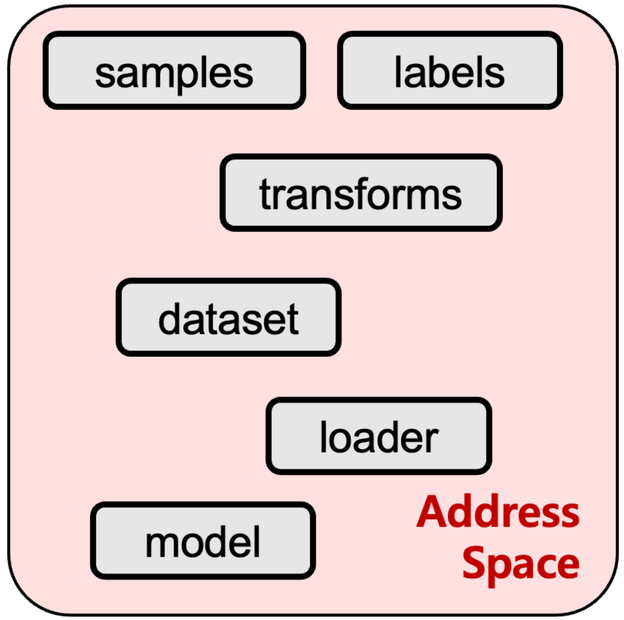

Address Space w/o DL-Sandbox (**UNSAFE**)

AI developers have
full control over the data

DL-Sandbox: Sandboxing AI Developer's Code

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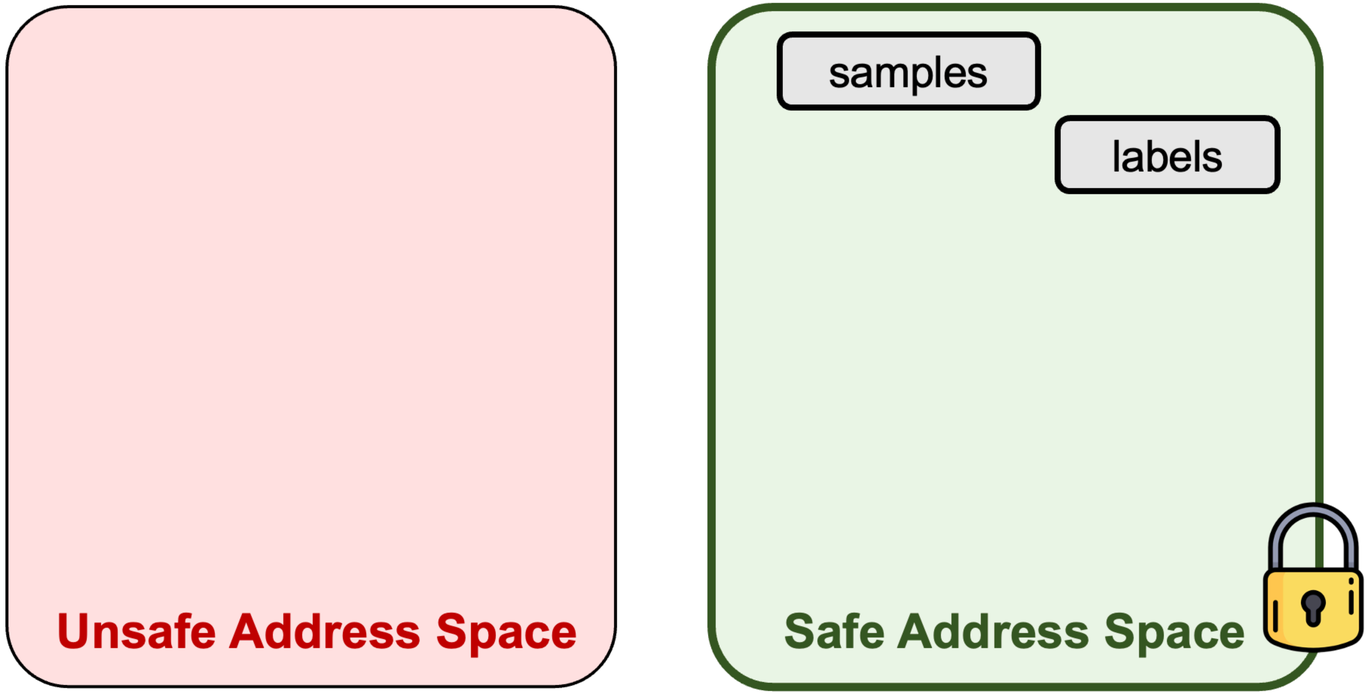

Isolated Address Space by DL-Sandbox (**SAFE**)

DL-Sandbox: Sandboxing AI Developer's Code

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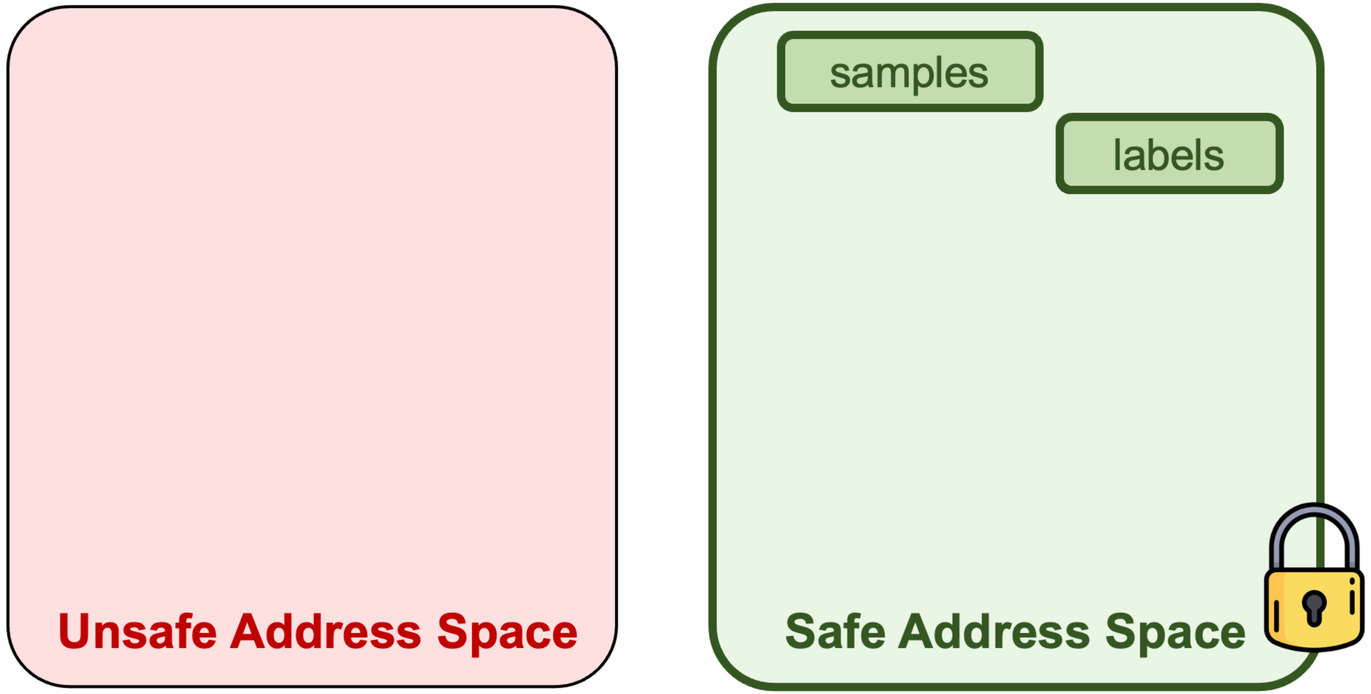

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Attackers **cannot directly access or modify** data

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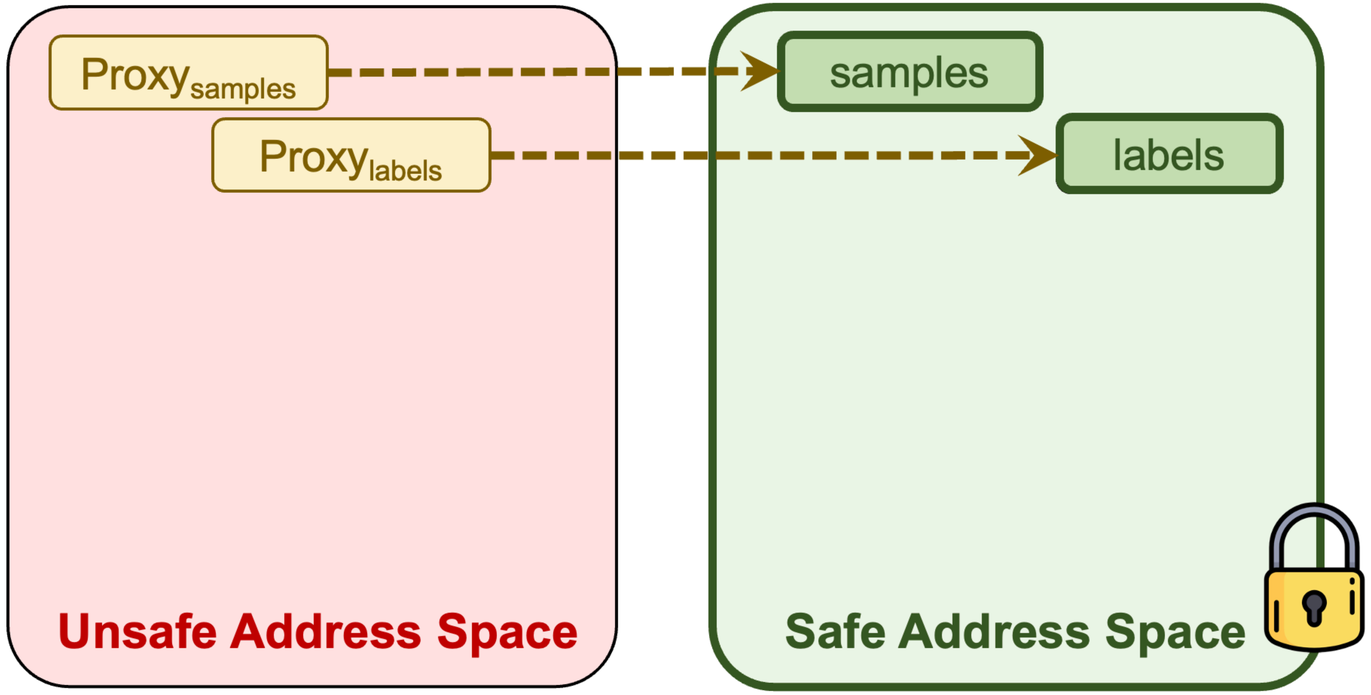

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Proxy to reference data

DL-Sandbox: Sandboxing AI Developer's Code

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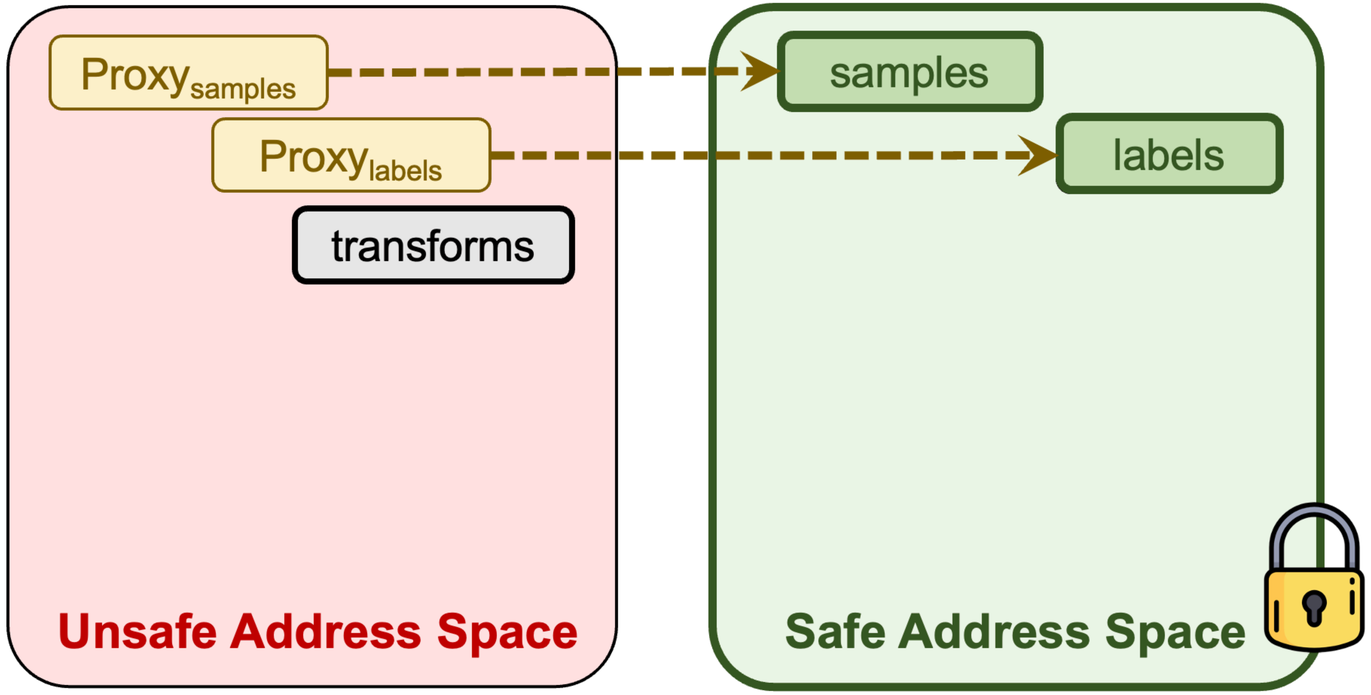

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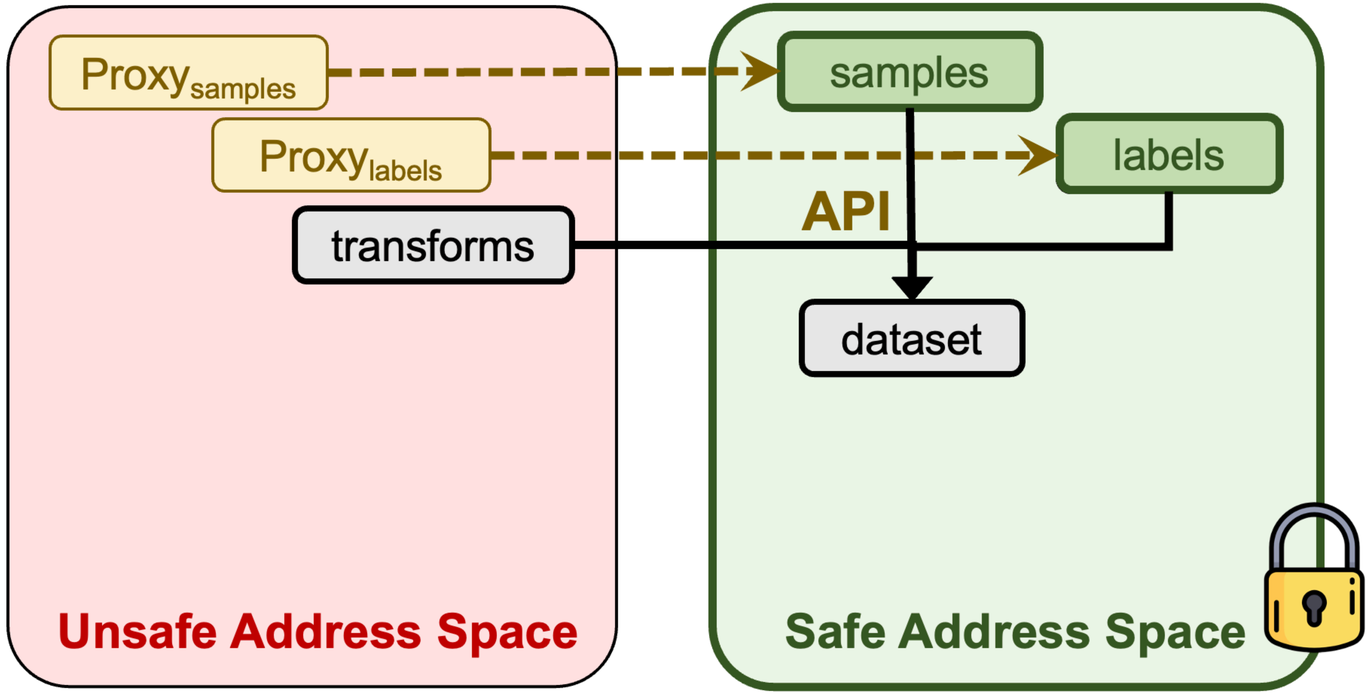

Isolated Address Space by DL-Sandbox (**SAFE**)

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Proxy to reference data & Operations through **API**

DL-Sandbox: Sandboxing AI Developer's Code

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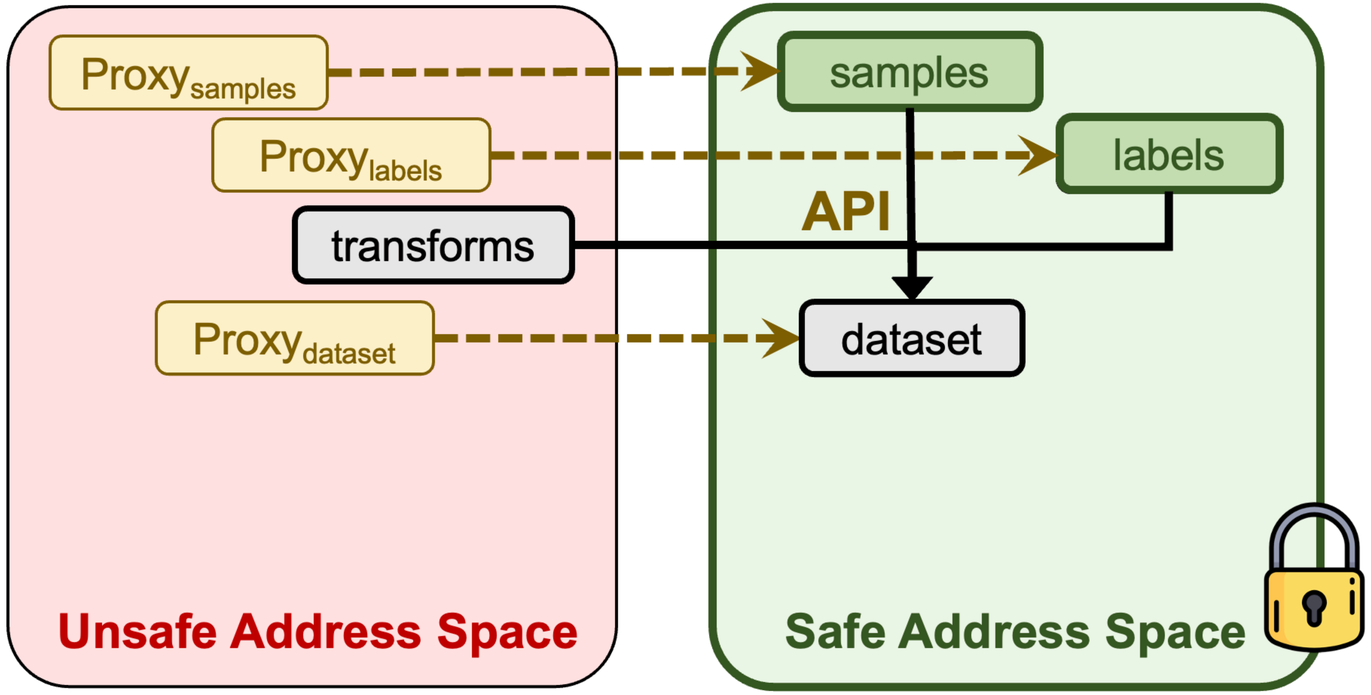

Isolated Address Space by DL-Sandbox (**SAFE**)

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Proxy to reference data & Operations through **API**

DL-Sandbox: Sandboxing AI Developer's Code

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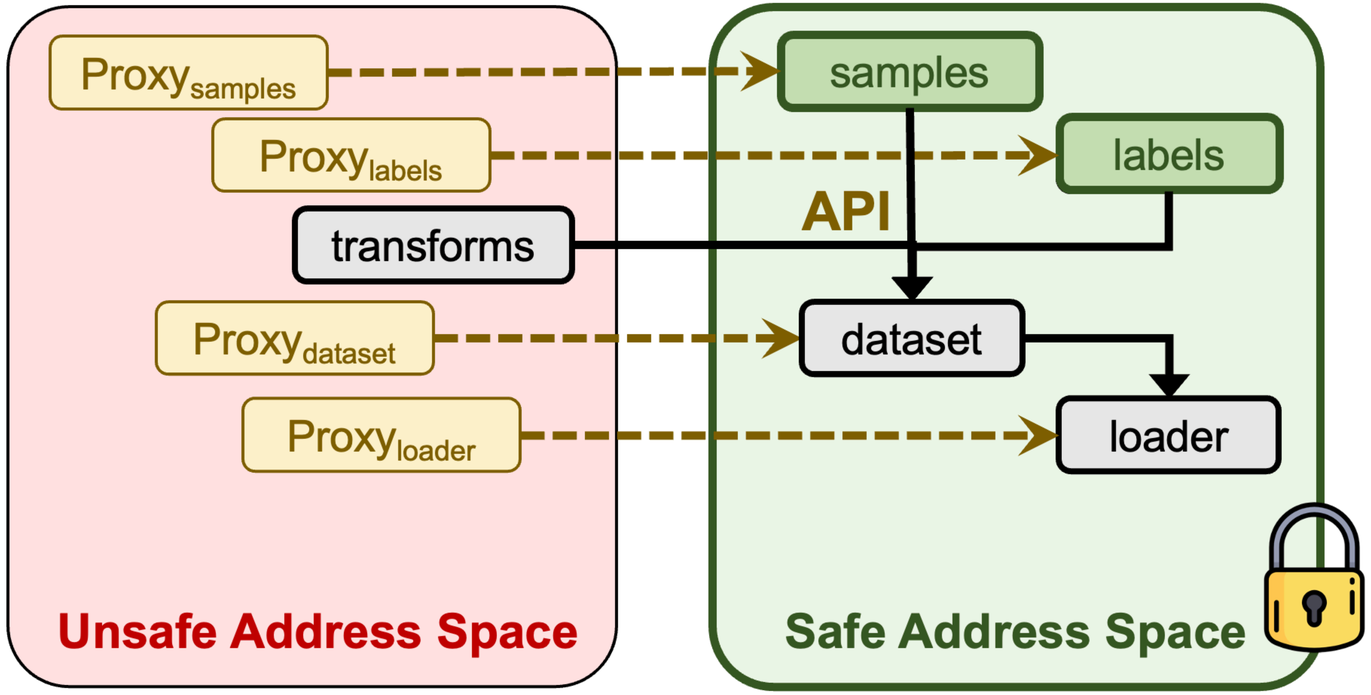

Isolated Address Space by DL-Sandbox (**SAFE**)

Attackers **cannot directly access or modify** data

Proxy to reference data & Operations through **API**

DL-Oracle: Taint Tracking Operations on Data

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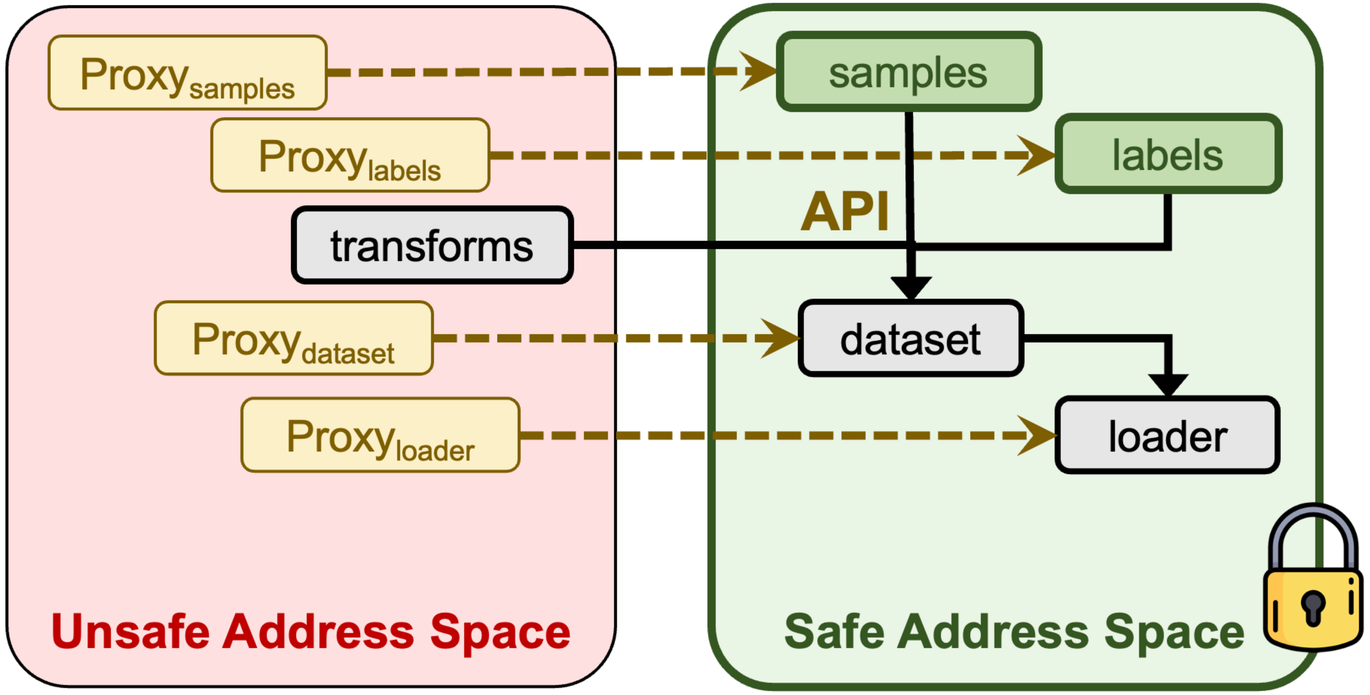

Isolated Address Space by DL-Sandbox (**SAFE**)

DL-Oracle: Taint Tracking Operations on Data

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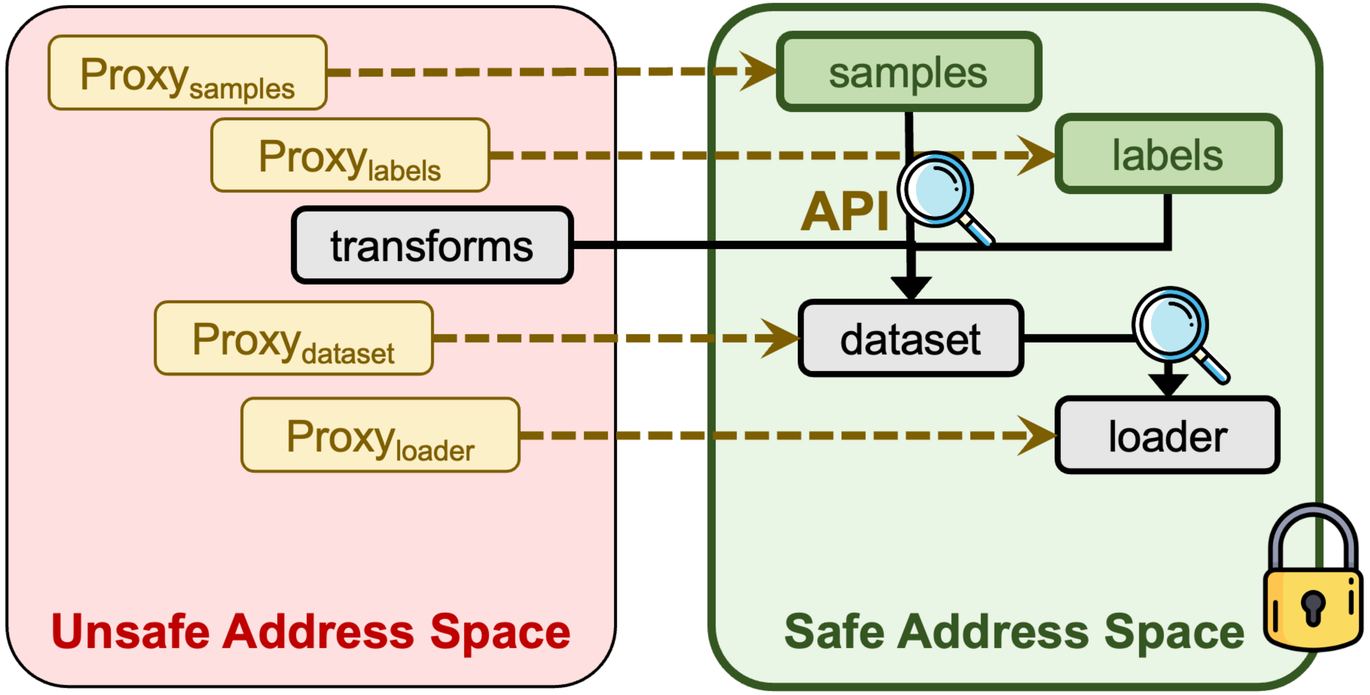

Isolated Address Space by DL-Sandbox (**SAFE**)

Taint track all operations on data

DL-Oracle: Taint Tracking Operations on Data

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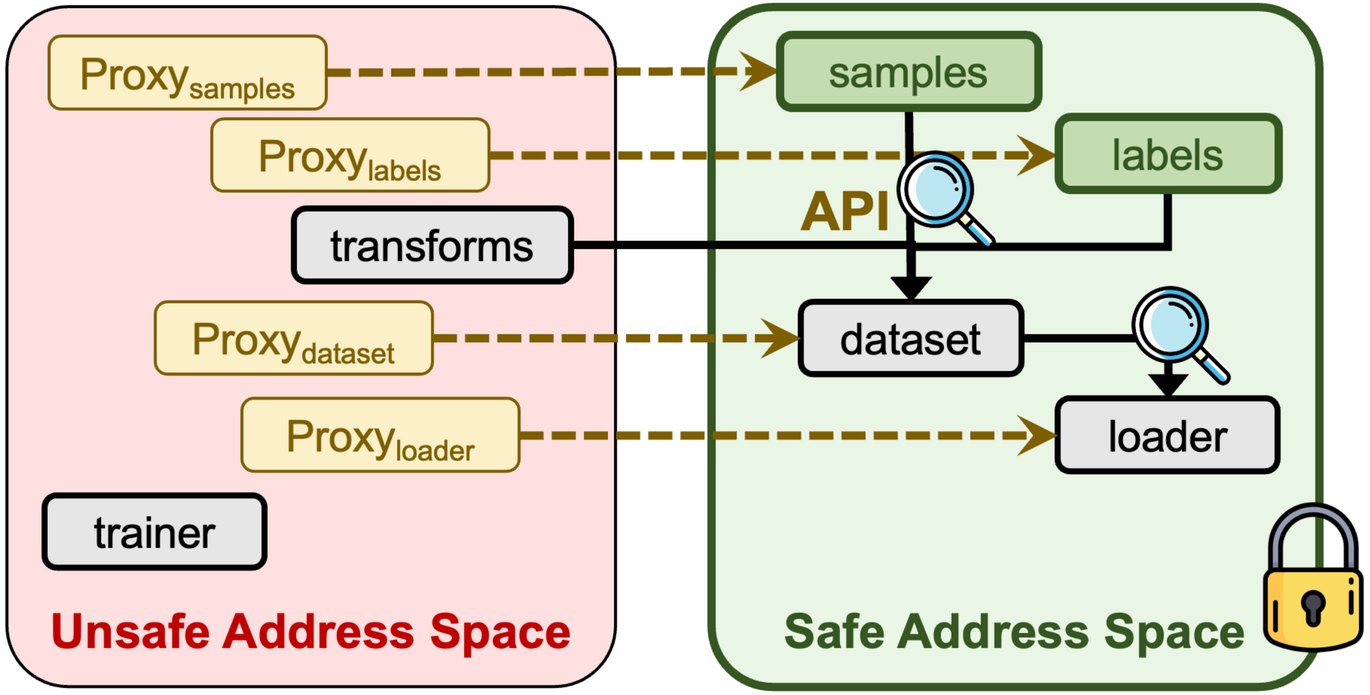

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Taint track all operations on data

DL-Oracle: Taint Tracking Operations on Data

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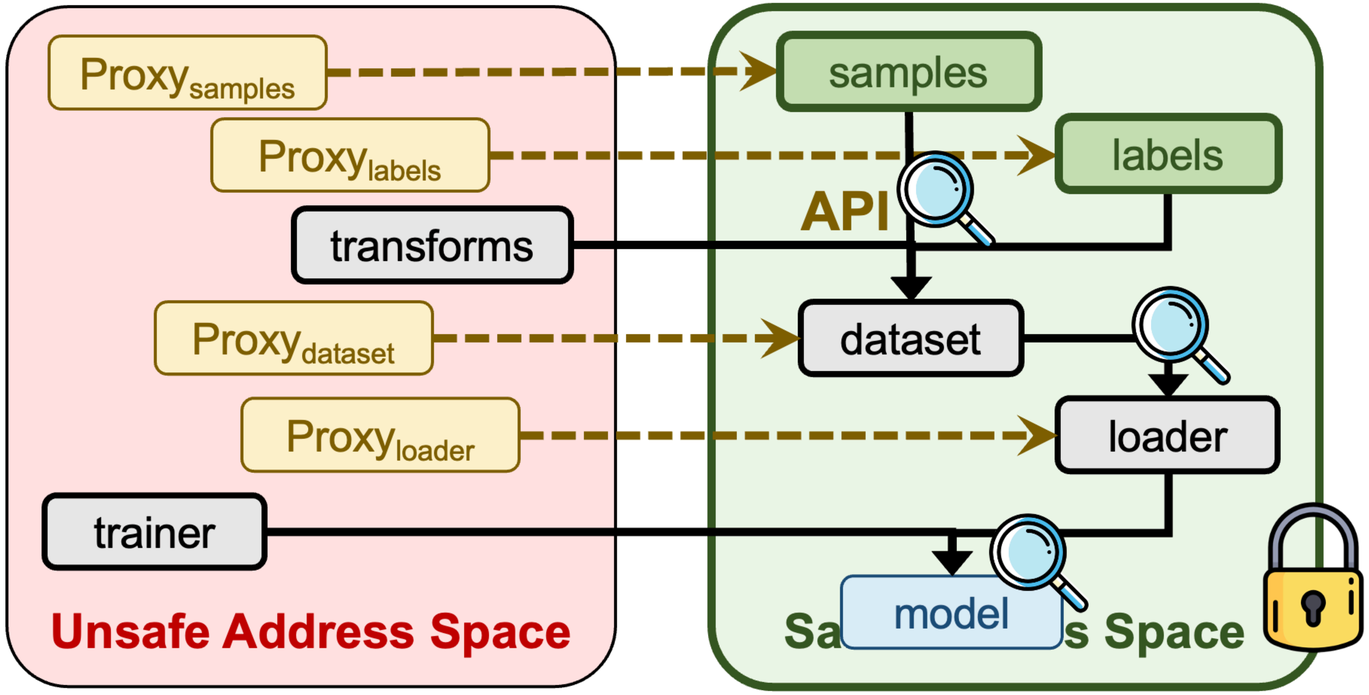

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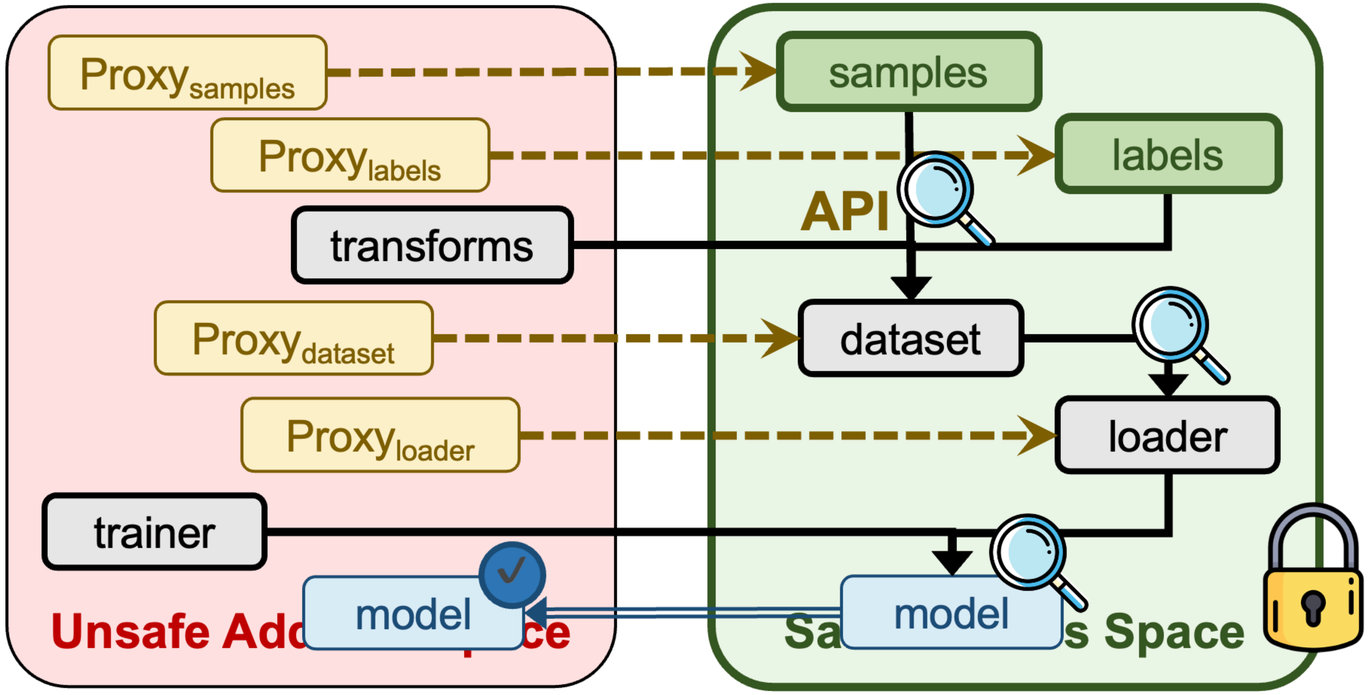
print("[mnist] done")
```



Isolated Address Space by DL-Sandbox (**SAFE**)

Taint track all operations on data

Return model only when **DGM-Rules are satisfied**

Implementation of DLBox

- Implemented on PyTorch library to support real-world datasets and ML models.
- Used confidential computing (i.e., AMD SEVSNP) to protect integrity and confidentiality.

Security Evaluation

- Number of samples leaked by one transfer of the (seemingly trained) model

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DLBox	Model-inversion	-	-	-

Performance Evaluation

- Performance overheads on training image & language models
  - 4% overheads of training time on average

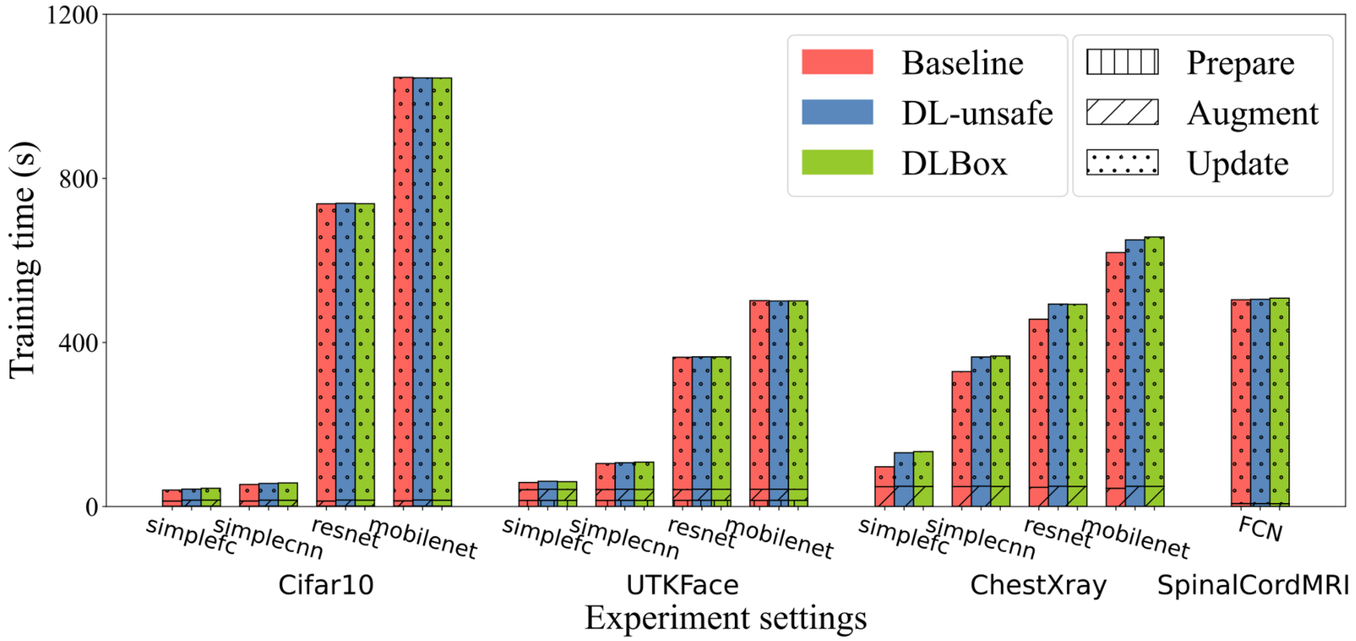
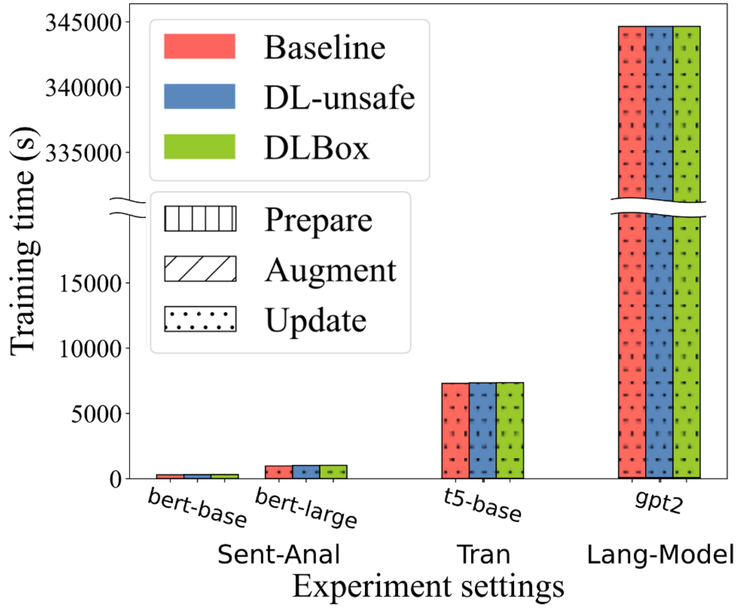


Image models



Language models

DLBox: Conclusion

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- We design **a new model training framework to protect training data**
- **DLBox** can foster the data sharing by protecting the right of data owners

Thank you