Exploring Generative Diffusion Models for Personalized Aesthetic QR Code Design

玩轉生成擴散模型，打造專屬美感 QR Code

廖家緯 Jiawei

Ph.D. Candidate in Computer Science

National Taiwan University

jwliao1209 jwliao1209

About Me

Education

BS in Math

MS in Applied Math

PhD Candidate in CSIE

Work Experience

Research Intern

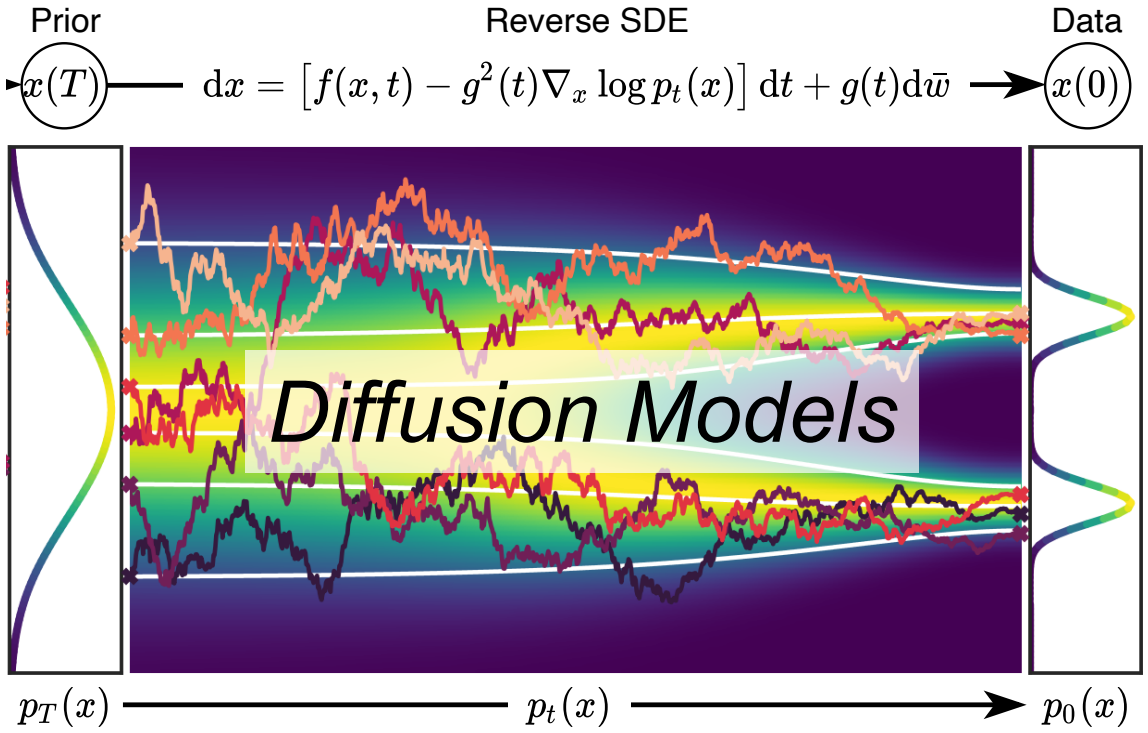
DA Intern

Research Assistant

AI Research Intern (US)

SWE Intern

Why Are You Here?



Agenda

1. **Personalized Aesthetic QR Code**
   - QR Code Basics
   - Optimization for Image and QR Code Fusion
   - Showcase of Results

2. **Generative Aesthetic QR Code**
   - Foundations of Image Generative AI & Diffusion Models
   - How Diffusion Models Make QR Codes Beautiful and Scannable
   - Hands-on with 🤗 Diffusers

3. **Q&A and Discussion**


詹記麻辣火鍋
\徵/
內外場夥伴
3或4月新展店招募
啦
約嗎在西門町!?
詹仆
祖籍 山東
『掃我額頭上1111打com』
嘿！～吻！
嘿嘿！～吻！
表！哥！台！北！
門！店！缺！人！
大！家！快！來！
嘿！～吻！
月均薪47,000 ~50,000
*$50,000含夜班津貼
*入職滿一年之待遇
*含四大獎金. 全勤獎金
【 四大獎金 】
1端午 & 2中秋獎金
＼依年資發放, 滿1年每節$7,500, 滿4年後每節$15,000／
3年終獎金 ＼每年發放1次, $30,000／
4紅利獎金 ＼每年發放1次, $50,000／
(*發放金額依公司當年度盈餘狀況、職等、評鑑並以面試現場說明為主)

Personalized Aesthetic QR Code

How QR Codes Work

https://tw.pycon.org/2025/zh-hant

QR Code Structure

Finder pattern (定位)

Timing pattern (定時)

Error Correction Levels

L – 7%

M – 15%

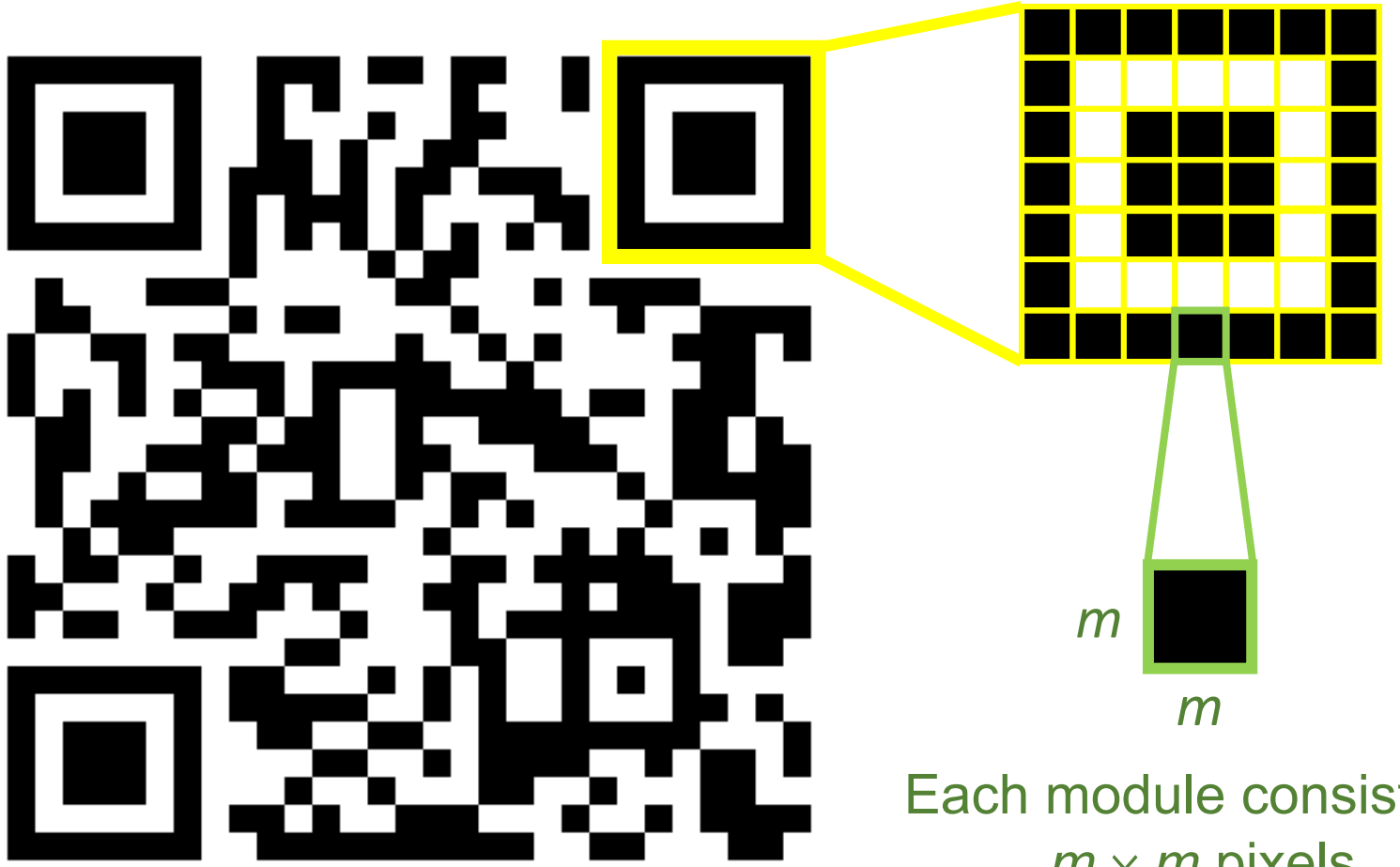
Q – 25%

H – 30%

Alignment pattern (校正)

QR Code Structure

QR Codes are defined in units of modules



Each module consists of
$m \times m$ pixels

Qart

Qart leverages the error correction of QR codes to embed image patterns into the code, blending visuals with functionality while keeping it scannable

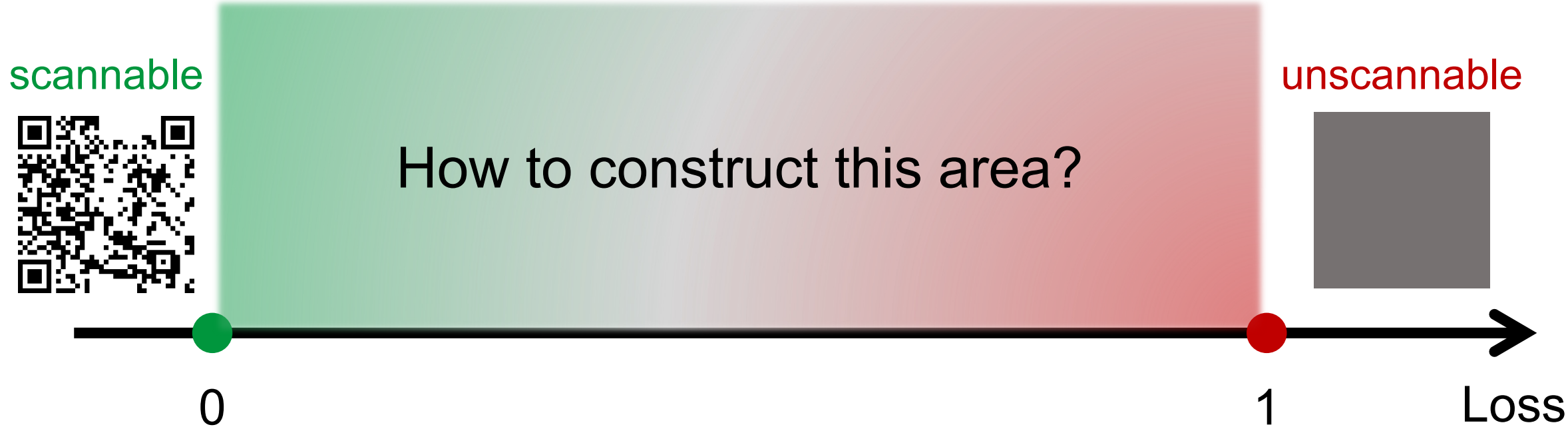






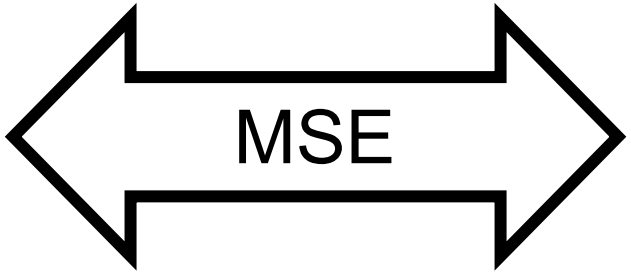

How to Evaluate the Scannability of QR Codes?

Our goal is to define a *smooth* loss function to measure the similarity between the image and target QR code → *Scanning Robust Loss (SRL)*



Is MSE a Good Choice?

Image Variable



Target QR Code

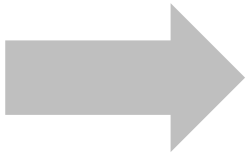
Binary Relaxation

Grayscale Loss

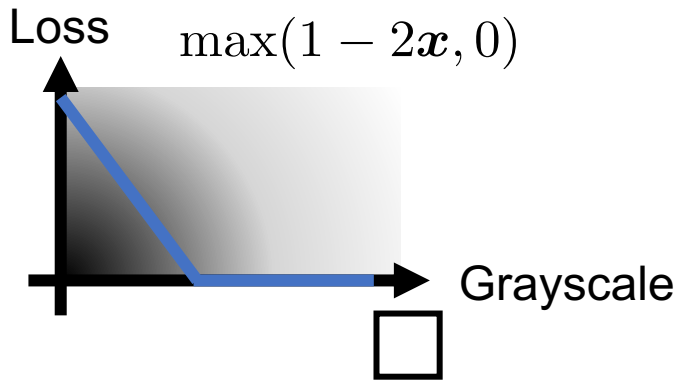
Original Image

Grayscale Image

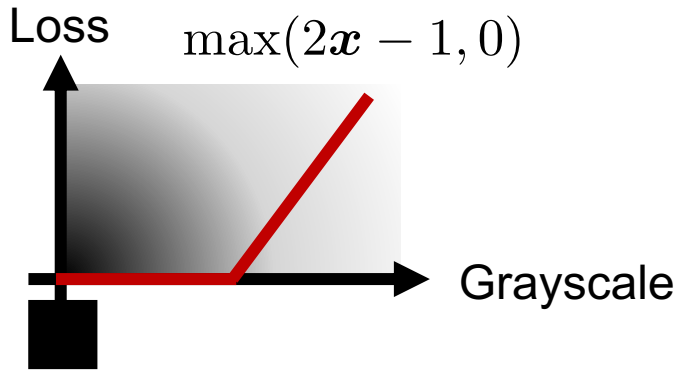
Target QR Code

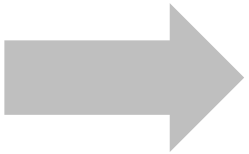


Target module is white



Target module is black

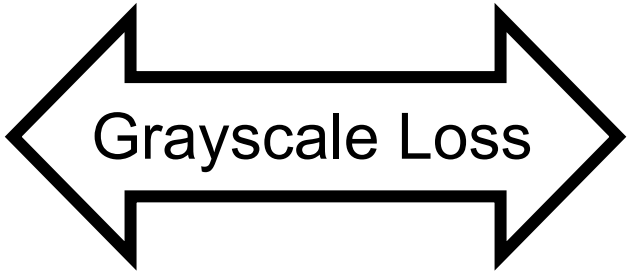




Error Image

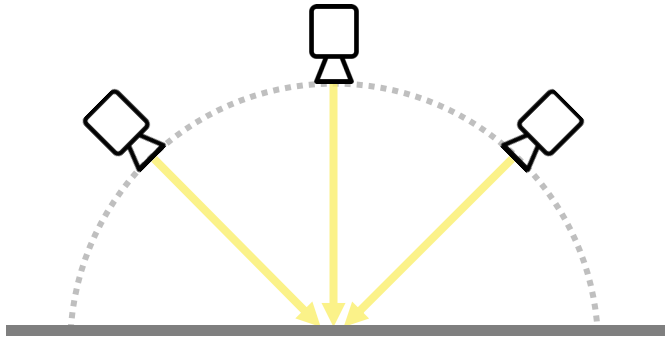
Applying Grayscale Loss

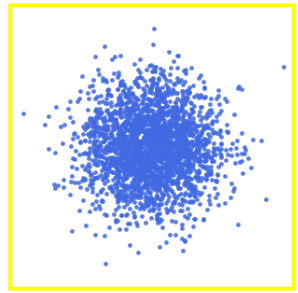
Image Variable

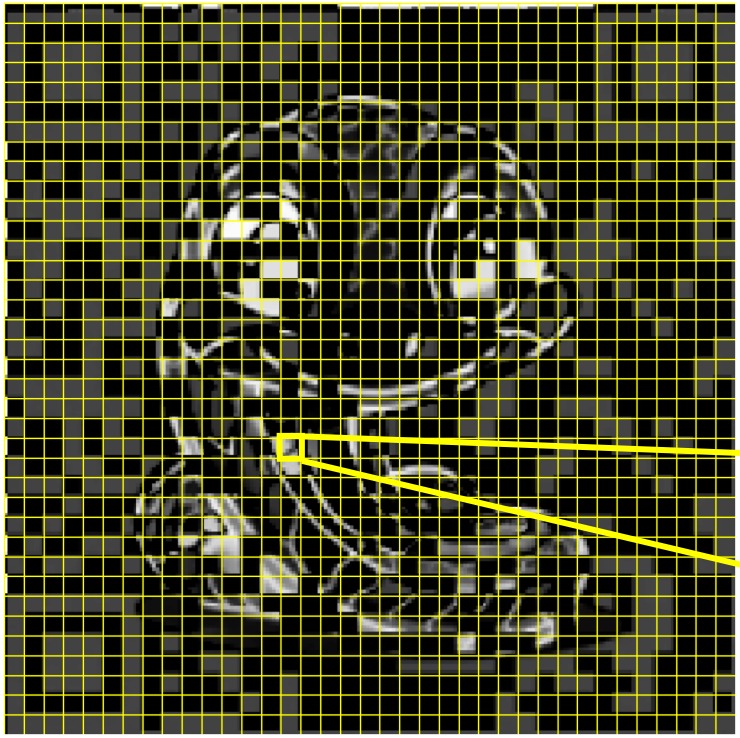


Target QR Code

Module Error Reweighting

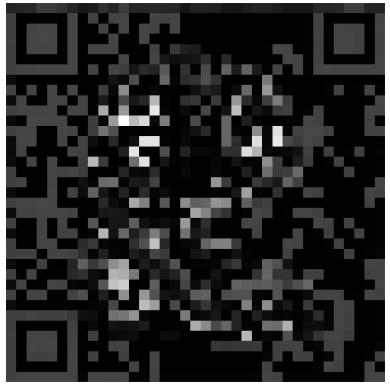






Error Image

Reweighted sum



Sampling Error Image

$\|\cdot\|_1$

SRL

Optimization for Image and QR Code Fusion

Target QR Code

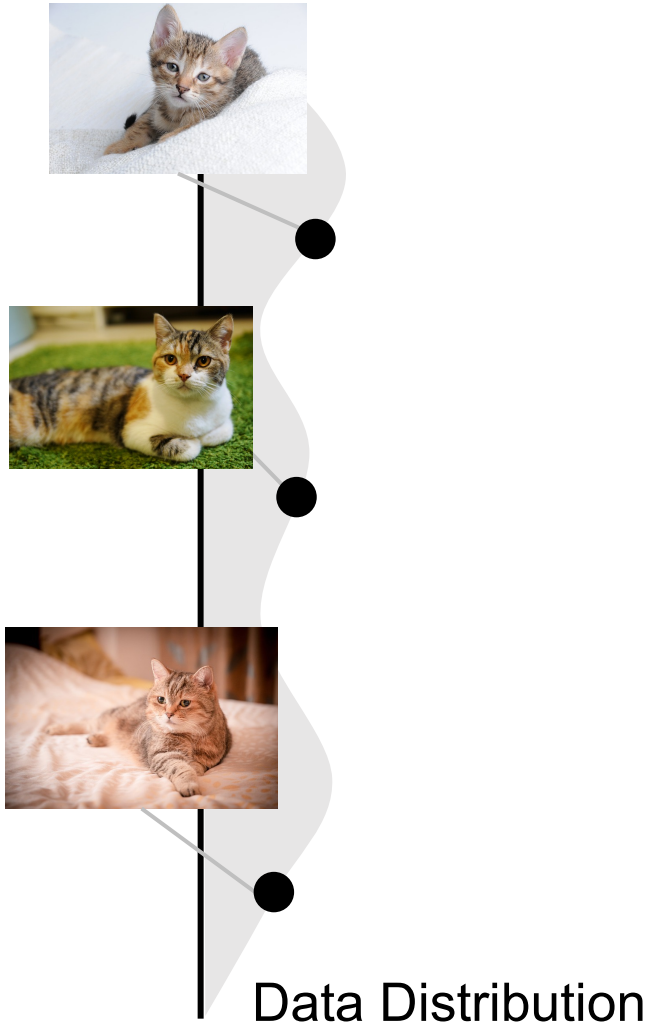
Image Variable

Reference Image

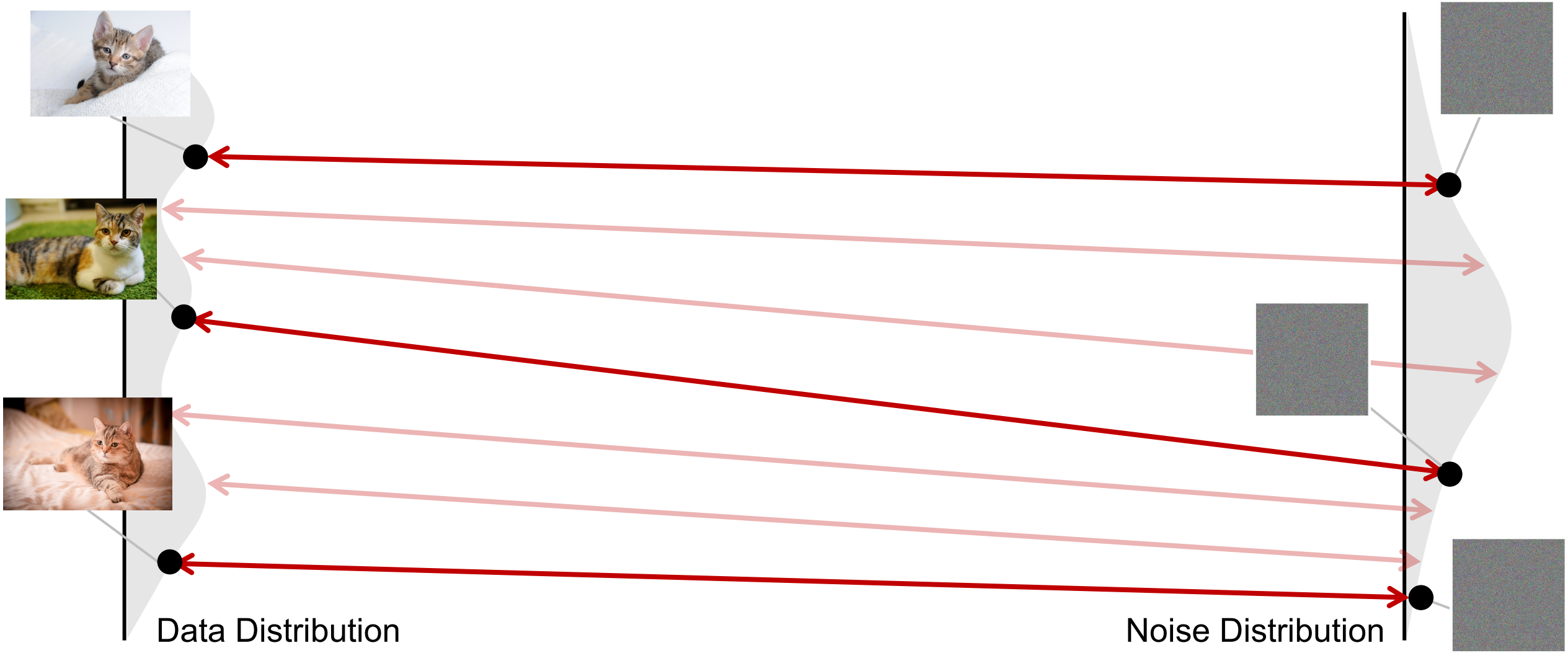
Generative Aesthetic QR Code

What is Generative Model Learning?

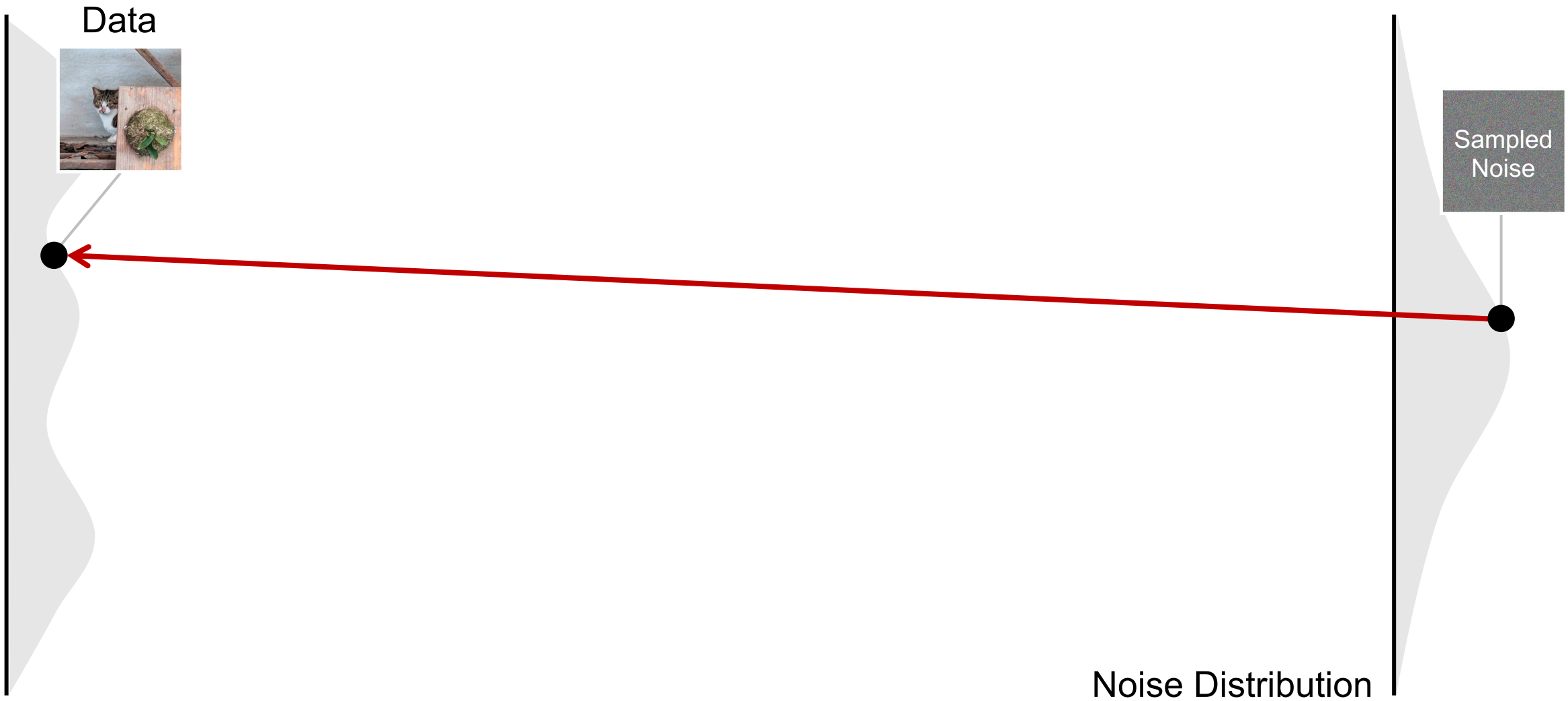
What is Generative Model Learning?



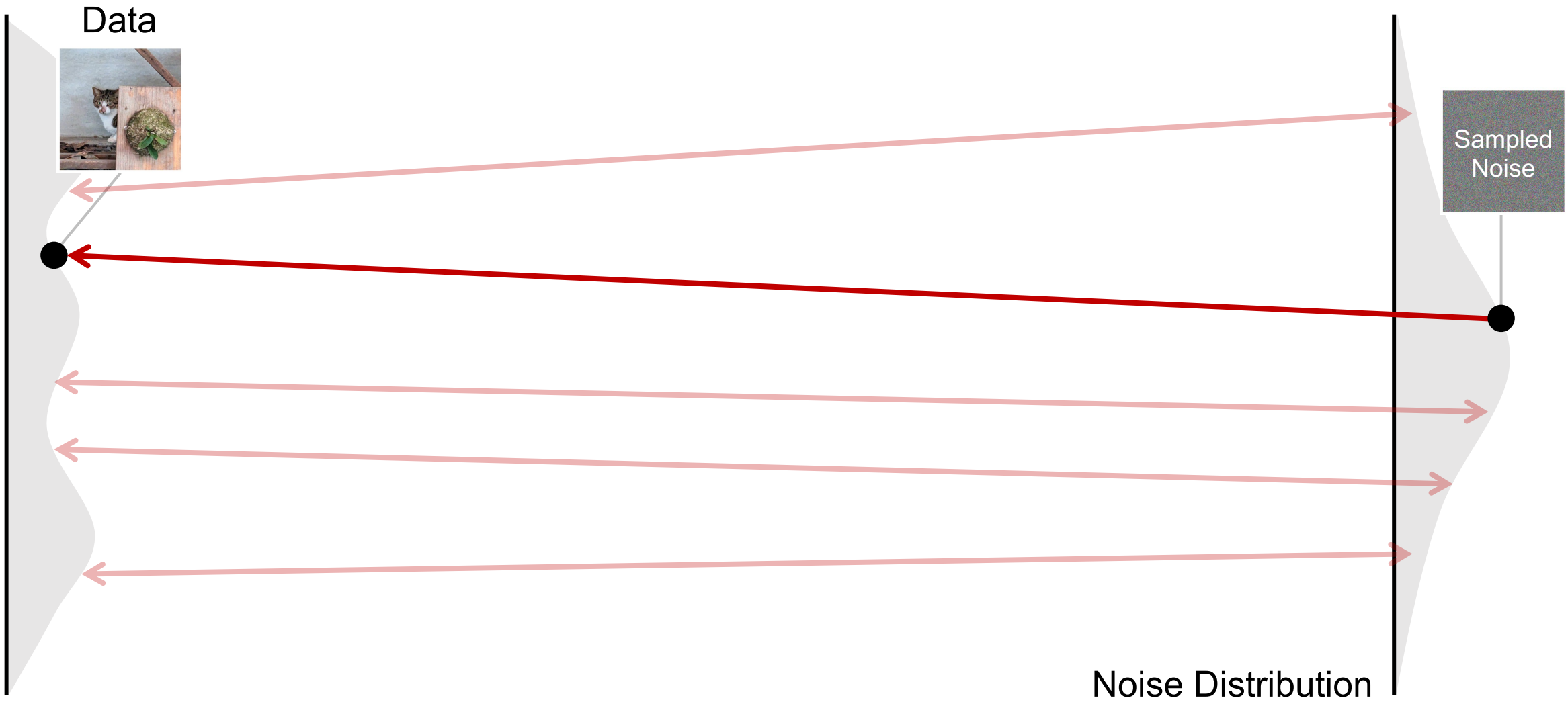
What is Generative Model Learning?



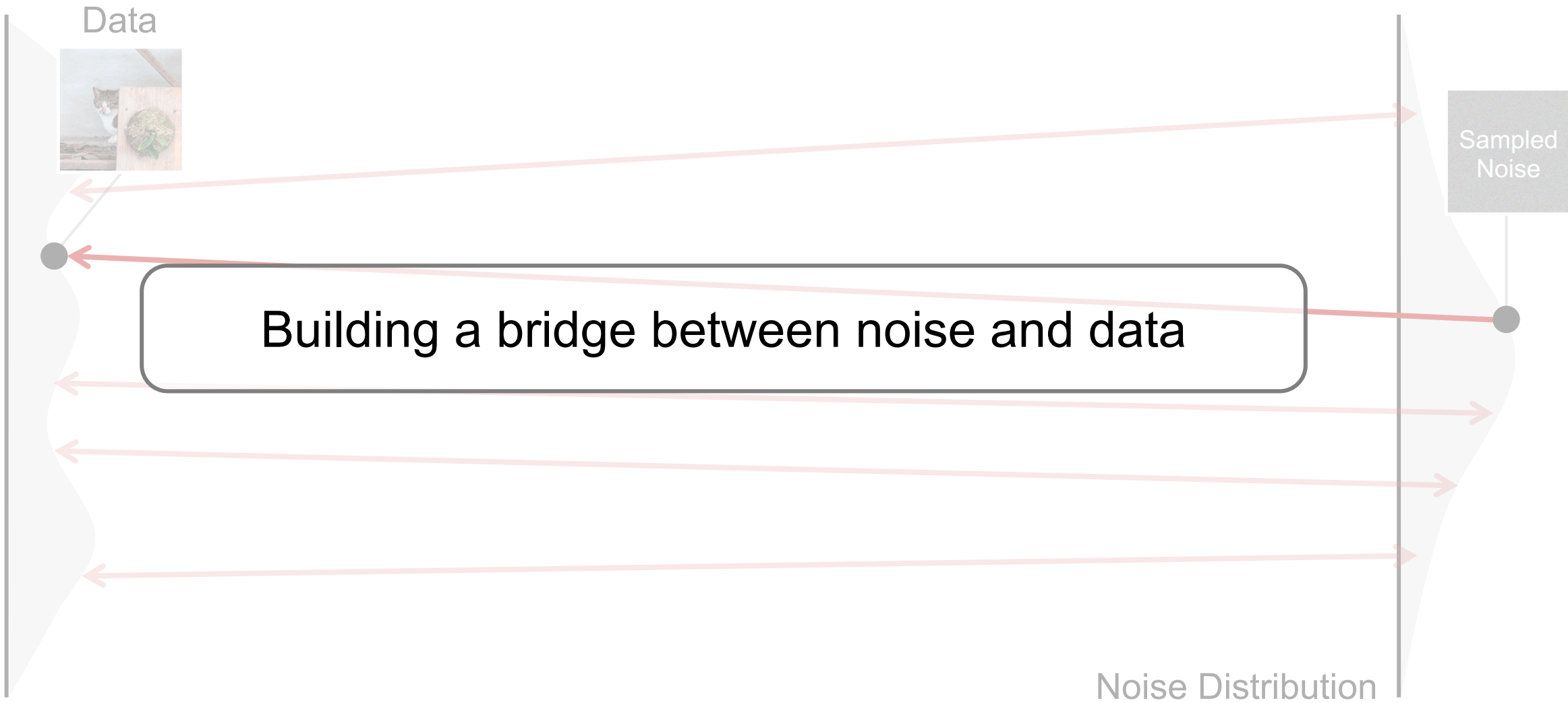
What is Generative Model Learning?



The Goal of Generative Model



The Goal of Generative Model



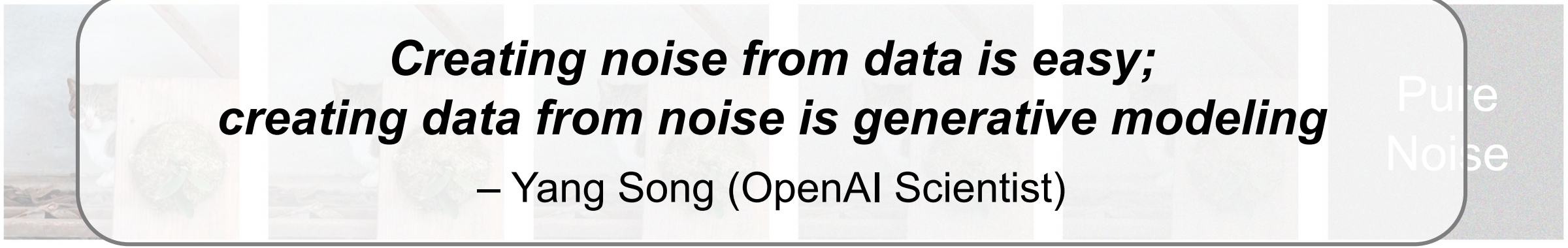
What is Diffusion Model?

Forward Process: add noise step by step, from data to pure noise

Reverse Process: generate data from pure noise by denoising

What is Diffusion Model?

Forward Process: add noise step by step, from data to pure noise

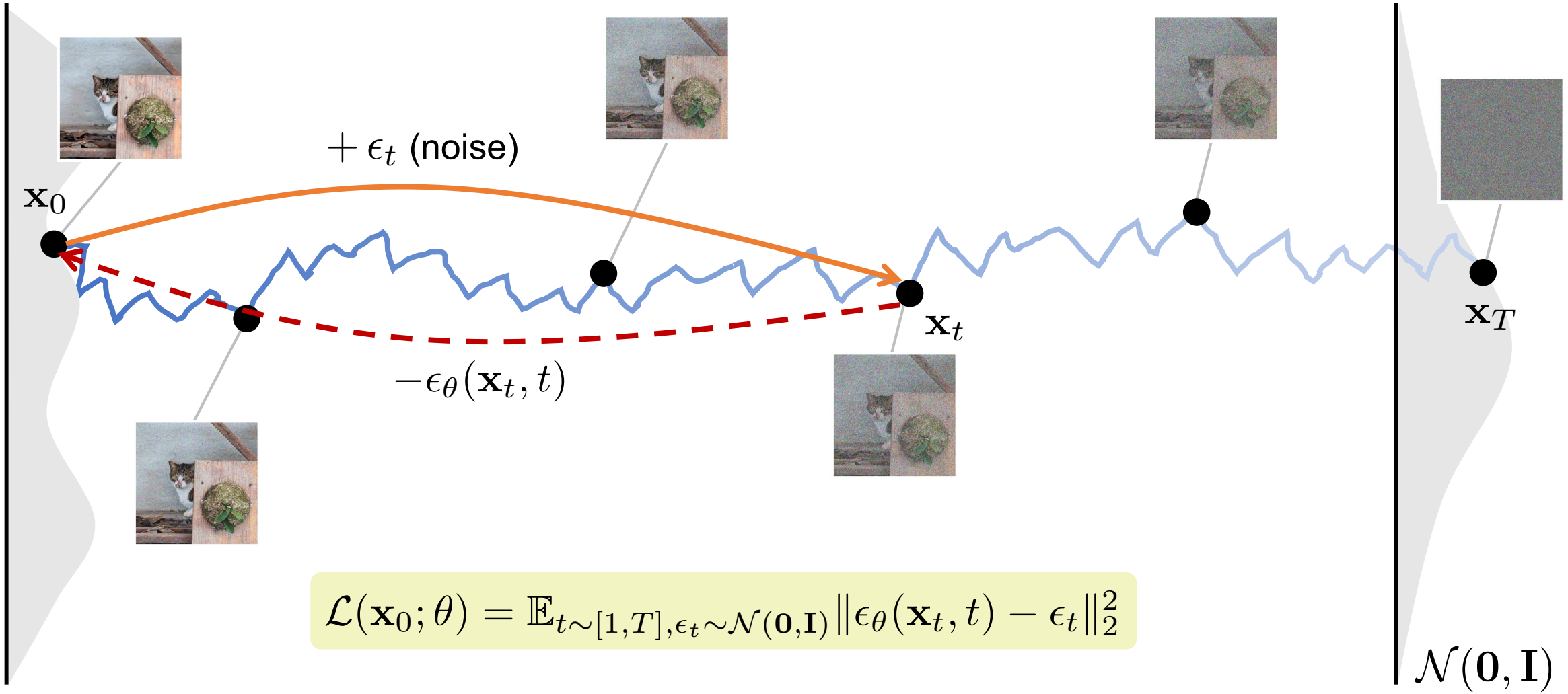


Creating noise from data is easy;
creating data from noise is generative modeling

– Yang Song (OpenAI Scientist)

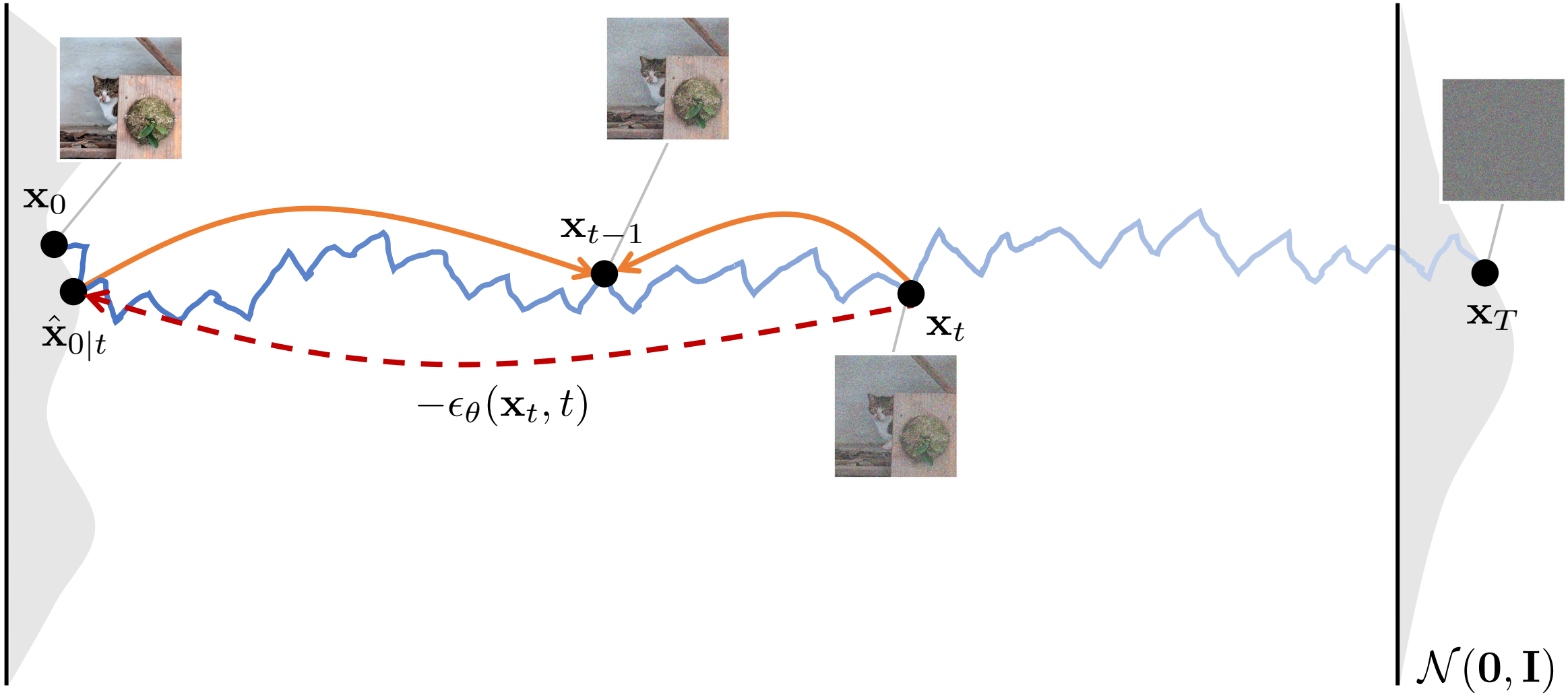
Reverse Process: generate data from pure noise by denoising

How Does It Work?



$$\mathcal{L}(\mathbf{x}_0; \theta) = \mathbb{E}_{t\sim[1,T],\epsilon_t\sim\mathcal{N}(\mathbf{0},\mathbf{I})} \|\epsilon_\theta(\mathbf{x}_t, t) - \epsilon_t\|_2^2$$

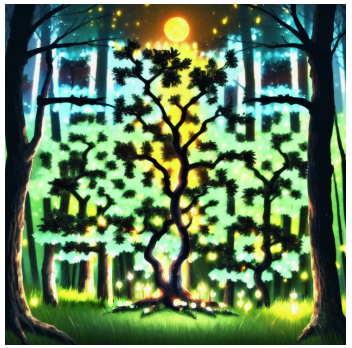
How Does It Work?



DiffQRCoder: Diffusion-based Aesthetic QR Code Generation with Scanning Robustness Guided Iterative Refinement

WACV 2025

Project Page



Paper

Code

Jia-Wei Liao

Winston Wang

Tzu-Sian Wang

Li-Xuan Peng

Ju-Hsuan Weng

Cheng-Fu Chou

Jun-Cheng Chen

Generative Aesthetic QR Code

QR Code + Prompt + Diffusion Model

Original QR Code

Winter wonderland, fresh snowfall, evergreen trees, cozy log cabin, smoke rising from chimney, aurora borealis in night sky.

Cherry blossom festival, pink petals floating in the air, traditional lanterns, peaceful river, people in kimonos, sunny day.

Majestic waterfall, lush rainforest, rainbow in the mist, exotic birds, vibrant flowers, serene pool below.

Abandoned amusement park, overgrown rides, haunting beauty, sense of nostalgia, sunset lighting.

Challenge

- There is no standard ground truth for aesthetic QR codes, we can’t employ supervised learning directly for training models
- Most Diffusion-based aesthetic QR code generation struggle to balance scannability and aesthetics

QR Code AI Art

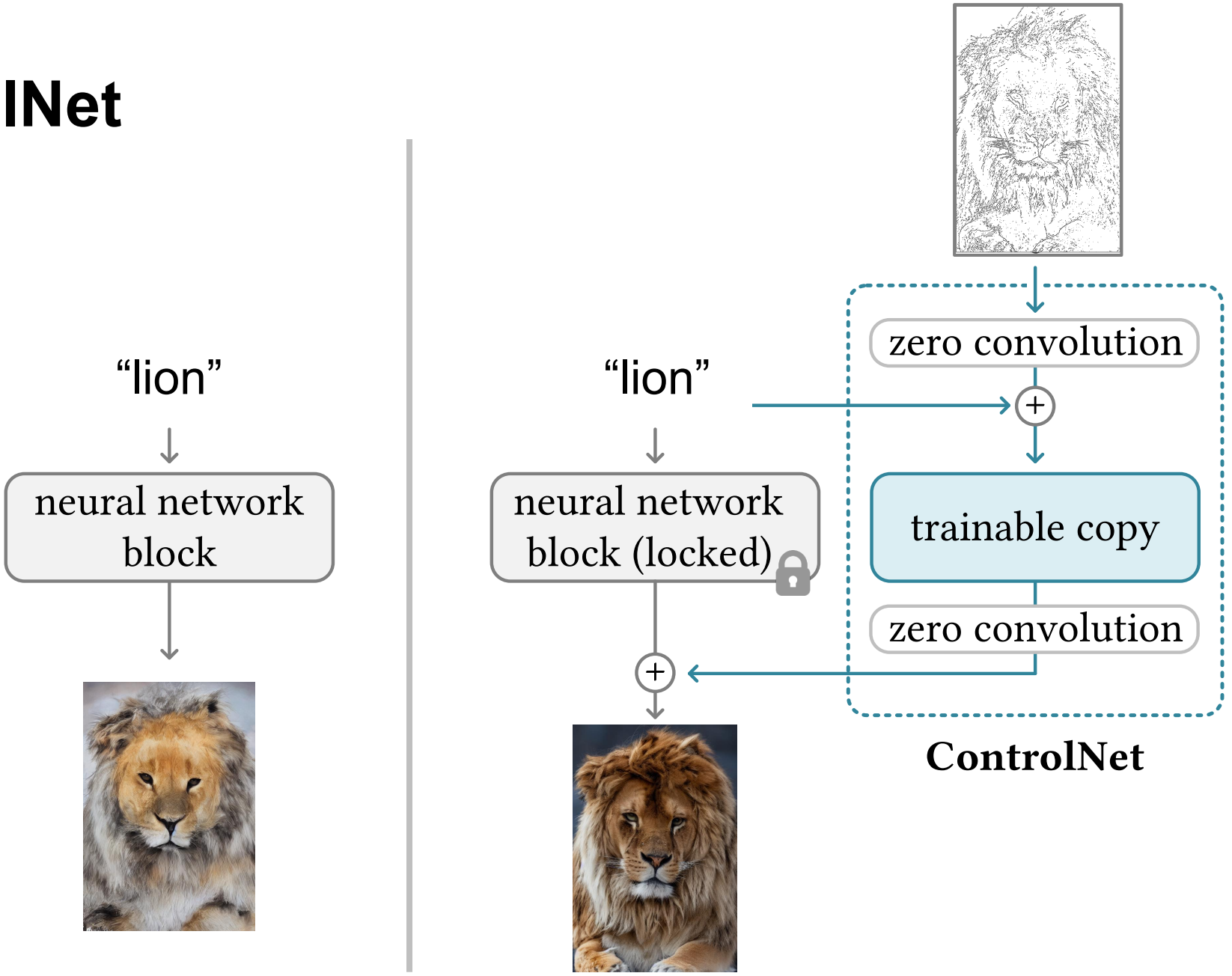
QR Diffusion

QRBTF

DiffQRCode (Ours)

Green: scannable, **Red:** unscannable

ControlNet

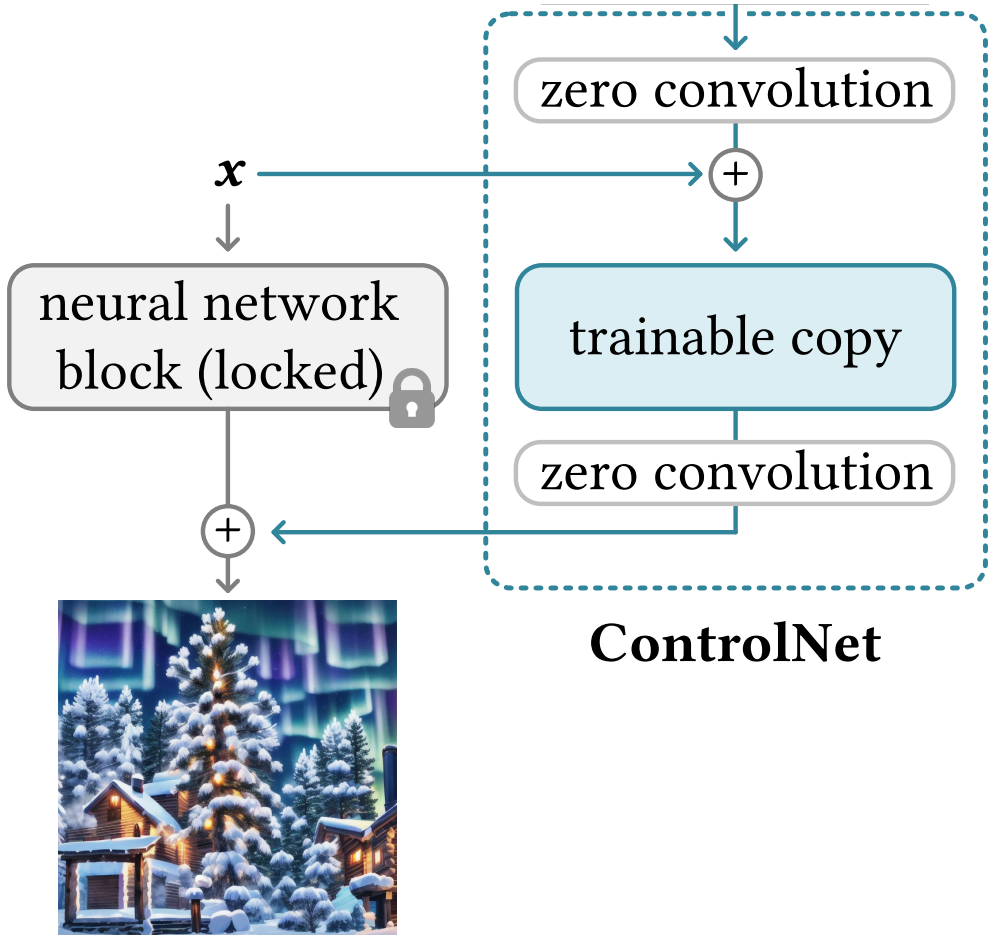

"lion"
neural network block
"lion"
neural network block (locked)
zero convolution
trainable copy
zero convolution
ControlNet

QRMonster

Training ControlNet with image–binary mask pairs

Image

Binarized image



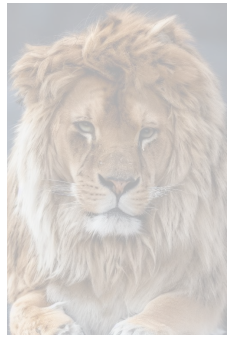
QRMonster

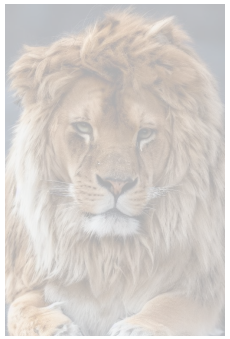
Training ControlNet with image–binary mask pairs

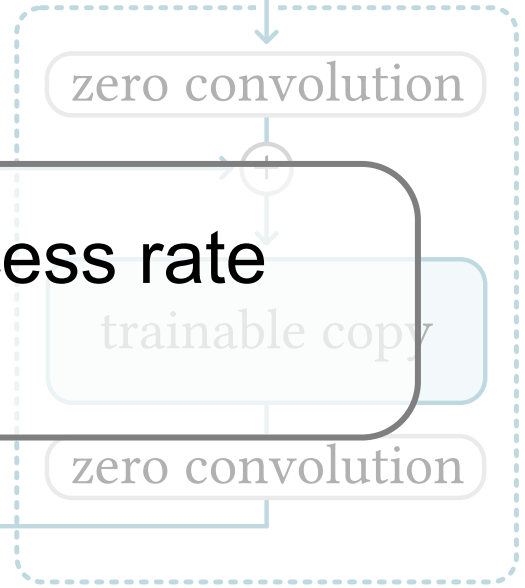
Image

Binarized image

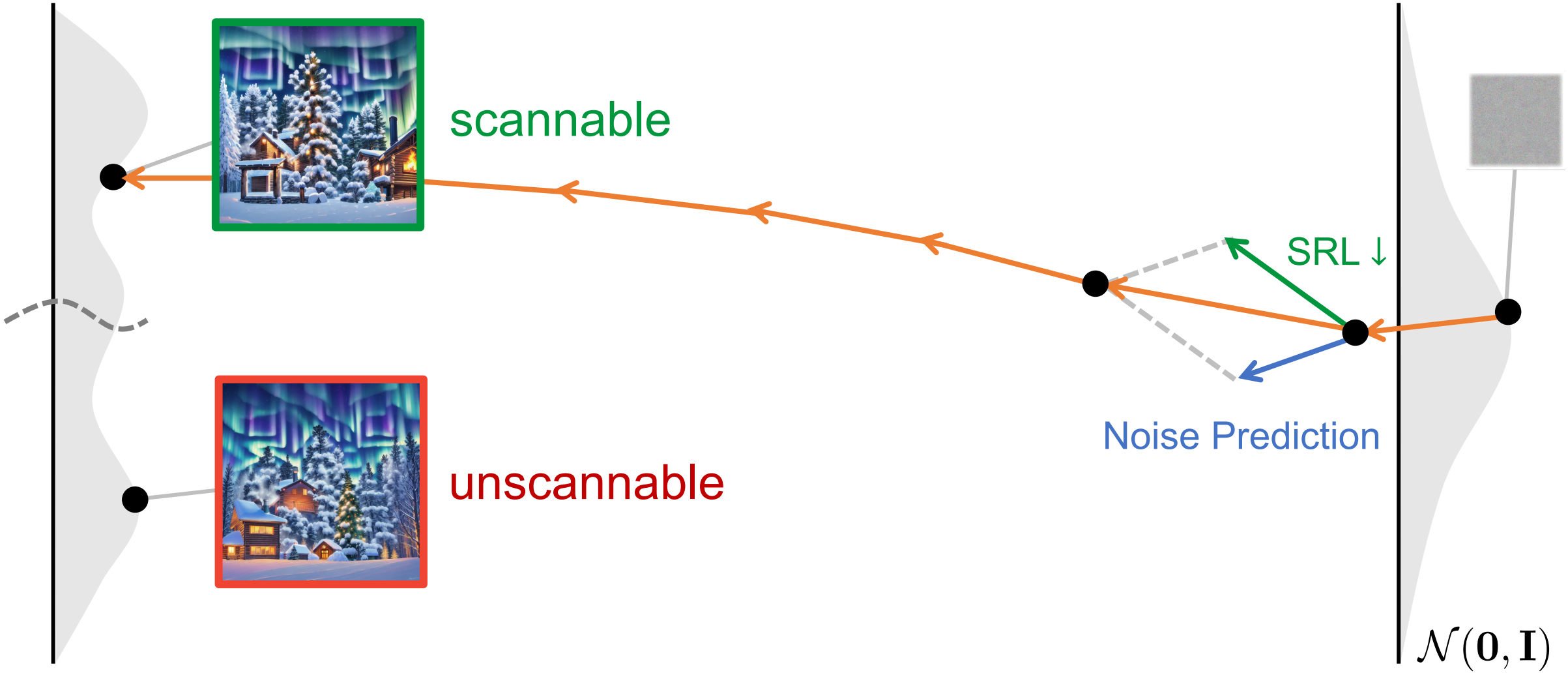
Even with ControlNet, a high scanning success rate cannot be guaranteed



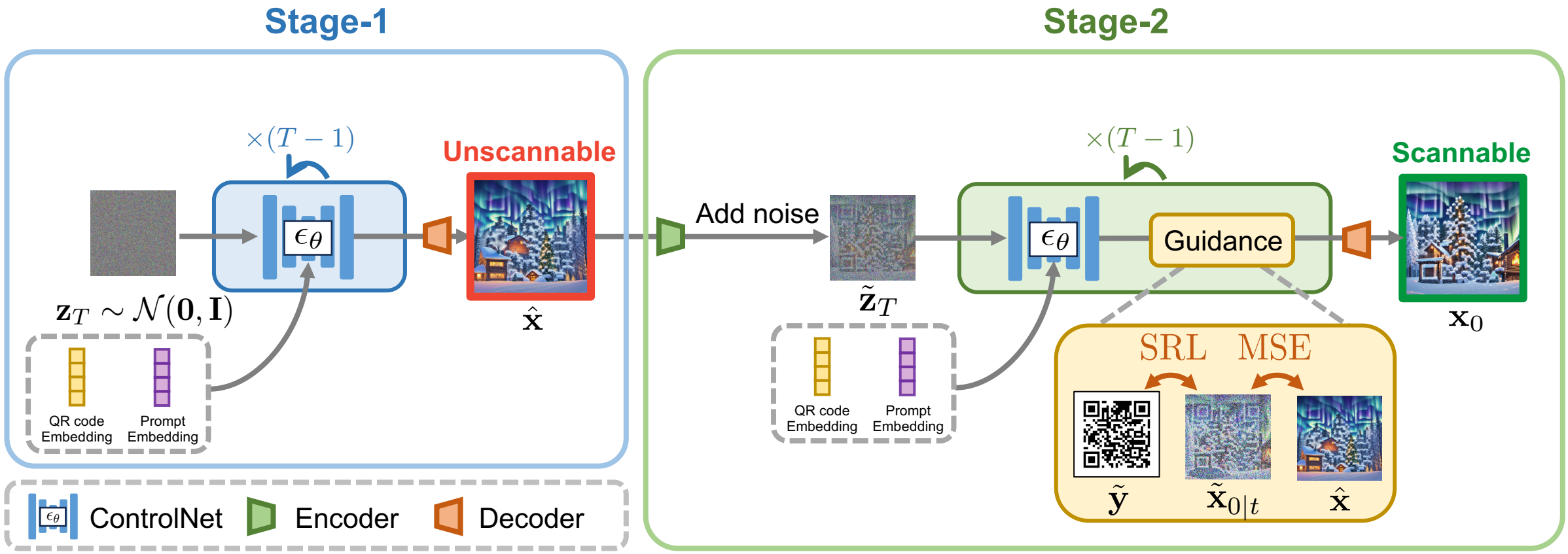




Guiding Diffusion Models



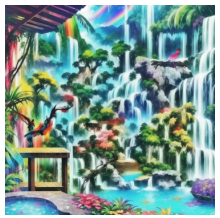
Two-stage Iterative Refinement Pipeline



Qualitative Comparisons

Prompt	QR Code AI Art	QR Diffusion	QRBTF	DiffQRCode (Ours)
Winter wonderland, fresh snowfall, evergreen trees, cozy log cabin, smoke rising from chimney, aurora borealis in night sky.				
(a) Encoded message: Thanks reviews!				
Old European town square, cobblestone streets, café terraces, flowering balconies, gothic cathedral, bustling morning.				
(b) Encoded message: I think, therefore I am!				
Forest clearing at night, fireflies, full moon, ancient oak tree, soft grass, mystical ambiance.				
(c) Encoded message: https://www.google.com.tw/				

Prompt

Error Correction Level	Original QR Code	Majestic waterfall, lush rainforest, rainbow in the mist, exotic birds, vibrant flowers, serene pool below.	Old European town square, cobblestone streets, café terraces, flowering balconies, gothic cathedral, bustling morning.	Enchanted forest path, magical creatures, ancient trees, glowing lanterns, fairy tale setting.	Foggy London street, vintage lampposts, double-decker bus, historic buildings, cobblestone pavement, early morning.	Secret garden behind an old mansion, hidden pathways, antique statues, undiscovered beauty.
L						
M						
H						
Q						

Quantitative Results (I)

- **SSR:** Utilize qr-verify to assess the scanning success rate
- **CLIP-aes.:** Utilize CLIP aesthetic predictor to quantify the aesthetic
- **CLIP-score:** Utilize CLIP to quantify the text-image alignment
- **Avg-rank:** Perform user subjective aesthetic preference study

Method	SSR ↑	CLIP-aes. ↑	CLIP-score ↑	Avg-rank ↓
QR Code AI Art [13]	90%	5.7003	0.2341	2.71
QR Diffusion [15]	96%	5.5150	0.2780	3.18
QRBTF [18]	56%	**7.0156**	**0.3033**	**1.86**
DiffQRCoder (Ours)	**99%**	6.8233	0.2992	2.25

Two Types of Aesthetic QR Codes

Personalization-based

VS

Generation-based

Summary

- By breaking down the QR code scanning process and underlying mechanisms, we can design a differentiable loss function.
- We can add control to diffusion models via customized deterministic loss function without relying on pre-trained models or adapting additional modules.

YouTube Channel

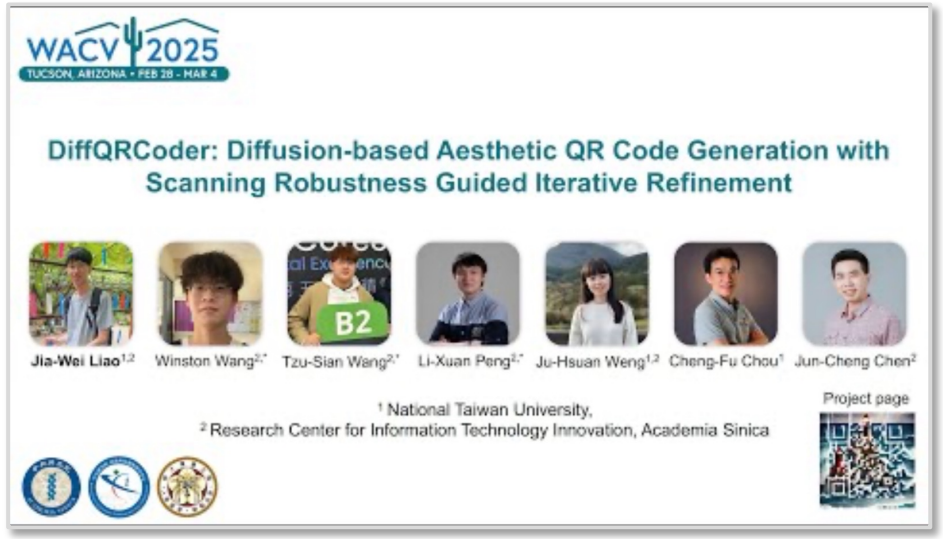
JWAI

@jwai1023 · 506位訂閱者 · 76 部影片

進一步瞭解這個頻道 ...顯示更多

訂閱

Diffusion Models and Their Applications



DiffQRCoder

Thank you