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

Jia-Wei Liao[1,2], Winston Wang[1*], Tzu-Sian Wang[1*], Li-Xuan Peng[1*], Ju-Hsuan Weng[1,2], Cheng-Fu Chou[2], Jun-Cheng Chen[1]
[1] Research Center for Information Technology Innovation, Academia Sinica, [2] National Taiwan University

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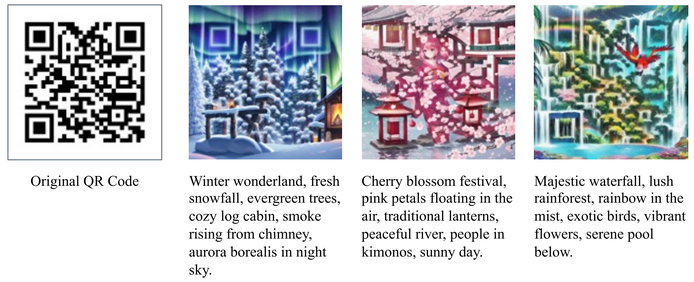
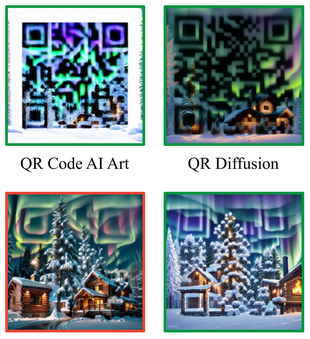
**Project Page**

## *Aesthetic QR codes generated from DiffQRCoder*



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.

## Motivation



QR Code AI Art | QR Diffusion | QRBTF | DiffQRCode (Ours)

Existing methods struggle to balance scannability and aesthetics. Although QRBTF generate visually appealing QR codes, they lack scanning robustness. Conversely, QR Code AI Art and QR Diffusion produce better scanning robust QR codes but are visually less appealing. Our approach can generate both attractive and scannable QR codes.

**Green:** scannable, **Red:** unscannable

## Key Insights

- We propose a two-stage iterative refinement framework with **Scanning Robust Perceptual Guidance (SRPG)** to create scanning-robust, visually appealing QR codes without training.
- We develop **Scanning Robust Manifold Projected Gradient Descent (SR-MPGD)**, achieving up to 100% Scanning Success Rate (SSR) through latent space optimization.
- Our pipeline Improve SSR from 60% to nearly 100% compared to ControlNet-only, maintaining aesthetics as validated by user evaluations.

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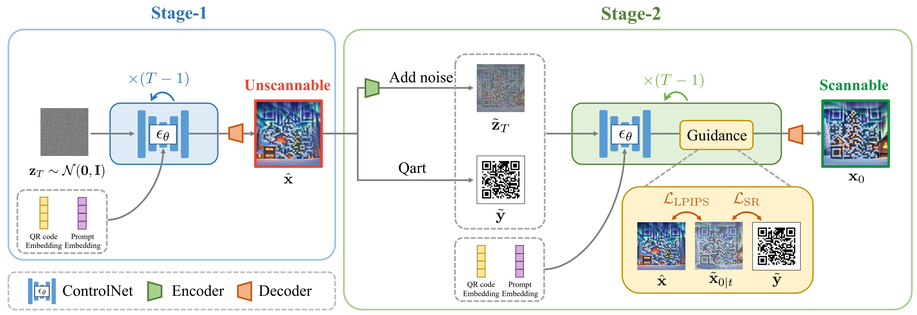
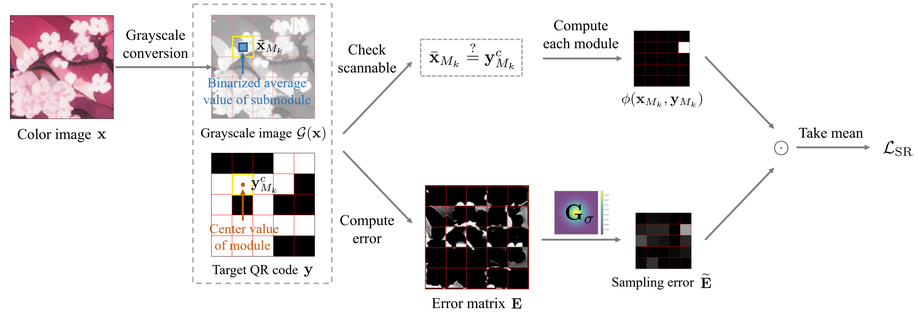
## Methodology

### *Two-stage Iterative Refinement Pipeline*

- **Stage-1:** Utilize the pre-trained ControlNet to generate an attractive yet unscannable QR code $\hat{\mathbf{x}}$.
- **Stage-2:** Convert the QR code from Stage-1 into a latent $\tilde{\mathbf{z}}_T$ by adding Gaussian noise and transforming the target QR code $\mathbf{y}$ to $\tilde{\mathbf{y}}$, which has a more similar pattern as $\hat{\mathbf{x}}$, using Qart. Finally, feed the latent and the transformed code into ControlNet, guided by SRPG, to create an aesthetic QR code with scannability.




### *Scanning Robust Perceptual Guidance (SRPG)*

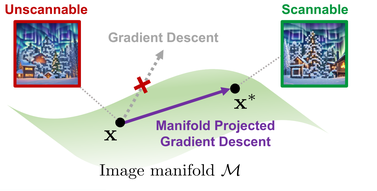



$$\hat{\epsilon}_t = \epsilon_\theta(\tilde{\mathbf{z}}_t, t, \mathbf{e}_p, \mathbf{e}_{\text{code}}) + \sqrt{1-\bar{\alpha}_t}\nabla_{\tilde{\mathbf{z}}_t}[\lambda_1 \mathcal{L}_{\text{SR}}(\tilde{\mathbf{x}}_{0|t}, \tilde{\mathbf{y}}) + \lambda_2 \mathcal{L}_{\text{LPIPS}}(\tilde{\mathbf{x}}_{0|t}, \hat{\mathbf{x}})]$$

### *Post-Processing*

Optimization Formulation: $\min_{\mathbf{x}\in\mathcal{M}} \mathcal{L}_{\text{SR}}(\mathbf{x}, \mathbf{y})$

### *Scanning Robust Manifold Projected Gradient Descend (SR-MPGD)*




$$\mathbf{z} \leftarrow \mathbf{z} - \gamma\nabla_{\mathbf{z}}[\mathcal{L}_{\text{SR}}(\mathcal{D}(\mathbf{z}), \mathbf{y}) + \lambda\mathcal{L}_{\text{LPIPS}}(\mathcal{D}(\mathbf{z}), \mathbf{x}_0)]$$ (Utilize pretrained Decoder)

## Experiments

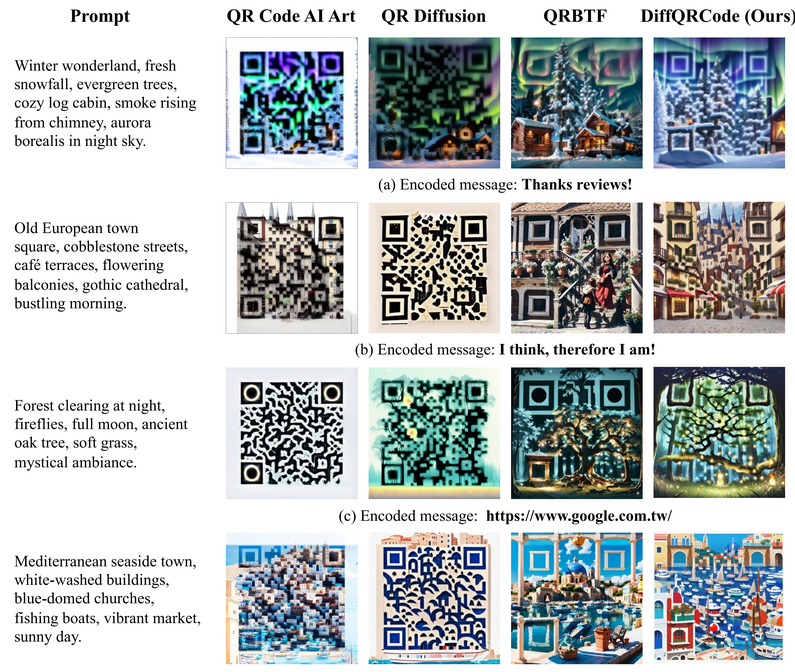



**Figure 1:** Qualitative comparison with other generative-based methods. DiffQRCoder can generate attractive and scannable QR codes with different encoded messages and prompts.

### *Evaluation Metrics*

- **SSR:** use qr-verify to measure the scanning success rate
- **CLIP-aes:** use CLIP aesthetic predictor to assess the aesthetic
- **CLIP-score:** use CLIP to assess the text-image alignment
- **Average Rank:** 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 |

**Table 1:** Quantitative comparison with other generative-based methods.

### *Ablation Study*

| Degree | 0° | 15° | 30° | 45° |
|---|---|---|---|---|
| SSR ↑ | 100% | 100% | 100% | 97% |

**Table 2:** Scannability of different rotated angles.

| Level | L (7%) | M (15%) | Q (25%) | H (30%) |
|---|---|---|---|---|
| SSR ↑ | 96% | 100% | 100% | 100% |

**Table 3:** Scannability of different QR code error correction levels.