LocDiff: Identifying Locations on Earth by Diffusing in the Hilbert Space

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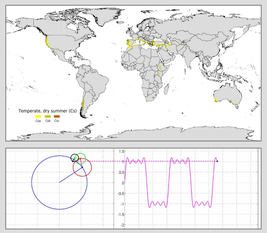
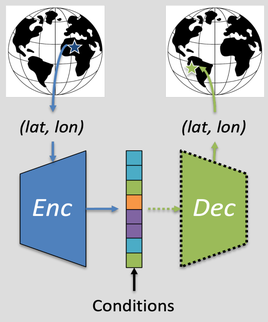
NEURAL INFORMATION PROCESSING SYSTEMS

Background

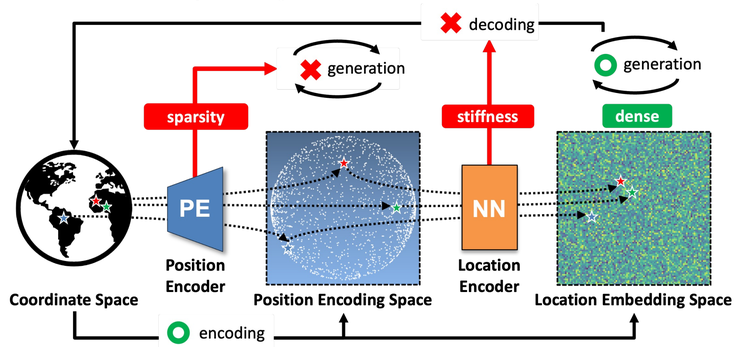
Multi-Scale Location Encoding



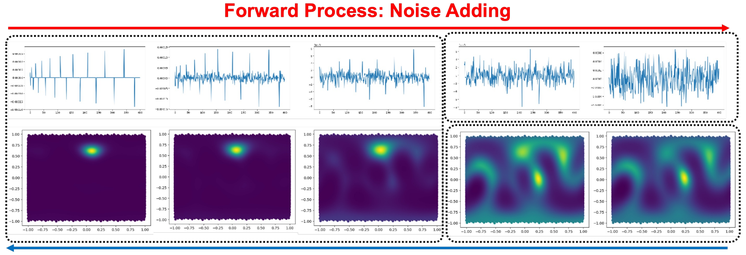
Conditional Location Decoding



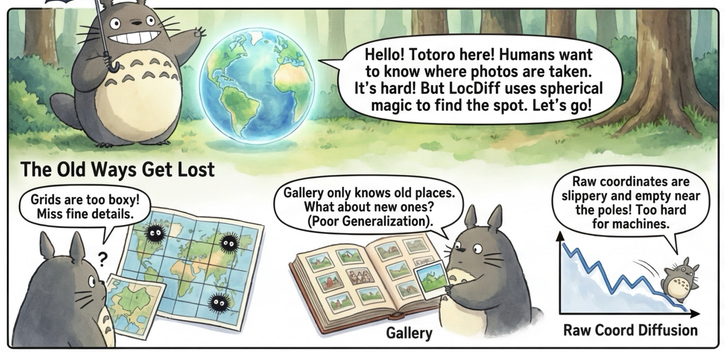
Motivation: Sparsity & Stiffness Problems

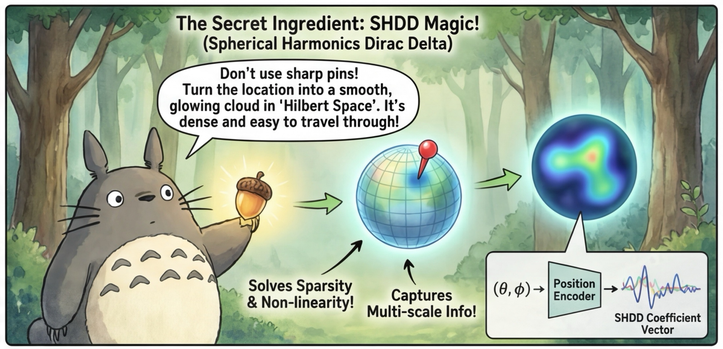


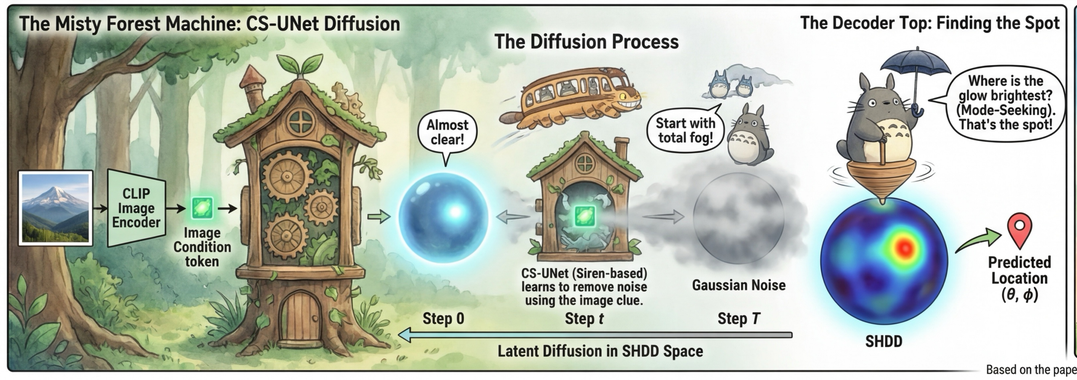
Goal: Latent (Location Encoding) Diffusion



Totoro's Guide to LocDiff: Finding Places with Hilbert Space Magic!





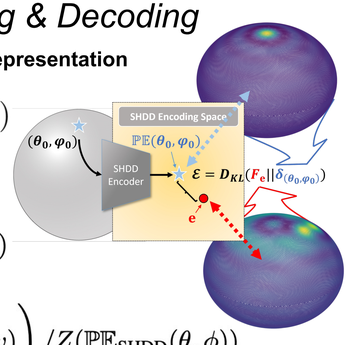


Based on the paper 'LocDiff: Identifying Locations on Earth by Diffusing in the Hilbert Space'.

Solution: SHDD Encoding, Learning & Decoding

Spherical Harmonics Dirac Delta-function (SHDD) Representation

$$\mathbb{PE}^{L}_{\text{SHDD}}(\theta_0, \phi_0) = \bigcup_{l=0}^{\infty} \bigcup_{m=-l}^{l} Y_{lm}(\theta_0, \phi_0)$$



SHDD Distributions

$$q_{\mathbf{e}}(u, v) := \exp\left(\sum_{l=0}^{L} \sum_{m=-l}^{l} e_{lm} Y_{lm}(u, v)\right) / Z(\mathbf{e})$$

$$p_{(\theta,\phi)}(u, v) := \exp\left(\sum_{l=0}^{L} \sum_{m=-l}^{l} Y_{lm}(\theta, \phi) Y_{lm}(u, v)\right) / Z(\mathbb{PE}_{\text{SHDD}}(\theta, \phi))$$

SHDD KL-divergence Loss Function

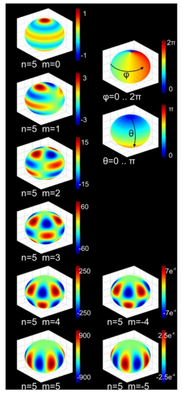
$$\mathcal{L}_{\text{SHDD-KL}}(\mathbf{e}, (\theta, \phi)) := \int_0^{\pi} \int_0^{2\pi} q_{\mathbf{e}}(u, v) \log \frac{q_{\mathbf{e}}(u, v)}{p_{(\theta,\phi)}(u, v)} \mathbf{d}u\mathbf{d}v$$

SHDD Mode-seeking Location Decoding

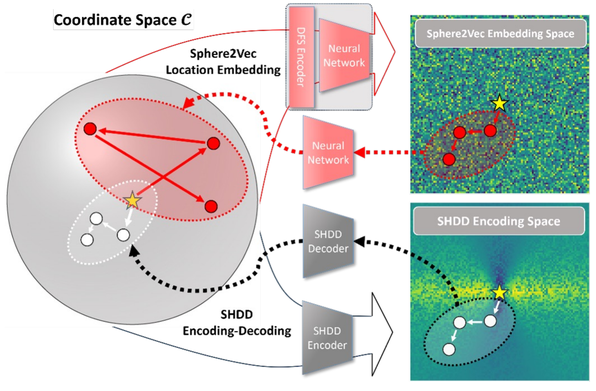
$$\mathbb{PD}_{\text{mode}}(\mathbf{e}; \rho) := \underset{(\theta,\phi)}{\arg\max} \left\{ \int_{\theta-\rho}^{\theta+\rho} \int_{\phi-\rho}^{\phi+\rho} \exp\left(\sum_{l=0}^{L} \sum_{m=-l}^{l} e_{lm} Y_{lm}(u, v)\right) \mathbf{d}u\mathbf{d}v \right\}$$

Advantages: Multi-Scale, Dense, Smooth & Stable

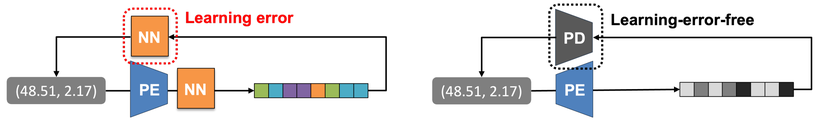
Spherical Harmonics



Dense & Smooth SHDD Encoding Space



Neural Encoding & Decoding v.s. SHDD Encoding & Decoding



Experimental Results

Geo-localization Accuracy Improvement

Model	Im2GPS3k					YFCC-26k					GWS15k				
	Street 1 km	City 25 km	Region 200 km	Coun. 750 km	Cont. 2.5k km	Street 1 km	City 25 km	Region 200 km	Coun. 750 km	Cont. 2.5k km	Street 1 km	City 25 km	Region 200 km	Coun. 750 km	Cont. 2.5k km
[L]kNN, σ=4 [46]	7.2	19.4	26.9	38.9	55.9	-	-	-	-	-	-	-	-	-	-
PlaNet [47]	8.5	24.8	34.3	48.4	64.6	4.4	11.0	16.9	28.5	47.7	-	-	-	-	-
CPlaNet [38]	10.2	26.5	34.6	48.6	64.6	-	-	-	-	-	-	-	-	-	-
ISNs [30]	10.5	28.0	36.6	49.7	66.0	5.3	12.3	19.0	31.9	50.7	0.05	0.6	4.2	15.5	38.5
Translocator [32]	11.8	31.1	46.7	58.9	80.1	7.2	17.8	28.0	41.3	60.6	0.5	1.1	8.0	25.5	48.3
GeoDecoder [6]	12.8	33.5	45.9	61.0	76.1	10.1	23.9	34.1	49.6	69	0.7	1.5	8.7	26.9	50.5
GeoCLIP [45]	14.1	34.5	50.7	69.7	83.8	11.6	22.2	36.7	57.5	76.0	0.6	3.1	16.9	45.7	74.1
PIGEON [10]	11.3	**36.7**	53.8	72.4	85.3	10.5	25.8	**42.7**	63.2	79.0	0.7	9.2	31.2	65.7	**85.1**
LocDiff (L=47)	10.9	34.0	53.3	72.5	85.2	9.6	22.8	37.5	58.6	76.8	**2.1**	**12.4**	**33.7**	**67.0**	85.0
LocDiff-H (L=23)	**15.3**	36.5	**56.4**	**75.2**	**87.4**	**13.2**	**26.0**	41.9	**64.5**	**80.3**	0.9	7.4	33.5	66.2	85.0

Spatial Generalizability Improvement

Model	Gallery/Anchor	Size	Street 1 km	City 25 km	Region 200 km	Country 750 km	Continent 2500 km
GeoCLIP	MP16	100 k	14.11	34.47	50.65	69.67	83.82
	Grid	1 M	0.03 (↓99.79%)	9.18 (↓73.37%)	33.47 (↓33.90%)	55.32 (↓20.63%)	75.34 (↓10.11%)
		500 k	0.03 (↓99.79%)	7.17 (↓79.21%)	29.40 (↓41.96%)	52.29 (↓24.94%)	73.11 (↓12.80%)
		100 k	0.00 (↓100.00%)	2.67 (↓92.25%)	22.39 (↓55.81%)	47.35 (↓32.05%)	68.77 (↓17.94%)
		21 k	0.00 (**↓100.00%**)	0.87 (**↓97.48%**)	19.55 (**↓61.41%**)	43.78 (**↓37.17%**)	64.33 (**↓23.26%**)
LocDiff (L=23)	MP16	100 k	0.57	11.1	44.42	68.35	82.50
	Grid	1 M	0.01 (↓98.25%)	4.37 (↓60.63%)	43.04 (↓3.10%)	68.30 (↓0.07%)	81.66 (↓1.02%)
		500 k	0.07 (↓87.72%)	4.47 (↓59.73%)	43.18 (↓2.79%)	68.36 (↑0.01%)	81.65 (↓1.03%)
		100 k	0.07 (↓87.72%)	4.04 (↓63.60%)	42.91 (↓3.40%)	68.34 (↓0.01%)	82.18 (↓0.39%)
		21 k	0.03 (↓94.74%)	4.90 (↓55.86%)	43.44 (↓2.21%)	68.29 (↓0.09%)	81.68 (↓0.99%)