MinD-3D: Reconstruct High-quality 3D objects in Human Brain

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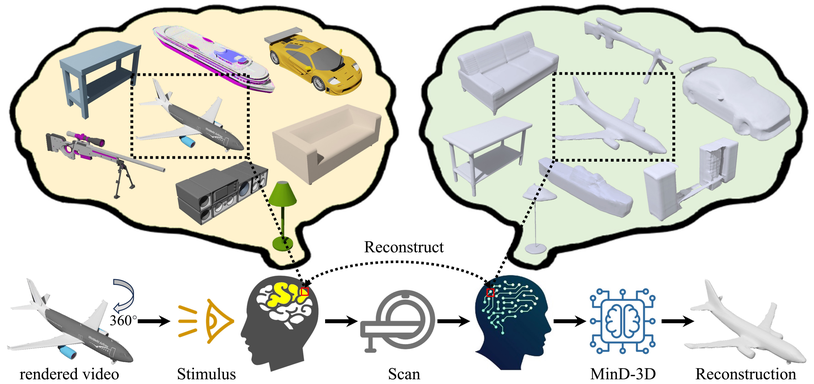
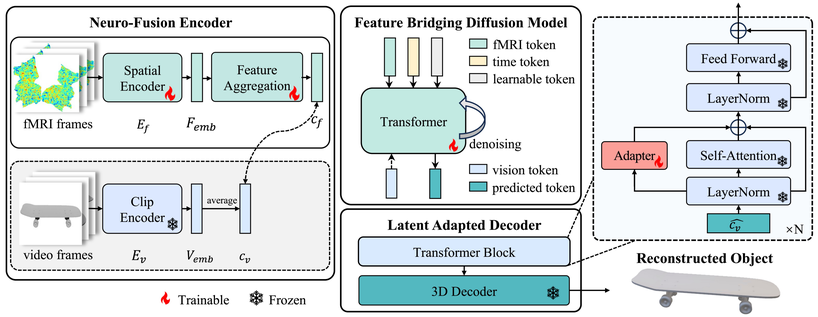
Introduction

This paper presents a novel framework **MinD-3D** and comprehensive dataset **fMRI-Shape** for 3D brain decoding.
Project page: **https://jianxgao.github.io/MinD-3D.**



Method: MinD-3D

Illustration of the MinD-3D Framework.

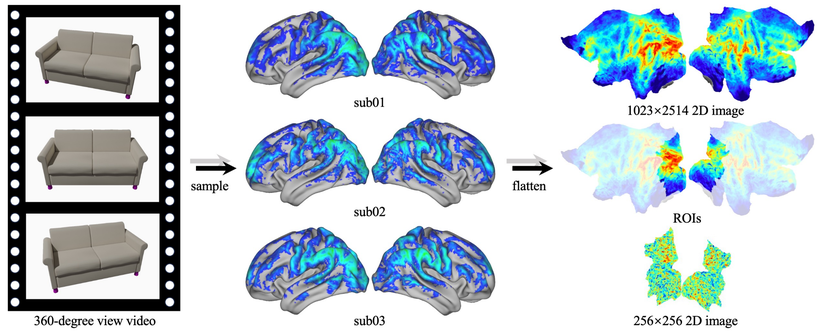


- It utilizes a pretrained encoder to extract features from fMRI frames.
- A transformer-based diffusion model is used to generate visual features based on the fMRI features.
- An adapted 3D generator is employed to create 3D object meshes conditioned on the generated visual features.

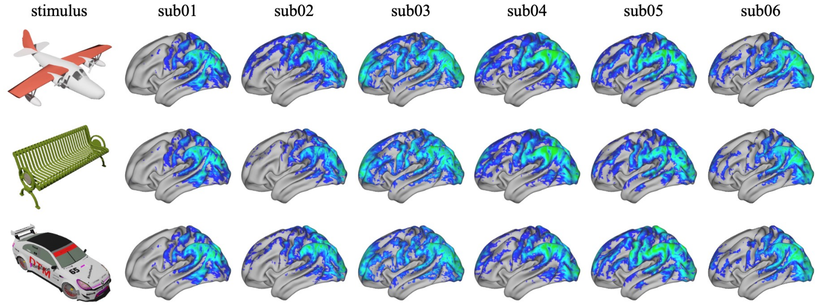
Dataset: fMRI-Shape

Data Acquisition Process

- Render 3D objects from ShapeNet into 8-second videos for participants.
- Map the fMRI signals to 2D images and select the visual ROIs.



Individual Differences in Brain Activation Patterns



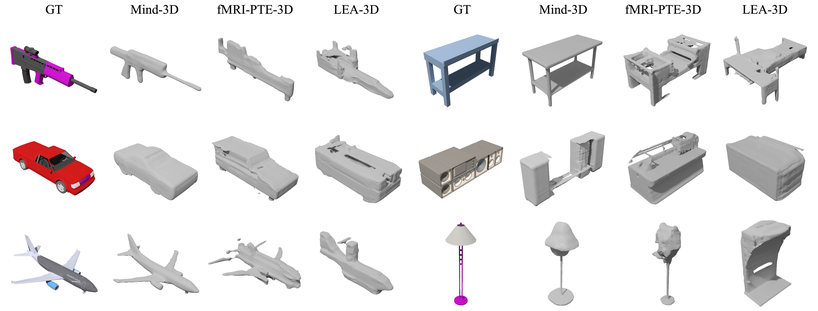
- It confirms significant variation across subjects, surpassing differences in object responses, posing a great challenge for OOD testing.

Details of fMRI-Shape Dataset

	Participant	Males/Females	Category	Objects	Frames
Core Set	8	4/4	13	1404	14040
AP Set	2	1/1	13	104	1040
APAC Set	4	2/2	55	220	2200
Total	14	7/7	55	1624	123200

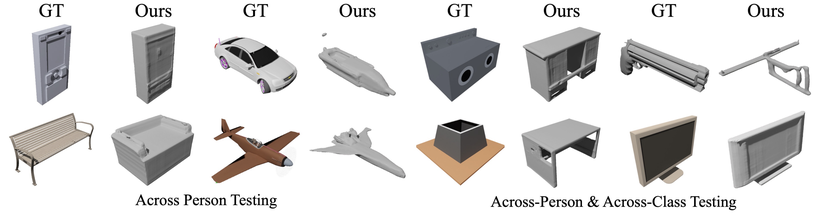
Experimental Results

Performance of Our Proposed MinD-3D



Methods	Semantic-Level 2-way↑	10-way↑	LPIPS↓	Structure-Level SSIM↑	FPD↓	CD↓	EMD↓
LEA-3D [34]	0.787	0.371	0.527	0.562	4.229	2.291	5.347
fMRI-PTE-3D [36]	0.815	0.392	0.433	0.694	3.571	1.992	4.621
w/o Both	0.789	0.367	0.479	0.616	3.694	2.205	5.073
w/o Diffusion	0.801	0.385	0.423	0.669	3.526	2.071	4.625
w/o Contrastive	0.823	0.419	0.319	0.701	3.315	1.826	4.027
MinD-3D (full)	**0.839**	**0.432**	**0.230**	**0.734**	**3.157**	**1.742**	**3.833**

Performance on Out-of-Distribution Testing



Conclusion

- We propose and, for the first time, demonstrate the feasibility of a novel task called **Recon3DMind**.
- We introduce the first large-scale fMRI-3D dataset, **fMRI-Shape**, with 14 participants, supporting various experiments settings.
- We present a novel framework, **MinD-3D**, for 3D brain decoding.