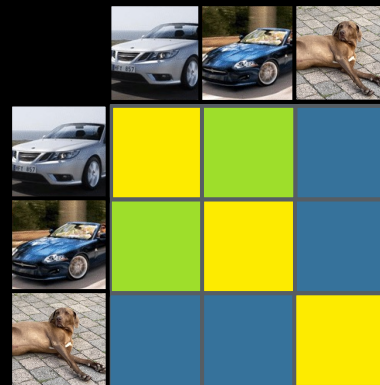


Decoupling Semantic Similarity from spatial alignment

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David Zimmerer, Stefan Denner, Michael Baumgartner,
Fabian Isensee, Priyank Jaini †, Klaus Maier-Hein †,*

8th of November 2024



Similarity of complex systems

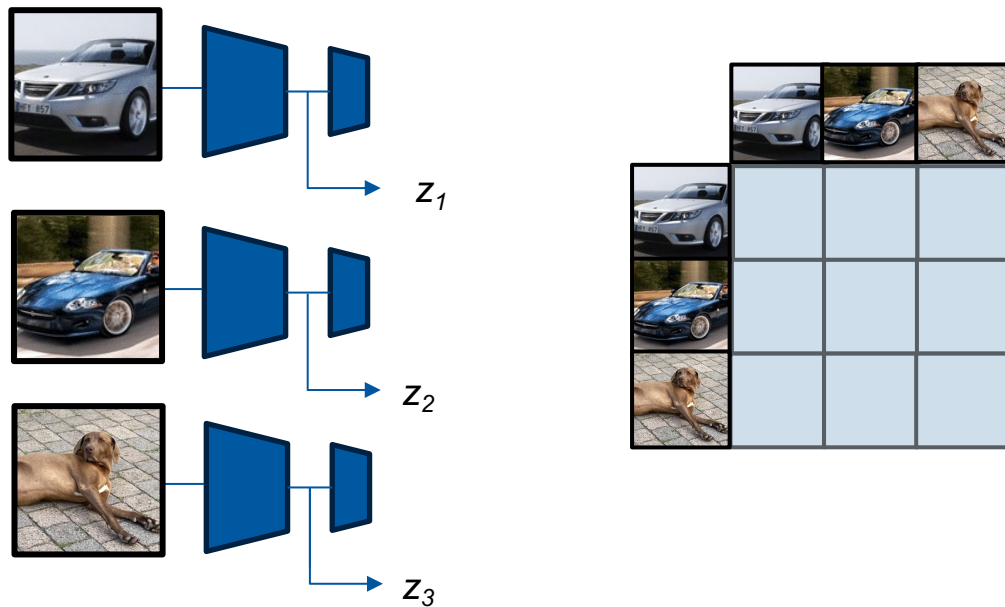


- *What do models learn?*
 - *How do they solve tasks?*
 - *Do ML systems process information similarly as humans?*
 - *How similar are two images for a network?*
- *Done through introspection of these complex systems*
- *In this paper: Representational Similarity Matrix (**RSM**) based similarity*

Background: RSMs



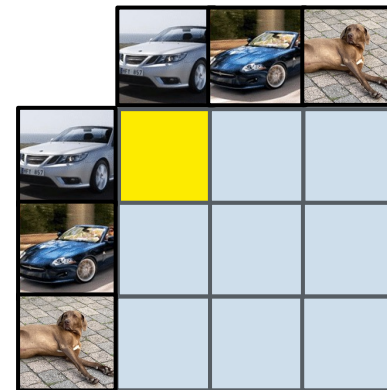
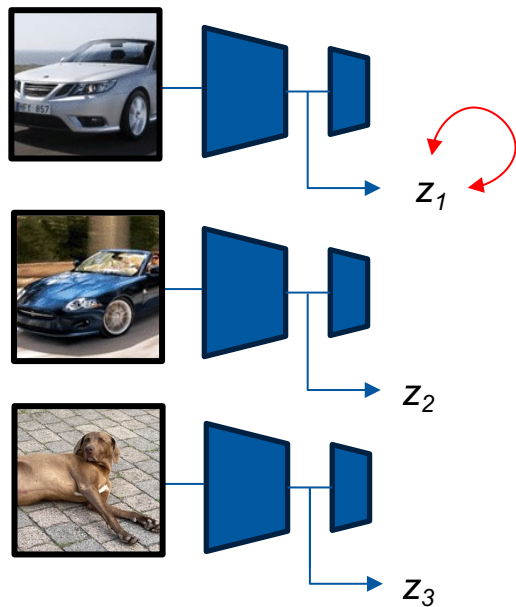
1. Extract representations z



Background: RSMs



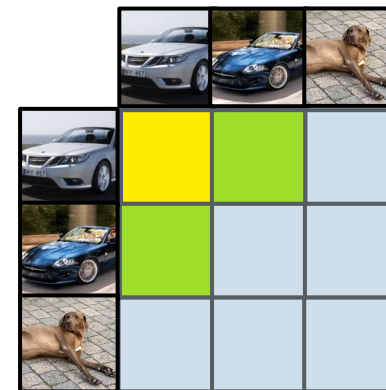
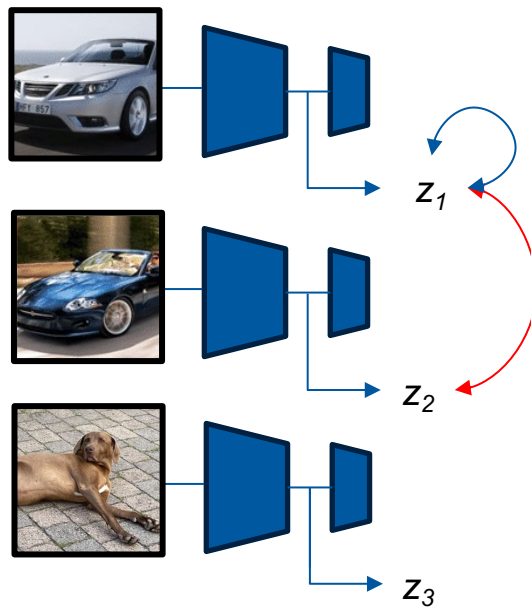
1. Extract representations z
2. Calculate similarity $k(z_i, z_j)$



Background: RSMs



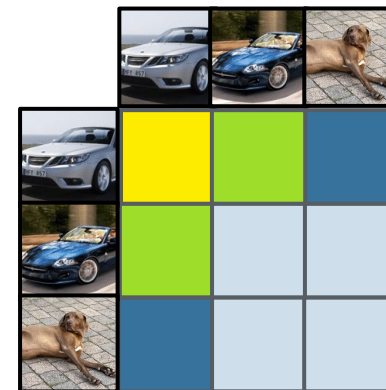
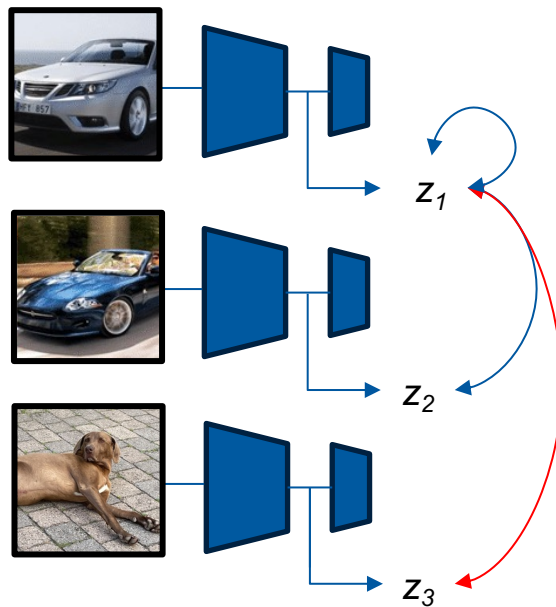
1. Extract representations z
2. Calculate similarity $k(z_1, z_2)$



Background: RSMs



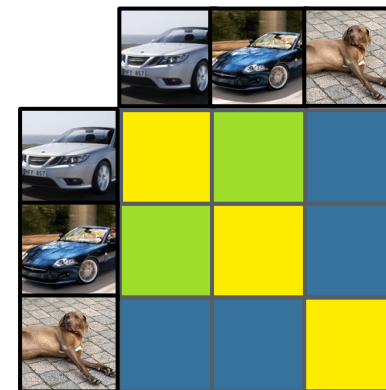
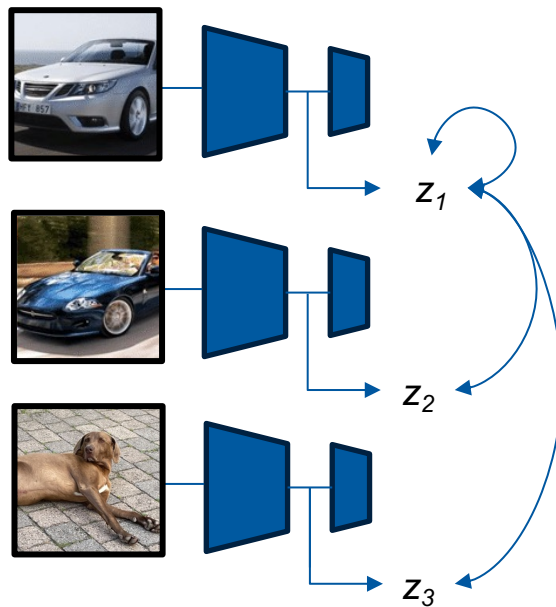
1. Extract representations z
2. Calculate similarity $k(z_1, z_3)$



Background: RSMs



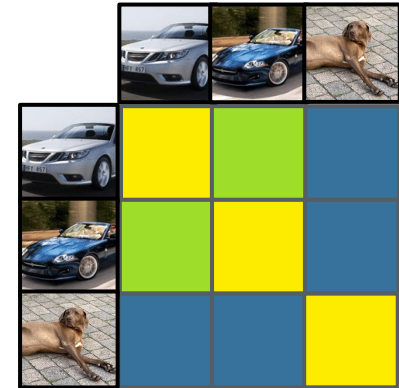
1. Extract representations z
2. Calculate similarity $k(z_i, z_j)$
3. Repeat for all images i, j



Background: RSMs




1. Extract representations z
2. Calculate similarity $k(z_i, z_j)$
3. Repeat for all images i, j

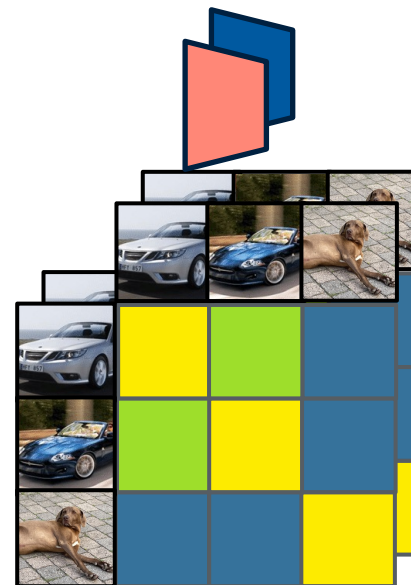


Background: RSMs



1. Repeat RSM construction for other system 

2. Compare  to  through RSM



Background: RSMs



1. Easy to compare across systems

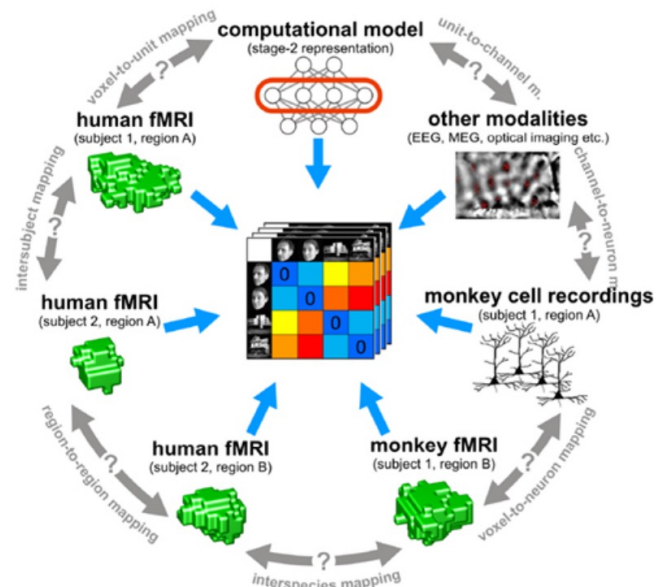


Image from: Kriegeskorte N, Mur M, Bandettini P. Representational similarity analysis - connecting the branches of systems neuroscience. *Front Syst Neurosci.* 2008 Nov 24;2:4. doi: 10.3389/neuro.06.004.2008

Research Questions



Focus on Representational Similarity Matrices (RSMs)

- ***RQ1:*** *What notion of similarity do RSMs capture?*
- ***RQ2:*** *How can we quantify quality of RSMs?*
- ***RQ3:*** *How should I calculate RSM?*



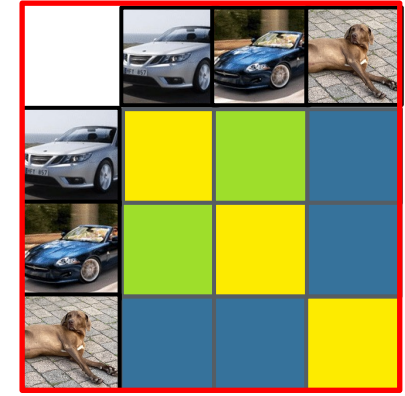
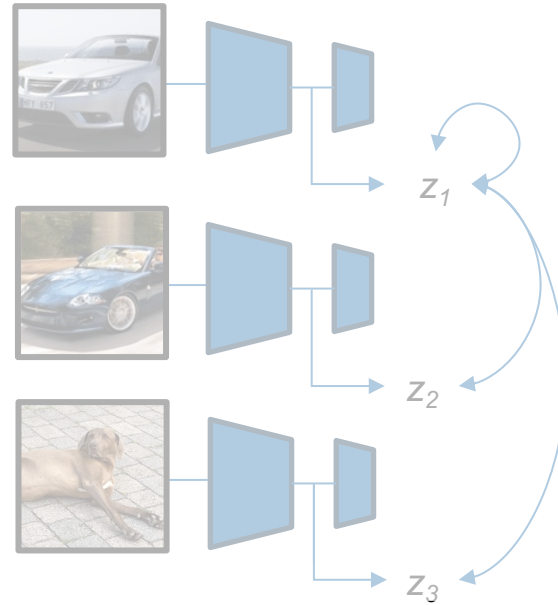
***Decoupling Semantic
Similarity from spatial alignment***



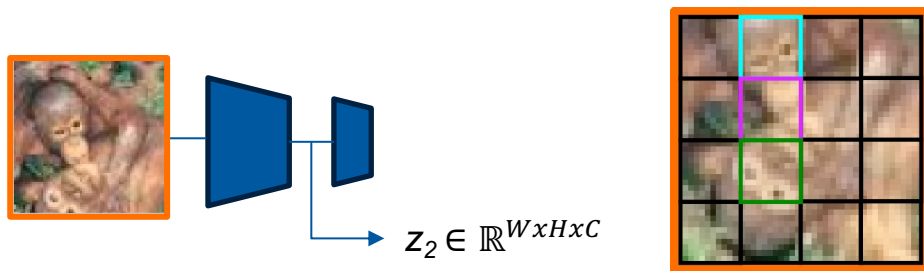
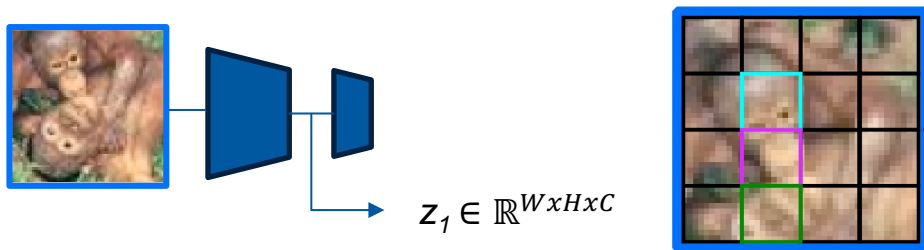
In this paper



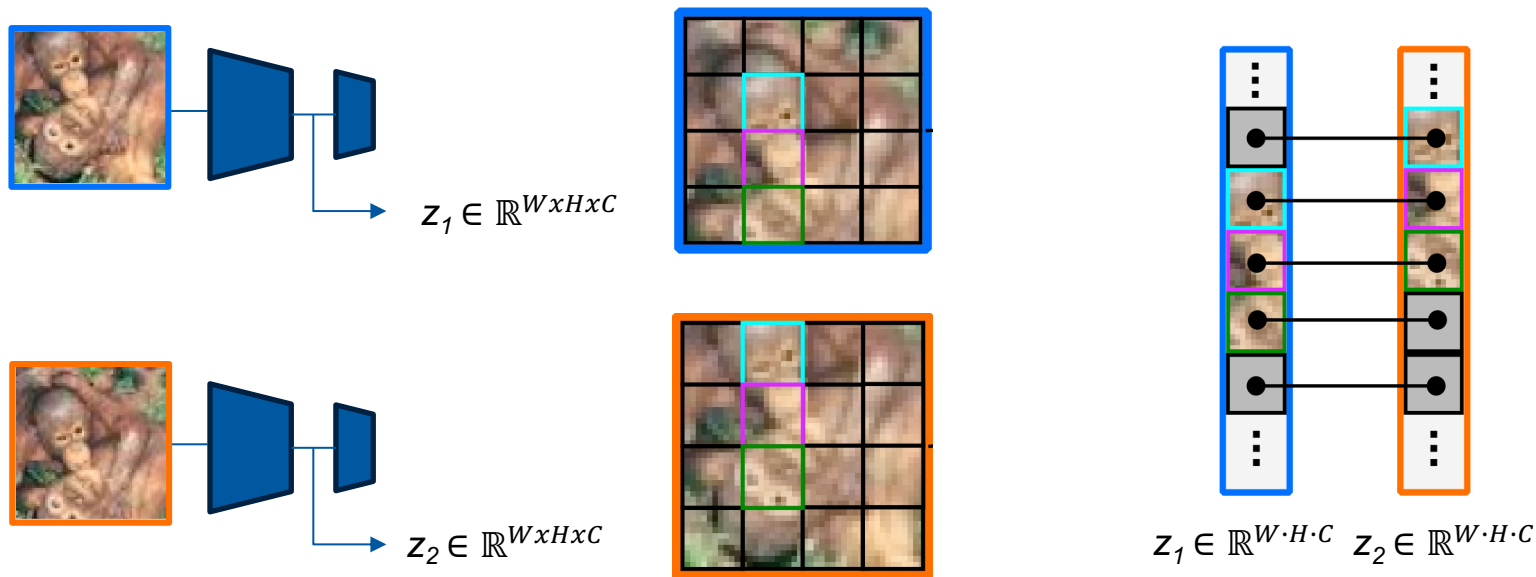
1. Extract representations z
2. Calculate similarity $k(z_i, z_j)$
3. Repeat for all images i, j



RQ1: What notion of similarity do RSMs capture?



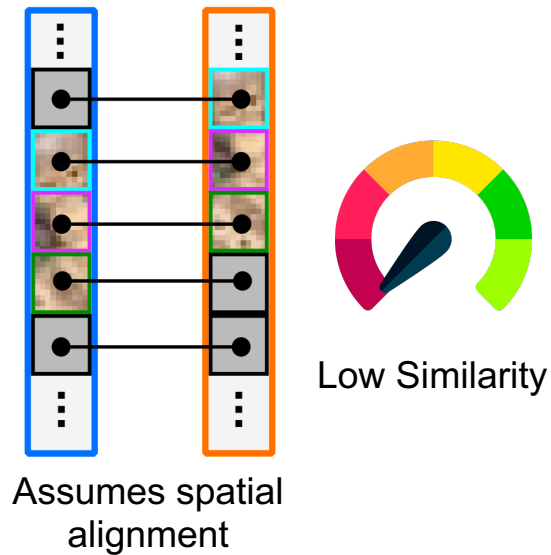
RQ1: What notion of similarity do RSMs capture?



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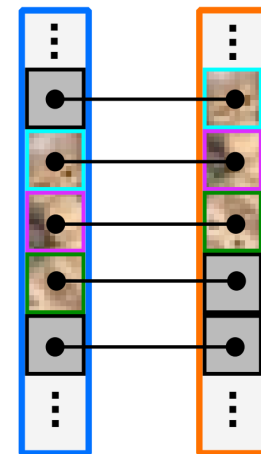
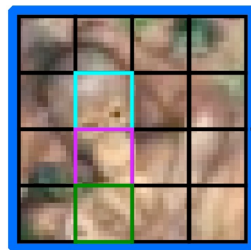
1. Similarity calculation between same positions
 1. Dependent on spatial alignment



RQ1: What notion of similarity do RSMs capture?



1. Similarity calculation between same positions
 1. Dependent on spatial alignment
2. Invariances are not reflected in this
 1. CNNs translation invariance
 2. Learned invariances through augmentation



Assumes spatial alignment

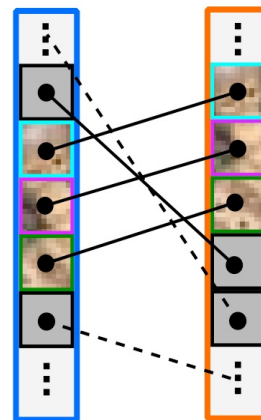
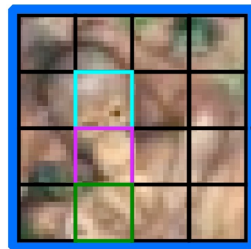


Low Similarity

Introducing Permutation Invariance



1. Similarity calculation between same positions
 1. Dependent on spatial alignment
2. Invariances are not reflected in this
 1. CNNs translation invariance
 2. Learned invariances through augmentation
3. Proposed Solution:
 1. Find permutation maximizing similarity

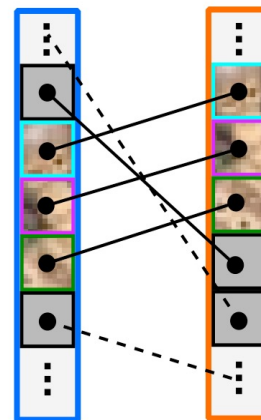
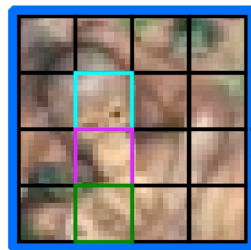


Finding optimal alignment

Introducing Permutation Invariance



1. Similarity calculation between same positions
 1. Dependent on spatial alignment
2. Invariances are not reflected in this
 1. CNNs translation invariance
 2. Learned invariances through augmentation
3. Proposed Solution:
 1. Find permutation maximizing similarity



Finding optimal alignment

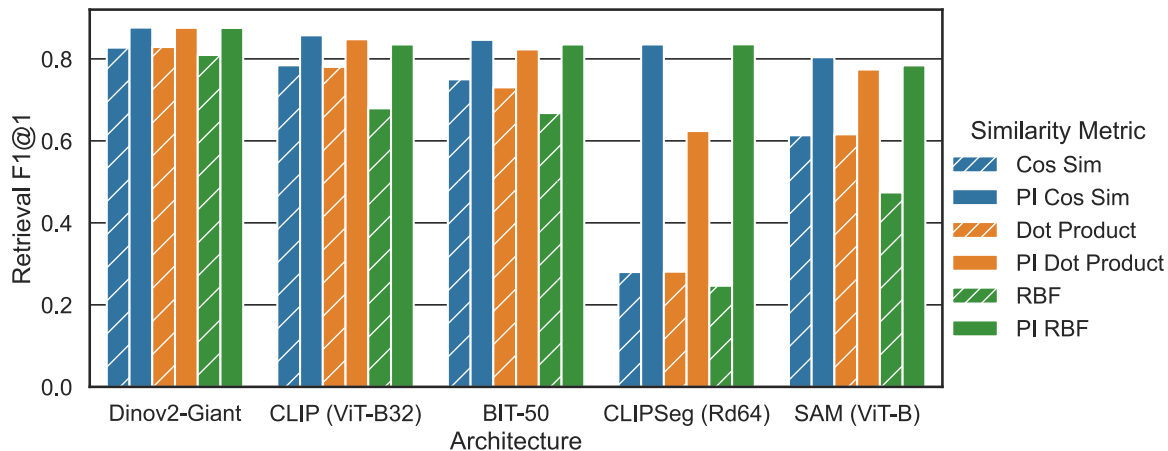


High Similarity

RQ2: How to quantify RSM quality?



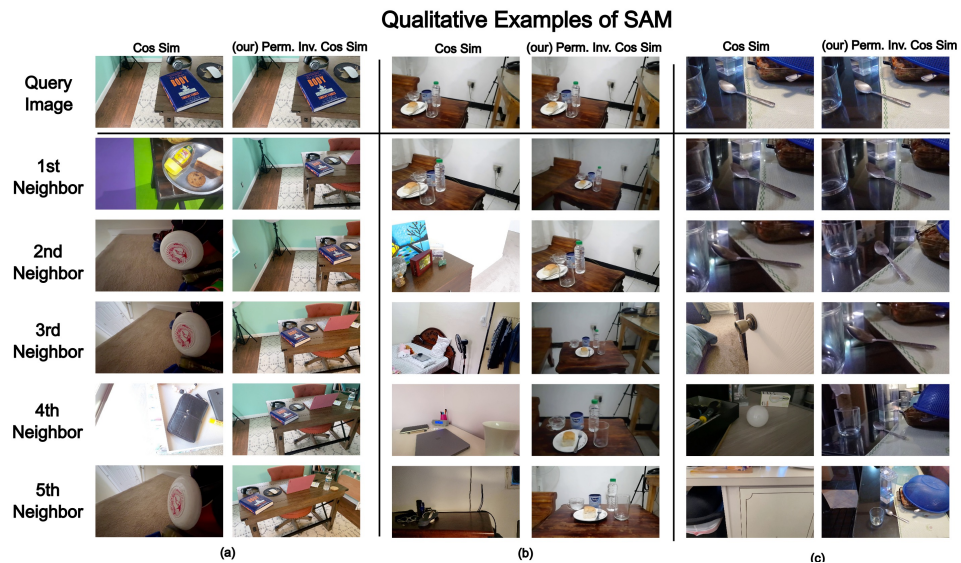
1. RSM based retrieval



RQ2: How to quantify RSM quality?



1. RSM based retrieval



RQ2: How to quantify RSM quality?



1. RSM based retrieval
2. Similarity of classifier output-probabilities to inter-sample similarity

Architectures	Pearson Correlation ρ					
	Cosine Sim.		Inner Product		RBF	
	-	(ours) PI	-	(ours) PI	-	(ours) PI
ResNet18	-0.276	-0.326	-0.259	-0.270	-0.176	-0.199
ResNet50	-0.248	-0.291	-0.243	-0.261	0.040	0.029
ResNet101	-0.192	-0.276	-0.174	-0.240	0.091	0.084
ConvNextV2-Base	-0.134	-0.098	-0.132	-0.171	0.117	0.090
ViT-B/16	-0.046	-0.100	-0.045	-0.026	-0.077	-0.122
ViT-L/32	-0.138	-0.188	-0.138	-0.144	-0.134	-0.166
DinoV2-Giant	-0.012	-0.044	-0.013	-0.031	-0.008	-0.048

RQ3: How to calculate RSMs?



1. To maximize quality of RSMs through ...
 1. Use permutation invariance to align semantic
 2. Use cosine-similarity to calculate similarity

For questions and collaborations get in touch!



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