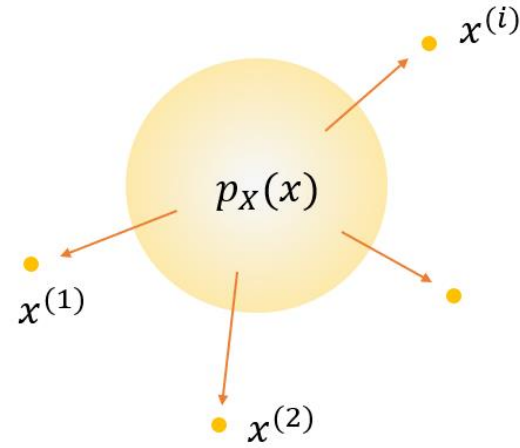


Cross-Domain Feature Augmentation for Domain Generalization

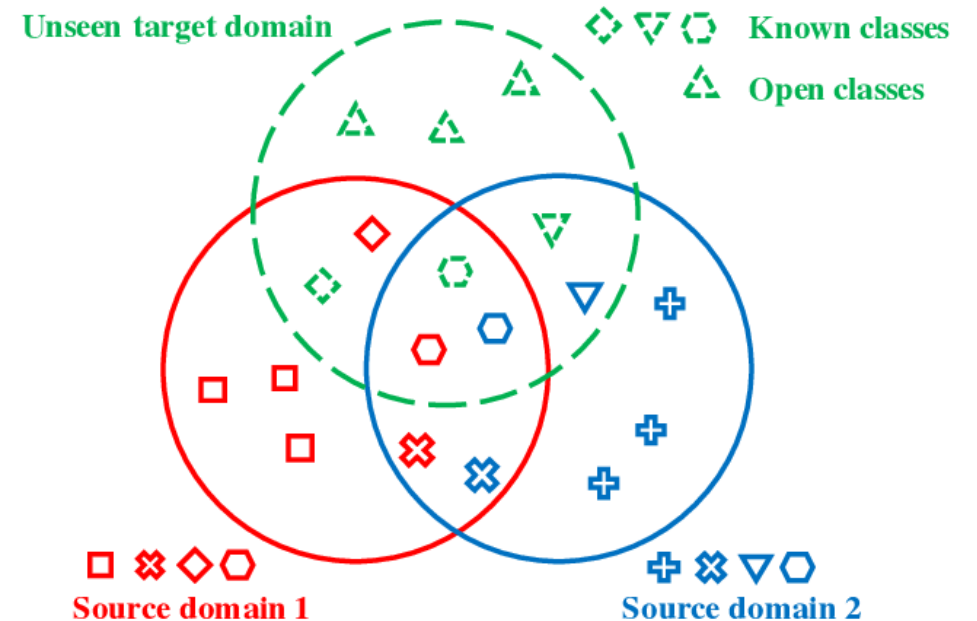
IJCAI 2024

1 Domain generalization

- Data in deep learning: i.i.d data



- Domain generalization: robust model for distribution shift



Related work

- Learning invariant representation
 - Employ regularizer
 - Data augmentation in input space



(1,0)

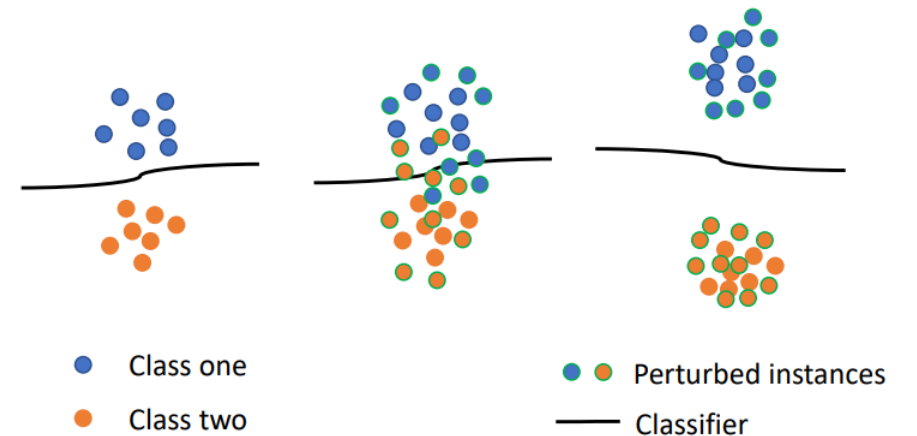
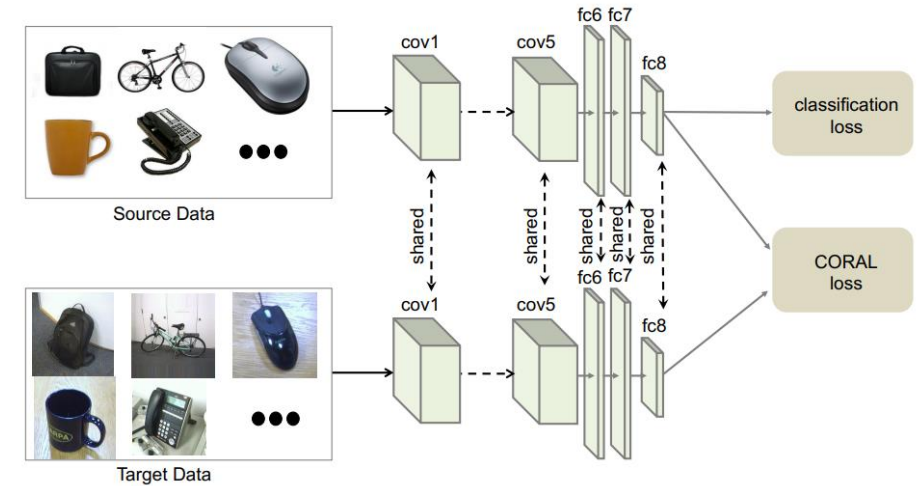


(0,1)



(0.5, 0.5)

- Data augmentation in feature space



- Learning invariant representation
 - Employ regularizer
 - Data augmentation in input space: diversity



(1,0)

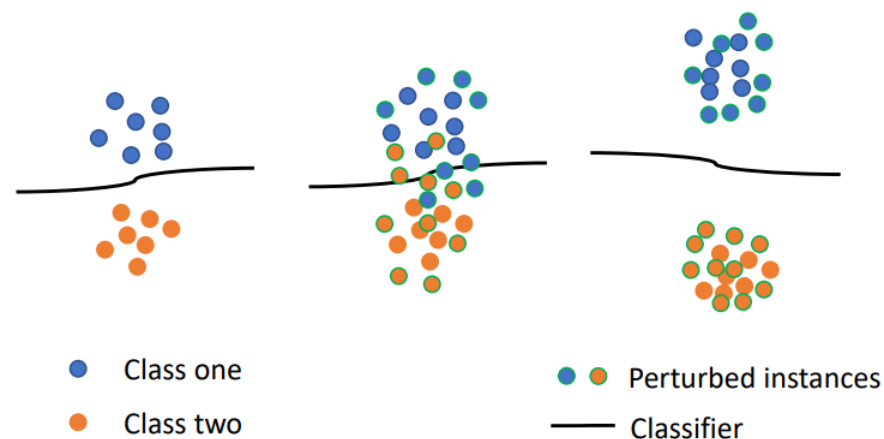
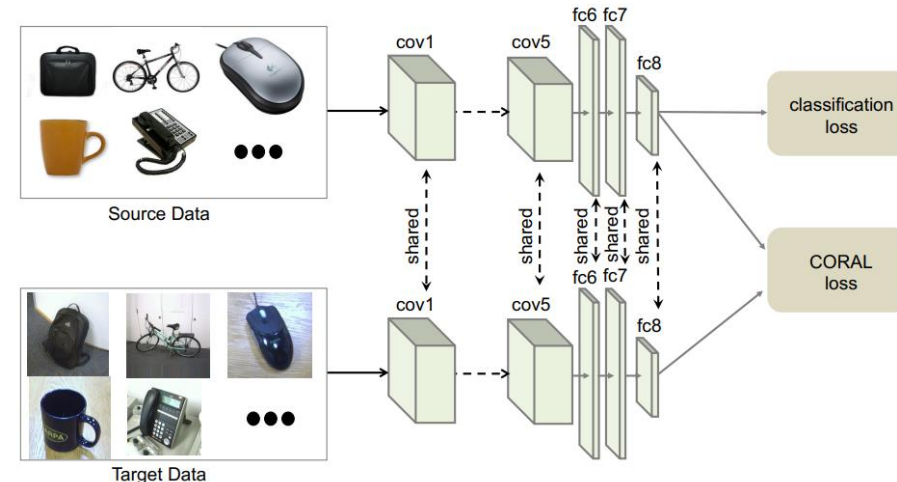


(0,1)

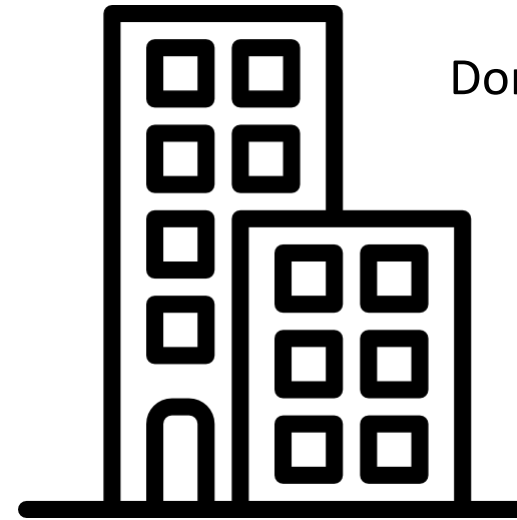


(0.5, 0.5)

- Data augmentation in feature space: feature semantics



- Feature semantics
 - Class-generic
 - Class-specific
 - Domain-generic
 - Domain-specific
- Robust model on domain shift

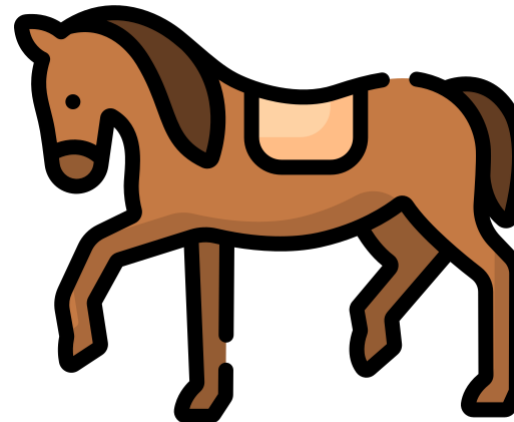


Class: building

Domain: icon

Class: horse

Domain: icon

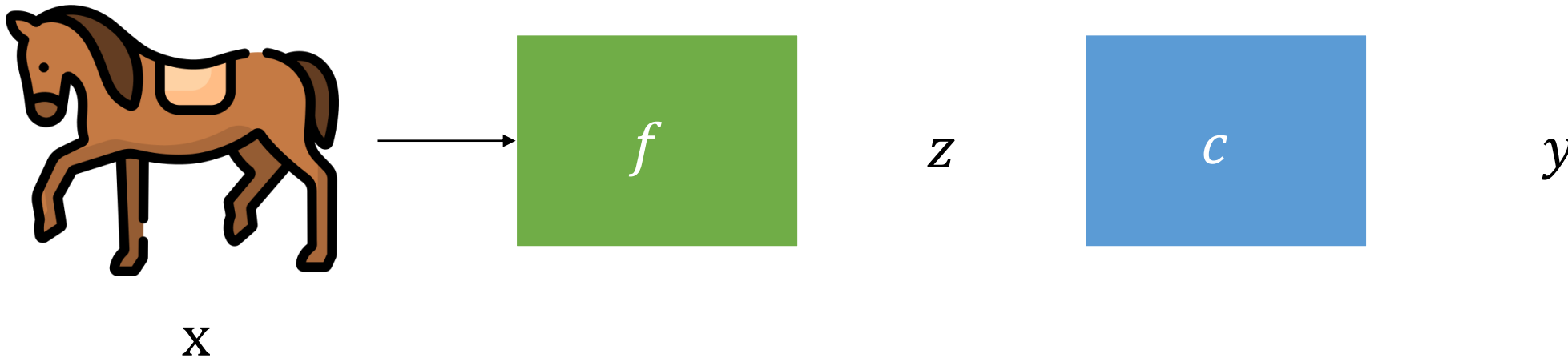


Class: horse

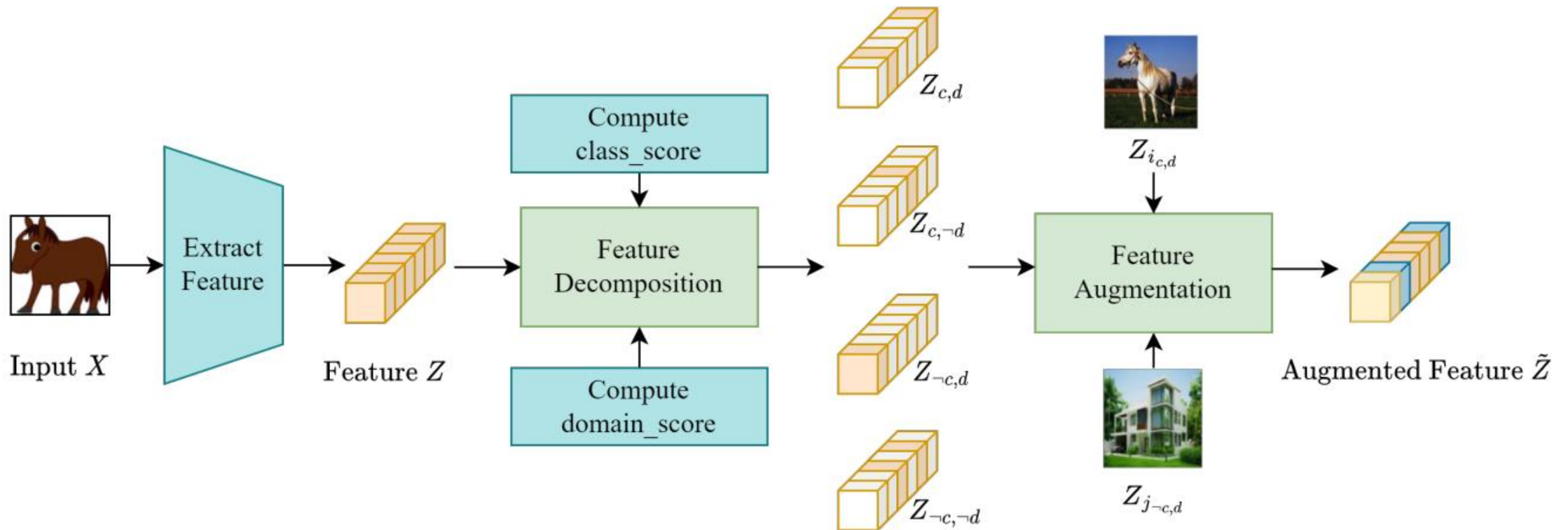
Domain: realistic



- Goal: f extracts domain-invariant class-specific information
 - Input/output: x/y
 - feature extractor $f: x \rightarrow z$
 - Classifier $c: z \rightarrow y$



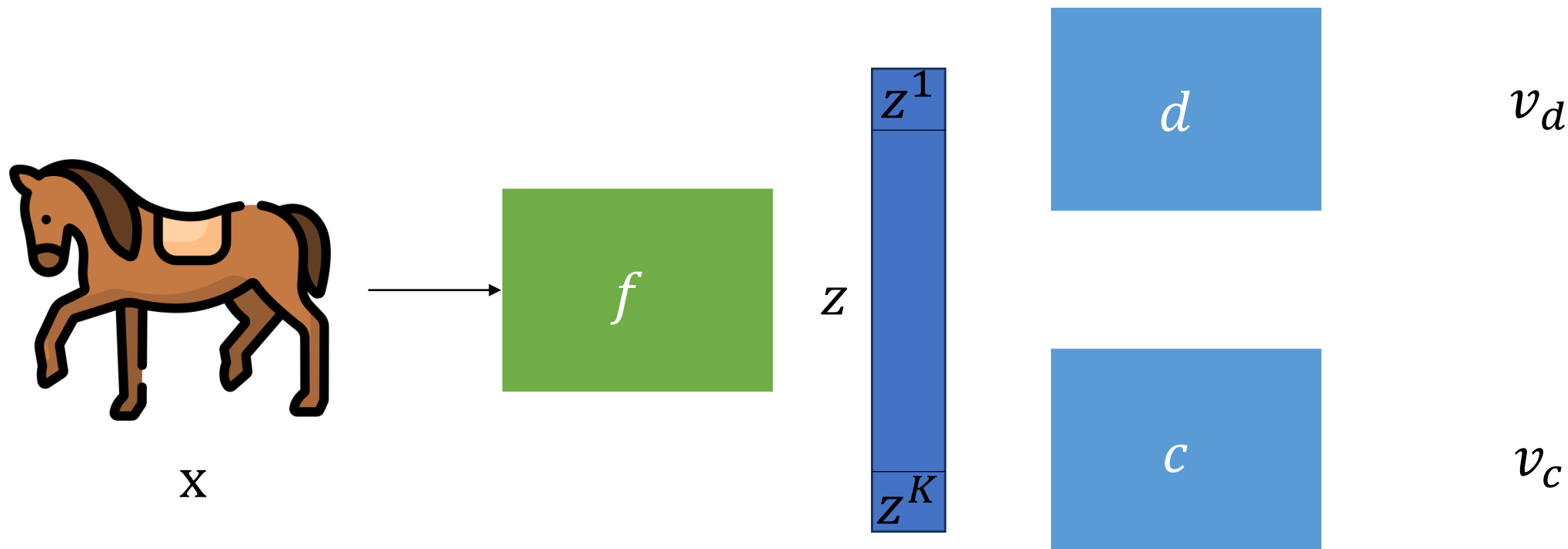
- Overview of augmentation
 - Domain-invariant class-specific
 - Two samples: (class-specific, domain-specific), (class-generic, domain-specific)



- Compute score

$$M_c[k] = \begin{cases} 1 & \text{if class_score}(z^k) > \tau_c \\ 0 & \text{otherwise} \end{cases}, \quad \text{domain_score}(z^k) = \frac{\partial v_d}{\partial z^k} z^k$$

$$M_d[k] = \begin{cases} 1 & \text{if domain_score}(z^k) > \tau_d \\ 0 & \text{otherwise} \end{cases}$$



- Compute score

$$M_c[k] = \begin{cases} 1 & \text{if class_score}(z^k) > \tau_c \\ 0 & \text{otherwise} \end{cases},$$

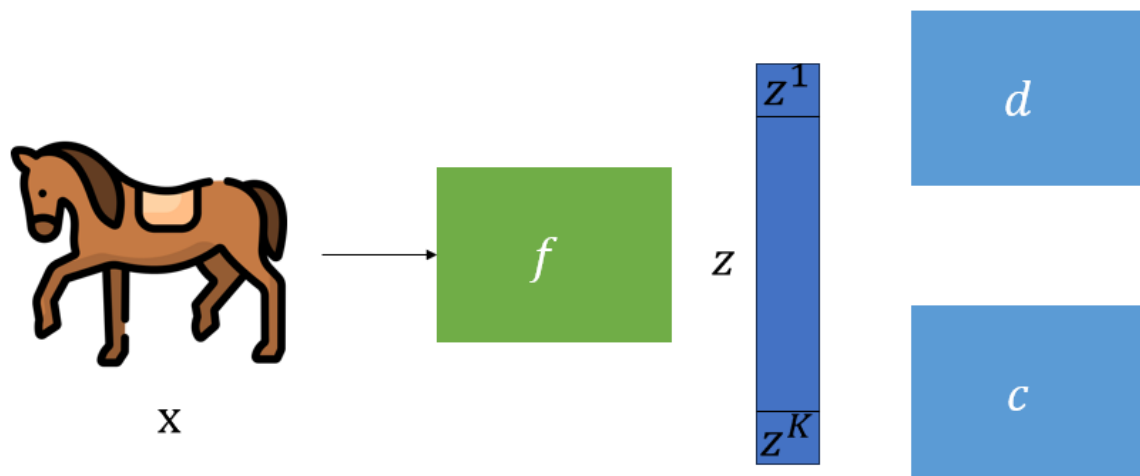
$$M_d[k] = \begin{cases} 1 & \text{if domain_score}(z^k) > \tau_d \\ 0 & \text{otherwise} \end{cases}$$

$$Z_{c,d} = M_c \odot M_d \odot Z$$

$$Z_{c,\neg d} = M_c \odot (\mathbb{1} - M_d) \odot Z$$

$$Z_{\neg c,d} = (\mathbb{1} - M_c) \odot M_d \odot Z$$

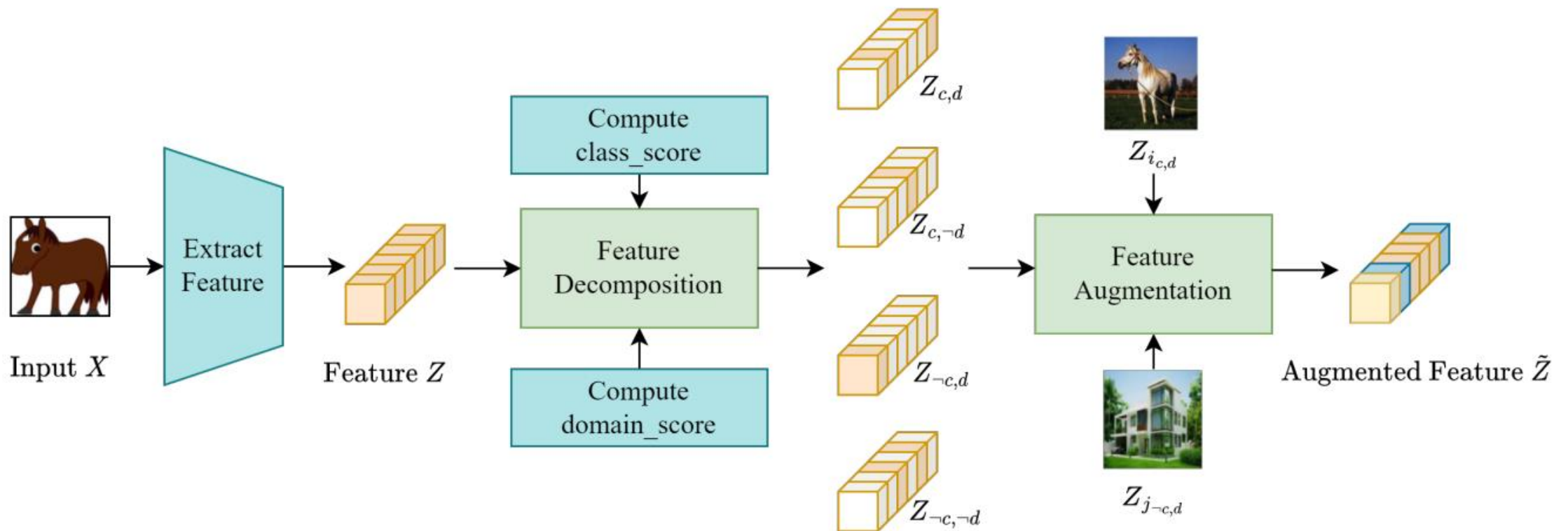
$$Z_{\neg c,\neg d} = (\mathbb{1} - M_c) \odot (\mathbb{1} - M_d) \odot Z$$



$$\text{class_score}(z^k) = \frac{\partial v_c}{\partial z^k} z^k$$

$$\text{domain_score}(z^k) = \frac{\partial v_d}{\partial z^k} z^k$$

- Overview of augmentation
 - Domain-invariant class-specific
 - Two samples: (class-specific, domain-specific), (class-generic, domain-specific)

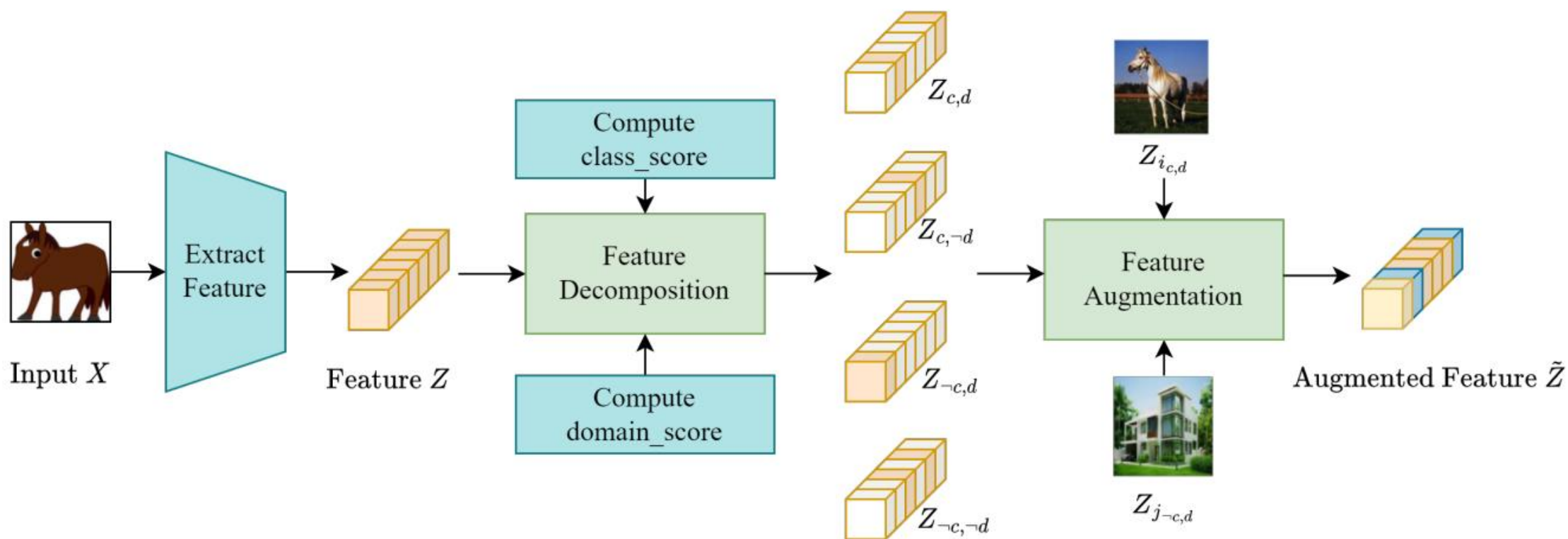


- Augmentation ratio

- $\lambda_1, \lambda_2: U(0,1)$

$$\tilde{Z}_{c,d} = \lambda_1 Z_{c,d} + (1 - \lambda_1) Z_{i_{c,d}},$$

$$\tilde{Z}_{\neg c,d} = \lambda_2 Z_{\neg c,d} + (1 - \lambda_2) Z_{j_{\neg c,d}}$$



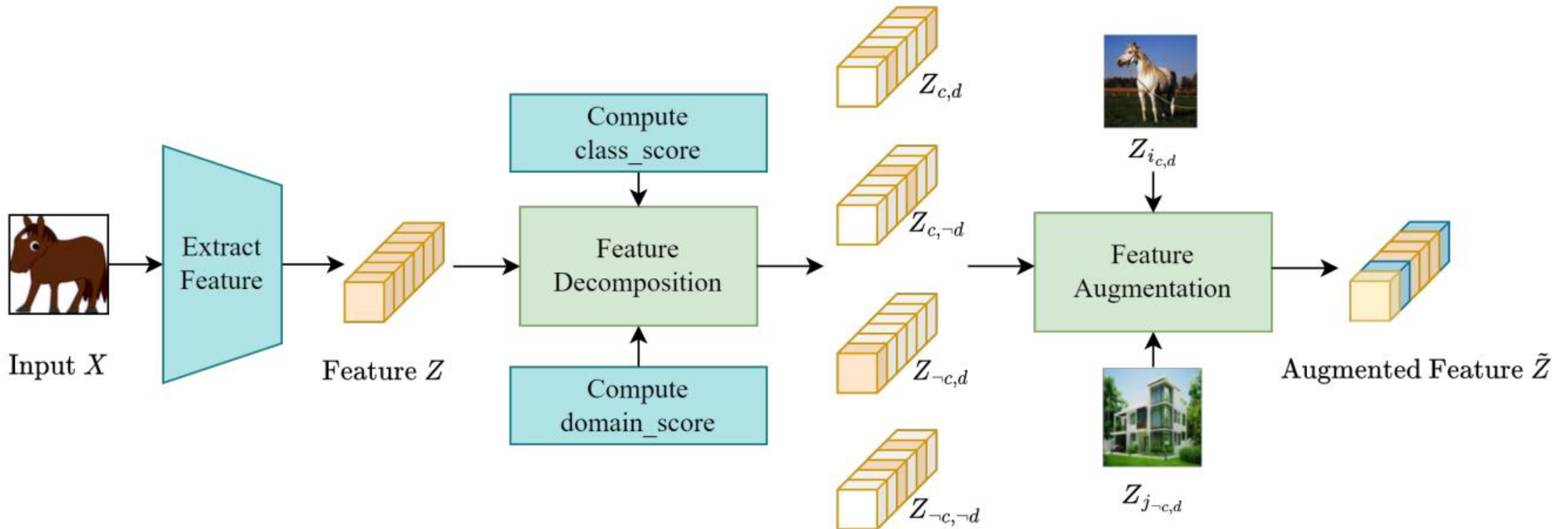
- Augmentation ratio

- $p: U(0,1)$

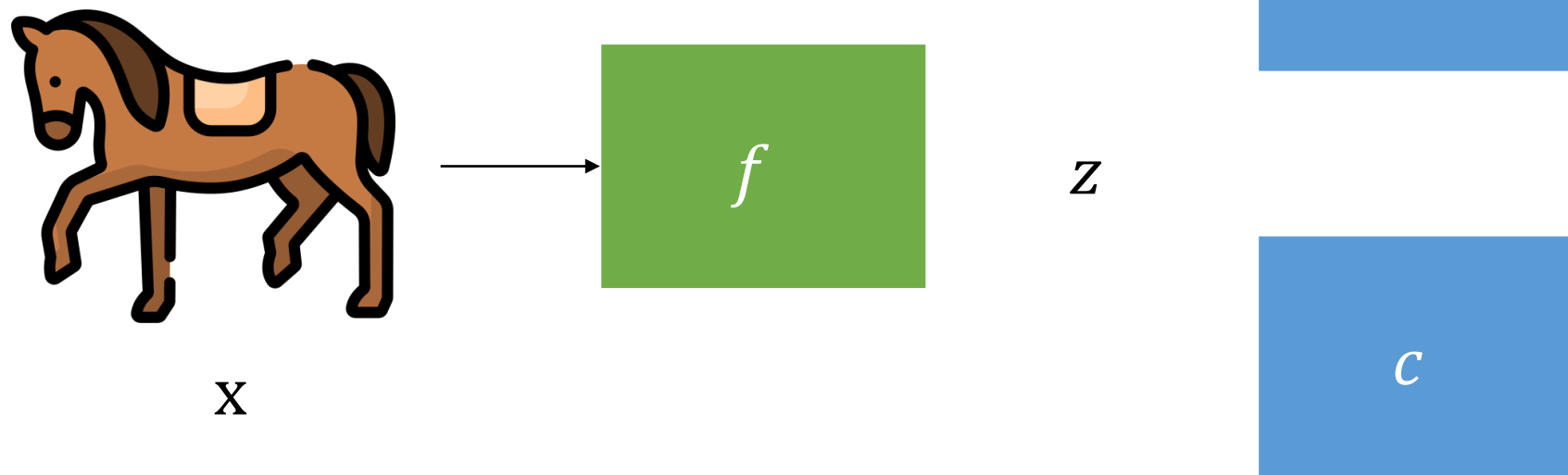
- Focus on domain-invariant features

- $p_{discard}: 0.2$

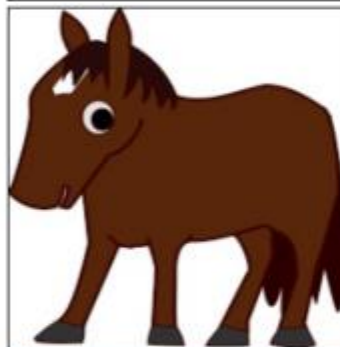
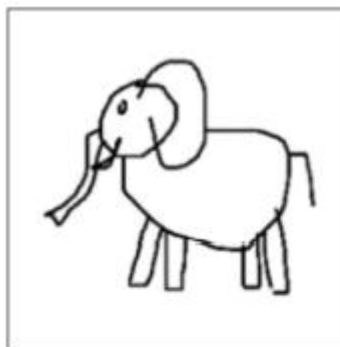
$$\tilde{Z} = \begin{cases} \tilde{Z}_{\neg c,d} + Z_{c,\neg d} + Z_{\neg c,\neg d} & \text{if } p \leq p_{discard} \\ \tilde{Z}_{c,d} + \tilde{Z}_{\neg c,d} + Z_{c,\neg d} + Z_{\neg c,\neg d} & \text{otherwise} \end{cases}$$



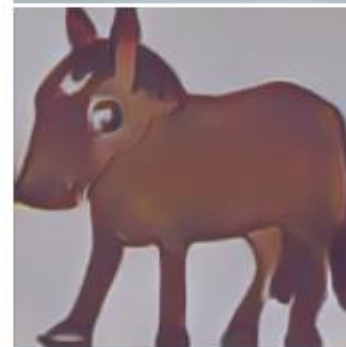
- Training
 - Phase 1: use original dataset
 - Phase 2: use original + augmented dataset
 - ✓ d : only use original dataset



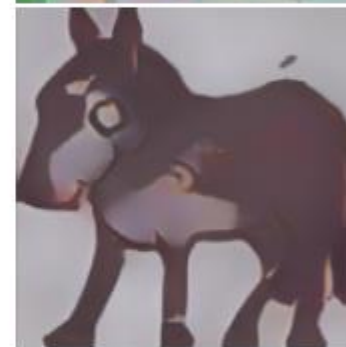
- Reconstruction of samples
 - Complex background
 - Diversity
 - Not similar to the original



(a) Original



(b) DSU

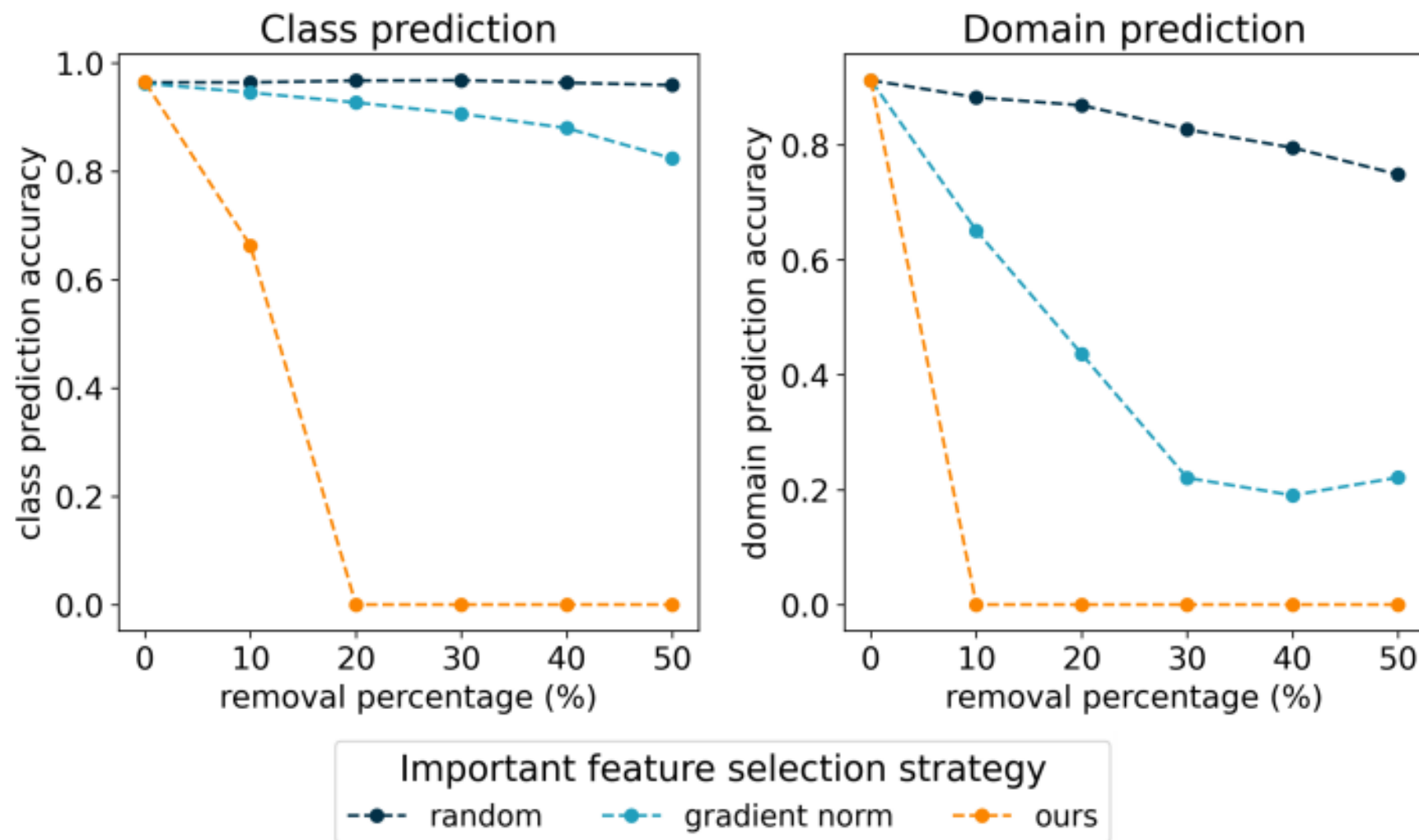


(c) XDomainMix

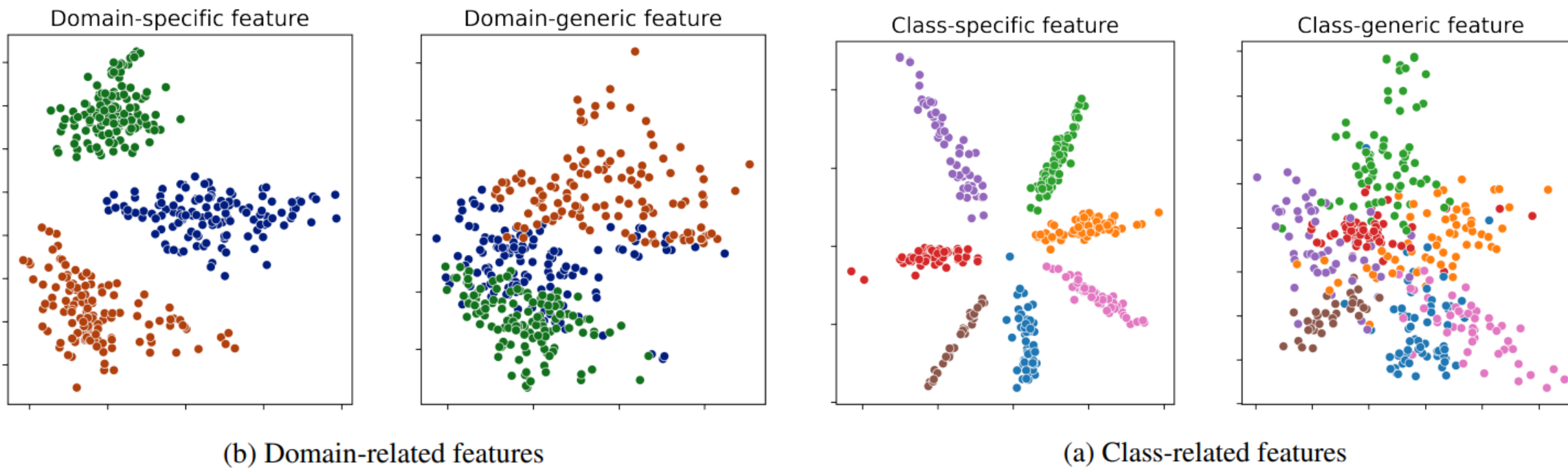
- Domain generalization performance

Method	Camelyon17	FMoW	PACS	TerraIncognita	DomainNet
ERM	70.3 ± 6.4	32.3 ± 1.3	85.5 ± 0.2	46.1 ± 1.8	43.8 ± 0.1
GroupDRO	68.4 ± 7.3	30.8 ± 0.8	84.4 ± 0.8	43.2 ± 1.1	33.3 ± 0.2
RSC	$77.0 \pm 4.9^{\wedge}$	$32.6 \pm 0.5^{\wedge}$	85.2 ± 0.9	46.6 ± 1.0	38.9 ± 0.5
MixStyle	$62.6 \pm 6.3^{\wedge}$	$32.9 \pm 0.5^{\wedge}$	85.2 ± 0.3	44.0 ± 0.7	34.0 ± 0.1
DSU	$69.6 \pm 6.3^{\wedge}$	$32.5 \pm 0.6^{\wedge}$	$85.5 \pm 0.6^{\wedge}$	$41.5 \pm 0.9^{\wedge}$	$42.6 \pm 0.2^{\wedge}$
LISA	77.1 ± 6.5	35.5 ± 0.7	$83.1 \pm 0.2^{\wedge}$	$47.2 \pm 1.1^{\wedge}$	$42.3 \pm 0.3^{\wedge}$
Fish	74.7 ± 7.1	34.6 ± 0.2	85.5 ± 0.3	45.1 ± 1.3	42.7 ± 0.2
XDomainMix	80.9 ± 3.2	35.9 ± 0.8	86.4 ± 0.4	48.2 ± 1.3	44.0 ± 0.2

- Effectiveness of class/domain scores



- Visualization of features



- Ablation study

mix $Z_{c,d}$	mix $Z_{\neg c,d}$	discard $Z_{c,d}$	Camelyon17	FMoW
			70.3 ± 6.4	32.3 ± 1.3
✓			78.3 ± 5.5	32.9 ± 2.2
	✓		79.1 ± 6.0	33.6 ± 1.1
✓	✓		79.6 ± 7.0	31.9 ± 0.4
✓	✓	✓	80.9 ± 3.2	35.9 ± 0.8

Table 4: Ablation study.