KIDELTA LEARNING

Scalable AI for Automated Driving

Final Event | March 09, 2023

Visual Transfer Learning using Knowledge Graphs

Sebastian Monka

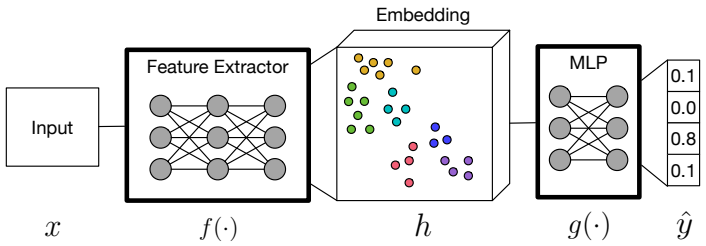
Problem Definition

Source Domain

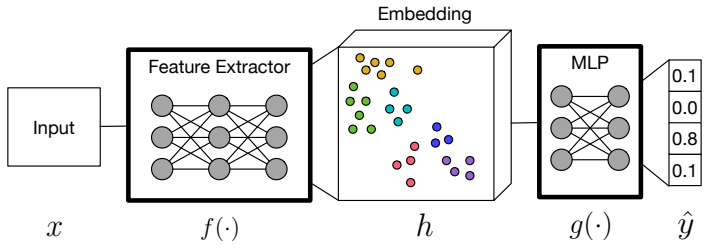
GTSRB / CTSD

Mini-ImageNet

Target Domain



~~i.i.d assumption~~

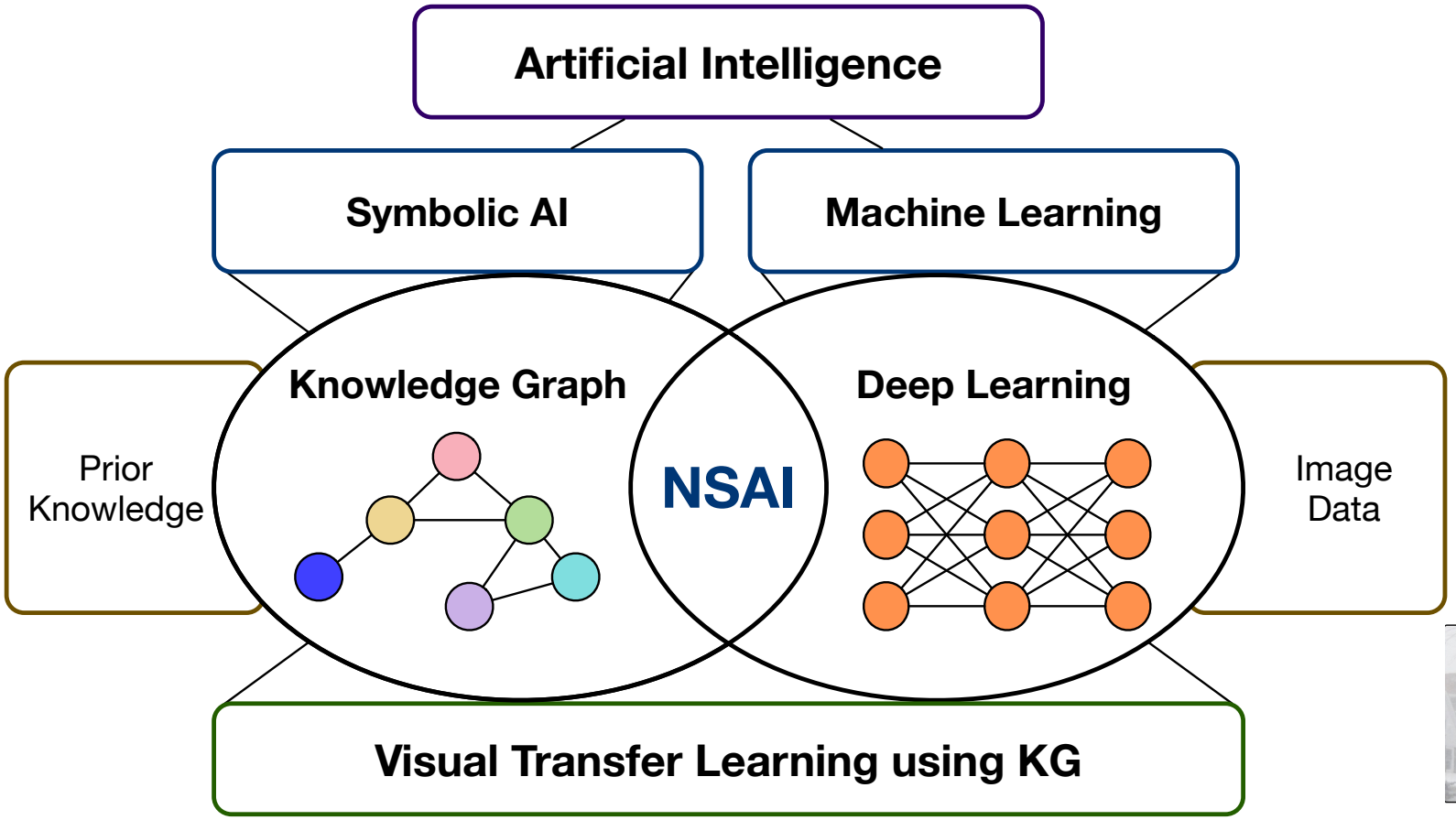


Minimize cross-entropy on **source domain**

Fails on **target domain**

→ The strong **dependence** on image data distribution must be relaxed

Overview



a) Training data

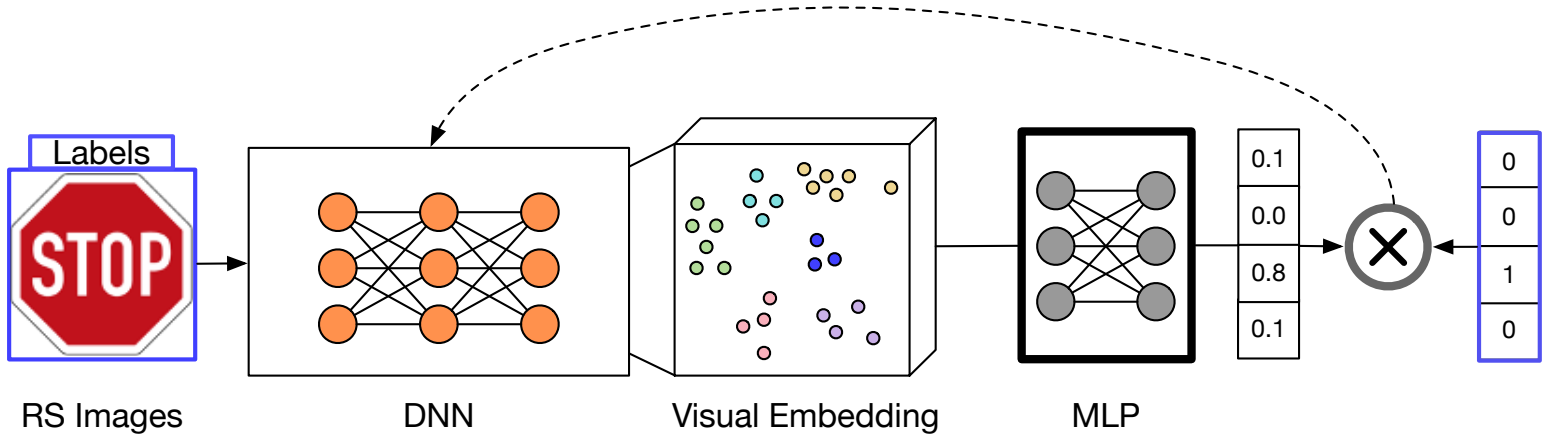
b) Weather change c) Artificial change d) Country change

→ Improve **generalization** of deep learning using **prior knowledge of a KG**

KG-NN – Learning Visual Models using a KG as a Trainer

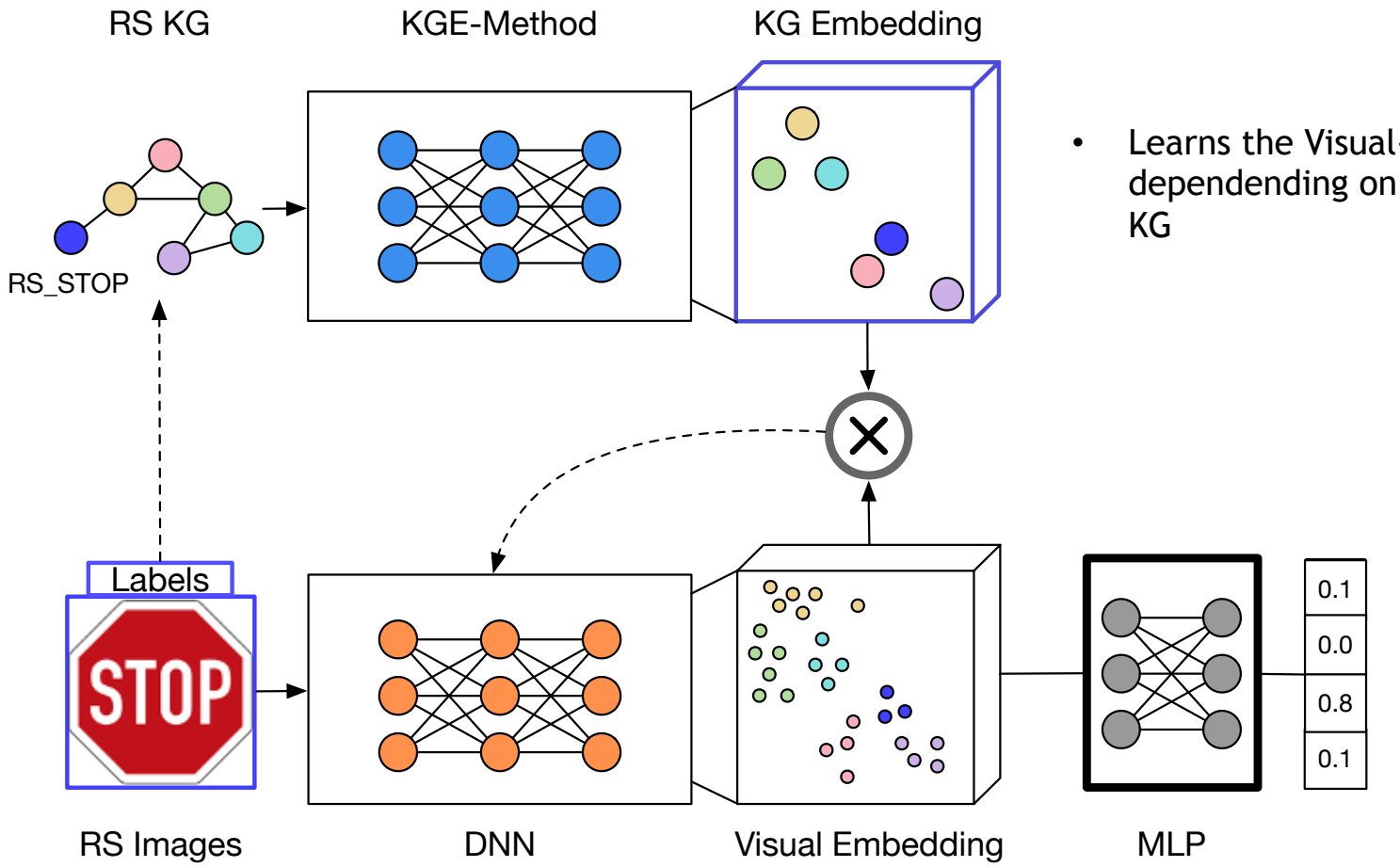
Cross-Entropy (CE)

- Learns the Visual Embedding depending on the **image data distribution**



KG-NN – Learning Visual Models using a KG as a Trainer

KG-NN (ours)



- Learns the Visual-Semantic Embedding dependending on the **prior knowledge** of the KG

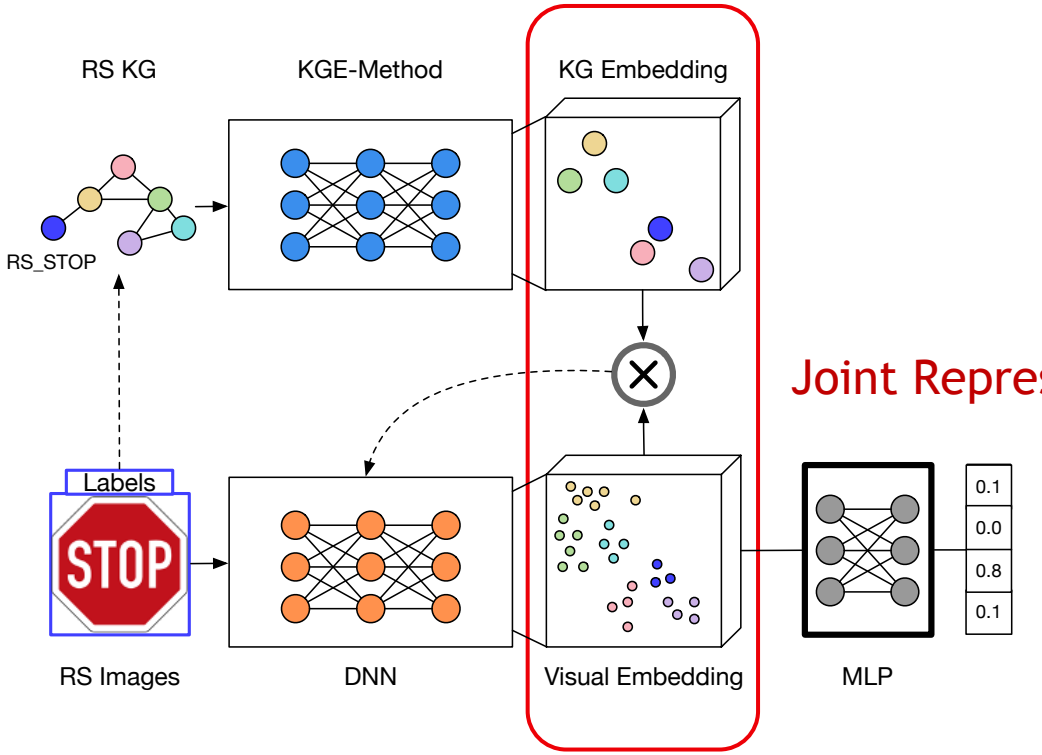
How can we integrate prior knowledge into DNNs?

1. Build KG

- Prior knowledge of domain
- Prior knowledge of related domains

2. Learn KGE

- KGE-Method
- Supervised vs. unsupervised GNN



3. Joint Embedding

- Align visual embedding of DNN to KGE
- Contrastive loss

4. Task Optimization

- Optimize DNN for task (e.g. classification)

→ Induction of **prior knowledge** of a KG into the DNN

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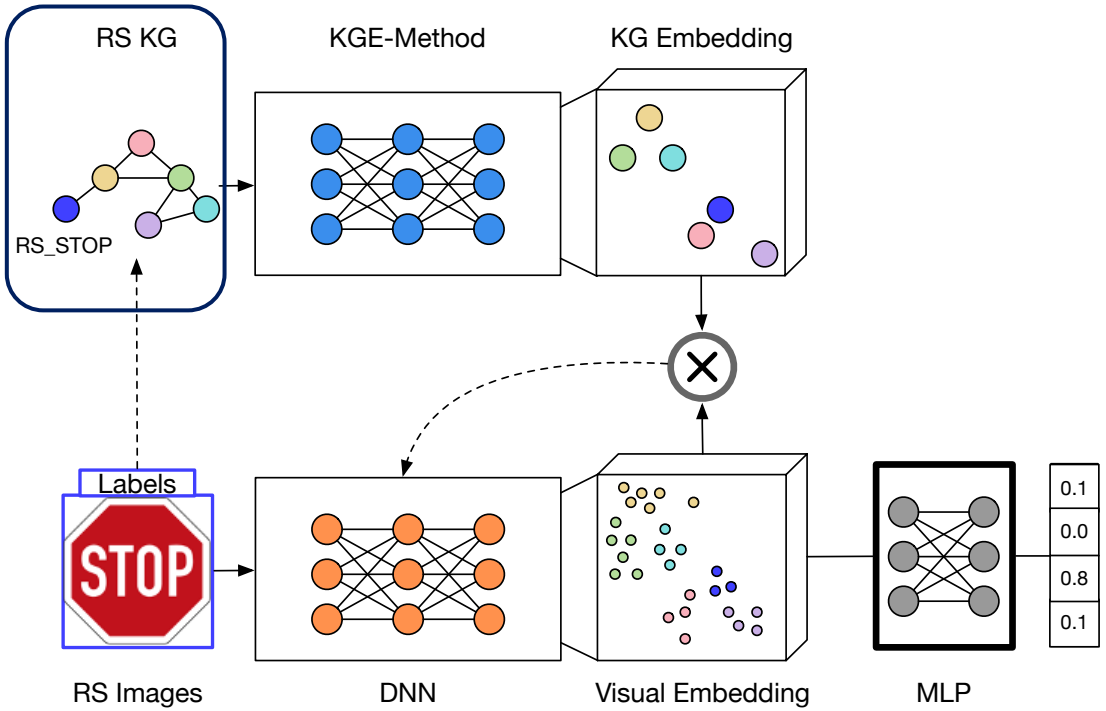

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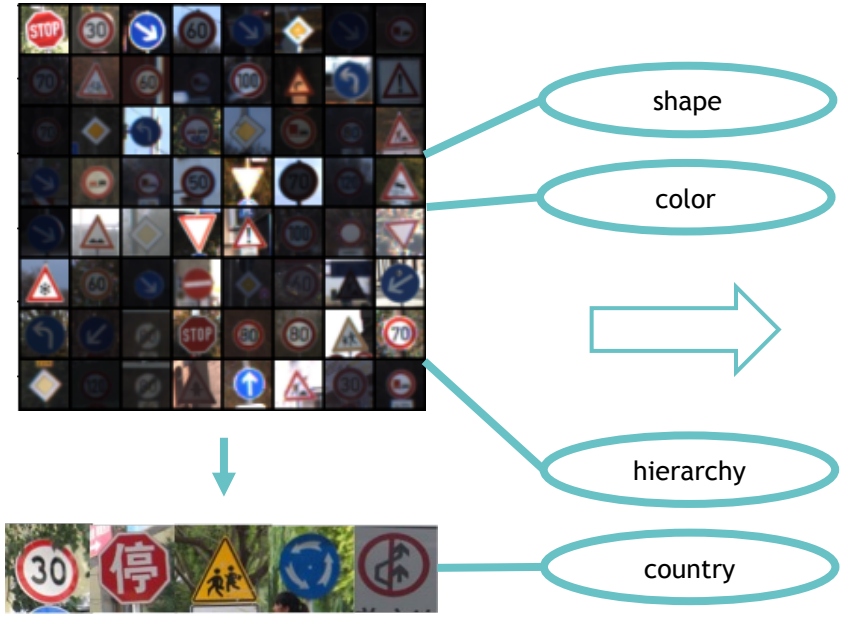
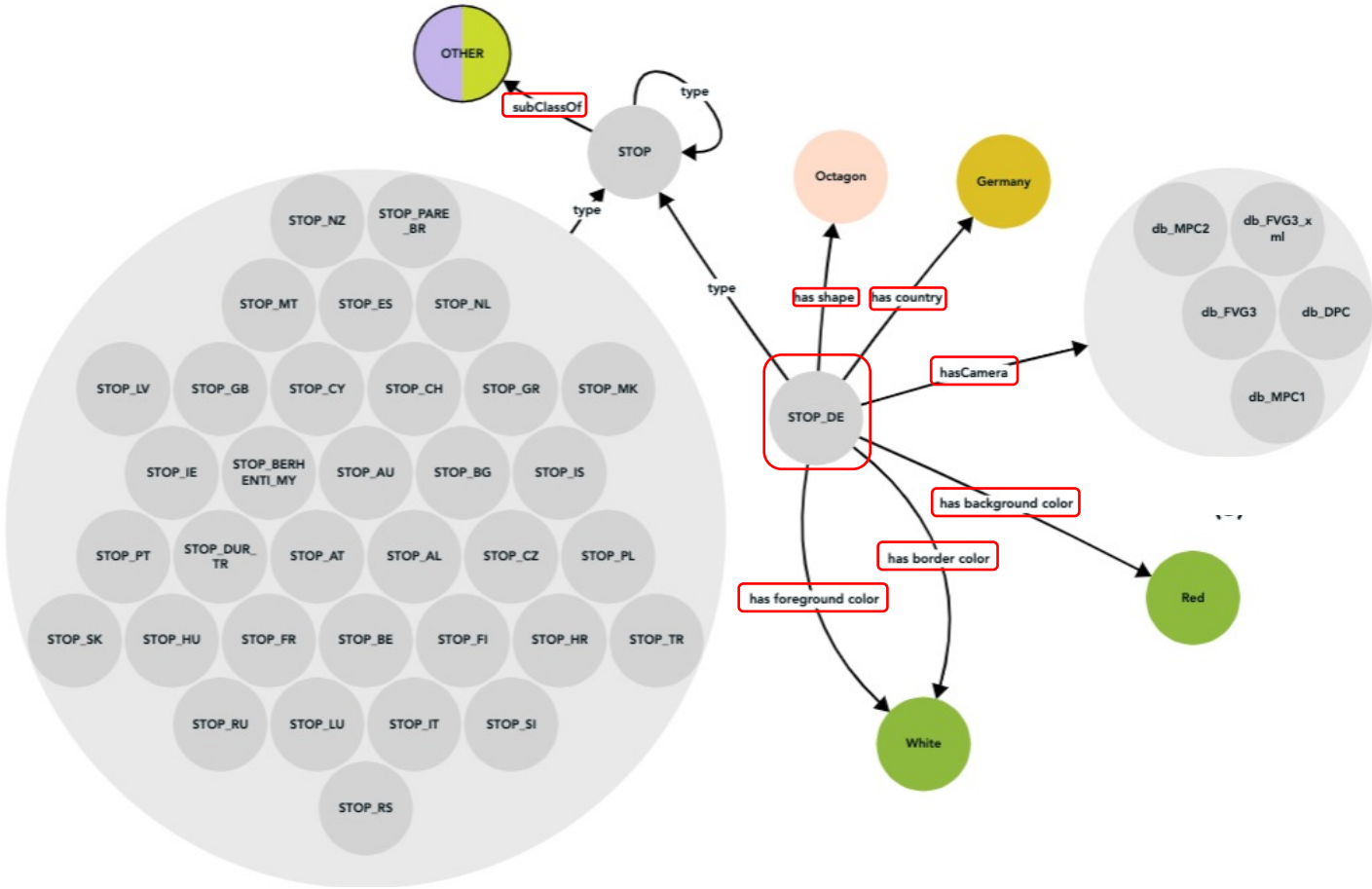
→ Encode **prior knowledge** in a KG

Build the Knowledge Graph

Knowledge Graph describes **class/image-relationships** based on:

- Prior knowledge of domain
- Prior knowledge of related domains





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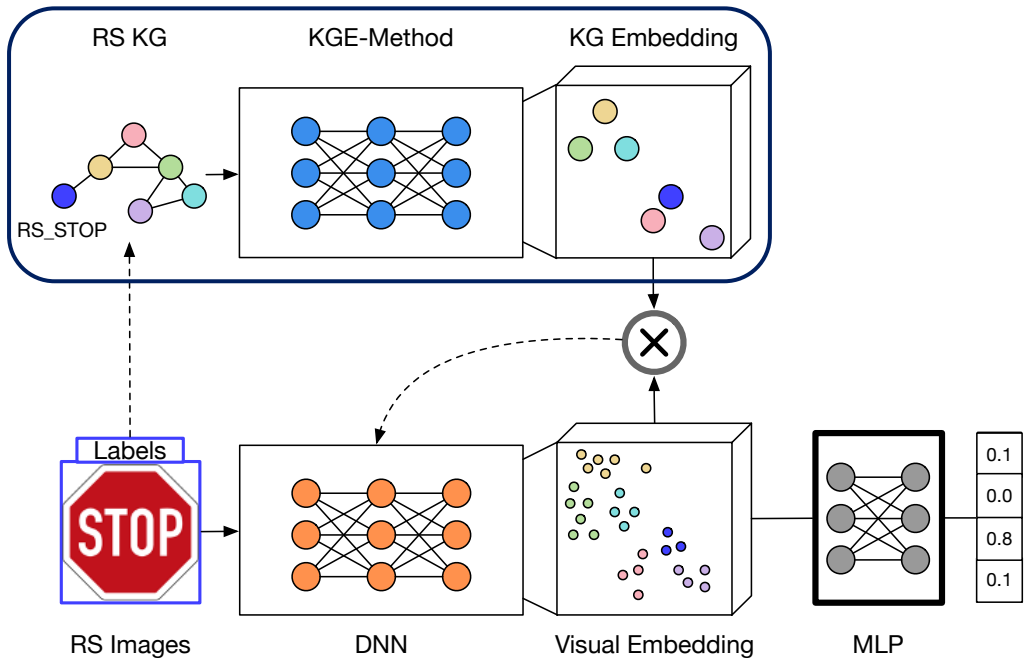

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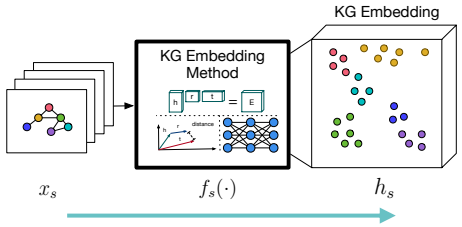
→ Transform KG to **vector space**

Learn Knowledge Graph Embedding

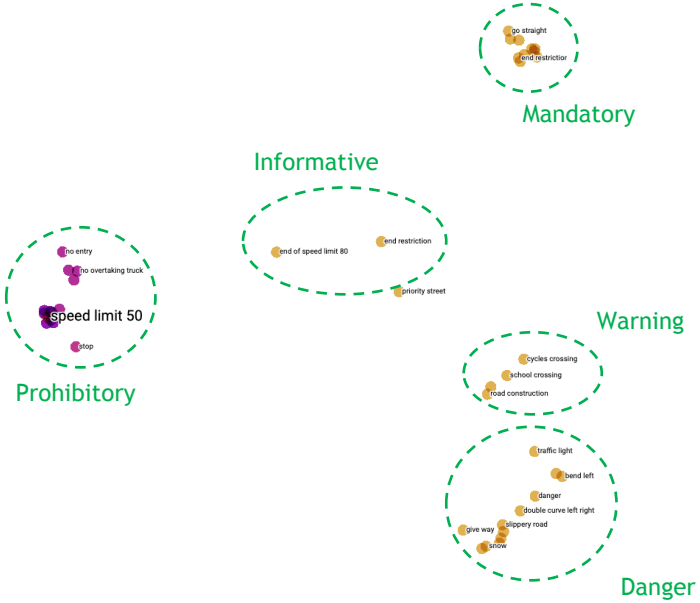
- Knowledge Graph and the class/image-relationships are transformed into **vector space**

Knowledge Graph

KGE-Method



Knowledge Graph Embedding



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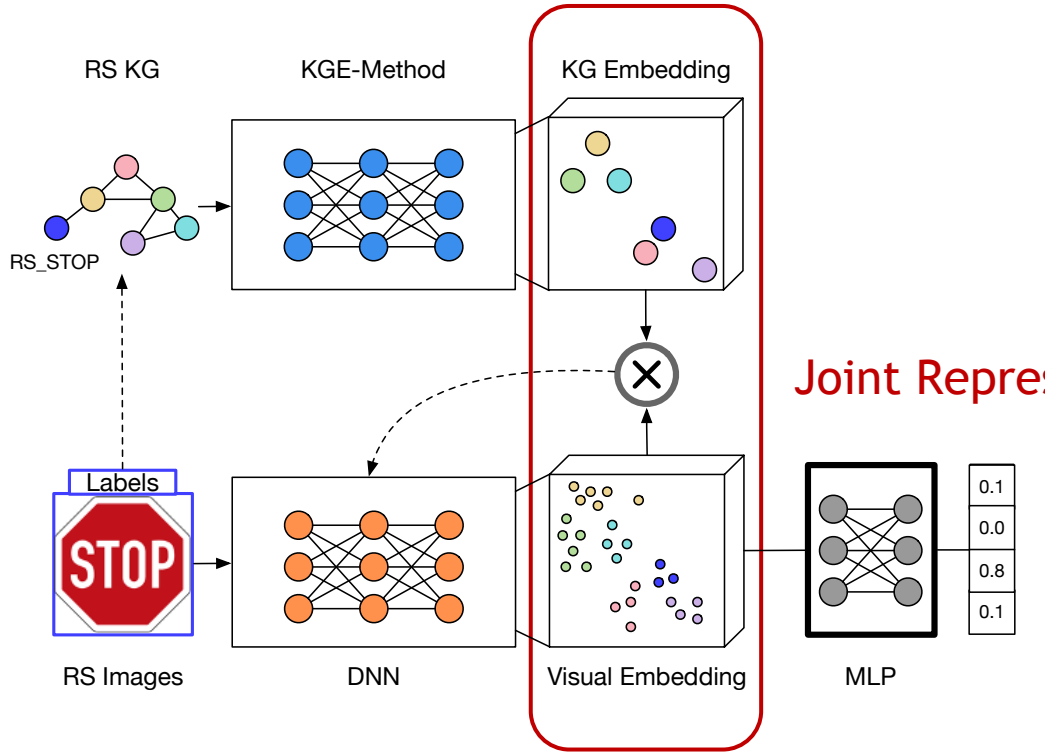

3. Joint Embedding

- Align visual embedding of DNN to KGE
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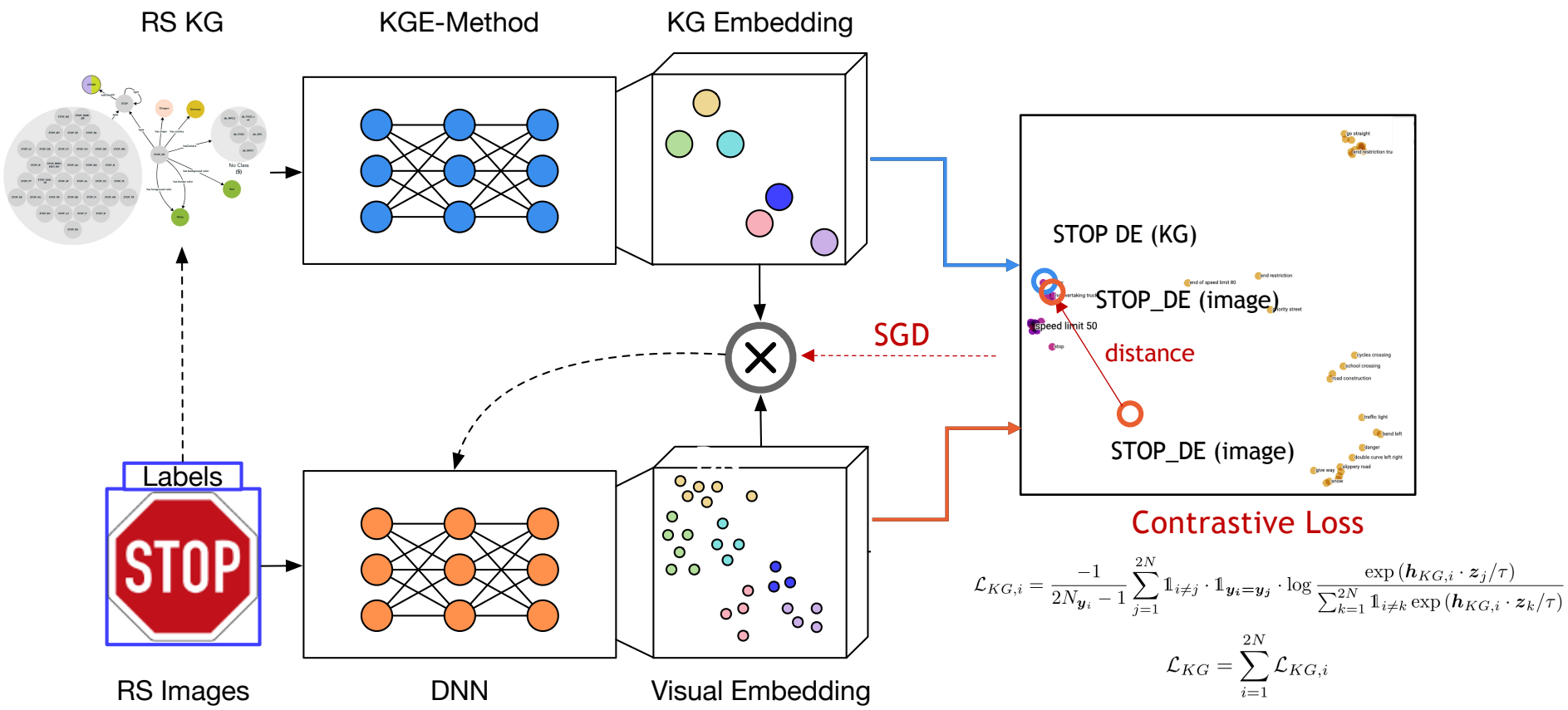
- Optimize DNN for task (e.g. classification)

→ **Align** visual embedding to KG embedding

Joint Embedding



$$\mathcal{L}_{KG,i} = \frac{-1}{2N_{\boldsymbol{y}_i} - 1} \sum_{j=1}^{2N} \mathbb{1}_{i \neq j} \cdot \mathbb{1}_{\boldsymbol{y}_i = \boldsymbol{y}_j} \cdot \log \frac{\exp\left(\boldsymbol{h}_{KG,i} \cdot \boldsymbol{z}_j / \tau\right)}{\sum_{k=1}^{2N} \mathbb{1}_{i \neq k} \exp\left(\boldsymbol{h}_{KG,i} \cdot \boldsymbol{z}_k / \tau\right)}$$

$$\mathcal{L}_{KG} = \sum_{i=1}^{2N} \mathcal{L}_{KG,i}$$

→ Learn transformation function from **source domain pixel space** into **knowledge graph embedding space**

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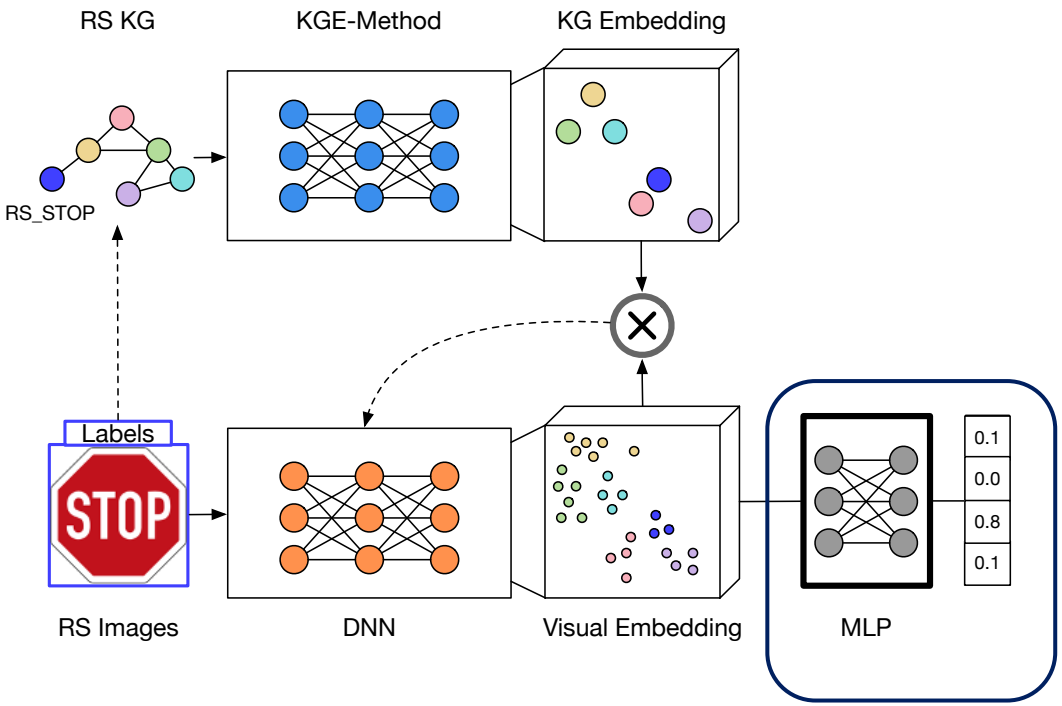

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- Optimize DNN for task (e.g. classification)

→ Optimize embedding for **downstream task**

Experiments

ResNet-50

		CE	SupCon	KG-NN
Source:	**GTSRB**	96.1	41.9	**96.9**
Target:	CTSD	+0.8%	+55.0%	

		CE	SupCon	GloVe	KG-NN
Source:	**Mini-ImageNet**	64.5	56.2	64.7	**66.2**
	ImageNetV2	+1.7%	+10.0%	+1.5%	
	ImageNet-R				
Target:	ImageNet-Sketch				
	ImageNet-A				

→ Improve **generalization** of deep learning using **prior knowledge of a KG**

Summary and Outlook

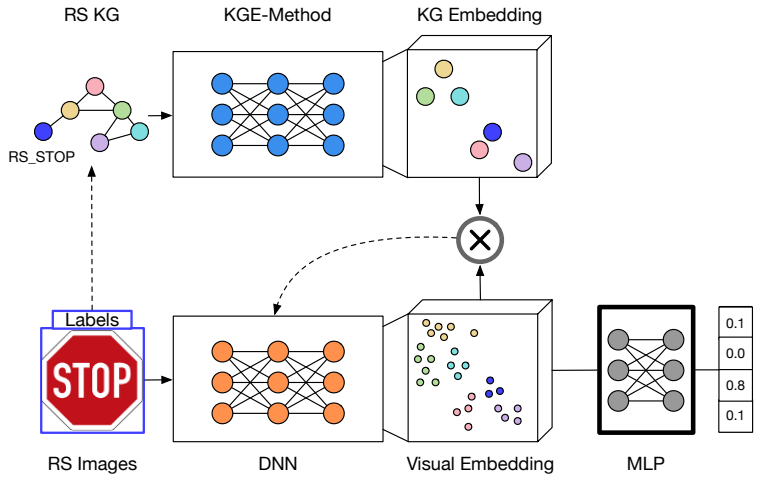
Summary:

- **Learn** DNNs using a KG

  Monka, S., Halilaj, L., Schmid S., Rettinger, A. (2021) - ISWC 2021
  Learning Visual Models using a Knowledge Graph as a Trainer.

→ KG-NN **improves generalization** of DNNs

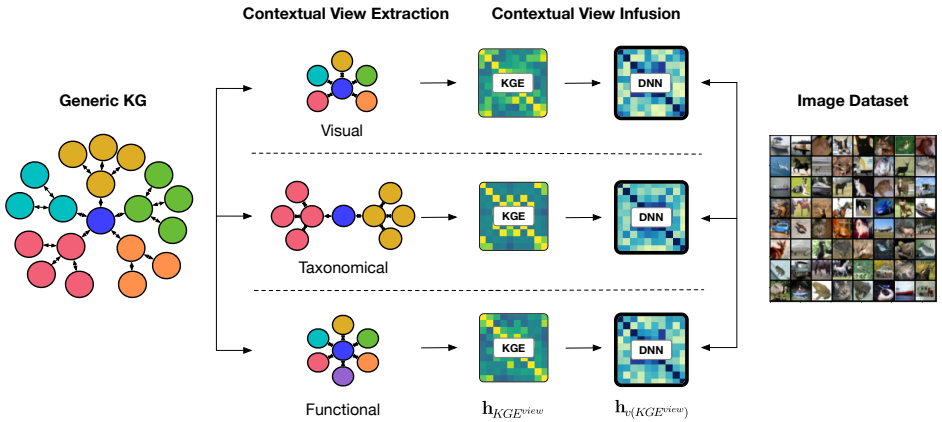
→ KG-NN **needs fewer training data** to adapt to a novel domain



- **Context** and **infusion method** are important

  Monka, S., Halilaj, L., Rettinger, A. (2022) - ISWC 2022
  Context-Driven Visual Object Recognition Based on Knowledge Graphs.

→ The **type of prior knowledge** influences the final performance of KG-NN



KIDELTA LEARNING

Scalable AI for Automated Driving

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KI Delta Learning is a project of the KI Familie. It was initiated and developed by the VDA Leitinitiative autonomous and connected driving and is funded by the Federal Ministry for Economic Affairs and Climate Action.

KI FAMILIE

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