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Fully Automated Traffic Sign Substitution in Real-World Images for Large-Scale Data Augmentation

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Natural traffic sign images (*left of arrows*) taken from the GTSRB dataset serve as basis for the automatic generation of various other realistic traffic sign classes.

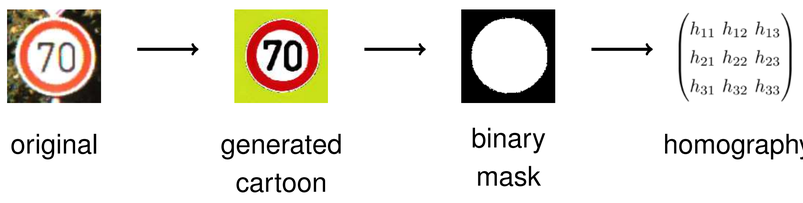
Motivation

- Automatic generation of images for training purposes
- Data augmentation
  - Enhance small datasets
  - Increase number of training samples for rare classes
- Traffic sign generation similar to GTSRB[1] samples
- Transferable to other image generation techniques with simple geometry

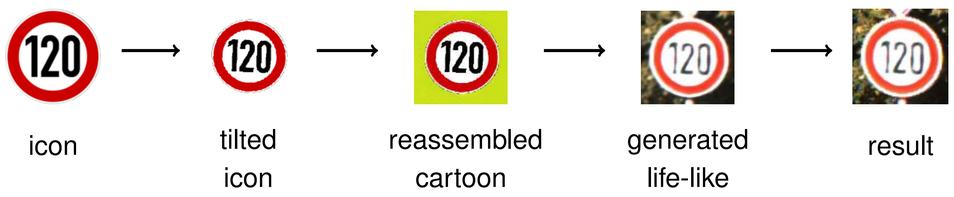
Method

- Use samples from GTSRB
- Substitute traffic sign by generated one but keep background
- Use previously presented CycleGAN[2] to transfer between life-like and cartoon domains
- Extract pose from original sample and apply to substitute

Extraction



Composition



Experimental Setup

- Multi-class SVM classifier on HOG features
- Training on dataset according to composition table
- Test on same set of real-world samples from GTSRB

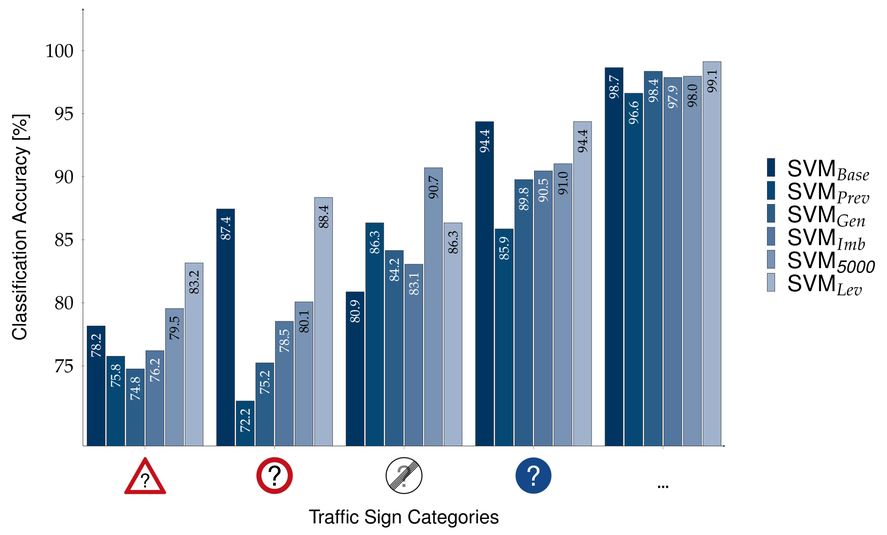
Key	Training Dataset Composition
SVM_{Base}	real images, GTSRB[1] training set; baseline | high variation in class size
SVM_{Prev}	generated images (previous method)[2] | *equal distribution of samples (449 per class)*
SVM_{Gen}	generated images (ours) | *equal distribution of samples (449 per class)*
SVM_{Imb}	generated images (ours) | *unbalanced class distribution equal to SVM_{Base}*
SVM_{Big}	generated images (ours) | *equal distribution of samples (5000 per class)*
SVM_{Lev}	mixture of real and generated images (ours) | *SVM_{Base} plus augmentation of underrepresented classes with generated samples for leveled classes; equal distribution of samples (1110 per class)*

Composition details of training datasets compared in various experiments

Results

Generated images in all classes

- Category-wise classification results
- All new training sets better than previous method
- SVM_{Lev} outperforms baseline classifier



One unseen generated image class

- Three different traffic sign replacements
- Accuracy of replaced class always better than previous method
- Overall accuracy comparable to baseline

Replacing Class "No Entry (Trucks)"

Classification Accuracy [%]

Class	SVM_{Base}	SVM_{Prev}	SVM_{Gen}	SVM_{Imb}	SVM_{5000}
	97.18	**88.73**	**100.00**	**100.00**	**100.00**
	72.73	72.73	72.73	**78.79**	72.73
	70.45	**72.73**	70.45	70.45	**72.73**
...	...	...	...	...	...
	99.58	99.58	**96.67**	**98.75**	**93.33**
	84.85	84.85	**69.70**	**72.73**	**63.64**
Total	88.01	87.87	87.85	87.62	87.73

Replacing Class "Attention Slippery Road"

Classification Accuracy [%]

Class	SVM_{Base}	SVM_{Prev}	SVM_{Gen}	SVM_{Imb}	SVM_{5000}
	67.11	**60.53**	**94.74**	**94.74**	**100.00**
	37.93	37.93	**41.38**	**41.38**	37.93
	85.11	85.11	85.11	85.11	**87.23**
...	...	...	...	...	...
	98.56	98.56	**97.84**	**97.84**	**93.53**
	81.58	81.58	**78.95**	**78.95**	**76.32**
Total	88.01	87.89	88.35	88.35	88.23

Replacing Class "Pass Right"

Classification Accuracy [%]

Class	SVM_{Base}	SVM_{Prev}	SVM_{Gen}	SVM_{Imb}	SVM_{5000}
	95.87	**78.47**	**88.50**	**88.50**	**93.22**
	96.92	**98.46**	**98.46**	**98.46**	**98.46**
STOP	92.36	**93.06**	**93.06**	**93.06**	**93.06**
...	...	...	...	...	...
	100.00	100.00	100.00	100.00	**98.31**
Total	88.01	87.06	87.65	87.65	87.89

Results for training on partially generated data. SVMs were trained on real-world data, with the exception of one generated class as stated in each table. Number of generated samples for replaced class follows dataset composition rules stated above. Highlighted numbers show deviating results from baseline.

Generation of realistic looking images from arbitrary (including ficticious) traffic sign icons.

1 Stallkamp, J., Schlipsing, M., Salmen, J., & Igel, C. (2011). The German Traffic Sign Recognition Benchmark: A multi-class classification competition. In *IEEE International Joint Conference on Neural Networks* (pp. 1453–1460).

2 Spata, D., Horn, D., & Houben, S. (2019). Generation of Natural Traffic Sign Images Usind Domain Translation with Cycle-Consistent Generative Adversarial Networks. In *IEEE Intelligent Vehicles Symposium (IV)* (pp. 622-628).