

Forensic License Plate Recognition with Compression-Informed Transformers

Denise Moussa¹, Anatol Maier², Andreas Spruck³, Jürgen Seiler³, Christian Riess²

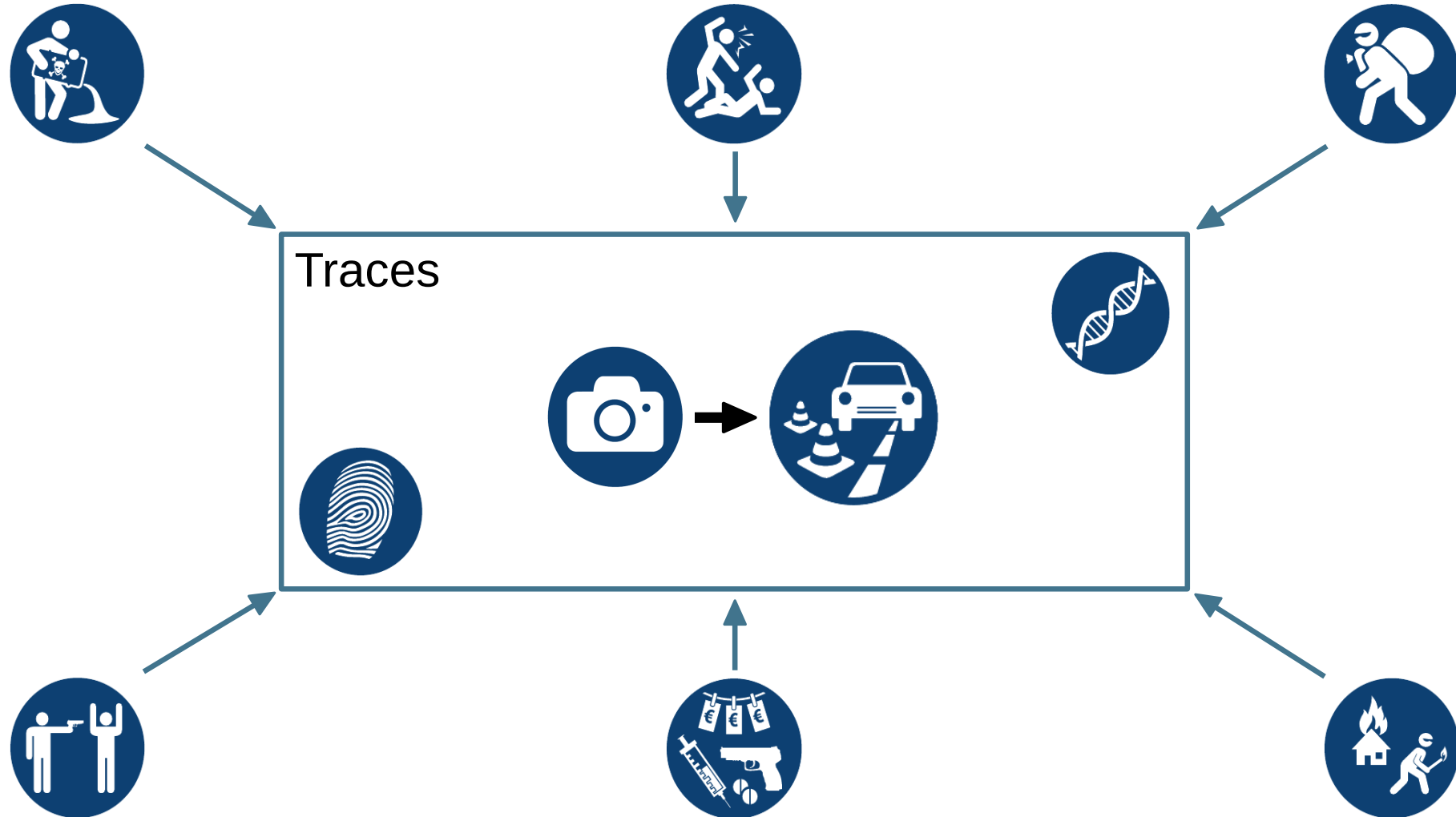
¹Federal Criminal Police Office (BKA), Germany

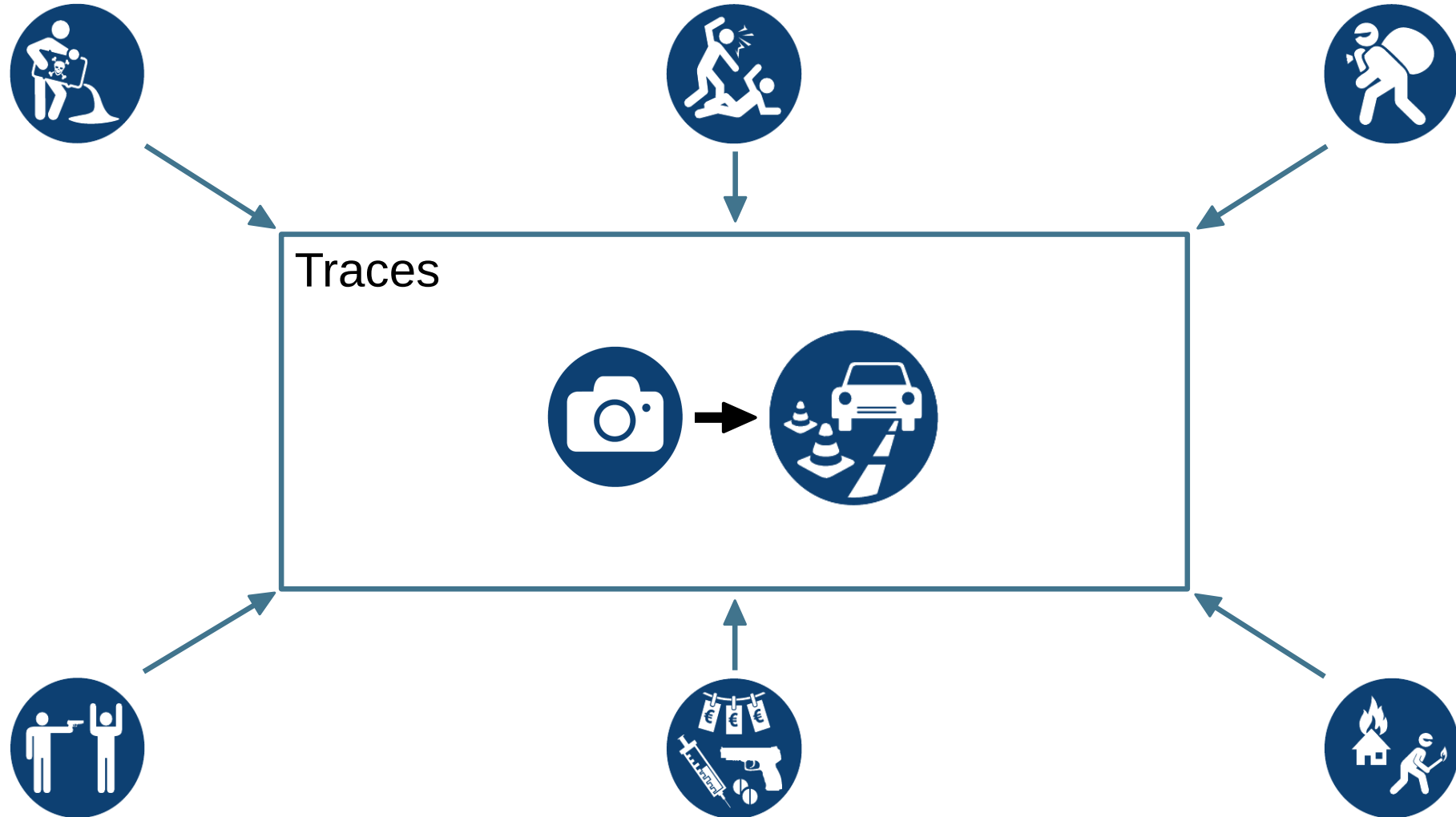
²IT Security Infrastructures Lab, Computer Science, Univ. of Erlangen-Nürnberg

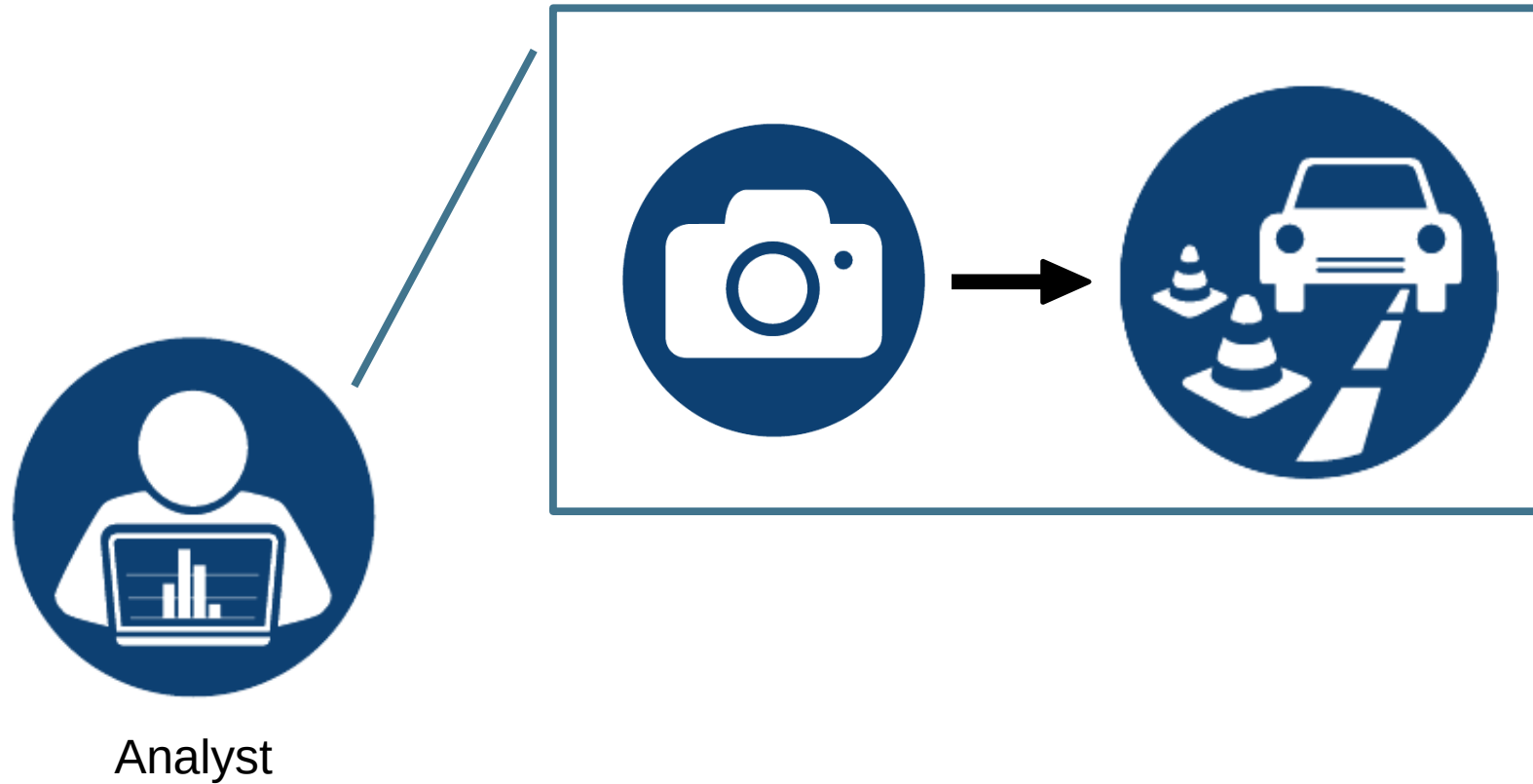
³Multimedia Communications and Signal Processing, Electrical Engineering, Univ. of Erlangen-Nürnberg

October, 2022











Analyst



What we hope for



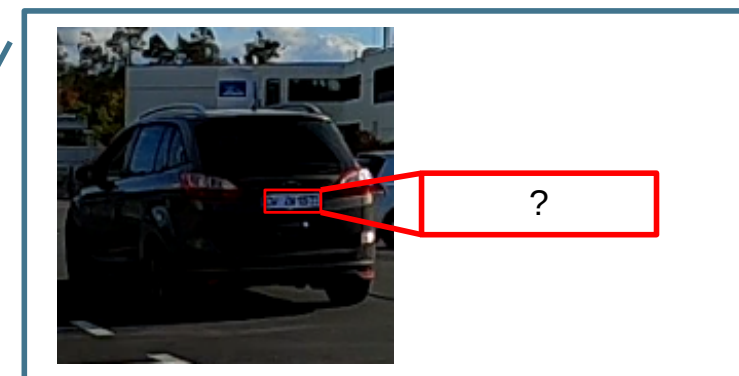
Analyst



What we may get



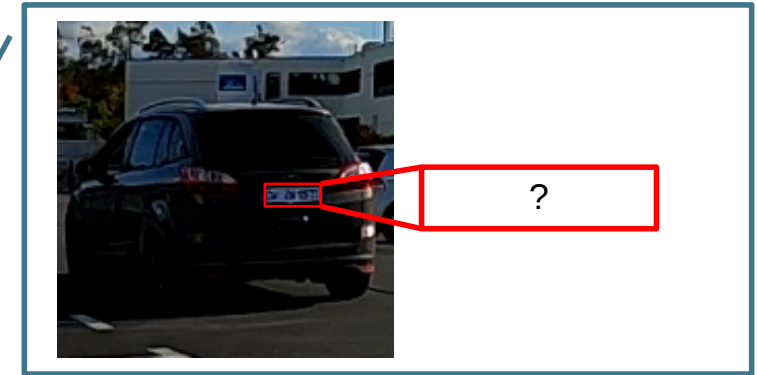
Analyst



Few Images Available



Analyst



Few Images Available



Very Low Image Quality



- High compression
- Low resolution



Analyst



Few Images Available



Very Low Image Quality

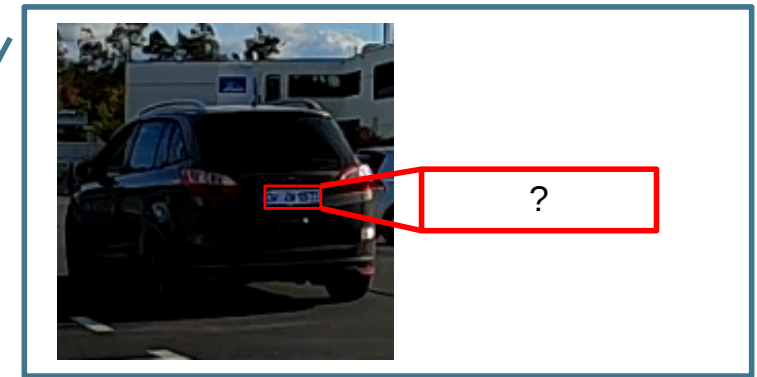


- High compression
- Low resolution

⇒ **Classic image enhancement methods may fail!**



Analyst



Research on FLPR

Vital For Police Work But Hardly Visited



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Research question: Can neural networks guess characters from very low quality LPs?

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⇒ **Driving forward the research on FLPR is vital for police work!**

- NNs may not create evidence but can deliver hints/clues
- We identify room for improvement w.r.t FLPR NN approaches



1. Improving the NN Architecture for FLPR

- Transformer sequence-to-sequence approach
- Higher performance
- More parameter efficient

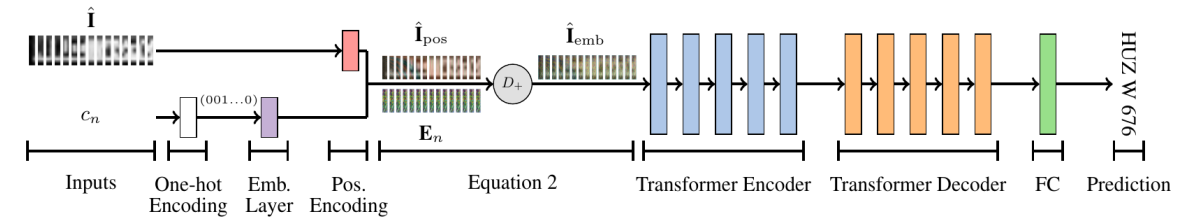


Fig. 1: The proposed Transformer architecture with knowledge embedding.

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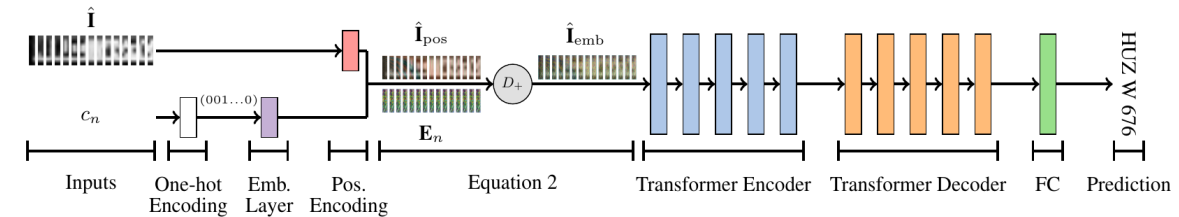
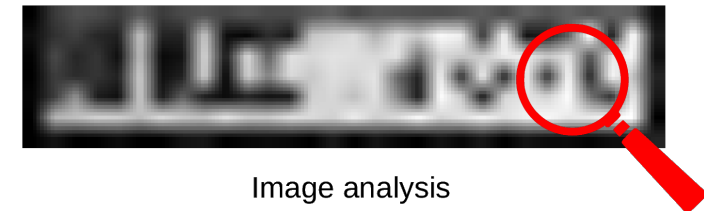


Fig. 1: The proposed Transformer architecture with knowledge embedding.

2. Exploiting Image Quality Information

- **Here:** Feed estimated compression level to NN
- Boosts performance for worst case scenarios



Improving the NN Architecture

Sequence-to-Sequence Transformer For FLPR

Why Sequence-to-sequence?



Column slices of length N



„HUZ W 676“

String of length M

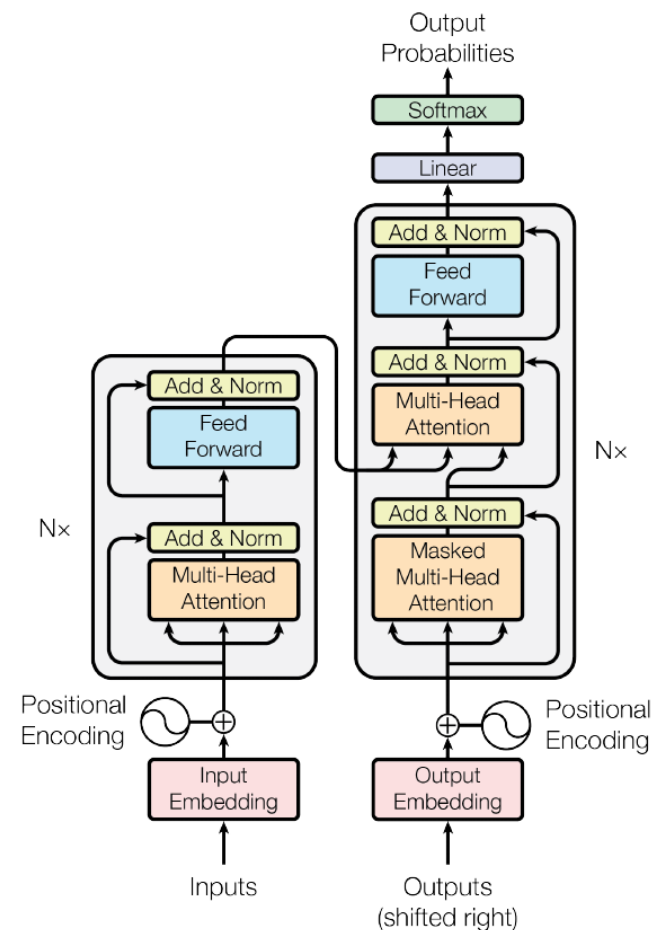
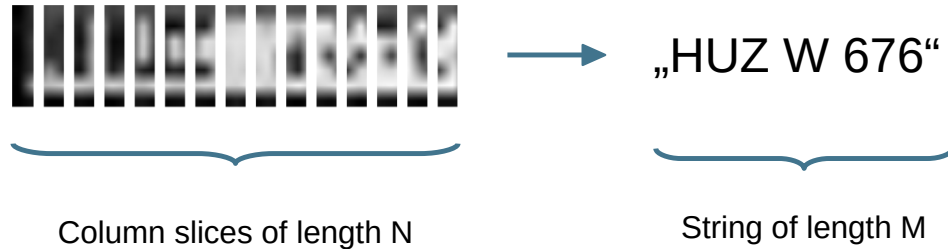


Figure: Transformer model proposed by Vaswani *et al.* [6]

Improving the NN Architecture

Sequence-to-Sequence Transformer For FLPR

Why Sequence-to-sequence?



- LPs contain textual sequence information
- Processing of variable input/output lengths

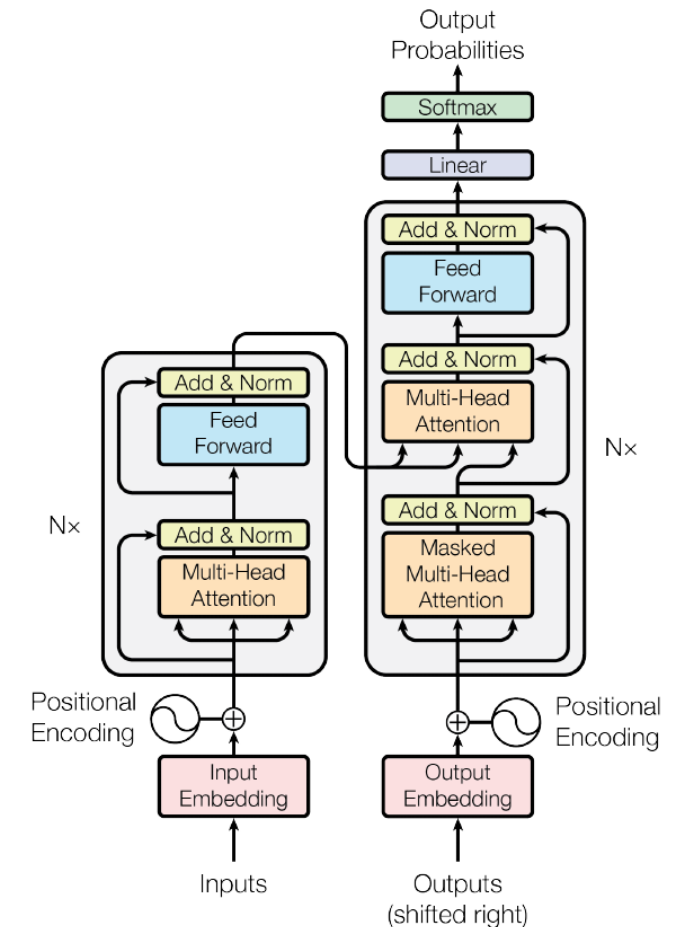
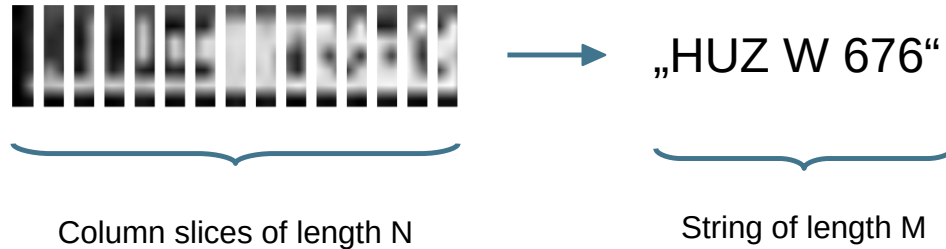


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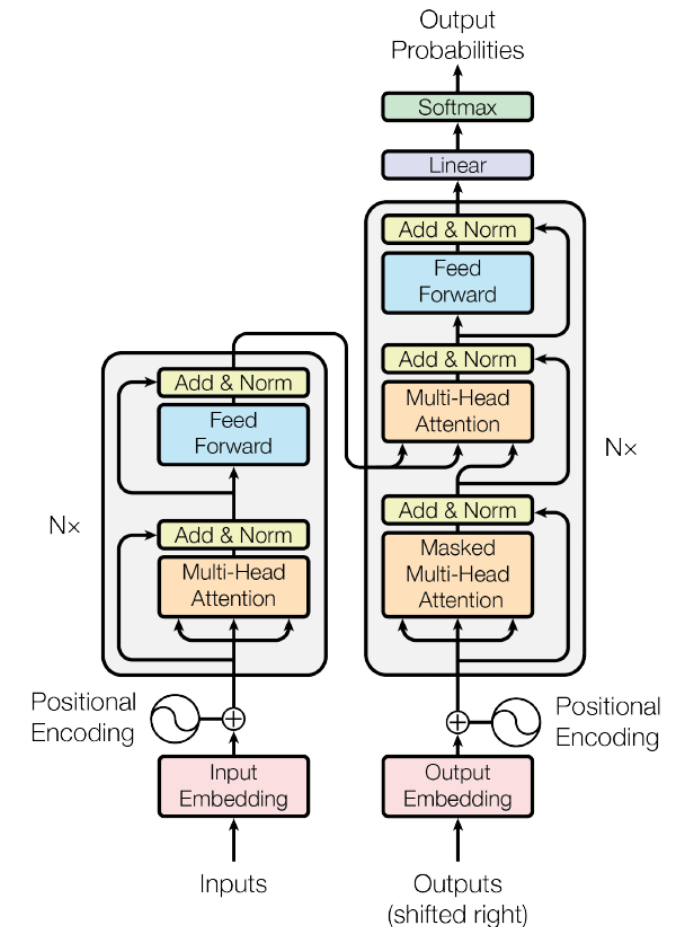
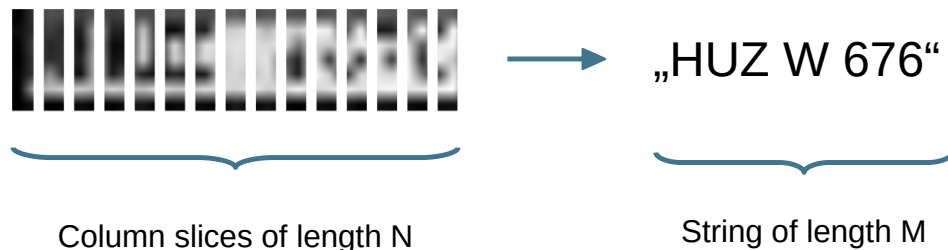


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Improving the NN Architecture

Sequence-to-Sequence Transformer For FLPR

Why Sequence-to-sequence?



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Why Transformers?

- Excels in various (sequence-to-sequence) tasks
- ⇒ Powerful attention mechanism

$$\text{Att}(\mathbf{Q}, \mathbf{V}, \mathbf{K}) = \text{Softmax} \left(\frac{\mathbf{Q}\mathbf{K}^T}{\sqrt{d_K}} \mathbf{V} \right)$$

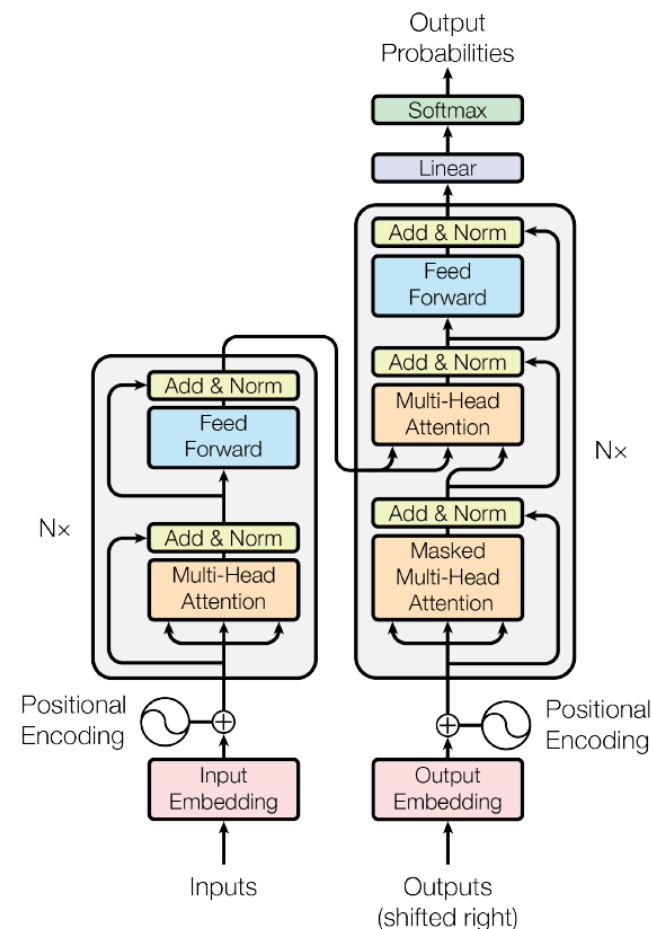


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Exploiting Side Information

Estimating Compression Quality From Images



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Compression...

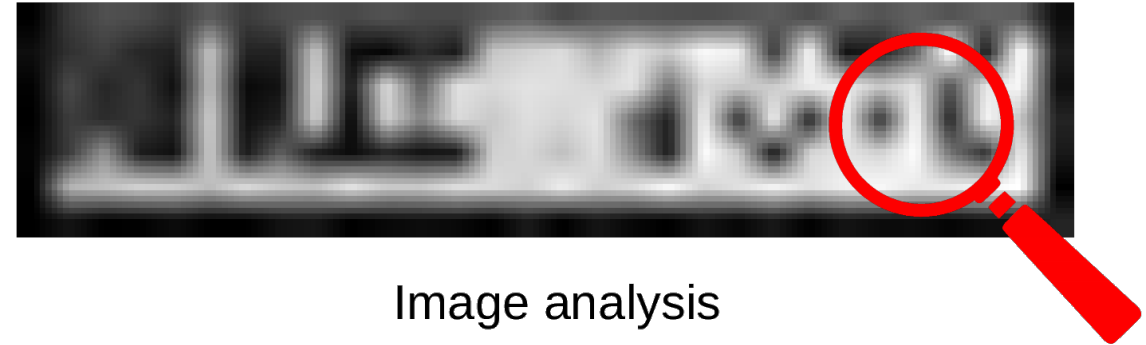


Image analysis

Exploiting Side Information

Estimating Compression Quality From Images



Compression...

- is a frequently occurring problem
- creates characteristic block patterns

r_w	JPEG quality factors		
	1	20	50
20			
30			
50			
70			
90			

Figure: Synthetic LPs of different pixel widths r_w and compression levels

Exploiting Side Information

Estimating Compression Quality From Images



Bundeskriminalamt



Compression...

- is a frequently occurring problem
- creates characteristic block patterns
 - ⇒ Estimate compression strength from images
 - ⇒ Feed the information to the NN

r_w	JPEG quality factors		
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Figure: Synthetic LPs of different pixel widths r_w and compression levels

- **JPEG Compression Quality**

- Mainly influenced by 8×8 quantization matrix \mathbf{M}_Q
⇒ **64 degrees of freedom**

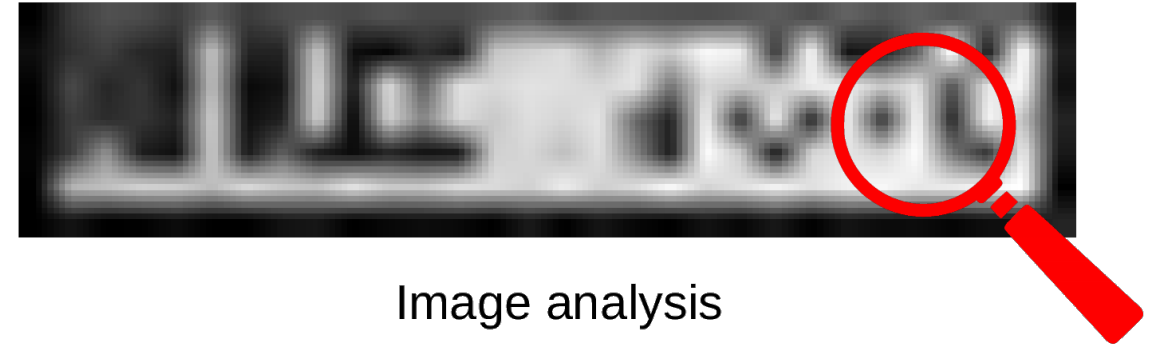


Image analysis

- **JPEG Compression Quality**
 - Mainly influenced by 8×8 quantization matrix M_Q
⇒ **64 degrees of freedom**
- **Solution: Estimate Standardized Quality Surrogate**
 1. Read/estimate M_Q from image data
 2. Regress to closest libjpeg standard quality factor QF [7, 8]⇒ **Result:** $QF \in [1, 100]$

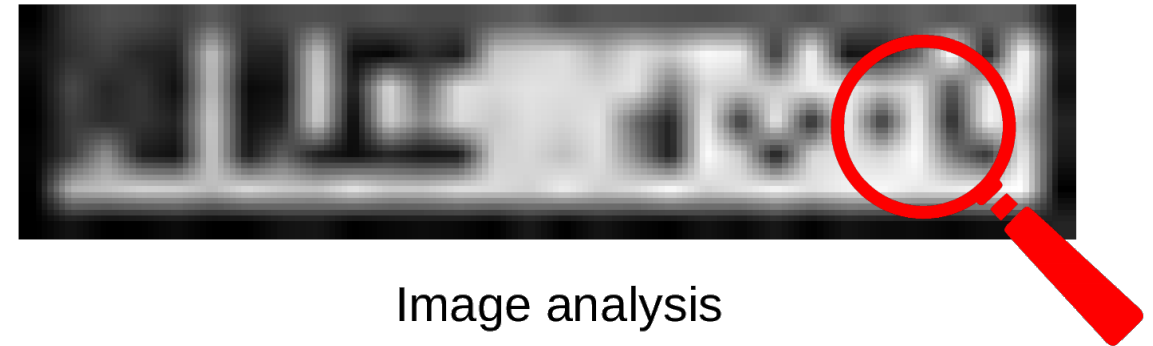


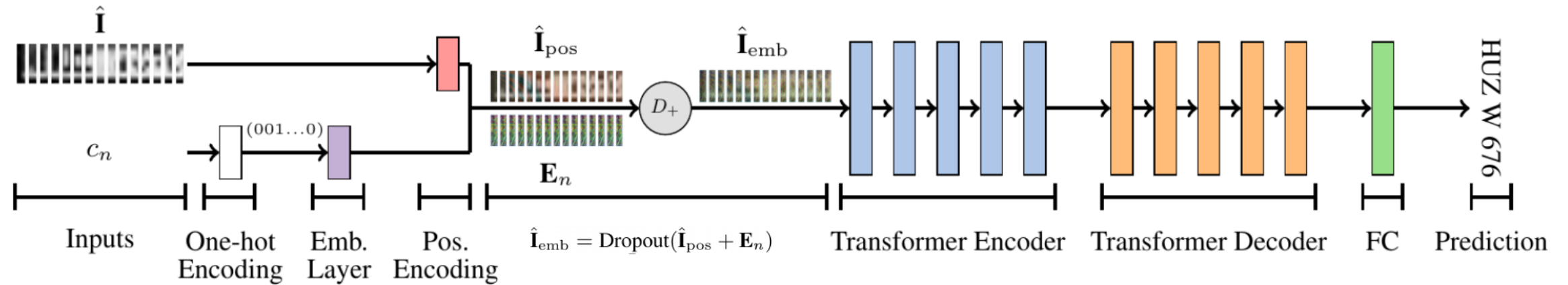
Image analysis

Our Resulting Architecture

Compression-Informed Transformer



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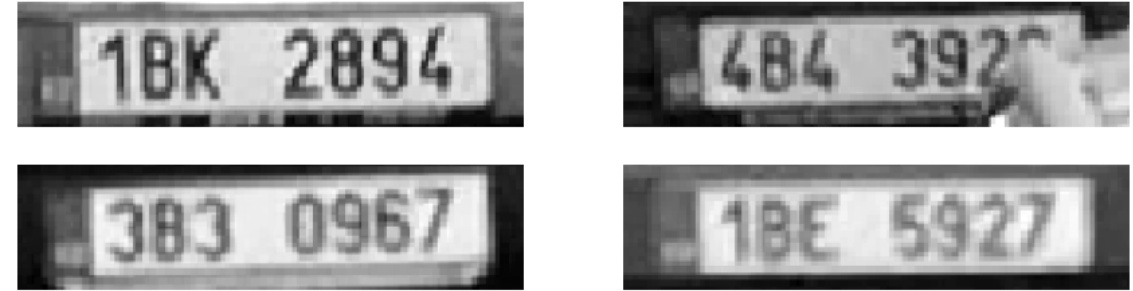
1: Data preparation

2: Fusion of
image and QF
information

3: Processing by seq2seq NN

Reld Dataset [9]

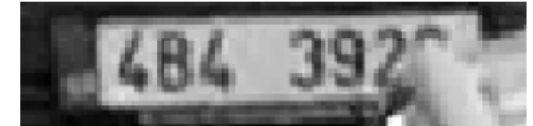
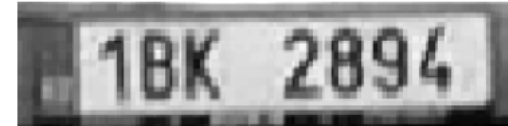
- Real (mostly) Czech LP data set
- Human readable but low quality



(a) Samples from Reld [9]

Reld Dataset [9]

- Real (mostly) Czech LP data set
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- ⇒ We first test Transformers for general LPR
- ⇒ Performance comparable to SOTA
- ⇒ More parameter efficient



(a) Samples from Reld [9]

Reld Dataset [9]




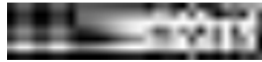







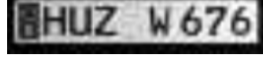

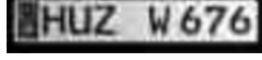
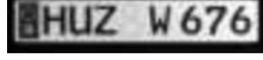
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(a) Samples from Reld [9]

Our SynthGLP Dataset

- Synthetic German LPs [10]
 - 900k/100k/1k Train/validation/test splits
 - JPEG Compression and resolution variations
- ⇒ simulate most challenging factors during criminal investigations

r_w	JPEG quality factors		
	1	20	50
20			
30			
50			
70			
90			

(b) Medium and low quality samples from our SynthGLP data set

Our Method for FLPR

Results On Our Synthetic German LPs



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- Analysis of degradation levels covered in training



Our Method for FLPR

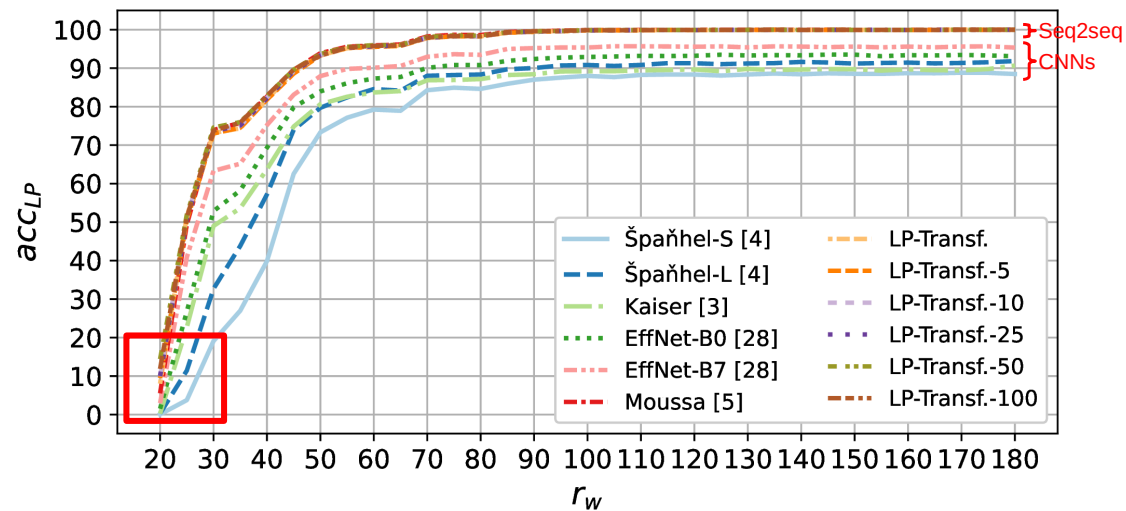
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Bundeskriminalamt



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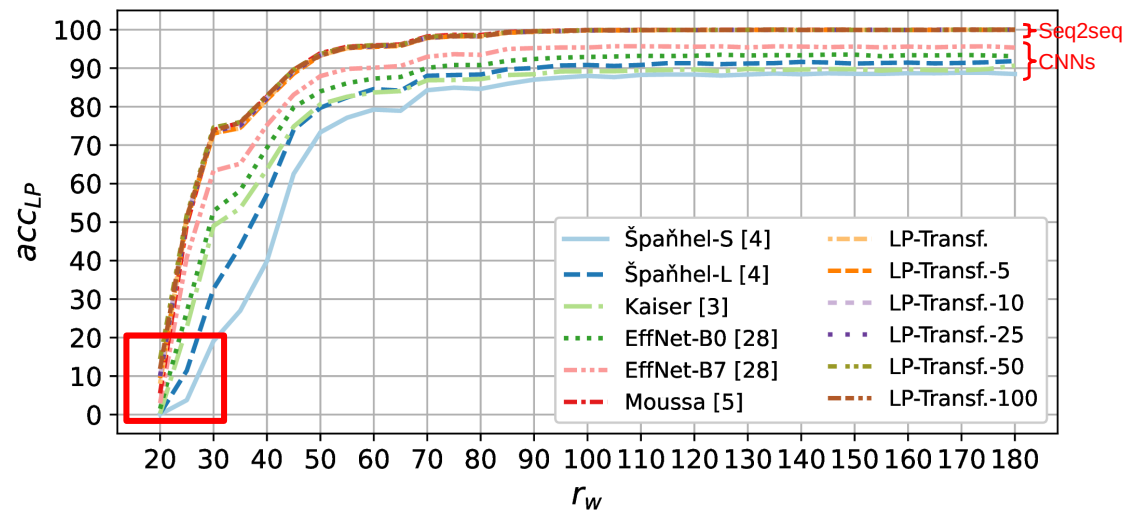
(a) $r_w \in [20, 180]$

Our Method for FLPR

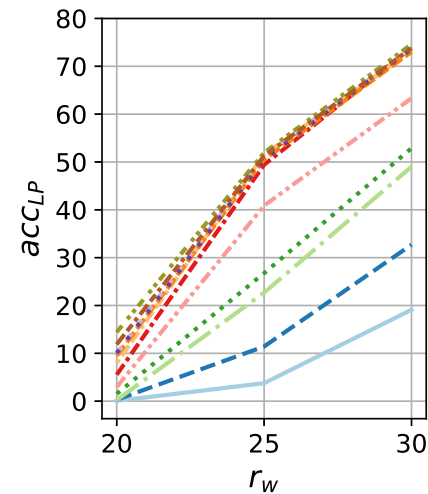
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(b) $r_w \in [20, 30]$

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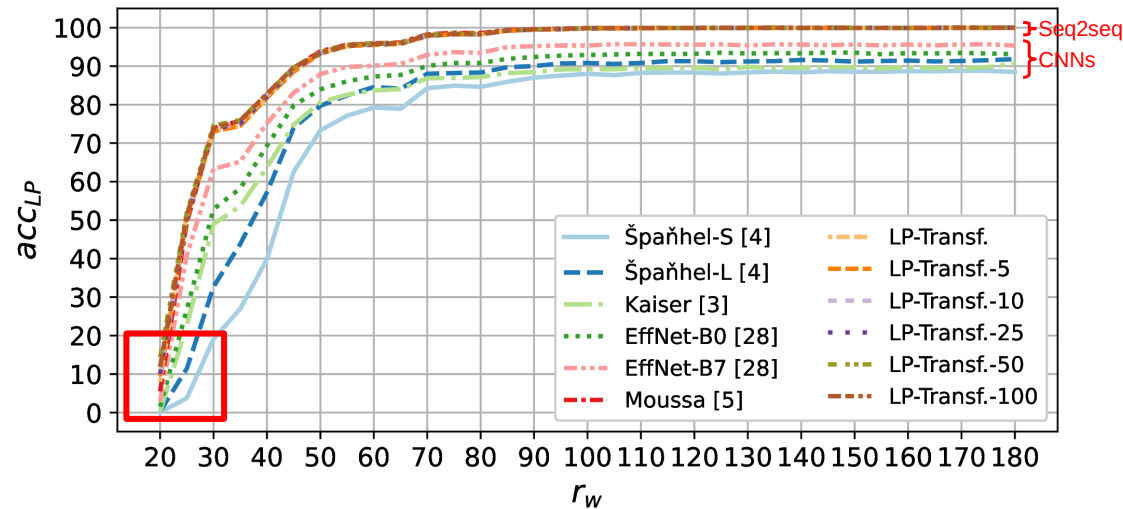
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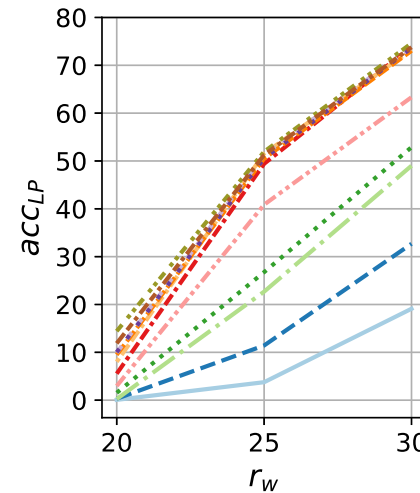
Bundeskriminalamt



- Analysis of degradation levels covered in training



(a) $r_w \in [20, 180]$



(b) $r_w \in [20, 30]$

Method	acc_{lp}	CER
Moussa [4]	5.53%	0.3496
LP-Transf.	8.02%	0.3254
LP-Transf.-5	9.48%	0.3131
LP-Transf.-10	9.94%	0.3046
LP-Transf.-25	10.04%	0.3046
LP-Transf.-50	14.43%	0.2848
LP-Transf.-100	11.88%	0.2990

(c) $r_w = 20$

Our Method for FLPR

Results On Our Synthetic German LPs



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- Analysis on very low quality LPs



Our Method for FLPR

Results On Our Synthetic German LPs



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- Analysis on very low quality LPs

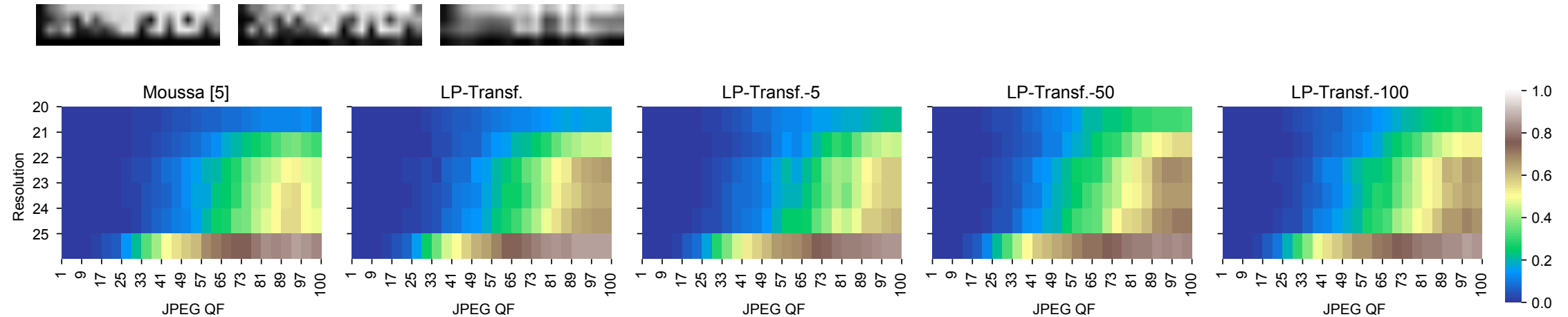


Figure: acc_{lp} for the best performing baseline CRNN [4] and our method.

Our Method for FLPR

Results On Our Synthetic German LPs



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- Analysis on very low quality LPs

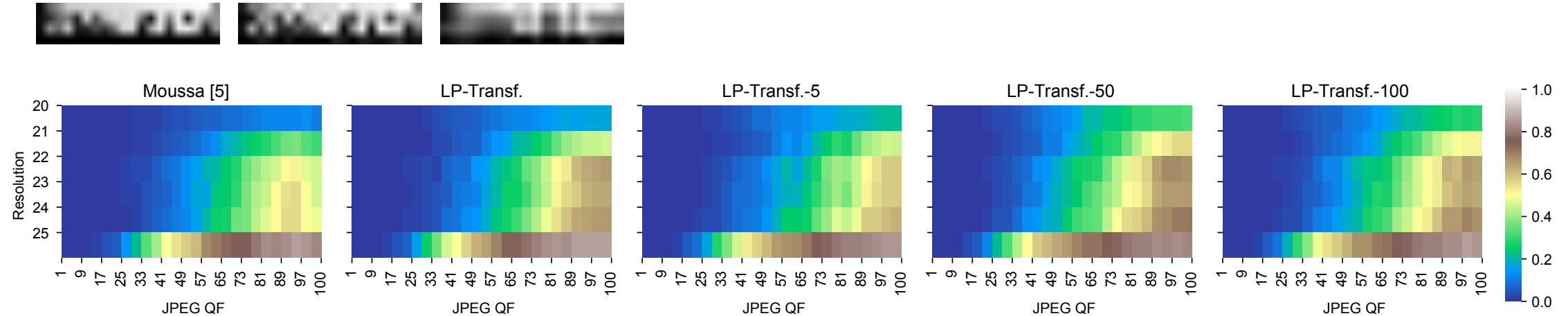


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1. Our models surpass the best baseline CRNN
2. Advantage increases with **decreasing** image quality
3. LP-Transf.-50 is best, e.g.:

Our Method for FLPR

Results On Our Synthetic German LPs



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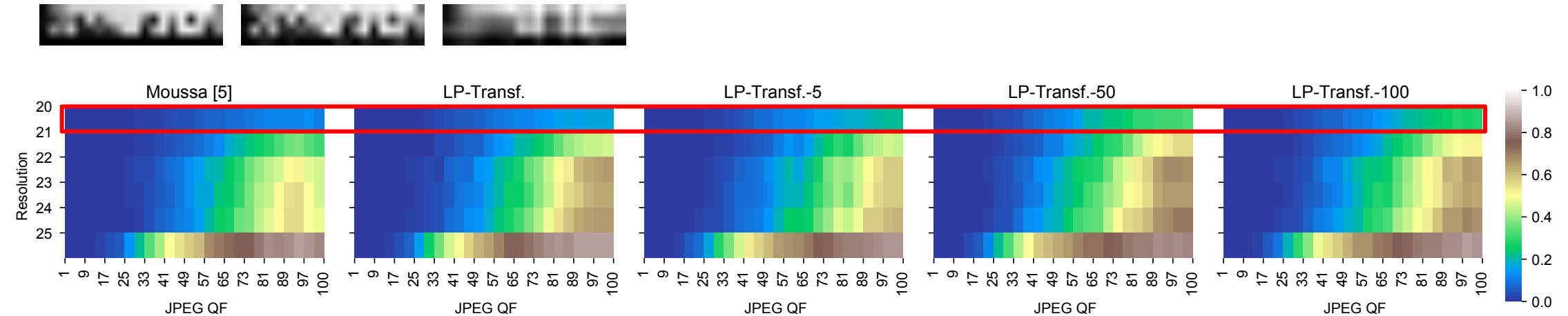


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1. Our models surpass the best baseline CRNN
2. Advantage increases with **decreasing** image quality
3. LP-Transf.-50 is best, e.g.:
 - **CRNN**: $\text{acc}_{\text{lp}} < 12\%$ for all $r_w = 20$
 - **LP-Transf.-50**: $\text{acc}_{\text{lp}} > 20\%$ for $r_w = 20$ and $\text{QF} \geq 61$

Ongoing Work

Driving Forward FLPR



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Exploiting more side information

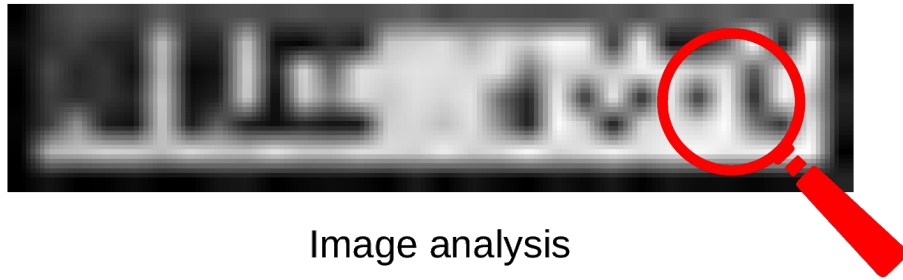
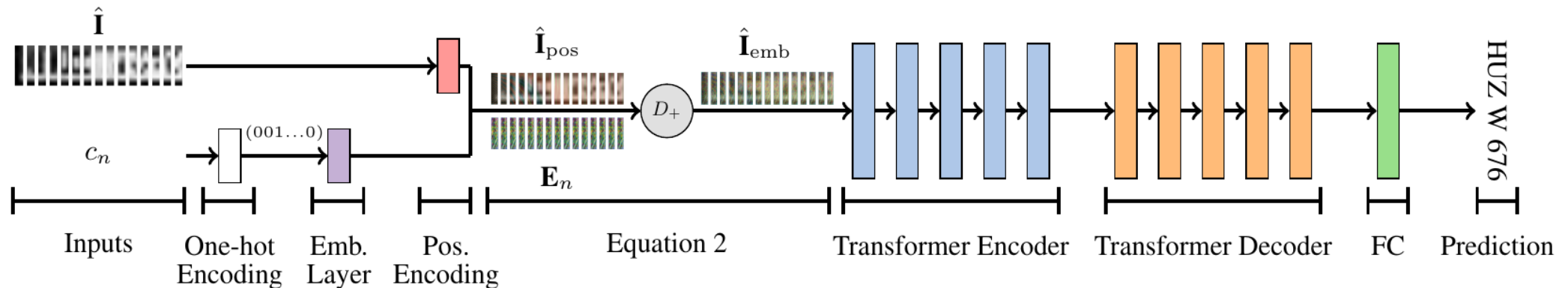


Image analysis

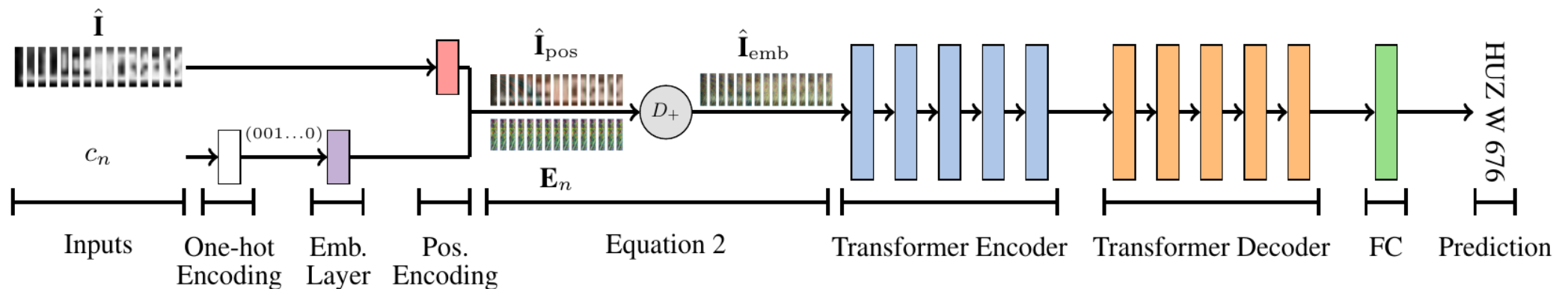
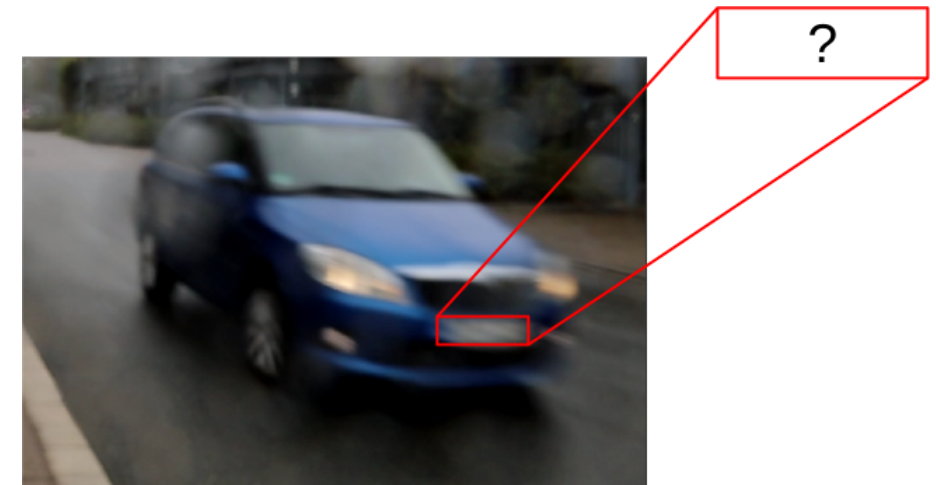
Exploiting more side information



Exploiting more side information



Acquisition of real world FLPR dataset



Conclusion

Forensic License Plate Recognition (FLPR)



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Contributions in a Nutshell

New SOTA method for FLPR

- Updated FLPR architecture: Transformer [6] sequence-to-sequence network
- Side Information Exploitation: Embedding of compression quality level in NN
⇒ better performance, less parameters



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Conclusion

Forensic License Plate Recognition (FLPR)

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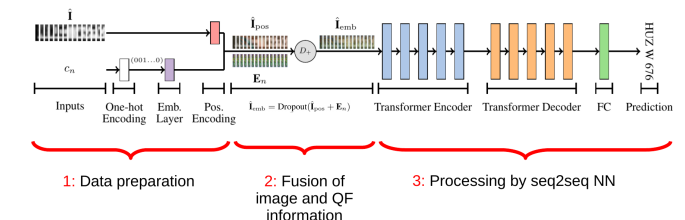
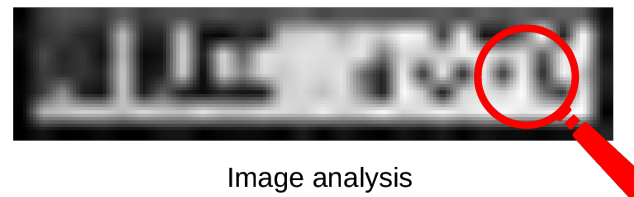
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Thank you for your attention! Any questions?

Contact: denise.moussa@fau.de

Code: <https://fau1-gitlab.cs.fau.de/denise.moussa/forensic-license-plate-transformer>



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- [1] S. Agarwal *et al.* “Deciphering Severely Degraded License Plates”. In: *Electronic Imaging 2017.7* (2017), pp. 138–143.
- [2] B. Lorch, S. Agarwal, and H. Farid. “Forensic Reconstruction of Severely Degraded License Plates”. In: *Electronic Imaging 2019.5* (2019), pp. 529–1–529–7.
- [3] P. Kaiser *et al.* “Learning to Decipher License Plates in Severely Degraded Images”. In: *Pattern Recognition. ICPR International Workshops and Challenges*. 2021, pp. 544–559.
- [4] D. Moussa *et al.* “Sequence-Based Recognition of License Plates with Severe Out-of-Distribution Degradations”. In: *International Conference on Computer Analysis of Images and Patterns*. 2021, pp. 175–185.
- [5] G. Rossi, M. Fontani, and S. Milani. “Neural Network for Denoising and Reading Degraded License Plates”. In: *International Conference on Pattern Recognition*. 2021, pp. 484–499.
- [6] A. Vaswani *et al.* “Attention Is All You Need”. In: *Advances in Neural Information Processing Systems*. 2017, pp. 5998–6008.
- [7] Independent JPEG Group. *Libjpeg*. <http://libjpeg.sourceforge.net/>. accessed: 2022-01-15.

- [8] D. Cozzolino and L. Verdoliva. “Noiseprint: a CNN-Based Camera Model Fingerprint”. In: *IEEE Transactions on Information Forensics and Security* 15 (2019). Implementation for JPEG QF Estimation, accessed 2021-11-01: <https://github.com/grip-unina/noiseprint/blob/afd0b8e7dd6c33a345ef9f09eb0b456cf0a28ee6/noiseprint/utility/utilityRead.py>, pp. 144–159.
- [9] J. Špaňhel *et al.* “Holistic Recognition of Low Quality License Plates by CNN Using Track Annotated Data”. In: *14th IEEE International Conference on Advanced Video and Signal Based Surveillance*. 2017, pp. 1–6.
- [10] BMVBS. *Verordnung über die Zulassung von Fahrzeugen zum Straßenverkehr*. 2011.