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MultiMedia FORensics in the WILD(MMForWILD) 2020

Neural Network for Denoising and Reading License Plates

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License Plates Reader

The first ANPR (**A**utomatic **N**umber **P**late **R**eader) was developed in 1976 in the UK.

The workflow follows these main operations:

- Improve image quality
- Localize the license plate
- Segment the characters
- Read the characters

ANPRs are used on videos produced by cameras designed to focus on license plates, unfortunately they do not work well on videos generated by CCTV cameras.

License Plates Reader

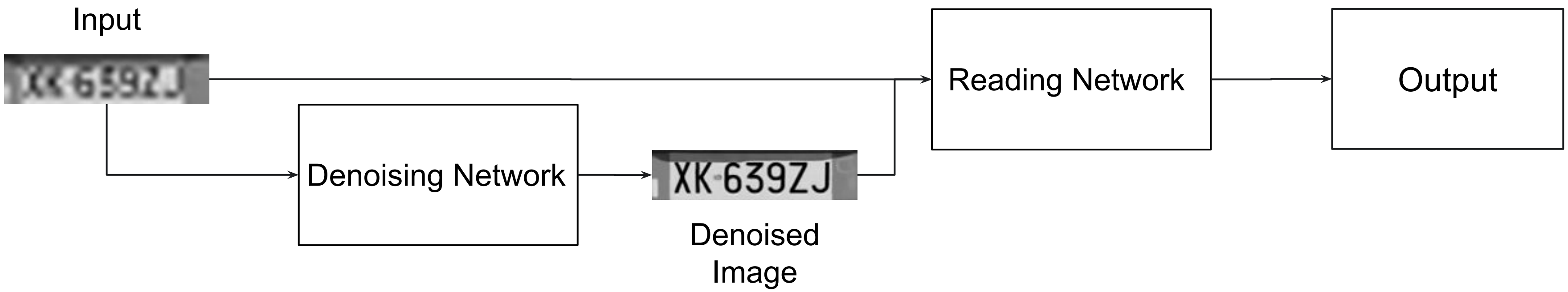
Many different approaches were used in the following years to improve the results of the ANPR.

Thanks to the research and study on the subject of Machine Learning it was possible to start using Deep Learning techniques to read degraded license plates.

This project was based on the work of Lorch et al.[1], where a Convolutional Neural Network is used to read the characters of a very degraded license plates.

[1] B. Lorch, S. Agarwal, and H. Farid, "Forensic Reconstruction of Severely Degraded License Plates," in Electronic Imaging, S.for Imaging Science & Technology, Ed., Jan 2019.

Objectives



Train a neural network on a synthetic dataset to be able to:

- Obtain a visually enhanced version of a degraded license plate
- Use the enhanced and original images to read the characters.

Define a synthetic dataset generation scheme, allowing generalization to different license plates patterns at little cost, avoid privacy issues over the license plates used.

Dataset

The neural network was trained on the current format of Italian license plates.

To make the license plates more realistic some transformations were applied to the synthetic images

- Random noise
- Shadow
- Crop

We had also generated a binary mask of the license plate to be used during the training of the denoising network.

Dataset

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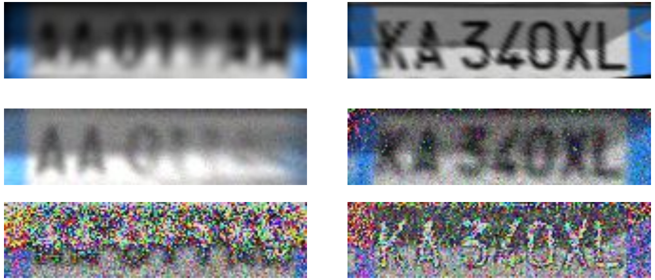
To simulate the different degradations we can have on a license plate (due to poor illumination, poor perspective, blur...) we added a combination of several transformations.

- Reduce the resolution
- Forward and backward perspective transformation with perturbed parameters
- Gaussian Blur
- Random Gaussian Noise



Dataset

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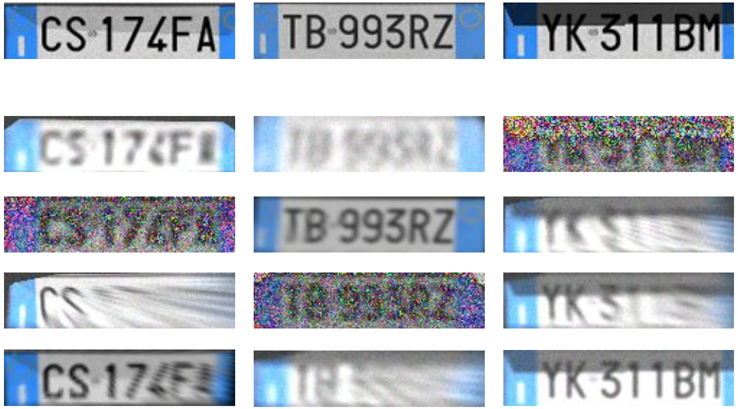
Training set



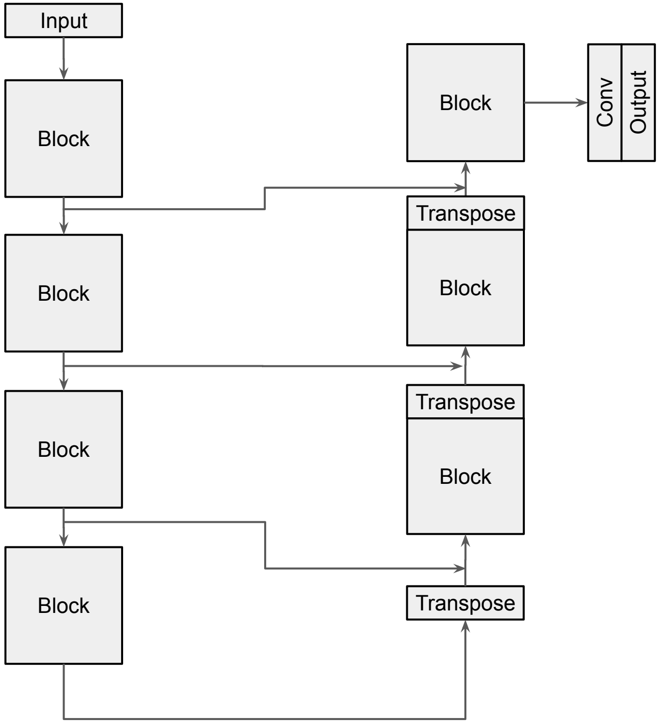
Test set

20000 synthetic license plates
~4M training images

884 real license plates
~170K test images

Denoising Network

It is based on the UNET architecture



Training parameters:
Batch size = 256
Optimizer = Adam
Learning rate = 0.05

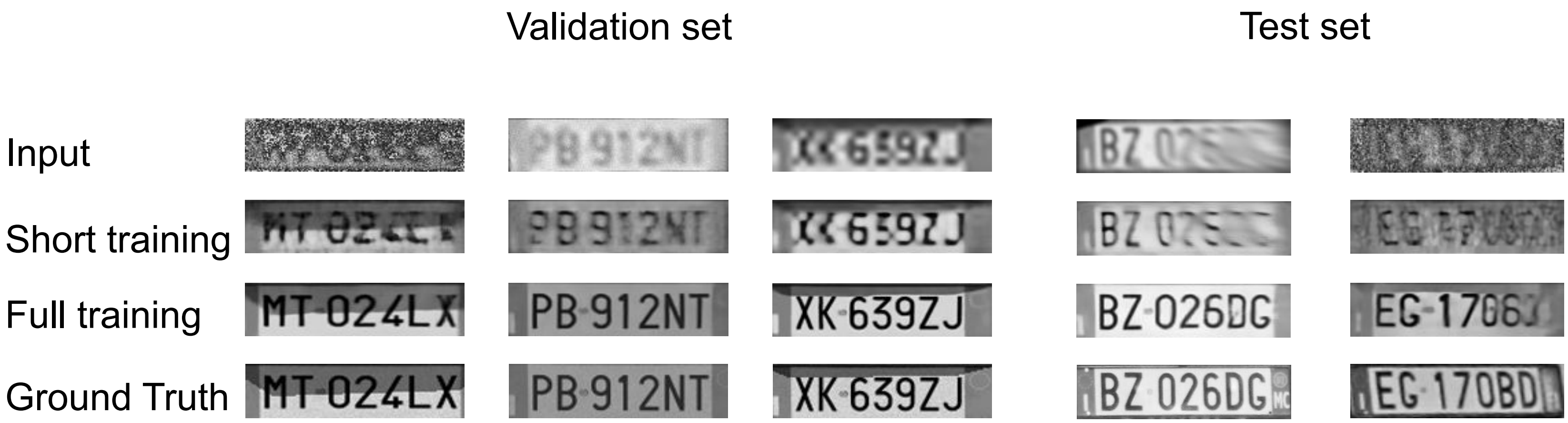
Loss function = sum of three intermediate losses:

$$\mathcal{L}_{MSE} = \frac{\sum_{i,j}(y_{i,j}^{true} - y_{i,j}^{pred})^2}{N}$$

$$\mathcal{L}_{wass} = 1 + \frac{\sum_{i,j}(y_{i,j}^{true} * y_{i,j}^{pred})}{N}$$

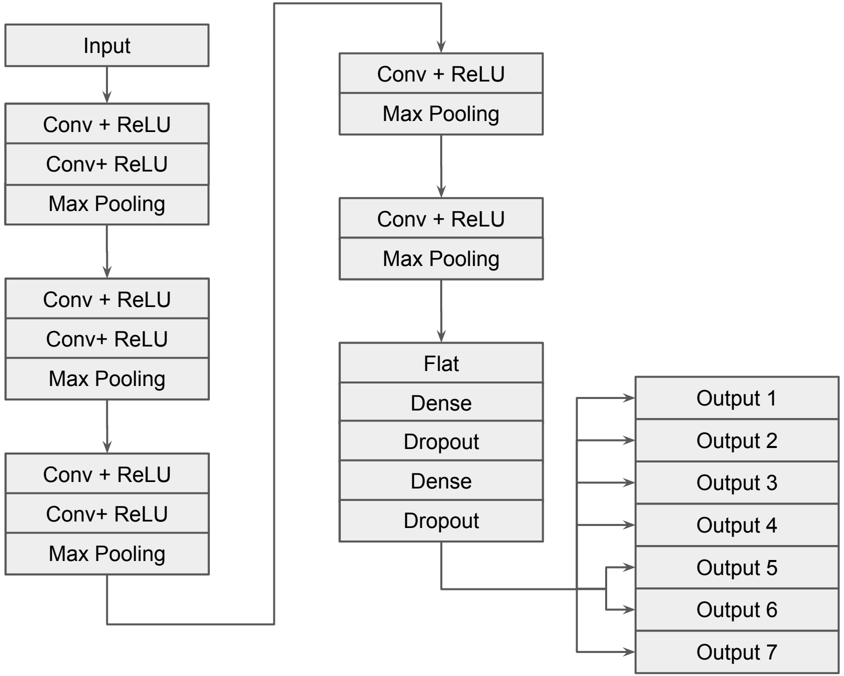
$$\mathcal{L}_{mask} = 1 + \frac{\sum_{i,j}(y_{i,j}^{pred} * \overline{y_{i,j}^{mask}})}{\sum_{i,j} \overline{y_{i,j}^{mask}}} - \frac{\sum_{i,j}(y_{i,j}^{pred} * y_{i,j}^{mask})}{\sum_{i,j} y_{i,j}^{mask}}$$

Denoising Network



Reading Network

It is based on the architecture by Lorch et al.[1]



Training parameters:
Batch size = 64
Optimizer = SGD
Learning rate = 0.05

We used both the denoised image and the original image because the Denoise network may have deleted some useful information from the the degraded image.

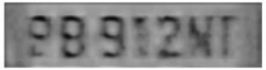
Loss Function = Sum of the binary cross-entropy losses.

[1] B. Lorch, S. Agarwal, and H. Farid, “Forensic Reconstruction of Severely Degraded License Plates,” in Electronic Imaging, S.for Imaging Science & Technology, Ed., Jan 2019.

Reading Network

Input Image

Ground Truth



Short train

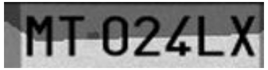
P	1.00000	B	1.00000	9	1.00000	1	1.00000	2	1.00000	N	1.00000	T	1.00000

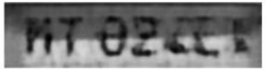
Long train

P	1.00000	B	1.00000	9	1.00000	1	1.00000	2	1.00000	N	1.00000	T	1.00000

Input Image

Ground Truth





Short train

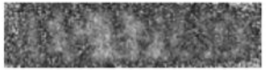
M	0.99996	T	0.99997	0	1.00000	2	1.00000	4	0.99998	L	0.99999	X	0.99099
Y	0.00002	Y	0.00003							E	0.00001	A	0.00893
												Y	0.00003
												L	0.00002

Long train

M	0.99972	T	0.99996	0	0.99955	2	1.00000	4	0.99999	L	0.99967	X	0.95971
N	0.00015	Y	0.00004	8	0.00034					A	0.00015	A	0.03777
R	0.00006			6	0.00008					C	0.00012	K	0.00088
H	0.00006									K	0.00003	Y	0.00059
F	0.00001									E	0.00001	C	0.00021
												V	0.00019
												J	0.00015
												W	0.00009
												N	0.00009
												G	0.00008

Reading Network

Input Image



Ground Truth

Short train

E	0.99997	G	0.92089	1	0.99980	7	0.99957	0	0.99298	B	0.74075	D	0.92044
F	0.00001	D	0.02757	0	0.00009	1	0.00015	1	0.00220	P	0.06166	Z	0.00943
		S	0.01890	5	0.00003	9	0.00011	3	0.00177	H	0.04738	J	0.00813
		F	0.01189	8	0.00002	2	0.00011	8	0.00098	D	0.03700	T	0.00734
		C	0.00831	3	0.00002	0	0.00003	2	0.00049	K	0.02712	L	0.00673
		W	0.00335	9	0.00002	3	0.00002	6	0.00041	R	0.02209	P	0.00661
		T	0.00225	6	0.00002			9	0.00038	E	0.01049	V	0.00618
		J	0.00138					4	0.00037	F	0.01026	B	0.00552
		B	0.00133					7	0.00029	S	0.00974	C	0.00422
		P	0.00131					5	0.00012	M	0.00748	G	0.00390

Long train

E	0.99983	G	0.99978	1	1.00000	7	0.99997	0	0.99625	E	0.51770	D	0.60310
G	0.00004	C	0.00008			3	0.00002	8	0.00325	B	0.15452	Z	0.18224
L	0.00003	S	0.00007					3	0.00020	N	0.07128	J	0.13710
K	0.00003	D	0.00003					9	0.00012	F	0.06928	L	0.02038
B	0.00002	W	0.00002					6	0.00009	H	0.05335	C	0.01375
N	0.00002							1	0.00004	S	0.05077	P	0.00722
F	0.00001							2	0.00002	R	0.02962	X	0.00622
S	0.00001							7	0.00002	P	0.01549	T	0.00576
										K	0.01368	B	0.00543
										D	0.01139	Y	0.00448

Input Image

Ground Truth

Short train

B	0.99990	Z	1.00000	0	1.00000	2	0.99997	6	0.99989	D	0.99892	G	0.99972
R	0.00009					7	0.00003	5	0.00010	Z	0.00072	C	0.00027
								8	0.00001	E	0.00018		
										B	0.00008		
										C	0.00004		
										L	0.00004		
										W	0.00001		

Long train

B	1.00000	Z	1.00000	0	1.00000	2	1.00000	6	1.00000	D	1.00000	G	0.99936
												C	0.00064

Results

	Average	position 1	position 2	position 3	position 4	position 5	position 6	position 7
TOP 1	**0.933**	0.930	0.943	0.962	0.960	0.952	0.920	0.867
TOP 3	**0.978**	0.973	0.985	0.991	0.991	0.989	0.970	0.946
TOP 5	**0.987**	0.984	0.992	0.995	0.996	0.995	0.980	0.965

Average accuracy on the test dataset using the proposed method.

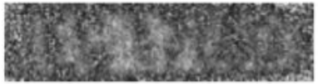
	Average	position 1	position 2	position 3	position 4	position 5	position 6	position 7
TOP 1	**0.932**	0.930	0.927	0.973	0.967	0.957	0.913	0.857
TOP 3	**0.979**	0.974	0.987	0.992	0.993	0.990	0.971	0.945
TOP 5	**0.988**	0.986	0.993	0.996	0.997	0.996	0.981	0.964

Average accuracy on the test dataset using Lorch’s network.

Results

	Average	position 1	position 2	position 3	position 4	position 5	position 6	position 7
TOP 1	**0.933**	0.930						
TOP 3	**0.978**	0.973						
TOP 5	**0.987**	0.984						

Average accuracy on the test c



E	0.99997	G	0.92089	1	0.99980	7	0.99957	0	0.99298	B	0.74075	D	0.92044
F	0.00001	D	0.02757	0	0.00009	1	0.00015	1	0.00220	P	0.06166	Z	0.00943
		S	0.01890	5	0.00003	9	0.00011	3	0.00177	H	0.04738	J	0.00813
		F	0.01189	8	0.00002	2	0.00011	8	0.00098	D	0.03700	T	0.00734
		C	0.00831	3	0.00002	0	0.00003	2	0.00049	K	0.02712	L	0.00673
		W	0.00335	9	0.00002	3	0.00002	6	0.00041	R	0.02209	P	0.00661
		T	0.00225	6	0.00002			9	0.00038	E	0.01049	V	0.00618
		J	0.00138					4	0.00037	F	0.01026	B	0.00552
		B	0.00133					7	0.00029	S	0.00974	C	0.00422
		P	0.00131					5	0.00012	M	0.00748	G	0.00390

We can cross check the results

	Average	position 1	position 2	position 3	position 4	position 5	position 6	position 7
TOP 1	**0.932**	0.930						
TOP 3	**0.979**	0.974						
TOP 5	**0.988**	0.986						

E	0.99983	G	0.99978	1	1.00000	7	0.99997	0	0.99625	E	0.51770	D	0.60310
G	0.00004	C	0.00008			3	0.00002	8	0.00325	B	0.15452	[illegible]	0.18224
L	0.00003	S	0.00007					3	0.00020	N	0.07128	J	0.13710
K	0.00003	D	0.00003					9	0.00012	F	0.06928	L	0.02038
B	0.00002	W	0.00002					6	0.00009	H	0.05335	C	0.01375
N	0.00002							1	0.00004	S	0.05077	P	0.00722
F	0.00001							2	0.00002	R	0.02962	X	0.00622
S	0.00001							7	0.00002	P	0.01549	T	0.00576
										K	0.01368	B	0.00543
										D	0.01139	Y	0.00448

Average accuracy on the test c

Results

Original

Ground Truth: CL444TR

Conservative approach

Short train

C	0.66964	C	0.48764	4	0.99788	4	0.99674	4	0.96664	T	0.99990	R	0.99657
E	0.21829	L	0.38758	8	0.00084	5	0.00156	2	0.01864	Y	0.00005	T	0.00063
L	0.05927	D	0.06431	0	0.00025	3	0.00051	9	0.00895	S	0.00002	V	0.00057
D	0.04129	T	0.02433	6	0.00024	6	0.00037	3	0.00230			X	0.00049
T	0.00475	E	0.01192	9	0.00020	0	0.00037	7	0.00170			K	0.00047
F	0.00168	G	0.00499	2	0.00015	2	0.00023	0	0.00075			P	0.00046
W	0.00126	W	0.00442	1	0.00015	9	0.00011	8	0.00036			B	0.00018
K	0.00089	R	0.00306	7	0.00015	1	0.00005	1	0.00031			S	0.00013
G	0.00062	J	0.00194	5	0.00011	7	0.00004	6	0.00017			H	0.00011
Z	0.00060	Z	0.00147	3	0.00002	8	0.00002	5	0.00015			M	0.00009

Aggressive approach

Long train

C	0.92070	L	0.87751	4	0.99998	4	0.99984	4	0.92828	T	0.99931	R	0.99536
D	0.03677	C	0.06415			2	0.00005	2	0.05228	Y	0.00039	B	0.00157
G	0.03305	D	0.01914			7	0.00003	0	0.00479	F	0.00009	K	0.00143
E	0.00322	T	0.00969			1	0.00002	3	0.00462	J	0.00007	H	0.00037
S	0.00229	E	0.00585			8	0.00002	8	0.00362	A	0.00004	P	0.00032
L	0.00168	J	0.00319			3	0.00001	7	0.00300	V	0.00002	X	0.00020
Z	0.00074	G	0.00267			5	0.00001	1	0.00229	S	0.00002	N	0.00019
K	0.00060	Y	0.00263					6	0.00047	H	0.00002	V	0.00014
M	0.00040	W	0.00261					5	0.00027	P	0.00001	M	0.00010
R	0.00012	A	0.00253					9	0.00026	Z	0.00001	A	0.00008

Original

Ground Truth: DS792HM

Conservative approach

Short train

D	0.99855	S	0.79219	7	0.55779	9	0.95550	2	0.99971	H	0.76853	M	0.90692
W	0.00072	L	0.12418	4	0.19767	5	0.04056	7	0.00015	W	0.11752	H	0.06259
J	0.00055	E	0.02985	8	0.06946	6	0.00230	3	0.00007	B	0.06831	N	0.00597
B	0.00005	F	0.01731	1	0.04773	3	0.00074	0	0.00002	J	0.01075	Y	0.00473
C	0.00003	Y	0.01373	3	0.03993	0	0.00036	9	0.00002	V	0.01018	T	0.00452
G	0.00003	C	0.00414	9	0.03763	1	0.00031			A	0.00688	D	0.00415
P	0.00002	J	0.00405	6	0.02091	8	0.00011			L	0.00653	P	0.00408
R	0.00001	D	0.00345	0	0.01787	7	0.00007			D	0.00437	V	0.00186
T	0.00001	V	0.00191	5	0.00457					N	0.00307	F	0.00148
S	0.00001	T	0.00161	2	0.00251					P	0.00147	R	0.00100

Aggressive approach

Long train

D	0.99500	S	0.98017	7	0.97015	9	0.99908	2	0.99989	H	0.93322	M	0.41134
W	0.00360	B	0.00703	3	0.00882	5	0.00053	0	0.00008	W	0.01396	H	0.35818
B	0.00045	J	0.00308	4	0.00744	3	0.00015	4	0.00002	V	0.01179	R	0.08277
J	0.00045	D	0.00305	1	0.00585	1	0.00011			B	0.00963	N	0.03312
S	0.00012	A	0.00186	0	0.00317	8	0.00010			J	0.00628	P	0.02163
L	0.00011	P	0.00101	8	0.00132	7	0.00001			N	0.00589	F	0.02155
G	0.00009	G	0.00080	9	0.00116					A	0.00475	D	0.01819
Z	0.00005	V	0.00079	2	0.00110					R	0.00456	B	0.01109
M	0.00005	W	0.00051	6	0.00056					K	0.00259	T	0.00786
H	0.00003	N	0.00043	5	0.00039					F	0.00206	S	0.00589

Conclusions

The architecture gives us good results, but there is still room for improvements.

We want to:

- further develop the transformations used for the degradation of the synthetic license plates
- train the neural network on other countries' license plates

The final results, even if promising, should not be used as evidence, but merely as a clue to help investigators when they can not identify vehicles with more traditional and reliable methods.

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