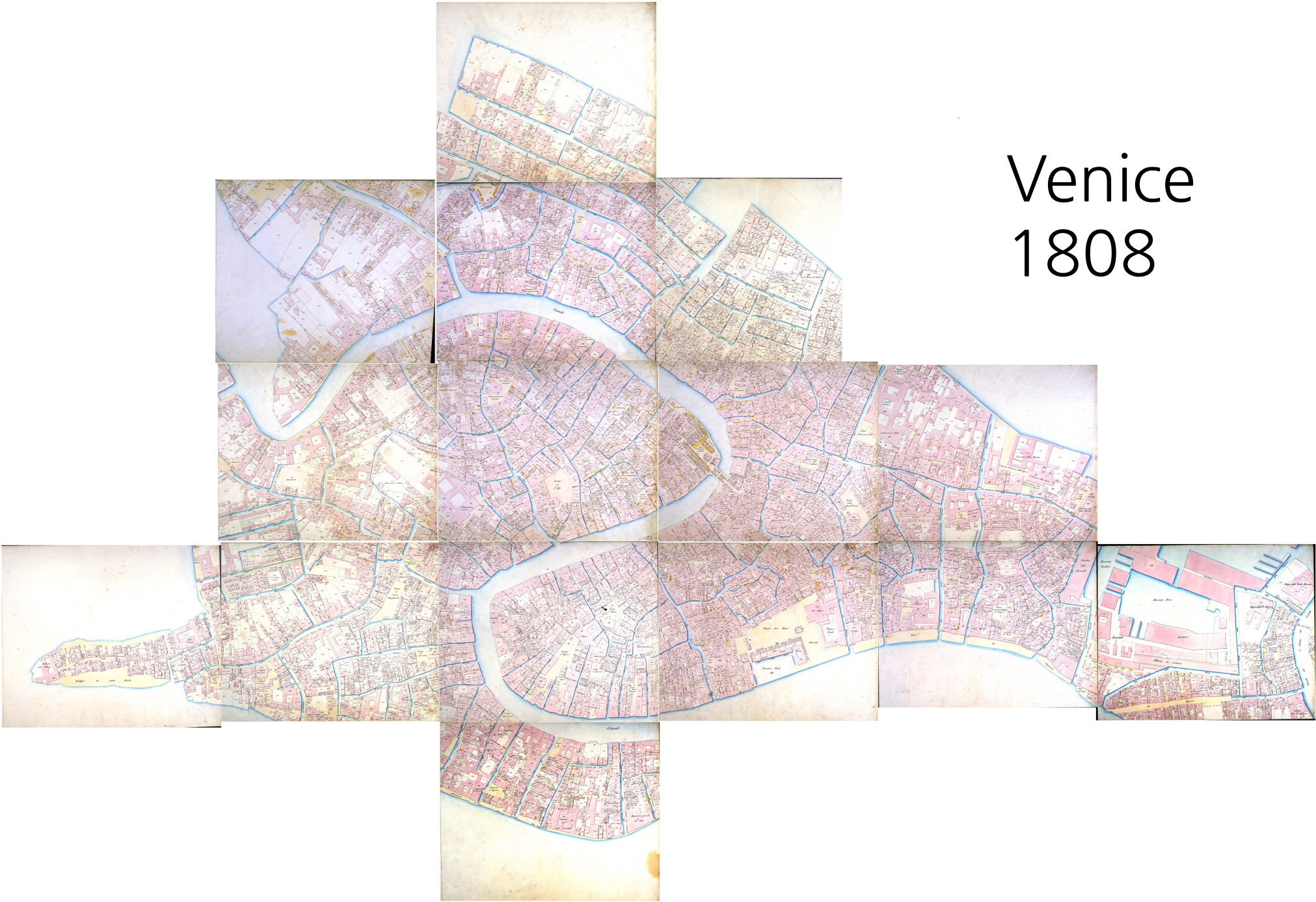


Machine vision algorithms on cadaster maps

Sofia Ares Oliveira

Venice 1808





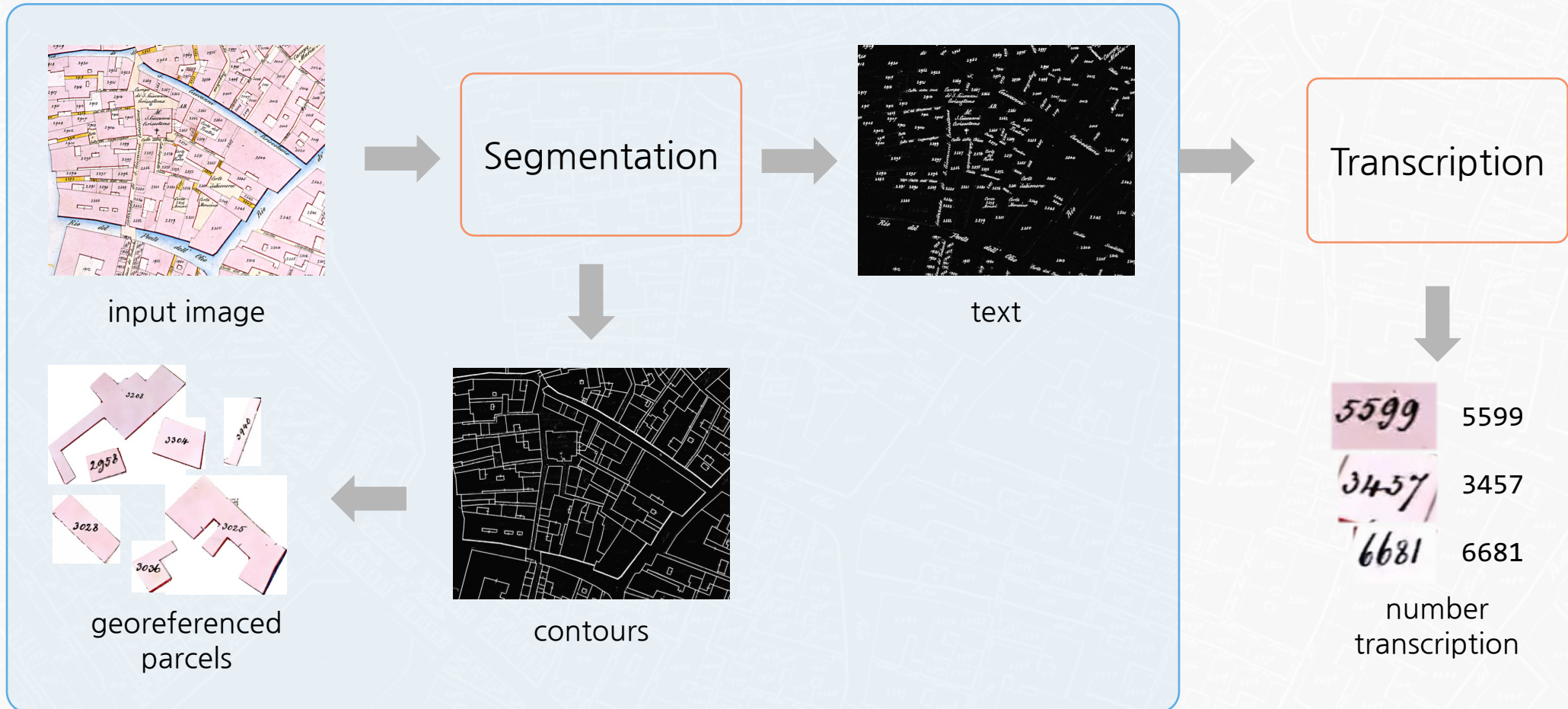
Numeri della Mappa	POSSessori	Denominazione dei Pezzi di terra	QUALITÀ		SUPERFICIE	
			Classe	Pertiche Censuarie	Centesimi	
		Porte di Rialto				
9001	Trimani	30				
9002	Marcello Marino q. ^o Guido	29	C.S.			
9003	Venier Bro' Serolamo q. ^o Pio: Batta	28	C.S.			
9004	Suddetto	27	C.S.			
9005	Marconi Giuseppe q. ^o Ant. ^o	26	C.S.			
9006	Raspi Fran. ^o q. ^o Pio: Maria	25	C.S.			
9007	Besenti Andrea q. ^o	4885	C.S.			
9008	Morosini Ant. ^o di Vincenzo Dolfin Luigi q. ^o Dolfin Marcant. ^o q. ^o Ferracina Niccolò q. ^o Betrogalli Pius. ^o q. ^o Berganti Pius. ^o q. ^o Dolfin Marianna q. ^o Cognepori indivisi	1580	C.S.			
9009	Maruzzi Costantino q. ^o Canno	4579	C.S.			
9010	Dolfin Leonardo q. ^o Bro'	4578	C.S.			
9011	Venier Serolamo q. ^o Pio: Batta	4577	C.S.			
9012	Erceli del fu Carlo Emilio Canal q. ^o Serolamo. Balbi Canal Mattia Ant. ^o Vedo va del fu Cristoforo Cognepori indivisi	4577	C.S.			
9013	Maruzzi Costantino q. ^o Canno	4587	C.S.			
9014	Correr Marcello Maria q. ^o Bro'	4586	C.S.			
9015	Zabio Fran. ^o q. ^o Canto Ant. ^o	4585	C.S.			
9016	Venier Bro' Serolamo q. ^o Pio: Batta	4584	C.S.			





Method

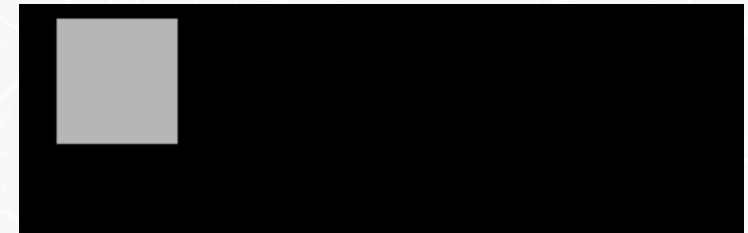
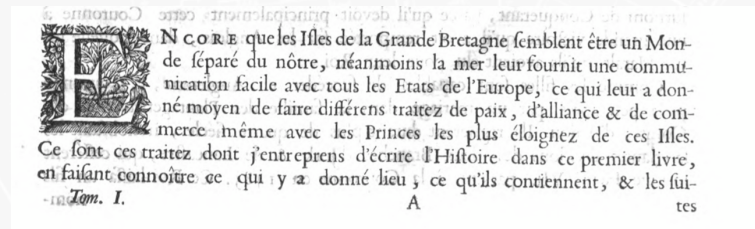
Overview of the system



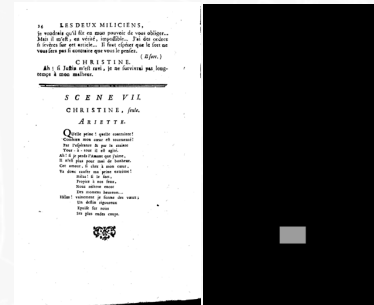
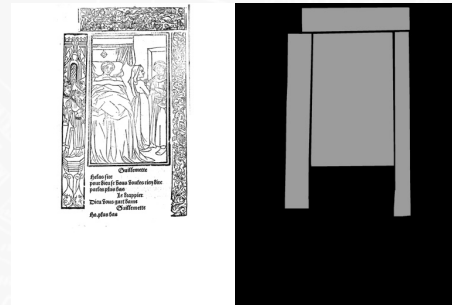
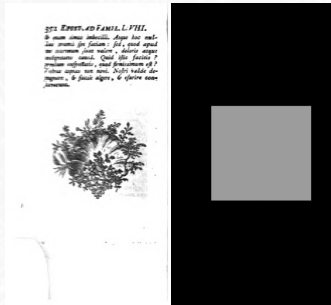
Segmentation

Deep learning pixel-wise segmentation

Assign to each pixel a label

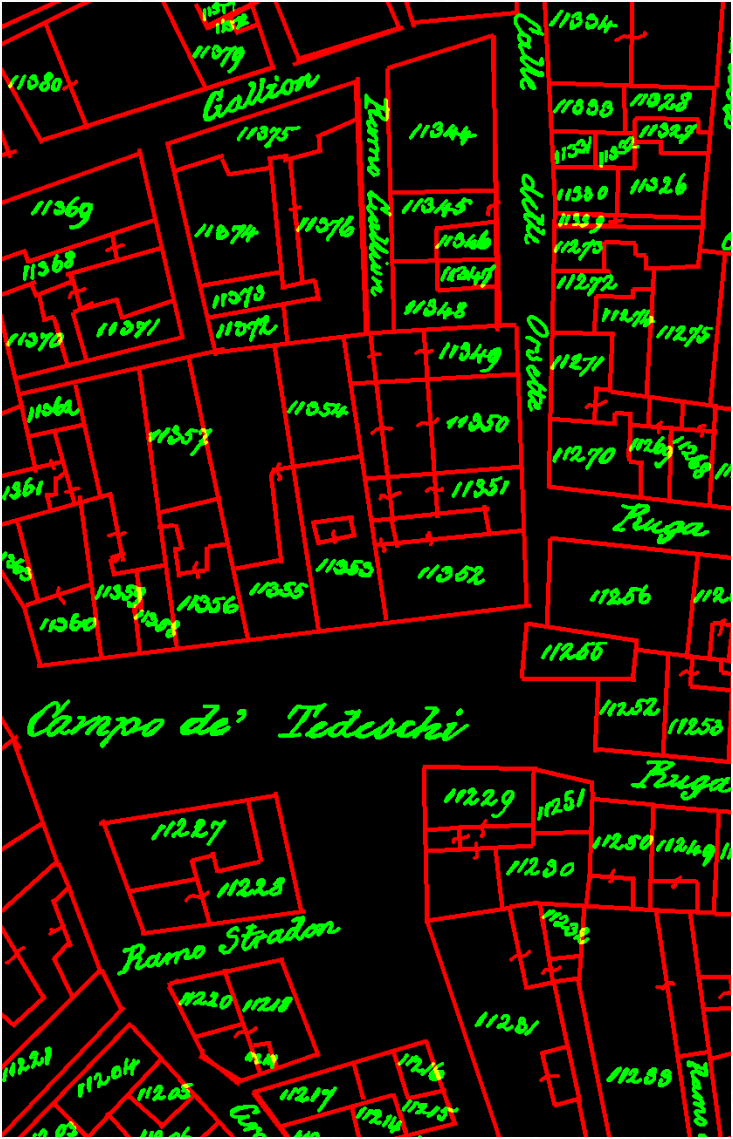


Train a neuronal network by showing several examples





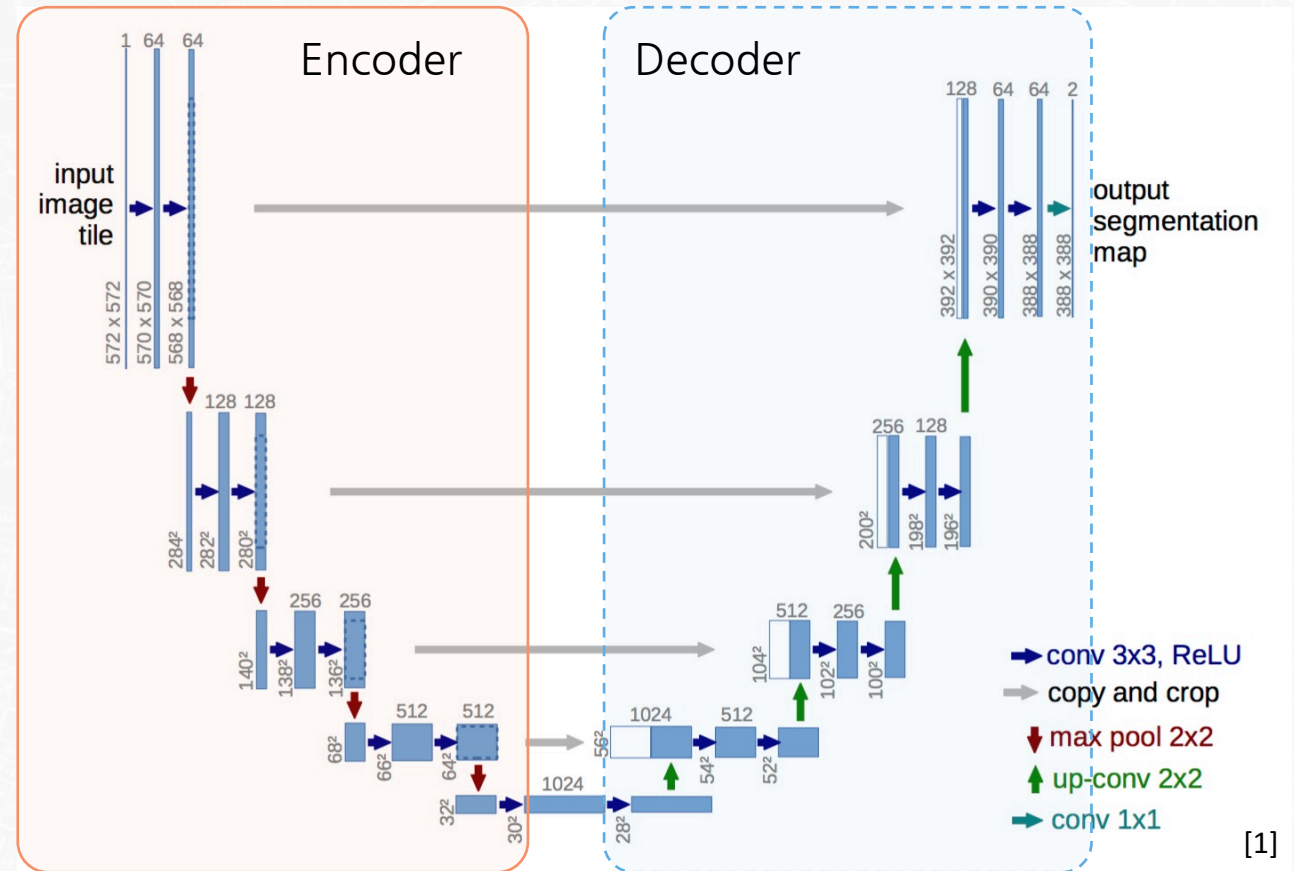
Data annotation
Pixel labelling



Architecture network

- Encoder is a pre-trained convolutional neural network
- Each encoding layer has a corresponding decoding layer

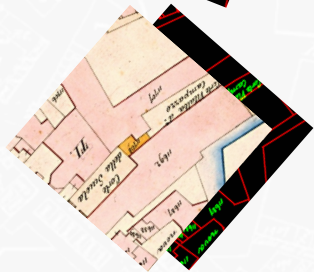
→ U-shaped architecture



[1] O. Ronneberger, P. Fischer, and T. Brox, "U-net: Convolutional networks for biomedical image segmentation", 2015

[2] V. Badrinarayanan, A. Kendall, and R. Cipolla, "Segnet: A deep convolutional encoder-decoder architecture for image segmentation", 2015

Training



Input {image, label}

data augmentation

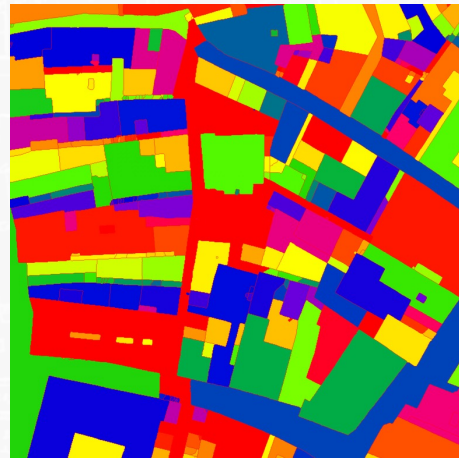
neural network

2-class prediction

Parcel extraction and georeferencing



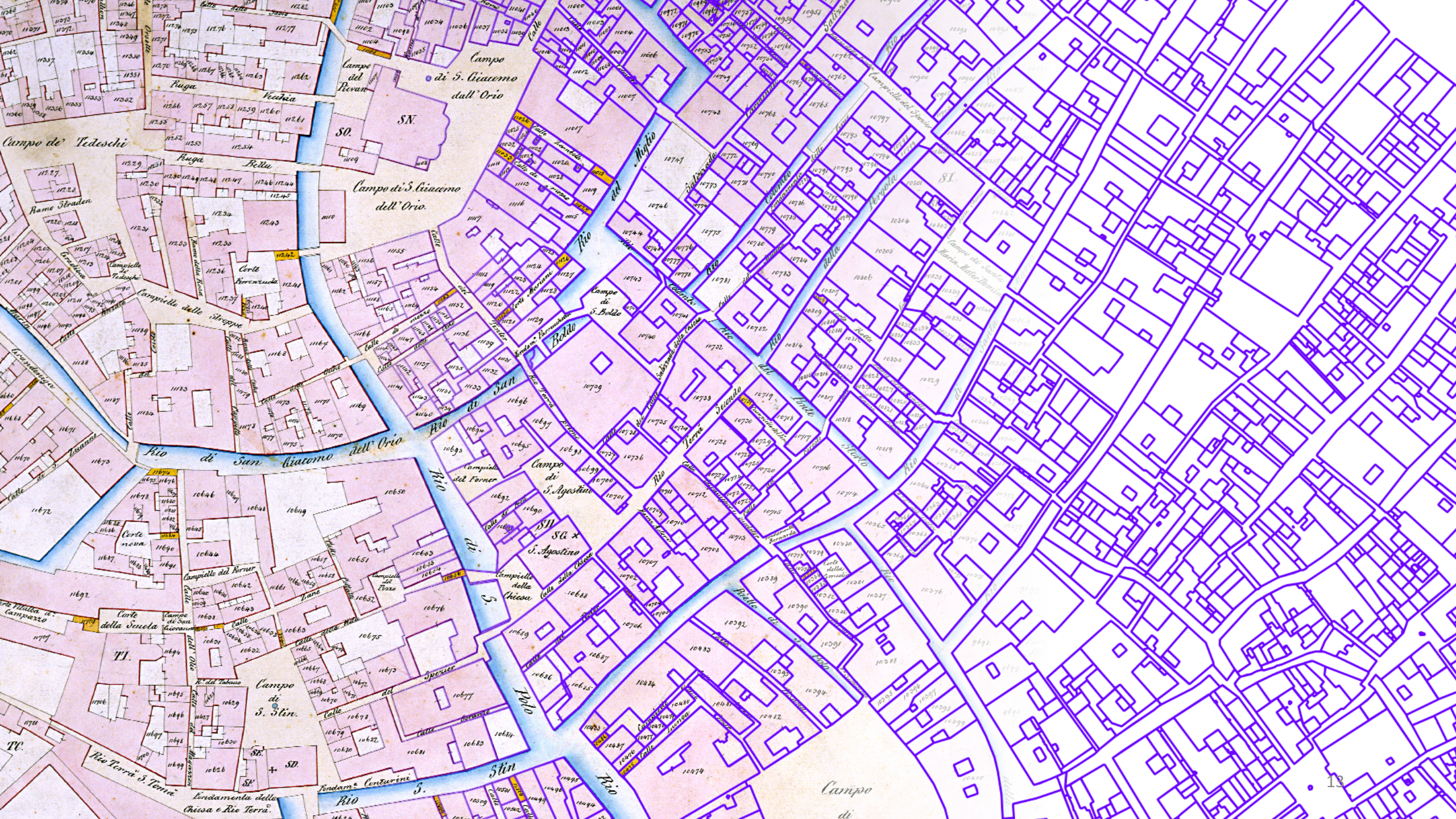
→
watershed



→
contour
extraction



If the image is georeferenced, the geographical coordinates are directly inferred and the parcels can be exported into a GIS system



Campo de' Tedeschi

Rame Straden

Campello delle Strozze

Corte nuova

Corte della Saicola

Rio Terra' S. Tomà

Campo di S. Giacomo dell'Orio

Campo di S. Giacomo dell'Orio

Campo di S. Agostino

Campo di S. Stan.

Fondamenta della Chiesa e Rio Terra'

Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

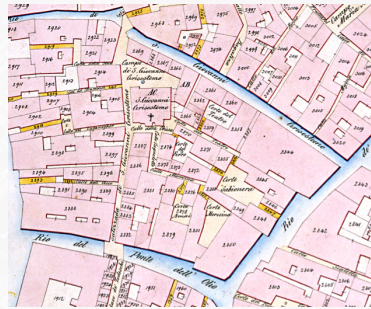
Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

Rio di San Giacomo dell'Orio

Pipeline



input image



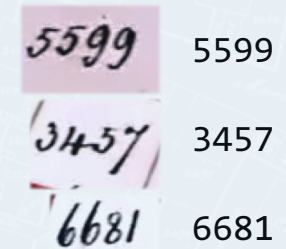
Segmentation



text



Transcription



number
transcription



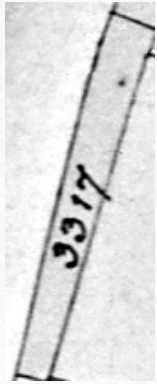
contours



georeferenced
parcels

Text extraction

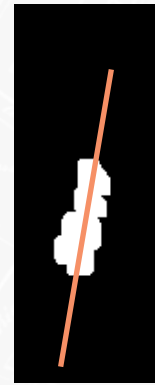
For each parcel, find its corresponding text region



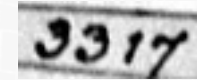
parcel
localization



text
probabilities



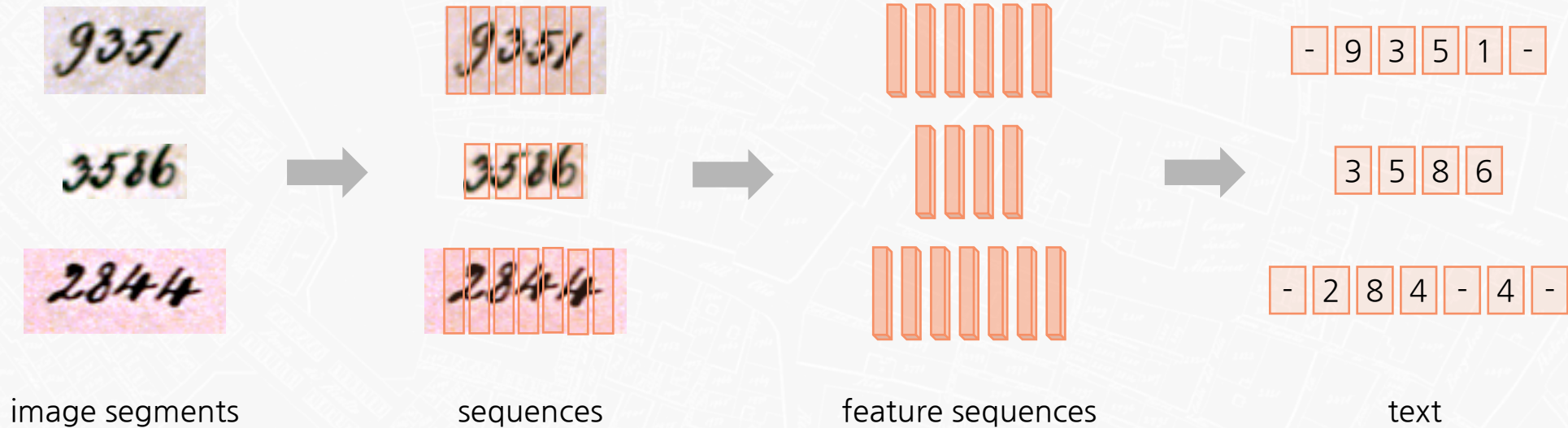
orientation
finding



rotation and
cropping

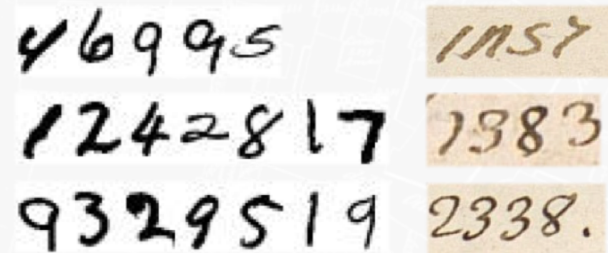
Transcription

Convert image segments into features sequences that will be mapped into text



Training data

- Synthetic data generated from MNIST dataset (100K)
- Handwritten numbers extracted from venetian archives (~ 30K)

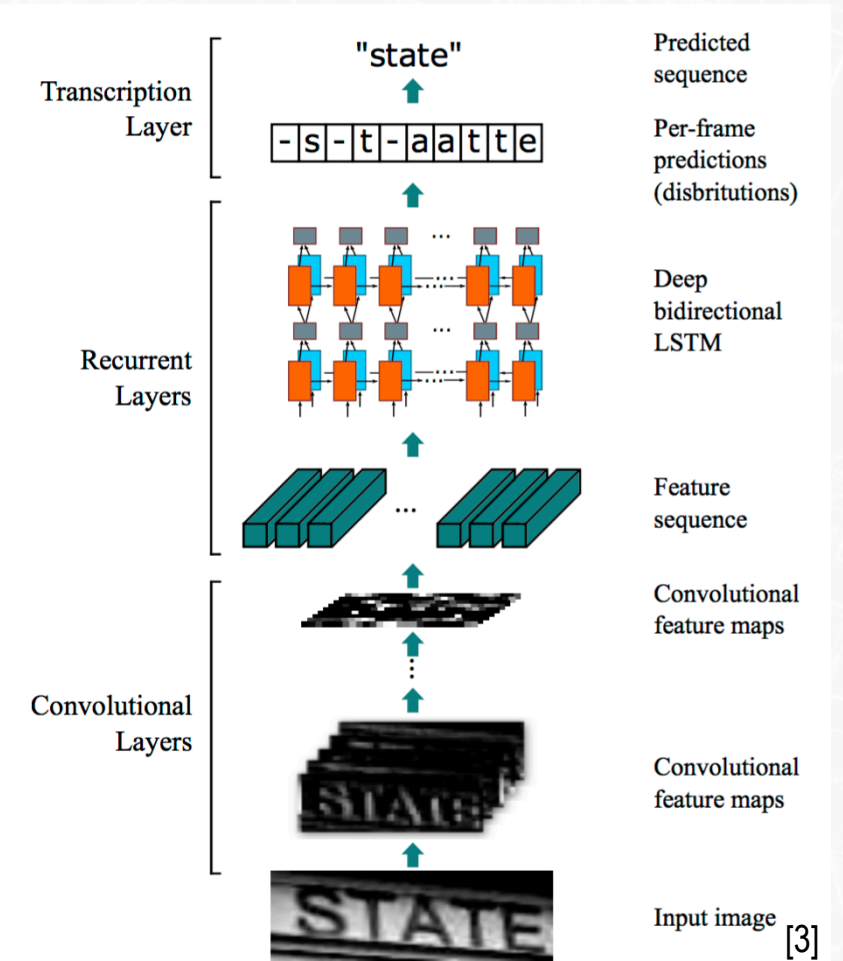


46995	1157
1242817	1383
9329519	2338.

+ data augmentation

Architecture network : CRNN

1. Convolutional neural network (CNN)
2. Recurrent neural network (RNN) with bidirectional Long Short-Term Memory (LSTM)
3. Mapping of separated time step labels to sequence label with connectionist temporal classification (CTC)



[3] B. Shi et al. "An end-to-end trainable neural network for image-based sequence recognition and its application to scene text recognition," 2017

[4] A. Graves, et al. "Connectionist temporal classification: labelling unsegmented sequence data with recurrent neural networks," 2016

Results

Parcel extraction results

IoU threshold	0.7	0.8	0.9
Parcel recall	0.90 (1062)	0.79 (941)	0.51 (605)
Parcel precision	0.50	0.44	0.28
Extracted parcels	2121		
Ground truth	1185		

$$recall = \frac{\text{true positives}}{\text{total ground truth}} \in [0, 1]$$

$$precision = \frac{\text{true positives}}{\text{total retrieved}} \in [0, 1]$$

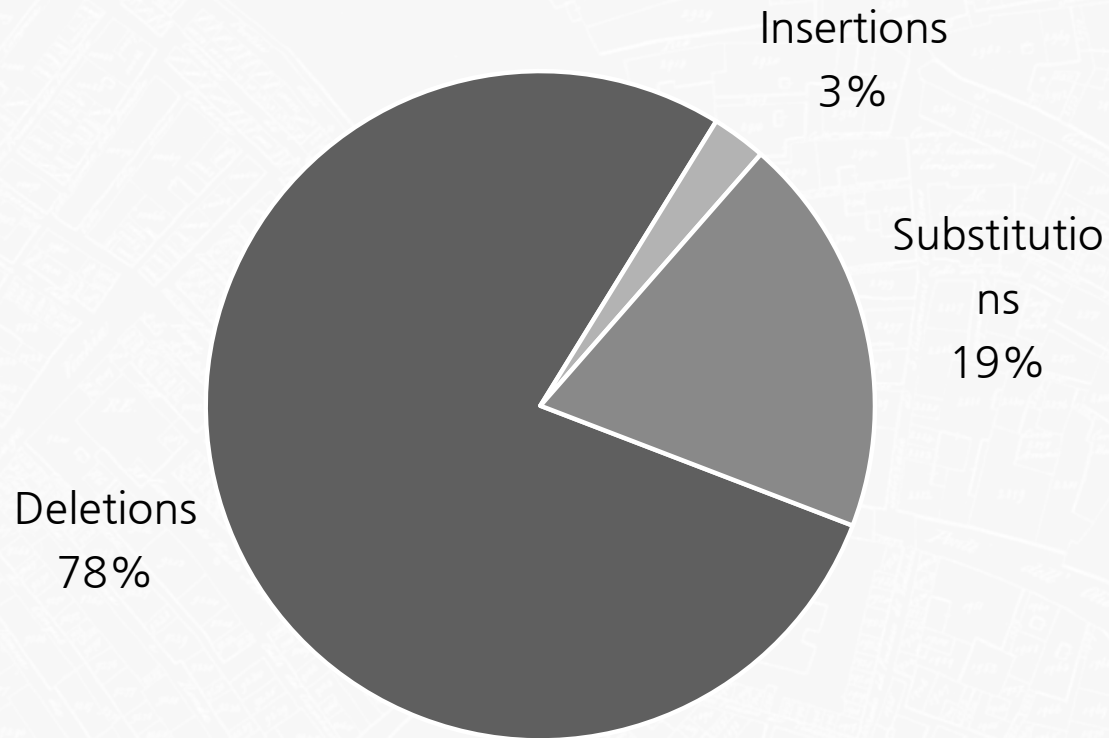
Label extraction and transcription results

Label locating	Inter : 0.8
Recall	0.86 (633)
Precision	0.37
Extracted labels	1693
Ground truth (labels)	736

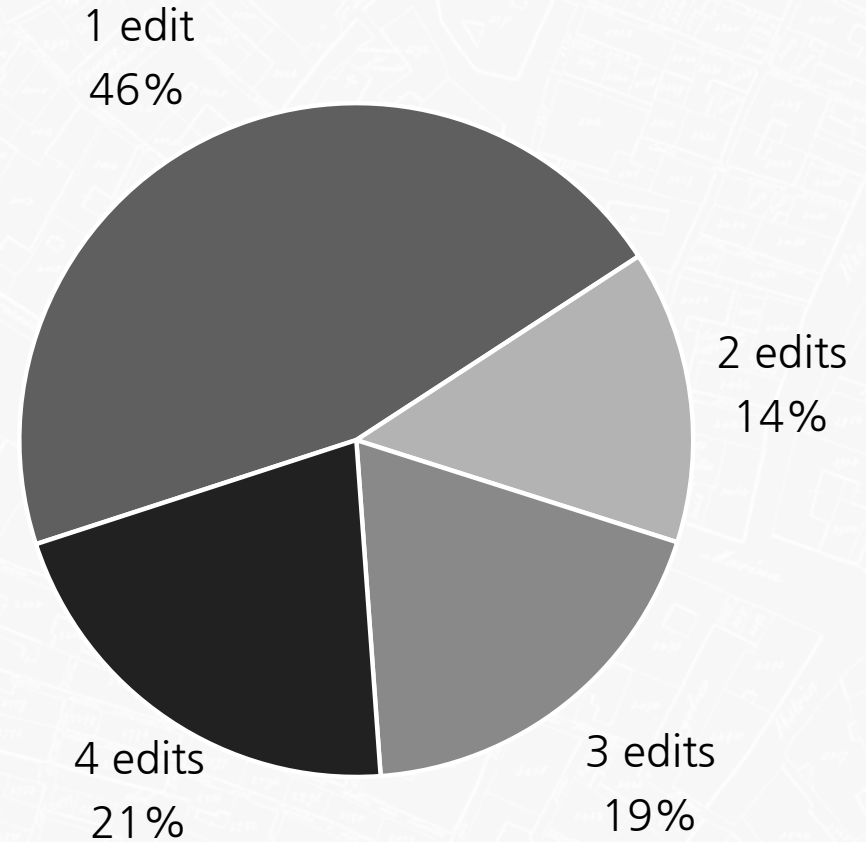
Label transcription	Inter : 0.8
Recall (correctly transcribed)	0.83 (608)
Precision	0.36
Character Error Rate (CER)	0.14
Ground truth (labels)	736

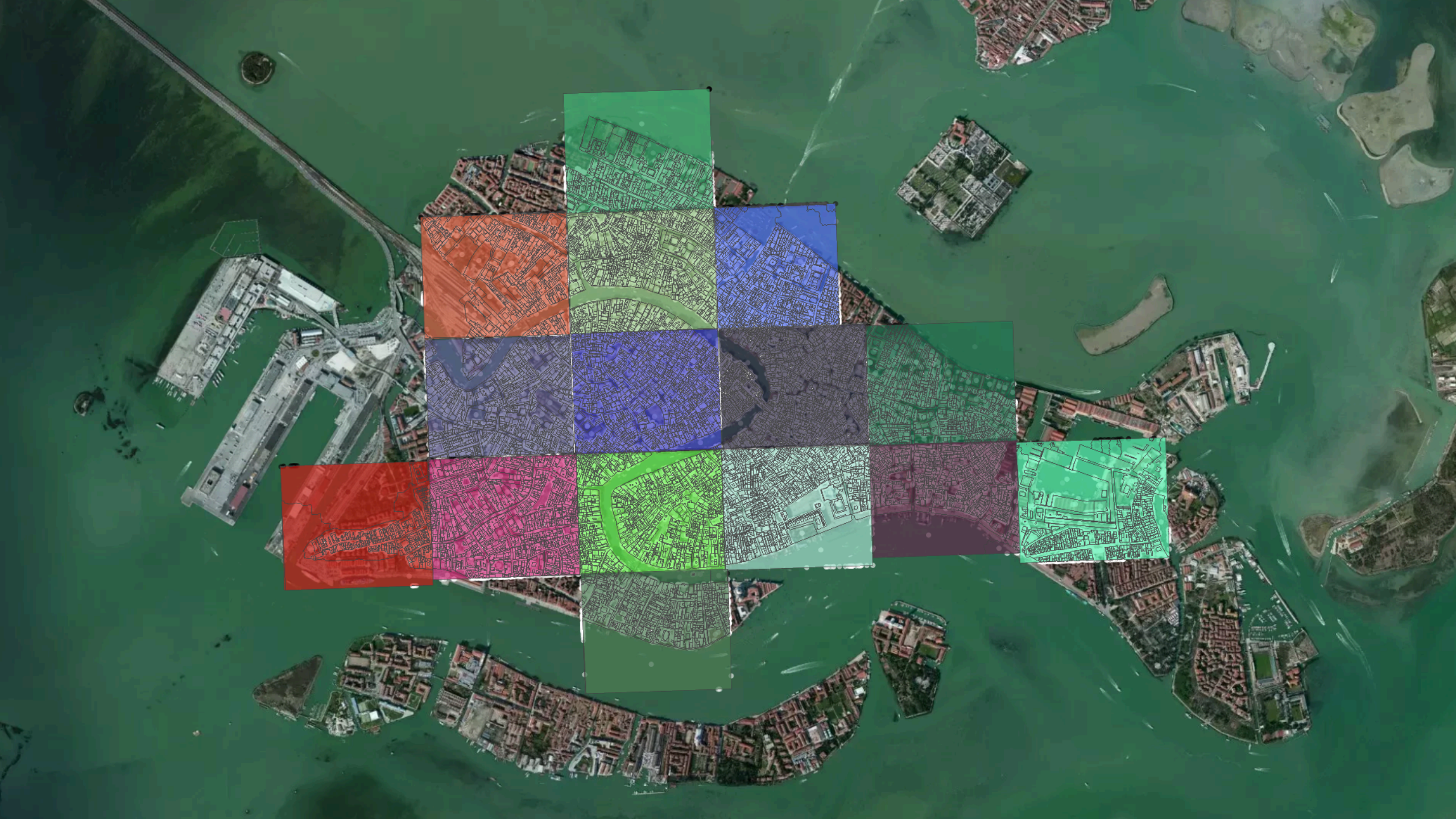
Label transcription: what are the errors ?

Type of errors



Edit distance





Conclusion

The system automatically extracts the parcels and their labels with high confidence level and opens new perspectives for spatial analysis in social, economic and urban structures.

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github.com/solivr

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1. RONNEBERGER, Olaf, FISCHER, Philipp, et BROX, Thomas. U-net: Convolutional networks for biomedical image segmentation. In : *International Conference on Medical Image Computing and Computer-Assisted Intervention*. Springer, Cham, 2015. p. 234-241.
2. BADRINARAYANAN, Vijay, KENDALL, Alex, et CIPOLLA, Roberto. Segnet: A deep convolutional encoder-decoder architecture for image segmentation. *arXiv preprint arXiv:1511.00561*, 2015.
3. SHI, Baoguang, BAI, Xiang, et YAO, Cong. An end-to-end trainable neural network for image-based sequence recognition and its application to scene text recognition. *IEEE transactions on pattern analysis and machine intelligence*, 2016.
4. GRAVES, Alex, FERNÁNDEZ, Santiago, GOMEZ, Faustino, *et al.* Connectionist temporal classification: labelling unsegmented sequence data with recurrent neural networks. In : *Proceedings of the 23rd international conference on Machine learning*. ACM, 2006. p. 369-376.