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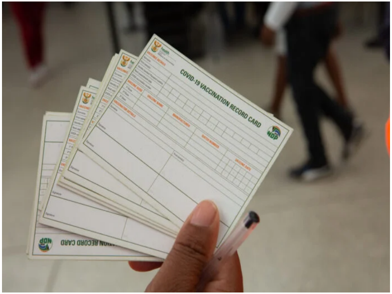
A framework for intelligent document image enhancement in pursuit of improved OCR performance

Ryno Kleinhans*
Supervisor: Dr GS Nel

SUnORE

Stellenbosch Unit for Operations Research in Engineering
Department of Industrial Engineering

Overview of the problem - Paper-based documents



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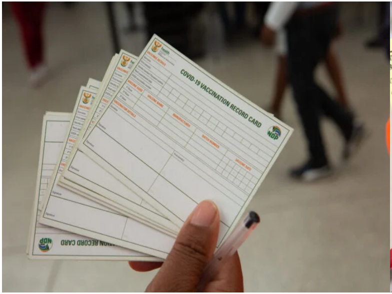

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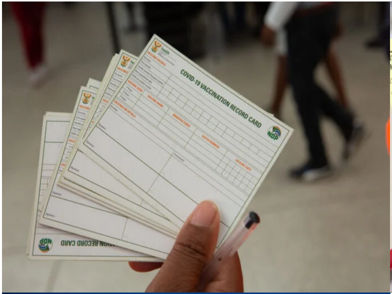

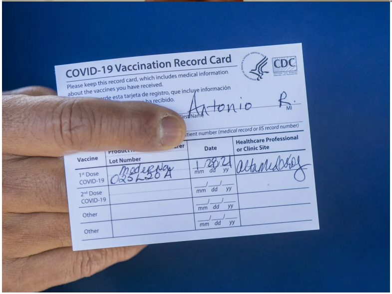

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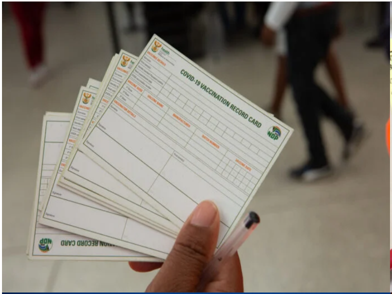

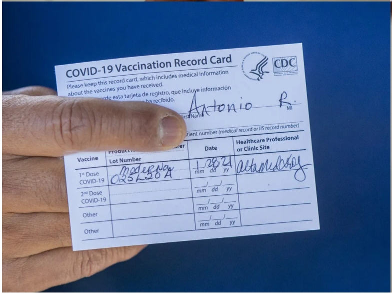

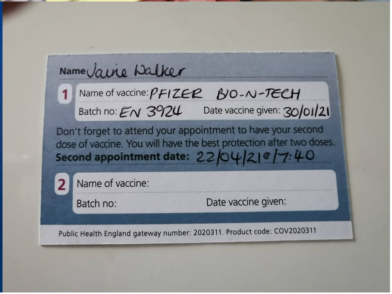

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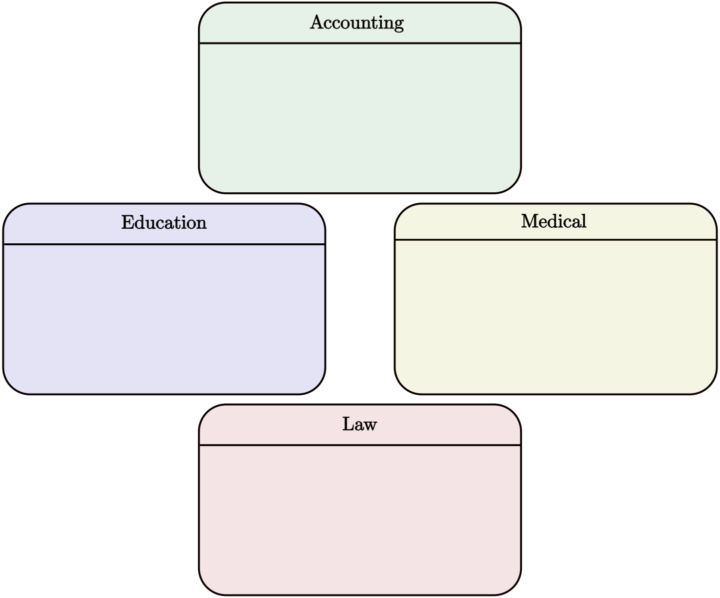

Overview of the problem - Paper-based documents

Accounting

- Single accountant prints 432 sheets of paper yearly
- 0.57 billion pages yearly (USA)
- Application forms, balance sheets, payslips, receipts

Education

Medical

Law

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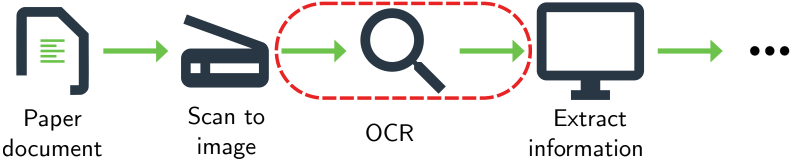
Law

- Single attorney prints 60 000 sheets of paper yearly
- 78 billion pages yearly (USA)
- Contracts, administrative documents, letters

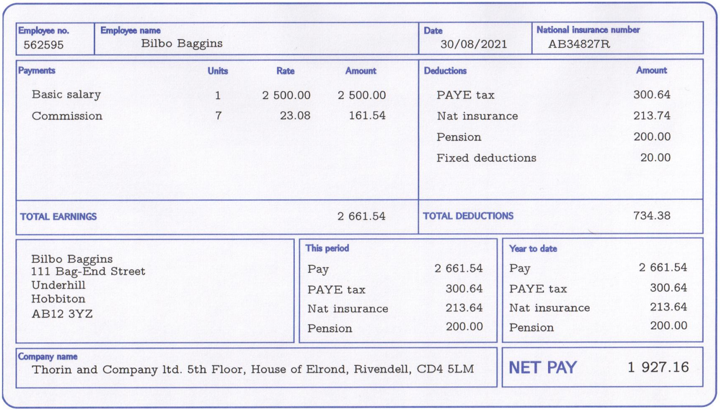
Overview of the problem - Automation example

OCR definition

Optical character recognition (OCR) is the electronic conversion of pixel-based text data (*i.e.* a captured image) comprising typed, handwritten or printed text into machine-encoded text.



Overview of the problem - Image processing



Employee no.	Employee name	Date	National insurance number
562595	Bilbo Baggins	30/08/2021	AB34827R

Payments	Units	Rate	Amount
Basic salary	1	2 500.00	2 500.00
Commission	7	23.08	161.54
TOTAL EARNINGS			2 661.54

Deductions	Amount
PAYE tax	300.64
Nat insurance	213.74
Pension	200.00
Fixed deductions	20.00
TOTAL DEDUCTIONS	734.38

Bilbo Baggins
111 Bag-End Street
Underhill
Hobbiton
AB12 3YZ

This period	
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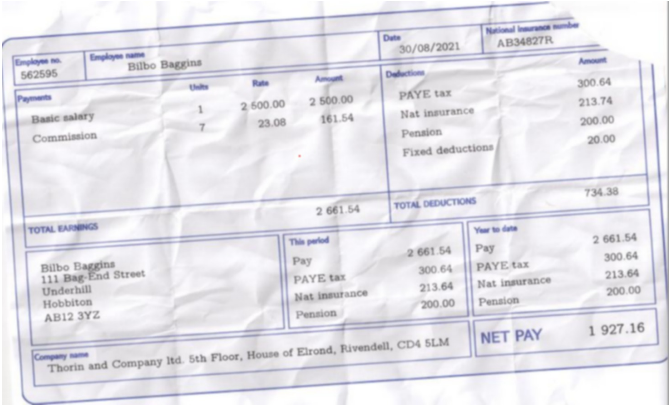
Company name
Thorin and Company ltd. 5th Floor, House of Elrond, Rivendell, CD4 5LM

NET PAY 1 927.16



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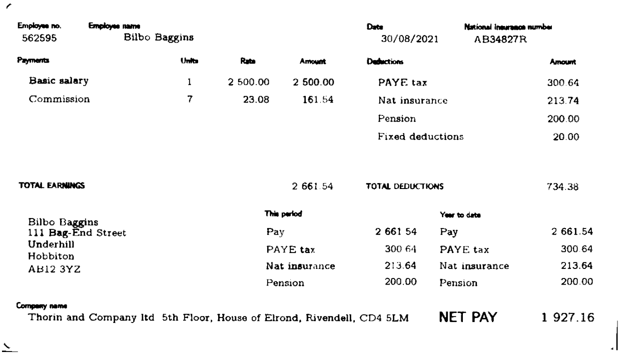

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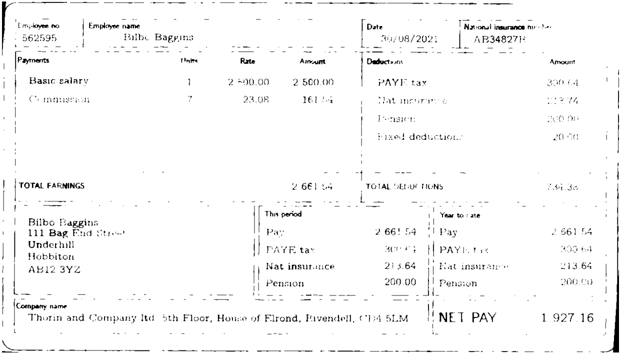

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Agenda

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1. Informal problem description

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2. Proposed framework walk-through

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3. Real-world payslip case study

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5. Future work

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  - Common document image enhancement techniques

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1. The **preparation** of previously annotated data and its document images for analysis,

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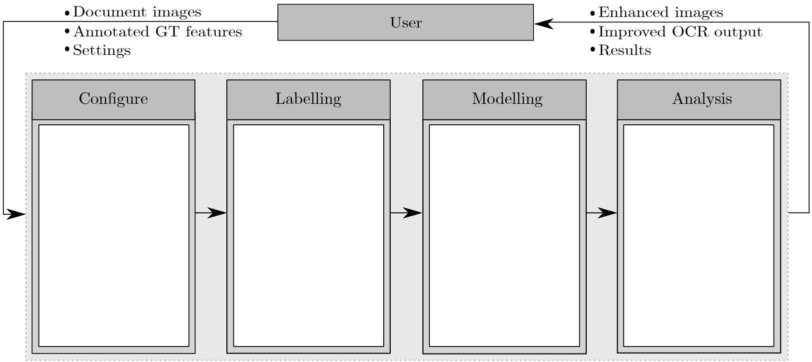
3. the **prediction** of the best enhancement procedure for each unique unseen document image,
4. as well as the **implementation** and **analysis** of the predictions.

Proposed framework - Subcomponents



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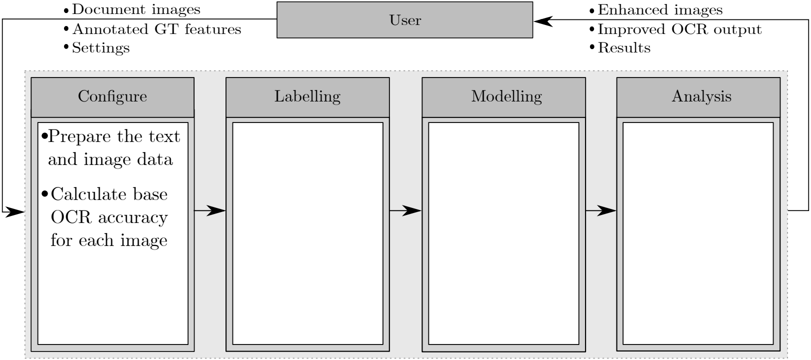

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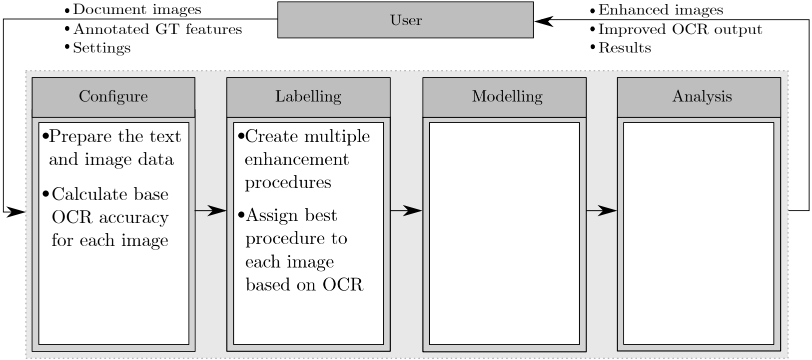

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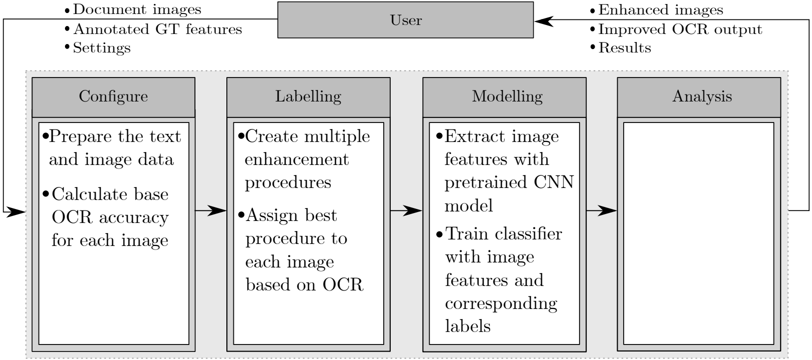

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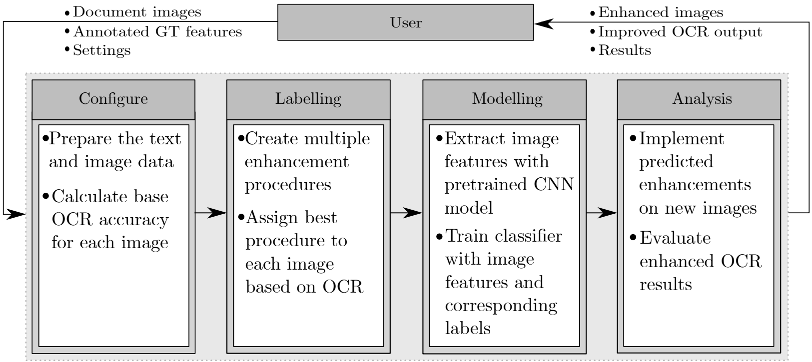
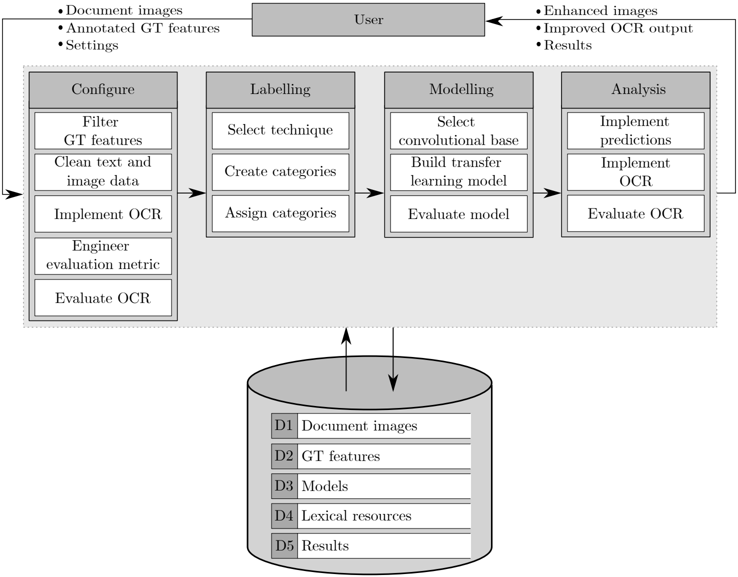


Proposed framework - Modules



Real-world case study - Industry partner data

- 2 000 PDFs of scanned client payslips

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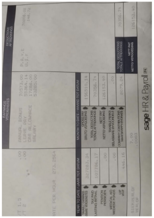
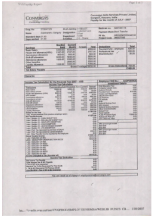
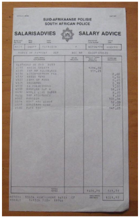
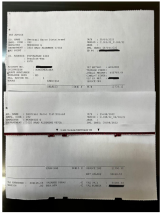
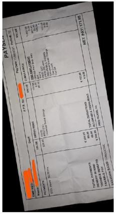


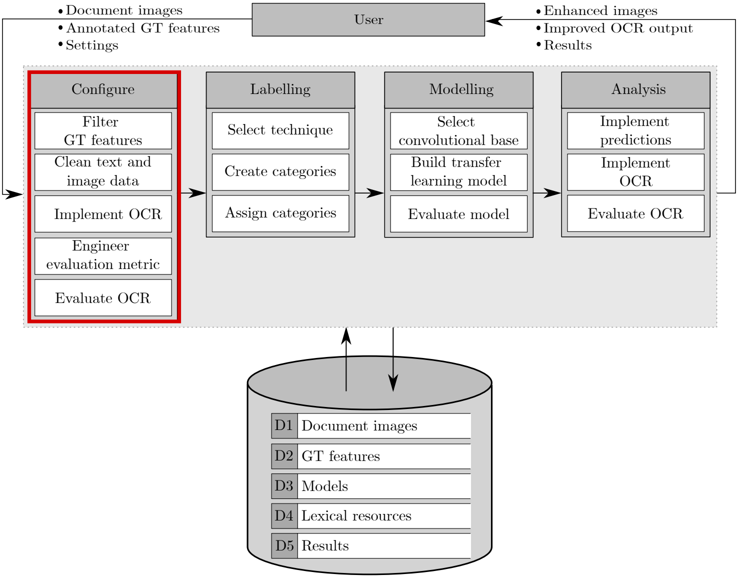








Real-world case study - Configure subcomponent



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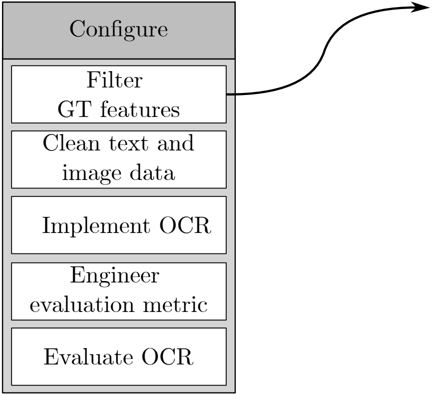

Employee code
Employee name
Employee surname
Date
Total earnings
Basic salary
Total deductions
Net pay
Company name
Occupation

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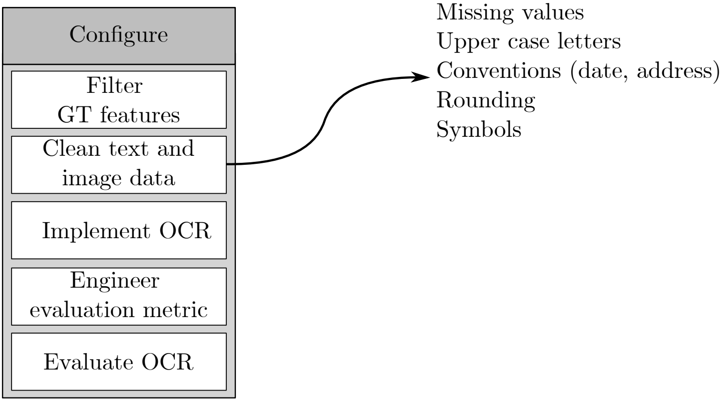

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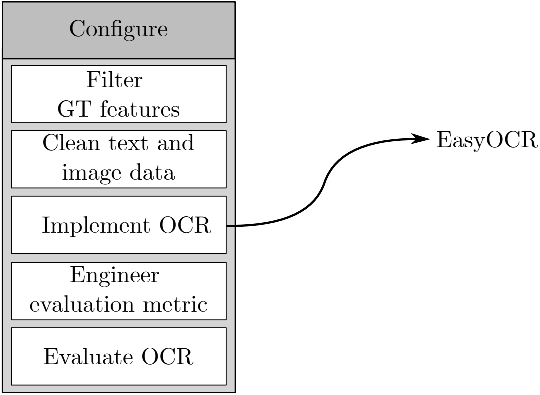

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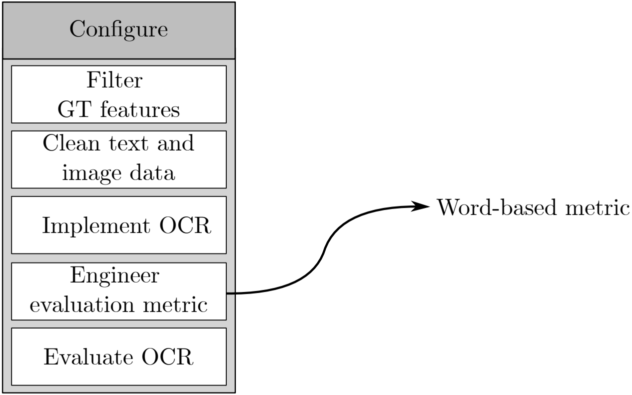

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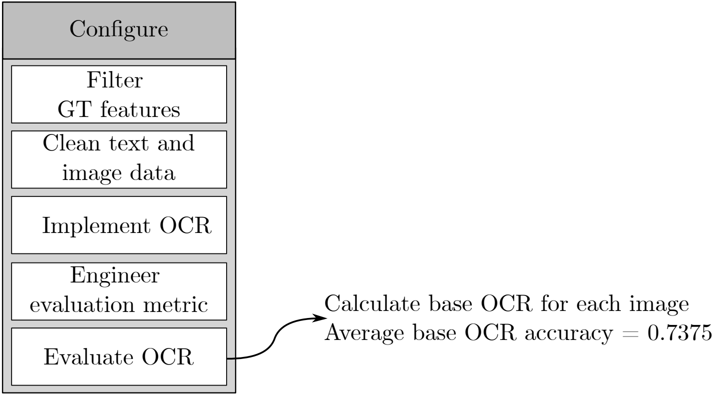
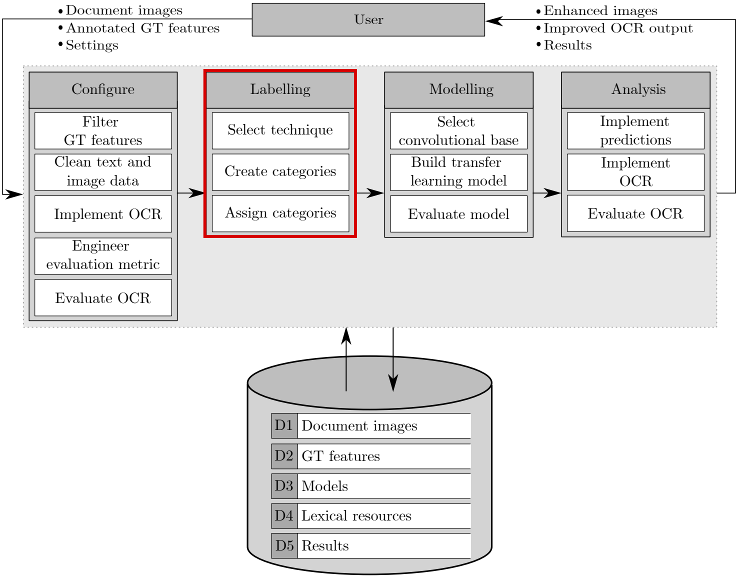


Real-world case study - Labelling subcomponent



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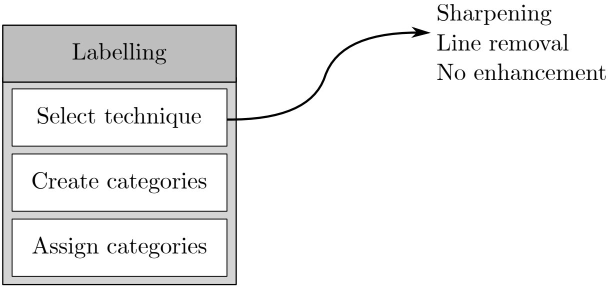

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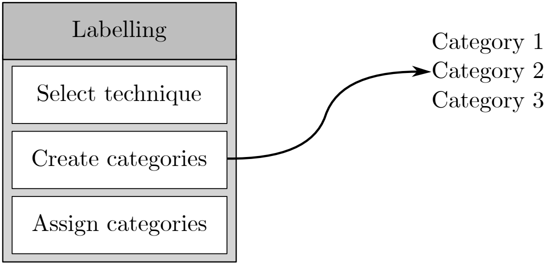

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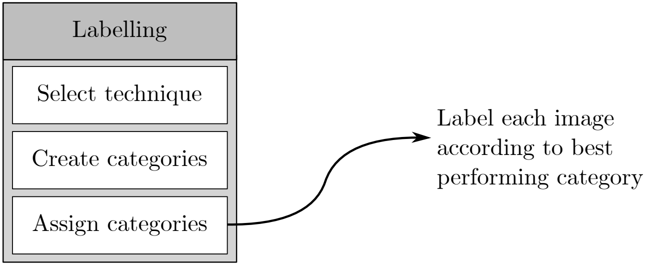
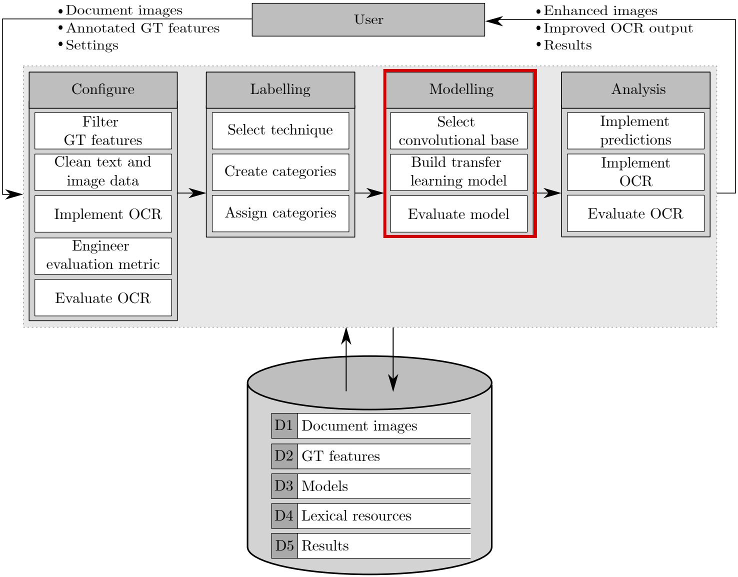


Real-world case study - Modelling subcomponent



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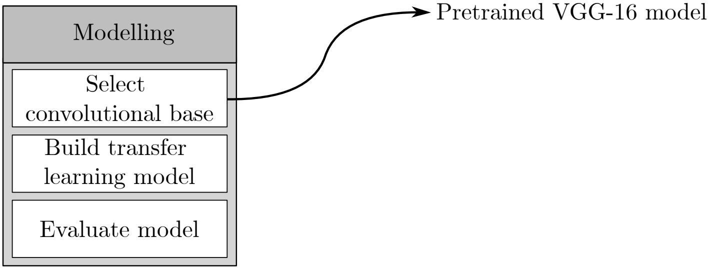

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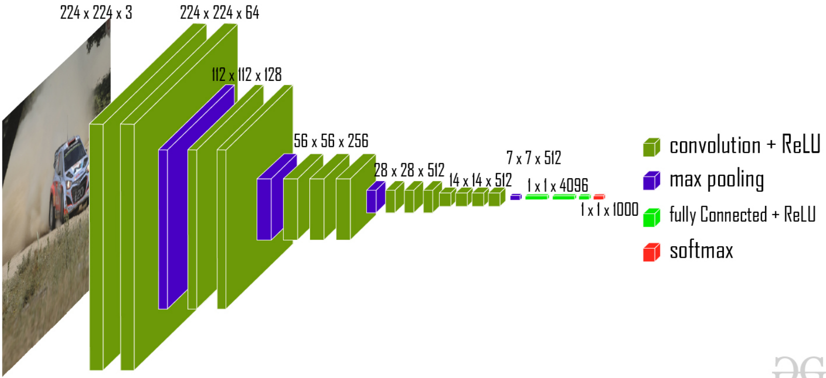

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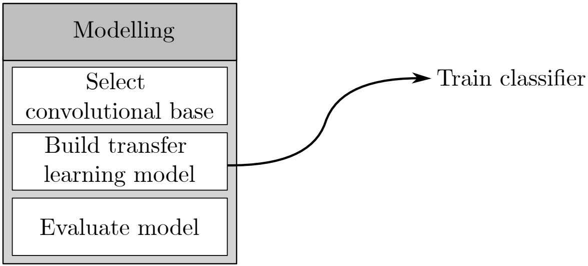

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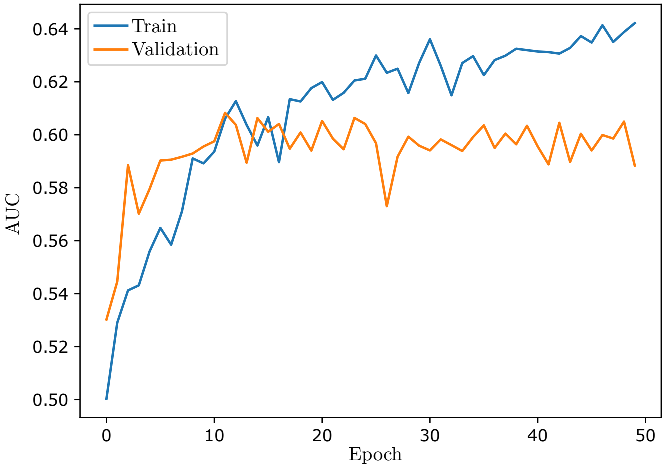


Real-world case study - Modelling subcomponent

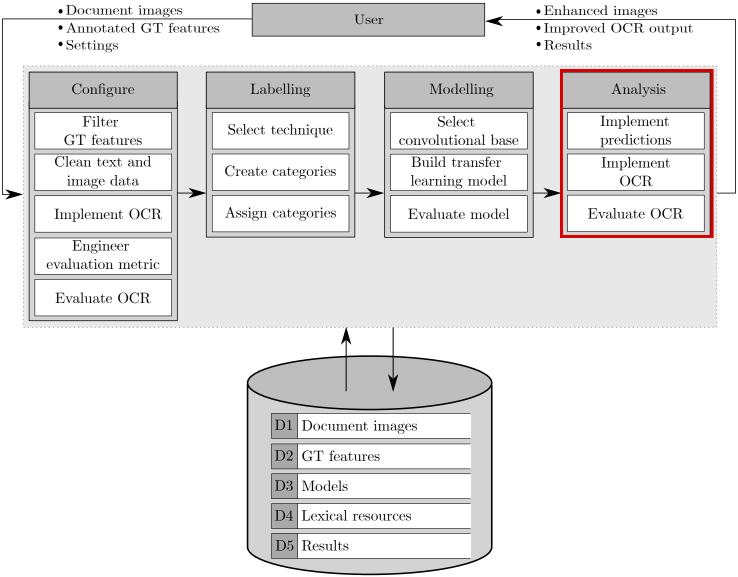
Predicted \ Actual	A	B	C
A	0.57	0.16	0.42
B	0.16	0.52	0.14
C	0.28	0.32	0.44

A: Base image

B: Line Removal

C: Sharpening

Real-world case study - Analysis subcomponent



Real-world case study - Analysis subcomponent

Test set category	Average OCR accuracy
Base	0.7382
Framework	0.7444

Real-world case study - Analysis subcomponent

Impact category compared with the original base OCR	Line removal on all images		Sharpening on all images		Only predicted images	
	Number	Ratio	Number	Ratio	Number	Ratio
Improved	60	0.16	73	0.20	59	0.16
Same	249	0.68	187	0.51	268	0.73
Deteriorated	59	0.16	108	0.30	41	0.11
Improved/deteriorated		**1.0169**		**0.6759**		**1.4390**

Real-world case study - Analysis subcomponent

Impact category compared with the original base OCR	Line removal on all images		Sharpening on all images		Only predicted images	
	Number	Ratio	Number	Ratio	Number	Ratio
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Case study 2 - Receipt results

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Predicted \ Actual	A	B
A	0.61	0.43
B	0.39	0.57

A: Base image

B: Sharpening

Case study 2 - Receipt results

Test set category	Average OCR accuracy
Base	0.7720
Framework	0.7827

Case study 2 - Receipt results

Impact category compared with the original base OCR	All images in test set		Only applied to predicted images in test set	
	Number	Ratio	Number	Ratio
Improved	38	0.30	22	0.18
Same	39	0.31	83	0.66
Deteriorated	48	0.38	20	0.16
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  1. Consider the inclusion of a confidence score for the OCR evaluation metric,
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  3. applying the framework to document images with handwritten characters.

References

SMITH R, 2007, *An overview of the Tesseract OCR engine*, Ninth international conference on document analysis and recognition (ICDAR 2007), **2**, pp. 629–633.

Jaided AI, 2020, *EasyOCR*, [Online], [Cited September 2021], Available from https://github.com/JaidedAI/EasyOCR