



# SelfDocSeg: A Self-Supervised vision-based Approach towards Document Segmentation

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# Outline

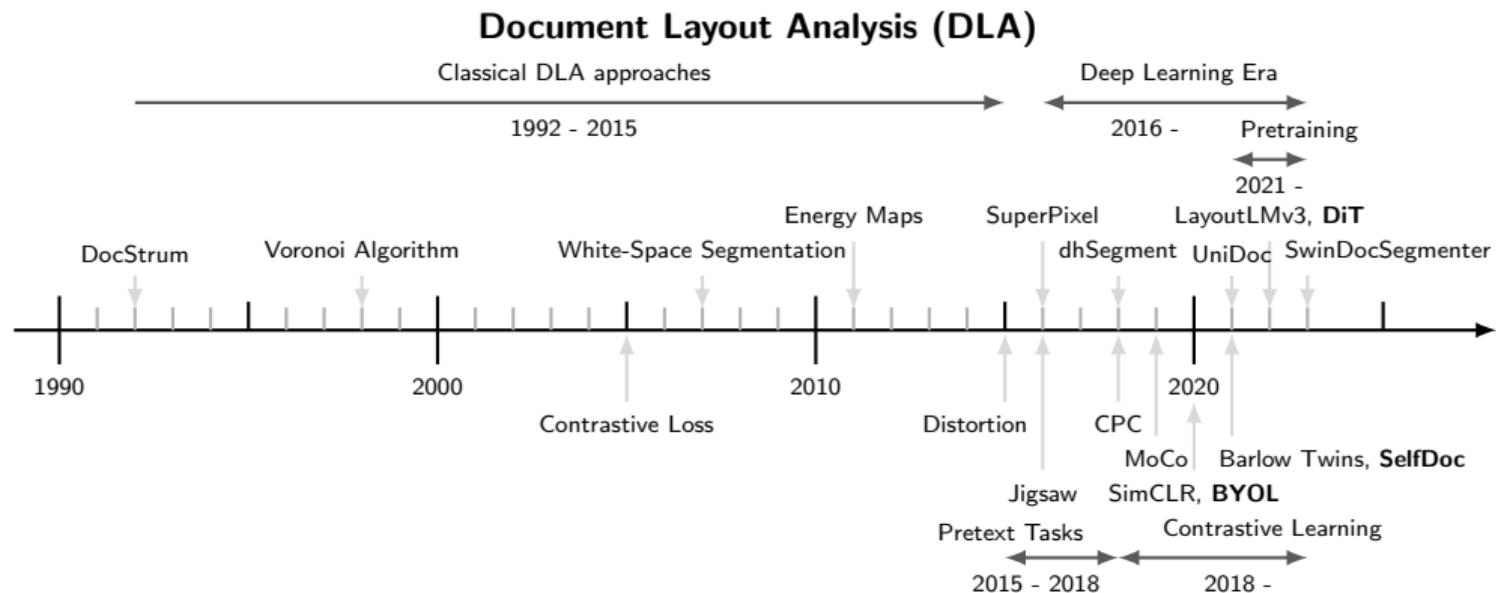
1 Background

2 SelfDocSeg

3 Experiments

4 Conclusion

# Going Back in Time



## Self-Supervised Learning

# Coming back to the Present Day

## Where DLA and Self-supervised Learning stand today?

- The classical image processing techniques for DLA had long been lost.
- Modern self-supervision is bringing the classical algorithms, like Felzenszwalb, Normalized Cuts etc. back for guidance.
- The current document pre-training techniques for DLA use *multi-modal* approaches and *large-scaled* datasets.

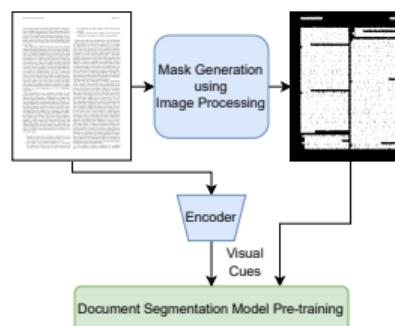
## What do we need?

- A strategy to use the document images without annotations for DLA.
- A *data-efficient* pre-training strategy with *unlabelled* document images to alleviate the usual requirement of computational resources.

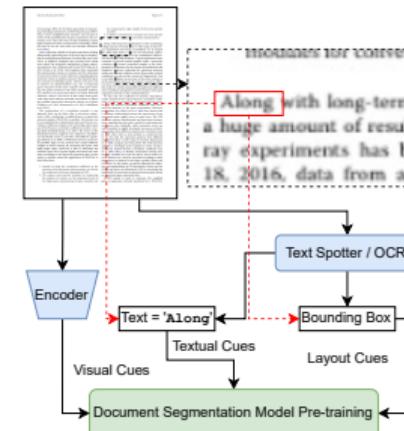
# Motivation behind SelfDocSeg

## What's different from prior state-of-the-arts (SOTAs)?

- No textual cue or layout cue from trained OCR. Only visual cues are enough to capture global and local context.
- Superior data efficiency



(a) SelfDocSeg



(b) Existing Self-supervised SOTAs

# Contributions

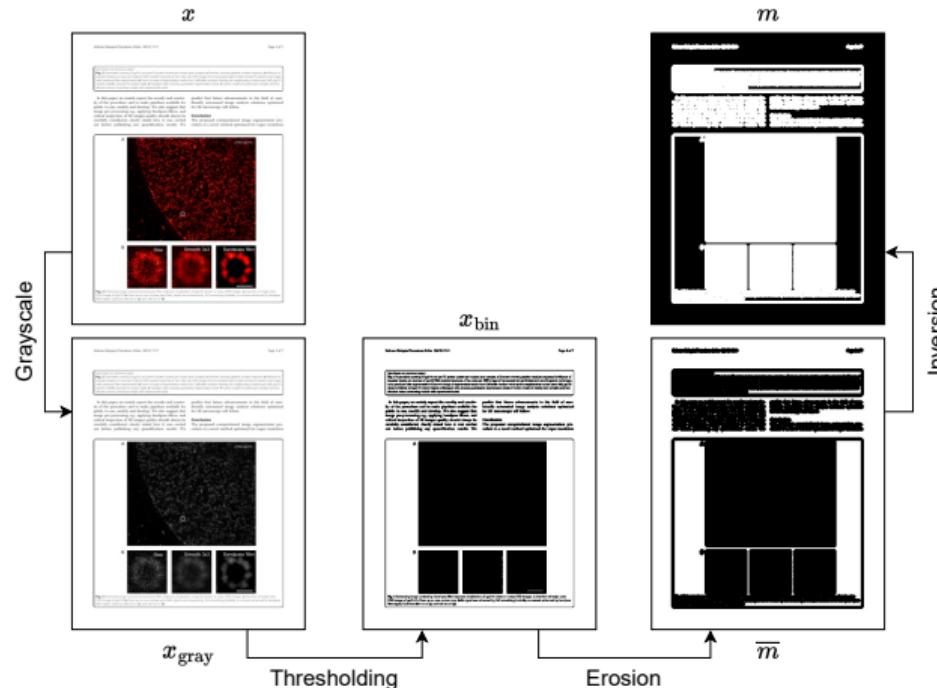
- A novel *vision-based self-supervised* framework, specifically designed to pre-train an image encoder for DLA task.
- A *pseudo physical layout guided strategy* for self-supervision in the region of interest localization for document segmentation.
- A *data-efficient pre-training strategy* to learn multiple document object representations simultaneously in the self-supervised setting

# Overall Algorithmic Overview of SelfDocSeg

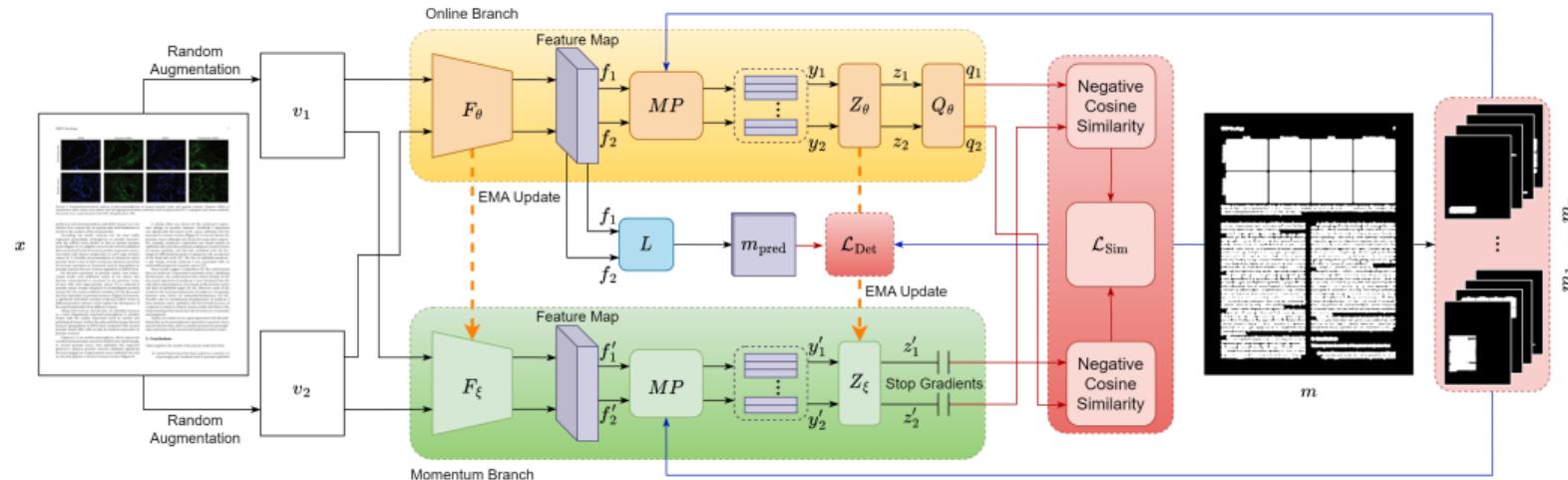
- 1 First, an approximate layout mask  $m$  is generated.
- 2 The image encoder is pre-trained with the help of  $m$  as visual cues in a non-weight-shared two-branch network similar to BYOL [28].
- 3 The encoder pre-training is done with two objectives - (a) *localization* and (b) *representation* of layout objects.
- 4 Localization objective is optimized using a detection loss  $\mathcal{L}_{\text{Det}}$ .
- 5 Layout object representations are extracted by *mask pooling* operation on encoded feature-maps for each object.
- 6 Representation objective is learnt via a similarity loss  $\mathcal{L}_{\text{Sim}}$ .

# Mask Generation

- 1 Grayscale Conversion:**  
CIE grayscale conversion on the document image  $x$
- 2 Thresholding:**  
Global thresholding with value 239 for 8-bit integer pixels
- 3 Erosion:**  
 $5 \times 5$  rectangular kernel
- 4 Inversion:**  
pixel values subtracted from 255 to get the layout mask  $m$



# Architecture



# Architecture Details

## Online Branch

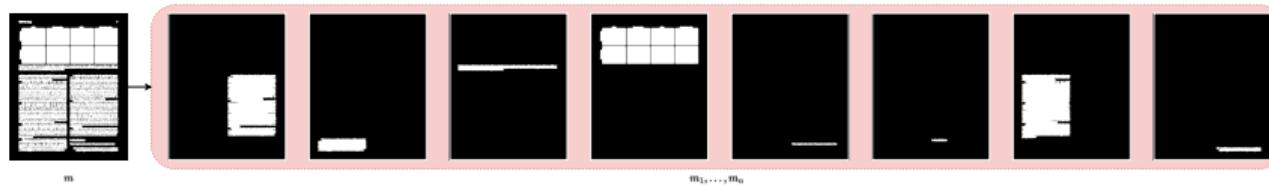
The online branch has an encoder  $F_\theta$ , a projector  $Z_\theta$  and a predictor  $Q_\theta$ . It is updated using backpropagation.

## Momentum Branch

The momentum branch has an encoder  $F_\xi$  and a projector  $Z_\xi$ . It is updated using an exponentially moving average (EMA).

## Layout Objects for Mask Pooling

The layout object masks  $m_1, \dots, m_n$  are separated from mask  $m$  as separate contours.



## Mask Pooling

Mask pooling [35] is used for extracting layout object representation from encoded feature maps. It is just an average pooling inside each contour masked by  $m$ .

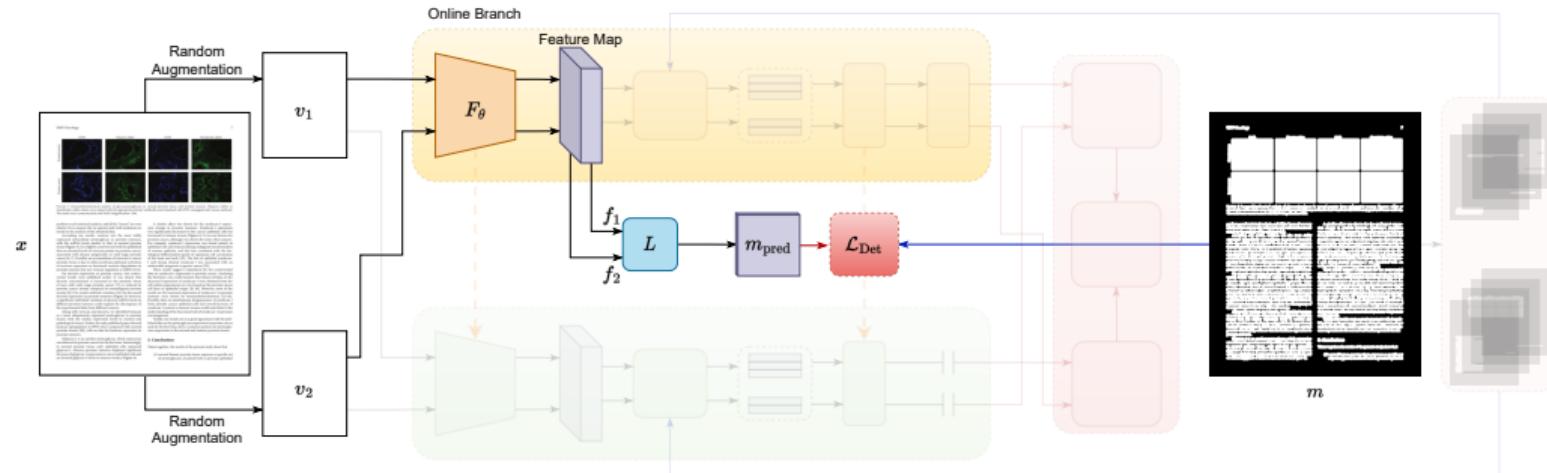
$$y^{(k)} = \frac{1}{\sum_{i,j} m_k[i,j]} \sum_{i,j} m_k[i,j] f[i,j]$$

## Weight Updates

**Online Branch:**  $\theta \leftarrow \text{optimizer}(\theta, \nabla_\theta \mathcal{L}_{\text{total}}, \eta)$

**Momentum Branch:**  $\xi \leftarrow \tau \xi + (1 - \tau) \theta$

# Learning to Localize Layout Objects



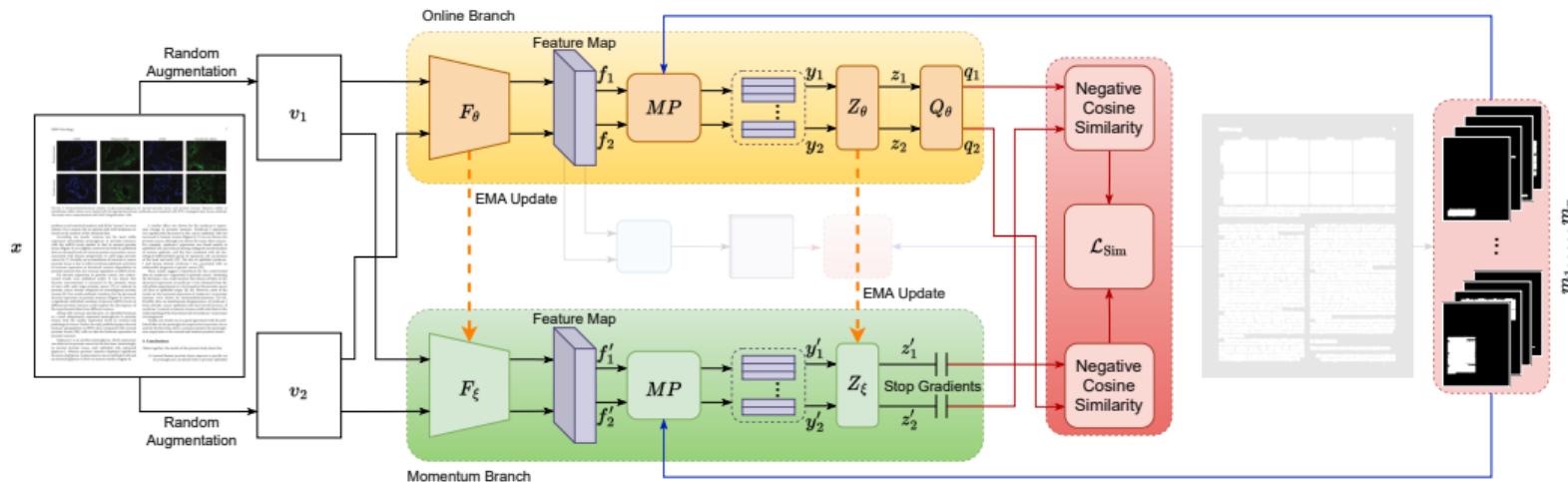
# Localization Pre-training Objective

- The mask predictor module  $L$  is used to predict the layout mask  $m_{\text{pred}}$ .
- $m_{\text{pred}}$  translates to the pixel-level probability of a layout object being present.
- We formulate this prediction objective as an imbalanced classification task and use Focal Loss [43]  $\mathcal{L}_{\text{Det}}$  for the same.

## Detection Loss

$$\begin{aligned}\mathcal{L}_{\text{Det}} = & -\frac{\alpha}{\sum_{i,j} m[i,j]} \cdot \sum_{i,j} (m[i,j](1 - m_{\text{pred}}[i,j])^{\gamma} \log m_{\text{pred}}[i,j] \\ & + (1 - m[i,j])m_{\text{pred}}[i,j]^{\gamma} \log(1 - m_{\text{pred}}[i,j]))\end{aligned}$$

# Learning to Recognize Layout Objects



# Representation Pre-training Objective

- Representation of each layout object is extracted from feature maps of encoders  $F_\theta$  and  $F_\xi$  in the online and the momentum branches using masked pooling.
- The encoder is trained using cosine similarity loss [28]  $\mathcal{L}_{\text{Sim}}$  between online predictor  $Q_\theta$  and momentum projector  $Z_\xi$ .

## Similarity Loss

$$\mathcal{L}_{\text{Sim}} = 4 - 2 \left( \frac{\langle q_1, z'_2 \rangle}{\|q_1\|_2 \cdot \|z'_2\|_2} + \frac{\langle q_2, z'_1 \rangle}{\|q_2\|_2 \cdot \|z'_1\|_2} \right)$$

# Experimental Setup

## Pre-training Dataset:

- DocLayNet [51]

## Fine-tuning Dataset:

- DocLayNet [51]
- PubLayNet [63]
- PRImA [2]
- Historic Japanese [54]

## Our Backbone:

- ResNet 50 [34]

## Competitors:

- DocSegTr [8]
- LayoutParser [55]
- Biswas *et al.* [9]
- Mask RCNN [33] (Fully supervised)
- LayoutLMv3<sub>Base</sub> [36]
- UDoc [29]
- DiT<sub>Base</sub> [40]

## Our Detector:

- Mask RCNN [33]

Frameworks: PyTorch, OpenCV, PyTorch Lightning, Lightly, Detectron2

Source code: <https://github.com/MaitySubhajit/SelfDocSeg>

## Results - Quantitative

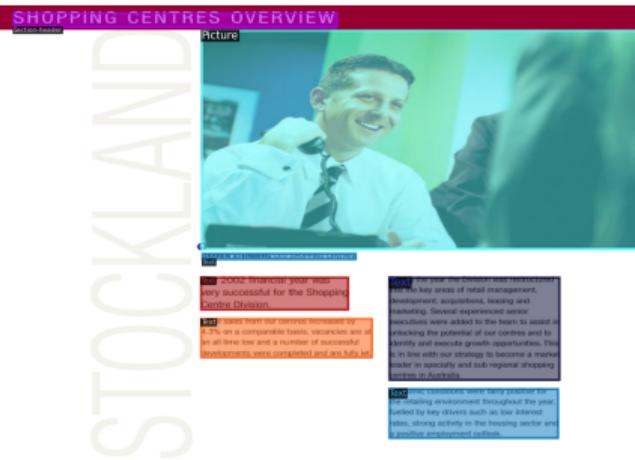
| Methods                         | Cues |   |   | # Data | DocLayNet<br>mAP | PubLayNet<br>mAP | PRImA<br>mAP | HJ<br>mAP   |
|---------------------------------|------|---|---|--------|------------------|------------------|--------------|-------------|
|                                 | V    | L | T |        |                  |                  |              |             |
| DocSegTr [8]                    | ✓    | ✗ | ✗ | -      | -                | 90.4             | 42.5         | <b>83.1</b> |
| LayoutParser [55]               | ✓    | ✓ | ✓ | -      | -                | 86.7             | <b>64.7</b>  | 81.6        |
| Biswas <i>et al.</i> [9]        | ✓    | ✗ | ✗ | -      | -                | 89.3             | 56.2         | 82.0        |
| Mask RCNN [33]                  | ✓    | ✗ | ✗ | -      | 72.4             | 88.6             | 56.3         | 80.1        |
| LayoutLMv3 <sub>Base</sub> [36] | ✓    | ✓ | ✓ | 11M    | -                | <b>95.1</b>      | 40.3         | 82.7        |
| UDoc[29]                        | ✓    | ✓ | ✓ | 1M     | -                | 93.9             | -            | -           |
| DiT <sub>Base</sub> [40]        | ✓    | ✗ | ✗ | 42M    | -                | 93.5             | -            | -           |
| BYOL [28]                       | ✓    | ✗ | ✗ | 81k    | 63.5             | 79.0             | 28.7         | 59.8        |
| <b>SelfDocSeg</b>               | ✓    | ✗ | ✗ | 81k    | <b>74.3</b>      | 89.2             | 52.1         | 78.8        |

# Results - Visual Comparison with Ground-truth

Section header 21%  
Text from our centres increased by 4.3% on  
a comparable basis, vacancies are at an all time low  
and a number of successful developments were  
completed and are fully let."



Text detail sales from our centres increased by 4.3% on  
a comparable basis, vacancies are at an all time low  
and a number of successful developments were  
completed and are fully let."



Left: Prediction

Right: Ground-truth

# Results - Visual Comparison with Ground-truth



6.2B SUBSEQUENT EVENTS  
Section-header 6.2B  
Section header 6.2B  
Section header 6.2B

## 5. FINANCIAL RISK MANAGEMENT OBJECTIVES AND POLICY

### EXPOSURE TO FOREIGN EXCHANGE AND INTEREST RATE RISK

Text 100% sales operations in 80 countries, so components of the financial statements are influenced by foreign currency translation effects, particularly by fluctuations in the US dollar. However, exchange rate fluctuations do not generate any operational risk, because each of the Group's subsidiaries invoices its revenues and incurs expenses in the same currency.

Red 99% An entity borrows instruments to manage its exposure to interest rate and foreign exchange rate risk.

#### 5.1.1 Analysis of sensitivity to interest rates

|  | Note | August 31, 2013 | August 31, 2012 |
|--|------|-----------------|-----------------|
| Financial liabilities excluding derivative financial instruments             | 4.15 | 2,607           | 2,686           |
| Fixed rate liabilities   |      | 2,324           | 2,403           |
| Variable rate liabilities  |      | 283             | 283             |
| Impact of interest rate and cross-currency swaps                             | 4.16 | (67)            | (21)            |
| On fixed rate liabilities  |      | 177             | 216             |
| On variable rate liabilities   |      | (244)           | (218)           |
| Financial liabilities after impact of interest rate and cross-currency swaps |      | 2,540           | 2,684           |
| Fixed rate liabilities   |      | 2,501           | 2,619           |
| Variable rate liabilities  |      | 39              | 65              |

Red 93% At August 31, 2013 and 2012, a 10.5% increase or decrease in interest rates would have had no material impact on net income before tax or on shareholders'

Equity as substantiating information at those dates were not available at date of filing.

Gold 93% Registration Document fiscal 2013 - 2013



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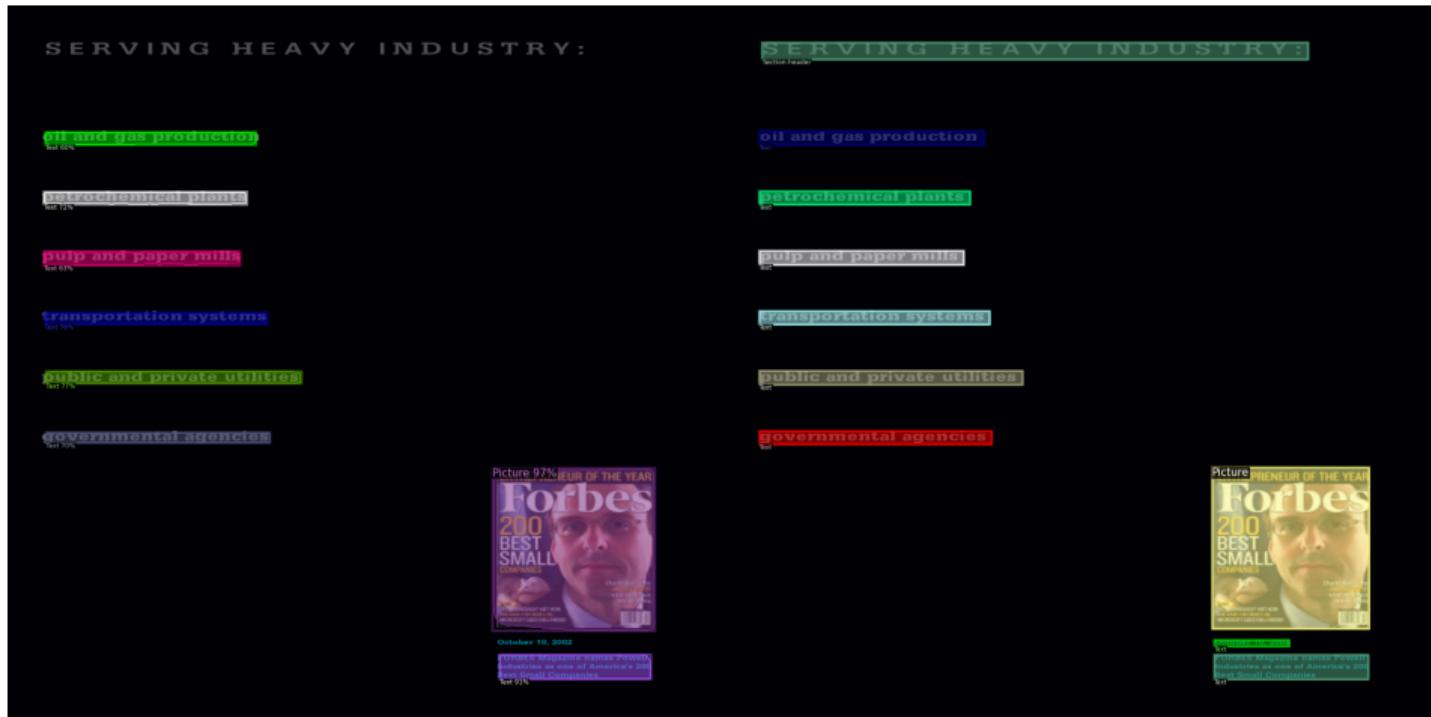
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Left: Prediction

Right: Ground-truth

# Results - Visual Comparison with Ground-truth



# Results - Visual Comparison with Ground-truth

| intangible assets                                      |              |                        |                               |                          |                         |              |
|--|--------------|------------------------|-------------------------------|--------------------------|-------------------------|--------------|
| ed group   |              |                        |                               |                          |                         |              |
| Secteur pétrolier                                      |              |                        |                               |                          |                         |              |
| <b>Table 98%</b>                                       |              |                        |                               |                          |                         |              |
| 2003   | Software     | Patents and trademarks | Capitalised exploration costs | Capital work in progress | Other intangible assets | Total        |
| <b>Cost</b>  |              |                        |                               |                          |                         |              |
| Balance at 30 June 2002                                | 738          | 543                    | 898                           | 307                      | 13                      | 2 517        |
| Acquisition of businesses (refer note 46)              | —            | 2                      | —                             | —                        | —                       | 2            |
| Additions  | 233          | 93                     | 63                            | 242                      | 3                       | 690          |
| To enhance existing operations<br>to expand operations | 209          | 8                      | —                             | 62                       | 1                       | 277          |
| Transfers  | 4            | 90                     | 63                            | 100                      | 2                       | 319          |
| Borrowing costs capitalised                            | 8            | —                      | —                             | —                        | —                       | 8            |
| Transfer from own property,<br>plant and equipment     | 70           | 107                    | —                             | (211)                    | —                       | (34)         |
| Disposal of foreign entities<br>(refer note 38)        | (23)         | (99)                   | (69)                          | (4)                      | —                       | (193)        |
| Disposals and scrapping                                | (7)          | (4)                    | (239)                         | —                        | —                       | (244)        |
| <b>Balance at 30 June 2003</b>                         | <b>1 093</b> | <b>644</b>             | <b>633</b>                    | <b>424</b>               | <b>16</b>               | <b>2 820</b> |
| <b>Amortisation and amounts written off</b>            |              |                        |                               |                          |                         |              |
| Balance at 30 June 2002                                | 142          | 372                    | 279                           | —                        | —                       | 733          |
| Acquisition of businesses (refer note 46)              | —            | 2                      | —                             | —                        | —                       | 2            |
| Costs of exploration                                   | 234          | 60                     | 35                            | —                        | 3                       | 216          |
| Impairment of assets (refer note 34)                   | —            | 5                      | —                             | —                        | —                       | 5            |
| Translation of foreign entities<br>(refer note 38)     | (20)         | (62)                   | (5)                           | —                        | —                       | (87)         |
| Transfer from property,<br>plant and equipment         | 24           | —                      | —                             | —                        | —                       | 24           |
| Disposals and scrapping                                | (1)          | (1)                    | (200)                         | —                        | —                       | (202)        |
| <b>Balance at 30 June 2003</b>                         | <b>361</b>   | <b>376</b>             | <b>29</b>                     | <b>—</b>                 | <b>3</b>                | <b>769</b>   |
| <b>Carrying value at 30 June 2003</b>                  | <b>722</b>   | <b>268</b>             | <b>624</b>                    | <b>424</b>               | <b>13</b>               | <b>2 051</b> |
| <b>Carrying value at 30 June 2002</b>                  | <b>594</b>   | <b>171</b>             | <b>679</b>                    | <b>307</b>               | <b>13</b>               | <b>1 834</b> |
| <b>Cost price of assets held put in use</b>            | <b>29</b>    | <b>—</b>               | <b>424</b>                    | <b>—</b>                 | <b>—</b>                | <b>453</b>   |
| <b>Cost of fully amortised assets in use</b>           | <b>14</b>    | <b>43</b>              | <b>—</b>                      | <b>—</b>                 | <b>—</b>                | <b>57</b>    |

| intangible assets                                      |              |                        |                               |                          |                         |              |
|--|--------------|------------------------|-------------------------------|--------------------------|-------------------------|--------------|
| sasol limited group                                    |              |                        |                               |                          |                         |              |
| Secteur pétrolier                                      |              |                        |                               |                          |                         |              |
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| intangible assets                                      |           |                        |                               |                          |                         |            |
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| Balance at 30 June 2002                                | 4 366     | 2 230                  | 2 067                         | —                        | —                       | 8 663      |
| Acquisition of businesses (refer note 46)              | —         | 308                    | 526                           | 54                       | —                       | 888        |
| Additions  | 206       | 295                    | 72                            | —                        | —                       | 503        |
| To enhance existing operations<br>to expand operations | 209       | 512                    | 87                            | —                        | —                       | 350        |
| Transfers  | 87        | 77                     | 54                            | —                        | —                       | 222        |
| Borrowing costs capitalised                            | 873       | 809                    | 800                           | —                        | —                       | 2 582      |
| <b>Cost price of assets held put in use</b>            | <b>29</b> | <b>—</b>               | <b>424</b>                    | <b>—</b>                 | <b>—</b>                | <b>453</b> |
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| intangible assets                                      |           |                        |                               |                          |                         |            |
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| sasol limited group                                    |           |                        |                               |                          |                         |            |
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Left: Prediction

Right: Ground-truth

# Discussion & Further Insights

## Generalizability & Effectiveness of Pre-training

Experimented with fewer annotations in a semi-supervised setting for fine-tuning.

| % Annotations | mAP  |
|---------------|------|
| 10%           | 41.3 |
| 50%           | 65.1 |
| 100%          | 74.3 |

## Contribution of Detection & Representation Objectives

Experimentation with  $\mathcal{L}_{\text{Det}}$  and  $\mathcal{L}_{\text{Sim}}$  in strip-down style.

| Loss                                      | mAP  |
|---|------|
| w/o $\mathcal{L}_{\text{Sim}}$            | 39.1 |
| w/o $\mathcal{L}_{\text{Det}}$            | 69.7 |
| Combined ( $\mathcal{L}_{\text{total}}$ ) | 74.3 |

# The Story so far

- **SelfDocSeg** being a *OCR-free pertaining strategy* is computationally less expensive, as large-scale OCR systems are difficult and time-consuming to train.
- Ideally **SelfDocSeg** provides a *wide range of flexibility with backbones and detectors* and can achieve better performance with a stronger backbone.
- **SelfDocSeg** is *data-efficient* compared to state-of-the-art pre-training methods for DLA and can *generalize quickly over different domains* in the fine-tuning stage.

# What's Next?

- Although being a superior pre-training strategy in terms of data efficiency, **SelfDocSeg** is not yet tested for data-hungry models like LayoutLMv3 or DiT.
- Following the recent trends to promote performance improvement, the scope of exploration remains in multi-domain and multi-lingual pre-training for introducing data variety.
- **SelfDocSeg** is particularly designed to cater to DLA. Thus, pre-training and fine-tuning for multi-task settings in downstream with vision-based self-supervision can be explored.

# Conclusion

- **SelfDocSeg** is *self-supervised* and *vision based* and is motivated by recent self-supervised works in computer vision.
- Self-supervision for documents is possible in a unimodal setting without dependency on OCR or textual knowledge.
- The complete visual representation approach of **SelfDocSeg** facilitates superior understanding and encoding of the visual modality in the layout-guided document understanding paradigm.

## To Know More



arXiv: <https://arxiv.org/abs/2305.00795>

Code: <https://github.com/Maitysubhajit/SelfDocSeg>

Project Page: <https://maitysubhajit.github.io/SelfDocSeg>