De-Identification of Medical Images in Dicom Format

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Agenda

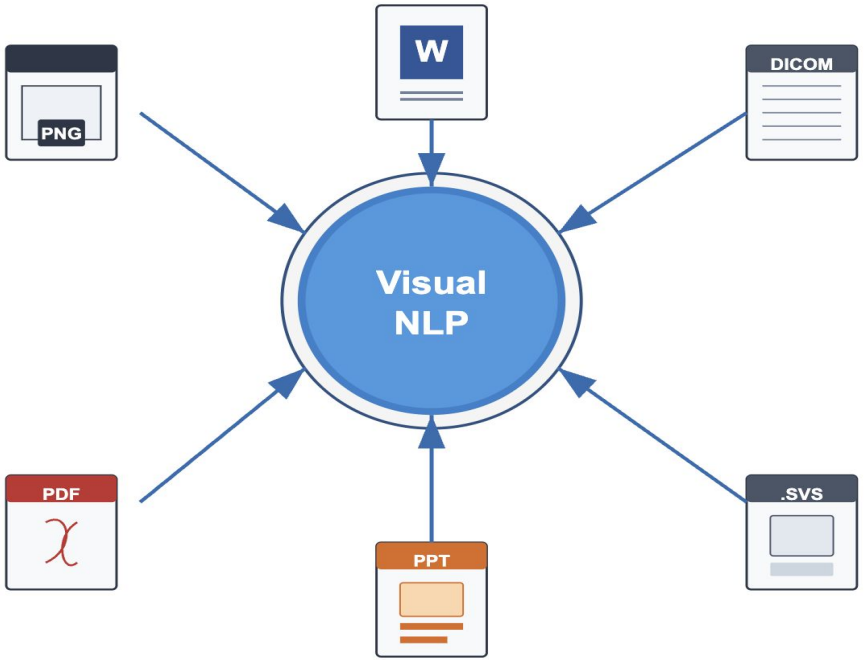
Topic	Reference Notebook / Links
Introduction to Visual NLP	Visual NLP
What is Dicom?	Dicom Standard
Dicom Tags	Private Tags
Dicom Pixels	Dicom Standard - Photometric Interpretation
Transfer Syntaxes in Dicom	Dicom Standard - Transfer Syntax
Visual NLP Dicom Pipeline	Dicom Training NB's
Metrics	Evaluation Repo

Introduction to Visual NLP

- Visual NLP as a library helps in unblocking textual information from scanned/digital/medical documents.

- Provides high-level capabilities
  - Text Detection
  - OCR
  - Table Detection/Recognition
  - Entity Extraction
  - VQA

- Entry points into Visual NLP
  - Images
  - PDFs (Digital & Scanned)
  - Document, PPT
  - Dicom
  - SVS



What is Dicom?

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- Dicom (**Digital Imaging And Communications in Medicine**)
  - International standard for medical information.
  - Allows healthcare professionals to easily view and understand medical information regardless of the equipment/software used to generate it.

- Dicom files have two fundamental parts
  - Pixels (Medical Images)
    - MRIs, CT Scans, X-Rays etc.
    - PHI burned into the pixels.
    - Overlay Pixels

  - Dicom Tags (Metadata)
    - Patient/Physician PHI
    - Equipment/Software-Related Information
    - Examination/Test-Related Information
    - Other Relevant Information (Pixels, Transfer Syntaxes, Compression level)

Dicom Tags

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- Dicom Tags are essentially metadata elements associated with a dicom object.
- They carry information about the dicom object, pixels, patient demographics, equipment etc.
- Tag Structure
  - Each Dicom Tag is a unique hexadecimal number in format (XXXX, YYYY)
  - The first four digits (XXXX) represent the group number.
  - The last four digits (YYYY) represent the element number.
- Each Tag also has Value Representation (VR), which denotes the data type and format of the tag’s value (String, Integer, Date, etc)
- To accommodate vendor-specific needs beyond the standard tags, DICOM supports 'private tags', which are always identified by odd group numbers.

Dicom Pixels

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- Active Photometric Interpretation (0028,0004)
  - Monochrome 1 & Monochrome 2
  - Palette Color
  - RGB
  - YBR_FULL, YBR_FULL_422, YBR_PARTIAL_420, YBR_RCT, YBR_ICT

- Pixel Representation (0028,0103) denotes whether the pixel values are signed/unsigned.

- Bits Allocated (0028,0100) is the number of bits allocated for each pixel.

- Bits Stored (0028,0101) is the actual number of bits used to represent pixel value.

- Image Pixel Data (7FE0,0010)
  - Uncompressed Transfer Syntaxes
  - Compressed Transfer Syntaxes (Lossy / Lossless)

- Visual NLP does not alter the Photometric Interpretation / Color Space of DICOM pixels in any way. The final DICOM file retains the same characteristics as the input.

```
Dataset.file_meta -------------------------------
(0002,0000) File Meta Information Group Length  UL: 186
(0002,0001) File Meta Information Version       OB: b'\x00\x01'
(0002,0002) Media Storage SOP Class UID         UI: Digital X-Ray Image Storage - For Presentation
(0002,0003) Media Storage SOP Instance UID      UI: 2.25.463628102274132074849128424375172598
(0002,0010) Transfer Syntax UID                 UI: Explicit VR Little Endian
(0002,0012) Implementation Class UID            UI: 1.3.6.1.4.1.22213.1.143
(0002,0013) Implementation Version Name         SH: '0.5'
(0002,0016) Source Application Entity Title     AE: 'POSDA'
-------------------------------------------------
(0008,0005) Specific Character Set              CS: 'ISO_IR 100'
(0008,0008) Image Type                          CS: ['ORIGINAL', 'PRIMARY', '']
(0008,0016) SOP Class UID                       UI: Digital X-Ray Image Storage - For Presentation
(0008,0018) SOP Instance UID                    UI: 2.25.463628102274132074849128424375172598
(0008,0020) Study Date                          DA: '20010705'
(0008,0021) Series Date                         DA: '20010705'
(0008,0022) Acquisition Date                    DA: '20010705'
(0008,0023) Content Date                        DA: '20010705'
(0008,0024) Overlay Date                        DA: '20010705'
(0008,0025) Curve Date                          DA: '20010705'
(0008,002A) Acquisition DateTime                DT: '20010705'
(0008,0030) Study Time                          TM: ''
(0008,0032) Acquisition Time                    TM: ''
(0008,0033) Content Time                        TM: ''
(0008,0050) Accession Number                    SH: '20010706E403961'
(0008,0060) Modality                            CS: 'DX'
(0008,0070) Manufacturer                        LO: 'GE MEDICAL SYSTEMS'
(0008,0080) Institution Name                    LO: 'Mccoy Medical Clinic'
(0008,0081) Institution Address                 ST: '45166 Morgan Walks Suite 852 East Aaron, KS 93919'
(0008,0090) Referring Physician's Name          PN: 'EATON^WILLIAM'
(0008,0092) Referring Physician's Address       ST: '12148 Donna Overpass Apt. 115 North Sherry, TN 60972'
(0008,0094) Referring Physician's Telephone Num SH: '752.671.3789x973'
(0008,1050) Performing Physician's Name         PN: 'ELLIS^PAUL'
(0008,1090) Manufacturer's Model Name           LO: 'Revolution XQi ADS_28.4'
(0008,1155) Referenced SOP Instance UID         UI: 2.25.181816462680784373513761473735268351478
(0009,0010) Private Creator                     LO: 'GEMS_IDEN_01'
(0009,1027) [Image actual date]                 SL: 20000101
(0010,0010) Patient's Name                      PN: 'MARTIN^CHAD'
(0010,0020) Patient ID                          LO: '339833062'
(0010,0030) Patient's Birth Date                DA: ''
(0010,0040) Patient's Sex                       CS: ''
(0010,1010) Patient's Age                       AS: ''
(0010,1040) Patient's Address                   LO: '68265 Mark Bridge Suite 049 Robinsonville, OK 55335'
(0010,21D0) Last Menstrual Date                 DA: '20010705'
(0013,0010) Private Creator                     LO: 'CTP'
(0013,1010) Private tag data                    LO: 'Pseudo-PHI-DICOM-Data'
(0013,1013) Private tag data                    LO: '87009668'
(0018,0015) Body Part Examined                  CS: 'CHEST'
(0018,0060) KVP                                 DS: '125'
(0018,1020) Software Versions                   LO: 'Ads Application Package VERSION ADS_28.4'
(0018,1110) Distance Source to Detector         DS: '1800'
(0018,1111) Distance Source to Patient          DS: '1750'
(0018,1150) Exposure Time                       IS: '43'
```

Transfer Syntaxes

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- Transfer Syntaxes are the language translators of Dicom objects, ensuring different systems understand each other.
- They dictate how data is stored and transmitted within Dicom objects.
- Without correct transfer syntax, data, especially pixel data can be misinterpreted, leading to processing errors.
- Compression Options:
  - Lossless preserves all image details, with no reduction in dicom object size.
    - JPEG-LS, RLE, JPEG 2000 Lossless
  - Lossy reduces file size but with some quality loss.
    - JPEG, JPEG 2000
- There are limitations to using a specific transfer syntax.
  - Not all Transfer Syntaxes support variations in Photometric Interpretation, Bits Stored, Pixel Representation, or their combinations.

Transfer Syntax	Color Space	Visual NLP Support	
		Encoding	Decoding
RLE Lossless	Monochrome 1, Monochrome 2, PALETTE COLOR, RGB, YBR_FULL	Yes	Yes
JPEG Baseline 8-Bit	Monochrome 1, Monochrome 2, RGB, YBR_FULL	Yes	Yes
JPEG 2000	Monochrome 1, Monochrome 2, RGB, YBR_FULL, YBR_RCT, YBR_ICT	Yes	Yes
JPEG 2000 Lossless	Monochrome 1, Monochrome 2, PALETTE COLOR, RGB, YBR_FULL, YBR_RCT	Yes	Yes
JPEG LS Lossless	Monochrome 1, Monochrome 2, PALETTE COLOR, RGB, YBR_FULL	Yes	Yes
JPEG LS Near Lossless	Monochrome 1, Monochrome 2, RGB, YBR_FULL	Yes	Yes
HTJ2K	Monochrome 1, Monochrome 2, YBR_ICT, YBR_RCT, RGB, YBR_FULL	No	Yes
HTJ2K Lossless	Monochrome 1, Monochrome 2, PALETTE COLOR, YBR_ICT, YBR_RCT, RGB, YBR_FULL	No	Yes
HTJ2K Lossless RPCL	Monochrome 1, Monochrome 2, PALETTE COLOR, YBR_ICT, YBR_RCT, RGB, YBR_FULL	No	Yes

Visual NLP Dicom Pipeline

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- **Dicom Metadata Only De-Identification Pipeline**
  - This pipeline demonstrates how to extract metadata from a DICOM file and apply de-identification techniques specifically on metadata tags.

  - Notebook: Dicom_Metadata_only.ipynb

- **Dicom Pixel De-Identification Pipeline**
  - This pipeline focuses on de-identifying Protected Health Information (PHI) within the image pixels as well as metadata.

  - It involves extracting metadata, detecting text regions in pixel data, extracting text, performing NER (Named Entity Recognition), and finally redacting identified PHI regions and metadata tags.

  - Notebook: Dicom_Deidentification.ipynb

Visual NLP Dicom Pipeline (Metadata - Deidentification)

- **Dicom Pixel De-Identification With Metadata Pipeline**
  - This pipeline focuses on de-identifying Protected Health Information (PHI) within DICOM image pixels using metadata as a supporting source.
  - Metadata extracted from the DICOM file is used to generate additional NER (Named Entity Recognition) entries, which can be combined with entities detected by Healthcare-NLP models.
  - This hybrid approach improves PHI detection by capturing entities that may be missed by the models but are present in the metadata.
  - The remaining steps follow the standard pixel de-identification process.
  - Notebook: Dicom_Deidentification_Using_Metadata.ipynb

Visual NLP Dicom Pipeline (Obfuscation)

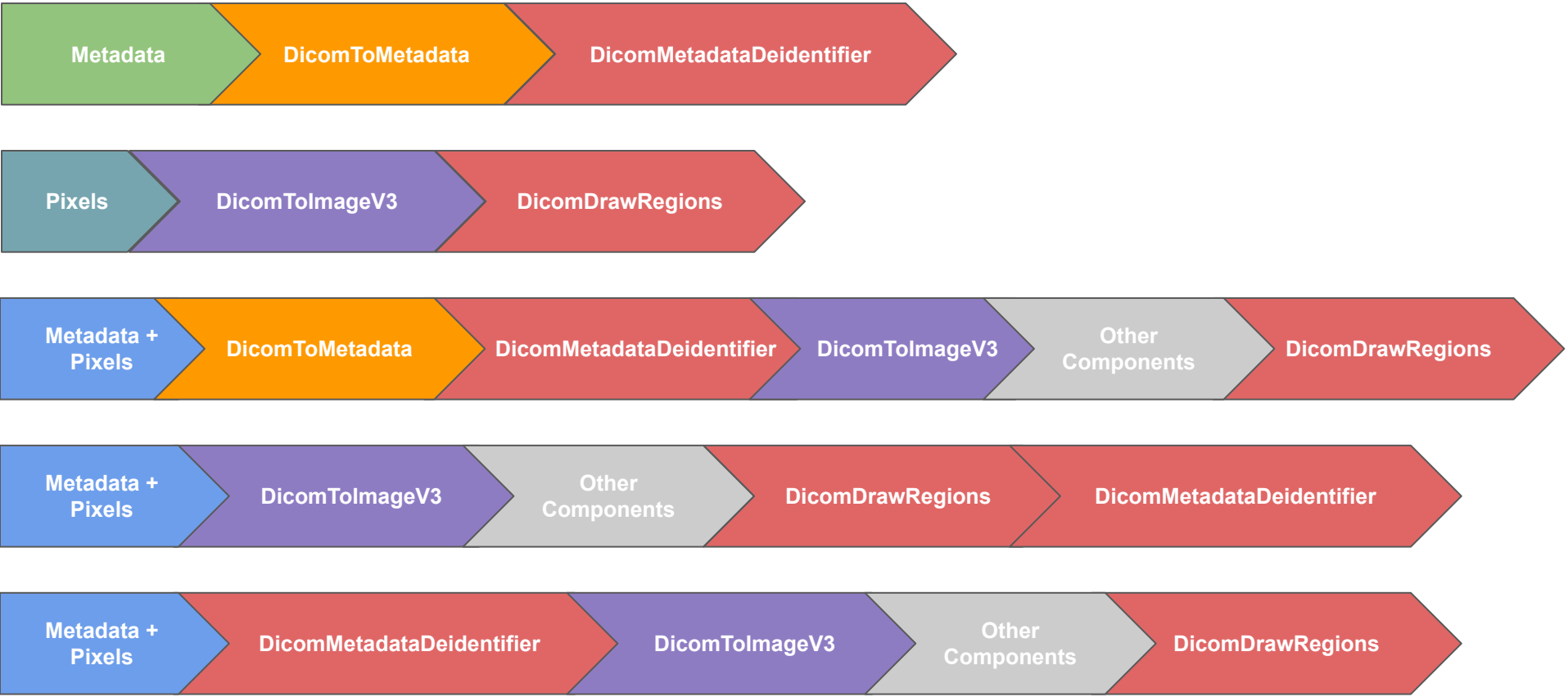
- **Dicom Pixel Obfuscation Pipeline**
  - This pipeline focuses on replacing original PHI text with newly rendered obfuscated text directly within the image.

  - Instead of redacting PHI regions using black boxes, it extends the concept of de-identification by generating visually consistent patches that contain obfuscated text, seamlessly overlaid in place of the original content.

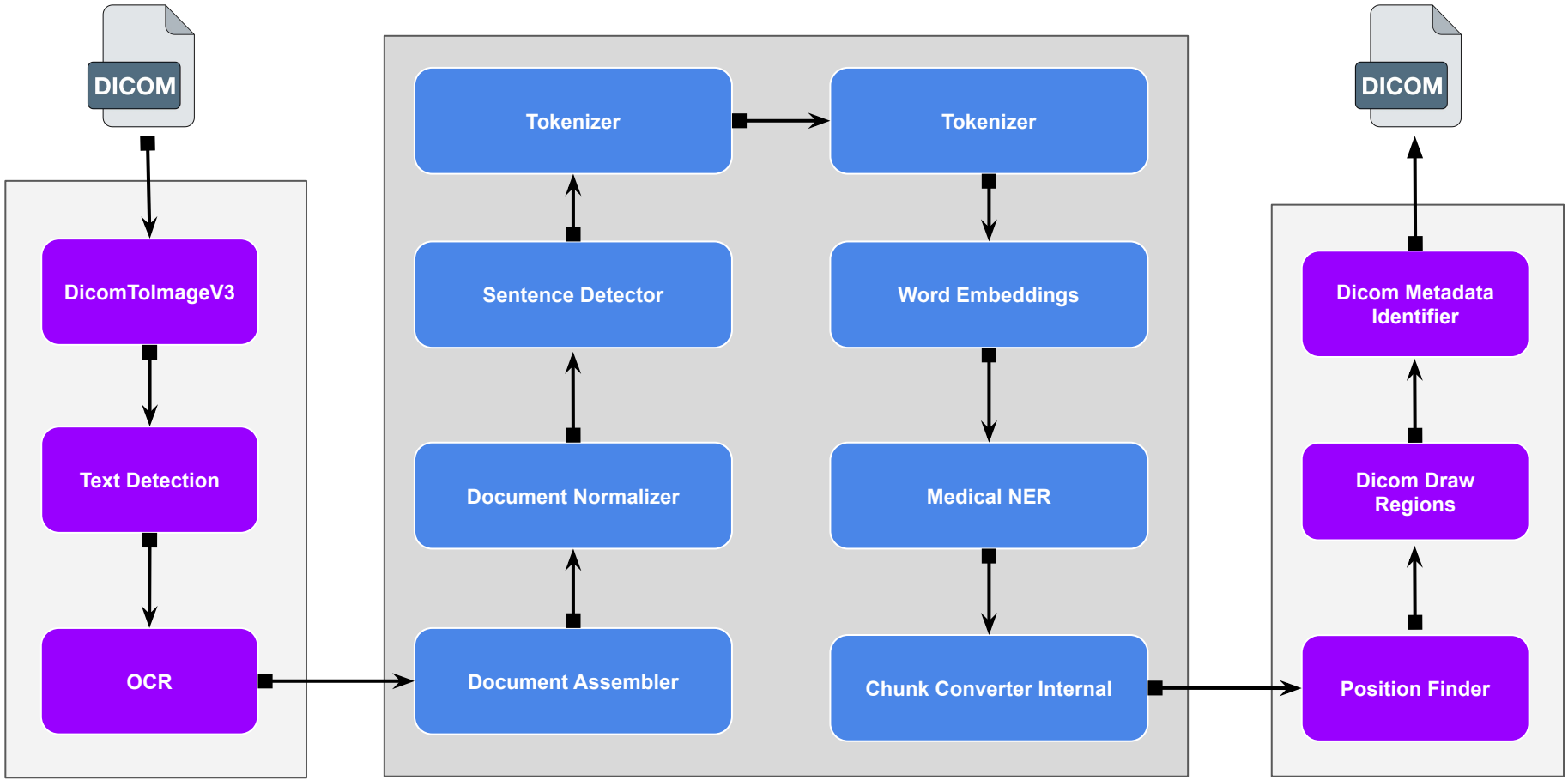
  - What is Obfuscation?
    - {original Text : “John Snow”, obfuscated Text : “Jane Knox” }
    - {original Text : “02/02/1999”, obfuscated Text : “20/12/2015” }
    - {original Text : “22”, “obfuscated Text : “33” }

  - Notebook: Dicom_Obfuscation_Methods.ipynb

Visual NLP Dicom (Pipeline Flows)



Visual NLP Dicom Pipeline



Dicom Metrics

- **Repo Link** https://github.com/JohnSnowLabs/dicom-deid-dataset
- **Google Collab**
  - CPU - HIGH RAM [8 Cores] - 0.18 Credits/hr
  - GPU - HIGH RAM [8 Cores] 1 X A100 GPU (40 GB) - 7.62 Credits/hr
- **Databricks**
  - **Cluster**
    - CPU - Driver 64 GB [16 Cores] m4.4xlarge, with minimum & maximum 8 Executors 32GB [8 Cores] m4.2xlarge - 15 dbu/h
    - GPU - Driver 64 GB Single GPU g4dn.4xLarge[T4], with minimum & maximum 2 Executors 16GB Single GPU g4dn.xLarge[T4] - 4.27 dbu/h
  - **Standalone**
    - CPU - Driver 64 GB [16 Cores] m4.4xlarge - 3 dbu/h
    - GPU - Driver 64 GB Single GPU g4dn.4xLarge[T4] - 2.85 dbu/h

Model	Precision	Recall	F1-Score	Google Collab (s)	Databricks Cluster CPU (s)	Databricks Cluster GPU (s)
ImageTextDetector + ImageToTextV2 (Base)	0.871	0.800	0.834	3.63	2.94	2.76
ImageTextDetector + ImageToTextV2 (Large)	0.892	0.822	0.856	4.06	3.59	3.2
ImageTextDetector + ImageToTextV3	0.741	0.433	0.547	0.68	1.83	1.0
ImageToText	0.436	0.289	0.348	0.31	0.85	0.89
Presidio	0.07	0.128	0.091	0.54	N/A	N/A

Important Links

- **Visual NLP:**
  - https://www.johnsnowlabs.com/visual-nlp/
- **Visual NLP Workshop:**
  - https://github.com/JohnSnowLabs/visual-nlp-workshop/tree/master
- **Healthcare NLP Workshop:**
  - https://github.com/JohnSnowLabs/spark-nlp-workshop/tree/master/healthcare-nlp
- **Spark NLP Workshop:**
  - https://github.com/JohnSnowLabs/spark-nlp-workshop
- **Visual NLP Pipeline Components:**
  - https://nlp.johnsnowlabs.com/docs/en/ocr_pipeline_components
- **Visual NLP Speed Benchmarks:**
  - https://nlp.johnsnowlabs.com/docs/en/ocr_benchmark
- **Visual NLP Helpers:**
  - https://nlp.johnsnowlabs.com/docs/en/ocr_structures
- **Dicom Deidentification Metrics:**
  - https://github.com/JohnSnowLabs/dicom-deid-dataset