EdIE-viz: A demo comparing Rule-based and Neural Network-based Information Extraction Systems for Brain Radiology Reports.

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Team


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Heather Whalley


Dominic Sykes

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Motivation

Brain Scan Radiology Report

There is loss of the neuronal tissue in the left inferior frontal and superior temporal lobes, consistent with a prior infarct. There is generalised cerebral volume loss which appears within normal limits for the patients age, with no focal element to the generalised atrophy. Major intracranial vessels appear patent. White matter of the brain appears largely normal, with no evidence of significant small vessel disease. No mass lesion, hydrocephalus or extra axial collection

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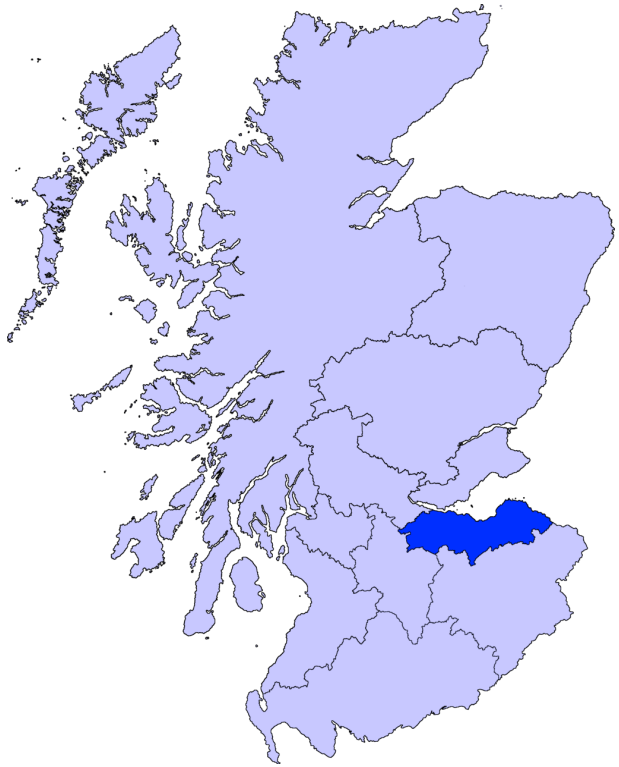

Figure: Map of Scotland

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Motivation

Extract granular stroke findings from radiology reports at scale.

Brain Scan Radiology Report

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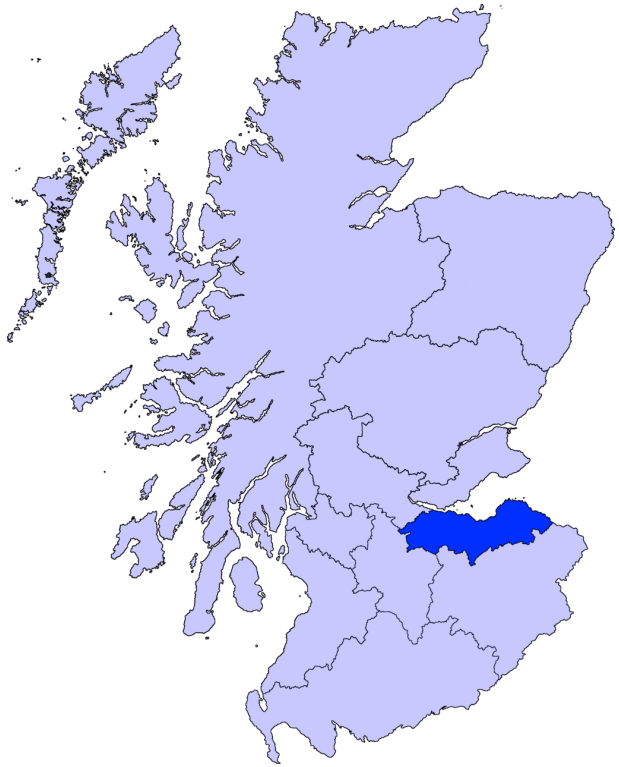

Figure: Map of Scotland

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Use cases

William Whiteley

- Large scale epidemiological analysis.

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- Prognosis of rarer lesions.

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Heather Whalley

- Understand links between psychiatric disorders and neurological conditions.

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Use cases

William Whiteley

- Large scale epidemiological analysis.
- Prognosis of rarer lesions.
- Cohort selection for large scale randomised trials.

Heather Whalley

- Understand links between psychiatric disorders and neurological conditions.
- Stroke patients who also suffer from depression usually have worse recovery.

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Overview

- Introduce Phenotyping

Overview

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- EdIE-viz Demo

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Overview

- Introduce Phenotyping
- EdIE-viz Demo
- Annotation Inconsistencies

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Information Extraction from Radiology Reports

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Data: Edinburgh Stroke Study (ESS)

Edinburgh Stroke Study (Prof. Cathie Sudlow) NHS Lothian[1]

- 1,168 CT and MRI reports

[1] Jackson et al. 2008.

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- 1,168 CT and MRI reports
- Consented data
- Hospital-based register of stroke and transient ischaemic attack
- 2 radiology expert annotators
- Correcting rule-based (EdIE-R) output

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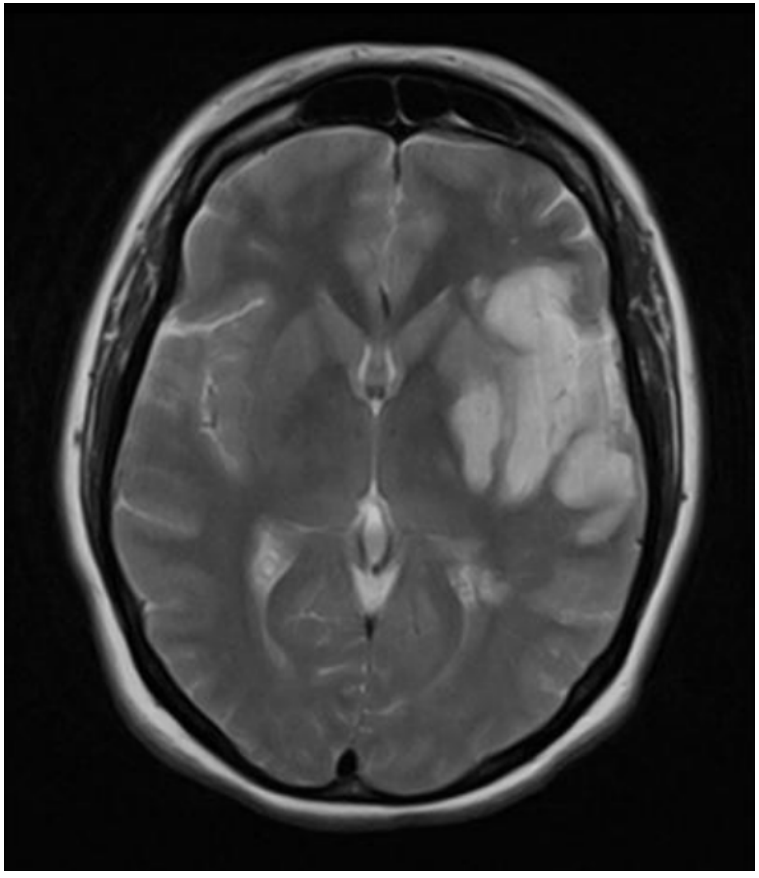
Goal: Document Labelling / Phenotyping

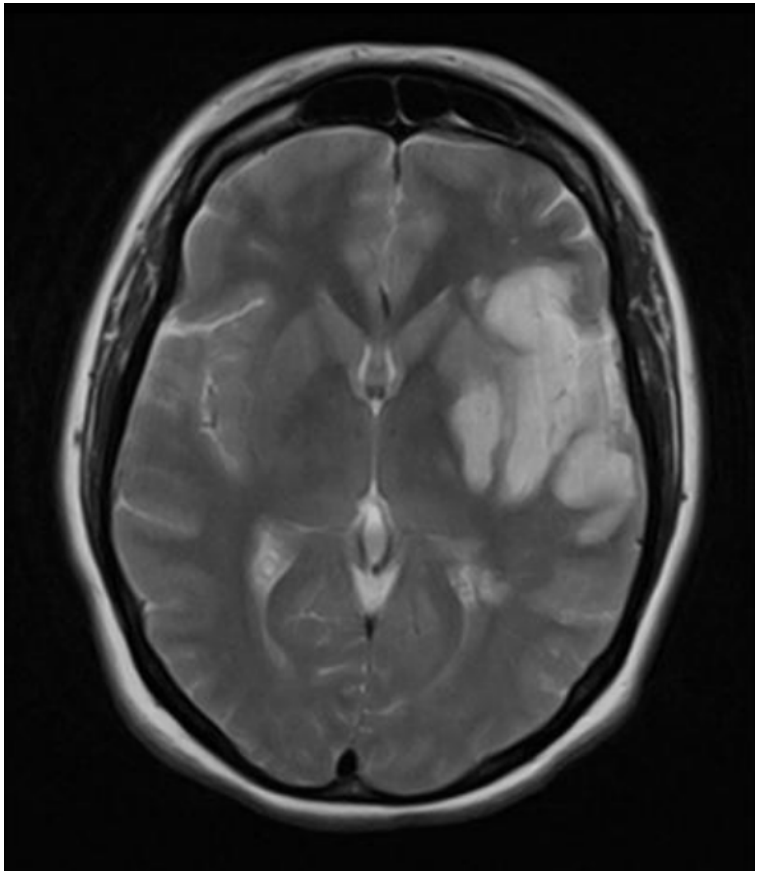


Source: https://radiopaedia.org/cases/left-mca-infarct-2

Goal: Document Labelling / Phenotyping

Example Radiology Report

Impression: Moderate volume loss.
Evolving left MCA infarction.
No acute haemorrhage.



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Goal: Document Labelling / Phenotyping

Example Radiology Report

Impression: **Moderate volume loss**.
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Document Labels

- Atrophy

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Goal: Document Labelling / Phenotyping

Example Radiology Report

Impression: Moderate volume loss.
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No acute haemorrhage.

Document Labels

- Atrophy
- Recent Cortical Acute Ischaemic Stroke

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Pipeline

Example Radiology Report

Impression: Moderate volume loss.
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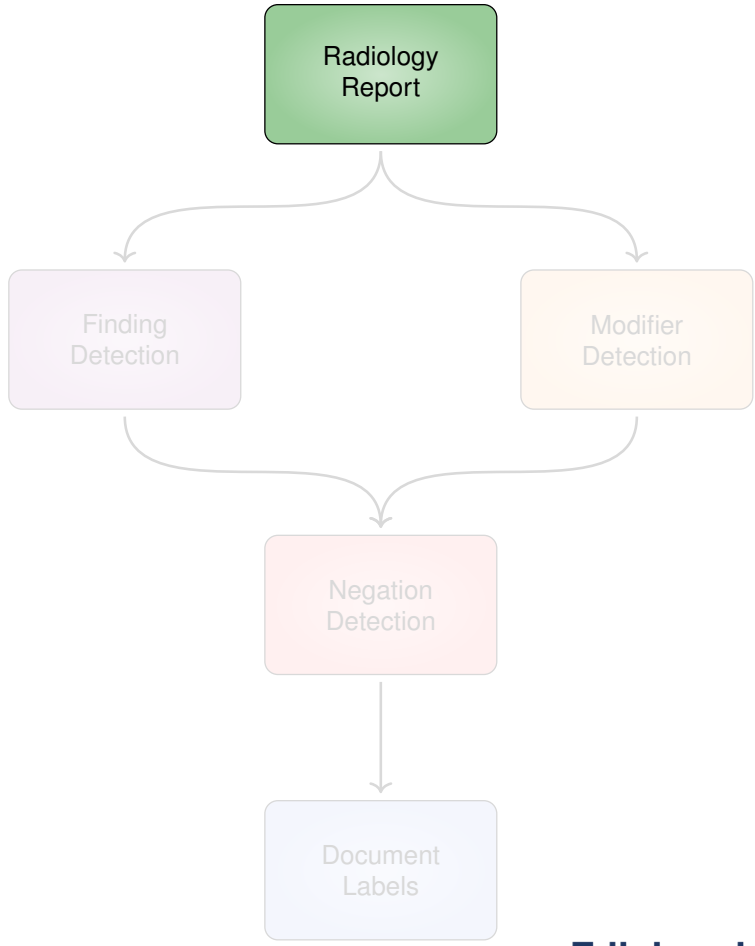
Subtasks

1. Findings (eg. atrophy, stroke etc.)
2. Modifiers (eg. time or location)
3. Negation



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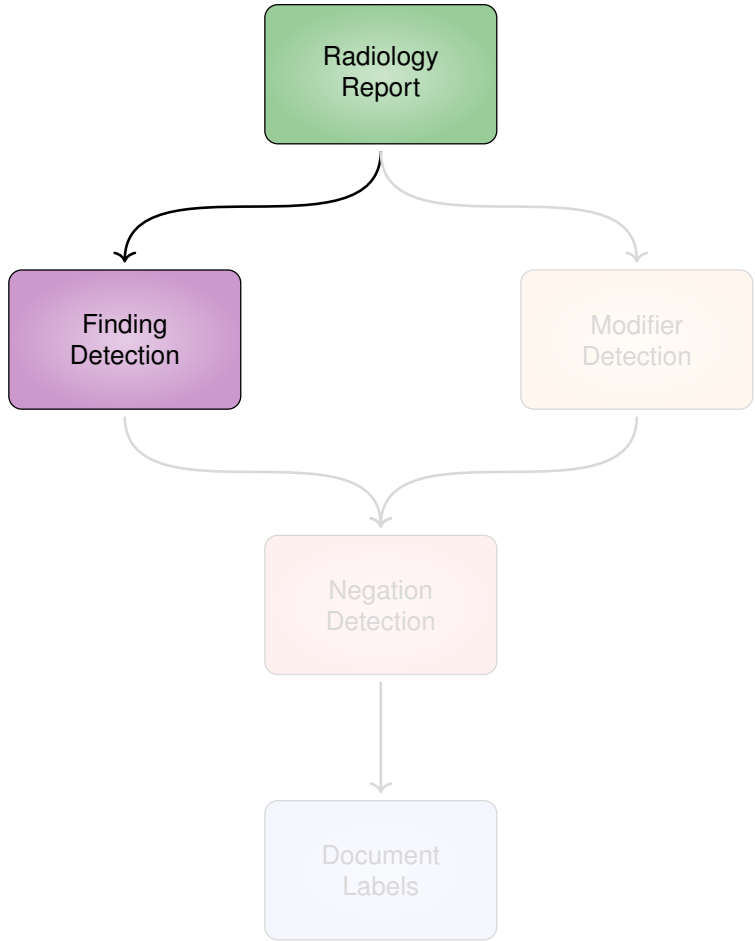

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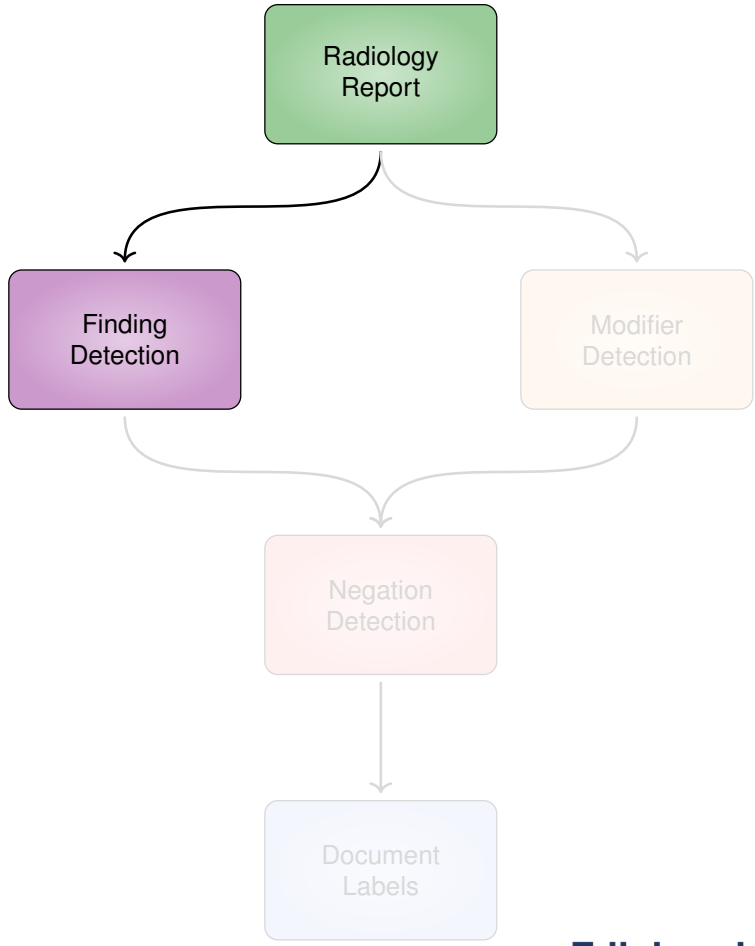

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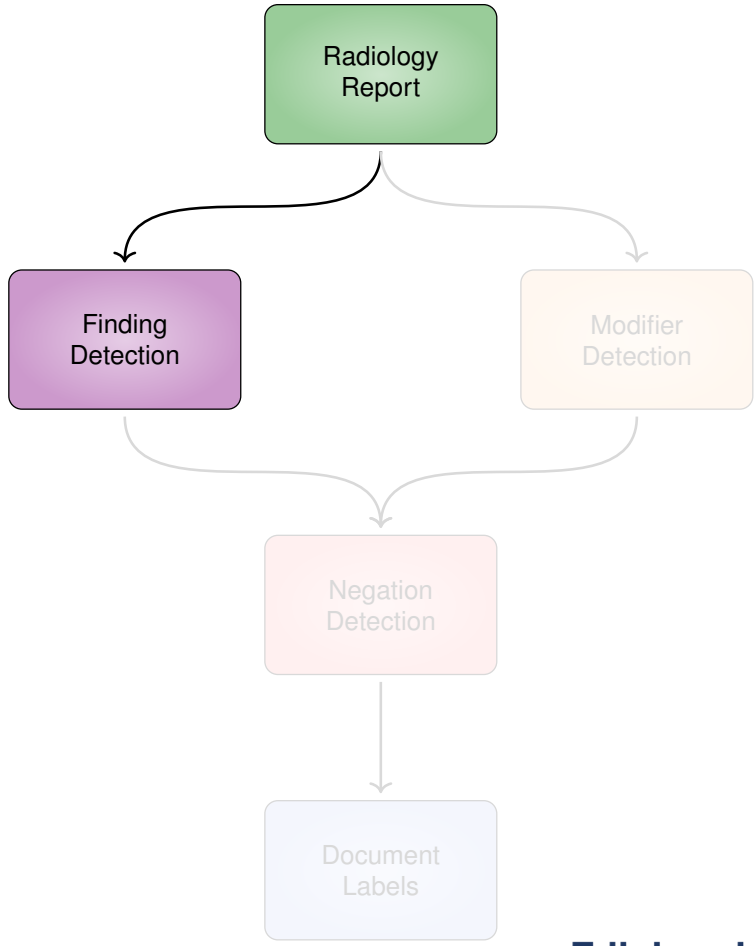

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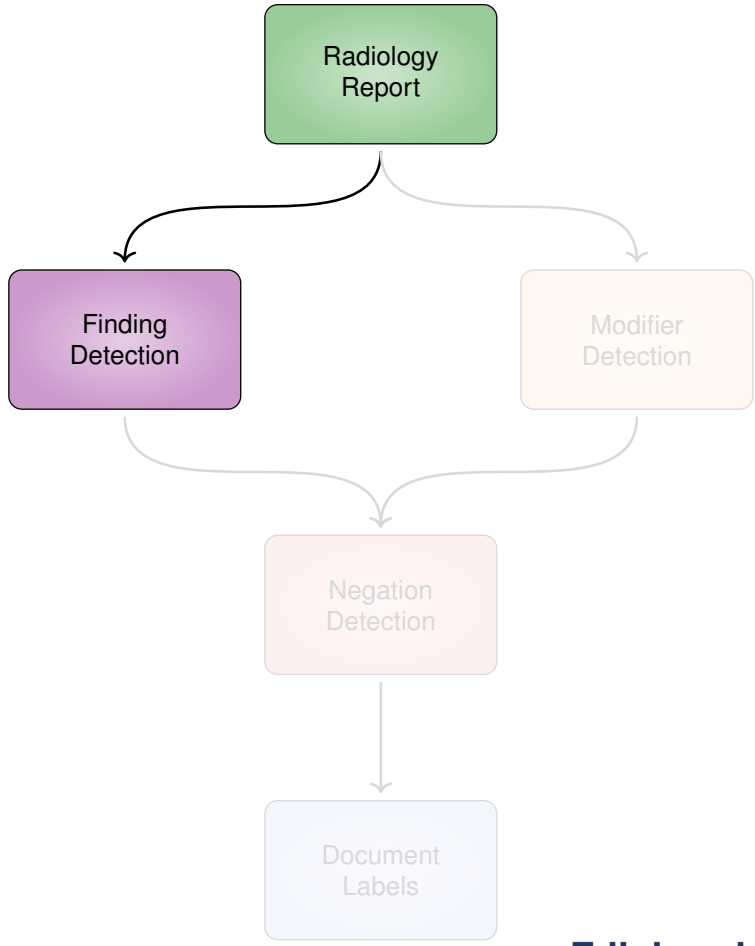

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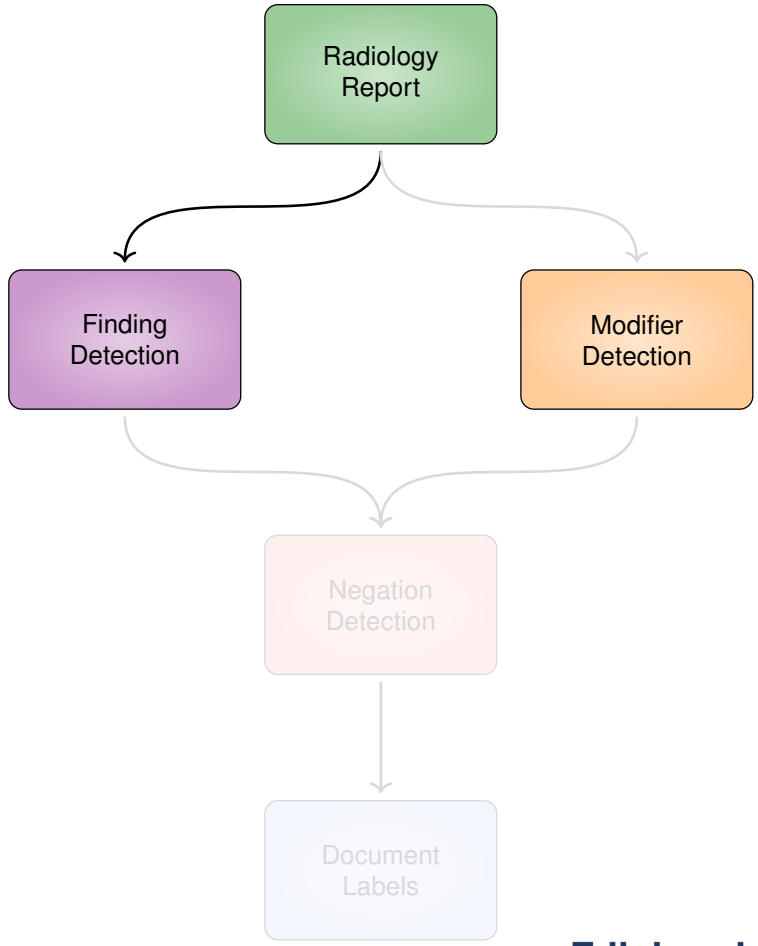

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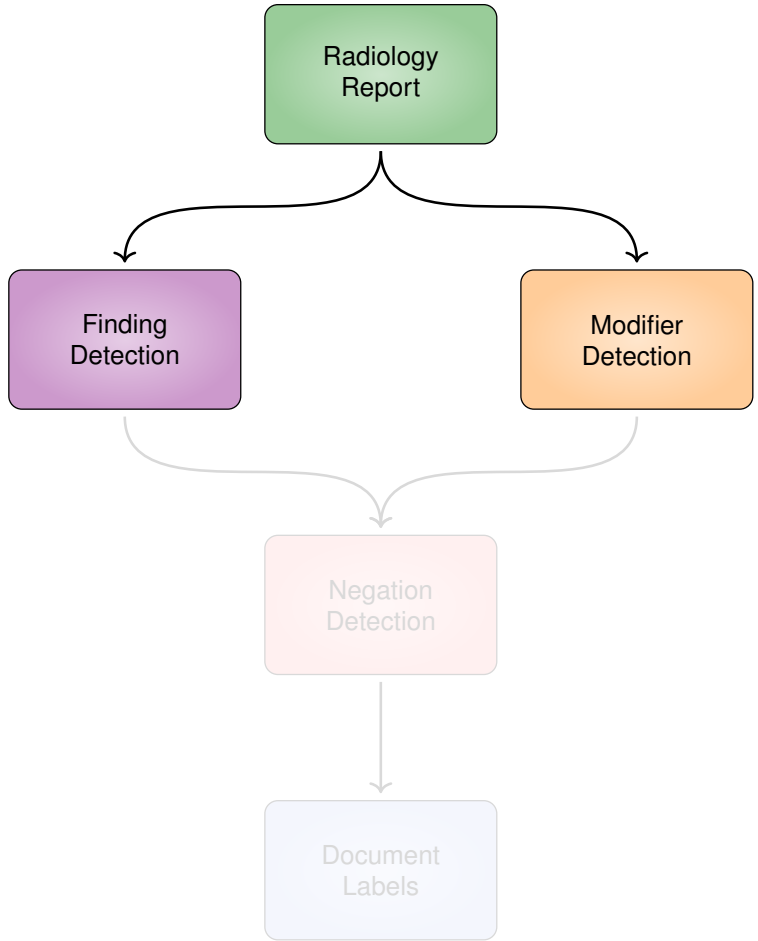

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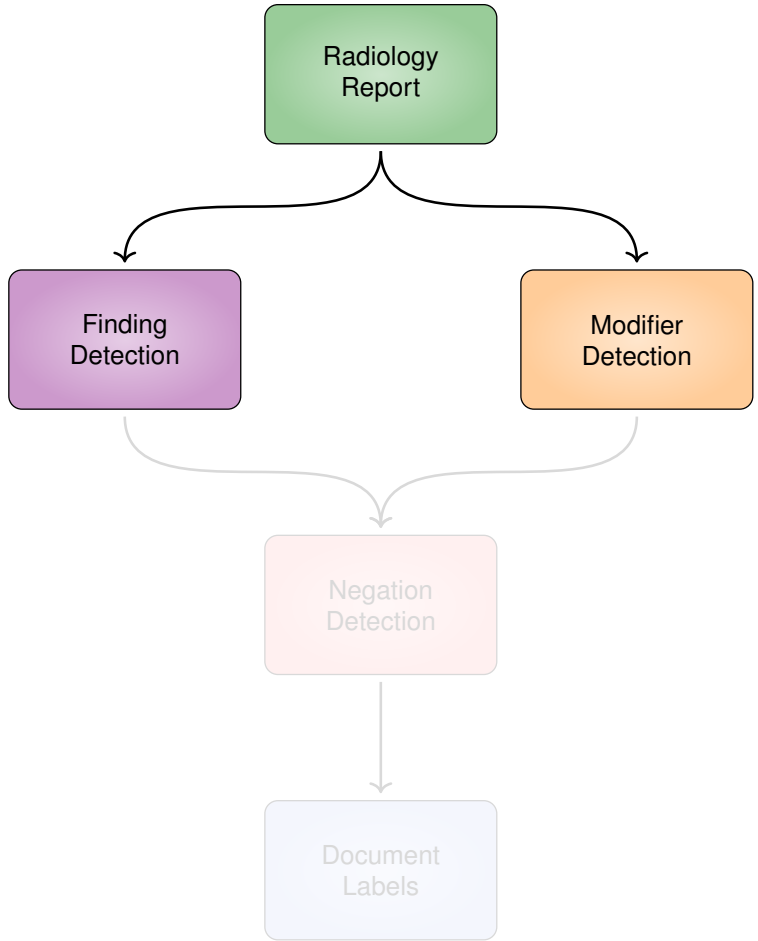

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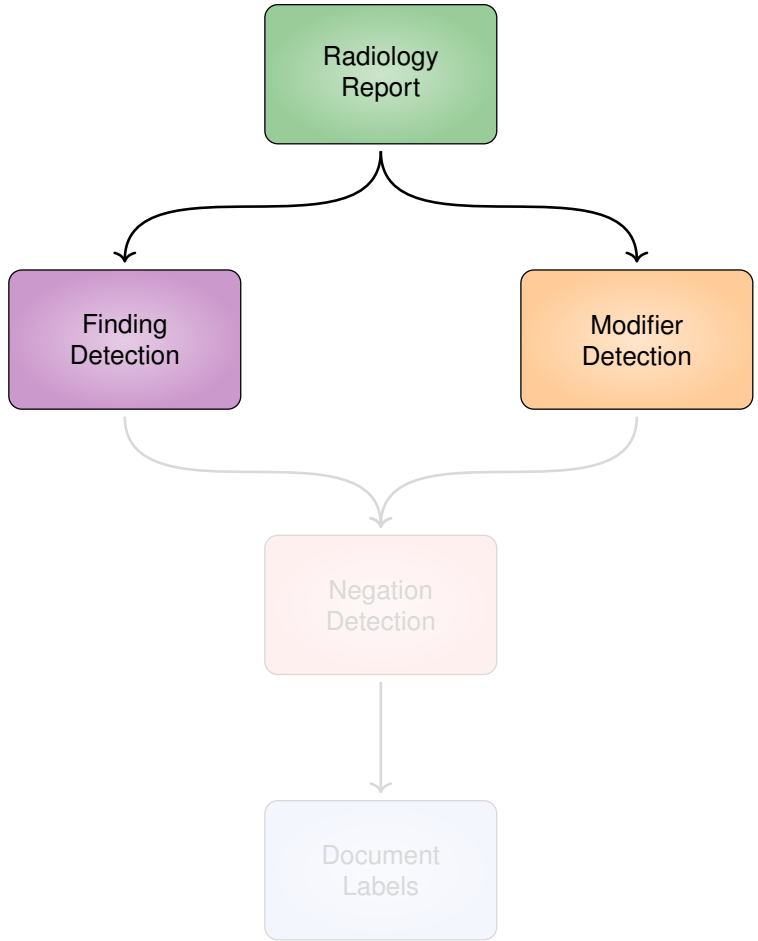

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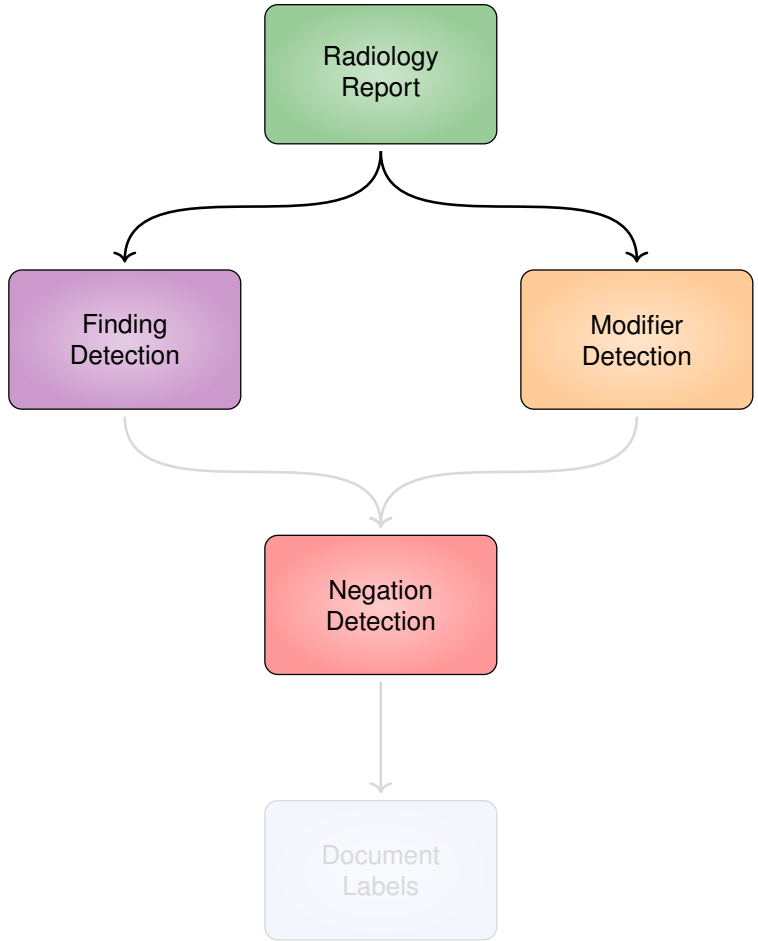

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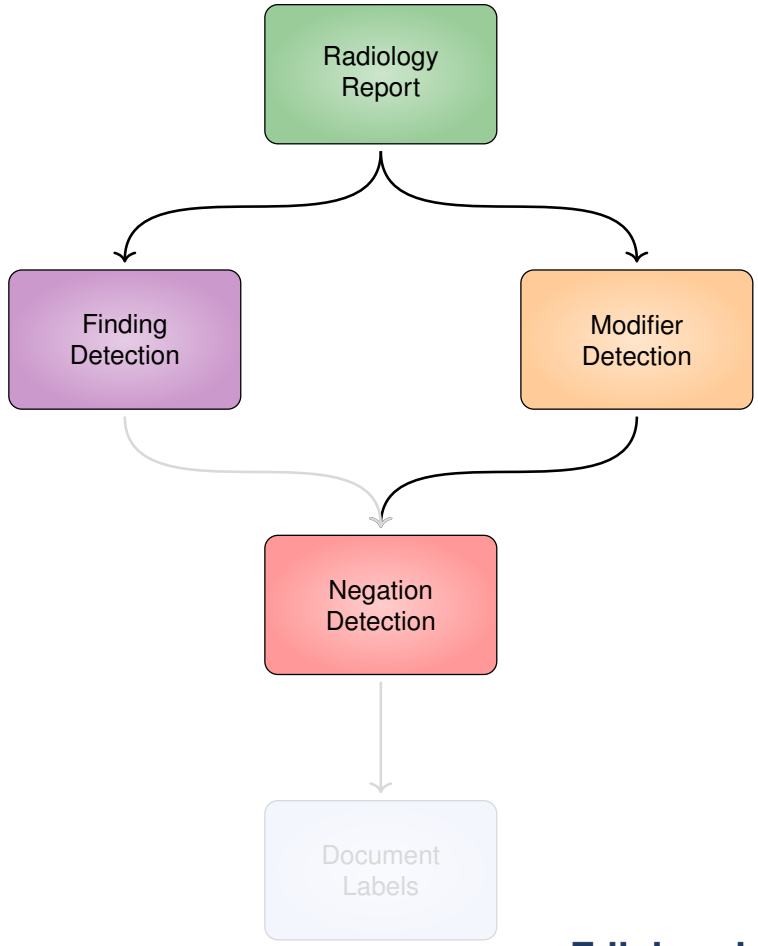

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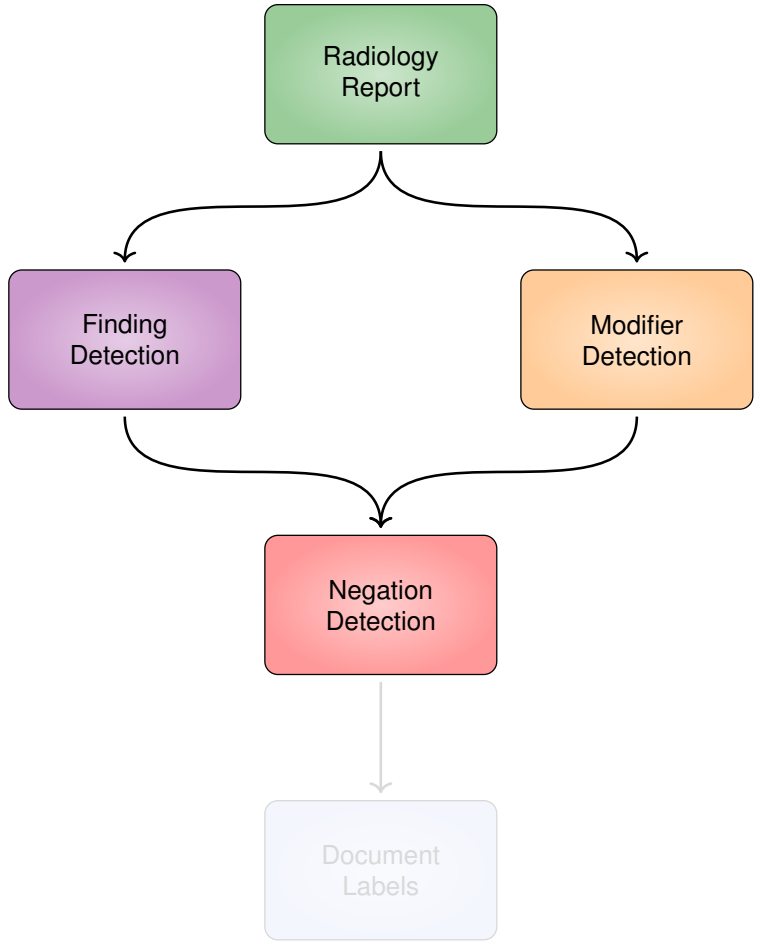

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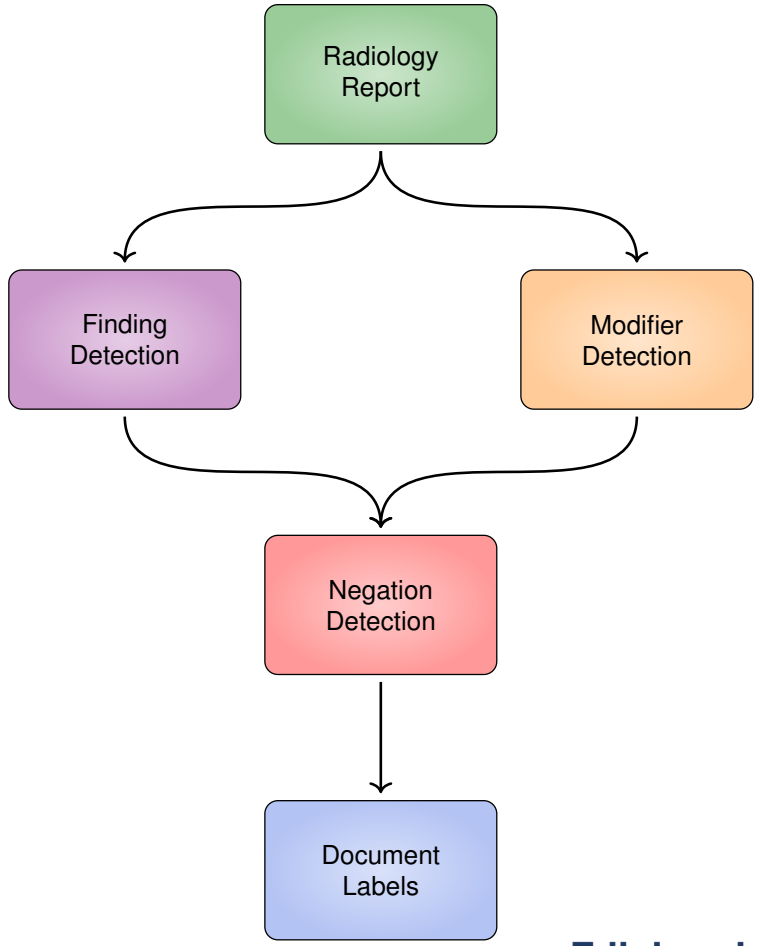

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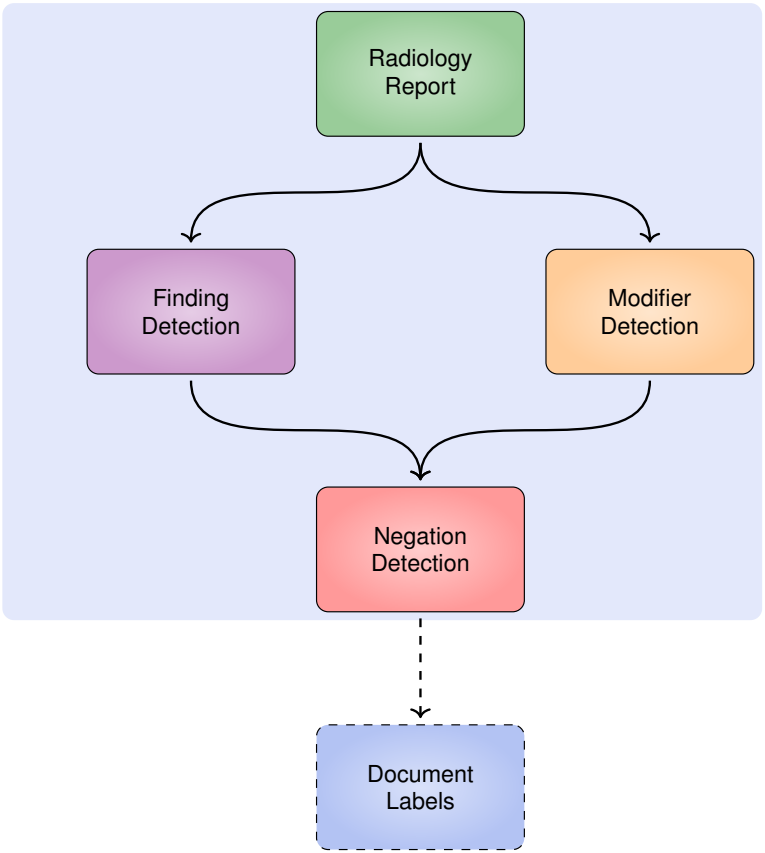
Rule-Based and Neural components

Rule-based

Pipeline Components



[1] Alex et al. 2019.
[2] Gorinski et al. 2019.
[3] Sykes et al. 2020.
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Rule-Based and Neural components

Rule-based

- EdIE-R [1,2,3,4]

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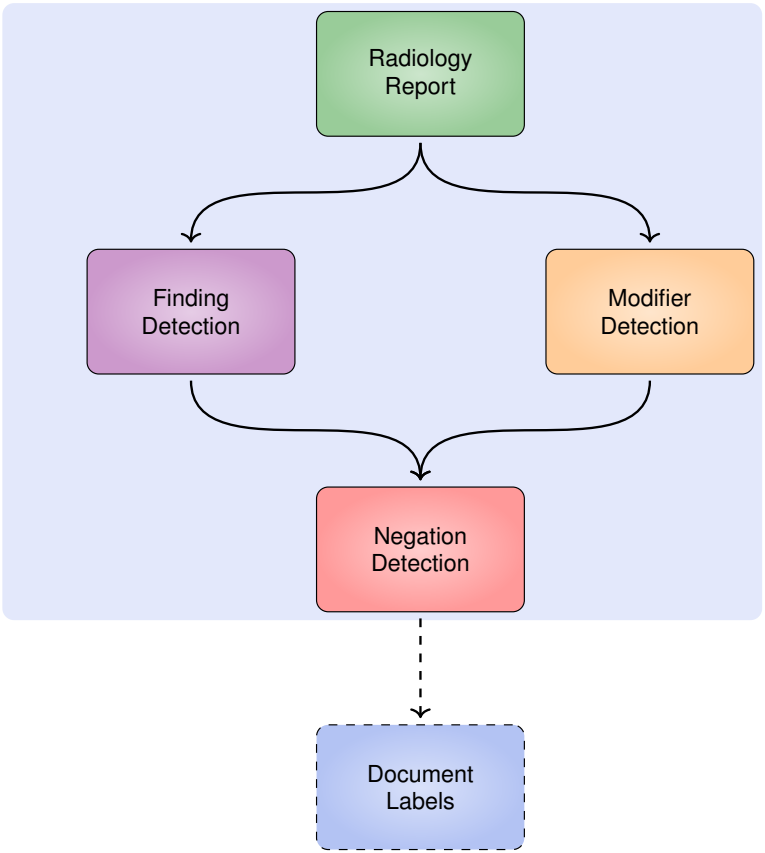

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Rule-Based and Neural components

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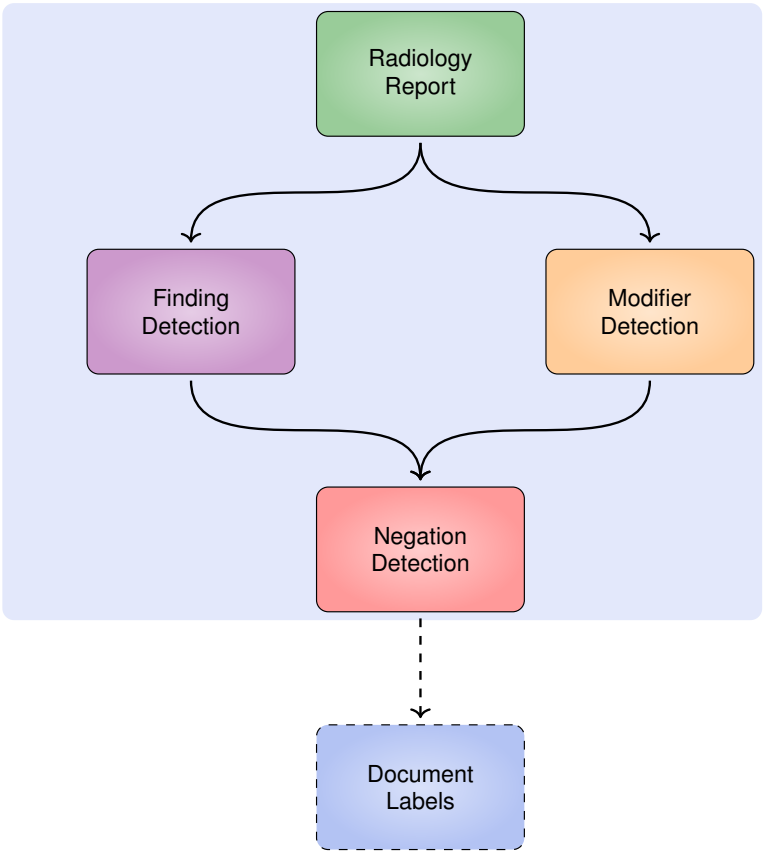
- EdIE-R [1,2,3,4]

Neural Network-based

Pipeline Components



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Rule-Based and Neural components

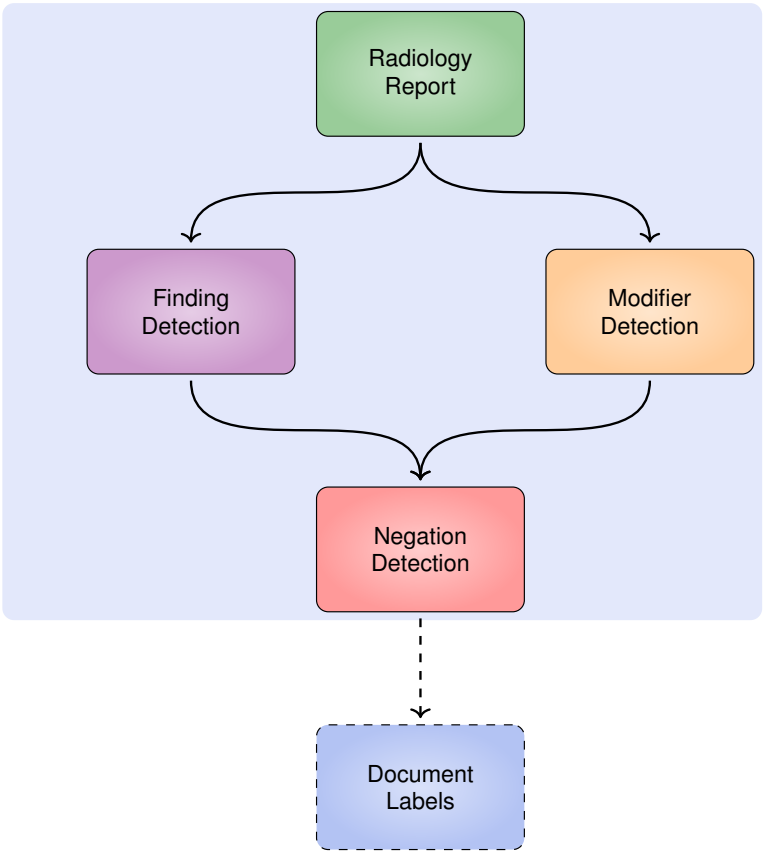
Rule-based

- EdIE-R [1,2,3,4]

Neural Network-based

- EdIE-BiLSTM: BiLSTM encoder [2,4]

Pipeline Components



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Rule-Based and Neural components

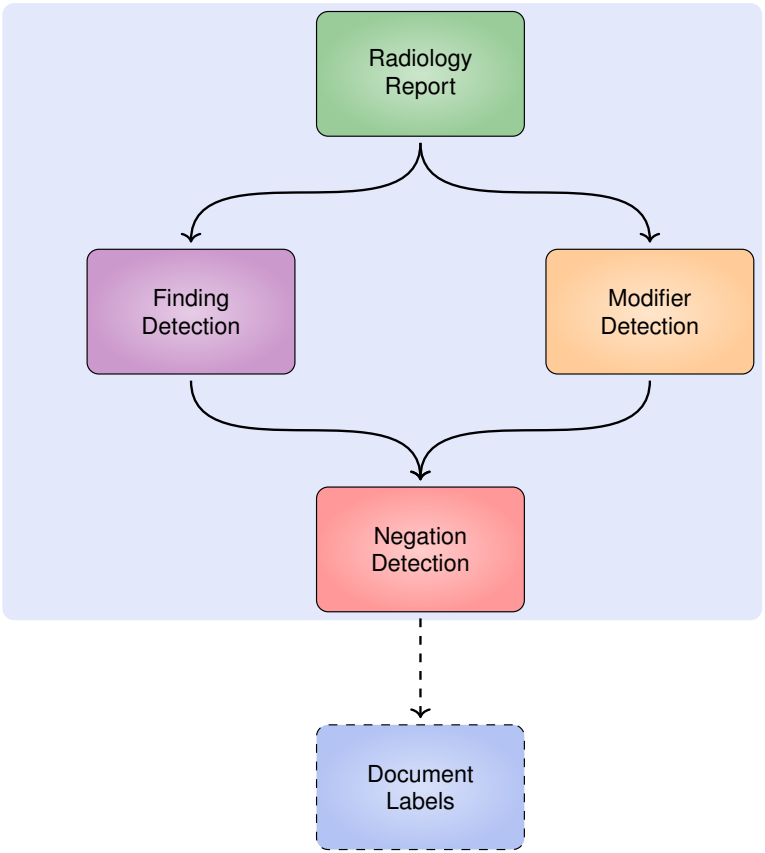
Rule-based

- EdIE-R [1,2,3,4]

Neural Network-based

- EdIE-BiLSTM: BiLSTM encoder [2,4]
- EdIE-BERT: BERT encoder [4]

Pipeline Components



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Extracting information from radiology reports

Radiology report before processing.

Clinical Details

Report

No previous brain imaging for comparison .

Cerebral involutional change , advanced for age .

Evidence of an old left posterior temporal / parietal infarct .

White matter hypoattenuation in keeping with moderate small vessel change .

No intracranial mass , infarct or haemorrhage .

The skull vault and skull base appear unremarkable .

Opinion :

Advanced cerebral atrophy , moderate small vessel disease and old infarcts as described above .

No acute intracranial finding .

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Extracting information from radiology reports

Radiology report after processing.

Clinical Details

Report

No previous TIME OLD brain imaging for comparison .

Cerebral involutional change ATROPHY , advanced for age .

Evidence of an old TIME OLD left posterior temporal LOC CORTICAL / parietal LOC CORTICAL infarct ISCHAEMIC STROKE .

White matter hypoattenuation SMALL VESSEL DISEASE in keeping with moderate small vessel change SMALL VESSEL DISEASE .

No intracranial mass TUMOUR , infarct ISCHAEMIC STROKE or haemorrhage HAEMORRHAGIC STROKE .

The skull vault and skull base appear unremarkable .

Opinion :

Advanced cerebral atrophy ATROPHY , moderate small vessel disease SMALL VESSEL DISEASE and old TIME OLD infarcts ISCHAEMIC STROKE as described above .

No acute TIME RECENT intracranial finding .

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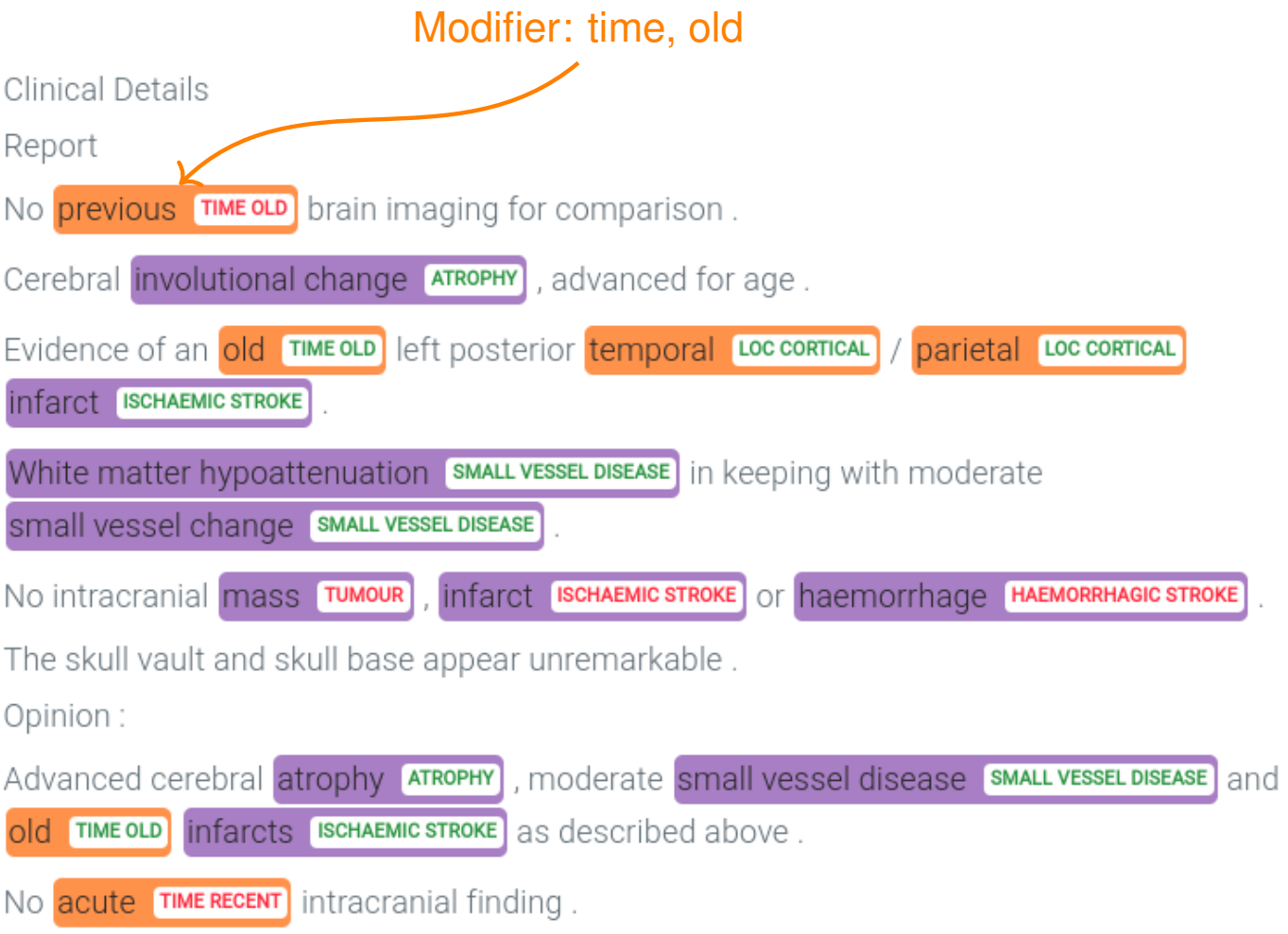
Extracting information from radiology reports

Radiology report after processing.



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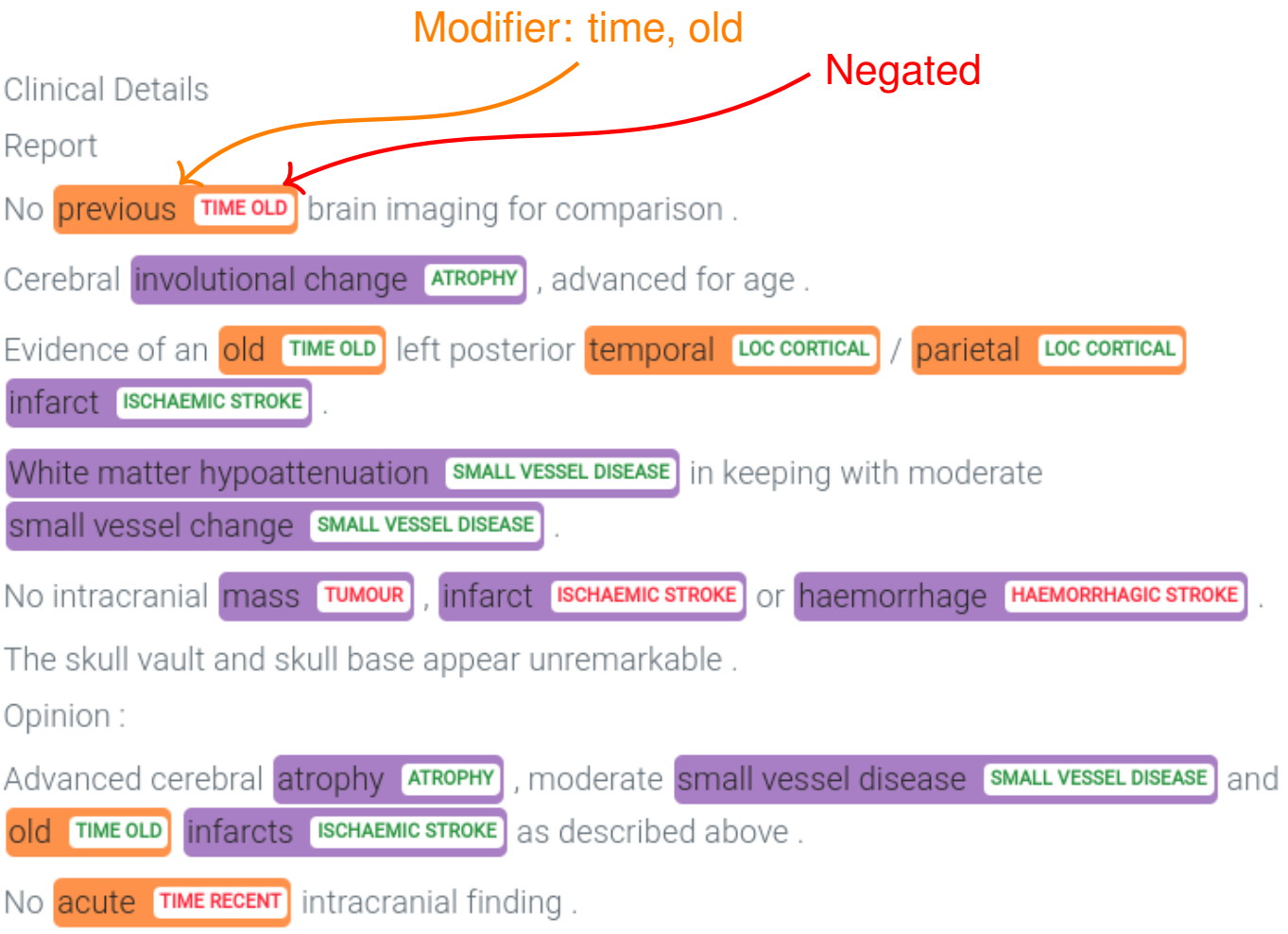

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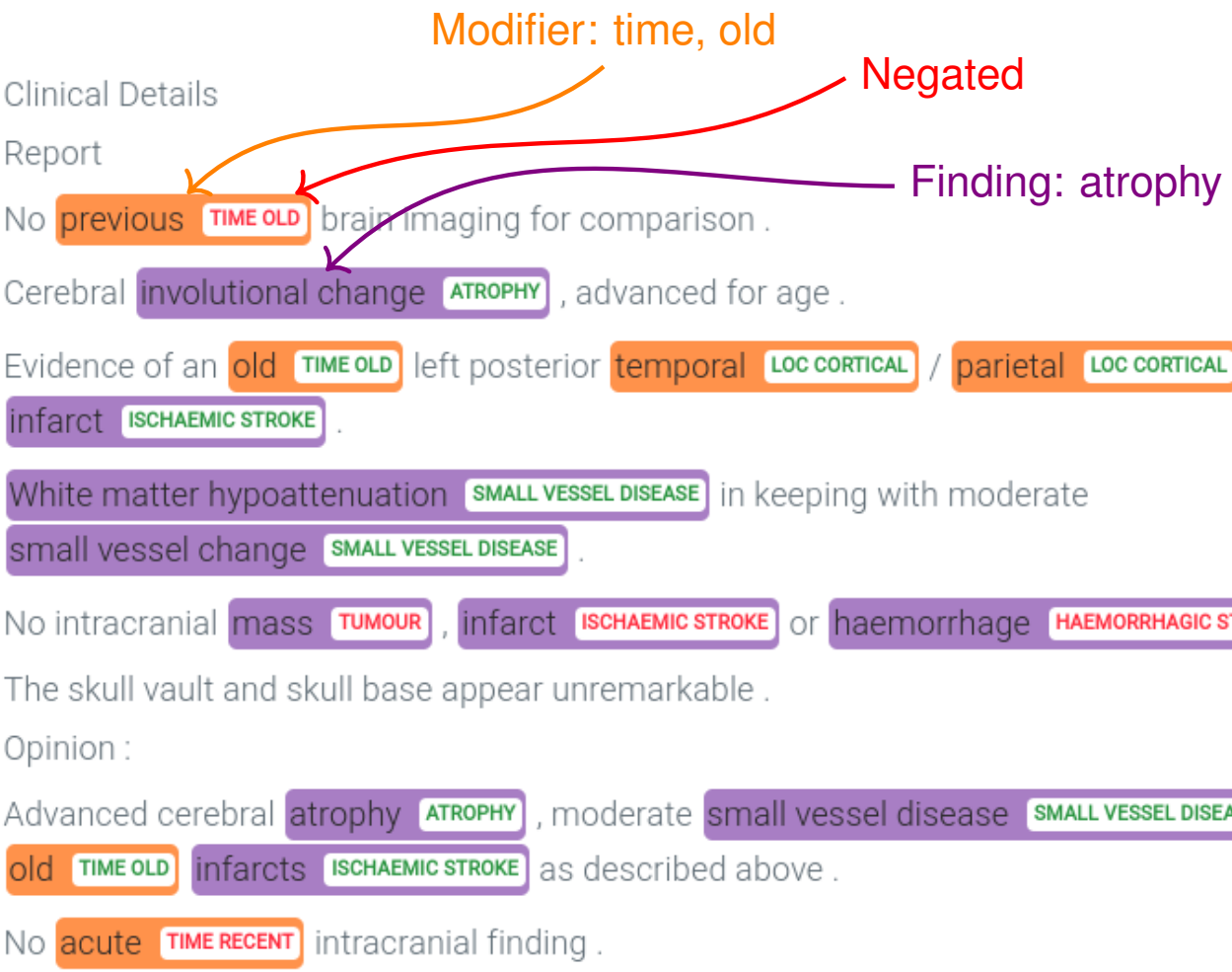

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EdIE-viz Demo

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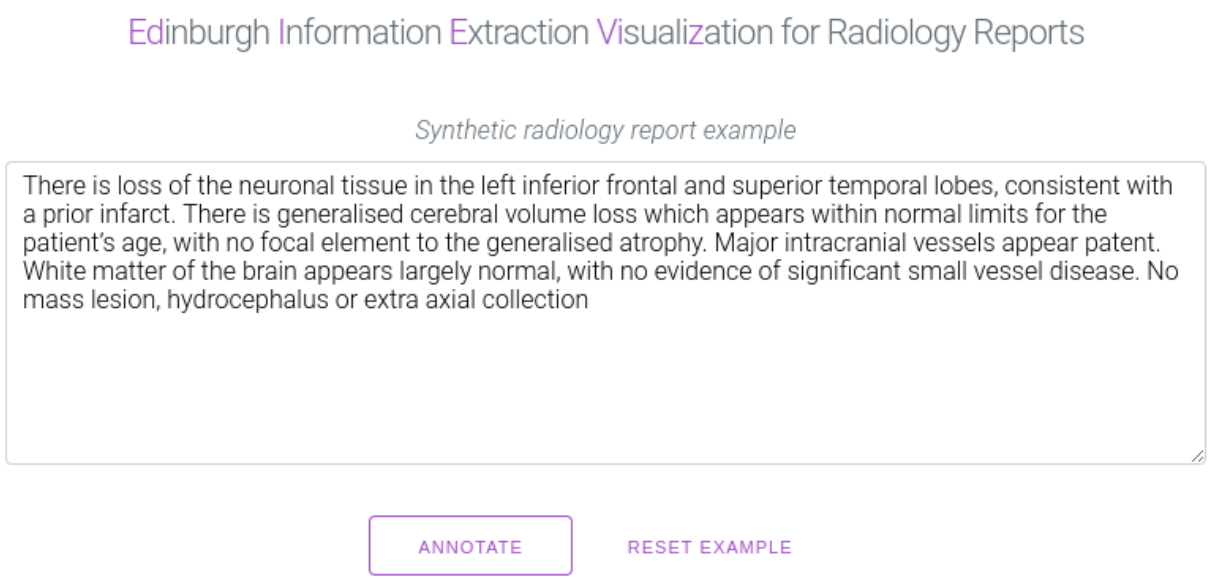
EdIE-viz



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Annotation inconsistencies

Current model results

System	Task	F1
EdIE-R	Mod	**96.48**
	Find	**93.06**
EdIE-BiLSTM	Mod	95.18
	Find	92.64
EdIE-BERT	Mod	95.68
	Find	90.33

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- High scores, with rule-based best overall

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- High scores, with rule-based best overall
- Unexpected: BERT worse than BiLSTM

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Identifying Annotation Inconsistencies (1)

Boundary Error Example

Truth: Moderate volume loss ATROPHY .

Identifying Annotation Inconsistencies (1)

Boundary Error Example

Truth: Moderate volume loss ATROPHY . **Pred:** Moderate volume loss ATROPHY .

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Identifying Annotation Inconsistencies (1)

Boundary Error Example

Truth: Moderate volume loss ATROPHY . **Pred:** Moderate volume loss ATROPHY .

$(L^2)^2$ Distance	**Retrieved training examples**
19.91	Moderate cortical volume loss .
33.51	Moderate generalised volume loss ATROPHY , not advanced for age .
35.14	Moderate generalised volume loss ATROPHY .

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Identifying Annotation Inconsistencies (2)

False Positive Example

Truth: No focal destructive bony lesion .

Identifying Annotation Inconsistencies (2)

False Positive Example

Truth: No focal destructive bony lesion . **Pred:** No focal destructive bony lesion TUMOUR .

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Identifying Annotation Inconsistencies (2)

False Positive Example

Truth: No focal destructive bony lesion . **Pred:** No focal destructive bony lesion TUMOUR .

$(L^2)^2$ Distance	**Retrieved training examples**
28.80	No destructive bony lesion.
28.87	No destructive bony lesion TUMOUR or calvarial fracture is evident .
41.09	No bony lesion or injury is seen .

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Takeaways

Resources

- Demo online: http://jekyll.inf.ed.ac.uk/edieviz
- Code & models available: https://github.com/Edinburgh-LTG/edieviz

Summary

- EdIE-viz highlights strengths and weaknesses of systems.

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Takeaways

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Summary

- EdIE-viz highlights strengths and weaknesses of systems.
- Detecting annotation inconsistencies important to further improve results.

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References

Alex, Beatrice et al. (2019). "Text mining brain imaging reports". In: Journal of Biomedical Semantics 10.1, p. 23. ISSN: 2041-1480. DOI: https://doi.org/10.1186/s13326-019-0211-710.1186/s13326-019-0211-7.

Gorinski, Philip John et al. (2019).
Named Entity Recognition for Electronic Health Records: A Comparison of Rule-based and Machine Learning Approaches. arXiv: 1903.03985 [cs.CL].

Grivas, Andreas et al. (Nov. 2020). "Not a cute stroke: Analysis of Rule- and Neural Network-based Information Extraction Systems for Brain Radiology Reports". In: Proceedings of the 11th International Workshop on Health Text Mining and Information Analysis. Online: Association for Computational Linguistics, pp. 24–37. DOI: 10.18653/v1/2020.louhi-1.4. URL: https://www.aclweb.org/anthology/2020.louhi-1.4.

Jackson, C. et al. (Feb. 2008). "Assessing the impact of the requirement for explicit consent in a hospital-based stroke study". In: QJM: An International Journal of Medicine 101.4, pp. 281–289. ISSN: 1460-2725. DOI: 10.1093/qjmed/hcm152. URL: https://doi.org/10.1093/qjmed/hcm152.

Sykes, D. et al. (2020). "Comparison of rule-based and neural network models for negation detection in radiology reports". In: Natural Language Engineering, pp. 1–22. DOI: 10.1017/S1351324920000509.

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Thank you

- Edinburgh Clinical NLP group:
  https://www.ed.ac.uk/usher/clinical-natural-language-processing
- Code:
  https://github.com/Edinburgh-LTG/edieviz
- Demo:
  http://jekyll.inf.ed.ac.uk/edieviz/

We are grateful for our funding:

- MRC Mental Health Data Pathfinder Award (MRC - MCPC17209)
- Turing Fellowships (EPSRC grant EP/N510129/1)
- MRC Clinician Scientist Award (G0902303)
- Scottish Senior Clinical Fellowship (CAF/17/01)

Rule-based reliable for negation

EdIE-R Predictions

no mass TUMOUR or extra-axial collections SUBDURAL HAEMATOMA present .

EdIE-N-BiLSTM Predictions

no mass TUMOUR or extra-axial collections SUBDURAL HAEMATOMA present .

EdIE-N-BERT Predictions

no mass TUMOUR or extra-axial collections SUBDURAL HAEMATOMA present .

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Neural models tolerant to spelling mistakes (1)

EdIE-R Predictions

Opinion : advanced cerebral atropy , moderate small vessel diseas and old TIME OLD infact as described above .

EdIE-N-BiLSTM Predictions

Opinion : advanced cerebral atropy , moderate small vessel diseas SMALL VESSEL DISEASE and old TIME OLD infact as described above .

EdIE-N-BERT Predictions

Opinion : advanced cerebral atropy ATROPHY , moderate small vessel diseas SMALL VESSEL DISEASE and old TIME OLD infact ISCHAEMIC STROKE as described above .

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Neural models tolerant to spelling mistakes (2)

EdIE-R Predictions

a cute ischemic stroke STROKE present

EdIE-N-BiLSTM Predictions

a cute TIME RECENT ischemic stroke STROKE present

EdIE-N-BERT Predictions

a cute ischemic stroke STROKE present

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Neural models tolerant to spelling mistakes (2)

But can overgeneralise.

EdIE-R Predictions

a cute ischemic stroke STROKE present

EdIE-N-BiLSTM Predictions

a cute TIME RECENT ischemic stroke STROKE present

EdIE-N-BERT Predictions

a cute ischemic stroke STROKE present

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Span inconsistencies

EdIE-R Predictions

Patchy peri-ventricular small vessel change SMALL VESSEL DISEASE .

EdIE-N-BiLSTM Predictions

Patchy peri-ventricular small vessel change SMALL VESSEL DISEASE .

EdIE-N-BERT Predictions

Patchy peri-ventricular small vessel change SMALL VESSEL DISEASE .

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BERT generalises to unseen vocabulary (1)

EdIE-R Predictions

This patient with normal carotids had a TIA , and was found to have a non-occlusive thrombus in the M1 segment on the left .

EdIE-N-BiLSTM Predictions

This patient with normal carotids had a TIA , and was found to have a non-occlusive thrombus in the M1 segment on the left .

EdIE-N-BERT Predictions

This patient with normal carotids had a TIA STROKE , and was found to have a non-occlusive thrombus in the M1 segment on the left .

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BERT generalises to unseen vocabulary (2)

EdIE-R Predictions

The density in melanoma is either due to blood product (haemorrhagic mets) or the melanin itself .

EdIE-N-BiLSTM Predictions

The density in melanoma is either due to blood product (haemorrhagic mets) or the melanin itself .

EdIE-N-BERT Predictions

The density in melanoma is either due to blood product (haemorrhagic HAEMORRHAGIC STROKE mets METAST TUMOUR) or the melanin itself .

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