Executive Summary

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1. **Title of the Project:**

   "Shushrut"- a System for Increasing Efficiency and Diagnosis- Accuracy in Clinical Workflow in Indian Radiology Using Automatic Speech Recognition and Natural Language Processing

2. **Date of Start of the Project:**

   1 February 2020

3. **Aims and Objectives:**

   3.1 Motivation and Challenges:
   Radiology is an integral part of medical care. Radiological imaging-based evidence (X-ray, MRI, CT, USG, *etc.*) is crucial in determining the nature of treatment in most hospitals. Once patients get themselves scanned, the radiologists have to prepare a report, which clinicians then use for determining the correct treatment. Conventionally, radiologists prepare the diagnosis notes by either dictating them to a voice recording device or writing them on paper. These notes are then handed over to a transcriptionist/secretary. The transcriptionist opens a scan-specific standard template corresponding to all normal findings (henceforth referred to as the normal template) and edits it based on the measurements and findings reported by the radiologist.

   India is a country with 1.3 Billion people and one radiologist per 100,000 population, a severely imbalanced ratio (the corresponding ratio in the US is 1:10,000 and for China it is 1:14,772). It results in very high patient inflows, which make radiologists incredibly busy and stressed out.

   The workflow mentioned above consists mainly of multiple humans in the loop- radiologists, transcriptionists, clinicians, *etc.* This leads to the following shortcomings :

   1. **Frequent delays :** Different time schedules of different human participants can lead to delay in report generation, often by multiple days.
   2. **Erroneous report generation :** Typographical and grammatical errors made by either radiologists during note taking, or by transcriptionists during report

generation can lead to erroneous diagnoses. This indirectly burdens the radiologists, as they have to verify the reports prepared by transcriptionists.

These challenges are further amplified considering the fact that in a densely populated country like India, the radiologists are already handling several patients every day.

3.2 Problem Statement:

Problem Statement 1 (pertains to Ultrasound):

Design a system that generates a structured patient-specific report from the radiologist's dictation and domain knowledge.

• The inputs to the system are

1. Input text (radiologist's dictation)
2. Generic radiology report with all normal findings (normal report template)

• The output of the system is

1. Radiology report with patient-specific findings

Domain knowledge comes from the knowledge graph (KG).

Sub-Problem:

Develop a system that automatically constructs a KG of essential medical information from radiology free-text reports.

- **Input:** Radiology free-text report corpus
- **Output:** A formalized representation of the essential medical information contained within the free-text reports in the form of a hierarchical KG

Problem Statement 2 (pertains to X-ray):

Design a system that generates a structured, patient-specific report from a radiology image, image tags (findings expressed in the image as per the radiologist), and domain knowledge.

• The input to the system is

1. Input radiology image

• The output of the system is

1. Radiology report with patient-specific findings

Domain knowledge comes from the Knowledge Graph.

3.3 Contributions over the Last Three Years:

1. Constructed ultrasound KGs of liver, gallbladder, pancreas, prostrate, uterus, urinary bladder and kidney.
2. Constructed a parallel dataset of radiologists' dictation and corresponding pathological descriptions (6860 nos.).
3. Implemented KG-grounding algorithm which carves out a subgraph from the KG based on the radiologist's dictation.
4. Integrated radiology KGs into deep learning models to generate reports with high accuracy. Specifically, trained KG-BART with triples from the radiology KG. Our

Work shows that the KG-BART model is more robust than other state-of-the-art models like T5-base/large and BART-base/large to generate radiology reports.

5. Constructed a Chest X-ray knowledge graph.
6. Developed a tool for radiology report generation for chest X-rays, that makes use of Chest KG and chest X-ray images.

3.4 Progress Made:

Completed

1. Information extraction from free-text reports
2. Building clinically accurate KGs
3. Generating pathological descriptions from radiologist's dictations
4. Integration of KGs with deep learning models to generate pathological descriptions with high accuracy
5. Mapping of generated pathological description at specific locations in normal report template

In Progress

1. Generating radiology reports from multimodal data (x-ray images, tags, and KG) for X-ray
2. Search for an appropriate normal report in the database for abdomen ultrasound scan
3. System testing and deployment
4. Documentation

Will be Done

1. Expand the scope of work encompassing all forms of SCANS- X-ray, MRI, CT
2. Introduce AI based pregnancy test; pregnancy test is a huge societal need facing the challenge of scalability and accuracy
3. Keep harnessing powerful deep learning models
4. Create rich datasets for scans (right now there is only a chest X-ray dataset with 3000 instances)

4. Significant Achievements

4.1 Publications:

1. Kaveri Kale, Pushpak Bhattacharyya, and Kshitij Jadhav, *Replace and Report: NLP assisted Radiology Report Generation.* ACL 2023, under review.
2. Kaveri Kale, Pushpak Bhattacharyya, Milind Gune, Aditya Shetty, and Rustom Lawyer, *KGVL-BART: Knowledge Graph Augmented Visual Language BART for Radiology Report Generation.* EACL 2023 accepted.
3. Kaveri Kale, Pushpak Bhattacharyya, Aditya Shetty, Milind Gune, Kush Shrivastava, Rustom Lawyer, and Spriha Biswas, *Knowledge Enhanced Deep Learning Model for Radiology Text Generation.* ICON 2022 accepted.
4. Kaveri Kale, Pushpak Bhattacharyya, Dr. Aditya Shetty, Dr. Milind Gune, Kush Shrivastava, Rustom Lawyer, and Spriha Biswas, *"Knowledge is Power": Constructing Knowledge Graph of Abdominal Organs and Using Them for Automatic Radiology Report Generation.* ACL 2023, under review.

4.2 Deployment:

1. Our industry partner Augnito India Pvt. Ltd. will be the user, and through Augnito, we have reached out to hospitals for technology adoption.
2. We have released a Minimum Viable Product (for Ultrasound) to the Beta users for testing and evaluation.
3. We are collecting the feedback of our system from 5-10 doctors.
4. There will be a continuous cycle of technology development-deployment-hospital feedback, leading to a robust, high-quality software.

4.3 Business Plan:

1. Our industry partner Augnito India Pvt. Ltd. will be the user, and through Augnito, we have reached out to hospitals for technology adoption. There will be a continuous cycle of technology development-deployment-hospital feedback, leading to a robust, high-quality software targeted to enhance radiology productivity in the range of 5-10 times.
2. We have released a Minimum Viable Product to the Beta users for testing and evaluation.
3. Through Augnito India Pvt. Ltd., the solution will be sold as an add-on module to an already available product for radiologists for an additional charge. This would be worked on early next year.

5. Concluding Remarks

We have reported our progress on automatic radiology report generation, in order to enhance clinical workflows. We have established a systematic procedure to construct organ wise KGs. Doctors have evaluated the constructed KGs, which are stored in standard RDF format, enabling their usage in various applications.

We have constructed a parallel dataset of radiologists' dictation and corresponding pathological descriptions. We have integrated KGs with a deep learning model to generate patient-specific reports. We also proposed a knowledge enhanced multimodal deep learning model KGVL-BART to generate X-ray radiology reports from X-ray images. Our results better the SOTA.

Our solution is aimed at ensuring that the radiologist does not have to type anything and can get a report generated within 30 seconds of performing a scan. We are collaborating with experienced Indian radiologists on continuously refining the tool.

Through our industry partner, Augnito India Pvt. Ltd., the solution will be sold as an add-on module to an already available product for radiologists for an additional charge. This would be worked on early next year.

We would like to expand the depth and breadth of our work (a) vertically, by including more bodily organs, and (b) horizontally, by capturing all modalities of speech, text, and image for improving the quality and efficiency of radiology report generation.