**SPECIMEN FORMAT FOR THESES OF MONTH**

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| **Faculty** | **:** | Engineering |
| **Department** | **:** | Electronics and Communication Engineering |
| **Branch/ Area:** | **:** | Image Processing |
| **Sub Subject Heading:** | **:** | Medical Imaging |
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| **Title of the thesis** | **:** | A Deep Learning Framework for Detection and Segmentation of Multiple Artefacts in Endoscopic Images |
| (i) In Roman Script | | - |
| (ii) In roman Script | | - |
| **Nomenclature of Degree**: | **:** | Doctorate of Philosophy |
| **Month & Year of Enrolment**: | **:** | July 2019 |
| **Month & Year of Registration**: | **:** | July 2019 |
| **Month &Year of Submission**: | **:** | May 2023 |
| **Month &Year of Award** | **:** | March 2024 |
| **Name of Supervisor** | **:** | Dr.B.Sargunam |
| **Designation of Supervisor** | **:** | Professor & Dean, School of Engineering |
| **Centre/department/school in which research was conducted** | **:** | Department of Electronics and Communication Engineering, School of Engineering |
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**Abstract within 300 words:**

Endoscopy is a standard procedure for disease surveillance, monitoring inflammations, detect cancer and tumor. During the procedure the organs are visualized. Artefacts, an artificial effect is found to be present in the resultant images. They play a dominant role in increasing procedure time by more than an hour. Hence an efficient algorithm to detect, segment and restore could assist clinician. The artefacts present in an endoscopic image include saturation, specular reflections, blur, bubbles, contrast, blood, instruments and miscellaneous artefacts. The presence of these artefacts acts as a barrier when investigating the underlying tissue for identifying clinical abnormalities. It also affect post processing steps where most of the images captured are discarded due to the presence of artefacts which in turn affects information storage and extracting useful frame for report generation. Endoscopic artefact detection dataset is the only available public dataset holding endoscopic images with annotations for multiple artefacts. Hence, a custom dataset is annotated using the same annotation protocol of endoscopic artefact detection dataset to maintain homogeneity. The algorithms are trained and tested with images from both public and custom dataset for artefact detection. State of the art object detection algorithms such as YOLOv3, YOLOv4 and faster R-CNN are used for detecting artefacts in endoscopic images. The detection algorithm focusses on three important performance parameters namely mean average precision, intersection over union and inference time. The ensemble model outperformed well across all the performance parameters compared with literature. The inference time is reduced by 8.63%, whereas the mAP and IoU are increased by 61.67% and 63.47% respectively.

Segmentation algorithms like U-Net with EfficientNetB3 backbone, Link-Net with EfficientNetB3 backbone and U-Net with SE-ResNeXt101 backbone are used to segment the artefacts. The results are assessed with performance parameters like F2 score and Jaccard score. The results prove a phenomenal increase in Jaccard score by 17.36% and F2 Score by 17.42% respectively.

**i) Major objectives** :

The following are the objectives set:

- Set benchmarks by tuning hyperparameters and training existing object detection algorithms such as, YOLOv3, YOLOv4 and Faster R-CNN on endoscopic images affected by artefacts.
- To design an ensembled architecture for endoscopic artefact detection for outstanding results.

- To design an ensembled architecture for endoscopic artefact segmentation.
- To implement a simple restoration and classification pipeline to project the necessity of artefact detection and segmentation.

**ii) Hypothesis**:

The use of Artificial Intelligence could effectively improve the detection and segmentation accuracy of multiple artefacts found in endoscopic images like saturation, specular reflections, blur, bubbles, contrast, blood, instruments and miscellaneous artefacts.

**iii) Methodology** :

**Custom dataset preparation**: Images from hospitals are collected, annotated and a custom dataset is prepared. The images available in the EAD public datasets are not just sufficient to train an model and propose effective results. Hence a new dataset is created and combined with images from EAD to improve the efficiency of artefact detectors in terms of mAP and IoU.

**Artefact detection:** Recently, deep learning based techniques give a better detection results. In this work, artefact detection is performed using deep learning based object detection algorithms. The pre-trained deep learning based object detection algorithms are retrained to detect artefacts like saturation, specular reflections, contrast, blur, bubbles, blood, instrument and miscellaneous artefacts. Deep learning based object detection algorithms like YOLOv3, YOLOv4 and Faster R CNN are adopted for this research. Images from the dataset are divided into train and test dataset. The training dataset is used to train endoscopic artefact detectors. The test set is used for evaluating model performance. Predictions of all three artefact detectors are combined using ensemble technique. Performance metrics like mean Average Precision (mAP) and Intersection over Union (IoU) and inference time are considered for evaluating the model.

**Artefact segmentation**: Deep learning based segmentation algorithms shows improved performance in the recent areas especially in the field of healthcare. Deep learning based segmentation algorithms like U-Net with Efficient Net B3, U-Net with SEREsNeXt101 and Link-Net with Efficient-net B3 are adopted for artefact segmentation. Endoscopic artefacts like saturation, specular reflections, contrast, bubbles and instrument are considered for segmentation. Images from EAD dataset is adopted for training and testing. Performance evaluation is achieved through metrics like F2 score and Jaccard Score

**iv) Findings:**

**Findings on Datasets:**

- DL based algorithms are essential to detect artefacts present in endoscopic images. The algorithms pine for massive dataset.
- EAD dataset is the only available public dataset for multi-class artefact detection. This dataset suffers from problems such as, class imbalance, repetition of frames, missing annotations and contains images of patients only from western countries.
- Hence a brand new custom dataset with 2400 images is curated embracing images of Indian patients to overcome the deficits of the EAD public dataset.
- The artefacts are annotated using the annotation protocol of EAD dataset with the clinician's assistance.
- The images from EAD and custom dataset are divided into train and test set for artefact detection. The former is manually data augmented to boost the dimensionality of the dataset.

**Findings on artefact detection:**

- The artefact detection model proposed in this research is an ensemble of three futuristic DL-based models. The models are YOLOv3, YOLOv4 and Faster R-CNN. These models are handpicked from the literature based on their performance in various applications.
- Transfer Learning approach is deployed for training the model in a shorter time. All the models are tuned, trained and tested with endoscopic images from public and custom dataset. All the three models are allowed to localize artefacts on test images.
- An ensemble model is proposed which combines the predictions of these three trained models. For each instance of an artefact there are three predictions. The predictions are ensembled based on a consensus voting strategy. NMS is applied to suppress the multiple bounding box. The final predictions are evaluated using the metrics mAP, IoU and inference time. The proposed model shows better performance metrics in terms of mAP, IoU and inference time. The inference time is reduced by 8.63%, whereas the mAP and IoU are increased by 61.67% and 63.47% respectively

- Most of the researchers have focused only on parameters such as, mAP and IoU. The inference time is found to be equally important. When such systems are deployed in real time inference time plays a major role. The proposed architecture shows a better performance in terms of all performance metrics.

**Findings on artefact segmentation:**

- To study the suitable algorithm for artefact segmentation and the need for DL based algorithms, few traditional and DL based algorithms are simulated. The traditional algorithms include Otsu binarization, Gray threshold, multi- threshold, adaptive threshold, active contour, lazy snapping and super pixel.
- DL algorithms under consideration include U-Net, FPN and Link-Net. All three algorithms holds EfficientNetB3 backbone. The algorithms are trained to segment single artefact.
- The traditional and DL algorithms are tested with random sample images from the EAD dataset and evaluated using metrics such as, sensitivity, specificity, accuracy, Jaccard score and dice score.
- The study focuses on analysing the performance of DL algorithms over traditional algorithms. It is concluded that no traditional algorithm segments all the artefacts well. When the artefact overlaps or the features of the same artefact vary vastly, the traditional algorithms fail. The DL algorithms shows a balanced performance across various test images.
- An endoscopic image contains instances of one or many artefacts. Hence it is vital to segment all the artefacts. To perform multiple artefact segmentation seven different transfer learning based DL algorithms are trained, experimented and tested with images from the EAD dataset.
- From the simulations, the best performing algorithms such as, U-Net with EfficientNetB3, Link-Net with EfficientNetB3 backbone and U-Net with SE- ResNeXt101 backbone are chosen. An ensemble of segmentation algorithm is proposed. Each trained model segments five different artefacts present in the image. Later all three binary masks are averaged and again converted to a binary image using the Otsu binarization.
- The model's performance is evaluated with metrics such as, Jaccard and F2 score. The proposed ensemble approach gives better results by effectively segmenting multiple

overlapping artefacts when compared with the literature. . The results proves a phenomenal increase in Jaccard score by 17.36% and F2 Score by 17.42% respectively.

- The research finding prove that the combination of DL based network architecture, backbone networks, hyperparameters and careful selection of images for training and test has yielded better results compared to results proposed in literature.

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