Deep Learning-based Classification of Reduced Lung Ultrasound Data from COVID-19 Patients

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Abstract

This study evaluates the performance of DL algorithm over LUS data with varying pixel and grey-level resolution. The algorithm is evaluated over a dataset of 448 LUS videos captured from 34 examinations of 20 patients. All videos are resampled by a factor of 2, 3, and 4 of original resolution, and quantized to 128, 64 and 32 levels, followed by score prediction. The results indicate that the automated scoring shows negligible variation in accuracy when it comes to the quantization of intensity levels only. Combined effect of intensity quantization with spatial down-sampling resulted in a prognostic agreement ranging from 76.4% to 82.2%. These results also suggest that such level of prognostic agreement can be achieved over evaluation of data reduced to 32 times of its original size. Thus, laying foundation to efficient processing of data in resource constrained environments.

Introduction

Recently, clinicians have started using ultrasound, providing the support for the assessment of COVID-19 due to its safety and wide availability [1]. For standardized LUS evaluation, standard imaging protocol and a 4-level scoring system has been introduced [2]. Following the standardized protocols, computer aided evaluation system [3] has been developed based on DL based scoring of LUS scans at frame, video [4] and exam level [5].

With the advancements in the Internet of Things (IoT) in health sector, remote diagnosis, patient monitoring, collection and transmission of health data from electronic devices is rapidly taking its share in the market. Remote Patient Monitoring (RPM) devices are non-invasive resource-limited electronic devices, enabling patients and clinicians to share health care data in convenience and ease. These devices are however limited on resources like energy, memory and processing power. Consequently, it is highly relevant to investigate how to minimize the size of data, while keeping intact the information content, and to analyze the effect of the reduced data over score prediction. This paper aims to extend the application of deep learning algorithms to LUS image samples that have undergone reduction in the pixel intensity values and pixel resolution, thus leading to smaller data size. The results obtained at the frame-level are further utilized to obtain the algorithm's performance at video level and exam level.

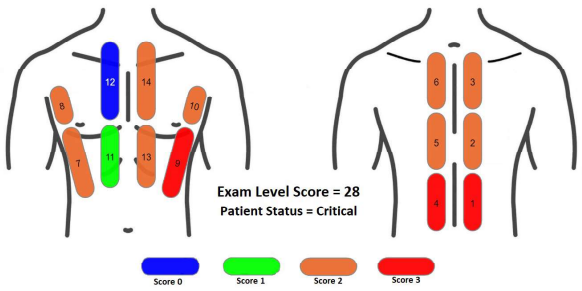

Figure 1. 4-score based LUS evaluation

Methods and Materials

Data is based on the acquisitions made at the Fondazione Policinico San Matteo (Pavia, Italy). LUS scans were acquired from 20 patients (12 male and 8 female), diagnosed as COVID-19 positive through a Reverse transcription RT-PCR swab test. A total of 34 exams were performed following the acquisition protocol described in [2], and 448 videos, comprising of 91,277 frames, were acquired.

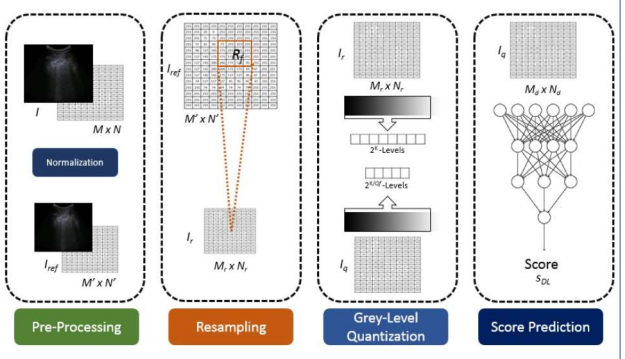

Figure 2. Proposed Methodology

Results

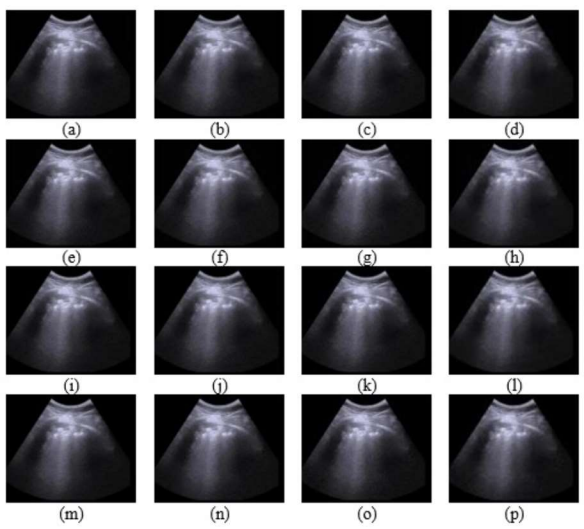

Figure 3. Combinations of Reduced LUS data sample

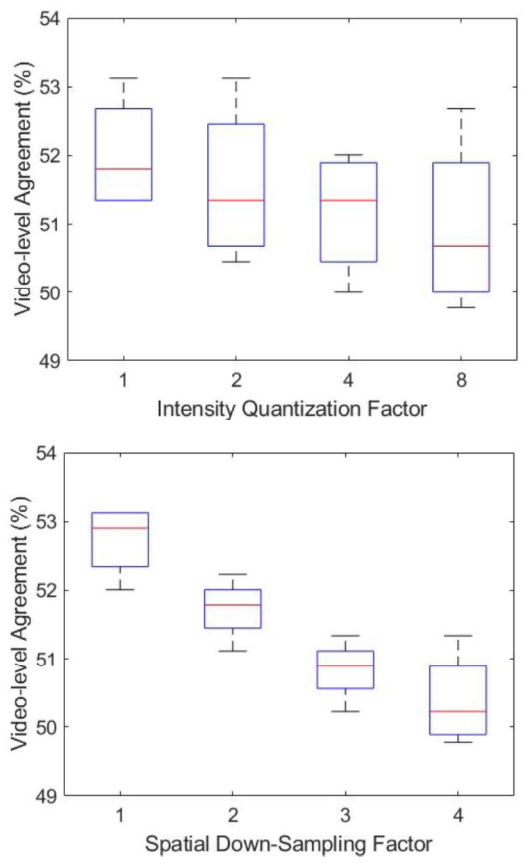

Figure 4. DL vs MD Video-Level Agreement

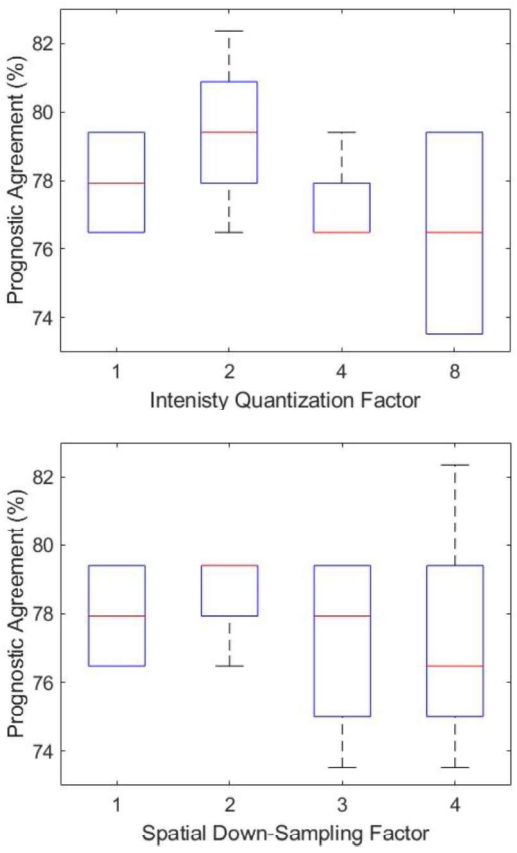

Figure 5. DL vs MD Exam-Level Agreement

Discussion

All the LUS videos were evaluated based on the optimal threshold percentage [4] and the video level agreement was calculated to evaluate the performance of the DL algorithm. It can be seen from the plots that in the case of video level agreement, for a fixed number of grey-levels, changing the pixel resolution adds significant variation in the resulting agreement values. However, among the different number of grey-levels, for a fixed spatial down-sampling factor, the variation in the video level agreement seems to be less. The results showed that for a fixed value of Qf, the variation within the prognostic agreement is also observed to be more than for different values of Qf keeping Rf as constant, although with a less clear trend that for the video-level case.

Conclusions

In this work we analyzed and demonstrated the effect on the prediction made by DL algorithm for dataset varying in pixel and grey-level resolution. The method took the LUS video frames as an input and normalized them to the lowest resolution found within the testing dataset, forming reference data. The reference frames then undergo pixel and grey-level resampling, reducing the number of pixels and grey-levels in the input video. Reduced image information is finally predicted by the DL algorithm. The proposed method was evaluated over the testing set of LUS video frames from COVID-19 patients in Pavia. The proposed model resulted in a maximum prognostic value of 82.35% with a data reduction up to 32 times. It showed that the effect on the score prediction of reduced grey-levels is smaller than that of reduced pixel resolution.

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