Hand wash Hygiene Monitoring during Covid19 using Deep Learning approach

Hand washing has been considered as one of the most important procedures to combat Covid19 situation. In this research, the VGG16 machine learning model architecture has been applied in order to monitor hand hygiene procedure adapted by individual. The model developed has been tested on a real time dataset. The software used is the Python. For categorizing the inputs (image classification) the deep learning in python is used. To optimize the accuracy, the Adam optimizer algorithm has been applied. Similarly, to minimize the loss of the model, categorical cross-entropy loss estimation method was used. The model was trained, tested and validated where the research found that the developed model is an excellent-fit for predicting and classifying the hand-washing gestures-based images. The model achieved 97% accuracy rate, through classification accuracy as the performance metric evaluation technique.

Keywords: *Hand-washing gestures, hand washing detection model, hand washing detector, VGG16, convolutional neural network, Adam optimizer, classification accuracy.*

Introduction

Hand washing as a hygienic practice has been followed mainly by the medical practitioners and other healthcare professionals than any other sector. During the pandemic (Covid19), the hand washing was made a standard process for every individual, globally to prevent from illness and diseases. However, hand washing as a method includes 7-steps, according to World Health Organization (WHO) and Centre for Disease Control (CDC). Based on these steps, the gestures and the proper method (time, humidity, temperature and the appropriate process of washing hands) will significantly ensure one's 'hygiene' that prevents from transferring illness and diseases to others (WHO, 2020a; WHO 2020b; WHO, 2021; CDC, 2020). During an outbreak of epidemic or pandemic diseases (like Plague, Ebola, Corona, Cholera, Lassa fever, Zika, Meningitis, MERS and more) people prefer to stay inside their homes and keep themselves diseases free and hygienic to prevent from respiratory and other chronic illness and to avoid fatal diseases (UNICEF, 2021). Among many methods, social distancing, wearing masks, washing hands regularly, vaccinating, avoiding outdoor activities and avoiding crowded areas have been proven effective in pandemic circumstances (Alzywood et al., 2020). To buy everyday products, foods, and groceries, people had to step out and purchase necessities and basic products that were not available through online portals (Rao et al., 2021) which also one-of-the significant reason behind spreading of diseases during Covid19 due to improper preventive methods like unhygienic practices. Few earlier studies (Mosler et al., 2012; Allegranzi, 2013; Lal, 2015; Stone et al., 2012) examined the effective methods that prevented individuals from diseases that could spread rapidly without prevention. Among the preventive methods, washing hands and wearing double surgical masks were found to be more effective, especially during Covid19 (Chiu, 2020; Fraley, 2020) than not wearing mask being with two or more people. Studies also found that, not washing hands properly for minimum 20 seconds (WHO, 2020b; WHO, 2021) and also not washing regularly after visiting from outside (Dwipayanti et al., 2021), using public restrooms/ bathrooms (Cairncross et al., 2010) before eating foods could affect an individual especially when another person has persistent coughing or sneezing issue (Kraker et al., 2022). Study by Aiello et al., (2008) found that, blowing nose and not washing hands tend to spread more pathogens from one host to another when there is no proper hygiene. Washing hands is more effective in preventing contagious and fatal diseases like hand, foot and mouth disease (HFMD), Corona, Ebola, Influenza, and more (WHO, 2020a; CDC, 2020; Kraker et al., 2022).

Machine learning (ML) models and researchers have been widening their focus upon the hand washing processes and developing a ML model that could identify and predict: the diseases, hand washing processes, gestures in washing hands, wearing masks, keeping social distances and more due to the effect of the Covid19 pandemic (Widodo et al., 2020). Though there are existing Ml models and researches that examine the effect and impact of Covid19, each has its own purposes and scope. Using deep learning and neural networking based architectures in the ML models the researchers have been developing the models with image classification and segmentation as primary priority (Thanh et al., 2019; Krageloh et al., 2021). The usage of the neural networking (NN) like artificial (ANN), recurrent (RNN) and convolutional (CNN) models to predict the process is found effective in the recent approaches (Khan et al., 2020) where the convolutional NN models are adopted majorly due to their simplicity, effectiveness and computer vision advantage over RNN and ANN and CNN is proven to be more powerful than RNN and ANN (Anubha, 2022). There are several architectures in CNN like, Xception Net, Dense Net, ResNet, Inception Net, VGG Net, Le Net, Alex Net, Google Net, and more where researchers adopt the best architecture for their intended purposes based on the classifications and networking (Singh et al., 2020).

Research Purpose

In this research, the VGG16 Net with CNN based architecture is adopted to predict and classify the hand washing gestures from the individuals. The research thus aims at predicting, classifying and storing the images post processing into multiple classes with CNN+VGG16 based architecture and computer vision algorithm.

Significance and scope

The developed architecture is based on ML and computer vision based object detection model that uses the VGG16 NN. The VGG Net among other

NN architecture is proven to be effective and highly accurate than ANN and RNN. Similarly, exiting studies (Irehovbude and Okoye, 2020; Ivanovas et al., 2020; Harrus and Wyndham, 2021; Wigglesworth, 2019) concentrates on hand washing process based on WHO's standard 7 steps through ML model. The current model developed focuses on 12 steps with multiple classes and aims at more accuracy than current models, which has more scope and significance in further researches.

Literature review

Machine learning models that focused on hand washing methods were examined and focused by researchers majorly to identify whether the hand washing process is a successful attempt or failure and to classify the hand washing processes into multiple classes based on hand washing gestures. Authors Naim et al., (2013) used computer vision algorithm with GUI based model to predict and identify the hand hygiene and safety. Their model focused and identified clean and unclean (stained and dirtied) areas of the individuals' hands in the healthcare sector. Similarly, authors Haque et al., (2017) also used computer vision in the healthcare sector to identify the hand washing process with contamination where only one person should be presented in the washing area (social distancing) through close-proximity detection. The inputs (images) are examined based on depth of the images, background, foreground and hand washing processes. The model attained 83% accuracy rate.

Authors Galkin et al., (2019) used Amazon web services (AWS) based NN and videos as inputs to monitor and identify the hand washing process. Hygiene monitoring through gestures was focused where the DeepLens camera was used for predicting gestures from videos and classifying the images into multiple classes. However, the model obtained 75% accuracy which was lesser than the model developed by researchers Zhang et al., (2017). Zhang et al developed a model to determine hand washing gestures and also to identify right environment of the hand washing process (temperature, humidity, location, live data of the washing station and other compliance events) to predict the success of the hand washing process as failure or a successful event without contamination and hindrances. Due to several parameters, the model acquired lesser accuracy (77%) and the researcher concluded that to procure higher accuracy, the model needed an optimization which will be added and adjusted in the further examinations. Thus, even a model focuses on multiple classes and parameters to identify and classify the inputs, to attain higher accuracy in ML, proper utilization and adoption of the deep learning algorithms and optimization algorithm are required. Similarly, the study by Yeung et al., (2016) used CNN based architecture with depth perception and computer vision classification algorithms to identify and predict the attempts of the hand washing process as two classes a negative attempt and positive attempt. The model was found efficient with 95% accuracy where the researcher avoided the compliance registry need to minimize computational time (the standard time of 20 seconds) of hand washing. Though different ML models in the earlier stages focused on the gestures, processes, time, environment and contamination in the process as parameters, the accuracy obtained was found to be lesser with the models when the class was multiple. Henceforth, obtaining higher accuracy from the ML models with multiple classes was later achieved by hand washing detection models, especially during and post Covid19 due to the necessity of artificial intelligence (AI) monitoring and predicting illnesses and diseases without human intervention.

The role of Covid19 upon developing new advanced and optimized ML models by authors Khan et al., (2021) was attempted with AI monitoring and predicting. The model used depth perception to predict and to identify corona diseases with the patients and whether they are hygiene or unhygienic to control the spread of the diseases. Though the model was deemed effective and efficient in accurate detection, the model used minimal class and thus used deep learning algorithm alone. Authors Islam et al., (2021) also developed a model that diagnoses the corona diseases among the patients in the healthcare sector to prevent the spreading of diseases. The model developed also finds and classifies the diseases according to its severity and categorizes the participants into several classes based on the severity. These models were used to identify the corona diseases to prevent the virus from spreading further and also to contain the affected individuals in secluded area in the hospitals to prevent mortality rates. The diseases prediction models were effective and thus human intervention in finding patients at hospitals with corona diseases were thus minimized.

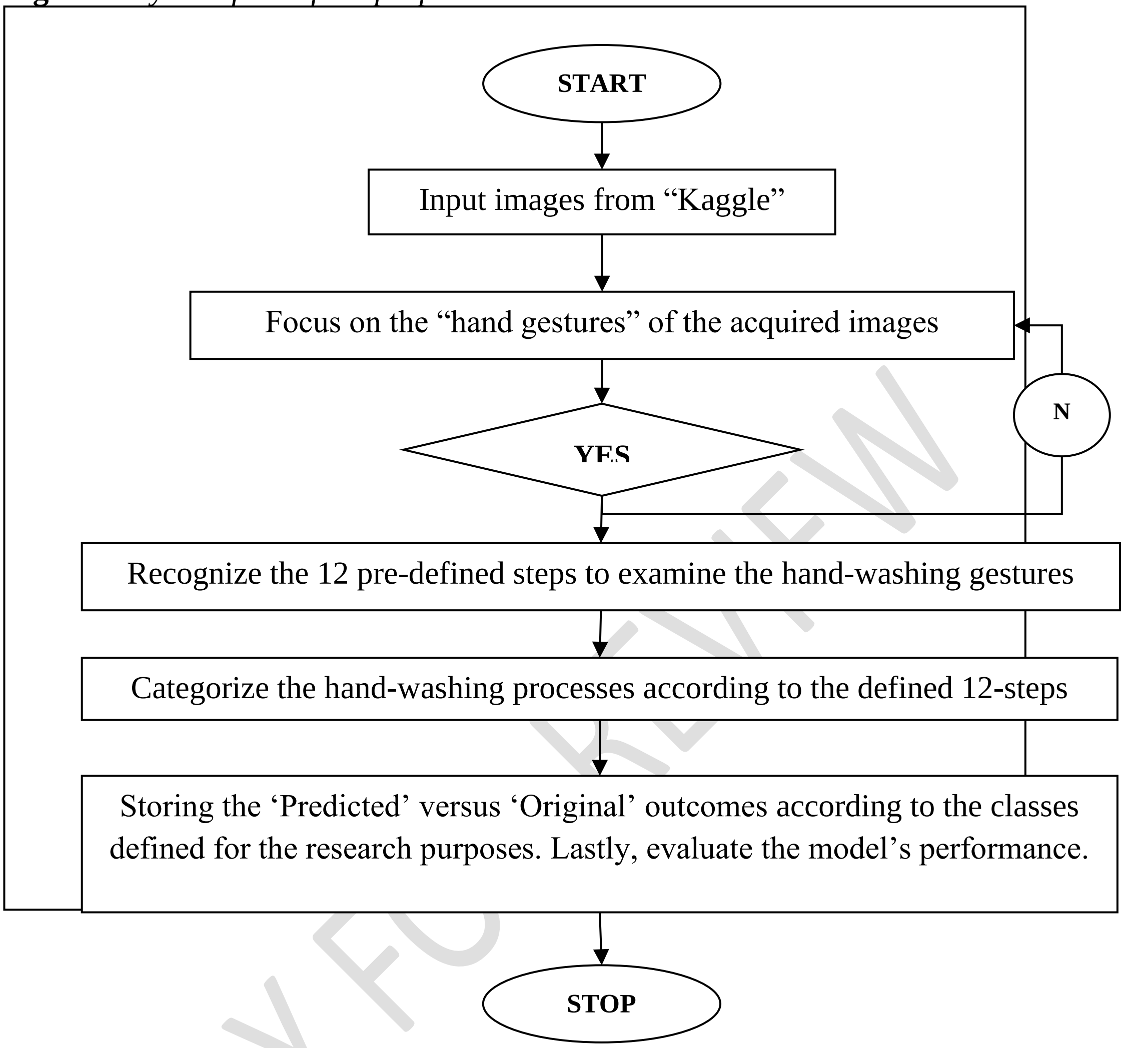
Vaishya et al., (2020) developed a model that focuses on hand washing gestures of the Covid patients at the hospitals. According to the study's findings using ML models to identify and predict diseases in hospital management reduces the risks of spreading corona faster and rapid unlike with human intervention. The risk of contamination of samples and environment with corona virus is also reduced when an AI is used. Senthilraja (2021) also developed an AI with CNN+VGG Net architecture. The author also used the model to predict and control the impact of the corona diseases through screenings, health check-up records, vital rates and medicinal or drug intake of patients. Based on these parameters the model identified the patients and classified them into two classes, respiratory assistances and medicinal assistance, where acute and chronic severity based outcomes from screenings were used as inputs.

Several authors like Zhong et al., (2021), Khamis (2020), Singh et al., (2020) developed a hand washing detection model that monitors and identifies the process of washing hands according to the parameters and compliance rights. The process was recorded as videos and the hand-washing as gestures were captured from videos and clipped as images for the model to process the hygiene and non-hygiene practices of the individuals. Authors Deshmukh et al., (2021) and Shahbandeh (2021) developed a CNN+Res Net, Inception Net and VGG Net based architectures and found the best method to identify and classify the hand washing gestures. The comparative analyses showed that in predicting and identifying the gestures, the VGG Net showed more efficient outcomes than the Res Net and Inception Net. Wang et al., (2022) studied pathogen transmission through unsuccessful hand washing method with a VGG Net and 3D CNN based architecture. The outputs were optimized with the method of probability smoothing where the model classified the outputs into 7 classes with accuracy of 98%. The minimum accuracy was achieved at 91% (90.64%) and post training with optimization algorithm it was increased further 7%. Thus the CNN+VGG Net model deemed as an effective ML model with optimization algorithm in predicting and identifying inputs and then classifying them into multiple classes. Thus, in this research, VGG Net with the CNN architecture is adopted with 12 classes for classifying the outputs based on the compliance protocol and hand washing gestures pre-determined by the researcher. Though different studies proved that multiple classes attained lesser accuracy, the usage of optimization algorithm was also proved to be effective in increasing the accuracy of the ML models in hand washing monitoring and detection.

Proposed method and approach

The model proposed for classifying the hand wash gestures through the Machine Learning (ML) approach is designed with VGG16 neural networking based architecture. The inputs are initially acquired as videos and images of pre-defined processes of the hand washing gestures as per the algorithm are clipped and stored under the dataset folders for further training, testing and classification. The original (12 steps) are compared and analysed against the predicted outcomes of the model and when the model achieves higher accuracy, the model is retained (refer figure 1).

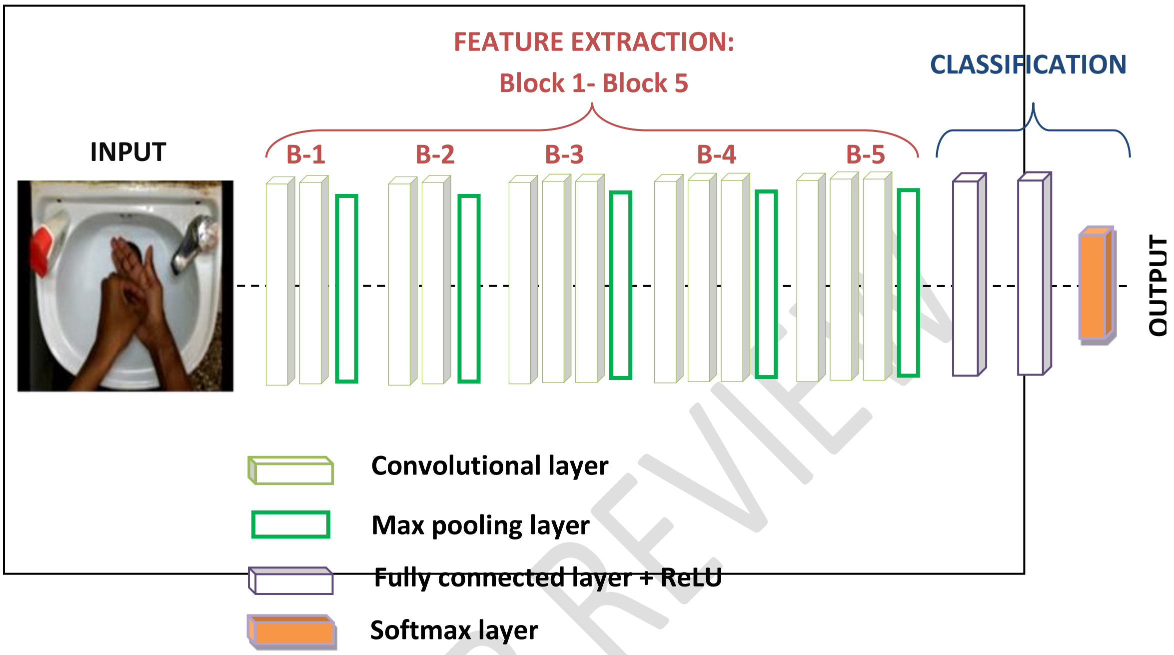
Figure 1. *System flow of the proposed model*



Proposed VGG16's architecture

The proposed ML model includes an input layer, feature extraction layer of 5 blocks, classification layers of ReLU + Fully-connected layer and Softmax layer and finally the output layer. The images as inputs are passed through the VGG ML model developed in the first stage, i.e. through the "Hand-Washing Gesture Detection" model. Once the inputs (images clipped from the videos acquired) are pre-processed where the color, depth, background, size, pixel, resolution and light exposure/ illumination are corrected as per the parameters of the research, the images are passed to the block layer-1. Next, the following stages two and three includes block-1 and block-2 which has 2 x Convolutional 2D layers and 1 x Max-pooling 2D layer, respectively. The stages four, five and six, i.e. block-3 to block-5 includes 3 x Convolutional 2D layers and 1 x Max-pooling 2D layer, each respectively. Finally in the classification layer, a fully-connected + ReLU layer with a Softmax classification layer is designed in the network to classify the inputs, accordingly and pass the outcomes to the output layer for storage (refer figure 2).

Figure 2. *VGG16 architeture based Hand-washing Gesture Detetion (HGD) model*



Thus the VGG16 based HGD model is developed and used for predicting and classifying the hand-gestures in this study. To classify the gestures as per required parameters, the appropriate algorithm should be utilized.

Algorithm adopted

There are different ML algorithms that are mostly adopted by the researchers in the CNN and DNN based ML models. The CNN optimizer algorithms that are frequently adopted are Stochastic-Gradient Descent (SGD), RMSprop, Gradient Descent (GD), AdaDelta, Mini-Batch (MB-SGD), Adam optimizer, Backpropagation (BP), Adaptive Gradient (AdaGrad) and Nesterov-Accelerated Gradient (NAG). The optimizer algorithms in ML models functions as a process that modifies and intensifies the NN attributes like learning rate and weights to obtain more accurate outcomes and lesser loss, especially in the image classification and prediction models (Yang, 2011).

Adopted algorithm

This research adopts the Adam Optimizer Algorithm (AOA). AOA is used for prediction and image classification models to minimize the loss and also to increase the accuracy. The AOA pseudo-code for the HGD is as follows:

Step 1: Start, $\boldsymbol{d_c} = \mathbf{0}$ and $\boldsymbol{x_1}$
Step 2: For, $\boldsymbol{n}$ = 1, ... , $\boldsymbol{N}$, do

$$\boldsymbol{d_n} = \boldsymbol{Q_1}_{,n} \boldsymbol{d_{n-1}} + (\boldsymbol{1} - \theta_{\boldsymbol{1},n}) \boldsymbol{k_n}$$

$$\hat{y}_n = L_n(\boldsymbol{k_1}, \boldsymbol{k_2}, \ldots, \boldsymbol{k_m})$$

$$\boldsymbol{x_{n+1}} = \boldsymbol{x_n} - \frac{\boldsymbol{j_n c_n}}{\sqrt{\hat{y}_n}}$$

Step 3: Stop.

Through the AOA, the hand gestures are identified through 12 steps of pre-defined process of hand-gestures towards focusing and classifying the hand-washing detection process. Later after processing the hand-gesture images as inputs that are acquired from videos through ‘kaggle’ as resource, the HGD model identifies, predicts and classifies the hand-washing processes, based on the optimizing algorithm into 12 classes as folders/directories. The loss of the model is evaluated through categorical cross-entropy method, whereas the accuracy is estimated through classification accuracy method. The images that are classified and stored are compared against the original sample datasets for evaluating the model performance and when the model attains higher accuracy the model is retained.

Pros and cons of AOA

Though AOA has more benefits it has its own drawbacks, they are:

Pros: Efficient computation; works efficiently upon unknown and large datasets; handles the noisy-datasets with sparse gradients pretty well; needs less memory and thus considered as memory efficient and finally the values of default hyper-parameters excels upon most complicated problems in ML models (Hinton et al., 2012).

Cons: It might suffer due to weight-decay issues similar to the AdamW; in some areas the AOA doesn’t converge as optimal solution which is considered as a motivation and drive for the AMSGrad and finally the most identified drawback is that, recent algorithms have been adopted by researchers for its rapidness and better accuracy than AOA (Duchi et al., 2011).

However, after studying more relevant literatures and studies upon the CNN models in image classification and prediction, the study adopts AOA for its computation and large noisy datasets handling efficiencies, for this research purposes.

System specifications

Hardware

The hardware used for the current research includes, a ‘Real-sense’ camera from the Intel. The research uses the ‘D435’ camera which is exclusively used in the ‘depth’ examinations. Since the research focuses on hand-washing gestures, the depth is the utmost parameter and thus depth camera is significant in capturing the input(s). For system configuration in this research, the Ubuntu Operating System (OS) with Jeston Nano-NVIDIA computing platform is used. The Cortex-A57 equipped with ARM Quad-core CPU (central processing unit) and 128-core of NVIDIA-CUDA architecture by the NVIDIA Maxwell for GPU (graphics processing unit) is used here. The memory for processing the operations in video capturing and storing requires the standard 4GB (gigabytes) memory. Here the researcher uses 8GB RAM (random access memory) with 64bit.

Software

The research uses the 'Python' as software since the developed model is based on machine learning model. The python as programming language is identified as the high-level language used by the researchers for object-oriented, functional programming and structured programming paradigms. It also acts as server-side language however the major uses of python is towards building and developing websites (web applications). The libraries in python like PyTorch, TensorFlow, OpenCV, NumPy, SciPy, Scikit-Image, Theano and more are also used by researchers easily to make the operations and functions rapid. Here OpenCV is used as the library for its vastness and operations to process video capturing and processing. Similarly, the image classification algorithms comes with the python library is used in this research, other than for estimating accuracy and loss with setting the parameter of 12-steps of hand washing.

Statistical formulae used

The research uses the AOA for optimizing the algorithm to classify the images more accurately. Other functions are:

Classification accuracy

The performance of a model is basically measured through metric evaluation methods. There are different methods like F1-score, Classification Accuracy, Logarithmic Loss, Area-under Curve (AUC), Confusion Matrix and more. Among these, the researcher adopts the respective accuracy evaluation techniques rather than adopting prominent technique in developing models (Kobs et al., 2021). The study adopts the classification accuracy for measuring the model's performance. This technique produces results, based on the predicted object's ratio (expected value) and the input sample totalling values (actual value). The formula is:

$$\textbf{Classification Accuracy (CA)} = \frac{\textbf{Tot no.of.Actual}-\textbf{predictions}}{\textbf{Tot no.of.Expected}-\textbf{predictions}} \text{..........................} \textbf{(1)}$$

Loss function

There are several loss estimation techniques namely, L1-loss or MAE (mean absolute error), L2-loss or MSE (mean squared error), RMSE (Root MSE), MBE (mean bias error), Hinge-loss, Huber-loss, Categorical cross-entropy, Binary cross-entropy, KL Divergence (Kullback-Leibler) and more. The study adopts the 'categorical cross-entropy' as the loss evaluation method, since it can be used for multi-class classification in image classification models. Since the current study focuses on 12 steps as different classes, the categorical cross-entropy is effective than other methods. The formula is:

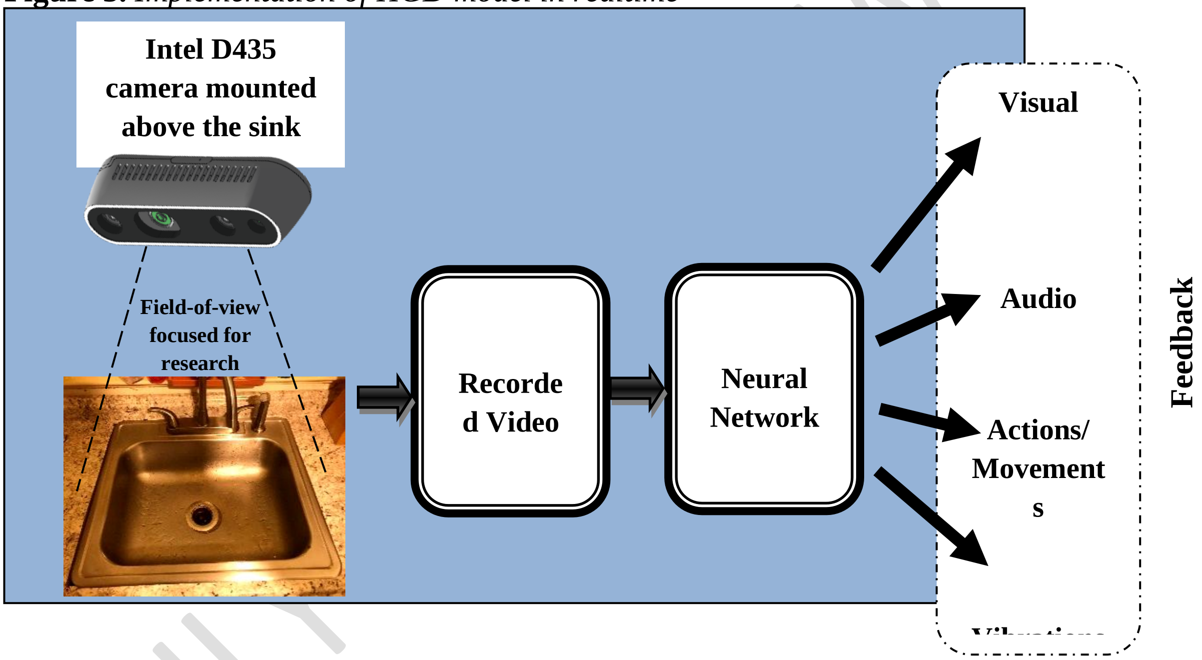
$$\mathbf{CCE} = -\sum_{n=1}^{N} \mathbf{L}_{\theta}(\mathbf{x}_n)\ \mathbf{Y}\ \log\left(\mathbf{L}_{\theta}(\mathbf{x}_n)\right) \quad \textbf{(2)}$$

where, based on the outcome the model is estimated as a great-fit, when the result is nearest to the value ‘0’, and contrarily when the result is nearest to the value ‘1’, model is deemed as unfit.

HGD implementation

The real time execution of the model includes participants and controlled environment (refer figure 3).

Figure 3. *Implementation of HGD model in realtime*



In ML models the images are predicted, classified and stored, where the model is evaluted for its accuracy. If the expected accuracy is achieved, the model is retained and used for larger datasets, if not, until the expected accuracy is obtained, the model is trained and tested with amending the algorithm and optimizing for better accuracy. Once the accuracy of the testing is satisfying, the model is implemented and used to obtain datasets.

The implementation process includes setting up the environment in the controlled or unit testing phase. In this phase, the environment is adjusted to the required parameters like light exposure, brightness, water temperature, room temperature and monitoring setup (computer and camera). Firstly, the depth camera is mounted at 90° above the sink/basin in the room. The room temperature along with the water temperature (35-45°Celsius) is monitored to make sure the hand-washing process is successful, since it may affect hand hygiene practices. Next, in the second phase the camera is switched on and connected to internet to record the videos of hand-washing processes and then store the recorded inputs in the client-end server. In the third phase, the video is accessed by the model through the ‘neural network’ for predicting the hand gestures, according to the pre-defined 12 steps. In the fourth stage of the implementation process, the HGD model is loaded and initiated to predict, identify and store the images, respectively according to their classes. In this stage, the model sends the feedback (as per the four states) to the system accordingly, where: “Wait” (until the process is initiated), In-progress (hand washing process is ongoing), “Good” (when hand washing process is completed as per norms like time: 20seconds) and lastly “Failure” (when any of the norms are not met). Finally, once the images are acquired from the model for each participant, the images are stored and accessed later on for performance evaluation.

Methods and Results

The study uses the “Kaggle” as the resource where the images are clipped, pre-processed and stored in the cloud by the researcher. The datasets are:

Datasets

The datasets used here are images converted from the video captured, from “Kaggle” as the internet as source. The datasets are acquired, pre-processed, formatted and annotated. The processes includes:

Acquisition:

- Dataset is obtained from "Kaggle" provided by author Real-timer (2020) for training and testing of the model, as images. The dataset includes 292 depth videos where 3504 clipped-images are obtained based on the 12 classess of hand gestures at 16-bit resolution and 15 frames/second with 480x640 reslution.
- In real-time implementation, the data are acquired from depth camera based recorded video of hand-washing process by the volunteered 24 participants (9-males and 15 females; all right-handed) at controlled environment by the researcher.

Annotation:

- Data annotation is done based on the pre-defined 12 steps, respective to the hand gestures identified.

Format:

- The recorded videos are stored in JSON format (.json). They are pre-processed and stored in .csv format.
- The recorded videos are later converted and stored as images in .jpeg and .png formats.

Pre-process:

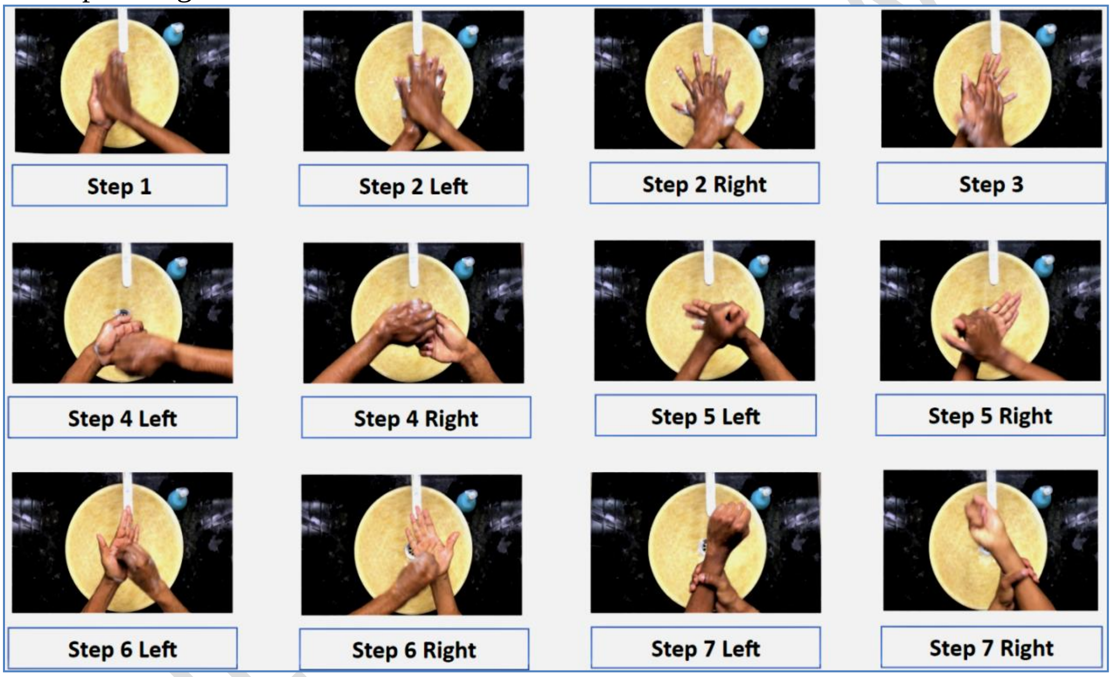
- The obtained images are pre-processed, where the parameters focused are: depth, color, size, pixels, resolution, illumination/ light and background.

Training results of HGD model

The training of the model is performed with 15 batches of epochs (learning rate iterations) to minimize the loss. The split ratio of training, testing and validating datasets are: 70/20/10, respectively.

The 12 steps which are extended from the World Health Organization's (WHO's) 7 steps of hand washing for the algorithm to classify the images in this study are:

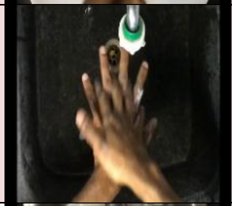
Figure 4. *Datasets of 12 classes*
1. Step 1,
2. Step 2 – Left,
3. Step 2 – Right,
4. Step 3,
5. Step 4 – Left,
6. Step 4 – Right,
7. Step 5 – Left,
8. Step 5 – Right,
9. Step 6 – Left,
10. Step 6 – Right,
11. Step 7 – Left, and
12. Step 7 –Right.

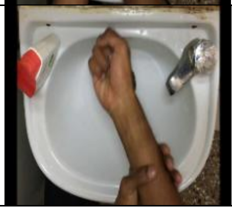


The model is trained to focus and obtain the gestures according to the pre-defined 12 steps and then to classify the images as 12 classes, respectively. The outcome of the HGD model's training is:

Table 1. *Results of training HGD model*

Steps	**7-step hand washing**	**Actual**	**Predicted**
1		Step 1	Step 1

2				Step 2: Right	Step 2: Left
3				Step 2: Left	Step 2: Right
4				Step 3	Step 3
5				Step 4: Left	Step 4: Left
6				Step 4: Right	Step 4: Right
7				Step 5: Left	Step 5: Left
8				Step 5: Left	Step 5: Right
9				Step 6: Left	Step 6: Left

10		Step 6: Right	Step 6: Right
11		Step 7: Left	Step 7: Left
12		Step 7: Right	Step 7: Right

From table 1, it is understood that though the HGD model is effective, it need more optimization to acquire higher accuracy in prediction and classification. Thus AOA is applied for optimization and the model is tested for accurate larger datasets.

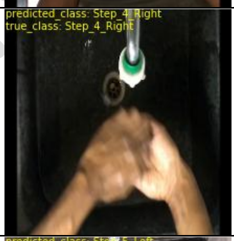
Testing results of HGD model

Though the training of the HGD model was successful, the accuracy was observed to be lesser and hence the algorithm was advanced with specific parameters to classify the outcomes more accurately and precisely. Thus the 12 steps are framed as:

1. ***Step 1:*** Wet hands and apply soap; the water temperature should be 35° to 45° Celsius.
2. ***Step 2 Left:*** Interlock the back of left hand fingers with right hand palm.
3. ***Step 2 Right:*** Interlock the back of right hand fingers with left hand palm.
4. ***Step 3:*** Rub both palms together.
5. ***Step 4 Left:*** Cup the left hand with right hand fingers.
6. ***Step 4 Right:*** Cup the right hand with left hand fingers.
7. ***Step 5 Left:*** Clean the left hand thumb with right hand fingers.
8. ***Step 5 Right:*** Clean the right hand thumb with left hand fingers.
9. ***Step 6 Left:*** Rub the left palm with right hand finger tips;
10. ***Step 6 Right:*** Rub the right palm with left hand finger tips
11. ***Step 7 Left:*** Wash the left hand wrist and
12. ***Step 7 Right:*** Wash the right hand wrist.

Based on the pre-defined 12 steps of the HGD model, the results obtained post testing the VGG16 network model are as follows:

Table 2. *Results of testing HGD model*

Steps	7-step hand washing	Actual	Predicted
1		Step 1	Step 1
2		Step 2: Left	Step 2: Left
3		Step 2: Right	Step 2: Right
4		Step 3	Step 3
5		Step 4: Left	Step 4: Left
6		Step 4: Right	Step 4: Right
7		Step 5: Left	Step 5: Left

8		Step 5: Right	Step 5: Right
9		Step 6: Left	Step 6: Left
10		Step 6: Right	Step 6: Right
11		Step 7: Left	Step 7: Left
12		Step 7: Right	Step 7: Right

Inference: The testing phase obtained more accurate outcomes than the training phase. Thus the model is retained for further predictions and classifications and also for real-time implementations in hand washing gesture capturing, identifying and classifying researches.

Loss and Accuracy results

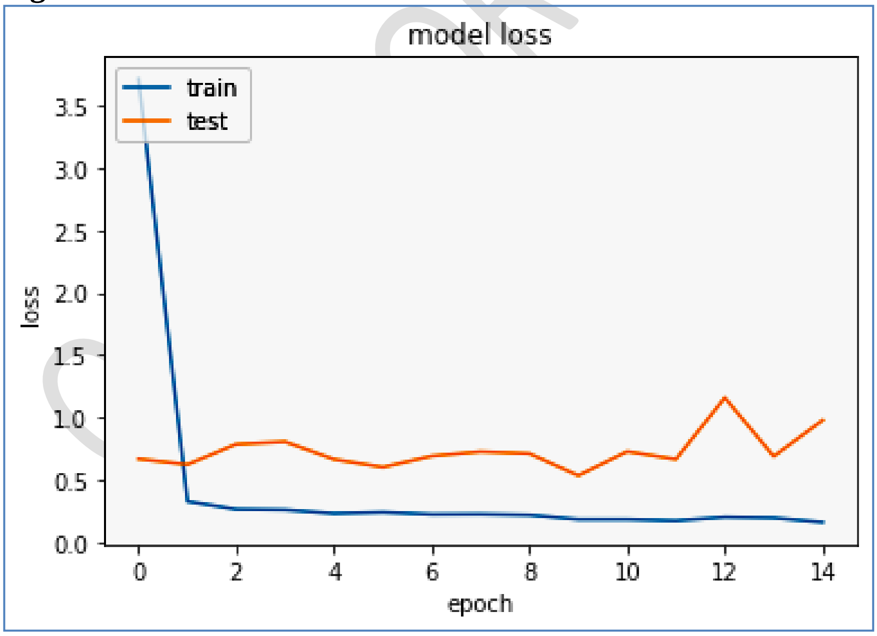
The training and testing loss along with the accuracy is estimated (refer table 3).

Table 3. *Loss evaluation - Epoch*

Epoch(s)	Time/step	Training: Loss	Training: Accuracy	Validation: Loss	Validation: Accuracy
1	392s 547ms	14.6000	0.6165	0.6682	0.8056
2	341s 492ms	0.3485	0.8904	0.6240	0.8142
3	344s 496ms	0.2643	0.9181	0.7860	0.7971
4	348s 503ms	0.2671	0.9202	0.8057	0.8159
5	342s 494ms	0.2229	0.9371	0.6652	0.8406
6	338s 488ms	0.2459	0.9330	0.6027	0.8363
7	397s 574ms	0.2520	0.9342	0.6911	0.8508
8	362s 522ms	0.2441	0.9416	0.7263	0.8321
9	371s 536ms	0.2364	0.9420	0.7111	0.8389
10	506s 731ms	0.1907	0.9531	0.5360	0.8721
11	372s 536ms	0.1780	0.9538	0.7276	0.8619
12	336s 485ms	0.1786	0.9551	0.6656	0.8500
13	342s 494ms	0.1932	0.9546	1.1593	0.8295
14	332s 480ms	0.1930	0.9562	0.6886	0.8696
15	333s 480ms	0.1490	0.9663	0.9784	0.8525

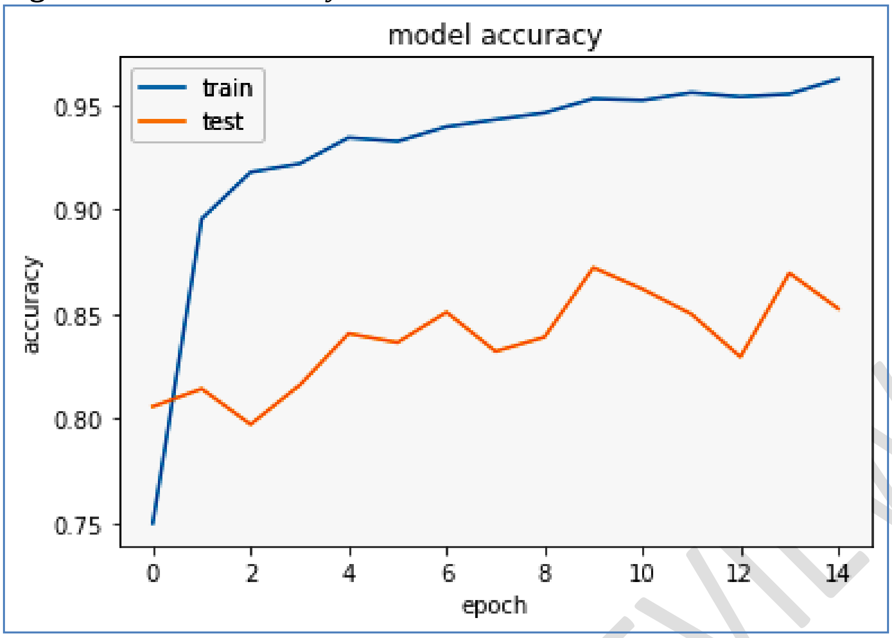
The loss is estimated (refer figure 5) to calculate the model's performance through training and testing outcomes.

Figure 5. *Model Loss*



Inference: From figure 5, the loss of the HGD model is estimated where at epoch 1 the training loss reduced from 3.7 to 0.3 at first iteration and remained same until the 15th iteration. During the testing phase, the loss is observed from 0.5-1.0 where at the 12th iteration, the loss was observed as higher.

Figure 6. *Model Accuracy*



Inference: The accuracy of the model (refer to figure 6) is estimated with training and testing outcomes. It is observed as during the training the peak accuracy attained was at 15th iteration and whereas during the testing phase the highest accuracy was obtained 10th iteration and again at 15th iteration.

Discussion and Conclusion

The death rate during the COVID-19 pandemic was found to be higher due to non-hygienic practices of people with distance keeping, washing hands and wearing masks (Wong, 2019). Though wearing masks and keeping distance in social or public gathering places, the hygiene practice of washing hands is proven to be effective in the studies by Lotfinejad, (2020), Stevens, (2020), Yang (2020) and Beiu, et al (2020). These studies found through extensive literature analyses and discussion that, hand hygiene practice prevents people from head-foot-and-mouth disease (HFMD). Sanitization through rubbing-alcohol in hospitals and using sanitizers at social/ public places prevent spreading of serious pathogens. Hence, in this research the hand-washing process has been focused exclusively than other prevention methods.

The study developed a VGG16 based neural networking (NN) model. The neural network used in this research is a convolutional NN. The model contains five block-layers as feature extraction layer and classification layer with ReLU function and Softmax. The input is acquired from ‘kaggle’ where it is initially recorded as video and images are clipped from processing the videos of the participants washing their hands. Based on the pre-defined 12 steps the images are predicted, classified and stored into 12 classes for the study’s purposes. The python is used as the software to build the model and to classify the images through AOA optimization technique. The study uses the categorical cross-entropy loss and found that the model built is efficient and has less loss. Accuracy is measured through classification accuracy evaluation. The model acquired 97% accuracy with value 0.3 as minimal loss. The model is a good-fit for image processing in identifying and classifying the hand-washing gestures. Future researchers could use this study as a base for multi-class with AOA optimization that uses VGG16 in CNN based architecture. Similarly, further contributions are that, different loss estimation and accuracy techniques could also be used to compare and measure the performance of the developed model.

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