Smart bacteria detection using trained datasets and CNN algorithm in Machine Learning

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Abstract: This bacteria detection using trained datasets and CNN algorithm in machine learning allows to detect the bacteria on hands using Digital Microscope and the inbuilt camera that is inside the Digital Microscope will capture the bacteria image once the bacteria is detected and send to system to compare with pretrained datasets and based on the bacteria contamination level on hands it displays output via LED Lights as alarm system(i.e-Less amount of bacteria displays green colour,medium amount of bacteria displays yellow colour and more amount of bacteria displays red color and through the LED Lights we can understand the bacteria level present on hands. Thus, our project leads in precautions in hands, alert the people intaking foods with proper hand hygiene, and protects their health.

**Keywords:** Bacteria detection, Convolutional Neural Network (CNN), Machine learning, Digital microscope, Image processing, Pretrained datasets, Contamination level, LED signaling, Hand hygiene, Public health, Infection prevention

**1. BACTERIA**

Particularly in healthcare and food related environments the problem of Bacterial contamination on human hands leading to public health concern, which contributes to problem of spreading infectious diseases. So by following the effective hand hygiene practices they are very important in preventing infections, but also there are many individuals who are not aware of the bacteria and microbes present on hands. When we focus on the traditional method, it focuses and more often they are time-consuming and they must require the special lab equipment to make them difficult for real-time monitoring in our day-to-day life settings. Bacteria are single-celled microorganisms that exist in diverse environments, including soil, water, air, and within the human body. They play essential roles in various ecological processes, such as nutrient cycling and decomposition.

Out of many bacteria some species may cause infections and disease to human beings, animals and also for plants whereas many bacteria they provide beneficial which aids in the process of digestion and they contribute to environmental factors.

Many people in the world they go for work where they do their work. So at that time whenever they do the work the bacteria contamination arising on hands possibility will be high and also by this problem it can cause health disease as people are not been aware of the problem of bacteria contamination on hands. This also becomes the regular practice and this lead in widespread of disease during the COVID pandemic situation.

**1.1 Resident Flora (Normal Skin Bacteria)**

The bacteria of Resident Flora will be naturally found on human hands and skin. They will be usually harmless .And also they play an important role by preventing harmful microorganisms hese bacteria are naturally found on the skin and are usually harmless. They play a protective role by preventing harmful microorganisms from removing heat from the skin.

* + 1. **Staphylococcus epidermidis**: It is a common type of bacterium which will form the part of the natural skin called Flora and also this type of bacterium will not spread disease but can infect people with low immune systems.
    2. **Corynebacterium species**: This type of bacterium will be involved in removal of the sweat and can contributes to the human odor which are harmless in nature.
    3. **Propionibacterium acnes**: This will be playing an important role in acne cause namely the hair follicles and sebaceous . It is also harmless one.
    4. **Transient Flora (Temporary Bacteria):** By the contact with the surfaces, humans, or animals this may lead in causing Transient Flora and also these causes infections if the hands are not washed. This type of bacterium can be removed easily if washed our hands else it can cause infections to people.

1. **Staphylococcus aureus**: This type of bacteria can be normally found on human skin which is harmful bacterium lead the infections like boils, impetigo and several more cases, MRSA(Methicillin-resistant Staphylococcus aureus) infections.

***1.1.1 Escherichia coli (E. coli)***

This E.Coli bacterium will be found on hands when the proper hygiene is not maintained and also it is associated with fecal contaminations. It can also lead in causing food poisoning or urinary track infections some times.

1. **Enterococcus species**: These bacteria are also associated with fecal contamination and can lead to infections, especially in immunocompromised individuals.
2. **Klebsiella species**: This bacterium can be found on hands, especially in healthcare settings, and may cause respiratory and urinary tract infections.
3. **Pseudomonas aeruginosa**: This bacterium can be found on hands and surfaces, especially in moist environments. It is a major cause of infections in hospital settings and can cause skin infections or pneumonia.

**1.2 Importance of Hand Hygiene**

By the practice of Hand washing with soap and water or any hand based sanitizer will be removing the most transient bacteria very effectively washing hands with soap and water or using alcohol-based hand sanitizers can effectively remove most transient bacteria and thus leads in reducing the risk of infection. Hence, the spread of harmful bacteria will be prevented by maintaining the proper hand hygiene.

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| --- | --- | --- | --- |
| **Table 1.** Bacterium table | | | |
| Bacterium | (Resident/Transient) | Approx. amount on hands | Reason for Presence |
| Staphylococcus  epidermidisa | Resident Flora | ~100,000 to 1 million cells/cm^2 | Naturally part of skin flora, Protective role |
| Corynebacterium Species | Resident Flora | ~10,000 to 100,000 cells/cm^2 | Breaks down sweat; Naturally found on skin |
| Propionibacterium acnes | Resident Flora | ~10,000 to 100,000 cells/cm^2 | Present in sebaceous glands; Contributes to acne |
| Staphylococcus aureus | Transient Flora | Varies; Can be high on contaminated hands | Transmitted through Contact, causes infections. |
| Escherichia coli(E.coli) | Transient Flora | Varies (trace to high) | From fecal contamination; Poor hygiene or contact |
| Enterococcus Species | Transient Flora | Varies (trace to high) | Fecal contamination; picked up from surfaces |
| Klebsiella Species | Transient Flora | Varies | Acquired from contaminated surfaces; healthcare settings |
| Pseudomonas aeruginosa | Transient Flora | Varies (trace to high) | Found in moist environments; hospital surfaces |

**2. Convolutional Neural Network**

It is possible for analyzing visual data such as images using Convolutional Neural Networks (CNN) a type of Deep Learning model. The CNN plays an important role in image data, classifying them and to produce accurate results in the project of Bacteria Detection on Hands using Digital Microscope. In processing, the data with a grid-like structure like images and it can be represented as a matrix of pixels using CNN, a class of Neural Networks. It has the ability to learn spatial hierarchies of features automatically from input images, and will make it effective in the process of object detection, classification and image recognition.

**2.1 CNN Architecture**

***2.1. Input Layer***

Through this Input layer, only the data is passed to the network. The input layer is typically a 3D tensor with dimensions in the case of Images where the dimensions represent height, width and channels (e.g. RGB channels for color image).

***2.2. Convolutional Layer***

The convolutional layer is used to apply a set of filters to the input creating feature maps. It performs a mathematical operations to detect features such as edges, corners, and textures by filtering each slides over the input images. From the input data the filters will be able to learn on extracting hierarchical features. The Convolutional Neural Network model generalizes the extracted features by the convolutional layer and also to recognize the features independently to the network. Hence by this, it reduces the computations in a network.

***2.3 Activation Layer(ReLU)***

An activation function like ReLU (Rectified Linear Unit) is applied after the convolution operation. It is used and helps in learning complex patterns by introducing non-linearity to the network. ReLU will retain only the positive values by replacing all negative values in the feature map having zero.

***2.4. Pooling Layer (Subsampling or Down sampling)***

The pooling layer is used in retaining important information and reducing the spatial dimensions that is height and width Tis will also mitigate the overfitting and helps in reducing the computational load. Common pooling methods include:

1. ***Max pooling****:* Max pooling is the feature extraction process to reduce the dimensionality. From a set of values from a defined region it will take the maximum value only.
2. ***Average pooling****:* The average pooling is used in computing the average value that is within a defined region.

***2.5. Fully Connected (Dense) Layer****:*

Fully Connected layer is a Dense layer which comes after the convolutional layer and pooling layers. It will typically flatten the 2D feature maps into a 1D vector. This layer will use the vector as input and then computes the final output. For an example we can say the class scores for classification tasks as final output. In the previous layer every neurons are interconnected.

***2.6. Normalization Layer (Batch Normalization)***

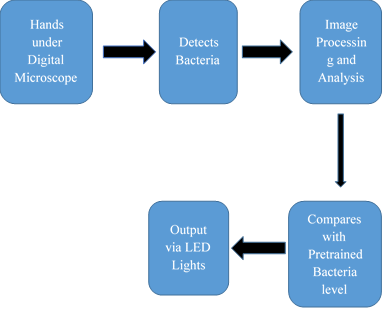
To help in speed up training and to improve the convergence the normalization layer will normalize the input of each layer to have zero mean and unit variance. It allows higher learning rate and reduces the internal covariate shift.

***2.7. Dropout Layer***

In dropout layer, to prevent overfitting it randomly drops a fraction of neurons during the training. It prevents the network from becoming too reliant on any single neuron or feature to generalize the network better.

***2.8. Softmax Layer (for classification tasks)***

At last in the final layer which is a softmax layer, it applies the softmax activation function for multi-class classification. It has the ability to convert the raw output scores into probabilities by using the normalization technique of range between 0 and 1.

**3. Block Diagram**

**Figure 1.** Workflow of the Smart Bacteria Detection System Using Cnn Algorithm

**4. Methodology**

**4.1 System Architecture**

In the architecture of the system, it comprises of the digital microscope in which there will be an inbuilt camera equipped along with it, image-processing unit based on CNN, and an output system using LED lights. The image captured by the digital microscope is sent for processing and then classifying bacteria levels based on the contamination of bacteria on hands via color-coded LEDs. Through this output it convenient for user to understand the result very easily within a short time.

**4.2 Dataset Preparation**

1. Data Collection: The bacterial contamination images are sourced from the different sources like online free sources, laboratory experiments and in public places.
2. Preprocessing: The preprocessing steps includes the image to be resized, normalize and augmentation technique including rotation, flip ping, etc. for robust and true training.
3. Labels: The preprocessed images will be categorized based on the bacterial contamination levels such as low, medium and high.

**4.3 CNN Model Design**

The CNN model also includes the components mentioned below:

1. Input Layer:
2. Convolutional Layers
3. Pooling Layers
4. Fully Connected Layers
5. Softmax Output

The training of the collected data is performed using the TensorFlow on a system by the categorical cross-entropy loss usage and by Adam optimization.

**4.4 Integration with Digital Microscope**

1. By integrating the digital microscope, it gives the high-resolution images of hands captured in real time. Then the image captured from Digital Microscope is passed for image classification using CNN model.

**4.5 LED Alert System Logic**

The bacteria levels are classified and mapped to specific LED color lights. Thresholds for bacteria levels were mapped to specific LED colors:

1. *Green:* Bacterial contamination of less than 25%.
2. *Yellow*: Bacteria contamination between 25% to 75%.
3. *Red:* Bacterial contamination of greater than 75%.

**5. Result and Discussion**

**5.1 Model Performance**

The model performance in CNN algorithm achieves an accuracy of 29% in testing data, resulting in the bacterial classification in very effective manner. There may have minimal misclassifications exists between the different levels in a confusion matrix.

**5.2 System Accuracy**

The system accuracy in Realtime applied in real world executes the results that is aligned with the contamination levels of lab reports. The specific LED color coded system provides the accurate result based on the contamination levels.

**6. Applications and use cases**

**6.1. Public Health Surveillance**

***Common areas****:* The system is deployed in urban and rural areas at public handwashing stations to support proper hand hygiene practice.

***Medicals****:* Used in hospitals and clinics for the health professional in preventing the infections.

***6.2. Food Hygiene***

***Diner*** *:* In restaurants ad food services it is applied to enhance the proper hand hygiene before having food to prevent the bacterial infections.

***Manufacturing plants*** *:* It is used for monitoring the workers in reducing the bacterial infections in the food packed.

***6.3. Educations***

***Schools****:* In schools, we use to educate children and produce awareness on proper handwash and its importance

***Awareness and training Programs****:* The awareness and training program among people on the bacterial infections due to improper handwash and practicing proper handwash.

***6.4 Home Health and Personal Use***

***Household Hygiene****:* Everyone in a family can identify the hand hygiene before the cooking of food and also after finishing the outdoor activities.

***Elderly Care****:* We can assess the caretakers of elderly individuals in maintaining the proper hand hygiene.

***6.5. Workplace***

***Pharmaceutical Industries***: We use in pharmaceutical industries in maintaining the sterility when preparing drug

***Laboratories*** *:* During any sensitive experiments in the lab the researchers can maintain free conditions.

***6.6. External environments***

***Parking stations:*** In high traffic areas we provide the hand monitoring to limit the pathogen spread at security checkpoints.

***Public Washrooms:*** We fix it in public washrooms for proper hand hygiene at public places and to provide immediate feedback.

***6.7. Cultivation Areas***

***Animal Husbandry:***In Animal Husbandry, we make it to monitor hygiene among farmworkers to prevent the zoonotic disease.

***Postharvest Handling****:* During the process of harvest and package, it is used to assess the hand hygiene to prevent bacterial contamination.

***Celebrations:*** During the celebrations, especially in crowded venues to assess the hand hygiene we use this.

***6.8. Home Automation***

***Home Automation:*** Through the mobile devices, we send the notification for users about their hygiene levels on hand.

**7. Challenges and Limitations**

1. ***Challenges in Dataset:*** The collection of large amount of bacteria images from the environments became a challenge.
2. ***Constraints in hardware:*** The different resolutions in the Digital Microscope affects the accuracy of classification for bacteria with minute size.
3. ***Bivalued results:* T**he factors such as environmental conditions and lighting issues and hand positioning affects the results giving false result.

**8. Future Enhancements**

**8.1 Machine to machine communication:**

The process of producing the real-time data of bacteria detection and contamination to connected devices is possible in Integration of devices with IoT. The connected devices can be smartphones, cloud platforms or even the tablets. By this way it is used in providing the useful information by remote monitoring, analyzing and sharing the data of hand hygiene mostly in healthcare system and food processing industries.

**8.2 Enhanced Dataset Training**

By having more number of Dataset like more than two to five lakh of dataset including more bacterial types to make more accurate result and making it applicable to more applications than the small units. The enhanced dataset training produces more accuracy and immediate results without any confusion or wrong prediction. It is used in producing true results.

**8.3 AI Training**

We need to implement the techniques of advanced CNN algorithms or the more effective algorithms to apply using new technologies. Also the transfer technique can be used in future implementation.

**8.4 Automated Feedback System**

To promote the more effective practice it is needed to implement the feedback system like providing the required instruction for the specified level rather than only lights. This provide the fully automated system providing the feedback based on the contaminated levels. For example, feedback like “Wash your hands for 20 seconds” by monitoring the bacteria content and also triggering the hand sanitization will be activated.

**8.5 Integration with Public Health Campaigns**

The device that is to be used in the schools and colleges campaigns in promoting the hand hygiene and also the effect of bacterial contamination on hands. And also this will be acting as the important tool in maintaining proper hand hygiene

**8.6 Predictive Analysis**

To control the spread of the bacteria we incorporate this using AI in monitoring the hand hygiene over the time and providing chat assistant to alert them alerting on their hand hygiene at the proper time to prevent them from containing bacterial infections. It will also store the day-to-day report such that during medical times the data ca be taken in short time and reduce in outbreak of the disease.

**9. Conclusion**

This project shows about a real-time monitoring of bacteria and providing the feedback via LED Lights based on the bacterial contaminations. For this process we use Digital Microscope where that helps in capturing high resolution images and the image is preprocessed, classified using the Convolutional Neural Network. This system can be implemented everywhere to enhance the hand hygiene monitoring system. The places of public washrooms, schools and colleges, medicals, agricultures, food industries this will be give an effective solution and hence resulting in reducing the bacterial infections. This will also provide the importance of hand hygiene and the effect that is created due to the bacterial contamination where by knowing this the awareness of hand hygiene will be spread over people and they can predict it earlier stage using the device.

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