Assessment of Autism Spectrum Disorder in Toddlers using Speech Features

Submitted By
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Introduction

We are trying to find the answer of following problem -

Can we predict onset of Autism Spectrum Disorder(ASD) in child in early stage?

Autism Spectrum Disorder:

It is a neurological disease in which the subject shows the following symptoms.

- persistent deficit in social interaction and communication.
- repetitive and restrictive behavior, activity.
- delay in learning to speak.
- odd quality of speech, stuttering.

Motivation

- At present, the diagnosis of Autism is only by a medical professional at Autism Centre.
- Parents generally ignore symptoms of ASD and that leads to late discovery of the condition.
- The basic idea is to make a mobile based application that would help parents to diagnose if the child is likely to be diagnosed for ASD.
- This application will use machine learning on various set of articulatory features of speech to diagnose the condition.

A review of state of the art

Study of Pitch Patterns in Children

- Following speech features are found in unusual style of speaking:
  - Pitch (F0) measures
  - Pitch Range
  - Pitch Excursion
- A lot variation in fundamental frequency (F0) over time
- large gap between the values of Mean Pitch, Mean Pitch Range and Mean Pitch Excursion in different group of children.

A review of state of the art(cont.)

Study of Speech Motor Functions in Children

Spectral analysis techniques are used on speech samples of children to make judgment whether articulatory features are good speech motor function. Speech modulation spectrum showed the energy in following three bands.

1. Syllabic Rhythm (SR) : Region between 2 to 10 Hertz.
2. Formant Transition (FT) : Region between 25 to 40 Hertz.
3. Place of Articulation (POA) : Region between 50 to 100 Hertz.

The correlation between articulatory features and behavioral features is analyzed to find patterns.

Milestones in Diagnosis of ASD

- Speech Sample Collection using Cloud based Android App

Classification Models:

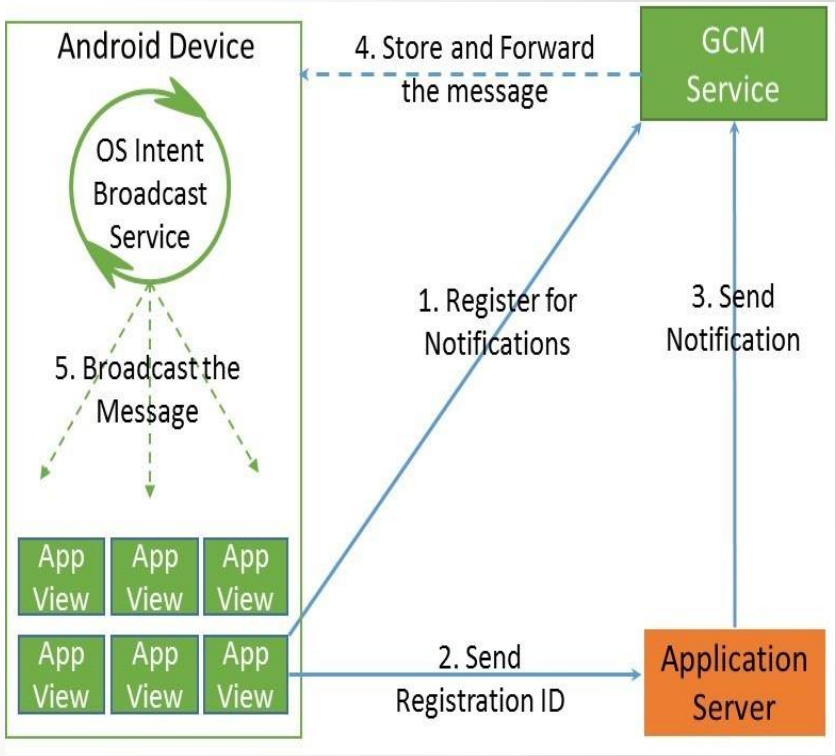
- SVM and Random Forest with MFCC features
- SVM and Random Forest with DWT and DWPA features
- Hidden Markov Model with Peak in STFT features
- Convolutional Neural Network with spectrogram.

Description of Dataset

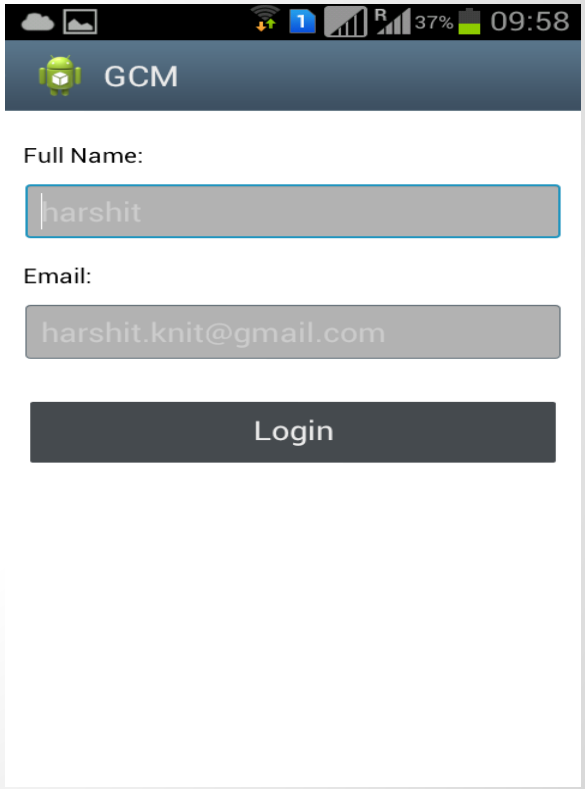
- Speech samples were obtained from National Brain Research Centre, Manesar, Gurgaon and Autism Centre, University of Washington, Seattle.
- Samples were collected during ADOS and PCI experiments at Autism Centre.
- 20 samples each from Autistic and Typical Children.
- Samples were 16-bit digitized and sampled at a rate of 44.1 KHz.

Android app for data collection

- Send data from servers to users' Android powered-devices
- Send "send to sync" messages.
- Send messages with Payload
- push back notifications.
- uses GCM service in background
- GCM is Android Cloud to Device Messaging (C2DM) service.



Snapshots of Android Application



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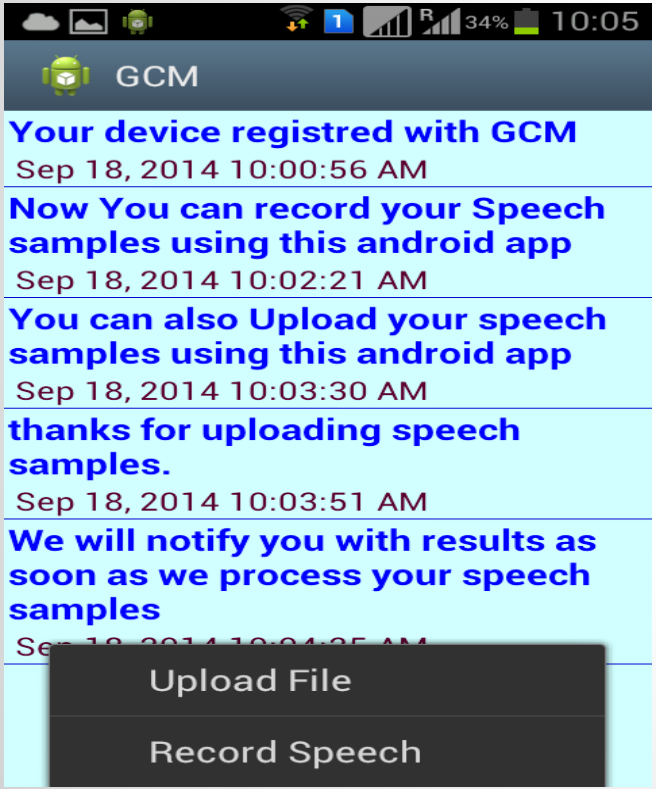

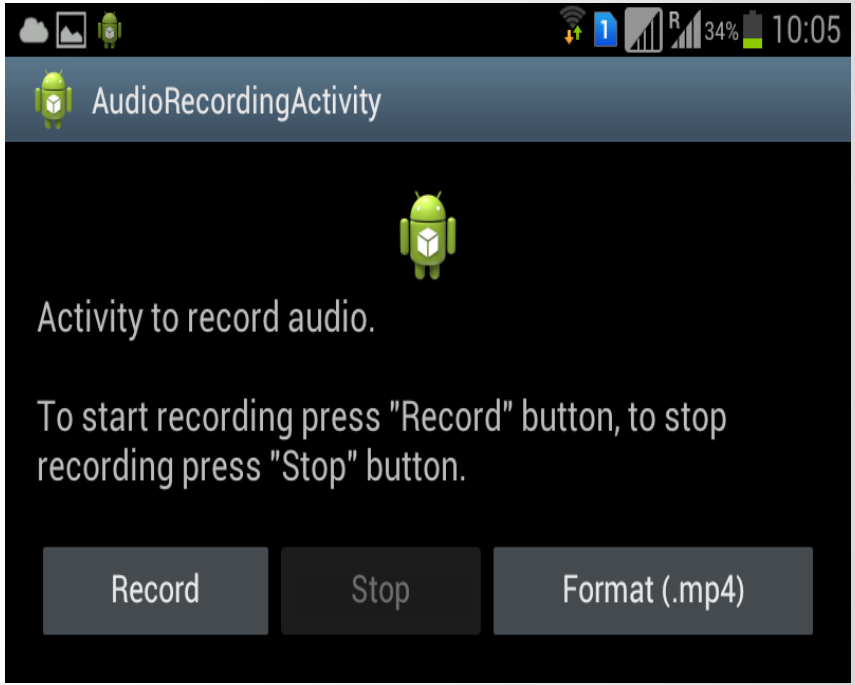

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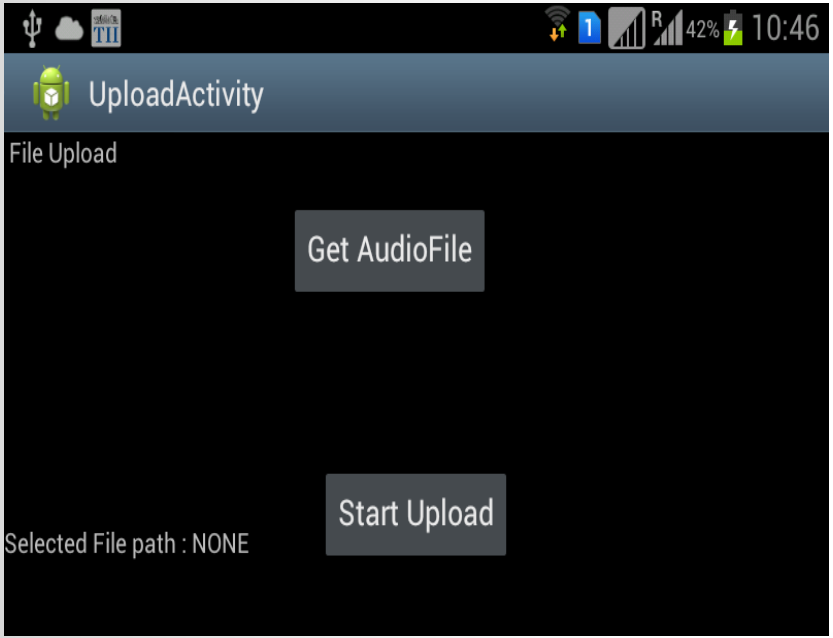

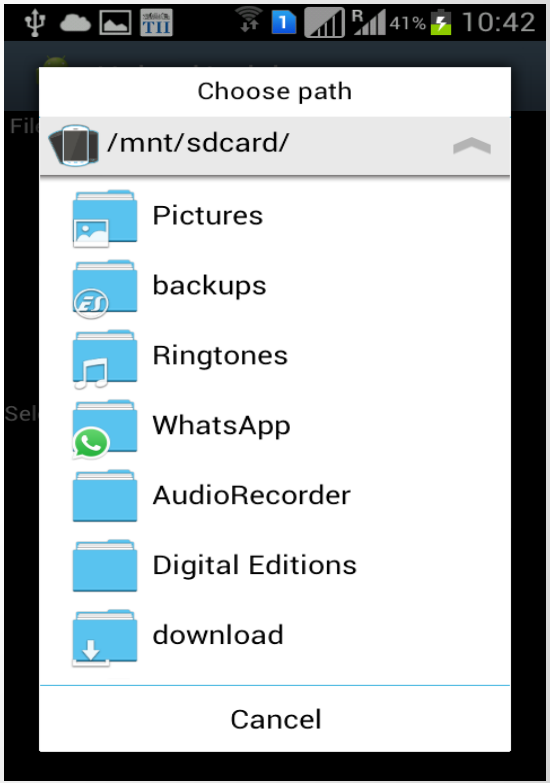

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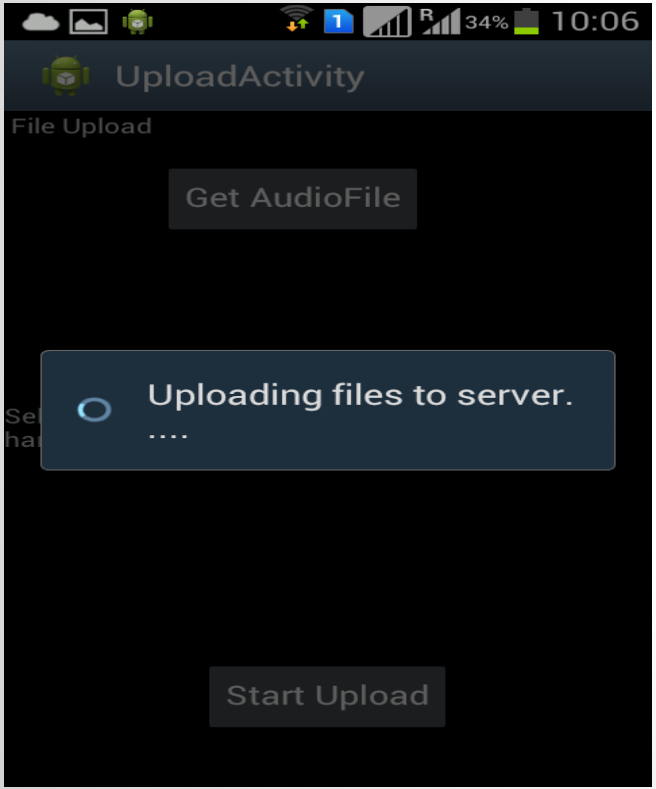
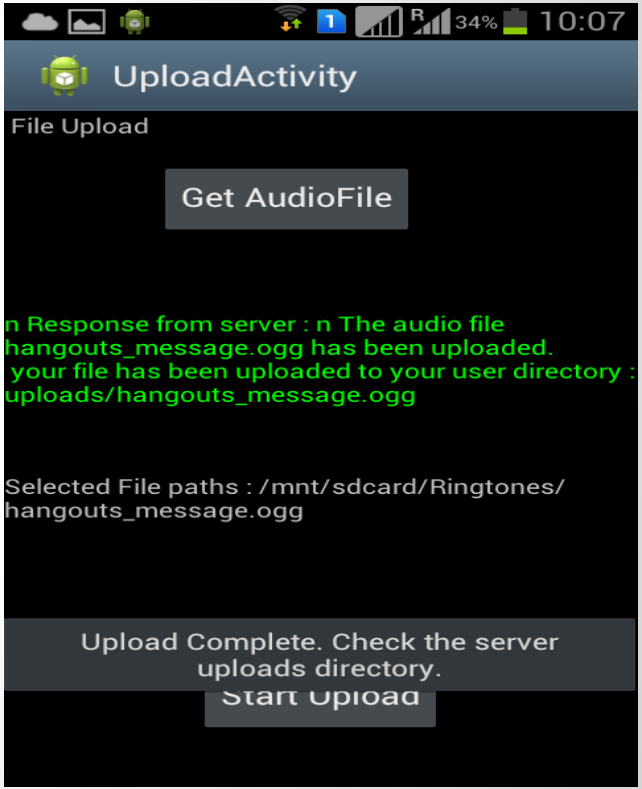
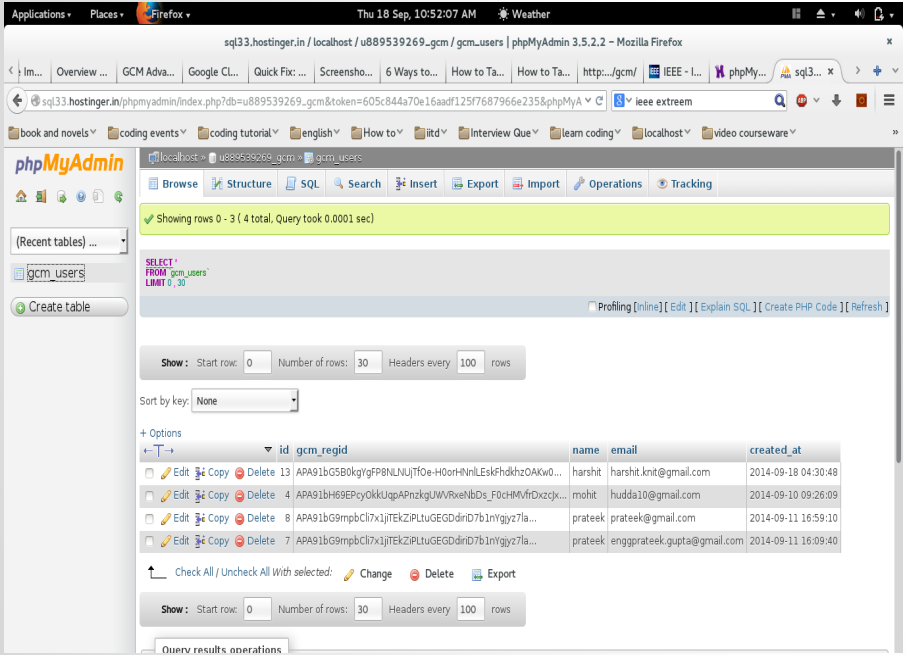
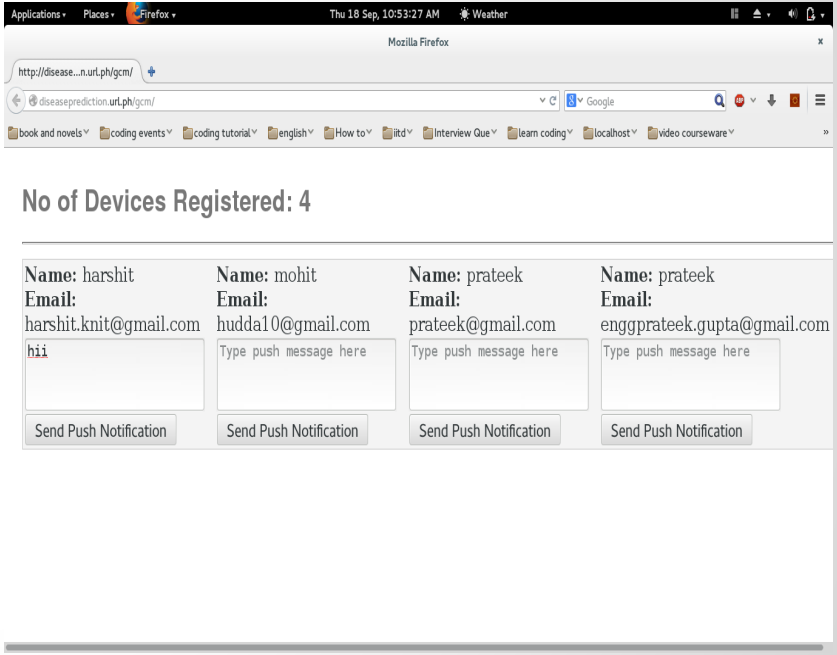


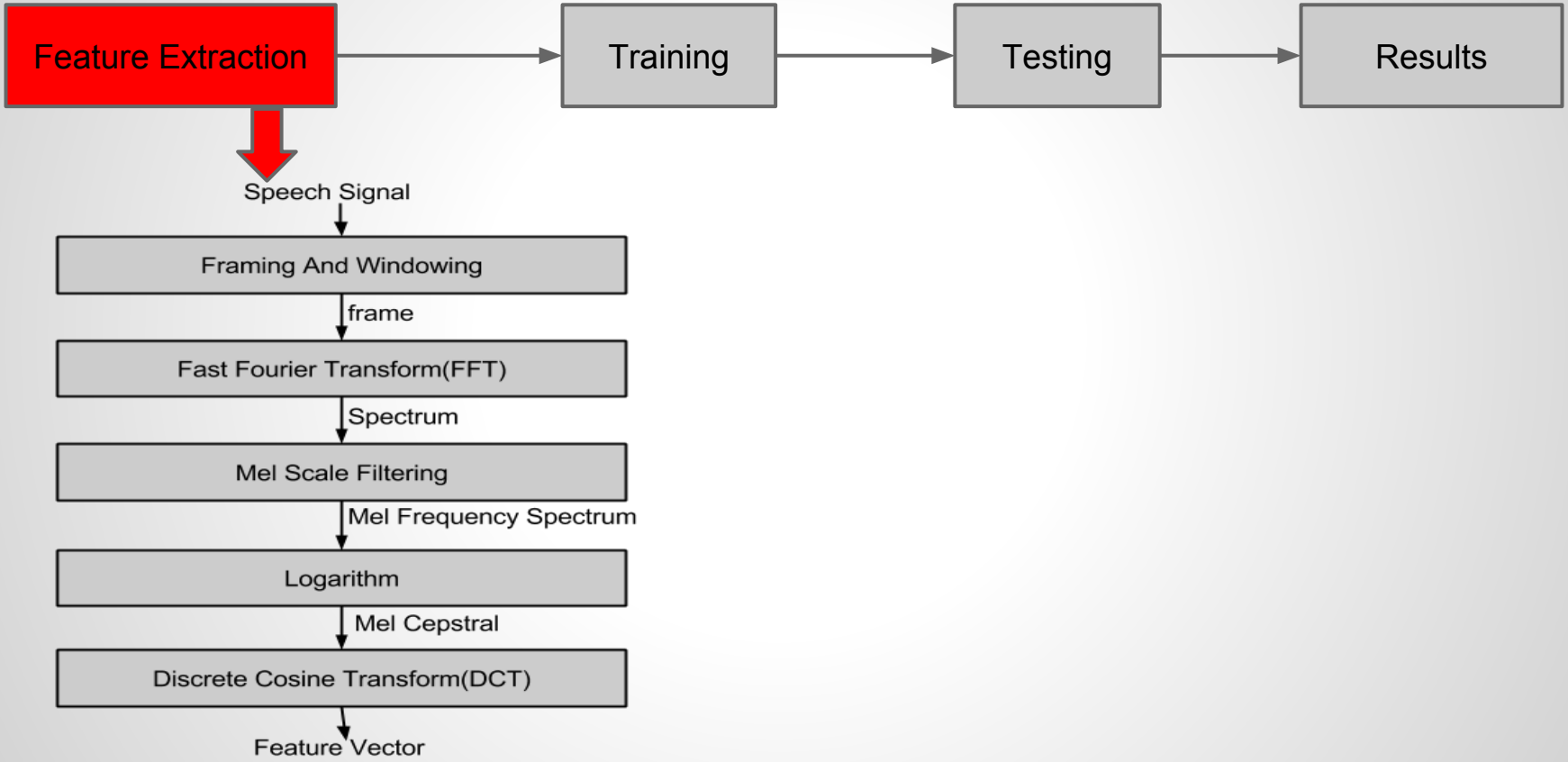


Snapshot of admin pages of website





Classification using MFCC Features



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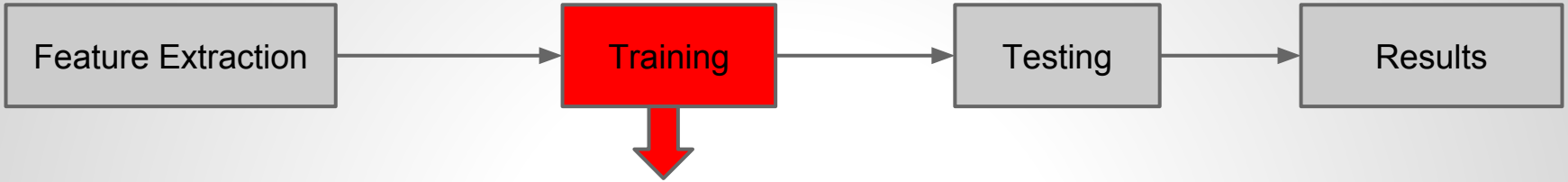

Support Vector Machine (SVM)

- Known as maximum margin classifier.
- Minimize empirical *classification error* and maximize *geometric margin.*
- Implement nonlinear classifiers by applying the kernel trick to maximum-margin hyperplanes.

Random Forest

- Ensemble classifier that consists of many decision trees.
- Bootstrap Aggregation And Random Selection of feature.
- Balance between high variance and high bias.
- Permutation to determine variable importance.

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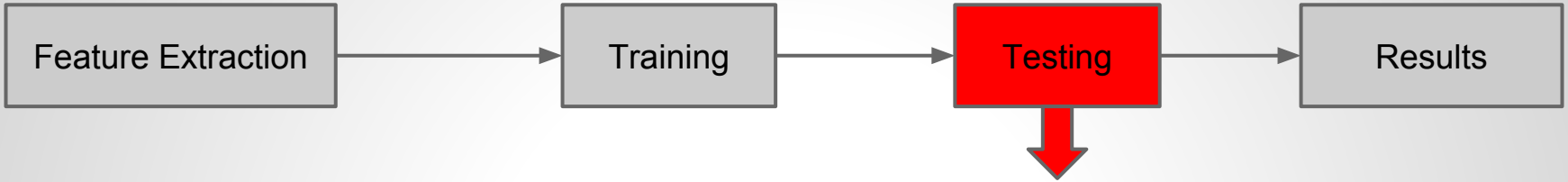

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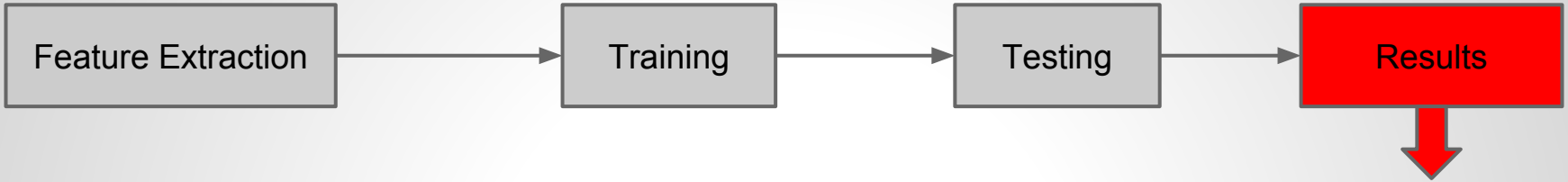
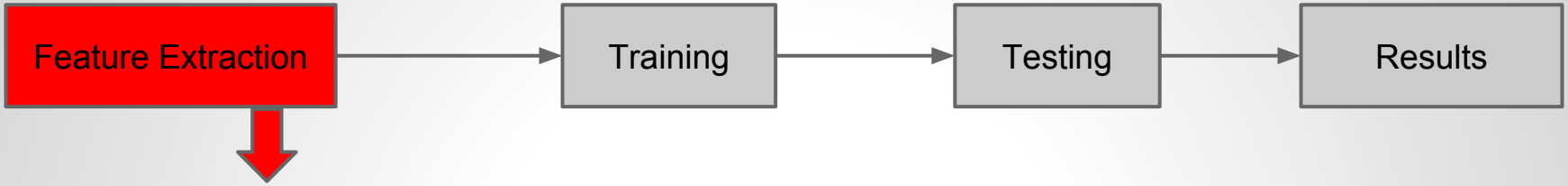
Classification using MFCC Features



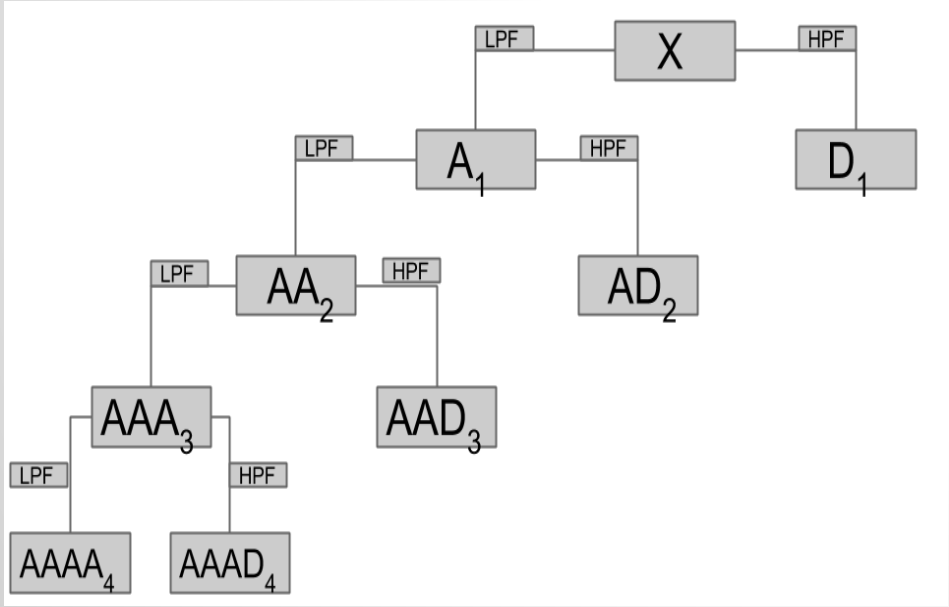
using SVM - 60%

using Random Forest- 65%

Classification using Wavelet Features



Discrete Wavelet Transform (DWT)



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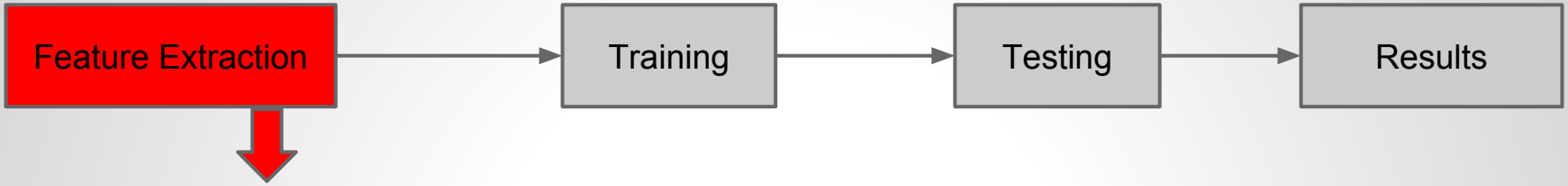
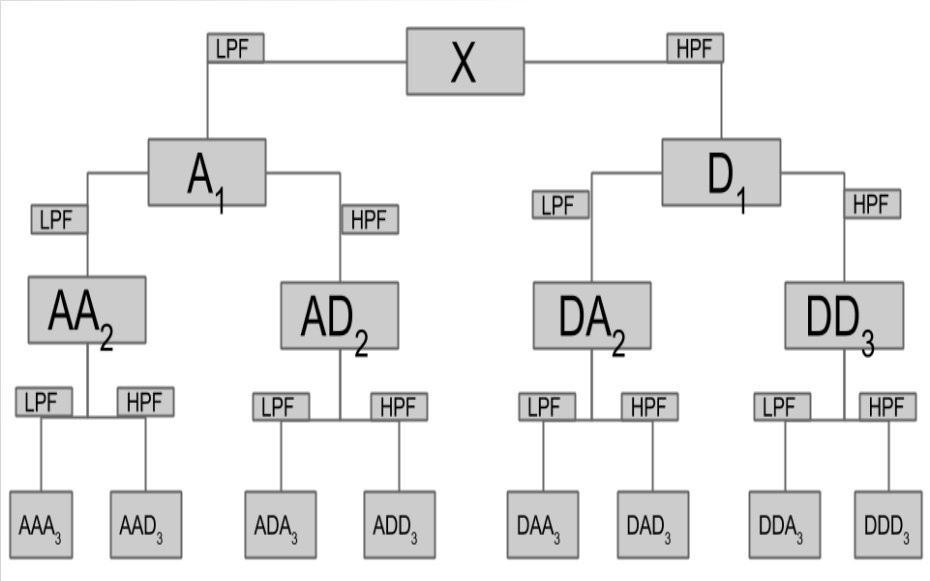


Discrete Wavelet Packet Analysis (DWPA)



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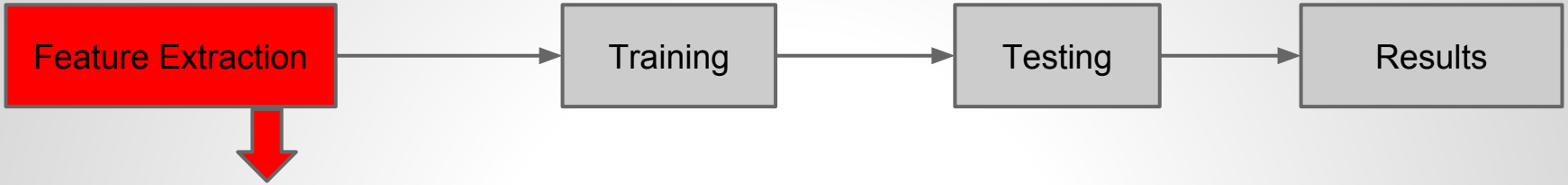
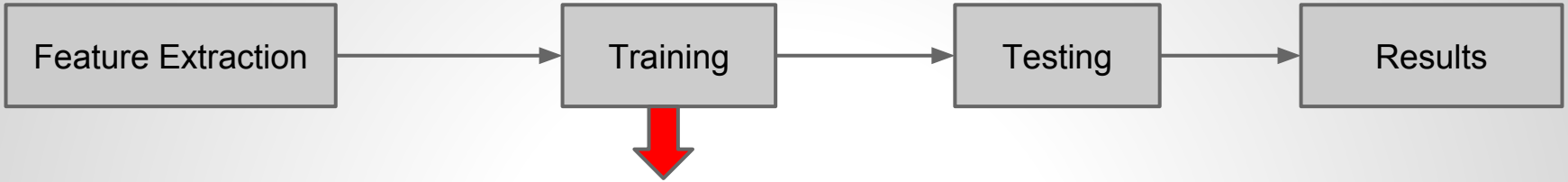


Feature Construction

F_i---> set of approximation or detail coefficients of frame number “i”

- mean(F_i)
- std(F_i)
- mean(F_i) - mean(F_{i-1})
- std(F_i) - std(F_{i-1})
- mean(F_{i+1}) - 2*mean(F_i) + mean(F_{i+1})
- std(F_{i+1}) - 2*std(F_i) + std(F_{i+1})

Classification using Wavelet Features



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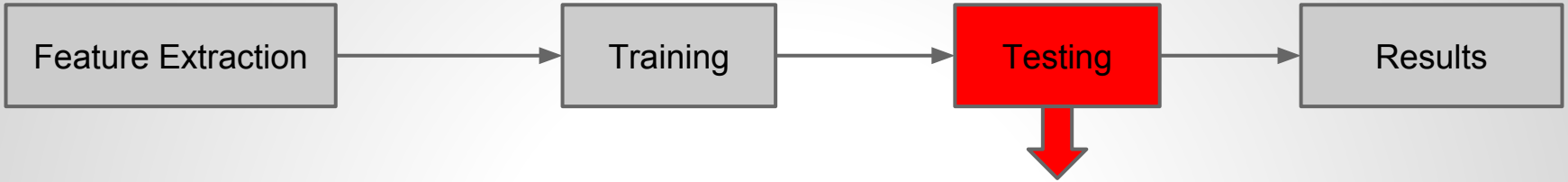

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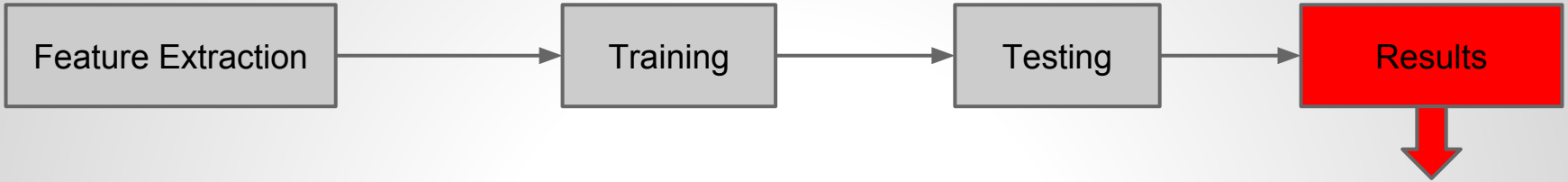


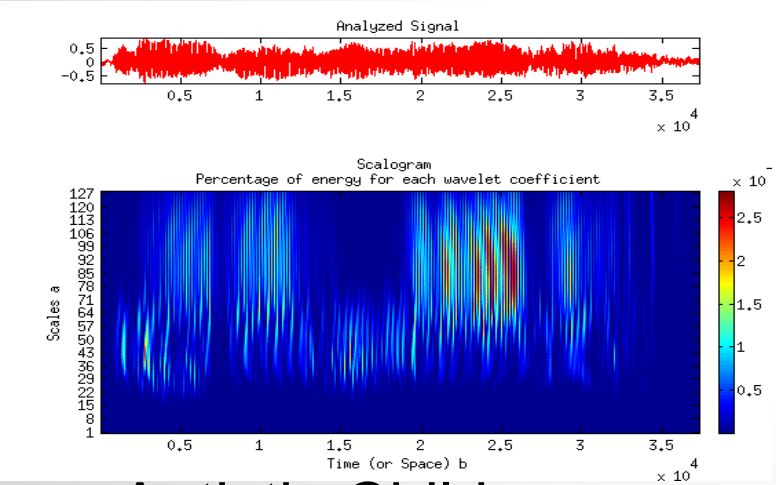
with DWT features
using SVM - 80% (+/- 3.1%)
using Random Forest- 77.5% (+/- 1.618%)

with DWPA features
using SVM - 85% (+/- 0.56%)
using Random Forest- 80% (+/- 3.37%))

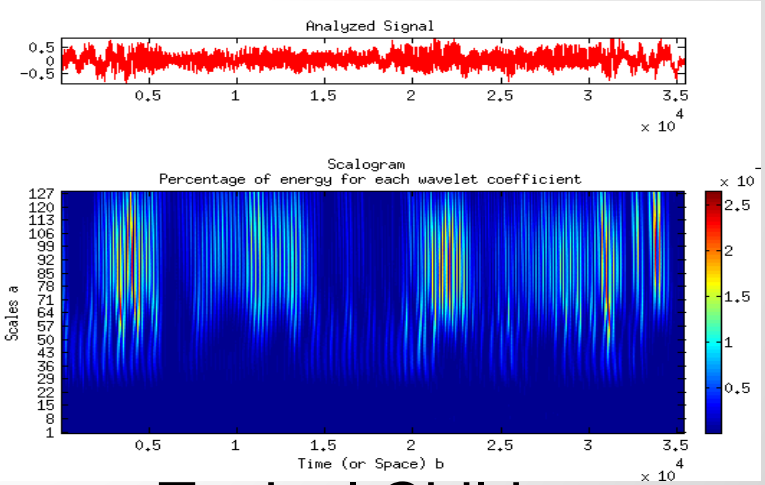
Daubechies 8 (db8) wavelet gives best results.

Scalogram

- Visual display of auto-correlation between signal and mother wavelet.
- By amount watching amount of cross-correlation in scalogram we can choose mother wavelet function

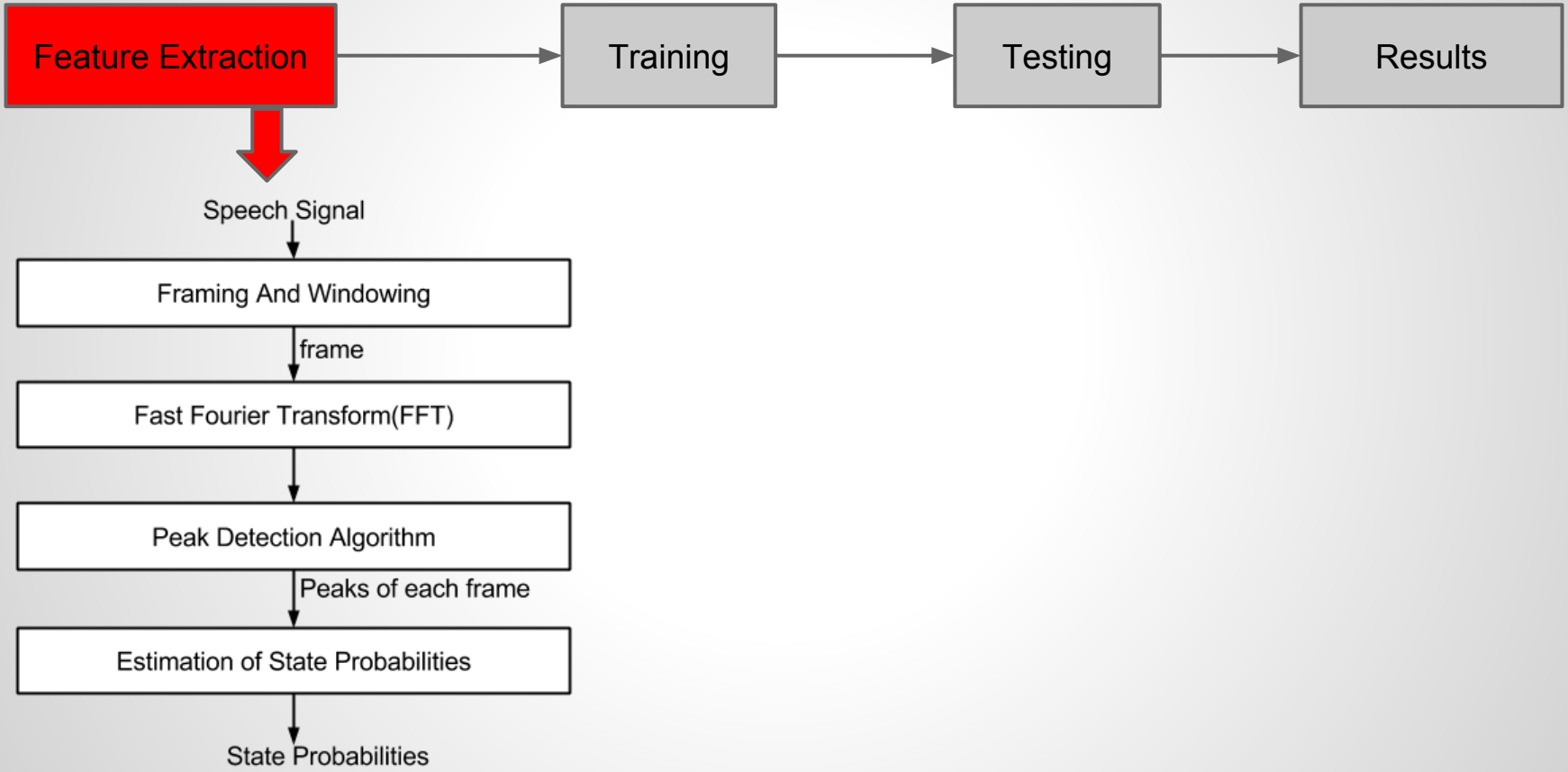


Autistic Child

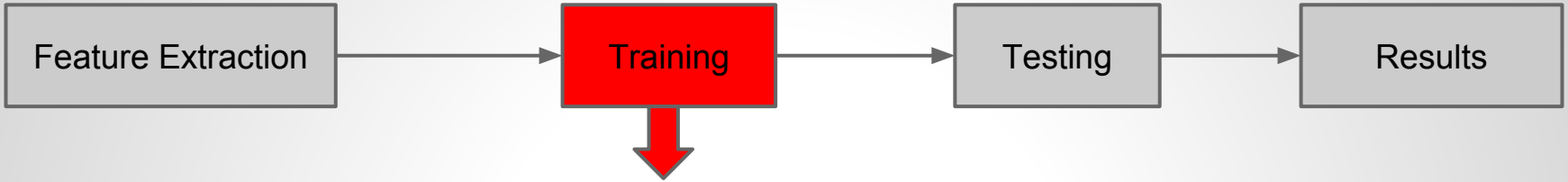


Typical Child

Classification using Hidden Markov Model



Classification using Hidden Markov Model

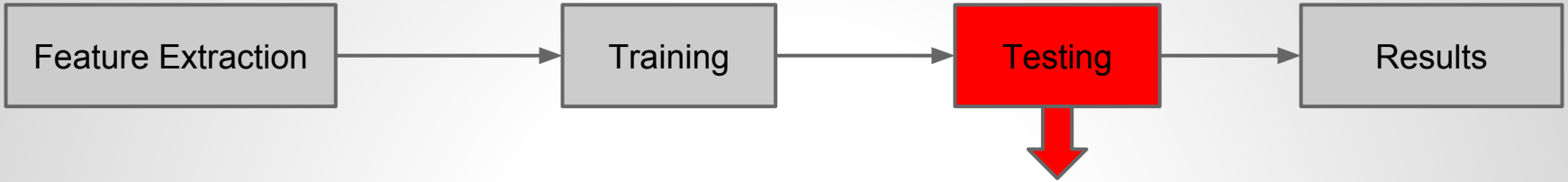


- Create Two HMM models for both classes
- Learn Parameters λ=(A, B, π) for both
  A= State transition probabilities

  B= Observation probability distribution

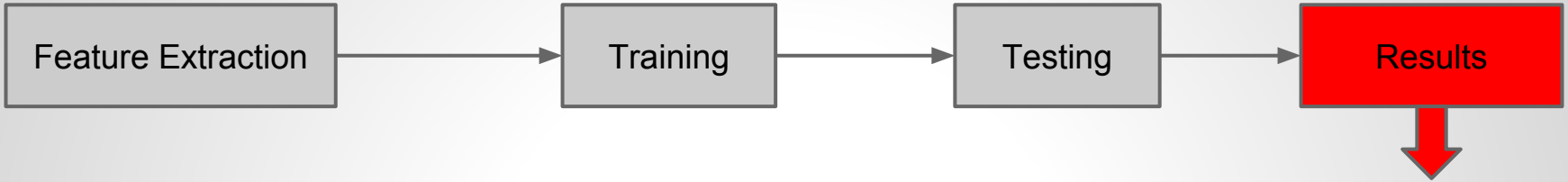
  π=initial state distribution

Classification using Hidden Markov Model



- **Maximum Likelihood Estimation Pr(O|λ)** from both models for test observation
- Test case belong to the class whose HMM Model which gives high probability

Hidden Markov Model



75%

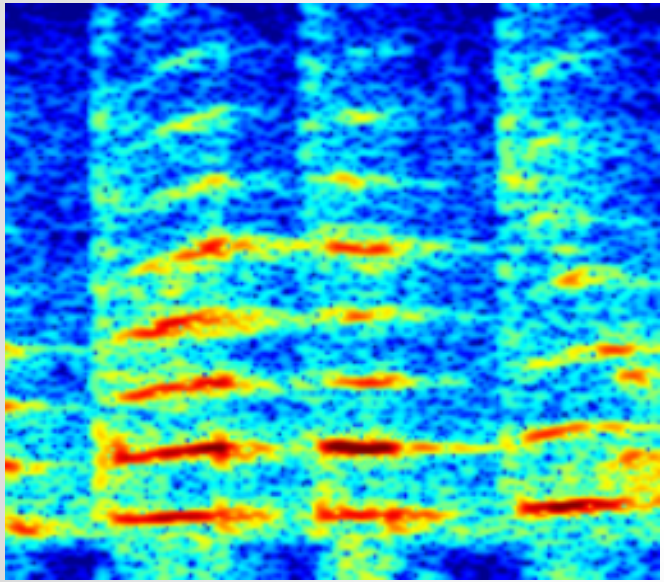
Convolutional Neural Network Why?

- Feature extraction using convolution
- Sparse Connectivity / Receptive Field
- Weight Sharing
- Sub Sampling
- Equivalent Activity
- Invariant Knowledge

In our case we will do classification using Spectrogram of speech samples of each class as input to CNN model.

Spectrogram

Offers visualization of spectral component vs time



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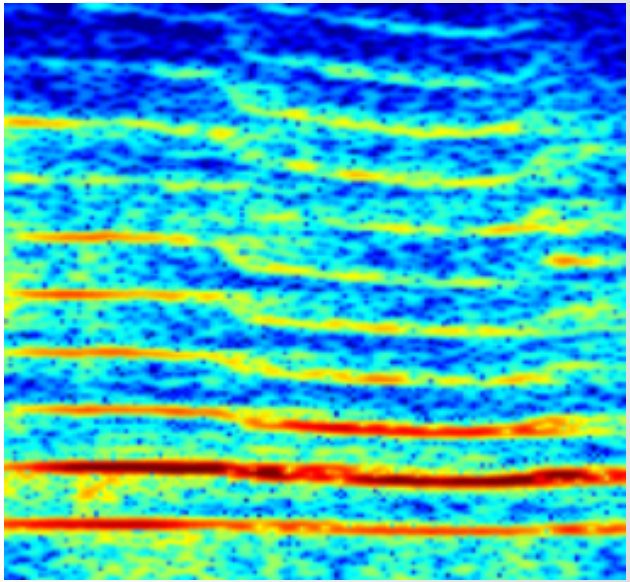
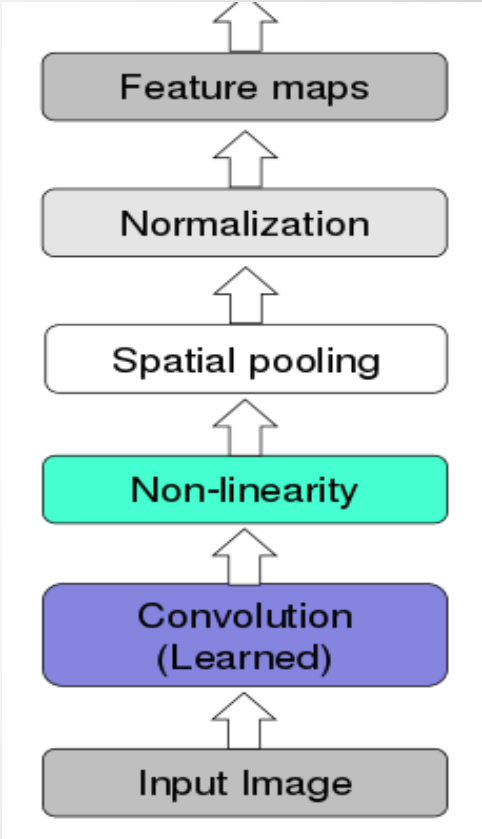


Typical Child

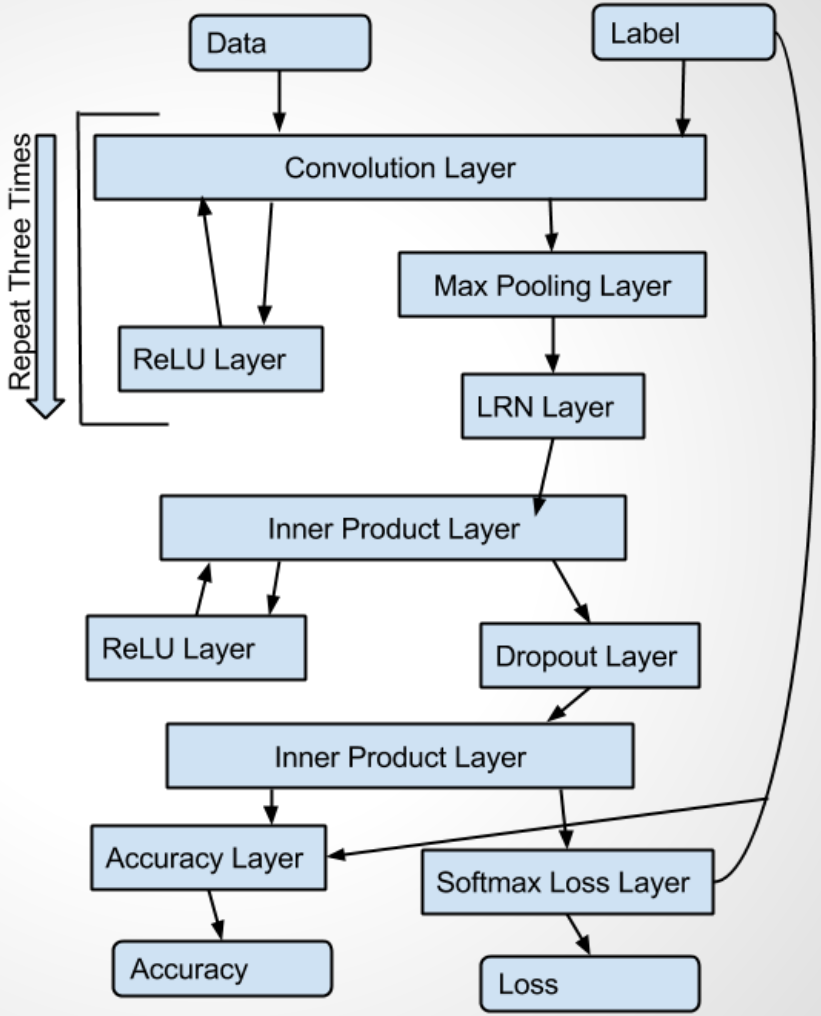
Different CNN Layers (CNN)

- Convolutional layer
- ReLU(Rectified Linear Unit) layer
- Pooling (Max/Average) layer
- Dropout layer
- Local Response Localization Layer
- Loss layer(Softmax)



Classification using CNN

- train using back-propagation
- accuracy=55%



Results

Proposed Model	Accuracy
MFCC features with SVM	60%
MFCC features with Random Forest	65%
DWT features with SVM	80%
DWT features with Random Forest	77.5%
DWPA features with SVM	85%
DWPA features with Random Forest	80%
STFT Features with HMM	75%
Spectrogram with CNN*	55%

Thank You