Leveraging Image Based Machine Learning Techniques to Determine the Predominant Spoken Language

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INTRODUCTION

Language plays a critical role in communication and education, especially in multicultural societies like that of Miami, where children from diverse linguistic backgrounds coexist and mix languages in elementary school settings. Understanding the spoken language of students is essential for effective classroom support. Past studies that aim to solve similar problems use Hidden Markov Models and Deep Learning to identify spoken language with audio recognition[1], and Deep Learning via image-based spectrogram analysis for instrument detection in polyphonic music[2].

The **objective** of this project is to develop a machine learning method to accurately predict the predominant language of speech of audio files by transforming audio into spectrograms and leveraging image-based classification machine learning techniques (Figure 1).

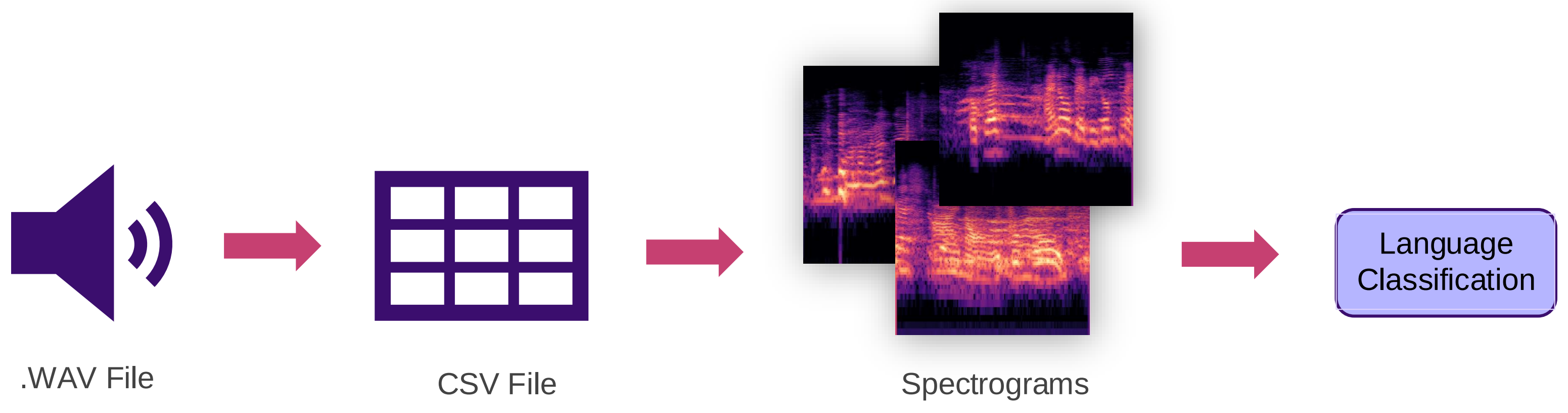

Figure 1 | **General approach for converting audio files to images**

MATERIALS AND METHODS

Creating an Original Dataset

1. Data Collection: Obtained audio recordings from elementary schools in Miami that consist of spoken language from children. Ensured that the recordings include a mixture of Spanish and English speech to reflect the linguistic diversity in the schools.

2. Annotation: We carefully listened to each audio clip and manually annotated the predominant language spoken in each sentence in a corresponding CSV file.

3. Preprocessing: The audio file was first sliced into segments as determined by the data stored in the CSV. To maintain homogeny of data, sentences less than 2 seconds were discarded, and sentences greater than two seconds were converted to 2 second segments.

4. Spectrogram Generation: Transformed each audio file segment into a spectrogram representation utilizing a signal processing library called Librosa[4]. A spectrogram therefore converted the audio signal into an image.

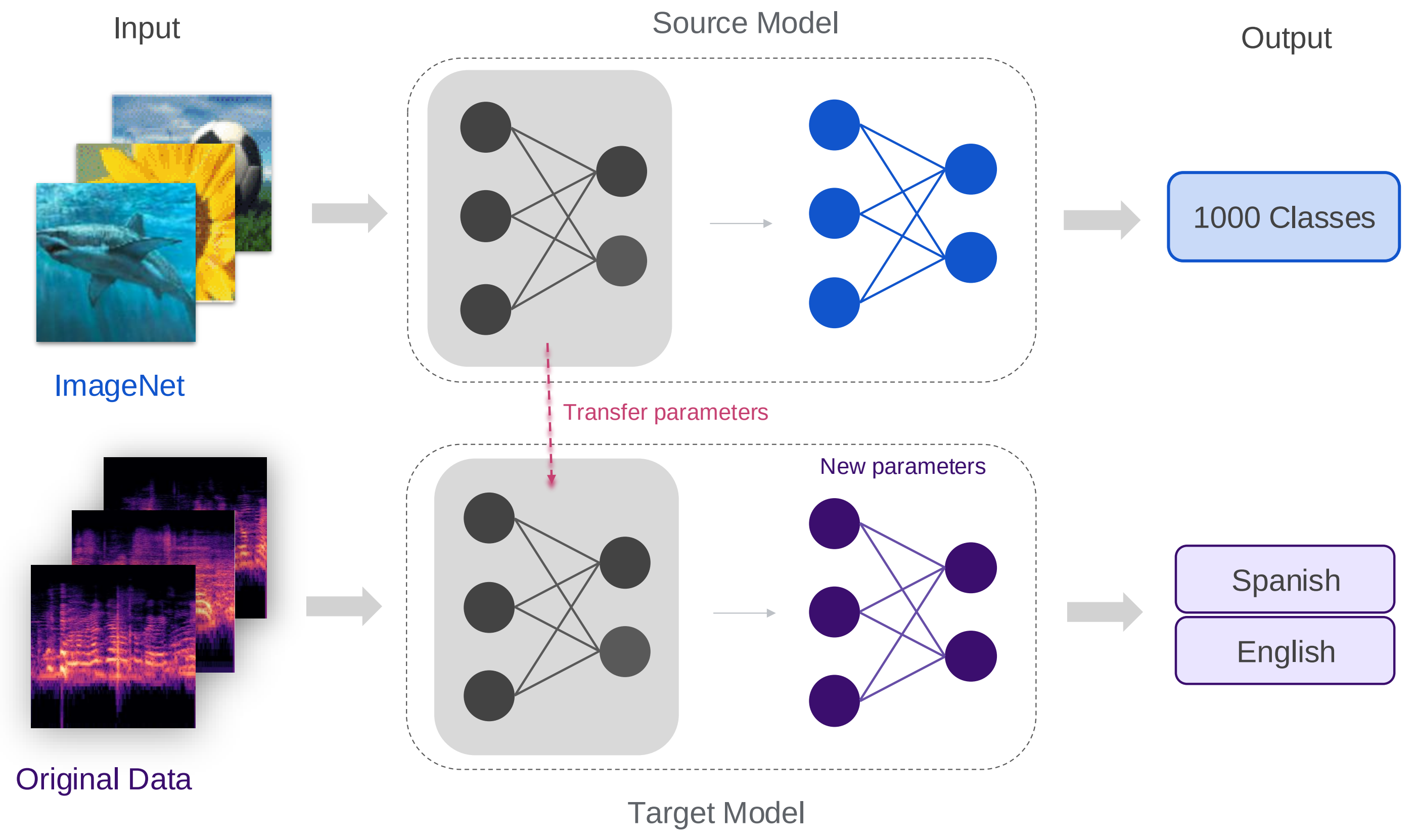

Figure 2 | **Transfer learning with ResNet18 trained on ImageNet**

Approach

- The "original dataset" described was utilized as input to a Convolutional Neural Network (CNN). CNNs are a type of artificial neural network utilized to analyze spatial data, particularly images, that have local dependencies.
- We divided the full dataset into train (80%), test (10%), and validation (10%) and employed stratified K-fold cross validation.
- We used ResNet18[3], which consists of 18 total layers, including 13 convolutional layers, 5 max-pooling layers, and 3 fully connected layers, to classify the images.
- We employed transfer learning with the ResNet18 model trained on the ImageNet dataset as our source model. Transfer learning allows incorporating prior knowledge by initializing a model with the majority of parameters from an already trained model (Figure 2)., thus requiring less data to train.

RESULTS

a.

Learning Rate	Loss	Accuracy	F1	ROC_AUC	PR_AUC
0.001	0.66854162	0.64091204	0.68856683	0.65168073	0.74990324

b.

		Predicted Values	
		Negative	Positive
Actual Values	Negative	60.6	70.6
	Positive	18.6	98.6

Figure 3 | **Metrics**

a. | Performance metrics for the ResNet18 model

b. | Confusion Matrix for the data set

CONCLUSIONS

- We developed a novel approach that utilizes mixed language audio clips for language identification. This approach proved to be effective in predicting the predominant language of speech in elementary school settings with linguistic diversity, such as those in Miami.
- By transforming audio into spectrograms and applying image-based classification techniques using Convolutional Neural Networks (CNNs), we achieved accurate language identification results.
- We leveraged ResNet18 architecture pretrained trained on the ImageNet dataset as the source model for transfer learning.
- Our model achieved 64% accuracy when testing on the original data set.

FUTURE WORK

- Expand the size of the dataset: We are currently collecting more data to increase the size of the input dataset. Utilizing a larger dataset should enhance the model's performance and generalization capabilities.
- Expand the diversity the dataset: Using audio recordings from different schools, age groups, demographics, linguistic accents, and areas of Miami would allow for a more robust model.
- Multilingual support: Expanding the dataset to include other languages spoken in the area: Haitian Creole and Brazilian Portuguese, for instance.
- Remove noise: Utilize the *Librosa*[4] library to clean the data from noise in the preprocessing stage to improve data quality, thus impacting the overall accuracy of the model.
- Test other CNNs as basis for the classifier: Test a more comprehensive set of CNNs for the classifier component of the proposed approach.
- Integration with other classroom data and models: Investigate combining with the related *Machine Learning Classification Characterization of Autism Disorder in Preschool Aged Children* project to provide more data and support to educators.

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