AFRODIGITS: A COMMUNITY-DRIVEN SPOKEN DIGIT DATASET FOR AFRICAN LANGUAGES

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ABSTRACT

The advancement of speech technologies has been remarkable, yet its integration with African languages remains limited due to the scarcity of African speech corpora. To address this issue, we present AfroDigits, a minimalist, community-driven dataset of spoken digits for African languages, currently covering 38 African languages. As a demonstration of the practical applications of AfroDigits, we conduct audio digit classification experiments on six African languages [Igbo (ibo), Yoruba (yor), Rundi (run), Oshiwambo (kua), Shona (sna), and Oromo (gax)] using the Wav2Vec2.0-Large and XLS-R models. Our experiments reveal a useful insight on the effect of mixing African speech corpora during finetuning. AfroDigits is the first published audio digit dataset for African languages and we believe it will, among other things, pave the way for Afro-centric speech applications such as the recognition of telephone numbers, and street numbers.

1 INTRODUCTION

Datasets are essential for the advancement of robust and beneficial deep neural networks in natural language processing (NLP) technologies Bender et al. (2021); Nekoto et al. (2020). The ImageNet (Deng et al., 2009) dataset is a prime example as it revealed the power of deep neural networks in image recognition (Krizhevsky et al., 2012; Russakovsky et al., 2015). That is to say, the more datasets there are for a given deep learning task, the better (in terms of robustness, fairness, and diversity) the model can get.

End-to-end deep learning models have pushed the state-of-the-art on speech processing tasks like automatic speech recognition (ASR) (Baevski et al., 2020; Babu et al., 2021; Radford et al., 2022), and speech synthesis (TTS). However, due to data scarcity, existing speech recognition technologies do not support African languages (Muhire, 2020; Dossou & Emezue, 2021; Afonja et al., 2021b;a). We believe that our voice defines who we are and therefore when languages are omitted from speech technologies, the identities and cultures of the speakers are gradually obscured. The AfroDigits project was created to fill this void of African speech corpora by using a community-based participatory approach (Nekoto et al., 2020) to build AfroDigits – a spoken digit dataset for all African languages. This dataset has a number of potential use cases, ranging from being used to easily introduce concepts in speech processing, to real-life applications like recognition of spoken telephone digits, street house numbers, etc.

The rest of the paper is structured as follows: we motivate AfroDigits and give an overview of our data collection efforts aimed to bridge the gap for languages in speech technology. Then we detail the AfroDigits project in section 3.2, present the AfroDigits dataset as well as some of its useful properties. Finally, to demonstrate a possible use-case of the dataset we perform finetuning experiments and discuss their results in section 4.

2 RELATED WORK

We focus on related efforts in building speech corpora for speech processing tasks. Some popular large-scale open-source *monolingual* speech datasets, which have dominated research in speech processing, include LibriSpeech (Panayotov et al., 2015) (as well as its variants like LibriCSS (Chen et al., 2020), LibriLight (Kahn et al., 2019)) and TIMIT (Garofolo, John S. et al., 1993). However

they do not have support for African and other non-English languages. Then came the wave of multilingual speech corpora, like Vox-Forge (vox), Babel (Gales et al., 2014), MAILABS (cai) and most notably, Mozilla's Common Voice (Ardila et al., 2019), to enable support for many more languages. However, the number of African languages supported is still meager. Out of the 2000+ African languages, only Kinyarwanda has 1000+ hours of audio on Common Voice (Muhire, 2020). Babel, the only project that contains a number of African languages, is 1) not open-source which limits its use to only those who can pay, and 2) has been shown to contain outdated styles of conversation that make it necessary to supplement models trained on it with datasets representing modern styles of communication for African languages (Dossou & Emezue, 2021).

Over the years many efforts have emerged, specially to fill the void of African speech corpora (van Niekerk et al., 2017; Dossou & Emezue, 2021; dig; Meyer et al., 2022; Afonja et al., 2021a; Oyewusi et al., 2022; Babirye et al., 2022). One notable property of some of these projects has been their use of a community-based, participatory approach to data collection. One advantage of community-based data collection is that, while being cost effective, it has been shown to ensure sustainability and scalability (Adelani et al., 2022a; Emezue & Dossou, 2020; Scao et al., 2022; Joshi et al., 2020; Bender et al., 2021; Nweya et al., 2022b;a). These works have mostly focused on text-speech corpora and not digits, which is what sets our work apart. Through AfroDigits, we contribute to the existing community-based efforts to build more African speech corpora, with a focus on digits.

3 AfroDigits

In this section, we expand on AfroDigits. This section begins with a description of the project, the interface and data curation process, and ends with an outline of the AfroDigits dataset.

3.1 The Project

The dataset presented in this paper was a result of the AfroDigits project. The AfroDigits project is meant to be a life-long community-driven tool for audio digit data collection. Our motivation for choosing the domain of spoken digits lies in our desire to create an Afro-centric minimalist dataset which can easily be used for speech processing tasks (e.g for making tutorials, introducing concepts or new models, training and evaluating a model), similar to the way MNIST (Lecun et al., 1998) is for the field of computer vision. The FSDD dataset (Jackson et al., 2018) which is most similar to ours in terms of the proposed use case, is English-based. The idea is that AfroDigits will 1) inspire African researchers to learn speech processing while working on their native languages, and 2) improve the discoverability of African languages to non-African researchers and practitioners. Another advantage of the digits domain is that while it's harder to find sentences (especially for African languages (Team et al., 2022; Adebara et al., 2022)), numerical digits are universal, which makes recording straightforward.

Our first challenge was the platform to use for recording the digits. We wanted a platform that required no technical expertise to use, since we were also targeting rural communities. To this end, we created the African Digits Recording platform on HuggingFace Spaces[1]. Figure 1 shows the recording platform. To make the recording entertaining, and inspired by the MNIST handwritten numbers dataset, we randomly displayed images of the numbers 0-9 for the participants to record. At the end of each recording session, when they had recorded numbers 0 through 9, the participants were shown a congratulatory image GIF and encouraged to do another round. Furthermore, we wrote down very simple instructions, displayed in Figure 2, at the top of the platform so that participants would quickly understand the task.

To encourage participation during the launch of the platform, we created the African Digits Recording Sprint which lasted for one month. Through widespread advertisement, especially within communities, such as Masakhane, with native speakers of African languages, we ensured active participation during the sprint. We further included prizes that were given to the top ten recording contributors. In order to obtain additional meaningful metadata besides the audio, we included optional fields for users to indicate their age, gender, accent, and country of residence. Additionally, we did not require the name, address, or any other personal information of the participants, following standard practice in audio data collection (Ardila et al., 2019).

[1] link to the Space will be revealed in the camera ready version

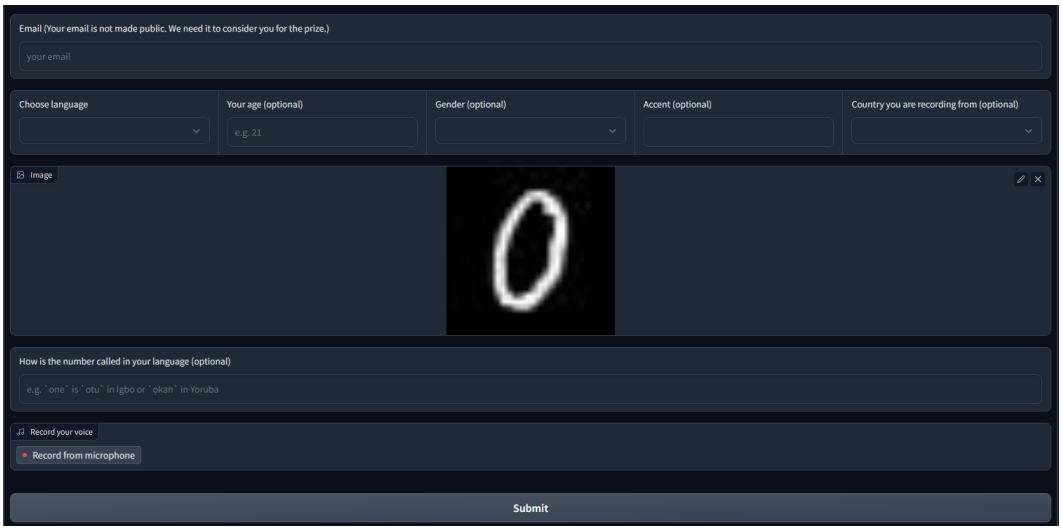

Figure 1: The AfroDigits recording platform. The participant is shown an image of the number, and recites it, while recording. The platform requires no log-in or sign-up making it very easy to use.

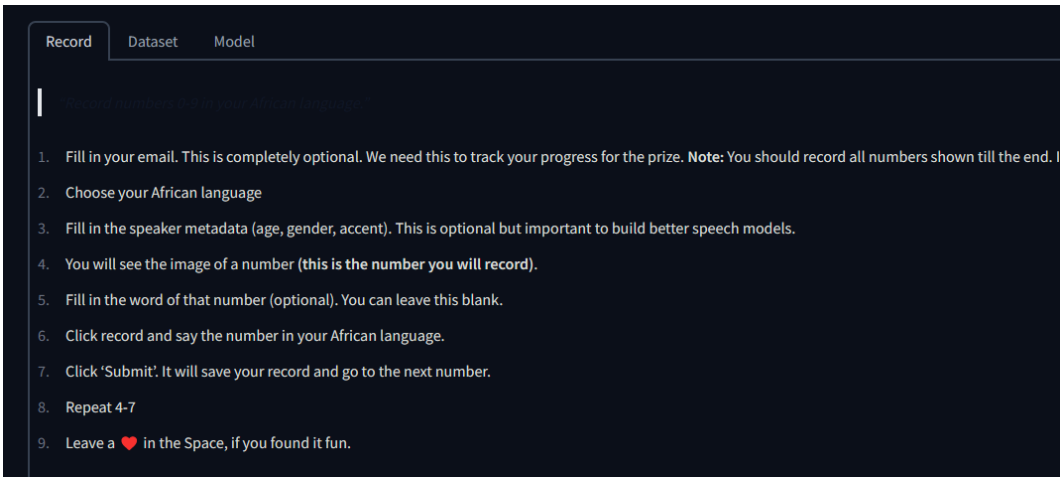

Figure 2: The set of instructions which the participant sees on entering the platform.

3.2 THE DATASET

Table 1 shows the current statistics of AfroDigits, which currently has 2,185 audio samples covering 38 African languages. AfroDigits is freely available for download. Following existing data governance principles (Benjamin et al., 2019; Jernite et al., 2022), the dataset is gated, meaning that one needs to provide details like name, email address and affiliation before getting access to the dataset. The whole dataset is housed in a `data` directory, which consists of sub-directories, each of which is named with randomly generated audio ids and contains an `audio.wav` file and a `metadata.jsonl` file where the metadata (audio id, language name, language id, digit, text of the digit, audio frequency, age, gender, and country of residence of the participant) for the specific audio file can be retrieved. All audios are mono-channel with a sampling rate of 48kHz. From Table 1, we see that Oshiwambo (kua) language has the highest number of recordings contributed (1,721).

Using the HuggingFace Datasets[2] and Transformers[3] (Wolf et al., 2019) libraries, one can integrate the dataset directly into their training pipeline.

Table 1: Current data statistics of AfroDigits. The table is sorted by the language ISO-639-3 code in alphabetical order.

Language	Code	# Clips	Duration
aasáx	aas	1	2.22
abua	abn	10	17.1
abon	abo	1	2.34
adamorobe sign language	ads	1	19.2
arabic, tunisian spoken	aeb	10	23.94
afrikaans	afr	11	25.02
qimant	ahg	2	5.27
amharic	amh	10	25.26
arabic, sudanese spoken	apd	5	12.96
arabic, moroccan spoken	ary	10	20.4
arabic, egyptian spoken	arz	1	2.64
bambara	bam	1	2.88
basaa	bas	10	33.6
andaandi	dgl	2	5.04
ezaa	eza	11	76.38
fon	fon	3	9.6
oromo, borana-arsi-guji	gax	40	83.1
hausa	hau	1	1.74
igbo	ibo	138	355.95
kinyarwanda	kin	21	84.96
oshiwambo	kua	1721	3376.34
dholuo	luo	1	1.92
luwo	lwo	10	47.34
massalat	mdg	1	10.8
ndebele	nde	12	51.3
ndonga	ndo	1	1.38
!xóõ	nmn	1	2.58
rundi	run	35	142.79
shona	sna	30	70.89
somali	som	12	11.54
swahili	swa	11	11.28
turkana	tuv	1	1.8
tswapong	two	10	9.81
makhuwa	vmw	10	40.38
wolof	wol	10	9.81
maay	ymm	1	3.42
yoruba	yor	28	27.48
zulu	zul	1	2.68

4 EXPERIMENTAL SETTING

To demonstrate the use-case of the AfroDigits dataset, we run finetuning experiments using pre-trained speech models. In this section we discuss the focus languages for our experiments, as well as the models utilized.

4.1 FOCUS LANGUAGES

For our experiments, we focused on the six African languages with the most significant number of audio samples in AfroDigits – Igbo (ibo), Yoruba (yor), Rundi (run), Oshiwambo (kua), Shona (sna), and Oromo (gax). The distribution of the digits and gender for each language is shown in Figures 5 - 16. Figure 3 shows the gender distribution across the number of recorded clips for the focus languages. We see representation of both male and female voices in yor, ibo and kua. Together with the pie chart on the right, there is a comparably similar representation of male and

[2] https://huggingface.co/docs/datasets/index

[3] https://huggingface.co/docs/transformers/index

female voices in all our audio samples. All this is in line with previous work (Ardila et al., 2019; Bender et al., 2021; Adelani et al., 2021) opining that community-based crowd-sourcing fosters a wide representation of participants and improves diversity in data collection, thereby making the dataset more representative and less biased to a particular gender, race or location.

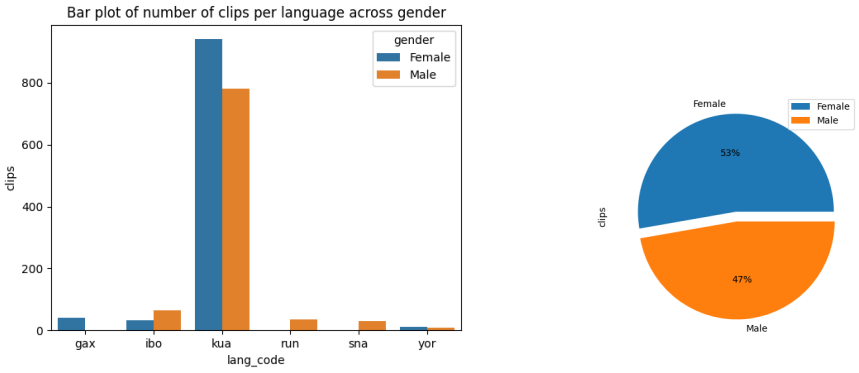

Figure 3: Left: Barplot of the number of clips for each of our focus languages segmented by the gender. Right: Gender distribution of audio samples for our focus languages

Table 2 shows information about each of our focus languages. XLS-R pretraining contained audio data from three of the six focus languages (namely yor,run,and sna) while Wav2Vec2-Large has none. The African audio data used in pretraining XLS-R came mostly from Babel Gales et al. (2014), which is not a free dataset. AfroDigits, being open-source and free for all, offers a major contribution to creating open-source and free speech data for African languages.

Table 2: Information about the languages used in our experiments, and their number of training and evaluation clips. For each pretrained model, we denote (✓) if the model was pretrained on audio data from that language and (✗) otherwise. `mixed` refers to the setting where we mix all the audio data from all languages.

Code	#Train / #Eval	XLS-R	Wav2Vec2-Large
ibo	96 / 42	✗	✗
yor	19 / 9	✓	✗
run	24 / 11	✓	✗
kua	1204 / 517	✗	✗
sna	21 / 9	✓	✗
gax	28 / 12	✗	✗
`mixed`	1392 / 600	-	-

4.2 MODELS

Pretrained speech models are powerful large neural network-based models that have been trained on a gigantic speech corpora. They are trained to learn and capture meaningful abstract features from speech (Schneider et al., 2019; Hsu et al., 2021; Radford et al., 2022). The knowledge learned can then be transferred to downstream tasks (Bengio, 2012; Wang & Zheng, 2015), and they are particularly useful in low-resource settings (Zoph et al., 2016; Radford et al., 2022; Adelani et al., 2022a). This motivates our choice of using pretrained speech models on the downstream task of spoken digit classification. For our finetuning experiments, we utilized two large pretrained speech models: Wav2Vec2.0-Large (Baevski et al., 2020) and XLS-R (Babu et al., 2021).

Wav2Vec2.0-Large: The Wav2Vec2.0-Large model was pre-trained through a self-supervised learning of representations from raw audio data by masking spans of its discretized latent speech representations, similar to masked language modeling (Devlin et al., 2018), and using contrastive

learning, where the true latent is to be distinguished from the false ones (van den Oord et al., 2018; Baevski et al., 2020; Rivière et al., 2020; Schneider et al., 2019). The authors note that jointly learning discrete speech units with contextualized representations helps Wav2Vec2.0 outperform the original Wav2Vec model (Schneider et al., 2019) in downstream recognition tasks.

XLS-R: In automatic speech recognition, researchers (Rivière et al., 2020; Schultz & Waibel, 2001; Stolcke et al., 2006; Huang et al., 2013; Hsu et al., 2021) have shown that it is beneficial to finetune with models that were pretrained on multilingual audio data – especially if the multilingual corpora contains some of the languages (or language family) of your downstream language. Motivated by this, we decided to include this model in our experiments. While the Wav2Vec2.0 model was pretrained on an English-only LibriSpeech corpus (Panayotov et al., 2015), XLS-R – built on the Wav2Vec2.0 backbone – was pretrained on a combined multilingual dataset of 128 languages, including 17 African languages. Table 2 shows which of our target African languages are represented in the XLS-R model.

XLS-R-Mix: Some studies have underlined the relevance of mixing training datasets in NLP, particularly for low-resource languages. In machine translation, Adelani et al. (2022b) showed that as low as 2000 translation sentences were sufficient to effectively finetune a large pre-trained model and obtain a significantly good performance. In the speech domain, Babu et al. (2021); Chan et al. (2021) demonstrated that combining audio data from several languages and domains improves transfer learning capabilities in settings where the training data is very small or noisy. Inspired by this, we set out to answer the following: since the individual train samples for each language are very small (see Table 1), can we have some improvement, for each language, if we finetune one model on the mix of audio samples from all the languages? For this, we finetuned XLS-R on a combined dataset from all the languages using the same hyperparameters above. The resulting model is called *XLS-R-Mix*.

Relatively Equal Model Parameters: The XLS-R model consists of $315,703,690$ model parameters while the Wav2Vec2.0-Large model has $315,693,962$ – a requirement enforced in order to ensure that neither model has an edge over the other based on their size.

Handling Class Imbalance: The AfroDigits dataset currently has very small audio samples for our focus languages, with an unequal balance of digits for each language (see Figures 5 - 16). In order to prevent the model from overfitting on the classes with many samples, we implemented weighted sampling (Monaco, 2013). With weighted sampling in the data loading process, different from the normal sampling which favors the majority classes (Caswell et al., 2020; Dunn, 2020; Fan et al., 2020), the labels are chosen with a probability inversely proportional to their size in the training set. This means that at each training step and for each language, the labels with few samples are more likely to be chosen for training the model. This is similar to studies (Arivazhagan et al., 2019; Team et al., ai) that have leveraged upsampling for under-represented languages during pre-training large language models in machine translation.

Training Setup All audio samples were resampled to 16kHz for the finetuning experiments. We froze the encoders of each model and finetuned for 100 epochs. We used the Adam optimizer Kingma & Ba (2015), with a learning rate of $3e-5$ for both models. We did not do any search for optimal hyperparameters but instead used the recommended settings from the authors. We ran our finetuning experiments with five different seeds, then we took the average over the different runs as well as the standard deviation. Training for each language took less than 30 minutes with a GPU, indicating the feasibility of the AfroDigits dataset as a 'Hello World' dataset for speech processing, just like MNIST is for computer vision. Finetuning the dataset on large speech models like Wav2Vec2.0-Large and XLS-R, however, needs a larger GPU resource. Where needed, we used an NVIDIA A100-SXM GPU.

5 Results & Discussion

In Table 3 we report the weighted F1 values on the held-out evaluation averaged over the 5 runs. Figure 4 shows the evolution of the finetuning performance on the held-out test set. We discuss our findings in the sub-sections below.

Table 3: Weighted F1 scores of each target language's evaluation set averaged over 5 runs. We see that in most cases, XLS-R performs better than Wav2Vec2-Large. XLS-R-Mix outperforms all other models in all languages.

Method	ibo	yor	run	kua	sna	gax
Wav2Vec2.0-Large	0.64 ±0.29	0.13 ±0.12	0.09 ±0.08	0.40 ±0.47	0.03 ±0.06	0.37 ±0.07
XLS-R	0.85 ±0.03	0.16 ±0.05	0.18 ±0.07	0.98 ±0.00	0.01 ±0.03	0.56 ±0.04
XLS-R-Mix	**0.86** ±0.02	**0.27** ±0.07	**0.55** ±0.10	**0.98** ±0.00	**0.65** ±0.08	**0.57** ±0.01

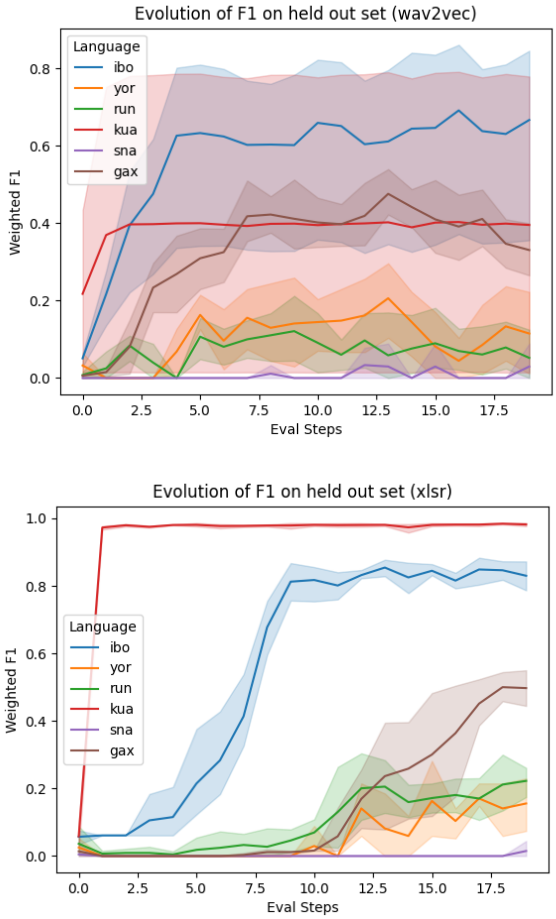

Figure 4: ↑ F1 scores for each evaluation epoch during finetuning on held-out evaluation set for each of our focus African languages. Top is for Wav2Vec2.0-Large and Bottom is for XLS-R

Bridging the gap for African Speech Datasets We observe, first of all, that despite being large pretrained models and finetuned for 100 epochs, the performance on some languages like yor, run, and sna is very low. This supports the claim by many research (Nekoto et al., 2020; Team et al., 2022; Fan et al., 2020; Kreutzer et al., 2021; Babirye et al., 2022; Oyewusi et al., 2022; Nweya et al., 2022b;a) that there is need to build more African datasets to improve the generalization of large pretrained models to low-resource African languages, and therefore the relevance of AfroDigits.

Effect of having African speech data in the model pretraining: We observe from Table 3 that the XLS-R model, which was pretrained on a larger set of African languages than Wav2Vec2-Large, performed better across all languages (except sna) than Wav2Vec2-Large which is Anglo-centric.

Furthermore, Figure 4 shows the evolution of each of the model's performance (F1 metric) while it was being finetuned on each language. Each evaluation point is actually an average of the 5 rounds, with the confidence interval. Using kua as an example, we clearly see that the XLS-R model was able to quickly attain a high performance very early on in the finetuning, unlike Wav2Vec2.0-Large.

We also see that both models had difficulty with languages like sna, yor, and run: for XLS-R, we see a slight improvement for these languages only after the 50th epoch of finetuning for XLS-R, while for Wav2Vec2.0-Large, their performance oscillates between a rather low F1 score of 0.0 and 0.2. Both models perform very poorly on sna.

Effect of mixing audio samples during finetuning: XLS-R-Mix, which is XLS-R finetuned on a mix of training audio samples from the six focus languages, outperforms all the other models as shown in Table 3. More interestingly, even in sna, run, and yor, where the previous models perform very poorly, we see a significant boost in the performance of XLS-R-Mix. While the effect of a multilingual speech corpora has been shown in pretraining models Conneau et al. (2020); Chan et al. (2021); Radford et al. (2022), we present a useful insight on the effect of the mixing (especially for low-resource African languages) while finetuning on spoken digit classification.

6 Conclusion

In this work, we present AfroDigits: a minimalist, community crowd-sourced dataset of recorded digits in African languages, which can scale to any African language through community effort. AfroDigits, the first African digits dataset of its kind, was created with the aim of filling the void in African speech corpora and is released as a freely accessible public dataset. We further present the current contents and statistics of AfroDigits and show spoken digits classification experiments on six African languages using the speech corpus.

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A Appendix

Analysis of gender and digits distribution in the recorded audio samples: In the figures below, we plot their distribution, for both gender and the digits, across the Igbo, Oshiwambo and Rundi languages.

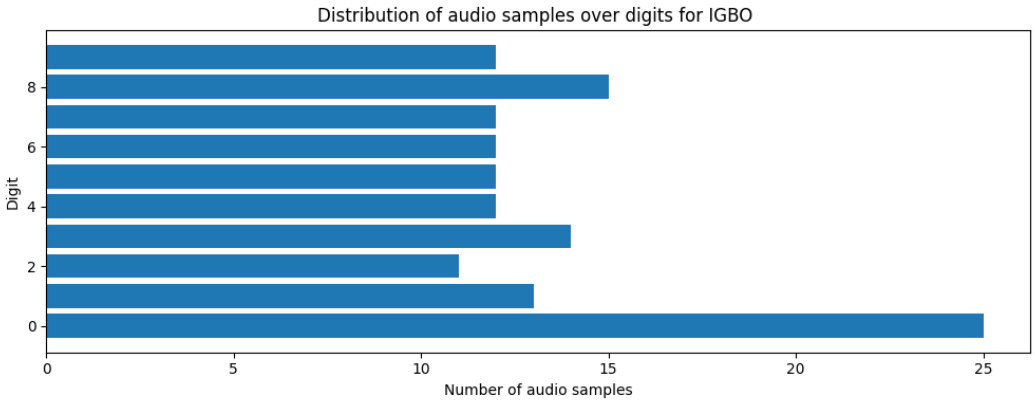

Figure 5: Distribution of recorded audio samples across the digits (ibo)

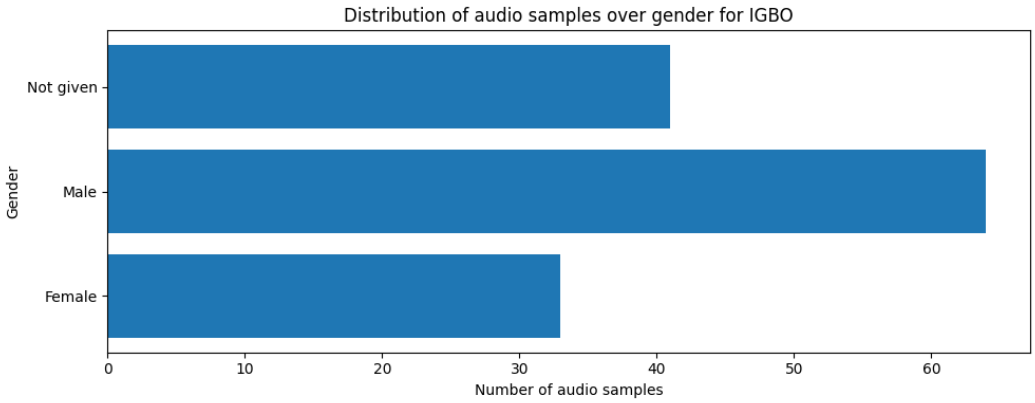

Figure 6: Distribution of recorded audio samples across the gender (ibo)

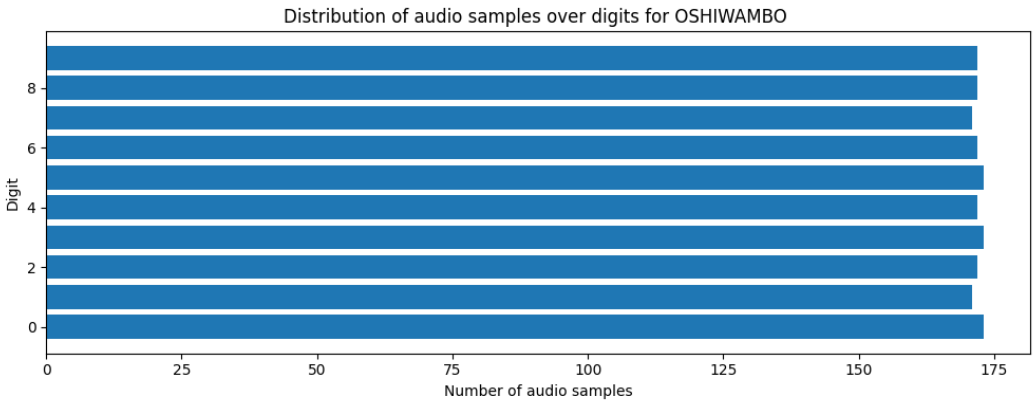

Figure 7: Distribution of recorded audio samples across the digits (kua)

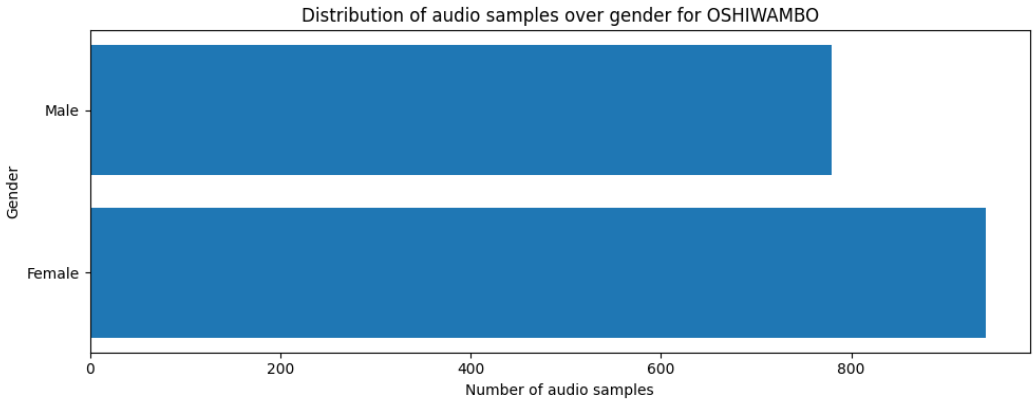

Figure 8: Distribution of recorded audio samples across the gender (kua)

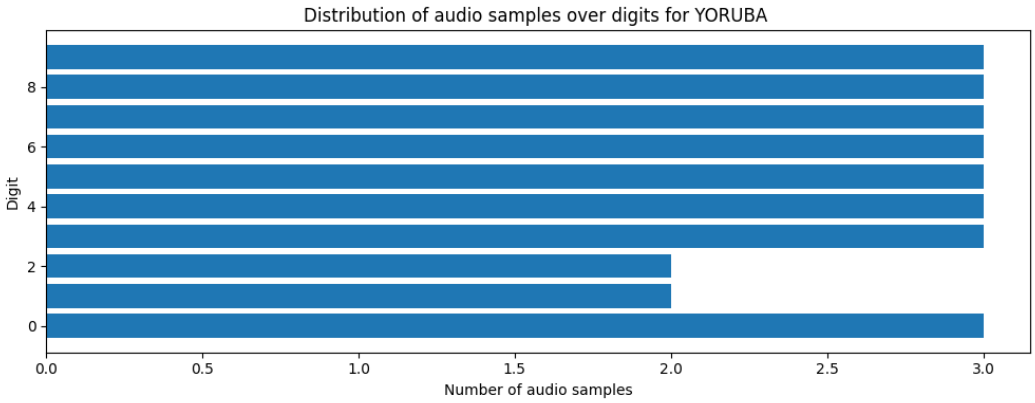

Figure 9: Distribution of recorded audio samples across the digits (yor)

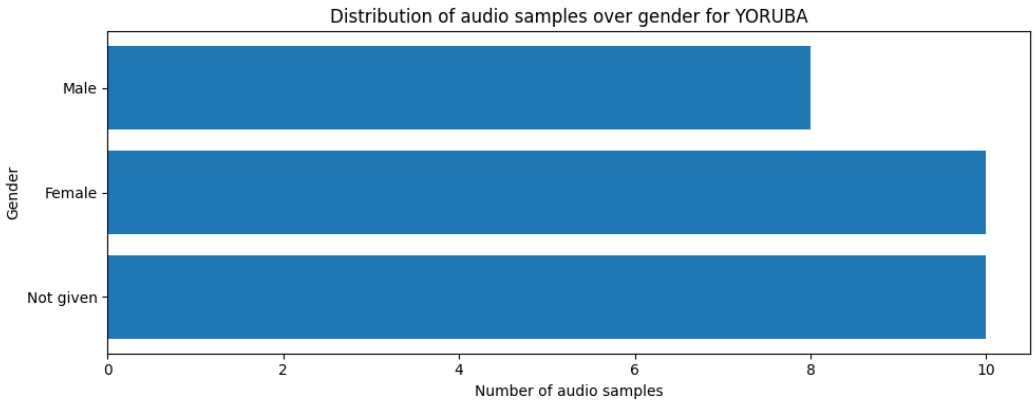

Figure 10: Distribution of recorded audio samples across the gender (yor)

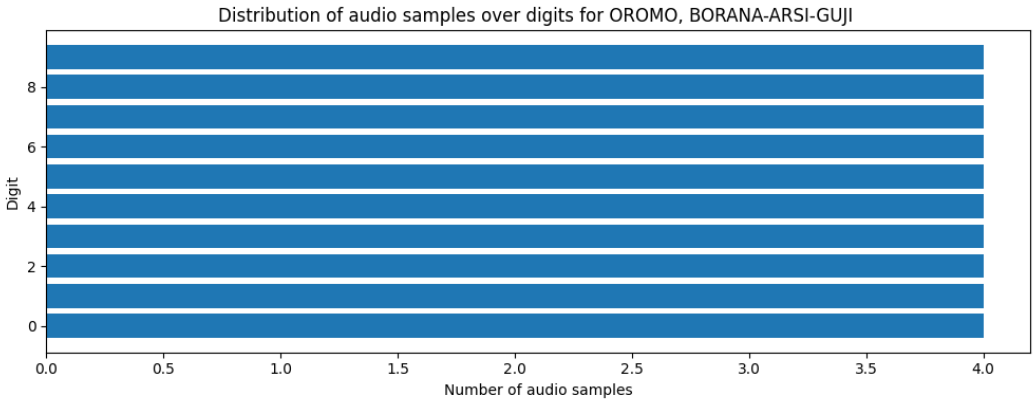

Figure 11: Distribution of recorded audio samples across the digits (gax)

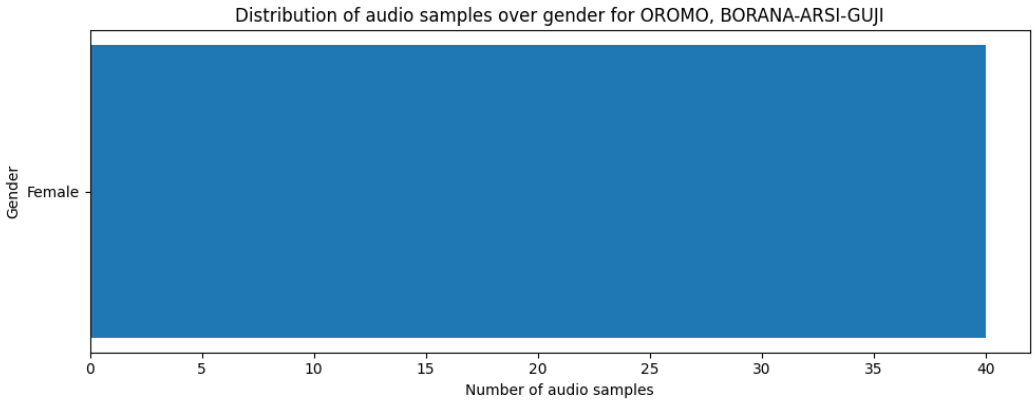

Figure 12: Distribution of recorded audio samples across the gender (gax)

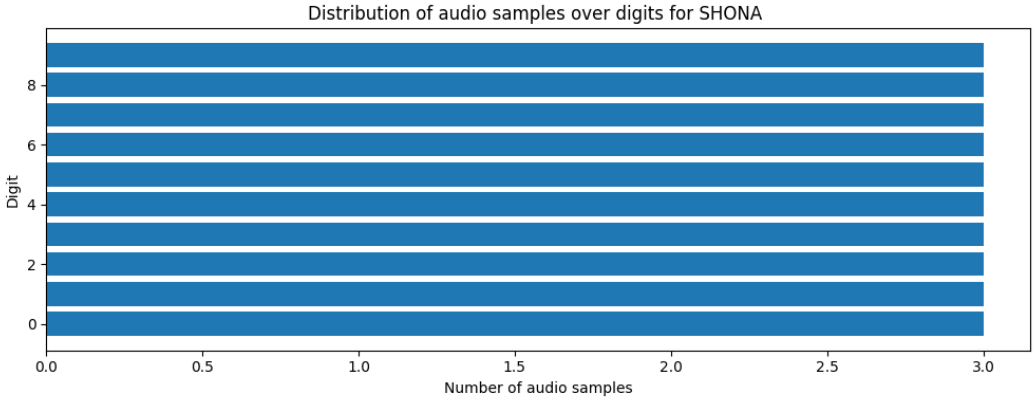

Figure 13: Distribution of recorded audio samples across the digits (sna)

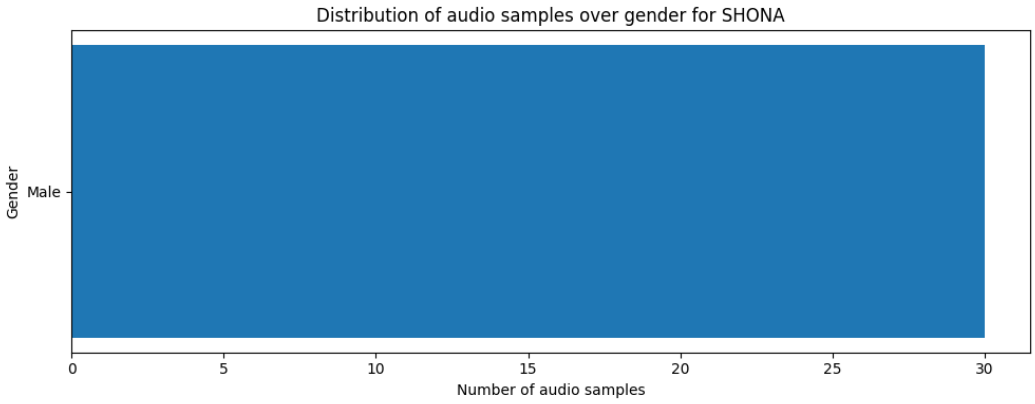

Figure 14: Distribution of recorded audio samples across the gender (sna)

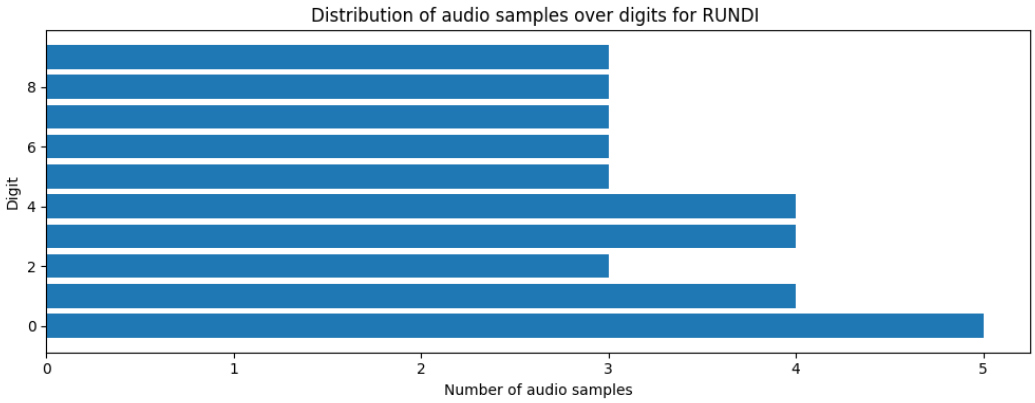

Figure 15: Distribution of recorded audio samples across the digits (run)

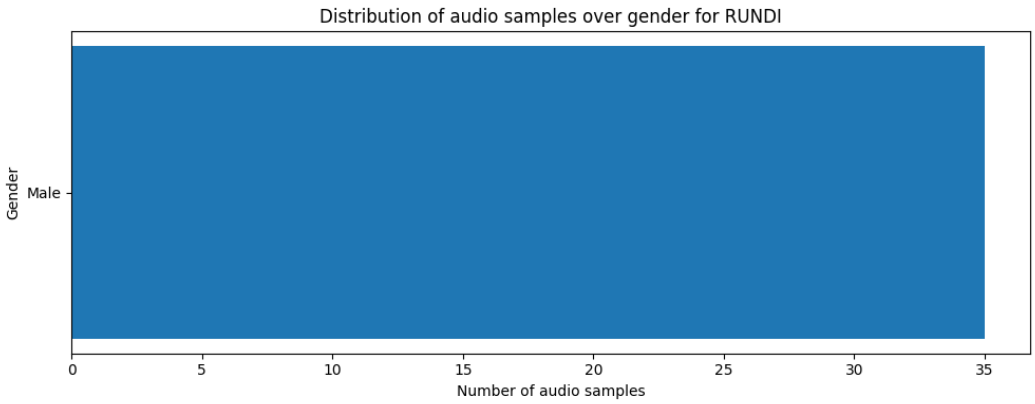

Figure 16: Distribution of recorded audio samples across the gender (run)