SpokeN-100

A Cross-Lingual Benchmarking Dataset for The Classification of Spoken Numbers in Different Languages

SpokeN

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Problem

Speech to numerical input


Automatic recognition of a pronounced phone number

What syste capable of:

→ + 4 9 7 2 1 3 3 2 4 4 1

Reality:

→ + 49 72 11 78 33 24 41

We want a local system that is able to perform this task – is there a dataset for this?

- **Speech Commands/AudioMNIST: numbers 0 to 9**
- **Most datasets are monolingual**
- **Combining different data sets leads to inconsistent data quality**

SpokeN-100

Classification of spoken numbers

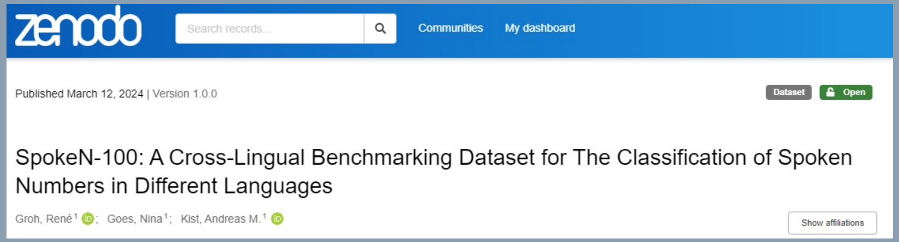
Spoken numbers from 0 to 99

32 different speaker

Four different languages: English, Mandarin, German and French

In total: 12,800 audio samples

Transparent, open-source, reproducible



→ **All data is artificially generated**

SpokeN-100 Dataset

Completely artificially generated data

LLM

	English	German	French	Mandarin
0	"Zero"	"Null"	"Zéro"	"零"
1	"One"	"Eins"	"Un"	"一"
2	"Two"	"Zwei"	"Deux"	"二"
…	…	…	…	…
N=99				

→ ChatGPT 3.5

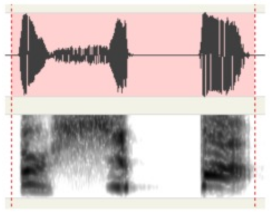
Generative Audio AI

IIElevenLabs

32 speaker

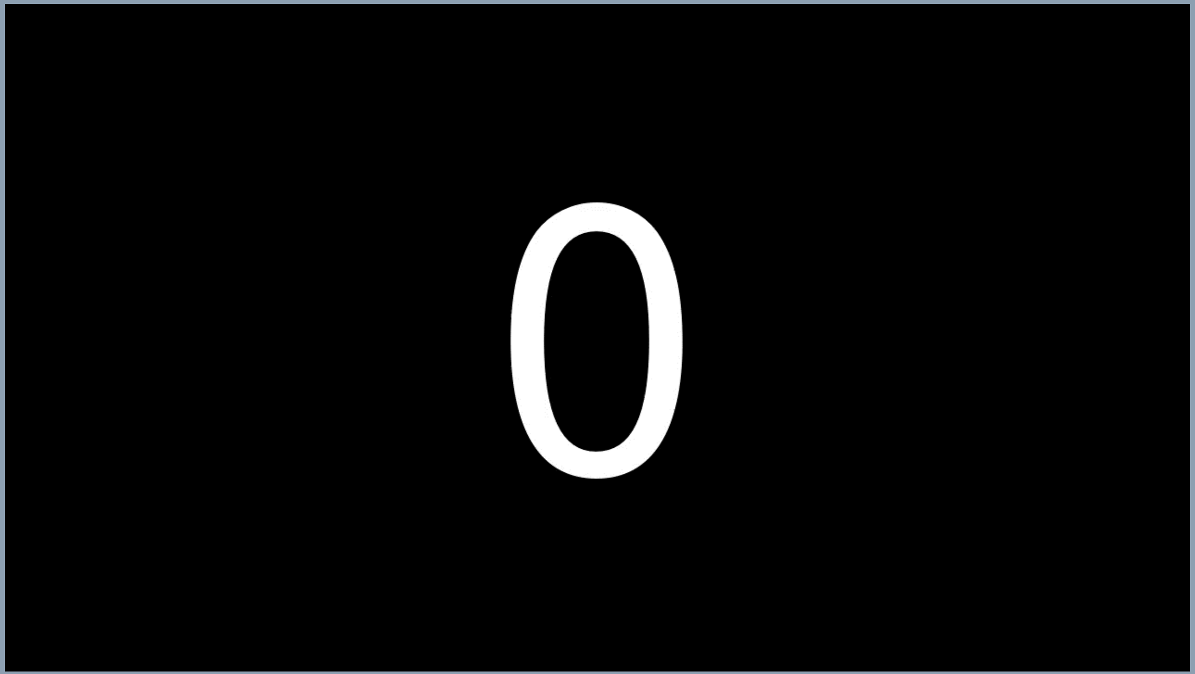
Audio Segmentation

WebMAUS



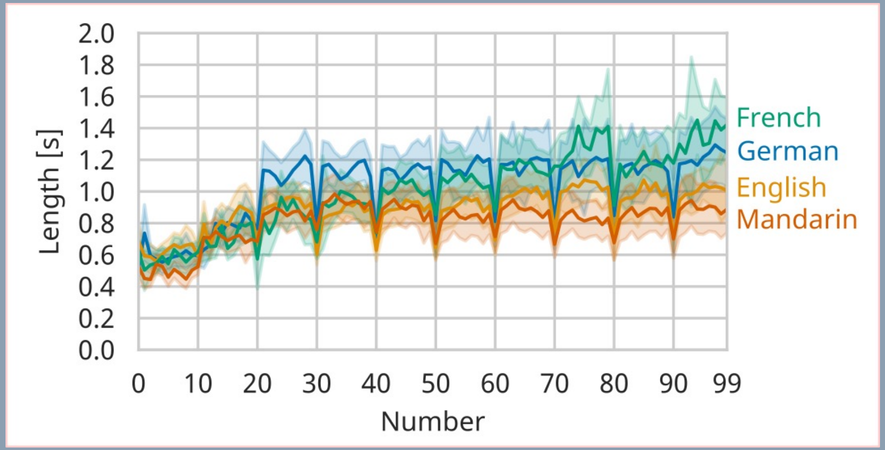
SpokeN-100 Dataset

Completely artificially generated data

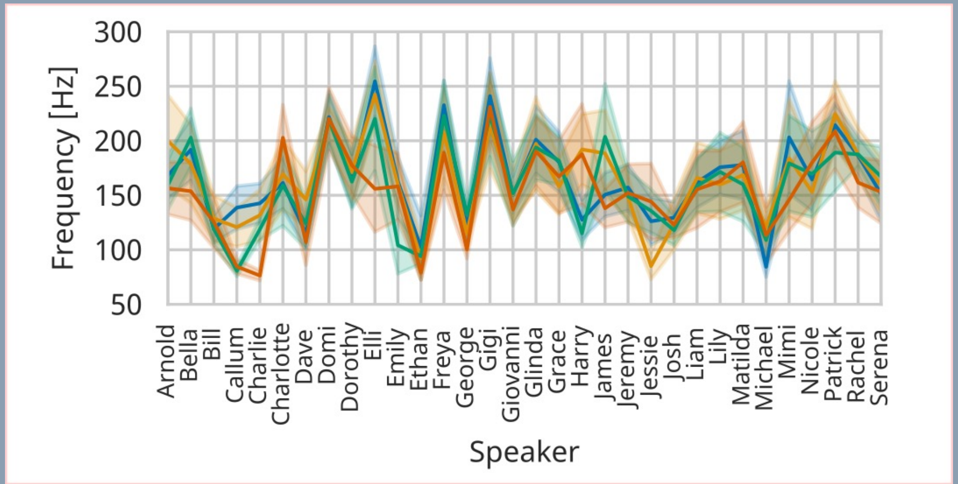


SpokeN-100 Dataset

Descriptive statistics of the generated data



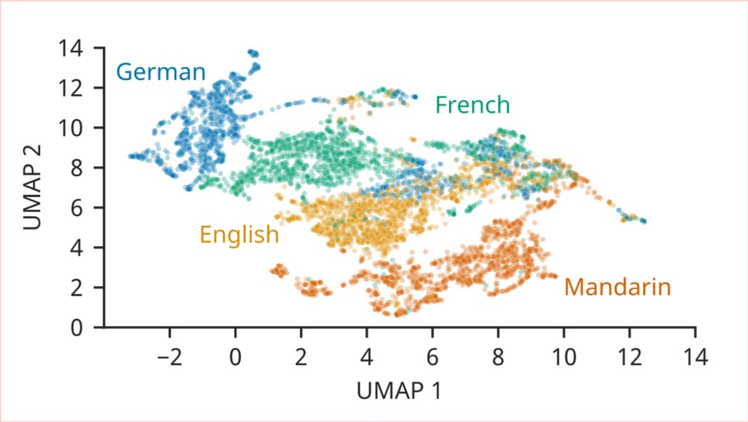
- Audio length increases as the numerical value increases
- Mandarin most efficient
- German numbers are the longest, except for higher numbers where French takes over

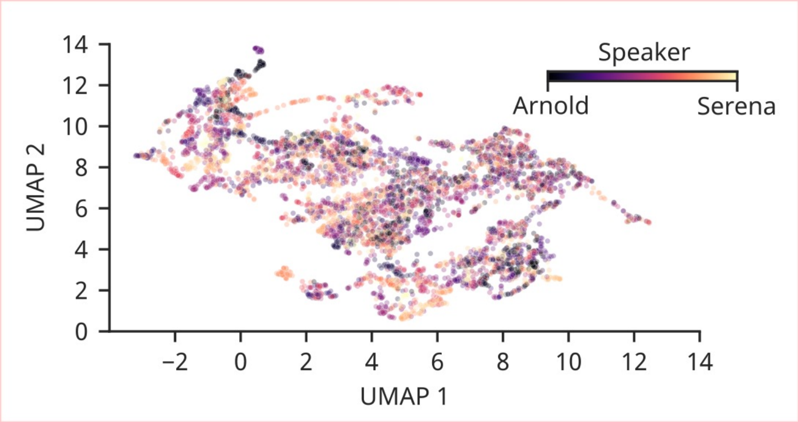


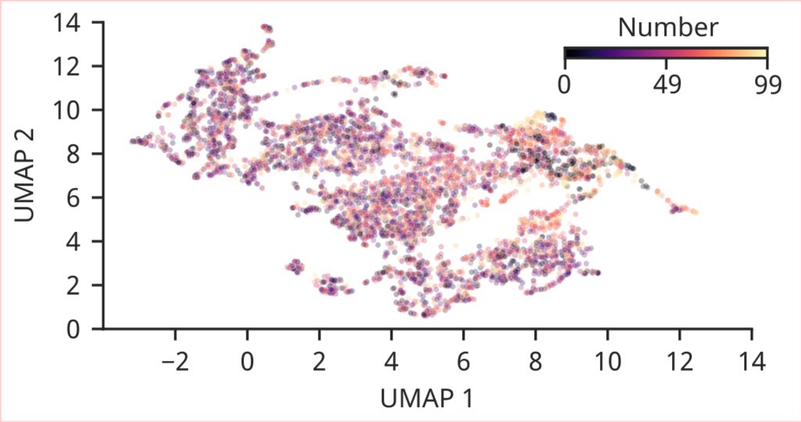
- Fundamental frequency similar for every speaker and every language
- Wide variety of fundamental frequencies

SpokeN-100

Dimensionality reduction of Mel-Spectrograms using UMAP







- Languages cluster together in the 2D visualization
- No clear clusters emerge when color-coded based on <u>speakers</u>
- No clear clusters emerge when color-coded based on <u>spoken number</u>

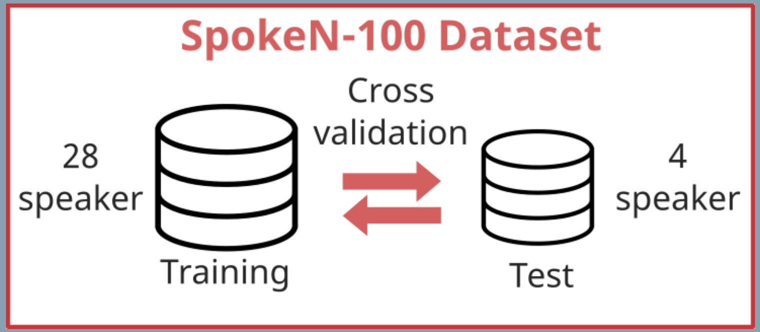
Benchmark task design

We introduce two classification tasks

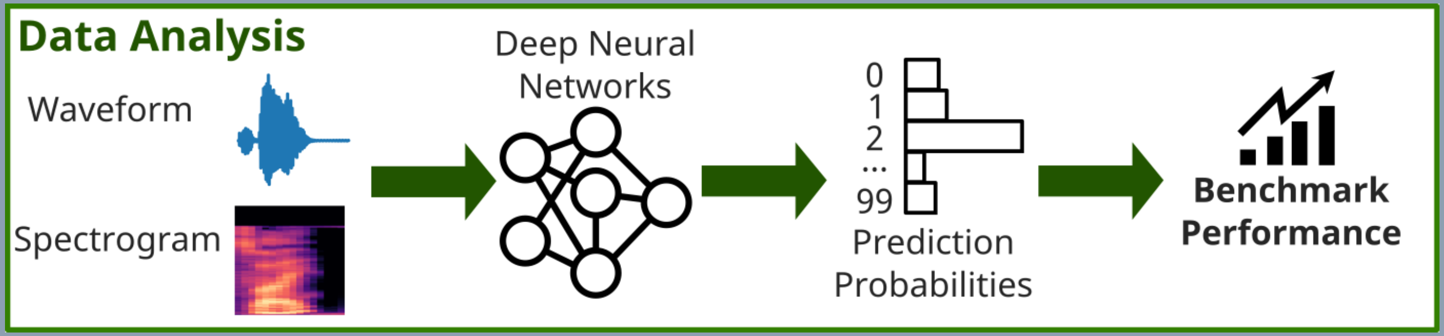
Classification of

a) **Languages** (Four classes)

b) **Spoken numbers** for <u>any language</u> (100 classes)

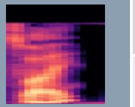


8-fold cross-validation



Results

Baseline performance



Architecture
1D CNN
2D CNN
RNN
EfficientNet-B0 CNN
Transformer

→ **Not deployable to a microcontroller**

Results

EvoNAS: Optimizing an architecture for MCU

Groh and Kist – „End-to-end evolutionary neural architecture search for microcontroller units“, 2023

nRF52840

- 64 MHz Cortex-M4
- 1 MB Flash
- 256 KB SRAM

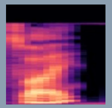
Source: https://www.nordicsemi.com/

Zephyr™ · TensorFlow

→ **Goal**: Maximize fitness which is a metric that combines multiple objectives (accuracy, inference time, energy consumption)

Results

Benchmark results for MCU-optimized architectures

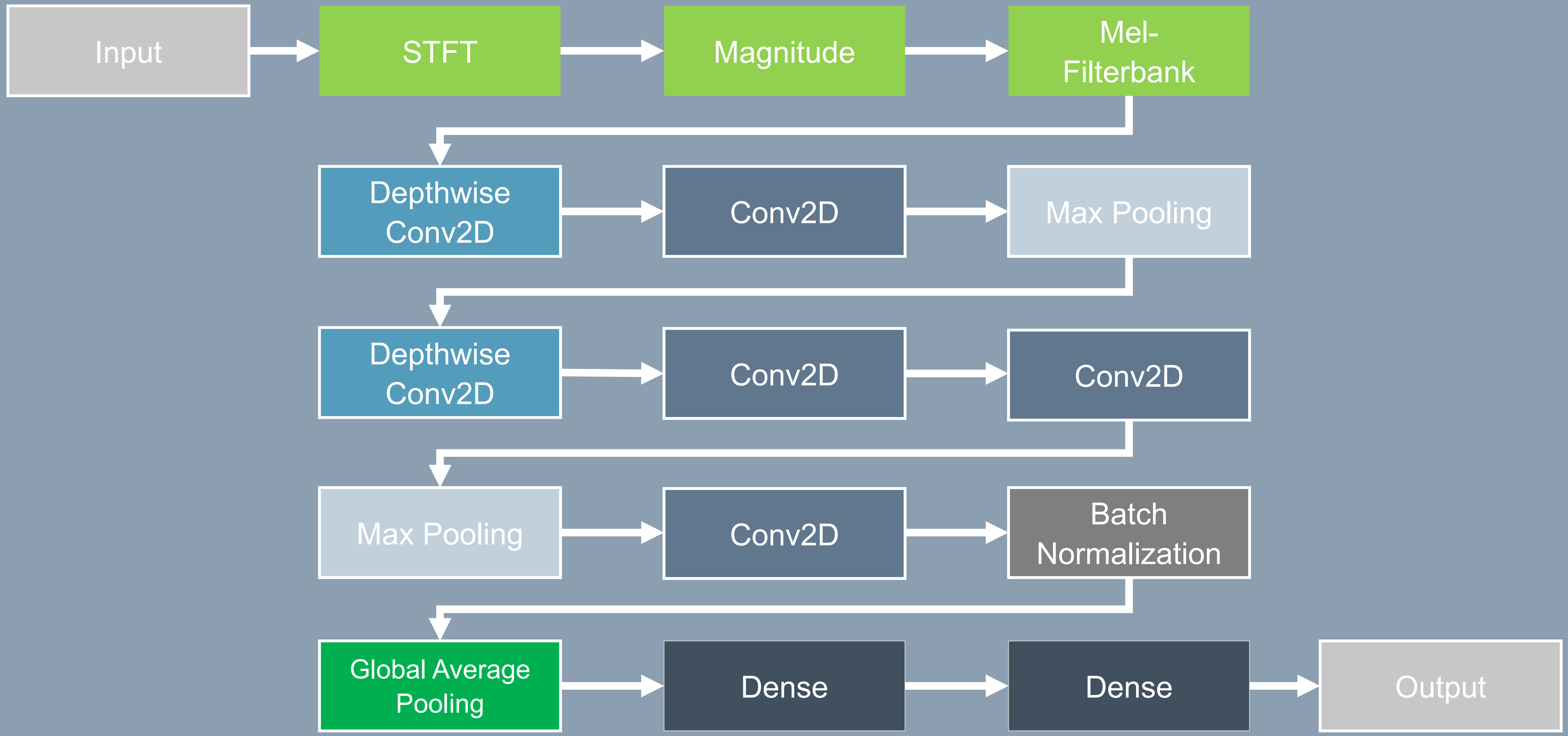


Architecture
EfficientNet-B0 CNN
Most accurate
Fastest
Fittest

→ **Proof-of-concept: huge optimization potential**

Results

Fittest model architecture



Conclusion

- SpokeN-100: Artificially generated speech recognition dataset with spoken numbers from 0 to 99 in four different languages
- It can serve as a benchmark for tinyDL datasets
- Data is not noisy, as with most other data sets → perfect for deep learning training, as you can control the amount of noise yourself
- High practical relevance for tinyDL applications: robot navigation, interaction with wearable devices, …
- Possibility to expand the database as required (voice cloning)

SpokeN

https://zenodo.org/records/10810044

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