Ballroom Dance Recognition from Audio Recordings

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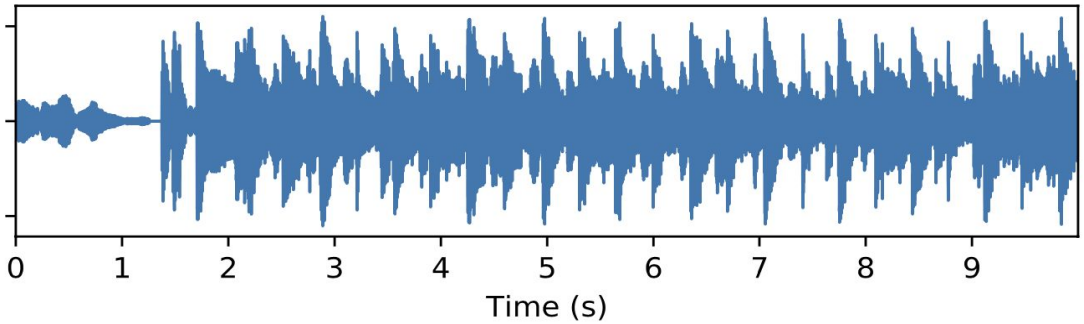
Objective of the Study

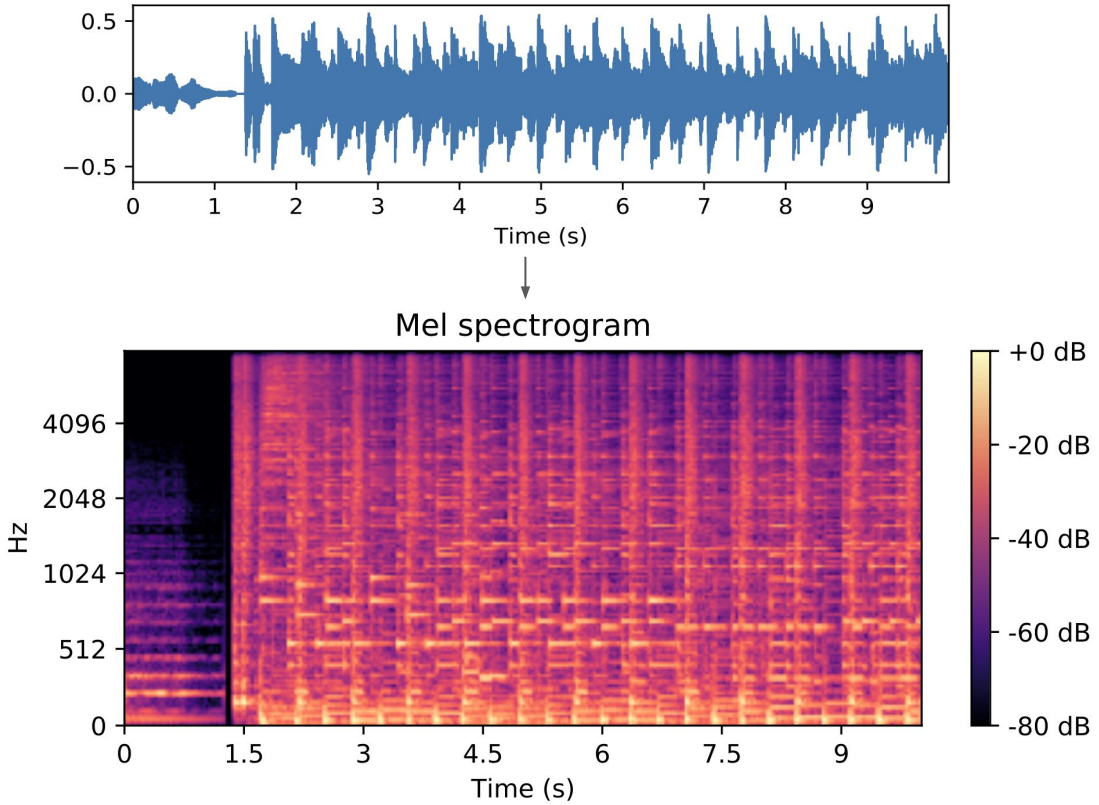
- *Input*: audio recording of dance music
- *Output*: classification into one of the 10 genres of ballroom dances, 5 standard and 5 latin



- **Cha Cha**
- **Jive**
- **Paso Doble**
- **Quickstep**
- **Rumba**
- **Samba**
- **Slow Foxtrot**
- **Slow Waltz**
- **Tango**
- **Viennese Waltz**

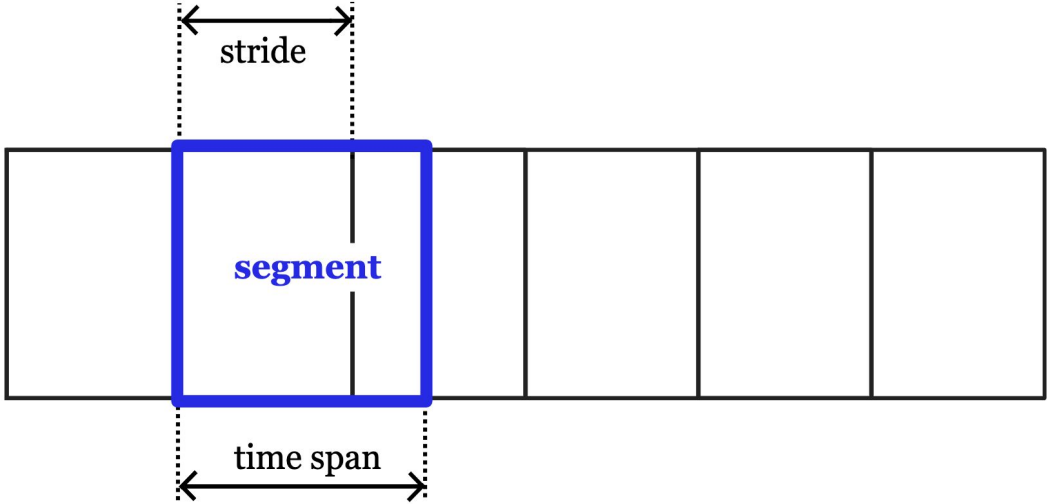
Step 1 - convert the audio recording to spectrogram

- Spectrogram is frequency-temporal 2D representation of the audio
- Standard representation in speech processing
- The 2D (image) representation allows us to use advanced CNN architectures that have been used for image categorization



Step 2 - cut the spectrogram to segments

- Cut the spectrogram to overlapping segments in sliding window fashion
- The segments are classified independently
- Each segment size is 224 × 224 which corresponds to **~5 seconds** (time span)
- Experiments show that ~5 seconds is long enough to predict correct dance style accurately, a dance music is “stationary”

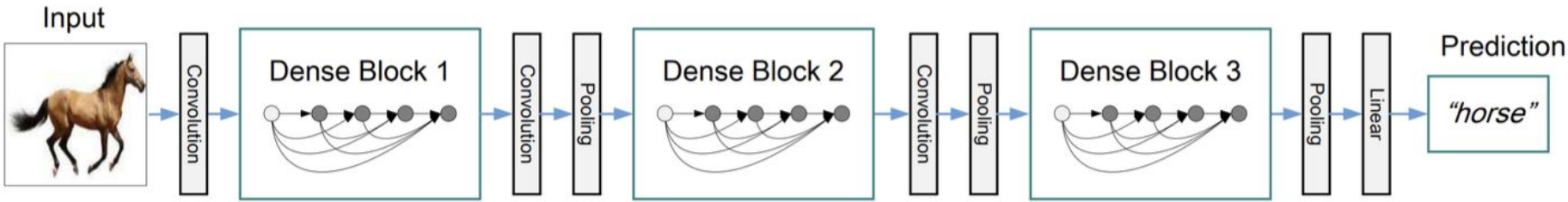


Step 3 - convolutional neural network

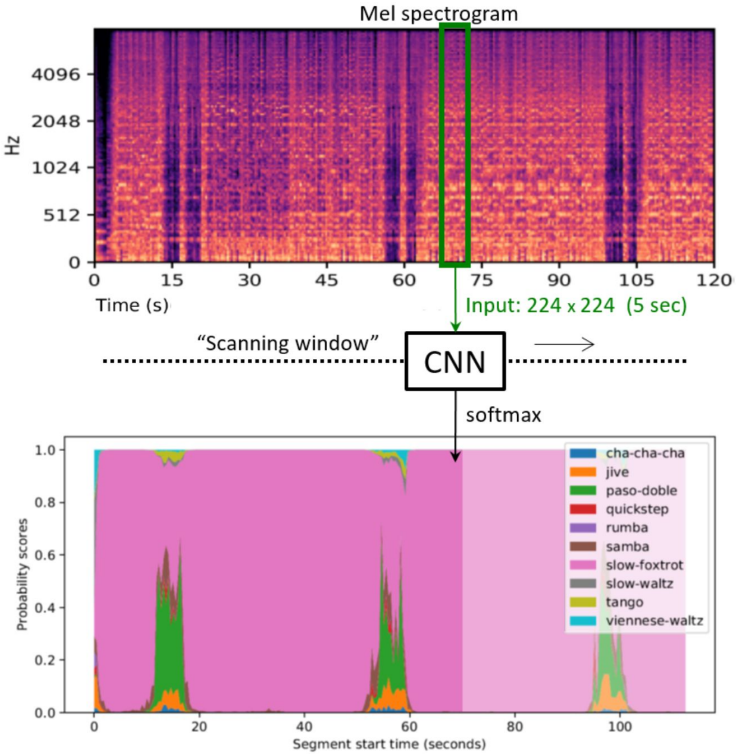
- **Dense Convolutional Network (DenseNet)** [*Huang, Liu, Van Der Maaten, and Weinberger, 2017*]

Input: spectrogram segment

Output: probability score, vector of size 10 (number of dance classes), softmax



Step 4 - aggregation of segment results



Classified Segments

- To predict samples that are longer than the segment duration of ~5 seconds
- The softmax outputs are averaged by arithmetic mean

Aggregation →

SLOW FOXTROT (95%)

Classified Recording

Training set

- private collection of ballroom dance music
- ~**4700** audio recordings
- **10** dance classes
- the recordings are ~**4 minutes** long
- studio quality

Dance Genre	**Count**
Cha Cha Cha	711
Jive	490
Paso Doble	112
Quickstep	458
Rumba	658
Samba	721
Slow Foxtrot	421
Slow Waltz	411
Tango	395
Viennese Waltz	281
Total	**4655**

Test and validation set

- Audio extracted from public YouTube videos
  - We make the dataset publicly available at http://dance.ironbrain.net/testset.zip
- Both datasets are **uniform** and consist of **10** classes of **6** recordings each (provides **60 recordings** each)
- The recordings are ~**3 minutes** long and are in studio quality
- The datasets do not overlap with each other and with training set

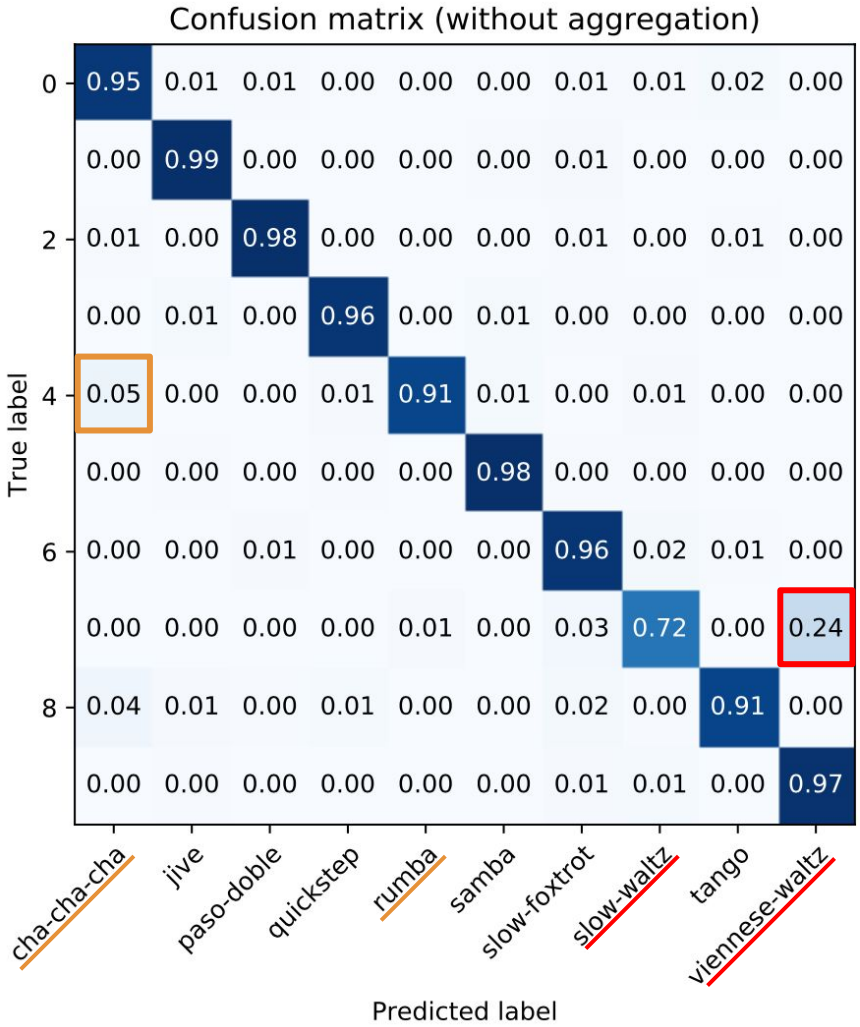
- Validation set is utilized for selecting epoch with highest accuracy
- Test set is used for testing resulting model only

Results

Results on Youtube test set

Method	Top-1 accuracy	Top-2 accuracy
Our method with aggregation	96.7%	100.0%
Our method without aggregation	92.2%	-

- Confusion of similar dances:
  - **Waltz x Viennese Waltz**
  - **Rumba x Cha-cha-cha**



Experiments

Architecture	Top-1 accuracy	Top-2 accuracy	Top-1 without aggregation
VGG 16	25.0%	41.7%	24.8%
ResNet-18	**96.7%**	**100.0%**	89.9%
ResNeXt-50 32x4d	95.0%	**100.0%**	89.6%
DenseNet 161	**96.7%**	**100.0%**	**92.8%**

Baseline: hand-crafted features classifier

- relies on hand-crafted audio features instead of a spectrogram
- classification using simple *SVM*
- accuracy **40%**

Configuration	Top-1 accuracy	Top-2 accuracy	Top-1 without aggregation
DenseNet-TL-C	63.3%	76.7%	42.9%
DenseNet-TL-DB4 (half)	80.0%	85.0%	62.7%
DenseNet-TL-DB4 (full)	83.3%	91.7%	64.5%
DenseNet-TL-DB4-N (n=24)	70.0%	85.0%	62.0%
DenseNet-TL-DB4-N (n=48)	76.7%	80.0%	63.3%
DenseNet-TL-DB4-N (n=72)	75.0%	86.7%	64.5%
DenseNet-FT	**96.7%**	**100.0%**	**92.8%**
DenseNet-RW	95.0%	**100.0%**	91.3%
DenseNet-RW-1C7x7	93.3%	**100.0%**	89.2%
DenseNet-RW-1C16x3	93.3%	**100.0%**	88.2%
DenseNet-RW-1C40x3	91.7%	98.3%	88.2%

Other cross-dataset tests

Dataset	Top-1 accuracy	Top-2 accuracy	Top-1 without aggregation
Extended ballroom	93.9%	97.5%	86.6%
YouTube test set	96.7%	100.0%	92.2%
Dance competitions	87.9%	98.6%	70.6%
StarDance	68.0%	78.0%	45.2%
Low Quality Recordings	72.7%	86.7%	58.0%

Extended ballroom

- publicly available dataset
- 4180 recordings
- each recording is 30 seconds long

YouTube test dataset

- 6 x 10 = 60 recordings

Dance competitions

- 360 recordings
- extracted from YouTube videos of dance competitions of *World DanceSport Federation (WDSF)*

StarDance

- extracted from 10th season of Czech TV show similar to Dancing with the Stars
- popular music
- 50 recordings

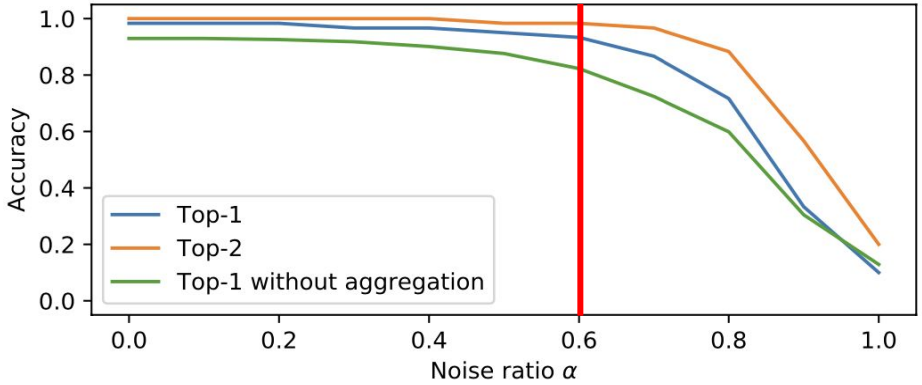
Low Quality Recordings

- recorded using mobile phone camera in dance competitions
- low audio quality (echo, people applauding, dancers steps)
- 128 recordings

Improving classification on low quality data

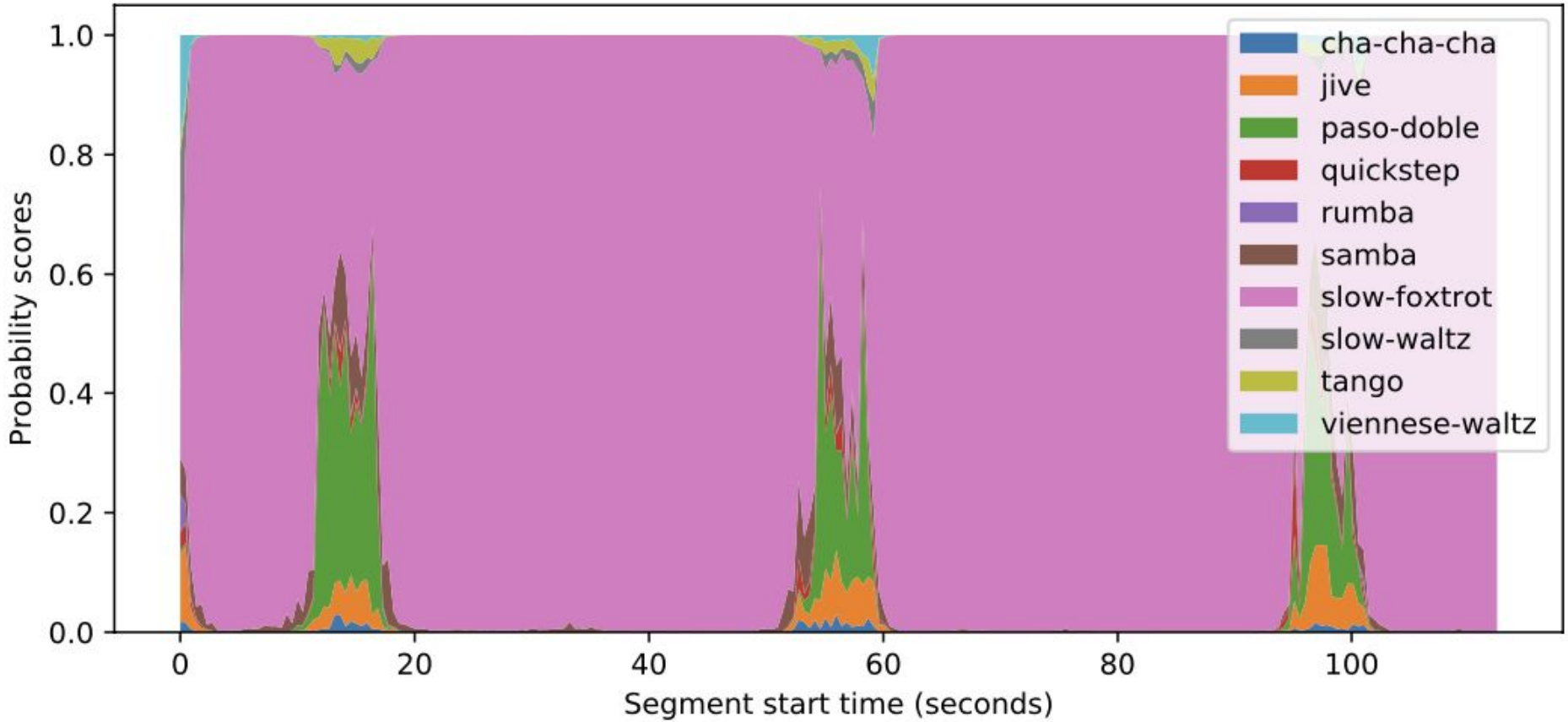
We added ~240 low quality recordings (4.9%) into the training set.

Dataset	Top-1 accuracy	Top-2 accuracy	Top-1 without aggregation
Extended ballroom	92.4%	96.9%	84.7%
YouTube test dataset	**98.3%**	100.0%	**92.7%**
Dance competitions	**93.7%**	**98.9%**	**75.7%**
StarDance	46.0%	74.0%	38.6%
Low Quality Recordings	**89.8%**	**95.3%**	**71.7%**

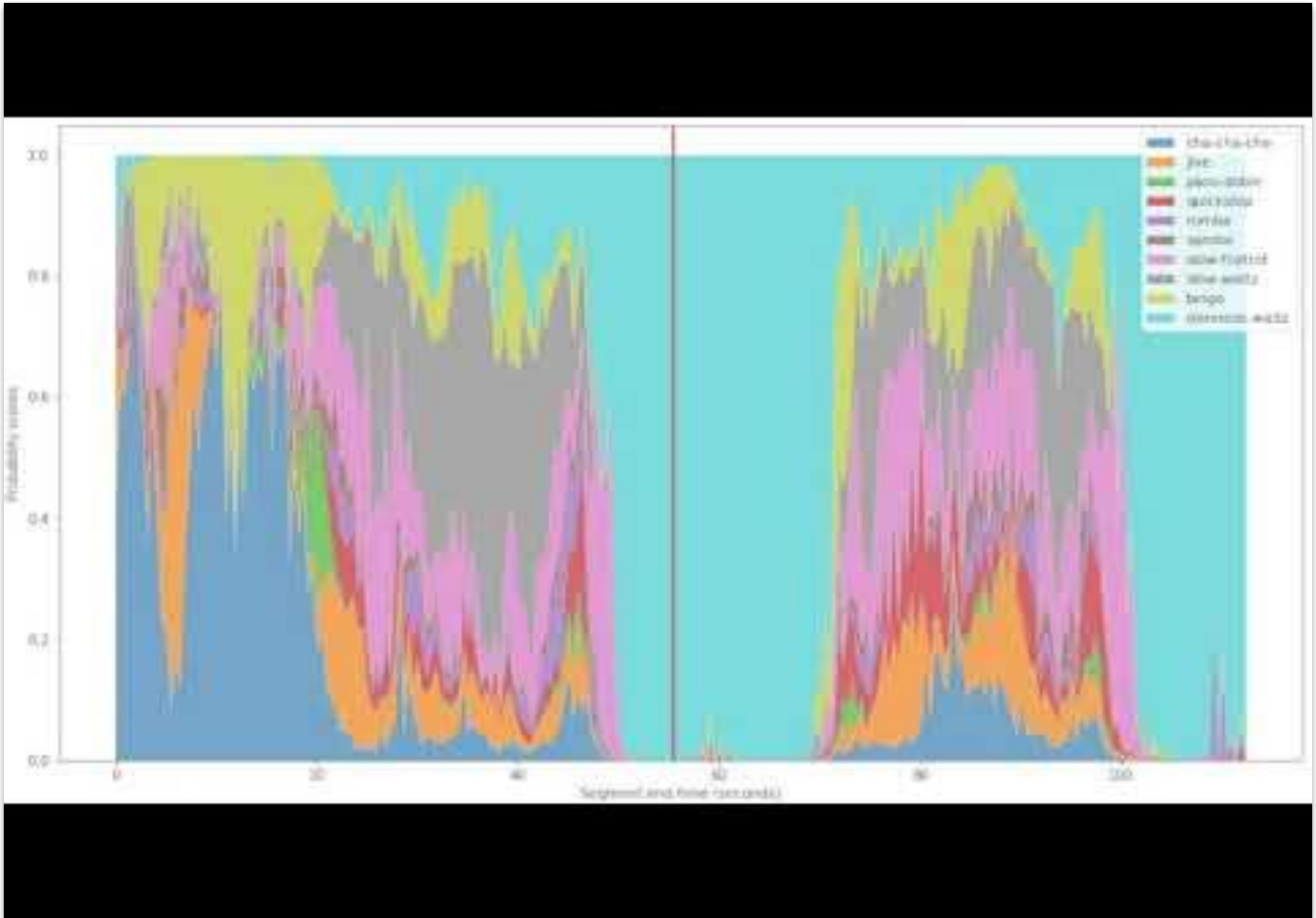


Perturbation experiment. A recording of crowd noise was mixed to the original test set recordings as a convex combination in the temporal domain.

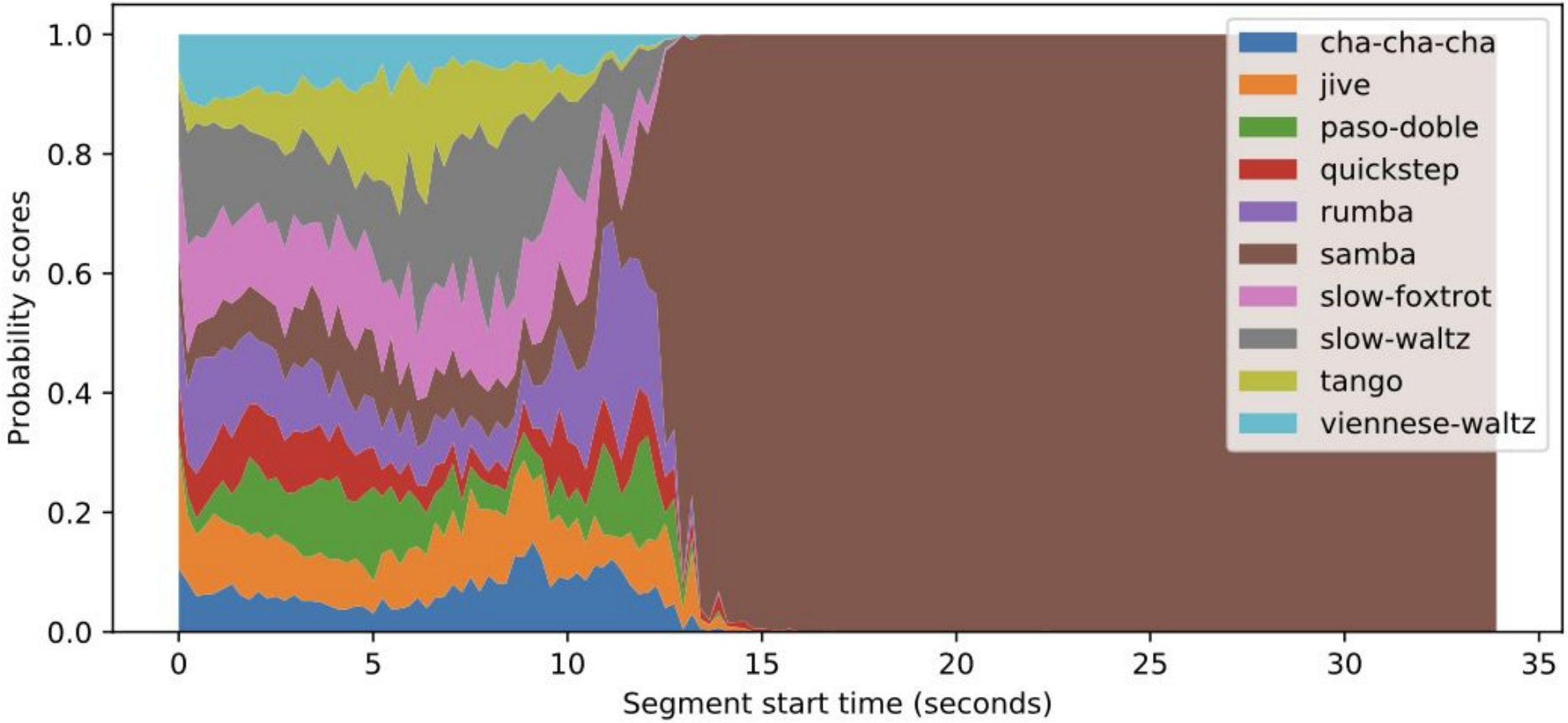
Qualitative Results - Slow Foxtrot



Qualitative Results - Slow Foxtrot

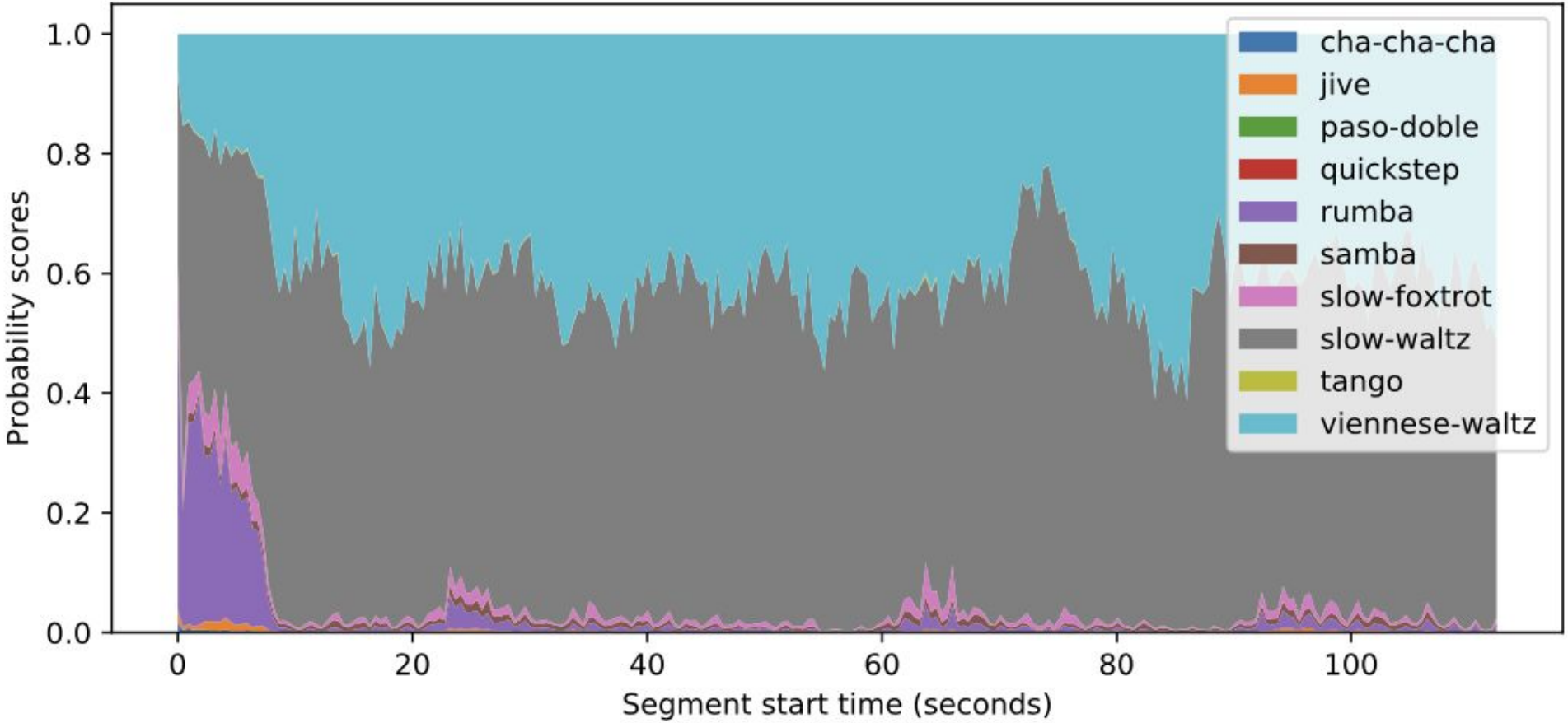


Qualitative Results - Samba



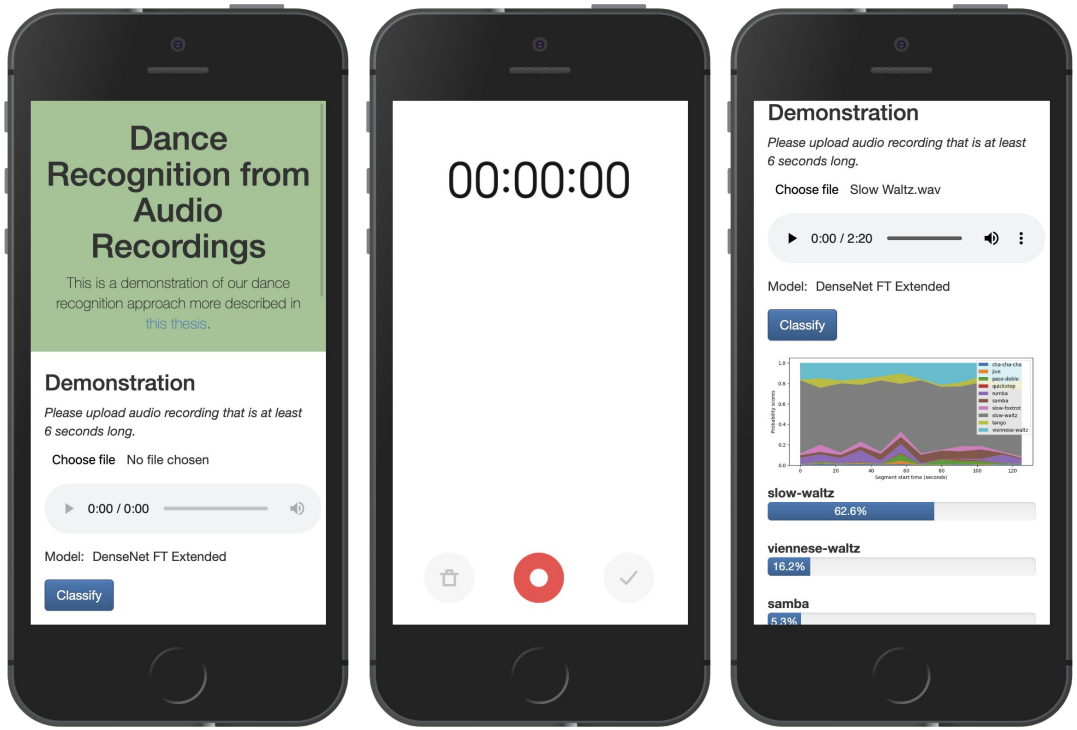
Qualitative Results - Samba

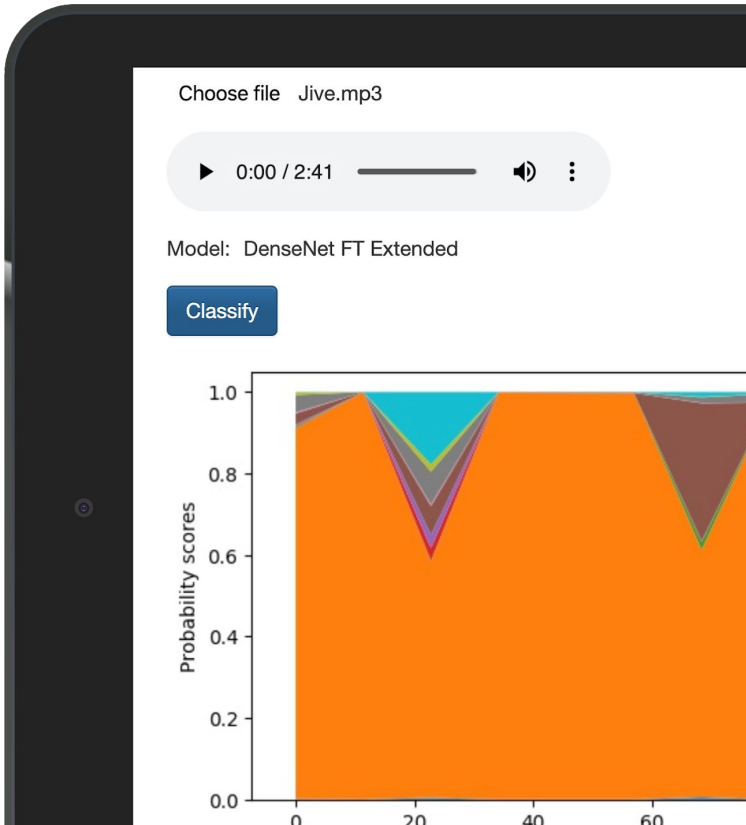
Qualitative Results - Waltz



Qualitative Results - Waltz

Web application as a demonstration





http://dance.ironbrain.net

Thank you