Practical classification method for birdsong with variable note sequences and its application to the whole day recordings

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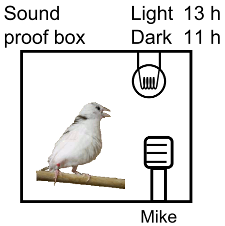
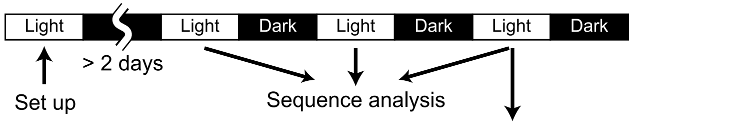
Goals

Classifying notes in the songs with as little human effort as possible.
Characterizing hour-scale modulation in the note sequence pattern.

Song Recording





3 birds

20523±5992 notes, 44.6±6.9 minutes in a day

Recognition

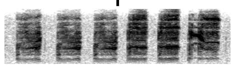
Output label sequence

A A A B B C

↑

Artificial neural network (ANN) + Graph transformer network

↑



Spectrogram

Training

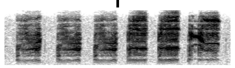
Correct label sequence

A A A B B C

↓ Error backpropagation

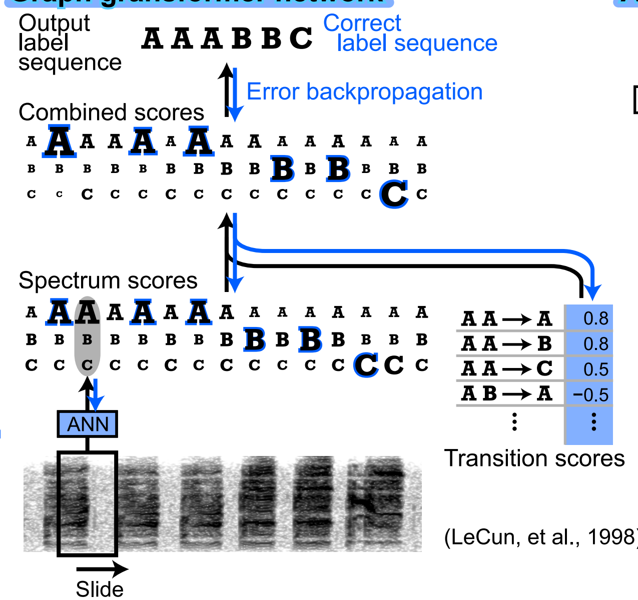
Artificial neural network (ANN) + Graph transformer network

↑

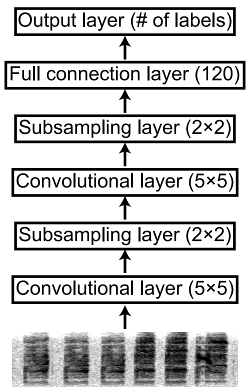


Spectrogram

Graph gransformer network



ANN



(LeCun, et al., 1998)

Tipical result

Detected note labels & intervals

Validation score

$$\text{Error ratio} = \frac{\text{Levenshtein distance between correct \& output sequences}}{\text{Length of correct sequence}}$$

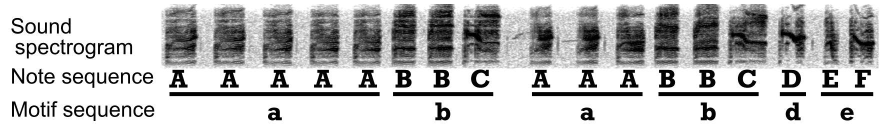
Note poisitions	Transition scores +	Transition scores −
+	**0.33±0.15%**	0.36±0.11%
−	0.21±0.14%	0.28±0.19%

(Ave.±sd over 3 birds)

Better with transition scores, note poisitions

Modeling of transition probabilities at branch points

Motif: frequently appearing sequence pattern



Branch points in motif sequences

$$\mathbf{b} \to \mathbf{a}: \quad P(x_t{=}\mathbf{a}|Data,\,w) = f_{\mathbf{b}\to\mathbf{a}}(t,\,Data,\,w)$$

$$\mathbf{b} \to \mathbf{d}: \quad P(x_t{=}\mathbf{d}|Data,\,w) = f_{\mathbf{b}\to\mathbf{d}}(t,\,Data,\,w)$$

Estimation of the transition probability

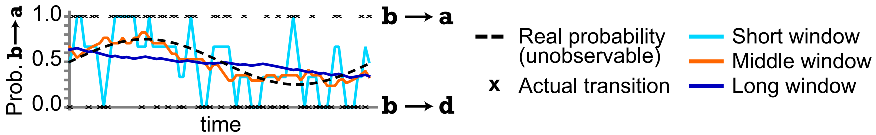
by the moving average of the motif frequencies

$$f_{\mathbf{y}\to\mathbf{x}}(t,\,Data,\,w) = \frac{n_{\mathbf{yx}}[t-\frac{w}{2},\,t+\frac{w}{2})}{n_{\mathbf{y}}[t-\frac{w}{2},\,t+\frac{w}{2})}$$

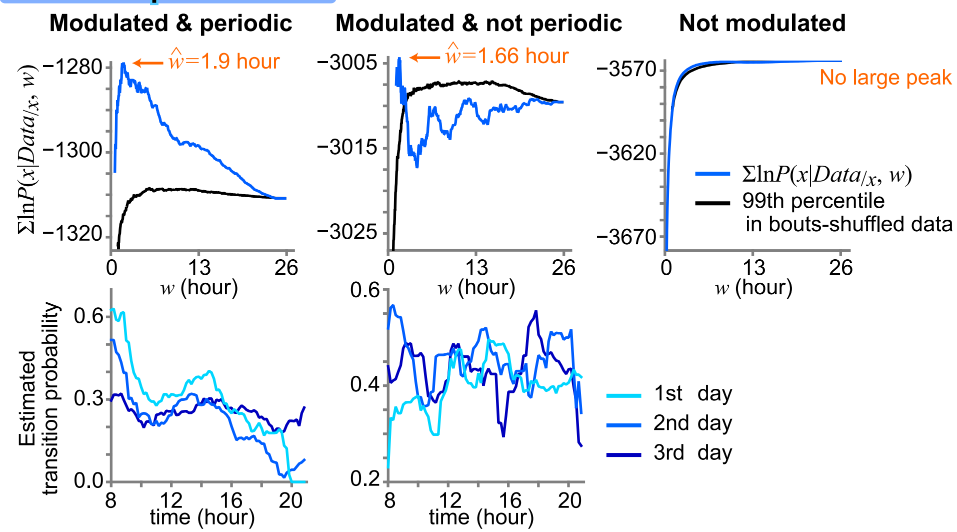
w: window width
n: # of occurrence of a motif

Determination of the most suitable window width

to best predict the observed data $\hat{w} = \underset{w}{\operatorname{argmax}}\left(\sum_{x\in Data} \ln P(x|Data_{/x},\,w)\right)$



Transition probabilities



Ave. correlation coefficients

0.77 (p=0.001) −0.0063 (p=0.49)

Result summary

	branches	modulated branches	transitions	periodic transitions
Bird A	5	5	12	5
Bird B	2	2	4	0
Bird C	2	1	4	0