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Problem Statement

The Zebra Finches are songbirds which learn the song of their tutor. They learn it from 20 days post hatch (DPH) to 80 DPH (Liu, Gardner, & Nottebohm, 2004). Their learning can be split in three phases: i) they have a babbling phase from 20 DPH to 40 DPH, then ii) a plastic song in which protosyllables from the tutor song are produced then iii) a crystallized song at 80 DPH with a fixed song which is a copy of the tutor's song.Zebra finches are commonly used as a model of speech acquisition.

check the days

Derégnaucourt, Mitra, Fehér, Pytte, and Tchernichovski (2005) showed that sleep plays an important role in the learning of tutor songs. Indeed, they showed that sleeping has a negative impact on song restitution by zebra finches in the short term but a positive impact on the long run. Indeed, song restitution is less complex and less similar to the tutor song from one morning to the previous day evening, but the greater this loss in performance was overall for one bird, the better this bird will reproduce the tutor song at the end of its learning. Dave (2000) has found replay sequences of neurones in the motor cortex which correspond to their activity pattern when the birds sing in adult zebra finches during their sleep. This shows that neurones that are highly correlated with bird's own song (BOS) are activated during the night.

Our hypothesis is that during its sleep, the zebra finch restructures the knowledge it has acquired so far. We hypothesize that this restructuring can account for the loss of performance in the short term and an improvement of performance in the long term.

The goal of this internship is to propose a model of the zebra finch song learning which can explain different behavioral data observed such as the correlation between the loss of performance every night and the overall performance at the end of learning, and the different phases of bird song learning (babbling, protosyllables, crystallized song).

Investigation/Research

We want to build a model which is the most plausible in a real world environment and which is biological plausible. To do so, we will use a bird song synthesizer made by Boari, Perl, Amador, Margoliash, and Mindlin (2015). This synthesizer is a biophysical model of zebra finch vocal apparatus. This synthesizer has the advantage that it be parametrized with relatively few parameters to produce realistic bird songs. As it models the zebra finch vocal apparatus, it is likely that the parameters we send to this synthesizer must be similar to the instruction sent by the zebra finch motor cortex to the vocal apparatus muscles. Indeed, the parameters for this synthesizer is the the labia tension $\alpha(t)$ and the air-sac pressure $\beta(t)$ in the apparatus.Amador, Perl, Mindlin, and Margoliash (2013), Boari, Perl, Amador, Margoliash, and Mindlin (2015) have managed to reproduce zebra finches song using this synthesizer. The synthetical songs they produced activated neurons in HVC which are highly selective to bird's own song (BOS). This shows that the synthesized songs are accurate reproduction of BOS.

check alpha and beta that I keep mixing up

Amador and Mindlin (2014), Boari, Perl, Amador, Margoliash, and Mindlin (2015) have already found interesting data by studying the parameters. Indeed, they have found that what can be seen as syllable in the sensory space can be seen as one or several gestures in the parameters space. Indeed, syllable are yield with continuous modification of the parameters. A new syllable will trigger a huge discontinuity in the parameter values.

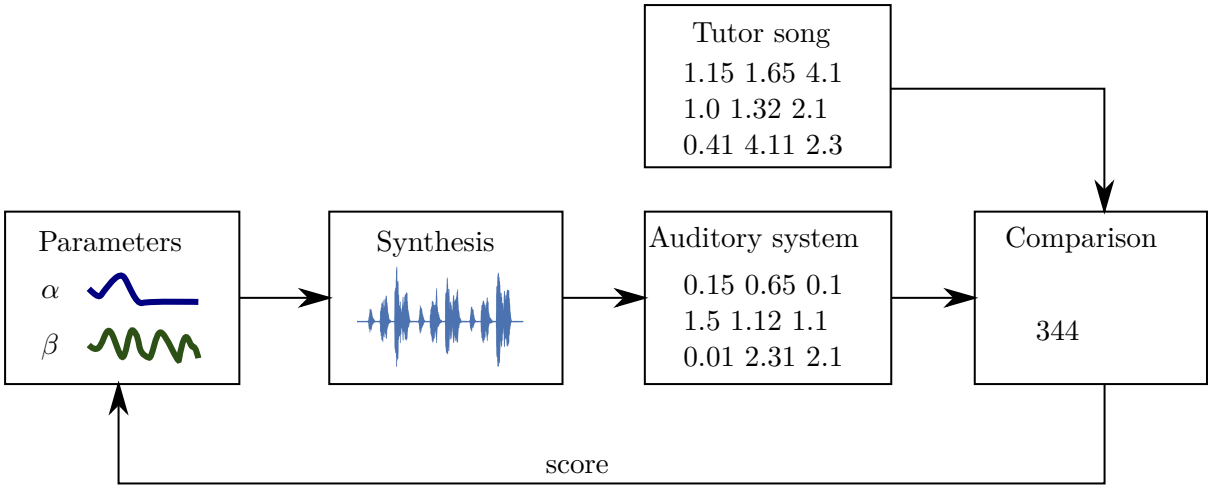

Figure 1: Simple hill climbing model

Amador, Perl, Mindlin, and Margoliash (2013) even claim to have found correlation with HVC neuron spikes in zebra finches and the gesture trajectory extrema (beginning, maximum, minimum and end) of these gestures. Though, very recent literature shows that these correlates might have been untrue (Lynch, Okubo, Hanuschkin, Hahnloser, & Fee, 2016; Picardo et al., 2016). Even though there is no neural correlate with gesture trajectory extrema (GTE), we hypothesize that GTE identification may play an important role in song learning, as they signal changes in the progression of the parameters through time.

Proposed Solution

Our goal is to design a simple hill climbing model (see Fig. 1) that fits one specific gesture.

Expected Implementation

Analysis & Testing

Final Evaluation

References

Amador, Ana and Gabriel B. Mindlin (2014). "Low dimensional dynamics in birdsong production." In: *The European Physical Journal B* 87.12. ISSN: 1434-6028, 1434-6036. DOI: 10.1140/epjb/e2014-50566-5. URL: http://link.springer.com/10.1140/epjb/e2014-50566-5 (visited on 11/03/2016).

Amador, Ana et al. (2013). "Elemental gesture dynamics are encoded by song premotor cortical neurons." In: *Nature* 495.7439, pp. 59–64. ISSN: 0028-0836, 1476-4687. DOI: 10.1038/nature11967. URL: http://www.nature.com/doifinder/10.1038/nature11967 (visited on 09/20/2016).

Boari, Santiago et al. (2015). "Automatic reconstruction of physiological gestures used in a model of birdsong production." In: *Journal of Neurophysiology* 114.5, pp. 2912–2922. ISSN: 0022-3077, 1522-1598. DOI: 10.1152/jn.00385.2015. URL: http://jn.physiology.org/content/114/5/2912 (visited on 12/08/2016).

Dave, A. S. (2000). "Song Replay During Sleep and Computational Rules for Sensorimotor Vocal Learning." In: *Science* 290.5492, pp. 812–816. ISSN: 00368075, 10959203. DOI: 10.1126/science.290.5492.812. URL: http://www.sciencemag.org/cgi/doi/10.1126/science.290.5492.812 (visited on 09/21/2016).

Derégnaucourt, Sébastien et al. (2005). "How sleep affects the developmental learning of bird song." In: *Nature* 433.7027, pp. 710–716. ISSN: 0028-0836, 1476-4679. DOI: 10.1038/nature03275. URL: http://www.nature.com/doifinder/10.1038/nature03275 (visited on 09/21/2016).

Liu, Wan-chun, Timothy J. Gardner, and Fernando Nottebohm (2004). "Juvenile zebra finches can use multiple strategies to learn the same song." In: *Proceedings of the National Academy of Sciences* 101.52, pp. 18177–18182. URL: http://www.pnas.org/content/101/52/18177.short (visited on 10/20/2016).

Lynch, Galen F. et al. (2016). "Rhythmic Continuous-Time Coding in the Songbird Analog of Vocal Motor Cortex." In: *Neuron* 90.4, pp. 877–892. ISSN: 08966273. DOI: 10.1016/j.neuron.2016.04.021. URL: http://linkinghub.elsevier.com/retrieve/pii/S0896627316301088 (visited on 12/08/2016).

Picardo, Michel A. et al. (2016). "Population-Level Representation of a Temporal Sequence Underlying Song Production in the Zebra Finch." In: *Neuron* 90.4, pp. 866–876. ISSN: 08966273. DOI: 10.1016/j.neuron.2016.02.016. URL: http://linkinghub.elsevier.com/retrieve/pii/S0896627316001094 (visited on 12/01/2016).