Chapter 1

Introduction

Zebra Finch song learning

Characteristic of zebra finch song learning

- Learn one song for its whole life, Close-end learner (opposition open-end learer)
- Learn the song of father
- Song divided in motifs, syllables and notes
- subsong (babbling), plastic song, cristallysation
- Sensory phase (memorisation of tutor song), sensory motor phase
- If no auditory feedback, cannot learn.

Why is zebra finch song learning studied

- Model of Human speech learning
  - Actual song learning, not innate
  - Song with complex structures
- Well studied Neuroanatomy
- Easy to study experimentally
  - Easily domesticated
  - Learn one song
  - Learn quickly (90DPH)
  - Easy to track song development

Neurobiology of the Zebra Finch

Neuroanatomy of the Zebra Finch song system

- Connection between RA, HVC, Area X, ... Inhibition, excitation

Pattern of activation in RA and HVC

- HVC clock like, temporal structure (Ali et al.)
- RA activation while singing at very precise time and sparse coding
  - Motor control (Ali et al.) Ali et al. shows real two different learning: spectral and temporal

Models of song learning

Only very few models have been created. Even less are actual computational models.

Reinforcement learning

- Proposed but no real explanation of what could be the state space, the action space, the reward function (Dave&Margoliash).
- Used in paradigm to test different hypothesis (averse reward to force change in behaviour of the bird)

Song preferences in selection (Marler)

- Behavioural model to explain how the bird select its template
- TODO: Add more

Coen's model

- Clustering technique with babbling (multimodal)
  - Cluster the tutor song syllables thanks to their characteristics
  - Babbling, create a mapping between the motor space and the identified cluster
- Use of a real synthesizer but not actually built to model zf vocal apparatus
- No quantitative means to see how good is the song reproduction
- The learning is only babbling, nothing is driving the model in a specific direction.

Song synthesizer

Description of Perl song synthesizer to reproduce Zebra Finch song

- Presentation of anatomy simulation, mass and spring...
- Parameters
  - Air sac pressure
  - Syringeal Labial Tension
- Parameters are close to actual motor actions, so close to actual motor command

Zebra Finches are sensible to song produced by the synthesizer

- Show results of Amador where RA neurons were activated by Synth song but not by conspecific song.

Gestures and song structure

- Boari's Gesture concept and automatic extraction of the gestures
- Could have been correlated to HVC activation but in fact no.

Influence of Sleep in the Zebra Finch song development

Margoliash results with song replay

- RA neurons activated while singing
- Also activated when the bird is asleep and listen to his own song
- Spontaneous activity with part of the song: Replays
- Replays can be consolidation of memory
- Replays can have another role

Derégnaucourt results about positive impact of sleep for development

- Extraction of syllables characteristics and track over time
- Global trend for the trajectory of a syllable over time
- Each day, the syllables characteristics are closer

A computational model of birdsong learning to explain the sleep influence

Interest of a computational model of birdsong learning

- Computational model helps understanding what are the *implementation constraints* of the learning mechanisms
  - Use of synthesizer
  - Realistic computational budget
- Easily make hypotheses that can be tested experimentally afterwards
- Abstracted and controlled environment

Goal: Build a modular two-step learning model and look for learning algorithm that can account for Derégnaucourt's results.

Chapter 2

Our Model

Global Architecture

Usage of Boari's implementation of the birdsong synthesizer

Measurement of song quality with standard measures

- Entropy, Pitch, Goodness, Amplitude, Frequency Modulation, Amplitude Modulation
- Imported from Matlab implementation, with qualitatively similar results

Two-step learning model

- Bird has several song models it trains to reach tutor
- tutor song is known
- day algorithm for parameters optimisation
- night algorithm for structure optimisation
- Hypothesis: structure optimisation yield unlearning short term, better learning long term

Song Model

Song Model

Gesture paradigm inherited from synthesizer

Song structure

- List of gestures and their duration
- Fixed duration of the song because of measurement

Gesture composed of two generators for the motor commands

- Abstracted in sum of sin & linear func

Day learning algorithm

goal

- Optimise gestures parameters

Hillclimbing

- really simple
- Choose song model, choose gesture
- Choose close parameters, if better keep, if worse trash
- Knows if better by comparison of weighted standard measurements
- Not whole song but only gesture trained to make faster computations
  - Actually creates unlearning

Prediction

- Should improve song production but get stuck in local maximum because bad structure

Night learning algorithms

Goal

- Find better structure to describe song motor command

Several variations of algorithm have been tested

- Evolutionary algorithm
  - Simple solution for structure variation
- with or without diversity

Algorithm

- Evolutionary algorithm Microbial GA
- Increase population size and add variation in structure
  - Remove, add, change, copy gesture
  - Song always the same length for comparison reasons.
- Compare by tournament
  - The winner put a variation of itself in place of the loser
  - Compare number of neighbour * score, lower the better

Predictions

- Structure variation yields unlearning short term but positive impact long term
- Diversity will increase this

Parameters

- Tried to be realistic
- most are fit through gridsearch
- Realistics: Number of days, number of syllables sung during all dev
- Gridsearch optimisation
- Default value for gesture parameters
- Learning rate
  - Prevent part of unlearing
  - Could be fitted to match real song learning rate
  - Coefficient for score optimisation
- Algorithm way better in score than Boari but qualitatively very different to the ear

- Look at which parameters boari's method was better than algo and put priority on them
- Amplitude and entropy
- Diversity threshold to maximise variance in diversity score
  - Value: 5000
  - Other parameters
- Number of song models during day and night: Depend of runs
- Boundaries for parameters values: Fixed
- Number of tournaments during night: depend of runs
  - Correlated with replay? By how much?

Chapter 3

Analyses and results

Learning method is as good Boari's method or better

- Using standard measure criteria in the birdsong community
- Simple description of motor params sufficient to produce good songs
- Qualitatively same amount of gestures
  - Can be due to luck

Too little training per model cause divergence

- maybe due to global vs local error

Derégnaucourt results not reproduced

- Syllables extracted by time of begin and end
- Without or with diversity
- No night deterioration
- Night deterioration has no impact in overall learning

Chapter 4

Discussion

The synthesizer which cannot produce every sounds

- Our score really close to boari's method (not way better or way worst), maybe we reached synthesizer limits

The parameters description we choose

- more simple/complexe possible than sum of sin and affine?

The unlearning during day due to the gesture learning

Fixed duration of songs in learning

- Dynamic Time Warping can correct that

Big artificial separation between structuration and gestures optimisation

Diversity not strong enough? What if only diversity during night?

- Maybe not convergence
- Maybe what we are looking for

Chapter 5

Conclusion

Learning algorithm with two step learning

- Very few of them
- Working with realistic synthesizer
- modular architecture, easy to test new models

Restructuration didn't yield the expected effect

- More parameters search might be able to fix it