Ecological Language Acquisition via Incremental Model-Based Clustering

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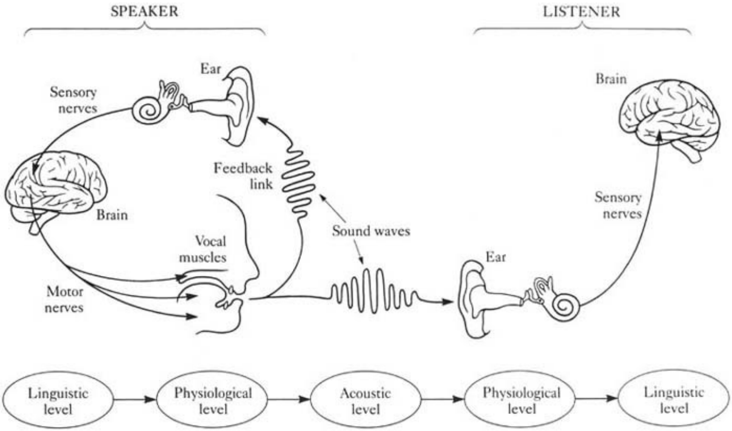
Nov. 2005

The Speech Chain



Denes and Pinson (1993)

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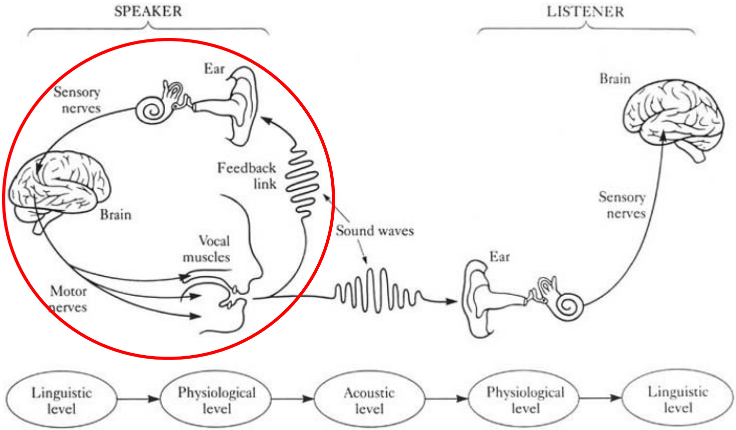

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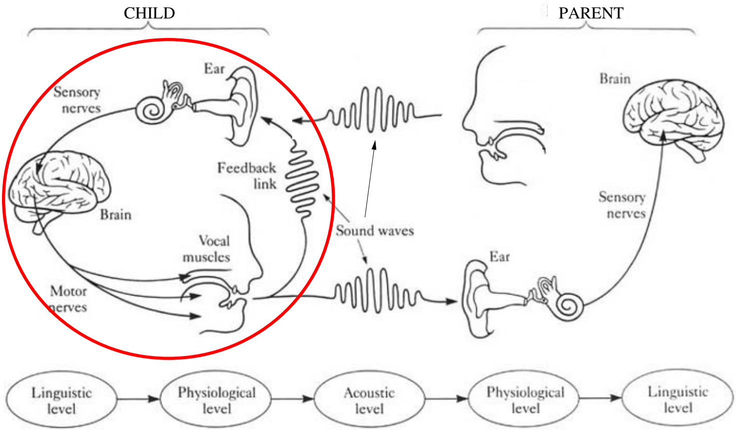

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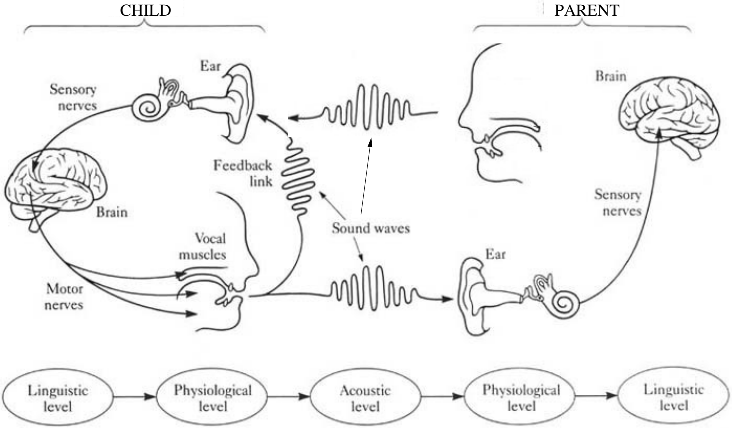

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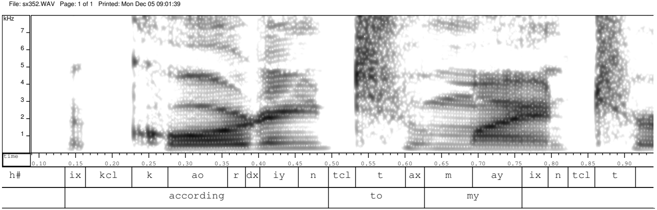
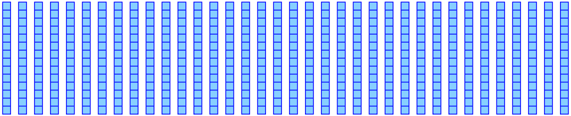
- Aim Interspeech 2005 (Salvi, 2005): acoustic features classification
  - unsupervised
  - incremental

Acoustic features

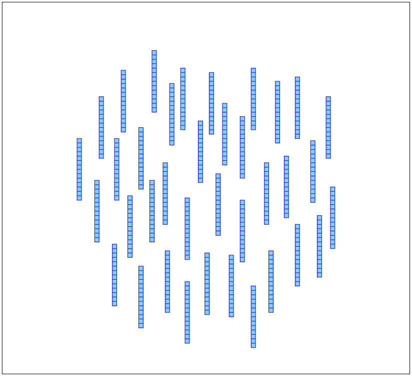
Equally spaced windows of speech





Assumption

Acoustic feature vectors independently drawn from mixture of Gaussian distributions



Method

- Model-Based Clustering (Fraley and Raftery, 1998)
  - data modelled as mixture of probability distributions
  - each distribution represents a cluster
  - each data point belongs to each cluster with a certain probability
  - model parameters estimated via Expectation Maximisation
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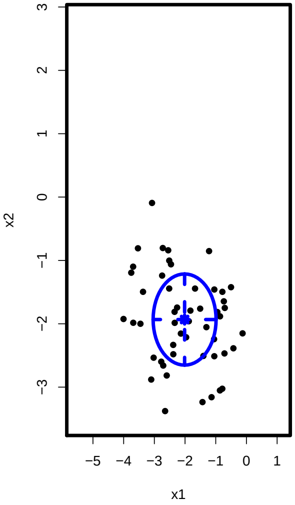
  - different models compared via Bayes information criterion (BIC)
- Incremental Model-Based Clustering (Fraley et al., 2003)
  - introduced for large datasets

Algorithm

1. start with a MCLUST model
2. get new data
3. adjust old model to new data
4. divide new data into well and poorly modelled points
5. try a more complex model, if better BIC set as best and go back to 4
6. set the current best model and go back to 2



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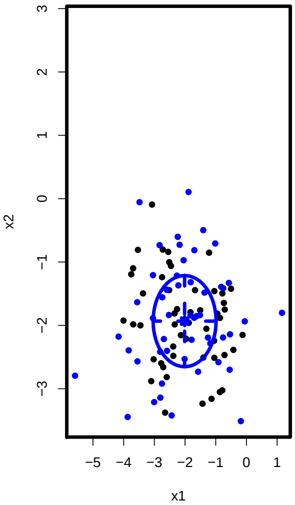

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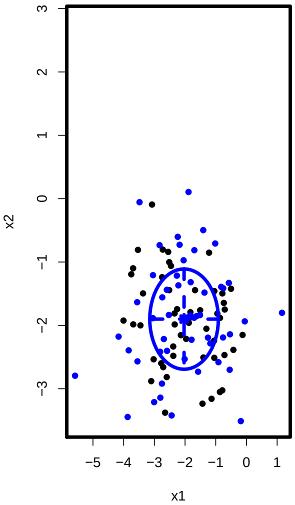

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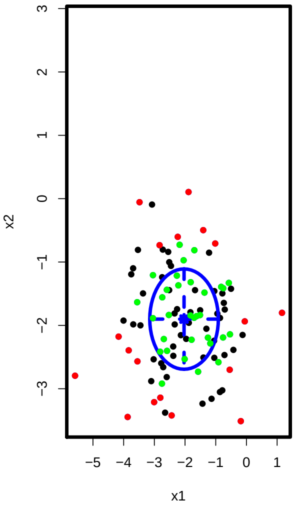

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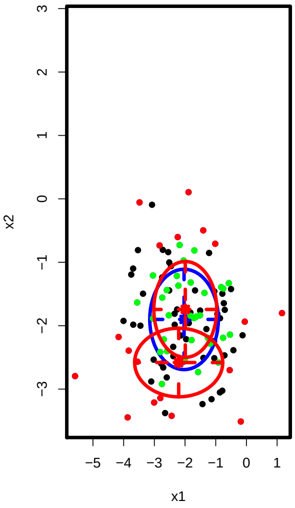

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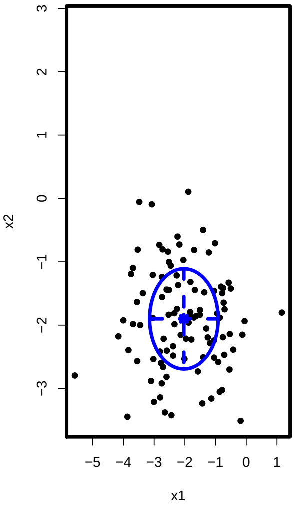

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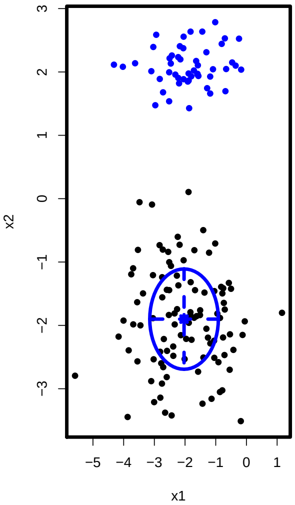

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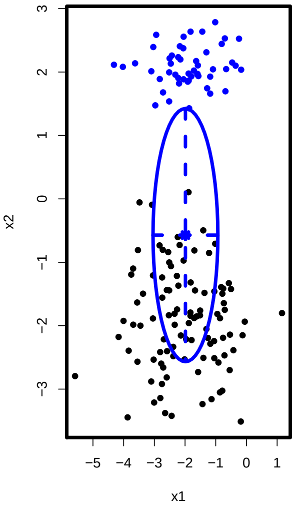

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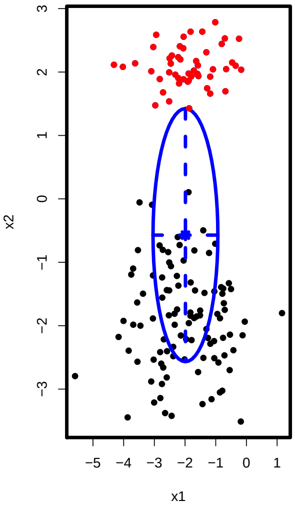

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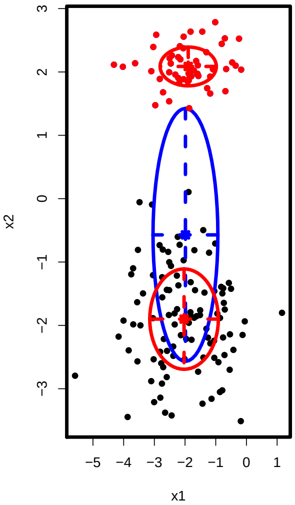

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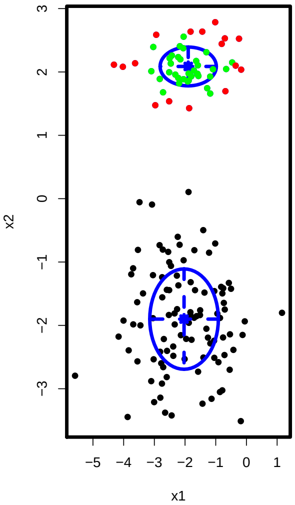

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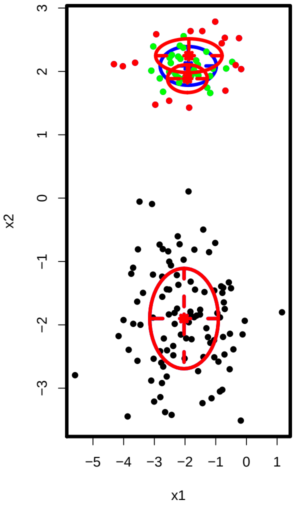

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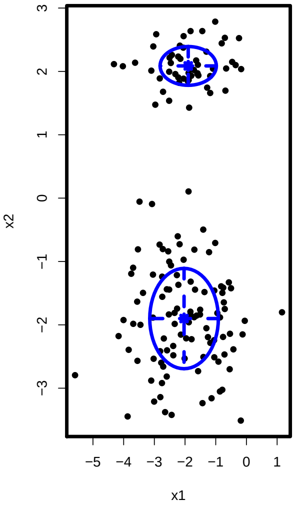

Experimental settings

- Data (ex1, ex2, ex3, ex4, ex5)
  - 12 minutes from the MILLE corpus
  - child directed speech (1 mother talking to her child)
  - Mel frequency cepstral coeffs computed every 10ms + differences of first and second order

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  - 12 minutes from the MILLE corpus
  - child directed speech (1 mother talking to her child)
  - Mel frequency cepstral coeffs computed every 10ms + differences of first and second order
- experimental factors
  - dimensionality of the data: from 3 to 39 dimensions
  - frame length: from 200msec to 3sec

Evaluation

- problem: there is no reference (at the moment)

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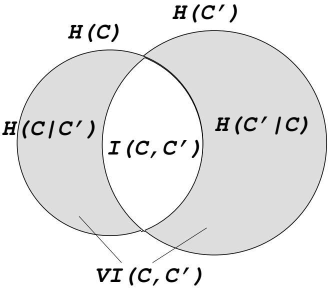
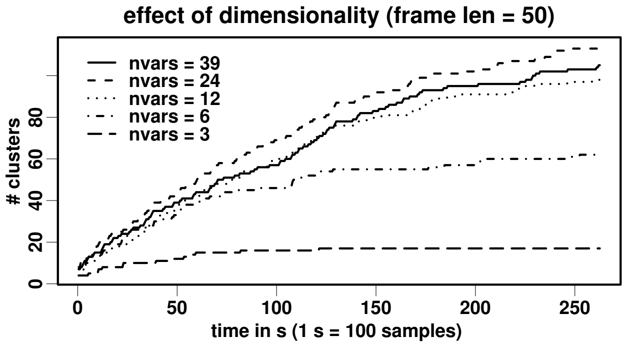
- relative evaluation:
- time evolution of number of clusters
  - dependency with number of feature coefficients
  - dependency with frame length
- agreement of classification in different conditions
  - variation of information (Meilă, 2002)

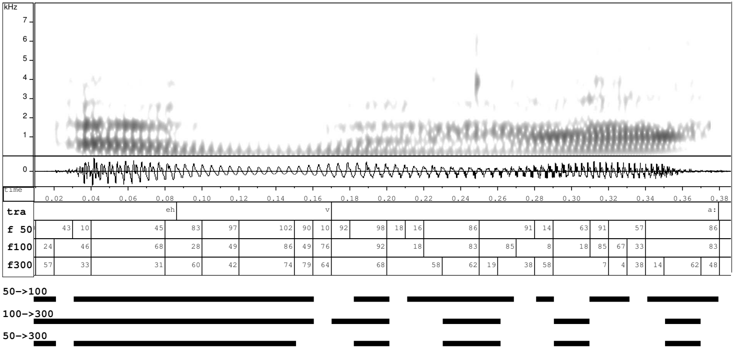


$$\mathbf{V}I(C, C') = H(C|C') + H(C'|C)$$

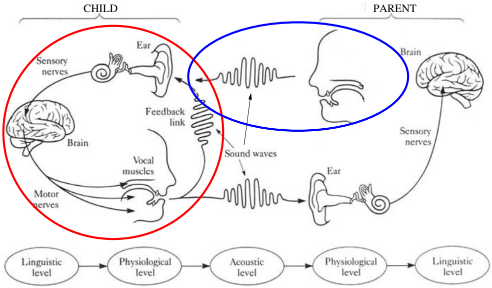
Results


effect of dimensionality (frame len = 50)
nvars = 39
nvars = 24
nvars = 12
nvars = 6
nvars = 3
# clusters
0
20
40
60
80
0
50
100
150
200
250
time in s (1 s = 100 samples)

Example


kHz
7
6
5
4
3
2
1
0
time
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36 0.38
tra eh v a:
f 50 43 10 45 83 97 102 90 10 92 98 18 16 86 91 14 63 91 57 86
f100 24 46 68 28 49 86 49 76 92 18 83 85 8 18 85 67 33 83
f300 57 33 31 60 42 74 79 64 68 58 62 19 38 58 7 4 38 14 62 48
50->100
100->300
50->300

Mismatch Child/Parent Voice



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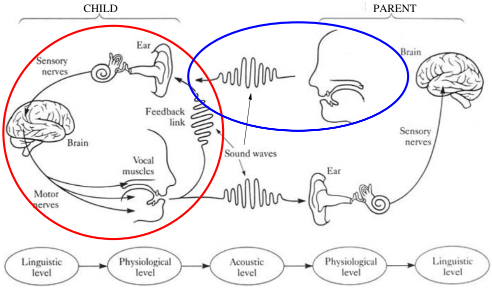
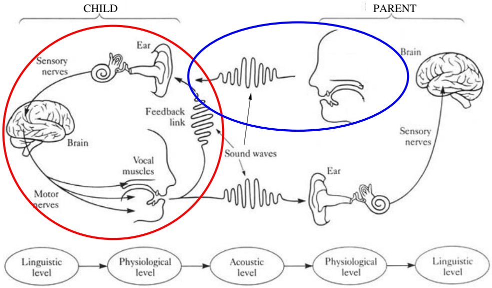


- ASR with children

Mismatch Child/Parent Voice



- ASR with children
- Normalisation
  - VTLN: Vocal Tract Length Normalisation
  - Adaptation: hard in this context

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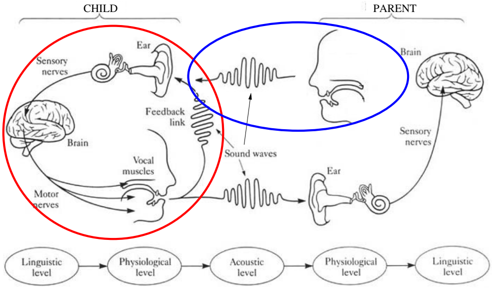

- ASR with children
- Normalisation
  - VTLN: Vocal Tract Length Normalisation
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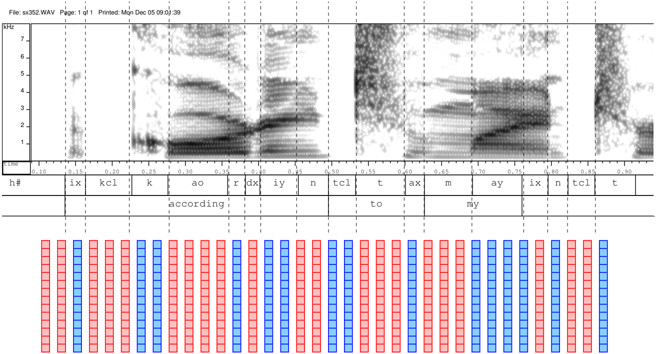
- Relative Features

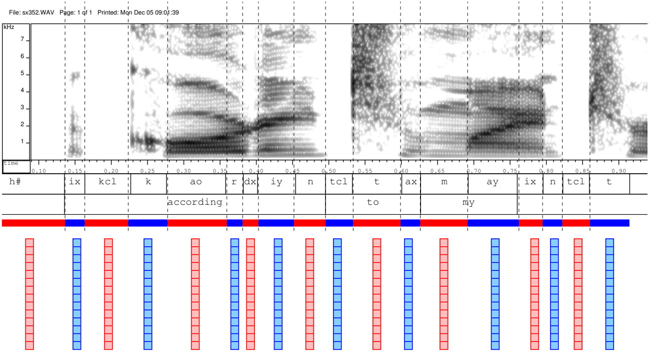
Acoustic Features

Frame Based



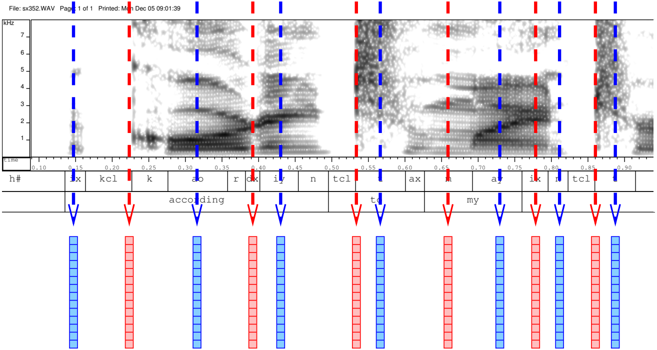
Acoustic Features

Segment Based

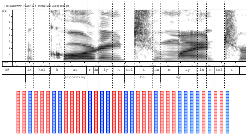


Acoustic Features

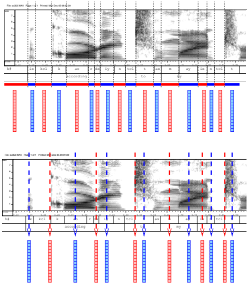
Landmark Based



Consequences



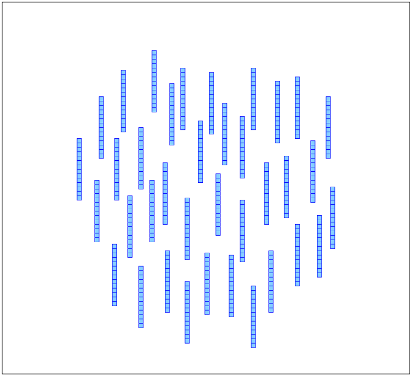
⇒ Sequence recognition (HMMs)



⇒ simpler relation acoustic categories/ linguistic units

Clustering Time Sequences

Acoustic vectors independently drawn from mixture of gaussian distributions



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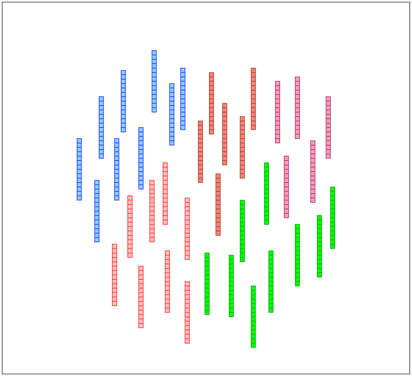

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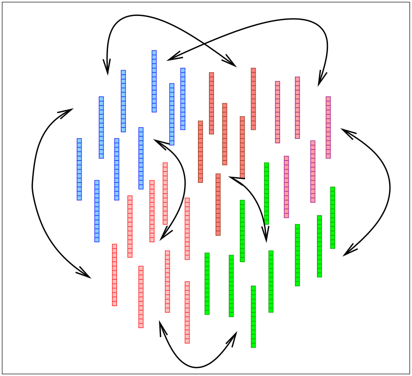
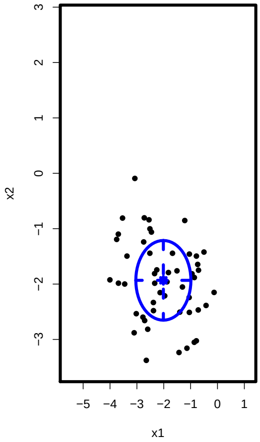
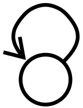


Modeling time evolution with Markov chains





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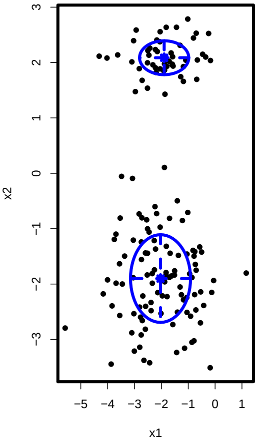

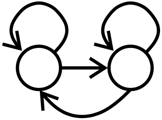

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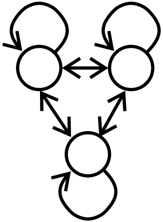

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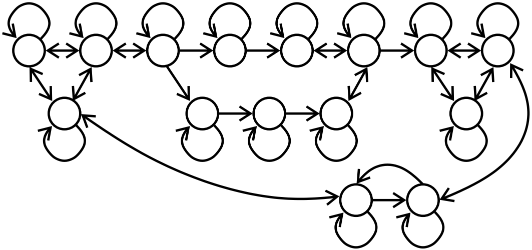

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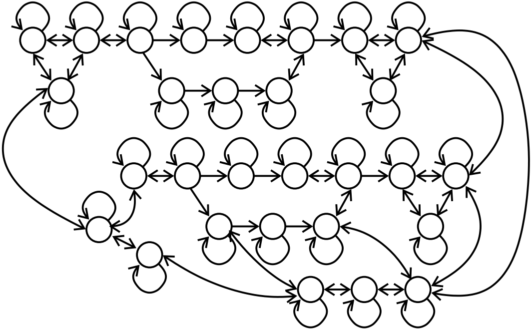

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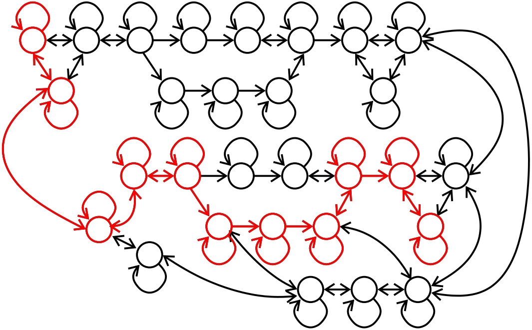
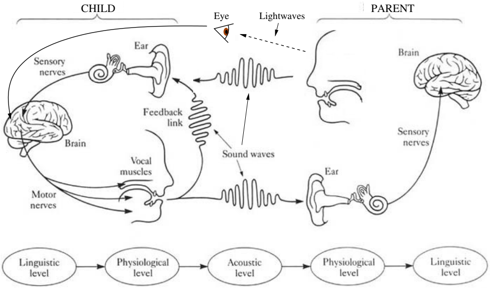


The Visual Channel



- No one-to-one relation acoustic/visual info

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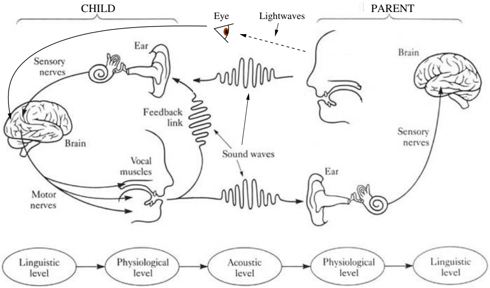


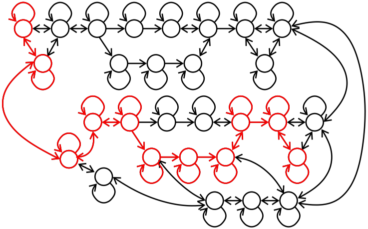
- No one-to-one relation acoustic/visual info
- Reinforcement Learning
  - perform match at higher levels (pseudo-words or -phrases)

The Visual Channel

Perform visual/acoustic match on the Markov chain

Visual Event

Acoustic Event



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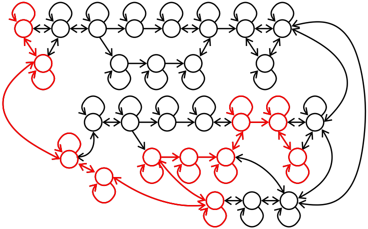

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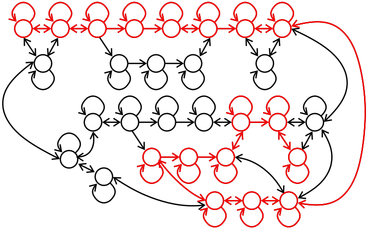

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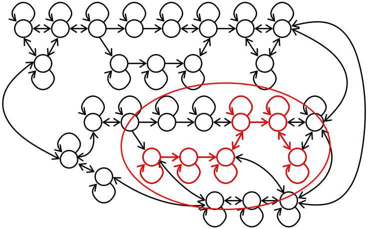

The Final Question

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- in the first case: model based clustering and growing Markov chains are separate processes.
- in the second case: need to integrate everything

Bibliography

http://www.speech.kth.se/~giampi

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