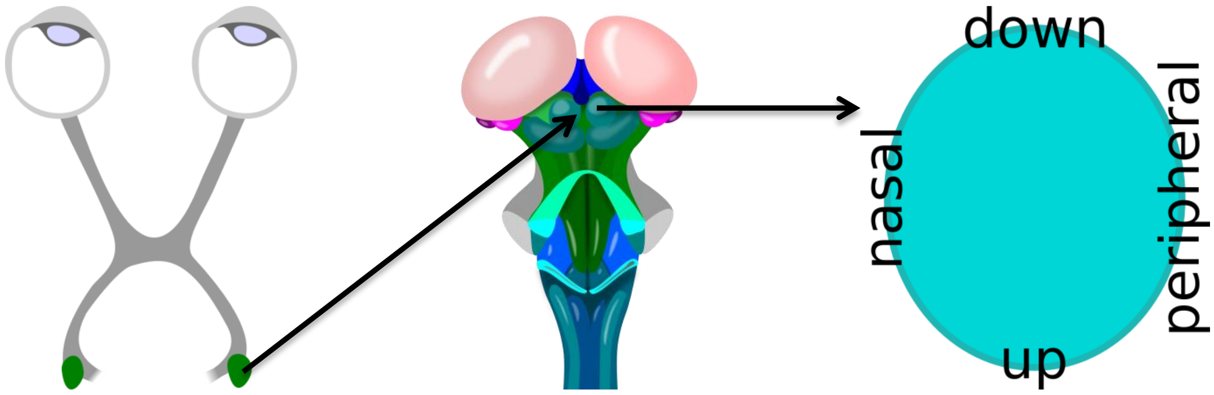
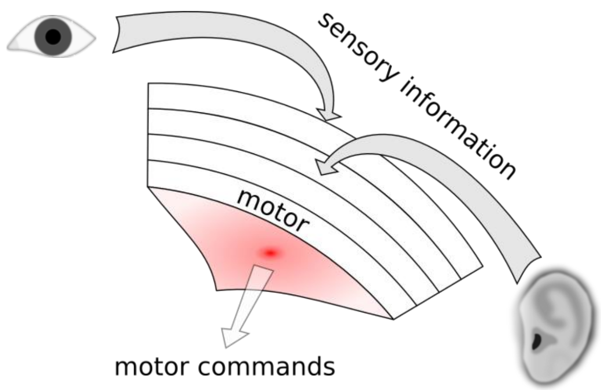
Learning Multi-Sensory Integration with Self-Organization and Statistics

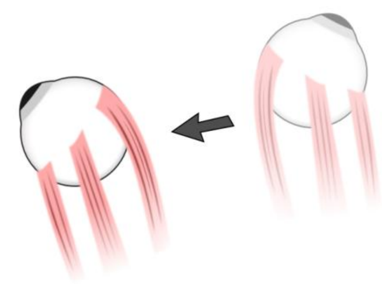
Johannes Bauer, Stefan Wermter

http://www.informatik.uni-hamburg.de/WTM/

The Superior Colliculus

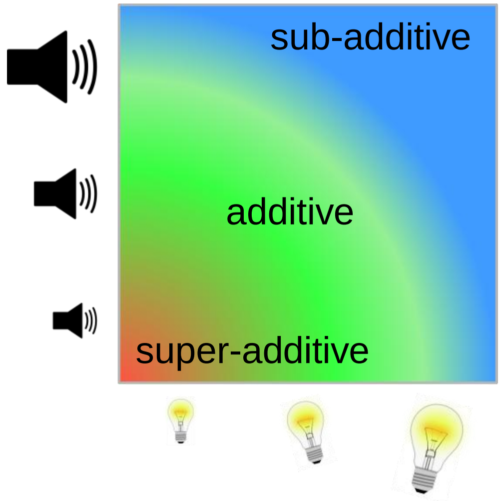




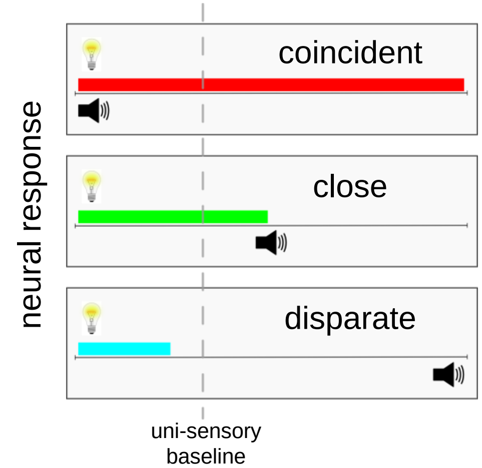


The Superior Colliculus

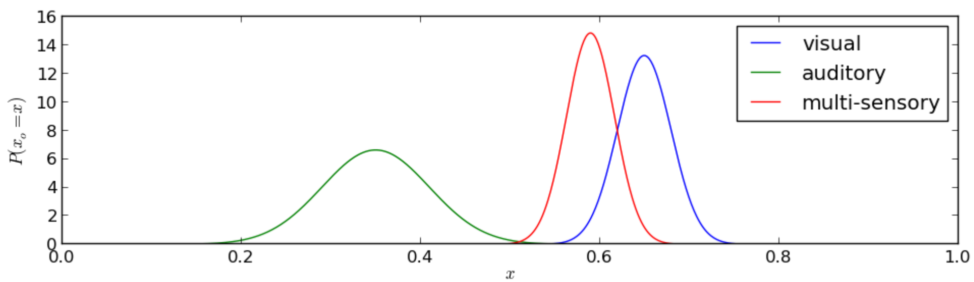
inverse effectiveness[1]



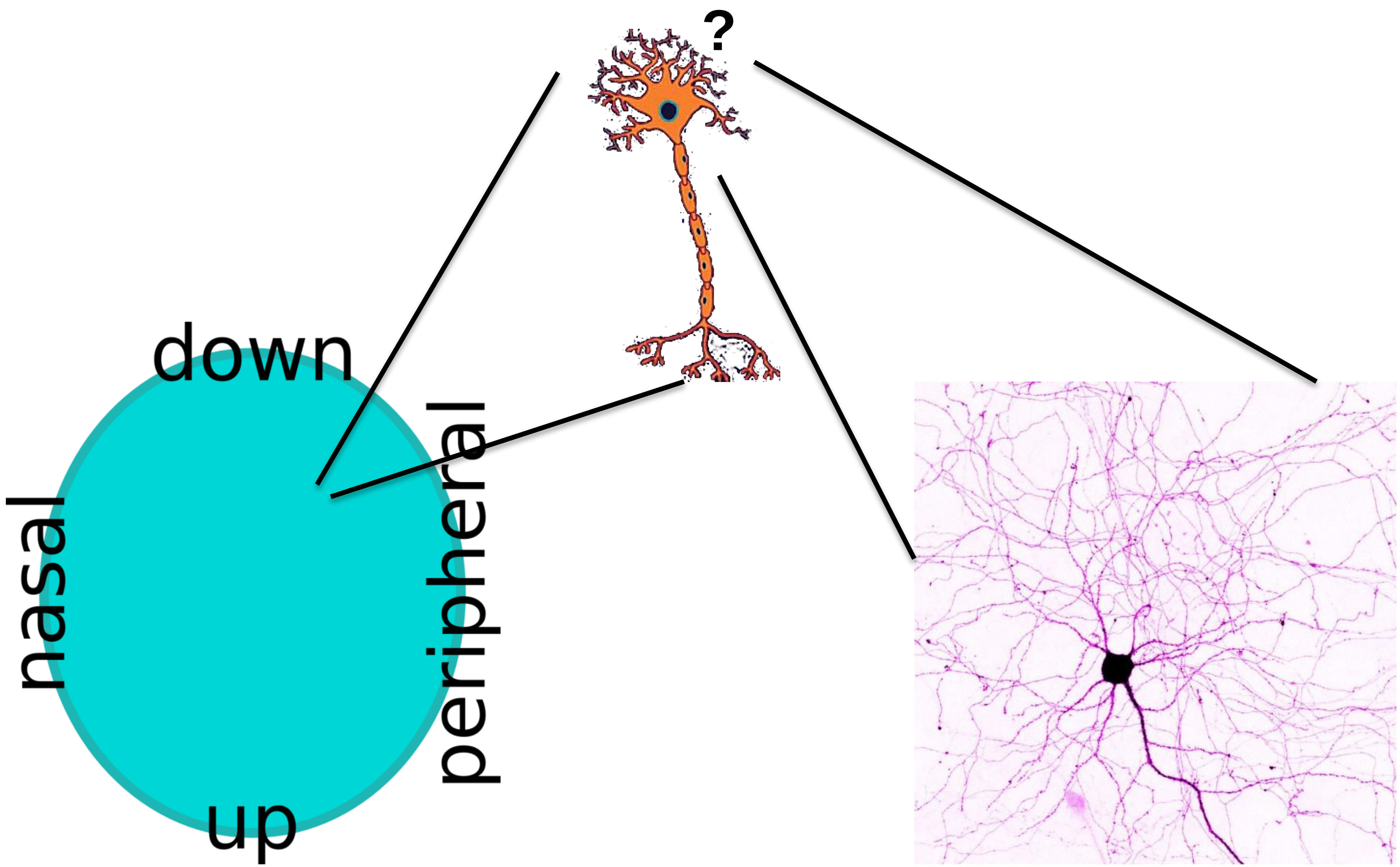
spatial principle[1]



optimal integration[2]



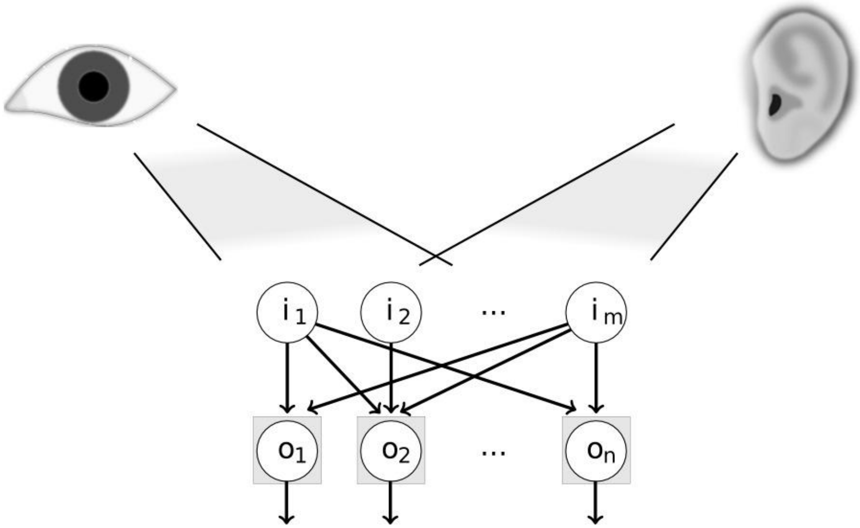
What's Interesting About That?



Place in SC

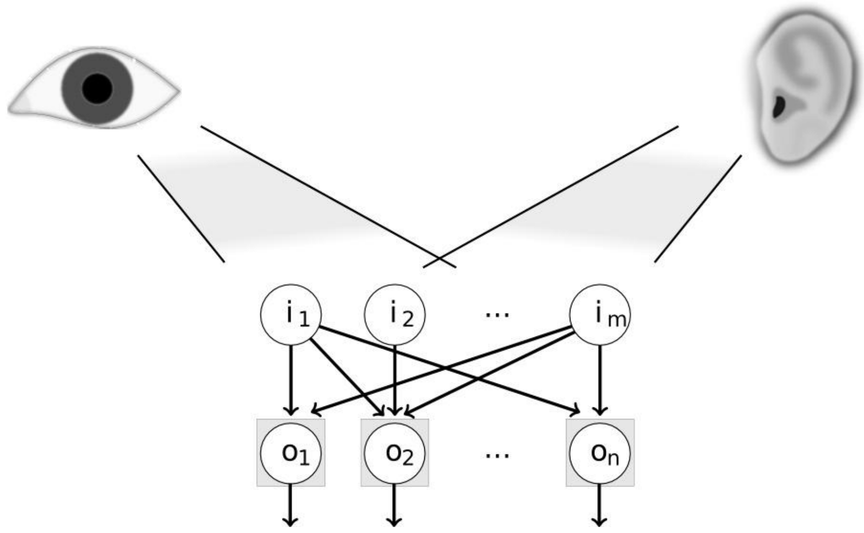
Meaning of Input

The Algorithm[3]



ρ: input stimulus
a_k: activity of i_k
ρ_l: preferred value of o_l

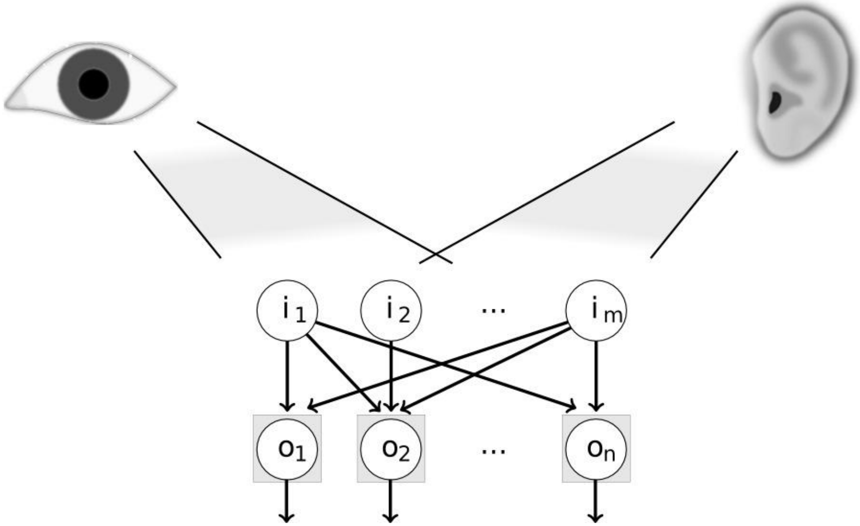
The Algorithm[3]



ρ: input stimulus
a_k: activity of i_k
ρ_l: preferred value of o_l

$$P(\rho = \rho_l \mid a_1, a_2, \dots, a_m)$$

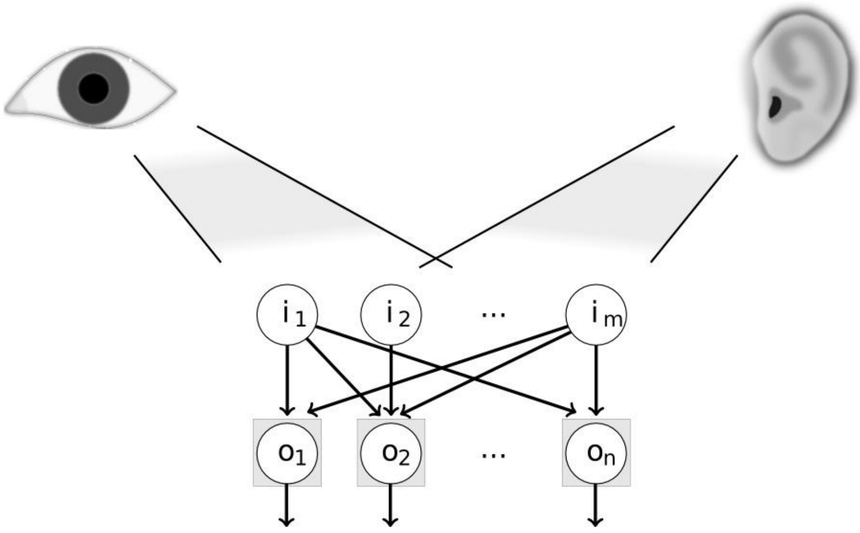
The Algorithm[3]



ρ: input stimulus
a_k: activity of i_k
ρ_l: preferred value of o_l

$$P(\rho = \rho_l \mid a_1, a_2, \dots, a_m) \sim \frac{P(a_1, a_2, \dots, a_m \mid \rho = \rho_l)}{P(a_1, a_2, \dots, a_m)} P(\rho = \rho_l)$$

The Algorithm[3]

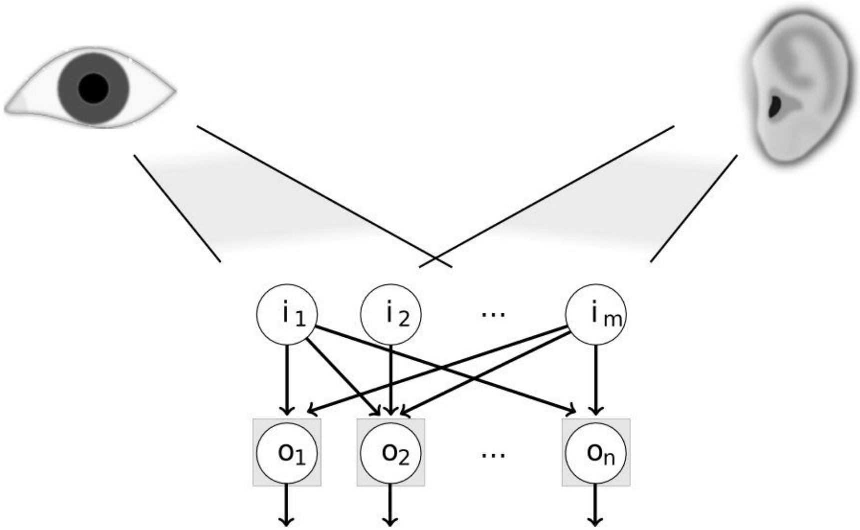


ρ: input stimulus
a_k: activity of i_k
ρ_l: preferred value of o_l

$$P(\rho = \rho_l \mid a_1, a_2, \dots, a_m) \sim \frac{\prod_k P(a_k \mid \rho = \rho_l)}{\prod_k P(a_k)} P(\rho = \rho_l)$$

Noise independent.

The Algorithm[3]



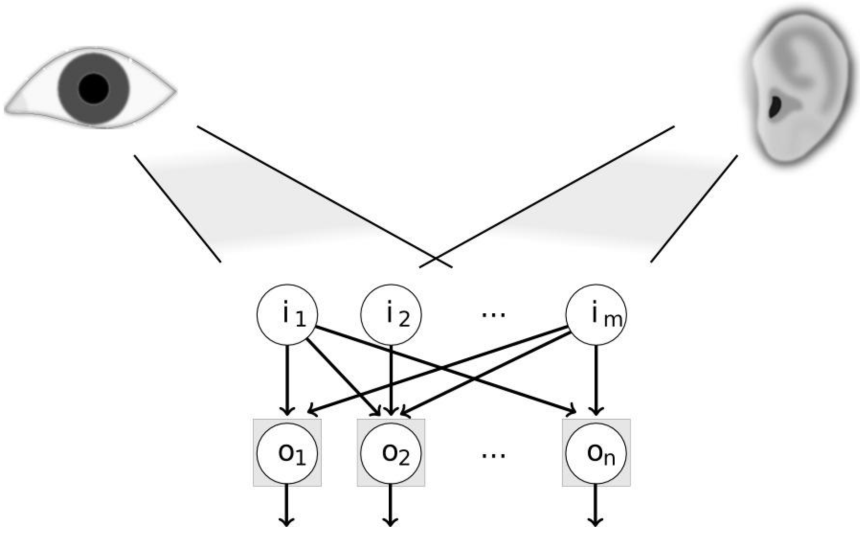
ρ: input stimulus
a_k: activity of i_k
ρ_l: preferred value of o_l

$$P(\rho = \rho_l \mid a_1, a_2, \ldots, a_m) \sim \frac{\prod_k P(a_k \mid \rho = \rho_l)}{\prod_k P(a_k)}$$

Noise independent.

ρ unif. dist.

The Algorithm[3]



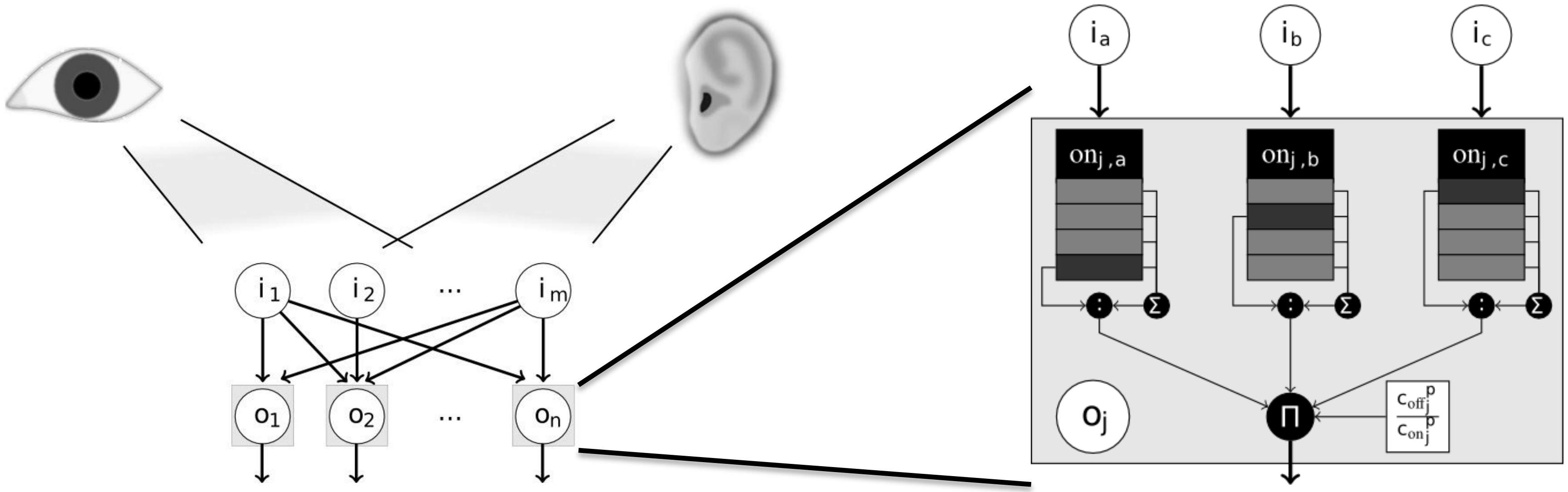
ρ: input stimulus
a_k: activity of i_k
ρ_l: preferred value of o_l

$$P(\rho = \rho_l \mid a_1, a_2, \ldots, a_m) \sim \prod_k P(a_k \mid \rho = \rho_l)$$

Noise independent.

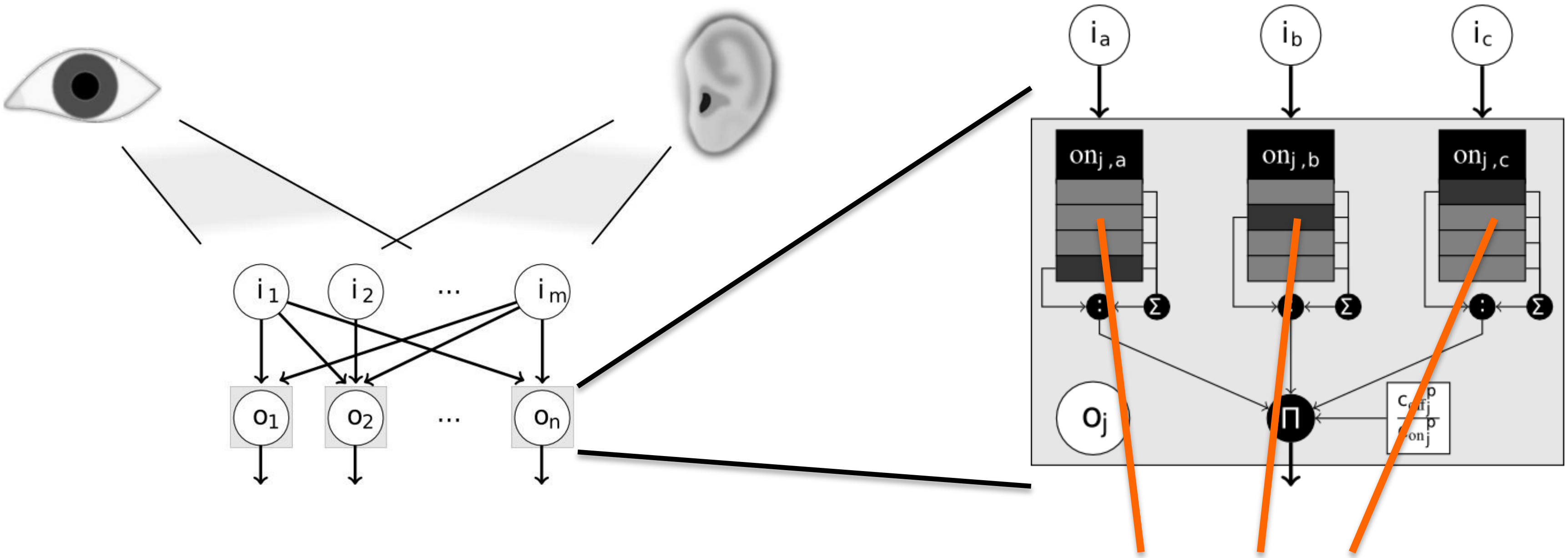
ρ unif. dist.

The Algorithm[3]



$$P(\rho = \rho_l \mid a_1, a_2, \dots, a_m) \sim \prod_k P(a_k \mid \rho = \rho_l)$$

The Algorithm[3]

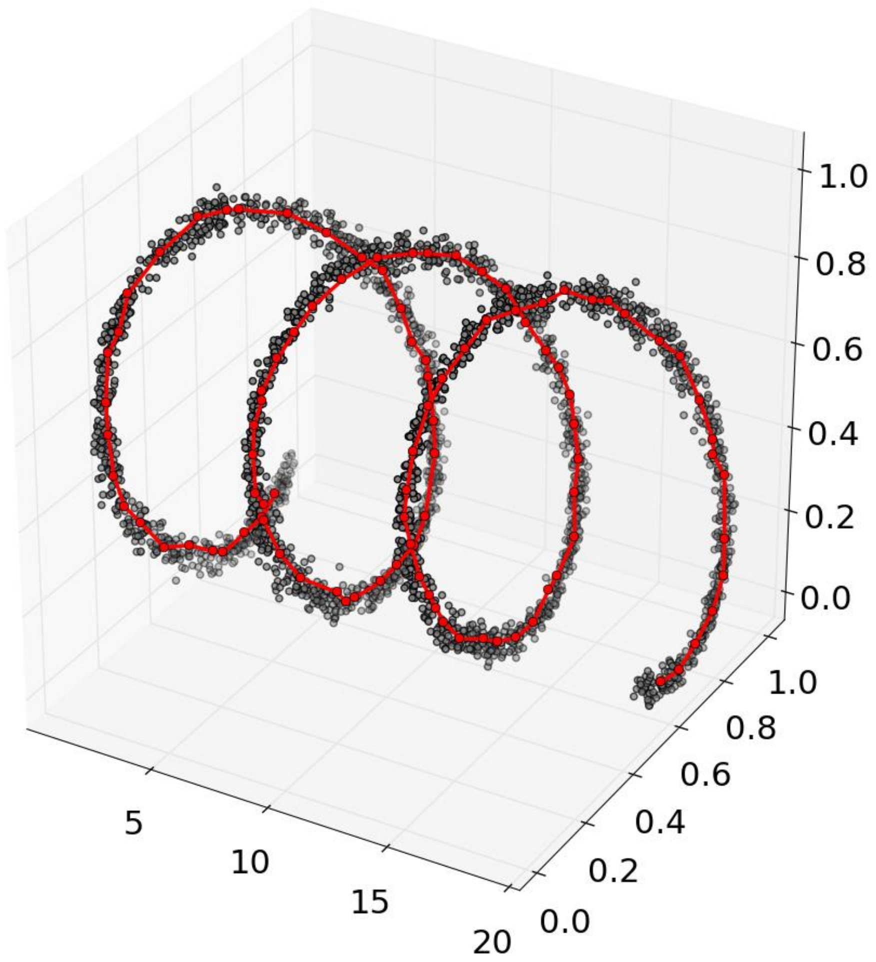


can be adapted SOM-like

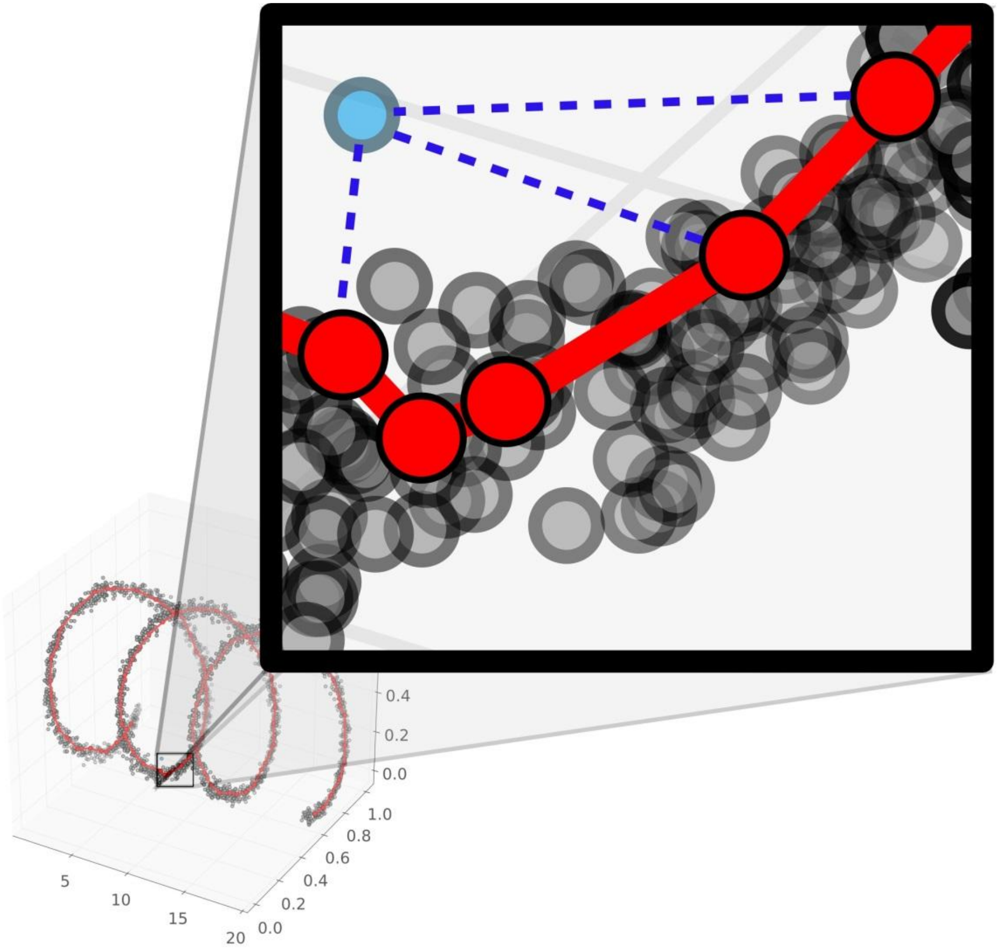
Assume $P(a_k \mid \rho = \rho_j) = \frac{on_{j,a}[a_k]}{\sum on_{j,a}}$, then

$$P(\rho = \rho_j \mid a_1, a_2, \dots, a_m) \sim \prod_l \frac{on_{j,l}[a_l]}{\sum on_{j,l}}$$

Comparison to regular SOM



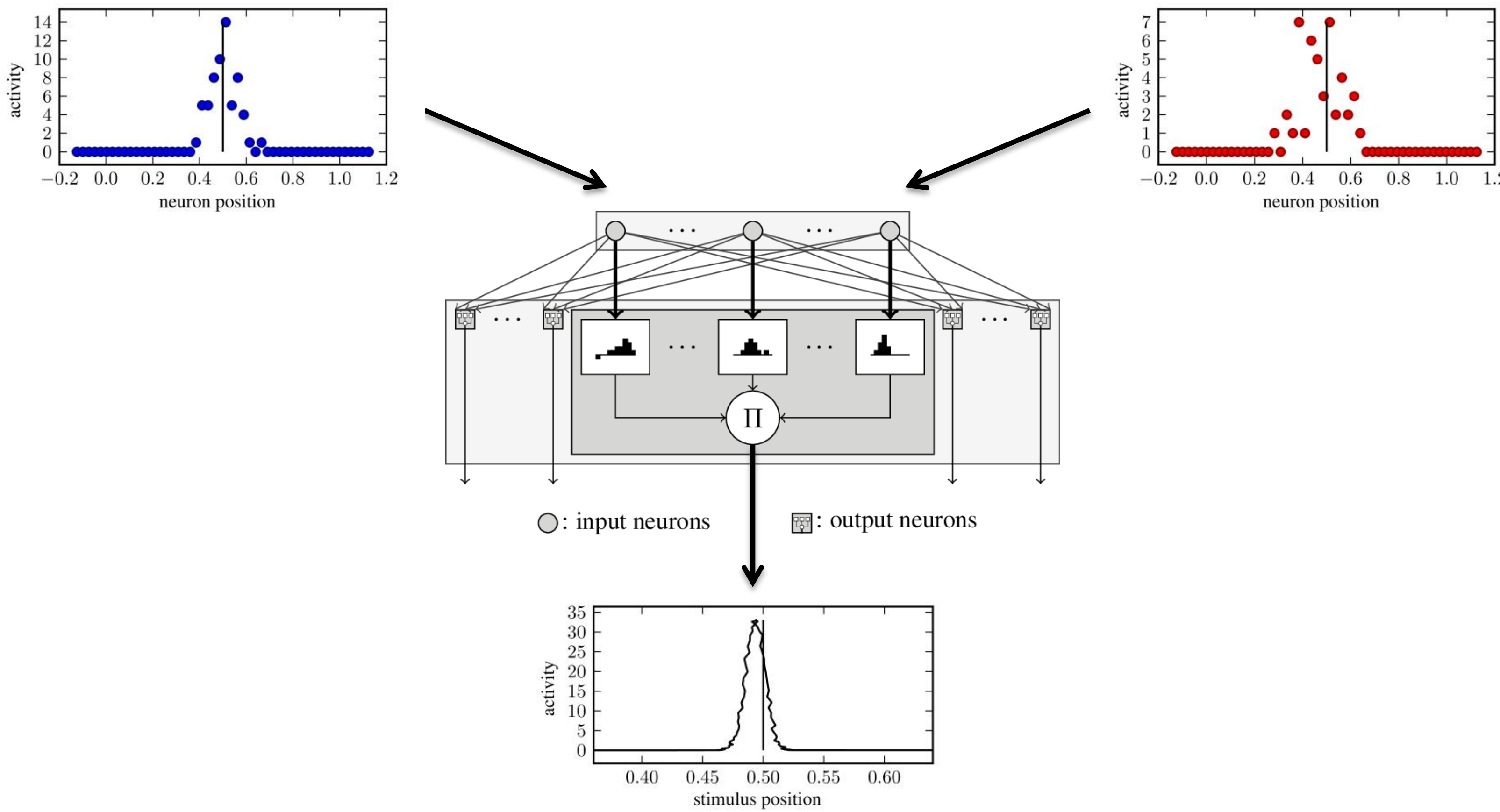
Comparison to regular SOM



The Network in Action

‘visual’ input

‘auditory’ input

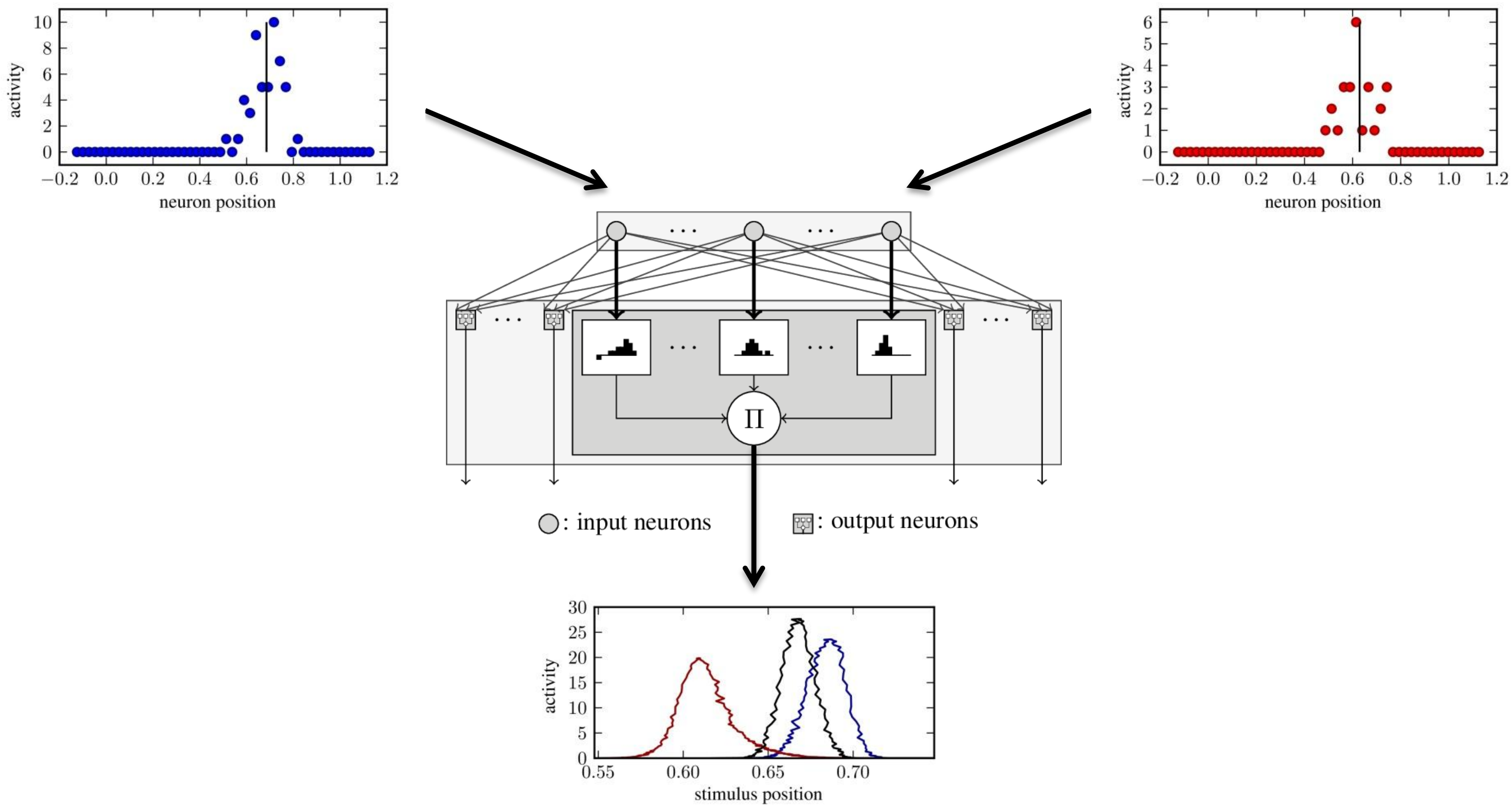


population-coded PDF

The Network in Action

'visual' input

'auditory' input

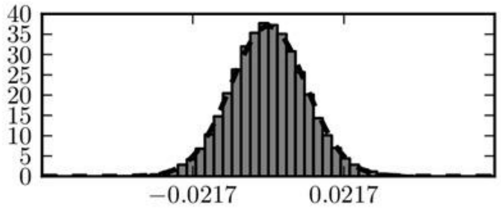


population-coded PDF

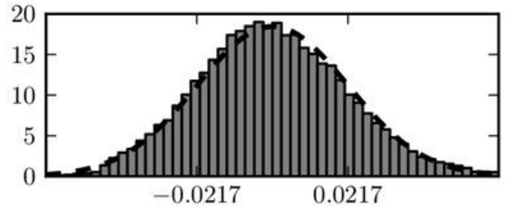
Performance

The network integrates multi-sensory information.

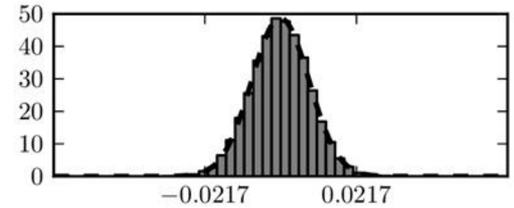
errors given ‘visual’ input



errors given ‘auditory’ input

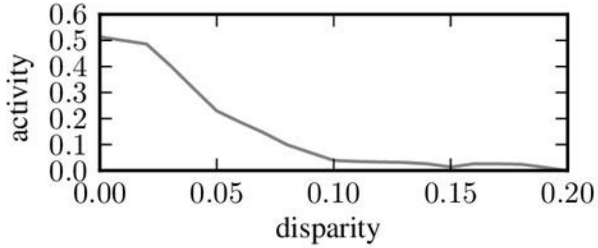


errors given multi-sensory input

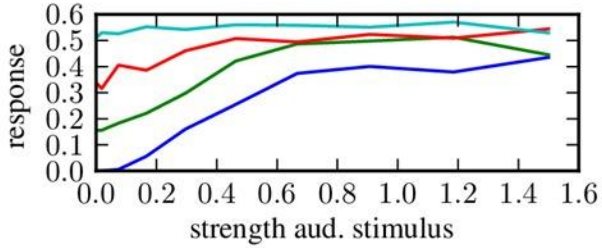


The network replicates biological phenomena.

Spatial Principle



Inverse Effectiveness



Conclusion

presented a novel self-organizing ANN algorithm which

- learns to combine information near-optimally
- shows spatial principle and MLE-like behavior
- shows benefit of multisensory integration
- learns to compute a PDF for latent variables
- is unsupervised
- has few inbuilt assumptions

The End

References:

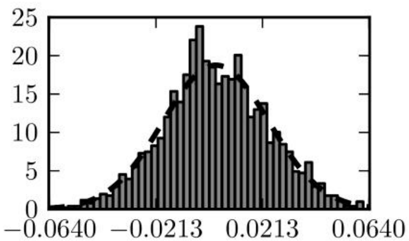
[1]: Stanford, T. R., Quessy, S., Stein, B. E., Jul. 2005. *Evaluating the operations underlying multisensory integration in the cat superior colliculus.* The Journal of Neuroscience 25 (28), 6499–6508.

[2]: Alais, D., Burr, D., Feb. 2004. *The ventriloquist effect results from Near-Optimal bimodal integration*. Current Biology 14 (3), 257–262.

[3]: Bauer, J. and Wermter, S., Sept. 2013. *Self-organized neural learning of statistical inference from high-dimensional data.* In: *Proceedings of the International Joint Conference on Artificial Intelligence 2013*.

Performance – Behavioral*

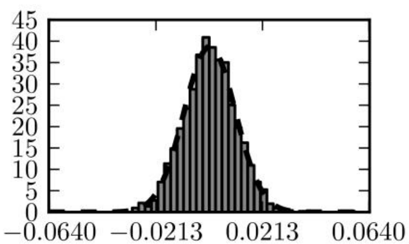
*simulation parameters differ from rest of talk.



auditory

$\sigma_a = 4.594 \cdot 10^{-4}$

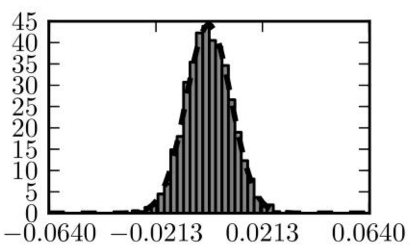
$p_a = 1.680 \cdot 10^{-1}$



visual

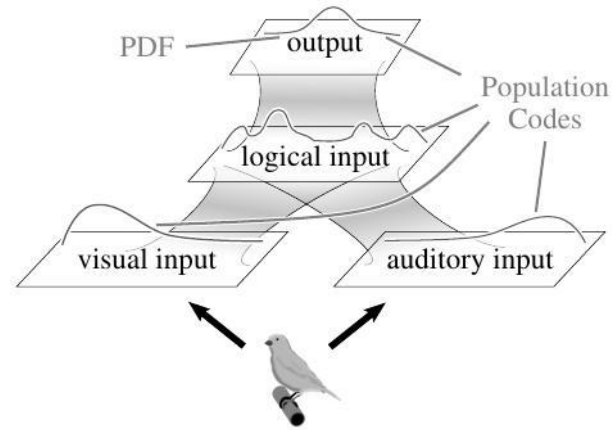
$\sigma_v = 1.061 \cdot 10^{-4}$

$p_v = 8.272 \cdot 10^{-1}$



multi-sensory

$\sigma_m = 8.153 \cdot 10^{-5}$



optimal

$$\sigma_{m,opt} = \sqrt{\frac{1}{\frac{1}{\sigma_v^2}+\frac{1}{\sigma_a^2}}} \approx 4.185 \cdot 10^{-5}$$

$p_{a,opt} \approx 1.876 \cdot 10^{-1}$

$p_{v,opt} \approx 8.124 \cdot 10^{-1}$