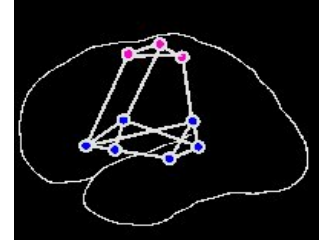




***MirrorBot***  
***Biomimetic multimodal learning***  
***in a mirror neuron-based robot***  
***IST-2001-35282***



**Stefan Wermter, Frederic Alexandre, Günther Palm,  
Friedemann Pulvermüller, Giacomo Rizzolatti/Vittorio Gallese**

**University of Sunderland**

**INRIA at Nancy**

**University of Ulm**

**Medical Research Council at Cambridge**

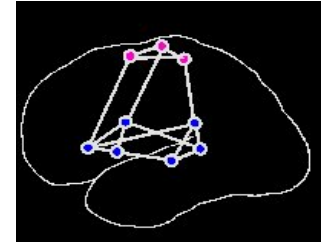
**University of Parma**



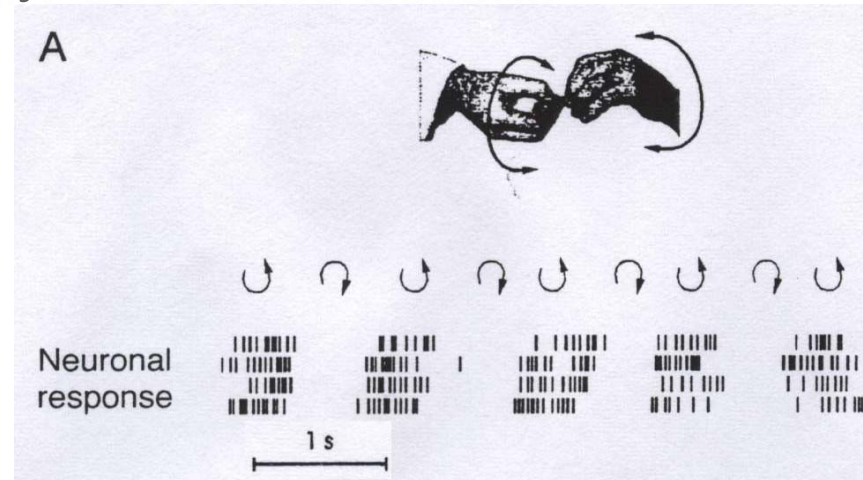
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**Project funded by the Future and Emerging Technologies arm of the IST Programme  
FET-Open scheme**

## Objectives of MirrorBot



- Mirror neurons fire for specific actions, visually observed actions and acoustically described actions

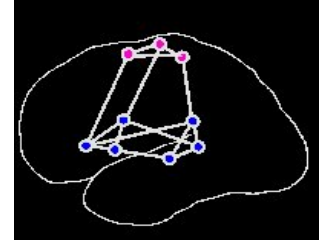


- How can mirror neuron-based associative networks be used for multimodal actions in robots?





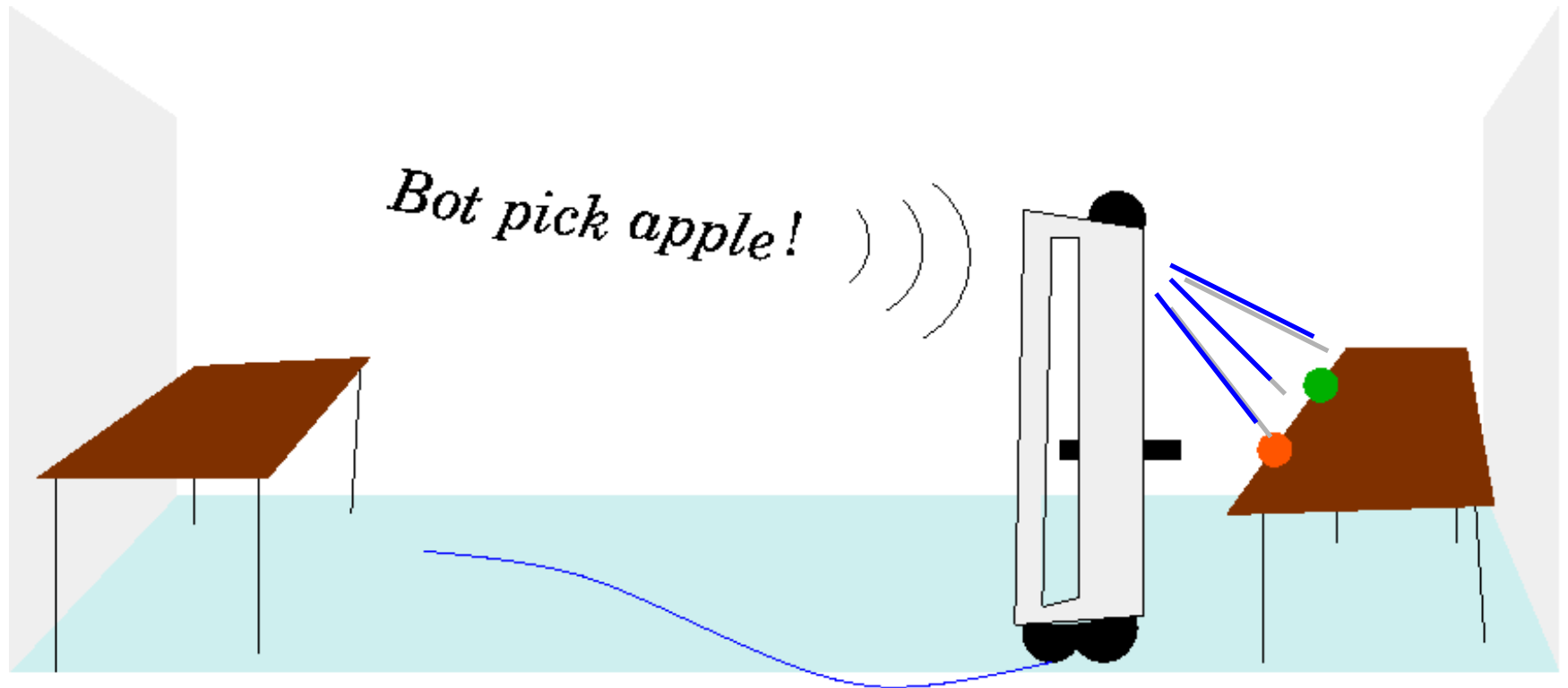
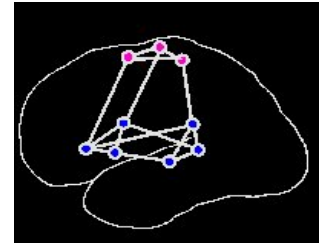
## *Individual goals*



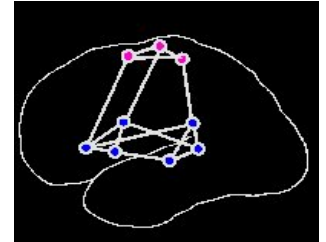
- collect imaging and neural recording data: EEG, MEG, fMRI, TMS
- identify neural architectures for perceptual visual and language data
- develop associative networks for mirror neuron concept
- train and evaluate the MirrorBot robot to perform actions



# MirrorBot scenario



## MirrorBot scenario



agent ::= SAM **action**  
BOT **action**

**action** ::= body\_action  
head\_action  
hand\_action  
stop

body\_action ::= go  
move\_body  
turn\_body

head\_action ::= turn\_head  
show

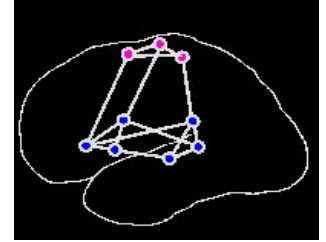
hand\_action ::= pick  
put  
lift  
drop  
touch

object  
x\_direction  
y\_direction  
y\_direction | z\_direction

object  
object  
object  
object  
object



## MirrorBot grammar



**x\_direction**::= forward | backward

**y\_direction**::= left | right

**z\_direction**::= up | down

**object**::= [colour] natural\_object

[colour] artefact\_object

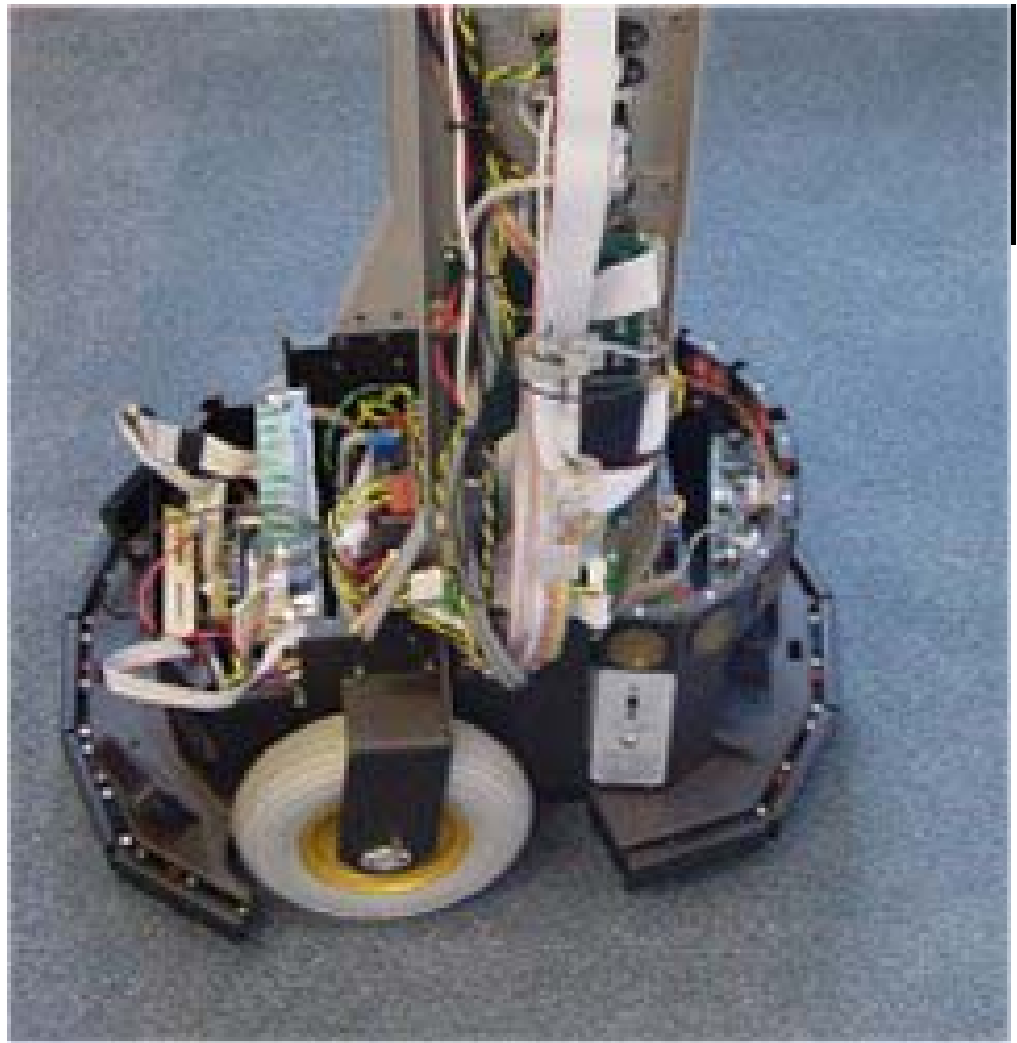
**colour** ::= brown | blue | black | white

**natural\_object**::= nut | plum | dog | cat

**artefact\_object**::= desk | wall | ball | cup

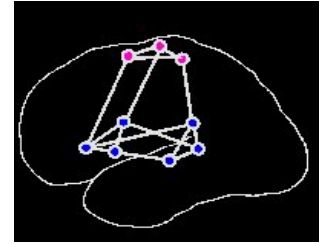


# MirrorBot platform



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## *Examples of ongoing Work*



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# *F5 Neuron Responses*

The response of an audio-visual F5 mirror neuron

## Audio-visual response

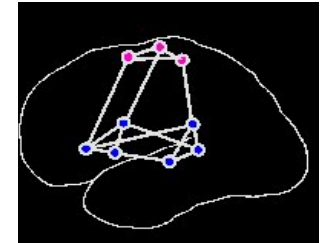
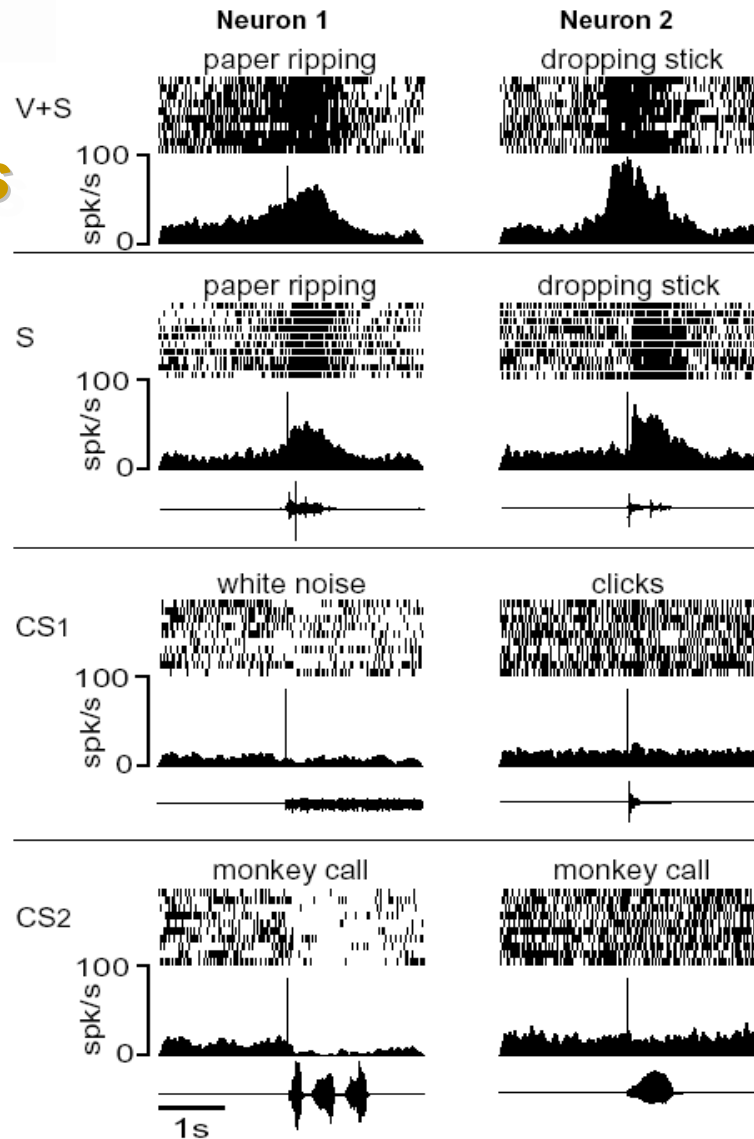
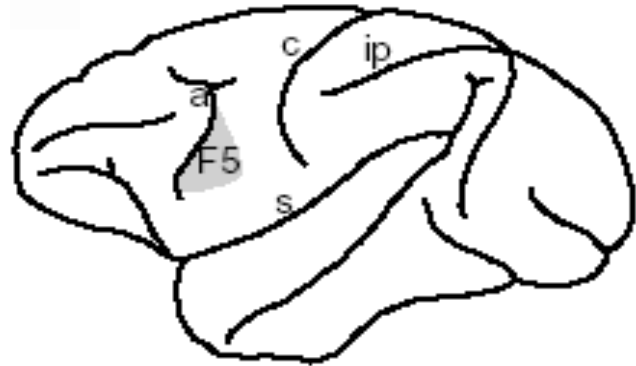


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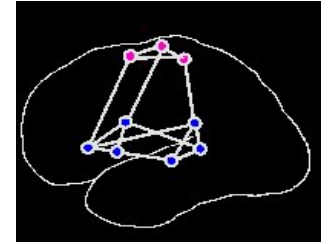
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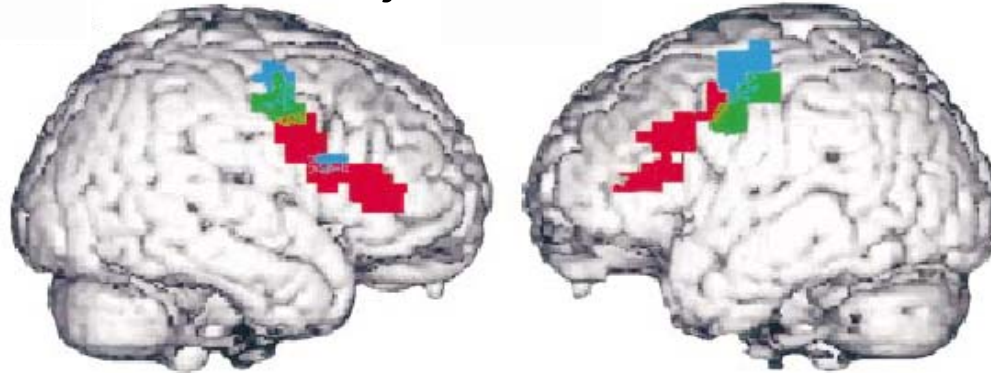
# F5 responses



# Somatotopy of visual action observation (fMRI)

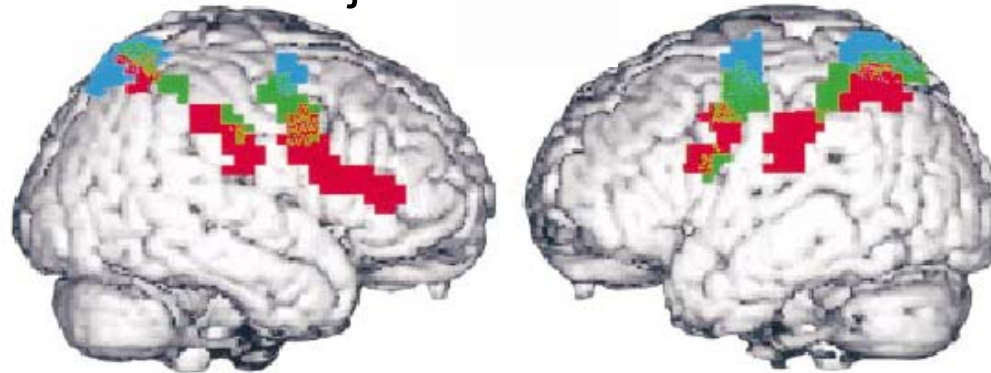


## Non-object-related actions



 **Foot Action**

## Object-related actions

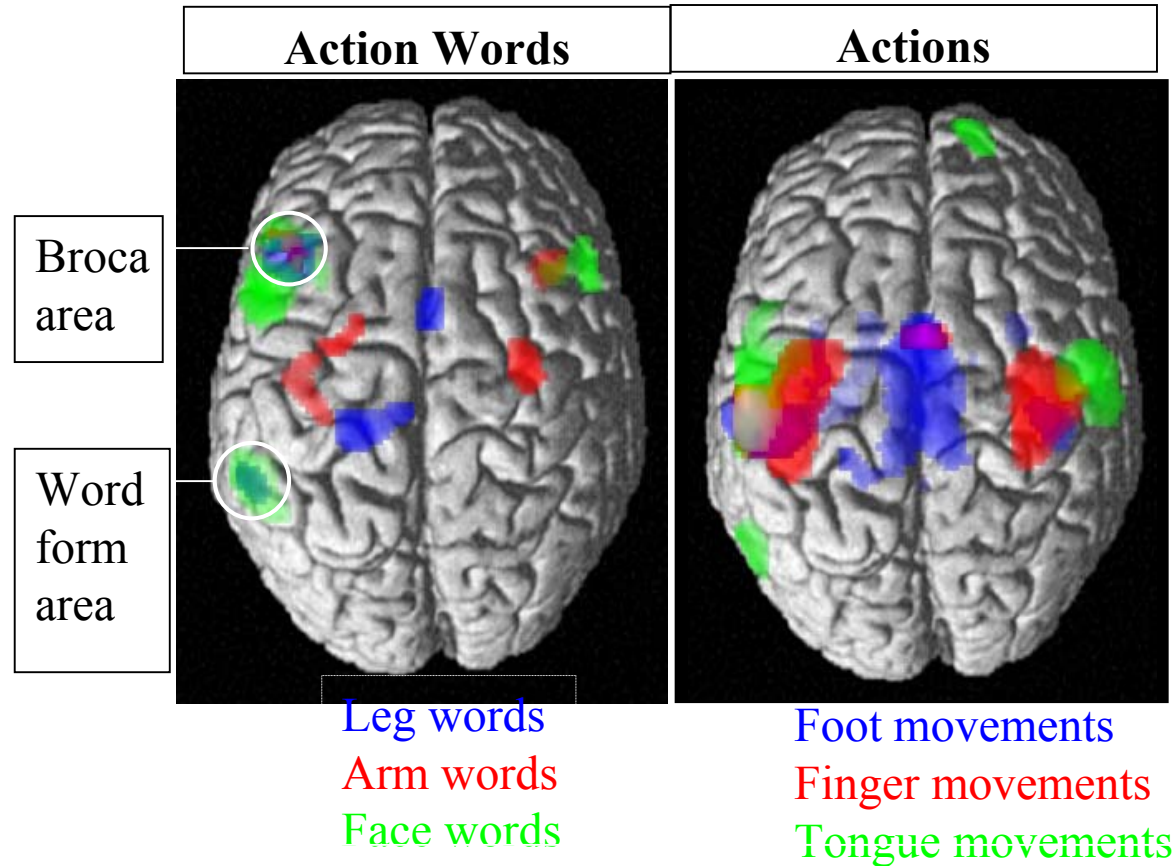
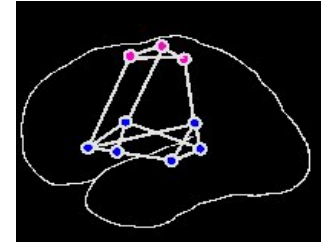


 **Hand Action**

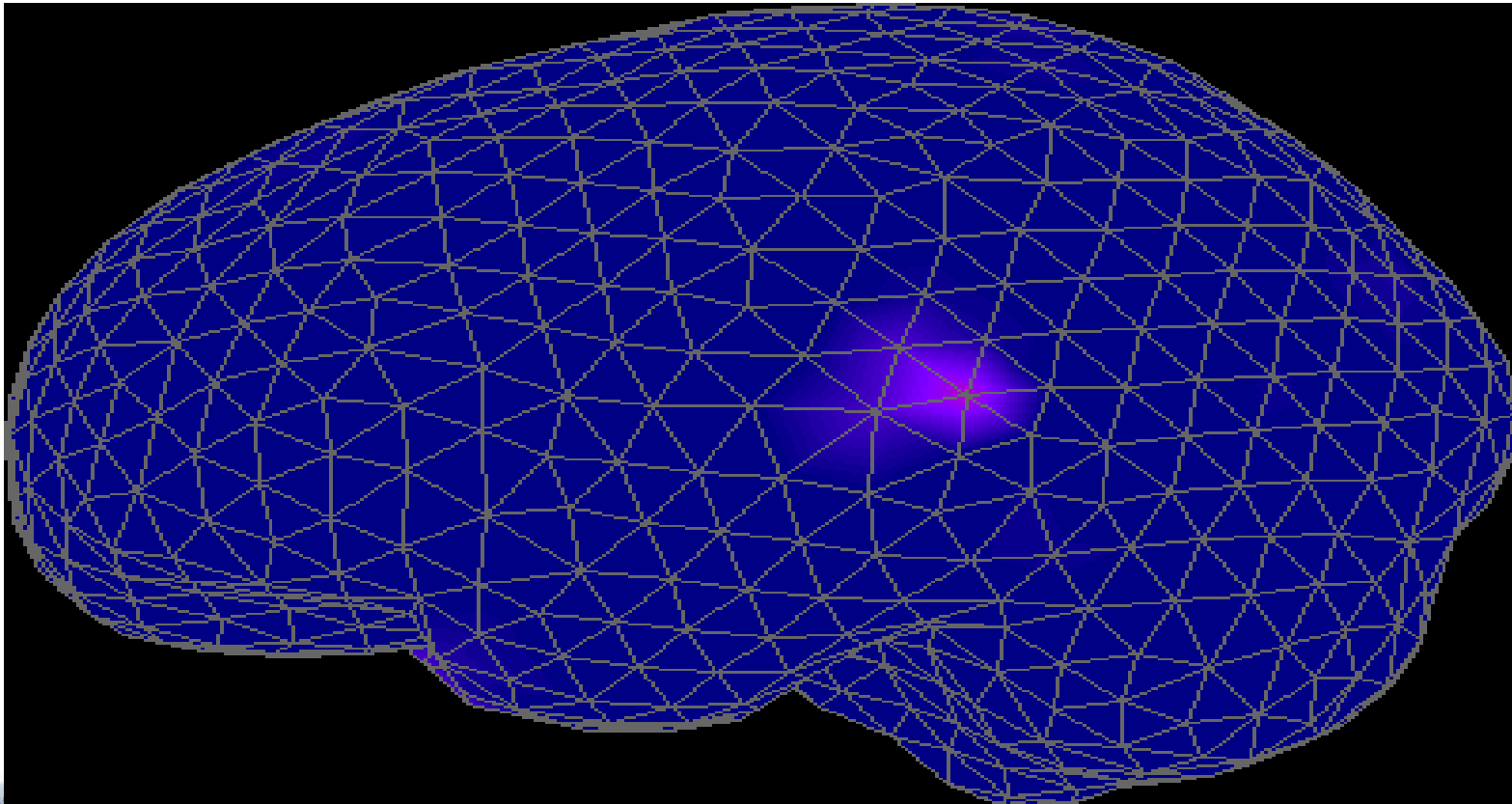
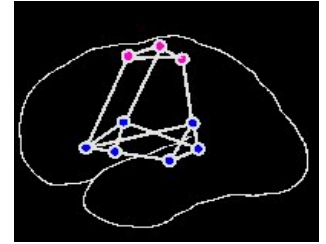
 **Mouth Action**



# Somatotopy of actions words and actions (fMRI)



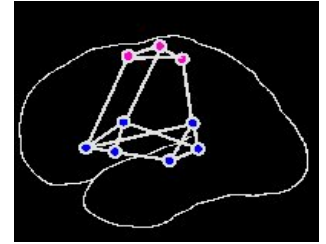
# Word-related neuronal ensembles distributed over perisylvian cortex



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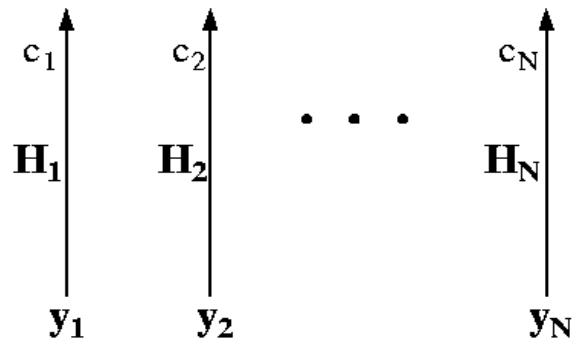
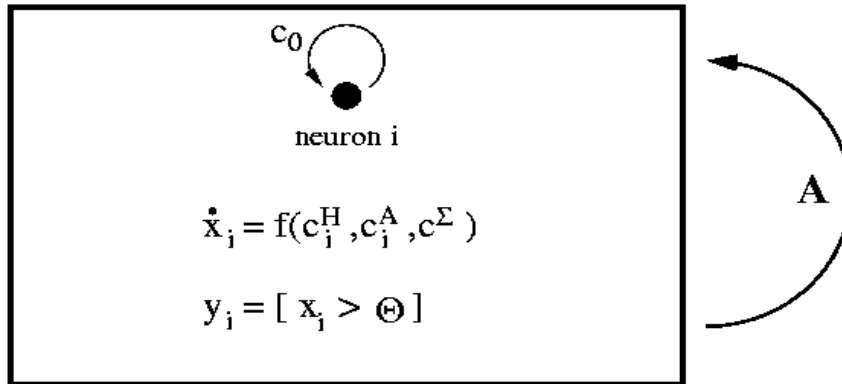
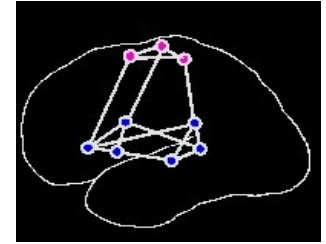
## *Findings*



- Performed actions, visually observed actions and actions described in language are associated with related cortical circuits
- The cortical circuits are topologically organised as areas for mouth, hand and leg areas
- How do we model these findings for language, vision, motor control?



# Associative spike counter model for a cortical language area

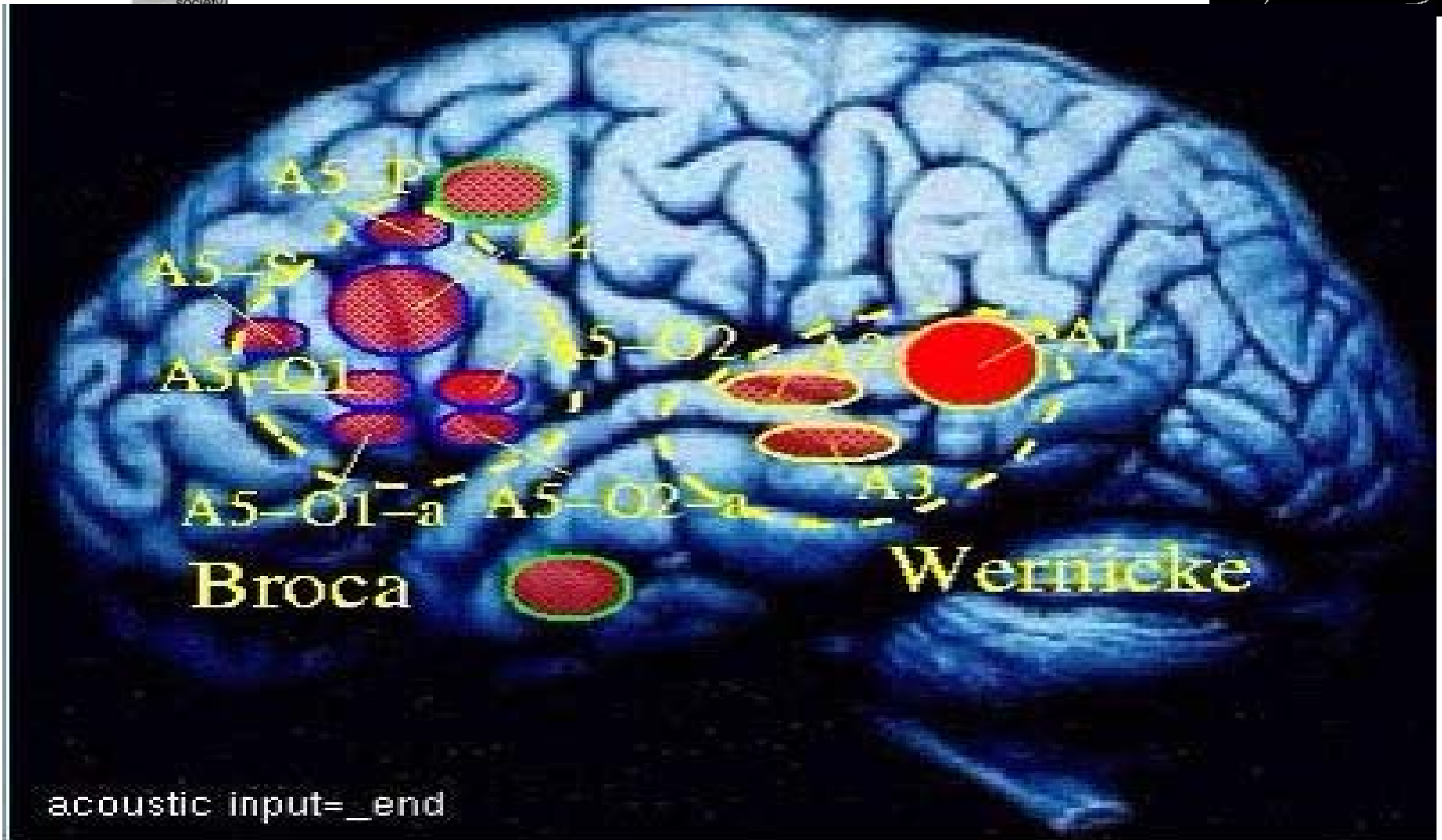
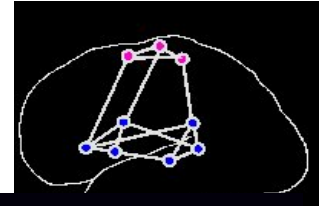


- spiking variant of binary Willshaw associative memory
- requires sparse binary patterns
- binary memory matrices:  
A auto-associative  
 $H_i$  hetero-associative
- sequence processing by delayed feedback (in H)





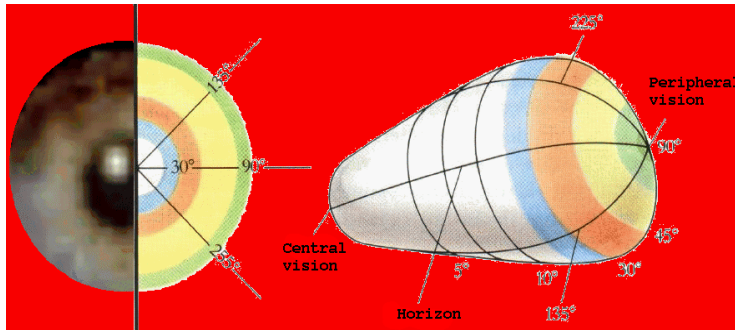
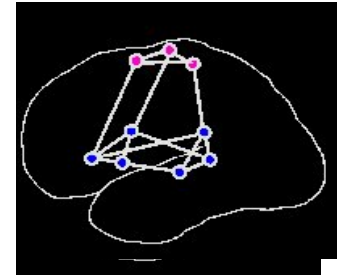
# Language areas of MirrorBot: Bot show red apple



acoustic input=\_end



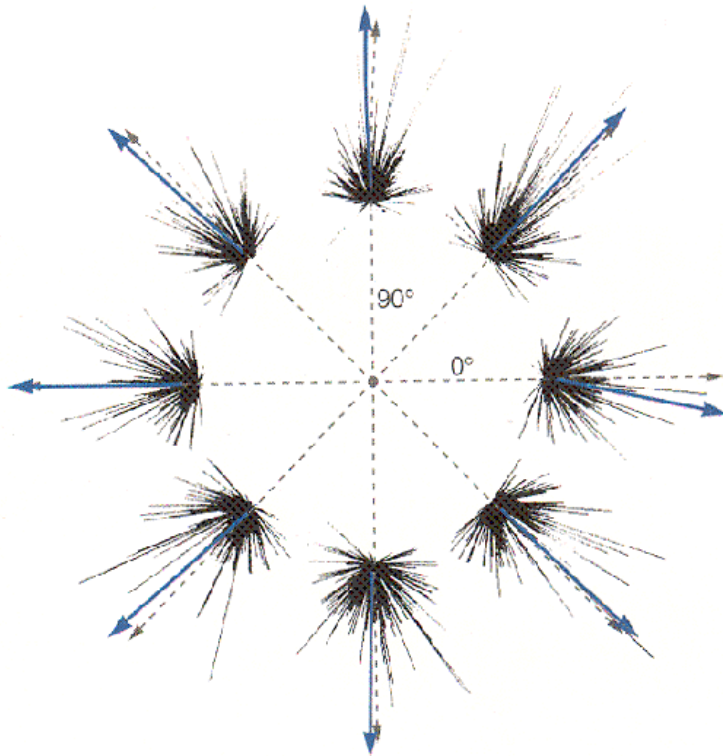
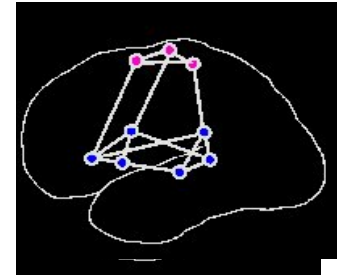
# Visual encoding



- Non-uniform distribution on the retina
- Visual neural filters
- Overlapping receptive fields



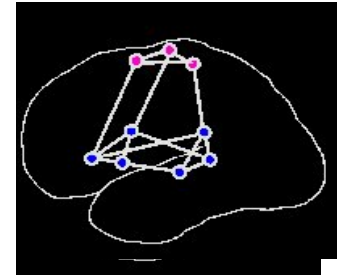
# Motor encoding



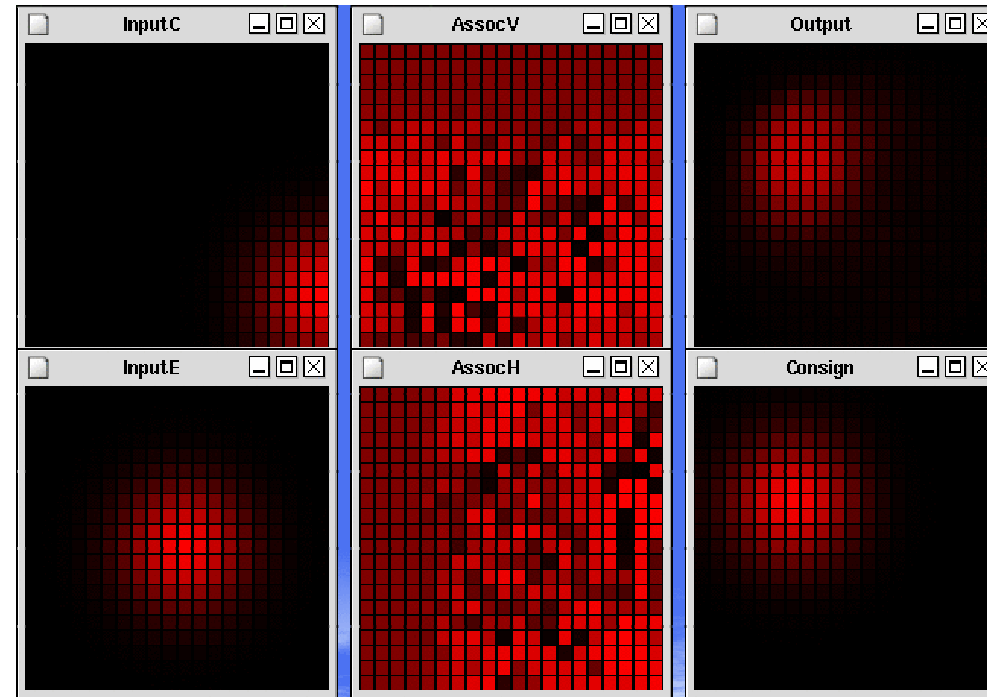
- Maximal activities when movement in preferred direction of neuron
- In M1, topographic organization: neighboring neurons have similar preferred directions
- Neural maps realise population encoding for motor commands



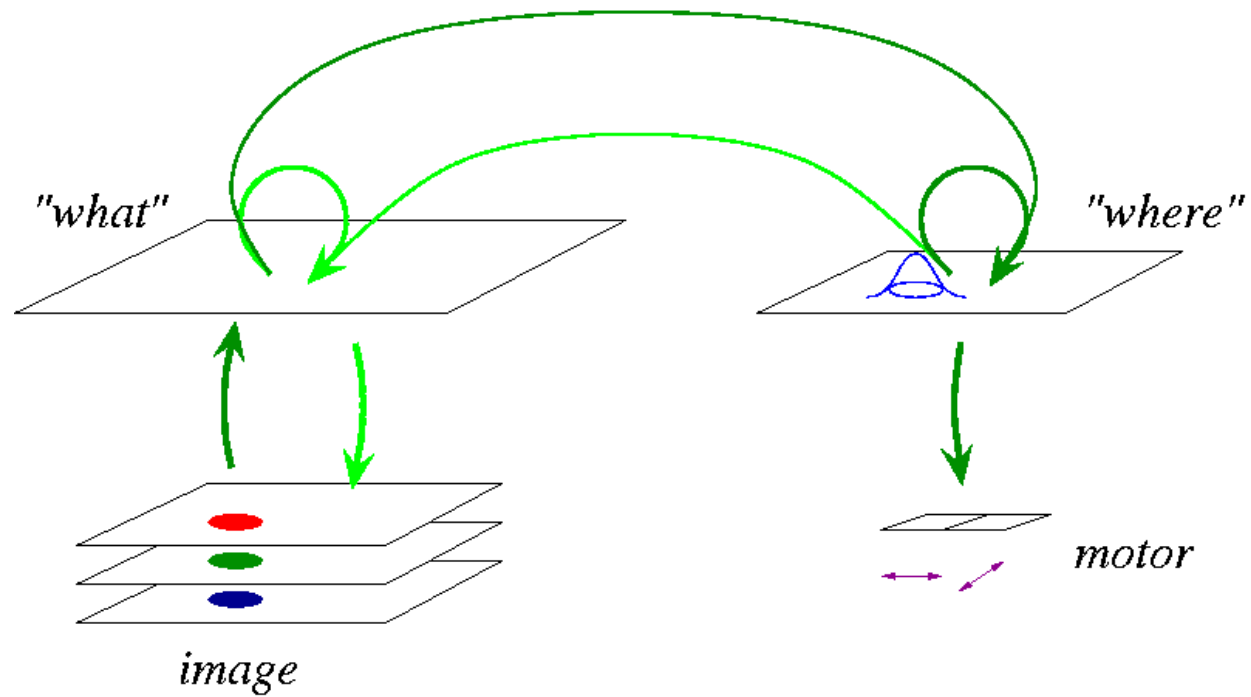
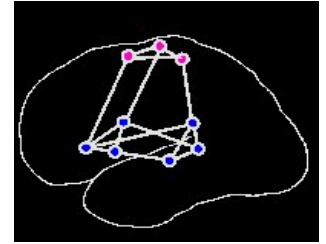
# Associative model for sensor motor representation



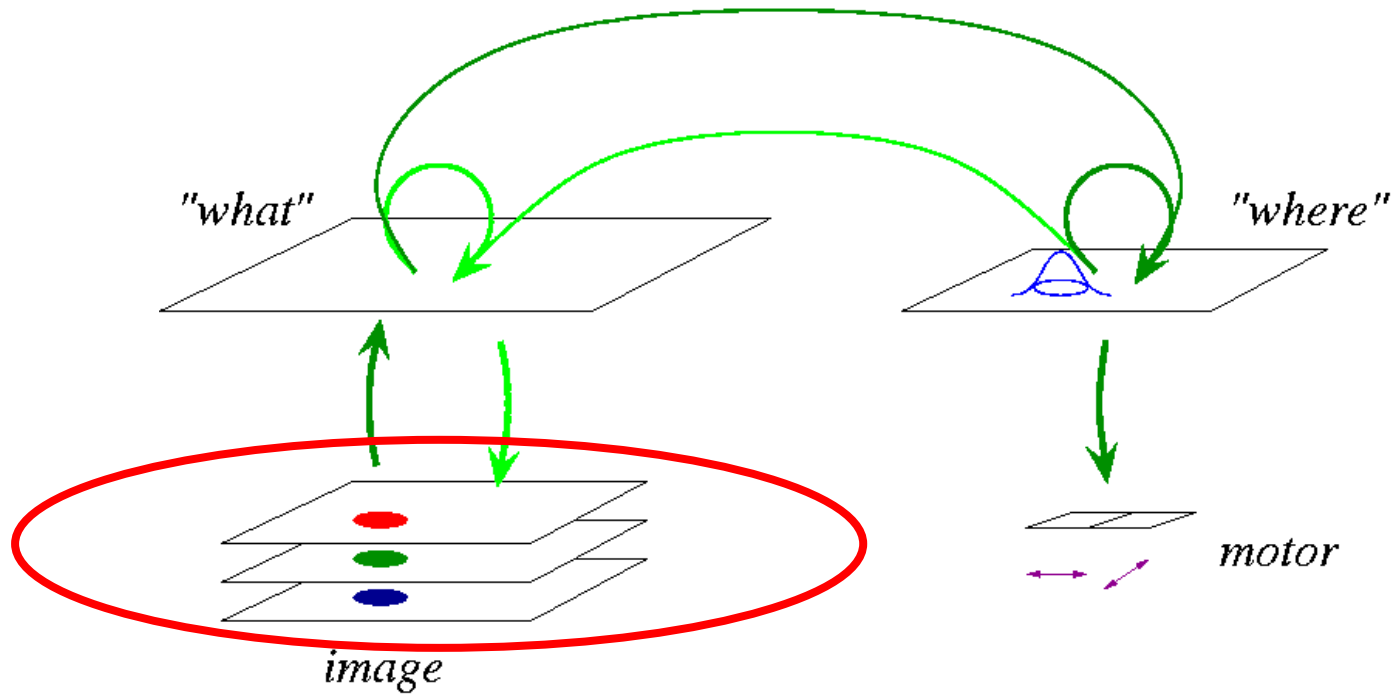
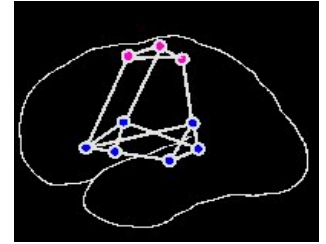
- control of saccadic eye movements towards a target



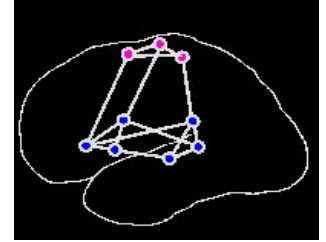
# Associative network for "Bot show orange"



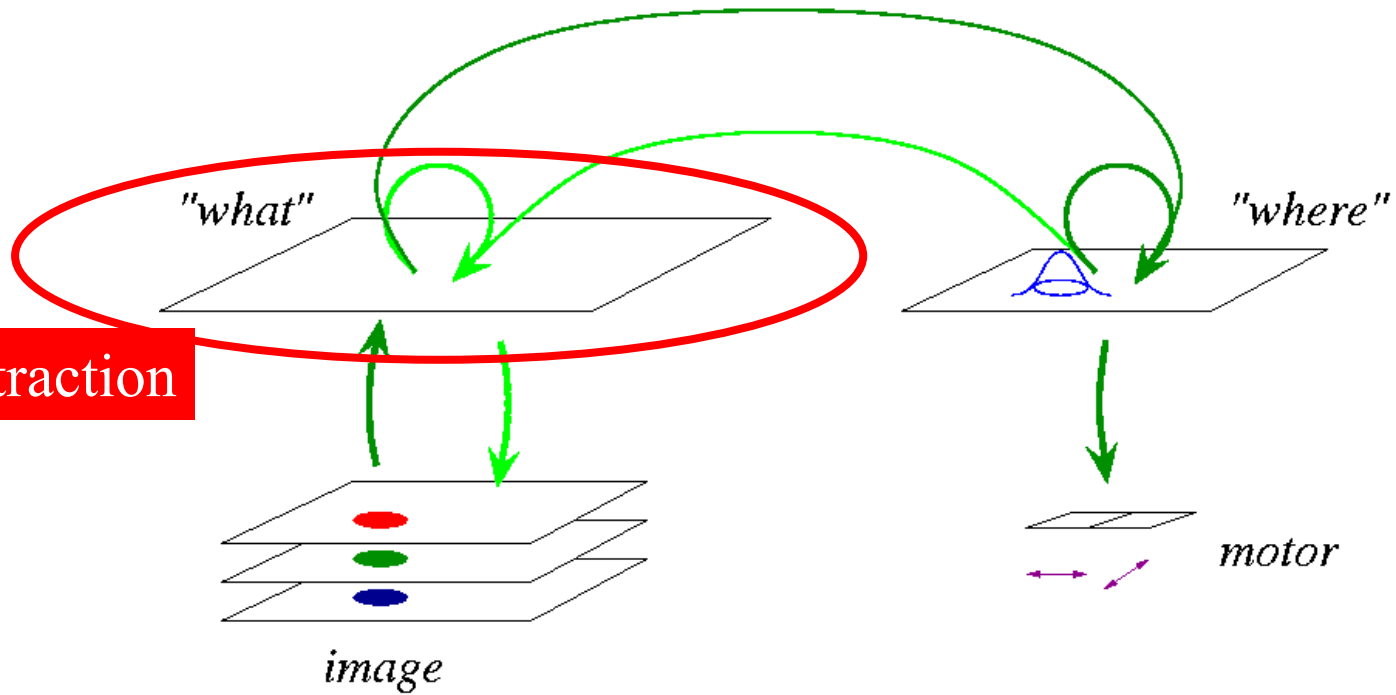
# Associative network for "Bot show orange"



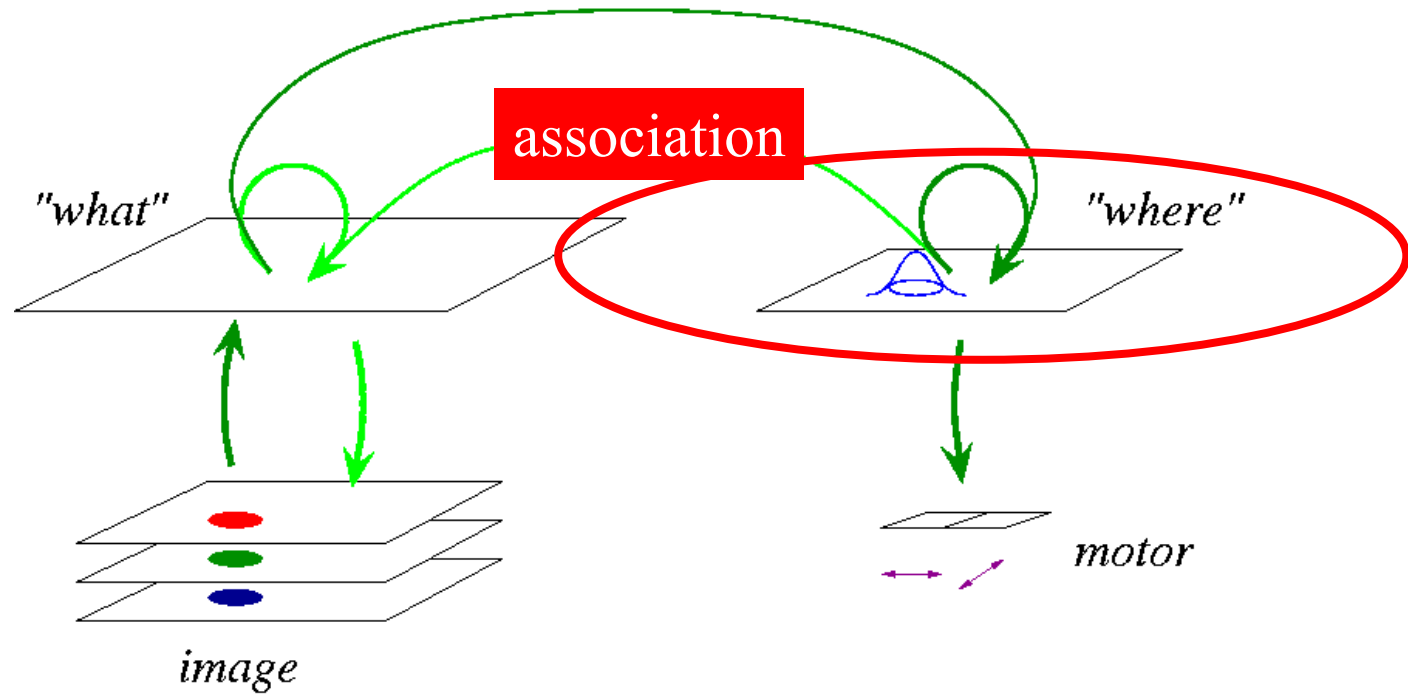
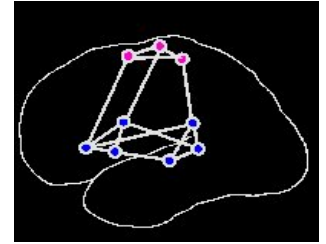
# Associative network for "Bot show orange"



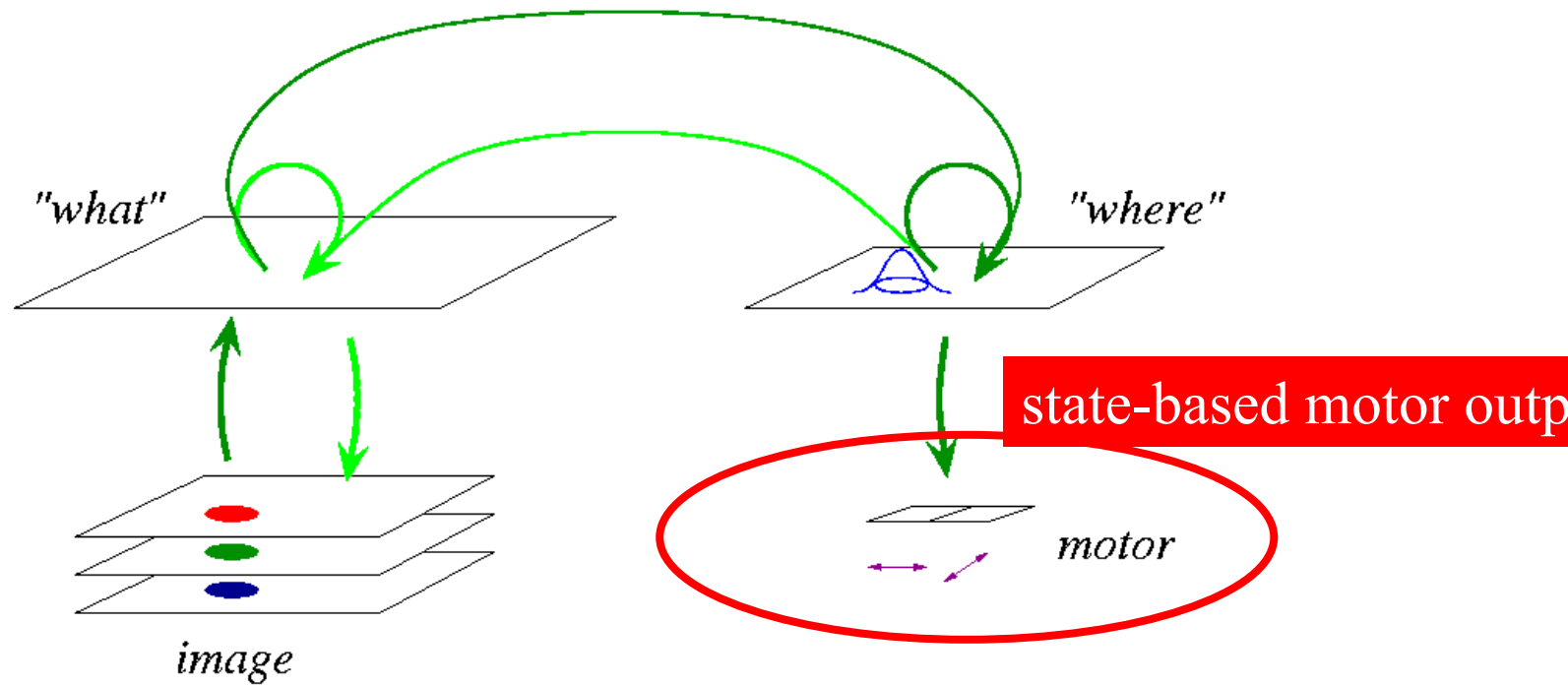
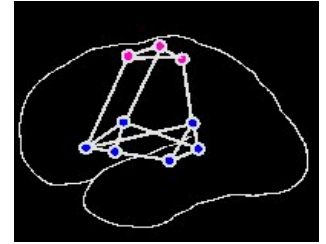
feature extraction



# Associative network for "Bot show orange"

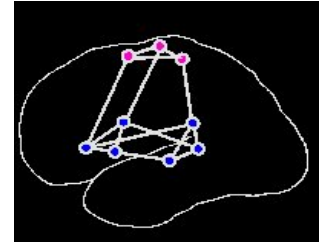


# Associative network for "Bot show orange"





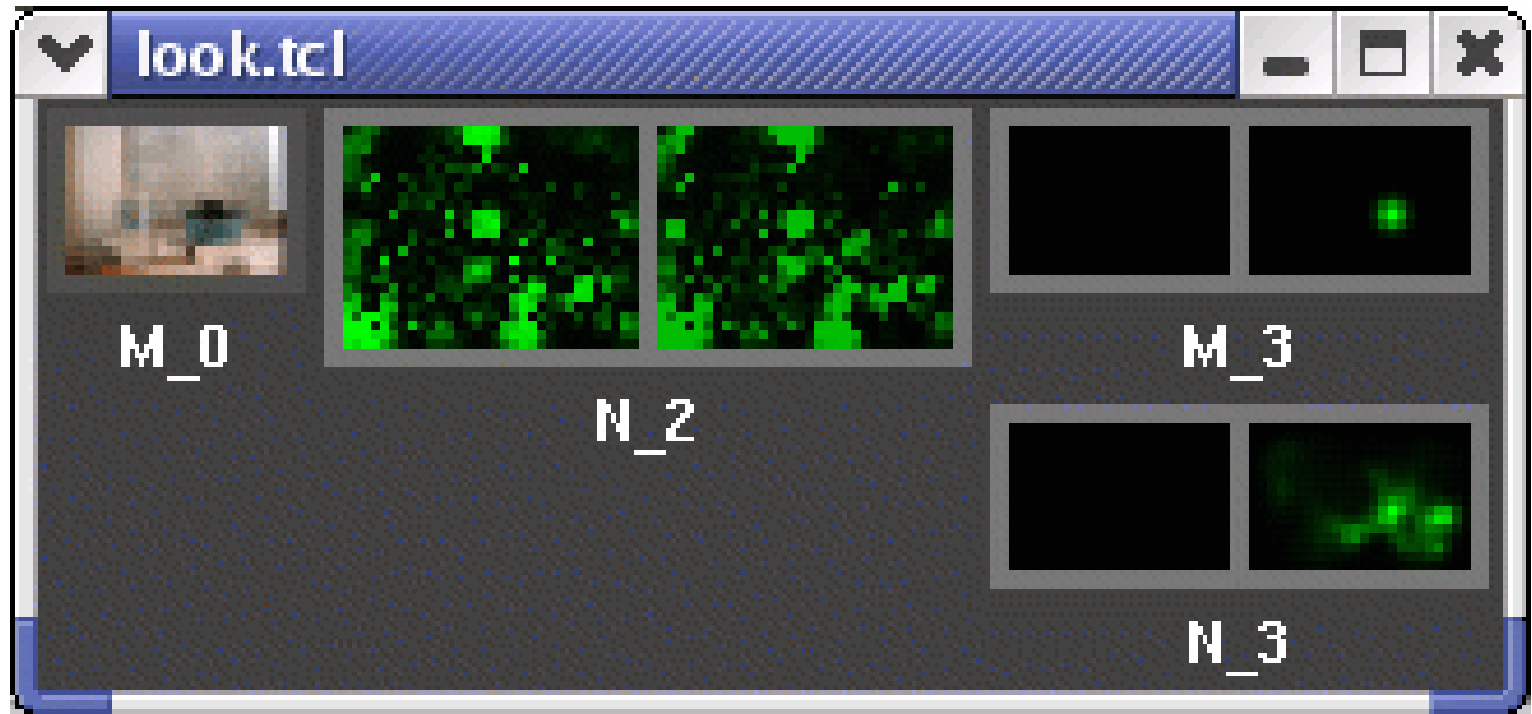
# Network activations



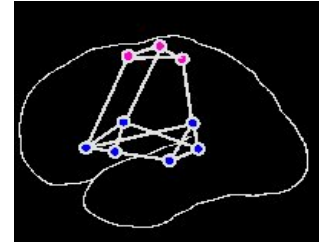
Image

“what”

“where”



# Docking



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# MirrorBot website

MirrorBot - Microsoft Internet Explorer provided by VNU New Media - www.vnunet.com

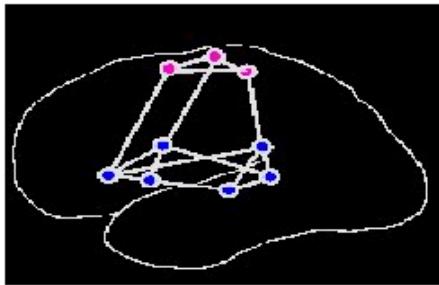
File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites Media Print Mail News Go Links

Address <http://www.his.sunderland.ac.uk/mirrorbot/>

## MirrorBot

**Biomimetic multimodal learning in a mirror neuron-based robot**

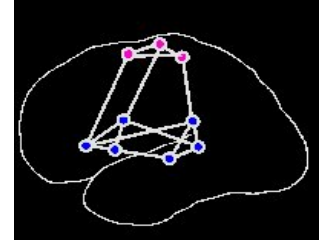
<a href="#">Project Description</a>	<a href="#">Contact</a>	<a href="#">Partners</a>	<a href="#">Location</a>
<a href="#">Research Groups</a>		<a href="#">HIS Site</a>	
<a href="#">Positions</a>		<a href="#">Associations</a>	
<a href="#">MirrorBot Internal</a>		<a href="#">Associated Staff</a>	
<a href="#">Events</a>	<a href="#">Related EU Projects</a>	<a href="#">Journals</a>	<a href="#">Publications</a>

Done Local intranet

■ [www.his.sunderland.ac.uk/mirrorbot/](http://www.his.sunderland.ac.uk/mirrorbot/)



## Conclusions

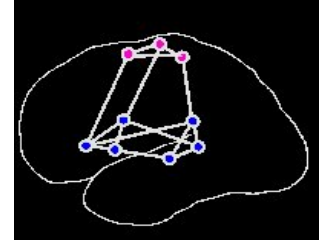


- Experiments on action-oriented cortical organisation
- Computational models for language, vision, action on robot
- Aim towards mirror neuron-based association of multiple modalities in neural models





## European MirrorBot Workshop



- A multidisciplinary approach for the study of frontal cortex
- 20 October 2003, Convention Centre, Nancy, France
- [www.his.sunderland.ac.uk/mirrorbot/](http://www.his.sunderland.ac.uk/mirrorbot/)



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Project funded by the Future and Emerging Technologies arm of the IST Programme  
FET-Open scheme