Modélisation du développement des couplages Homme/Homme et Homme/robot

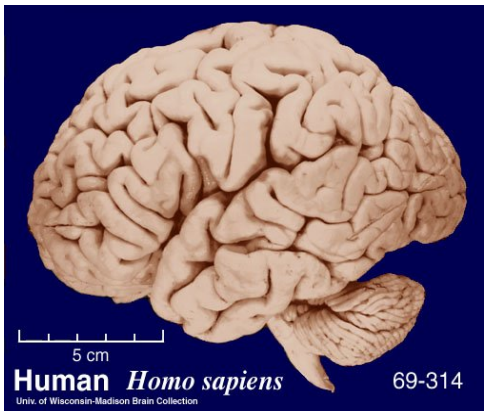
P. Gaussier

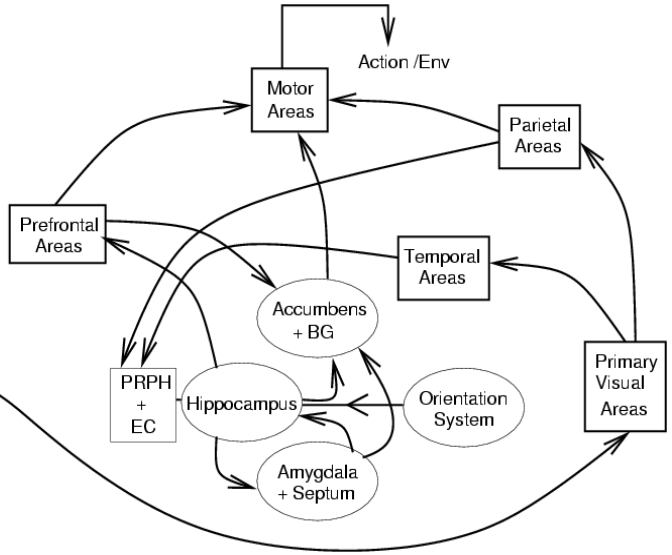
Dans notre labo.:

approche Neuro-cybernetique des sciences cognitives

Les robots comme outils pour modéliser le cerveau

Cognition, cerveau, neurones...





- Développement
- Interactions sociales

Les limites d'une approche réductioniste...

Laboratoire « Virtuel »

Travail en collaboration avec:

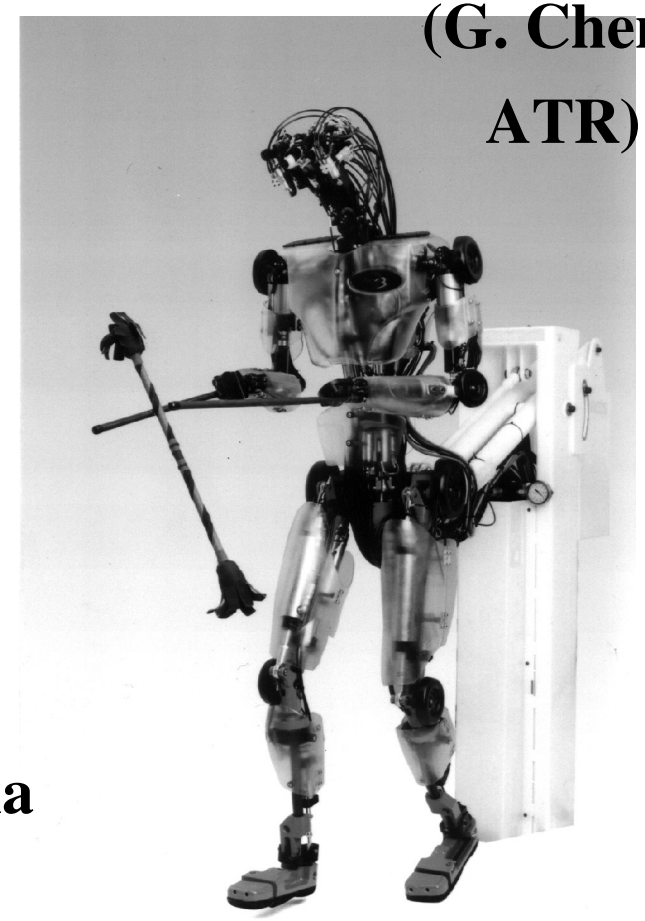
- Jean Paul Banquet : modélisation neurobiologique
- Bruno Poucet (Marseille 3C): neurobiologie
- Jacqueline Nadel: psycho pathologie du développement
- Projet européen Feelix growing (L. Canamero)

Les robots humanoides

Cog

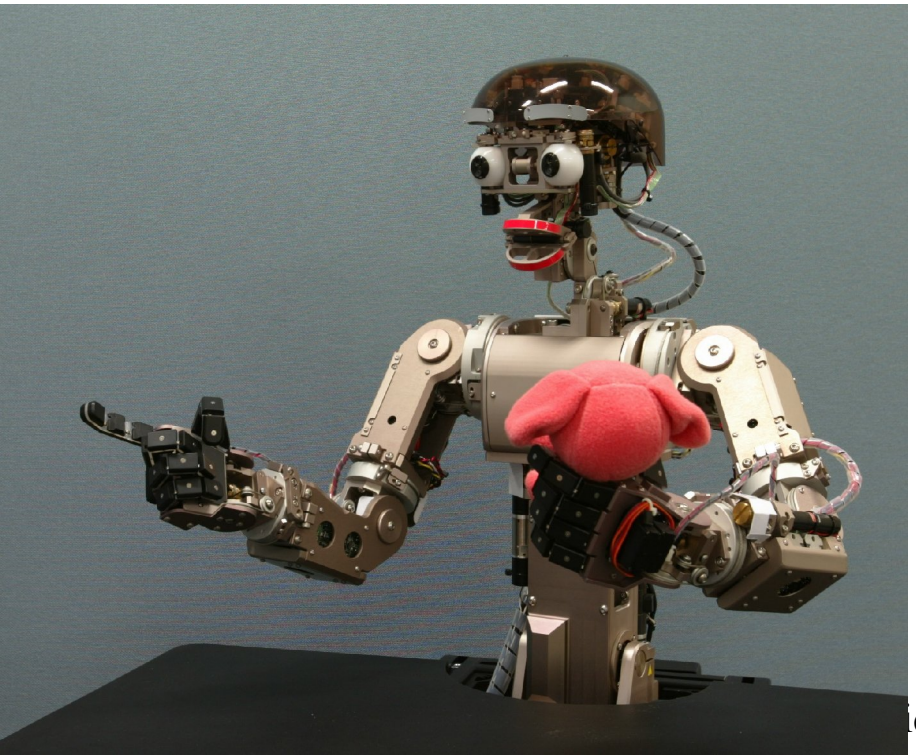
(R. Brooks

MIT)



(G. Cheng

ATR)



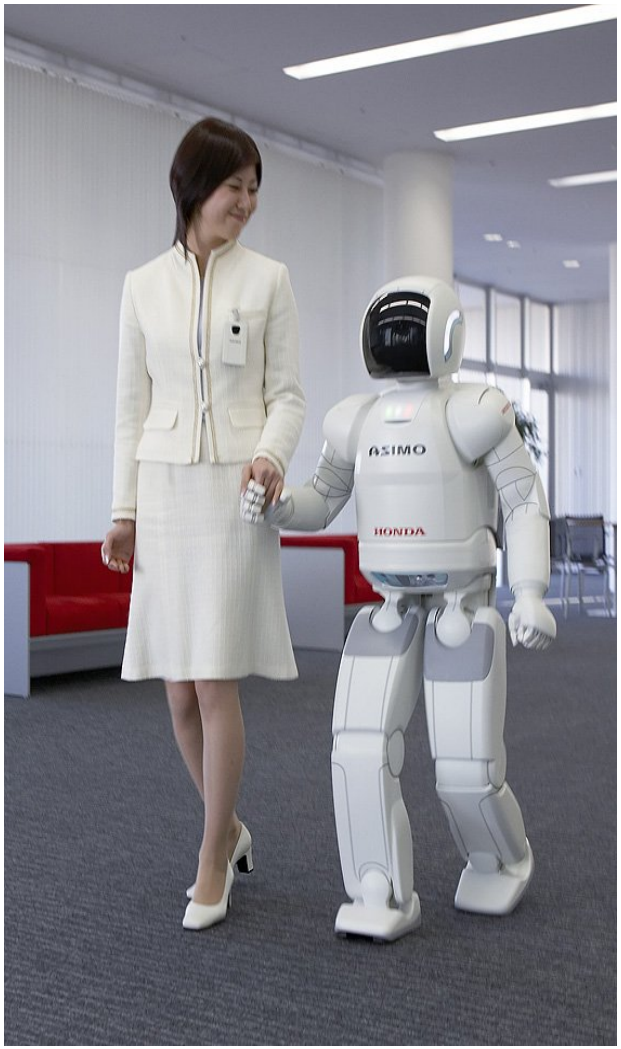
Infanoid

(I. Kosima

NICT)

…

Les robots quel type d'artefact?



Des ordinateurs champions d'échecs
Mais des robots qui ne savent pas très bien tenir debout ni mettre la table !!

Qu'est ce que la Perception ?

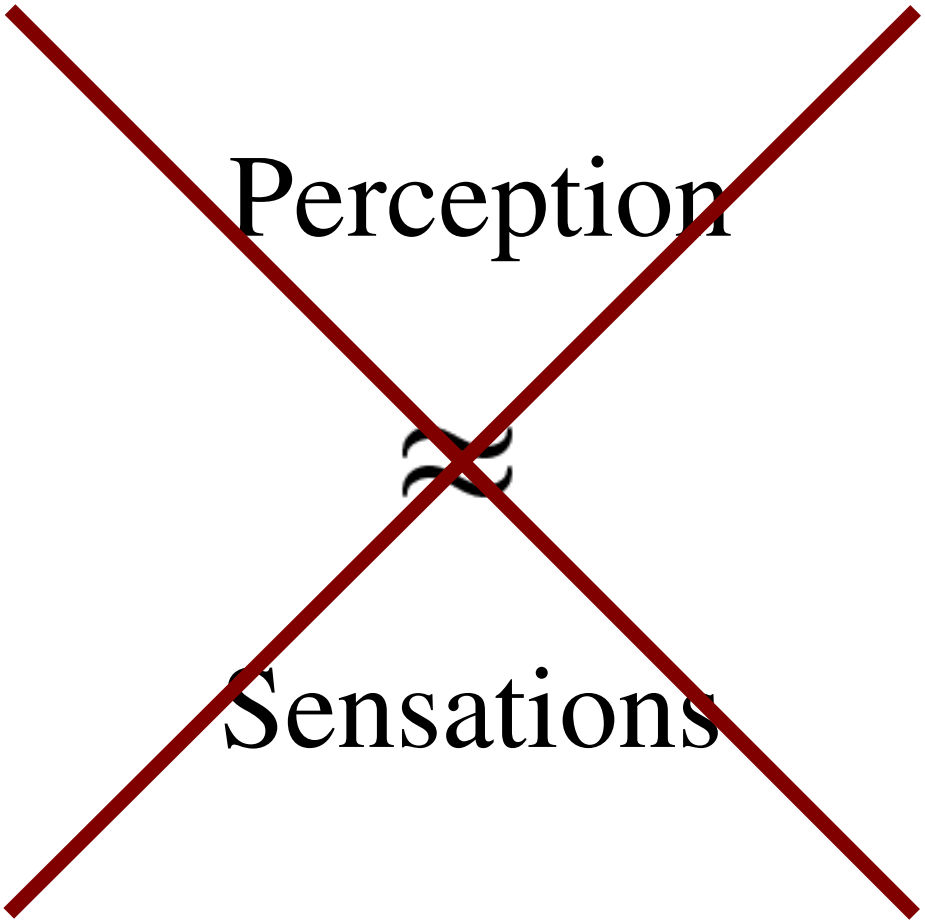
Perception

≈

Sensations

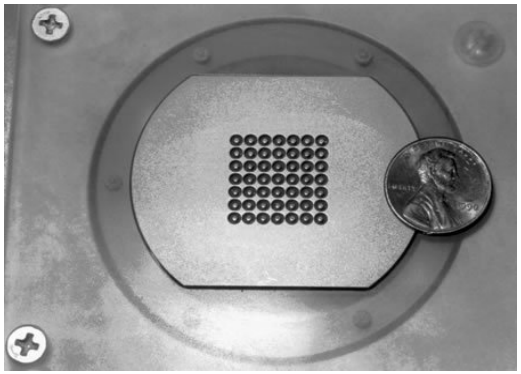
?

Qu'est ce que la Perception ?



Qu'est ce que la Perception ?

· Experiences en psychologie : Bach-y-Rita 1972



JRRD

Bach-y-Rita

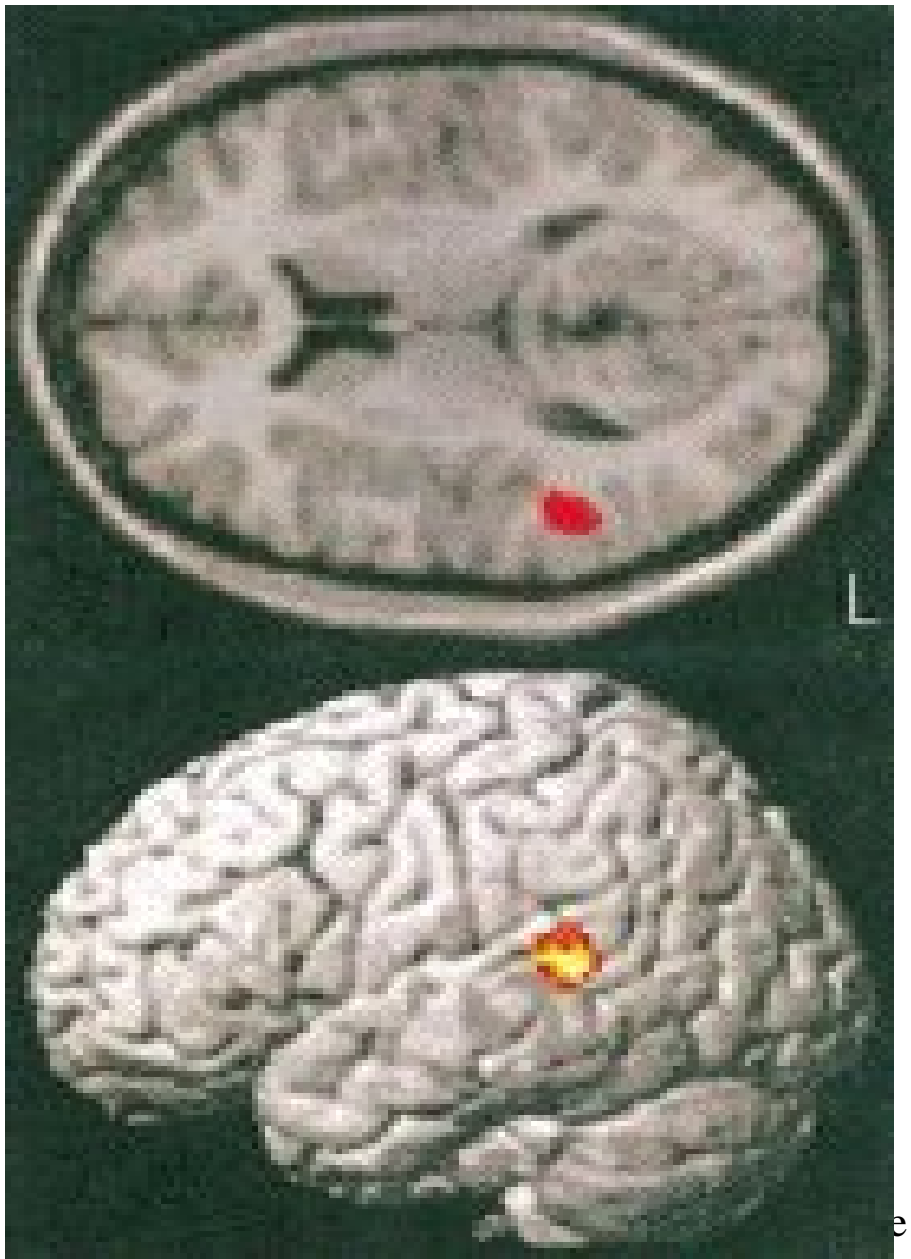
http://www.vard.org/jour/98/35/4/bachr354.htm

-> Très mauvaises performances sans action

-> Exteriorisation de la perception si action

Quel est le bon niveau pour étudier et modéliser les mécanismes cognitifs?

Imagerie médicale (PET, MRI...)

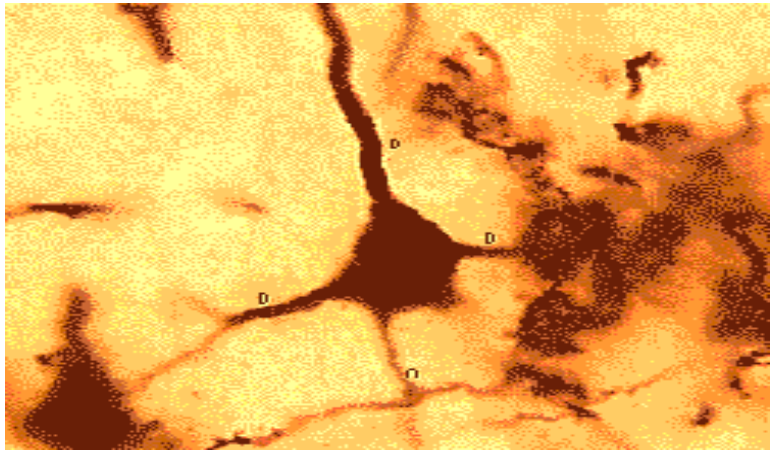


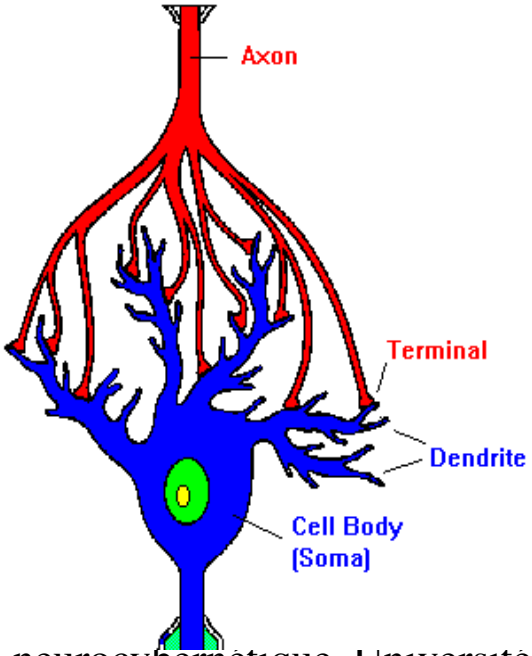
Activité différentielle de certaines structures cérébrales

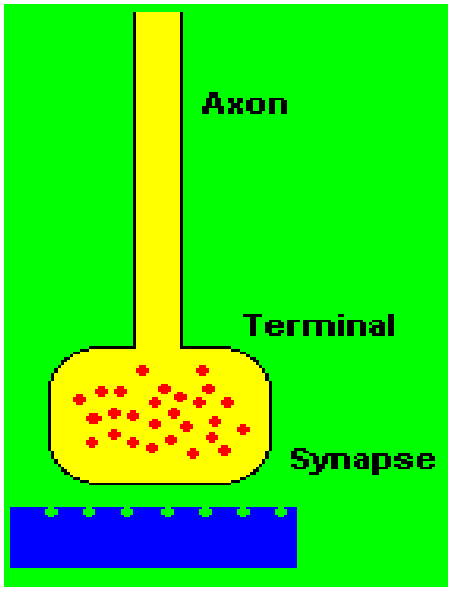
(ici durant une tache d'imitation)

[Decety et al. 02]

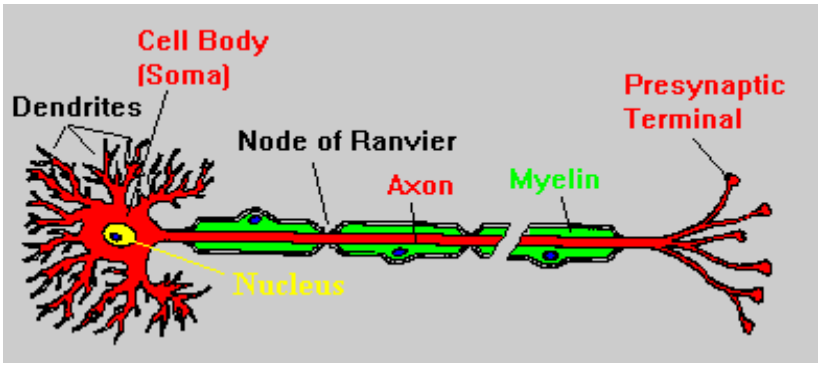
Ou au niveau neuronal ?



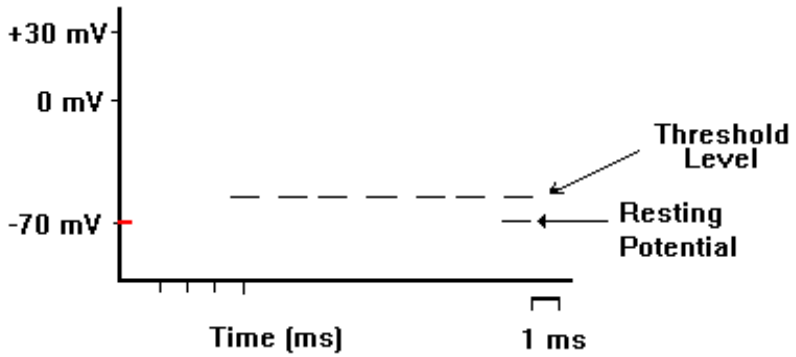


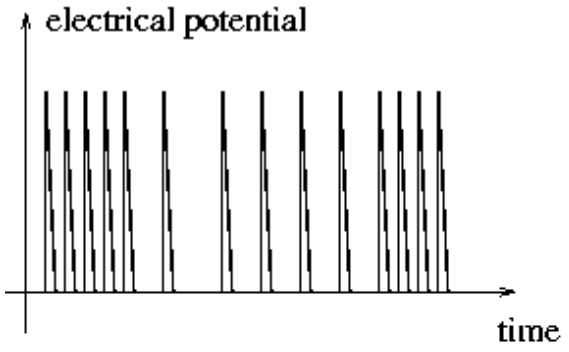


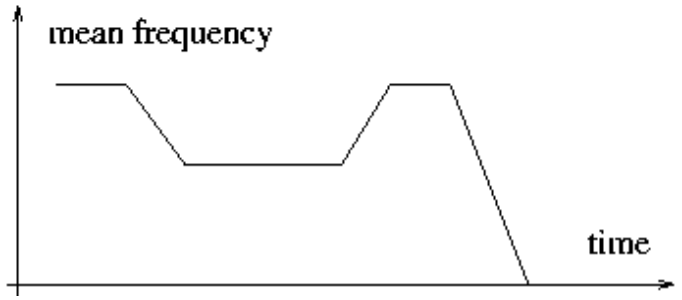
Modéliser l'activité neuronale?



Potentiels d'action







Anatomie du système visuel

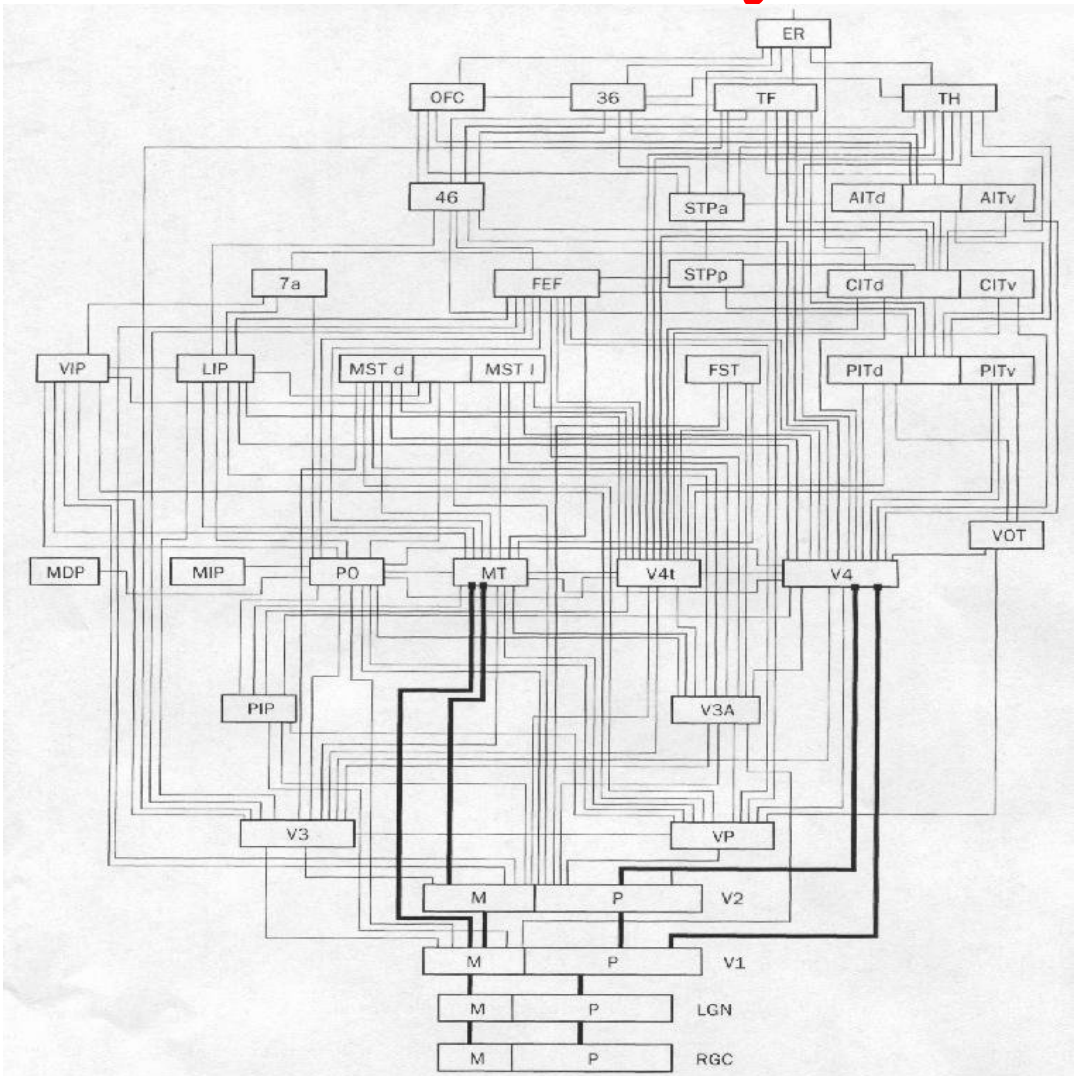


FIGURE 4.15 Diagram showing the hierarchical arrangement of visual processing stages, starting with the retina (bottom of diagram) and moving up through the multiple visual areas of the brain. The bold lines show the P and M pathways discussed in the text. (Adapted from Felleman and Van Essen, 1991.)

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Syst. Visuel des Primates

Trop complexe?

Comment tester un modèle à ce niveau?

Comment acceder au sens?

Y a t'il un code?

Pas de convention pré établie

Processus analogiques
/
non discrétisables

Notre approche

Trouver un modèle minimal justifié par des arguments théoriques forts:

- Prendre en compte un **minimum** de structures biologiques,
- Essayer de comprendre ce qu'apporte une entrée ou structure donnée pour un comportement global (sinon pas pris en compte),
- Utiliser les robots pour tester les implications comportementales d'un modèle (preuve par l'échec!)

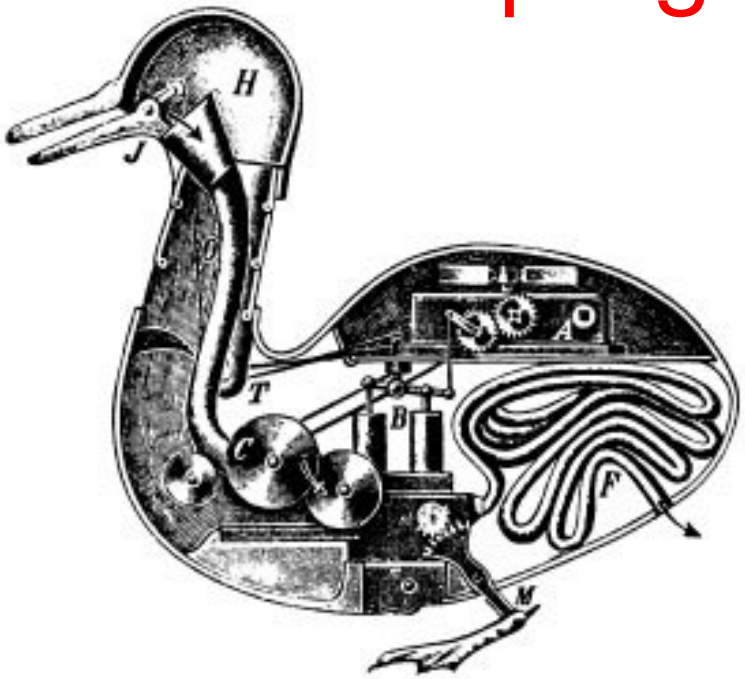
PLAN

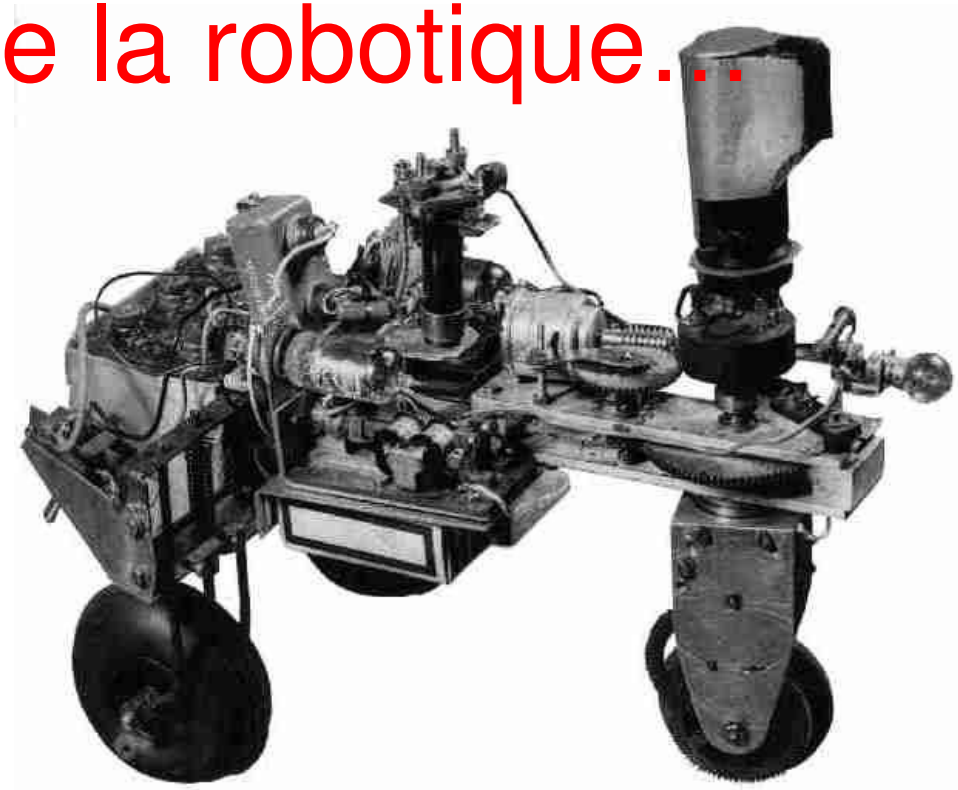
1. Notion de perception en tant que propriétés « émergentes »
   => couplages avec le monde physique
2. L'imitation
3. Les interactions (problèmes et intéret)
4. Artefacts et émotions
5. Conclusion

PARTIE 1

Etudes comportementales
de petits systèmes sensori-moteurs

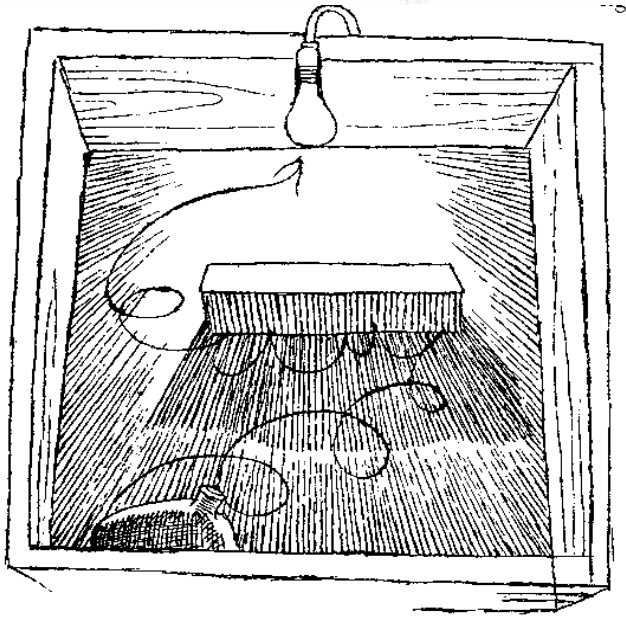
Les progrès de la robotique…





Canard de Vaucanson 1739

Tortue électronique G Walter 1950



Pas si loin des robots d'aujourd'hui…

(même en performances!)

Véhicules de Braitenberg

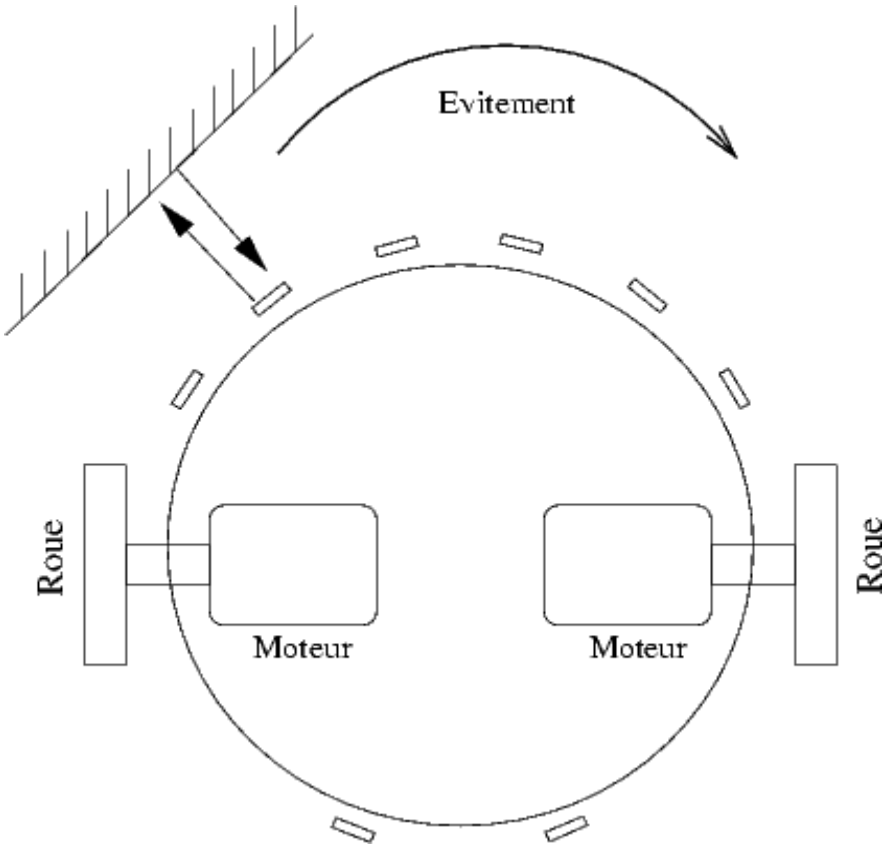
- Phototaxie: attraction par la lumière
- Evitement d'obstacles
- ...

Un réseau de neurones minimal:

- N capteurs
- 2 moteurs

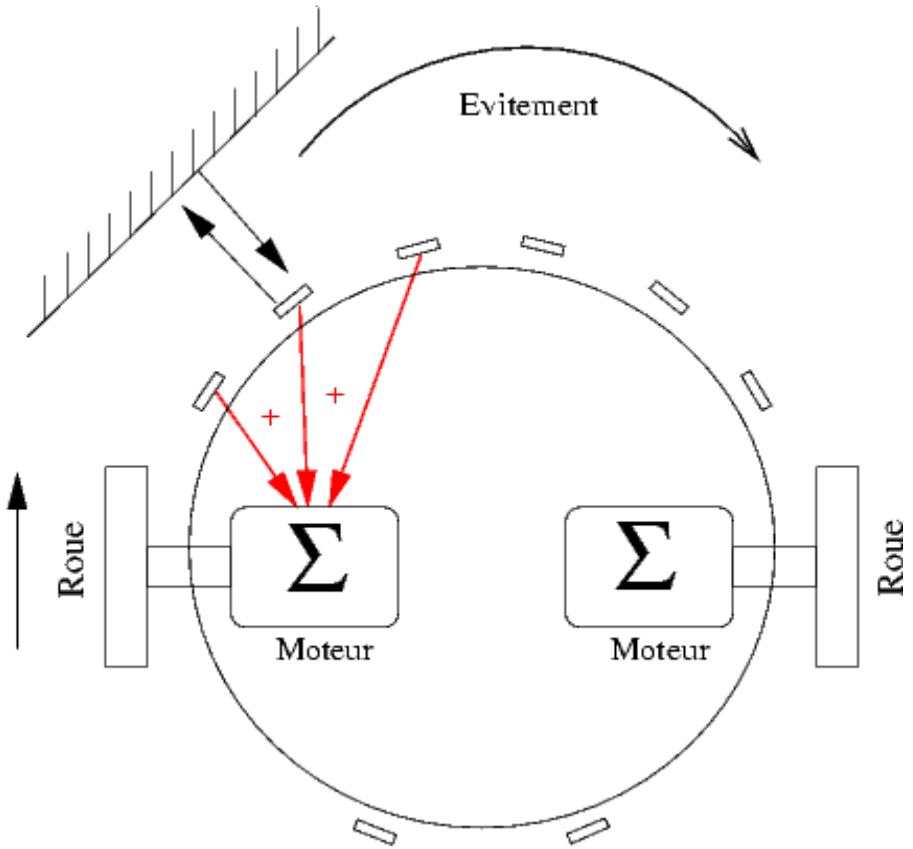
Véhicules de Braitenberg

Evitement d'obstacle



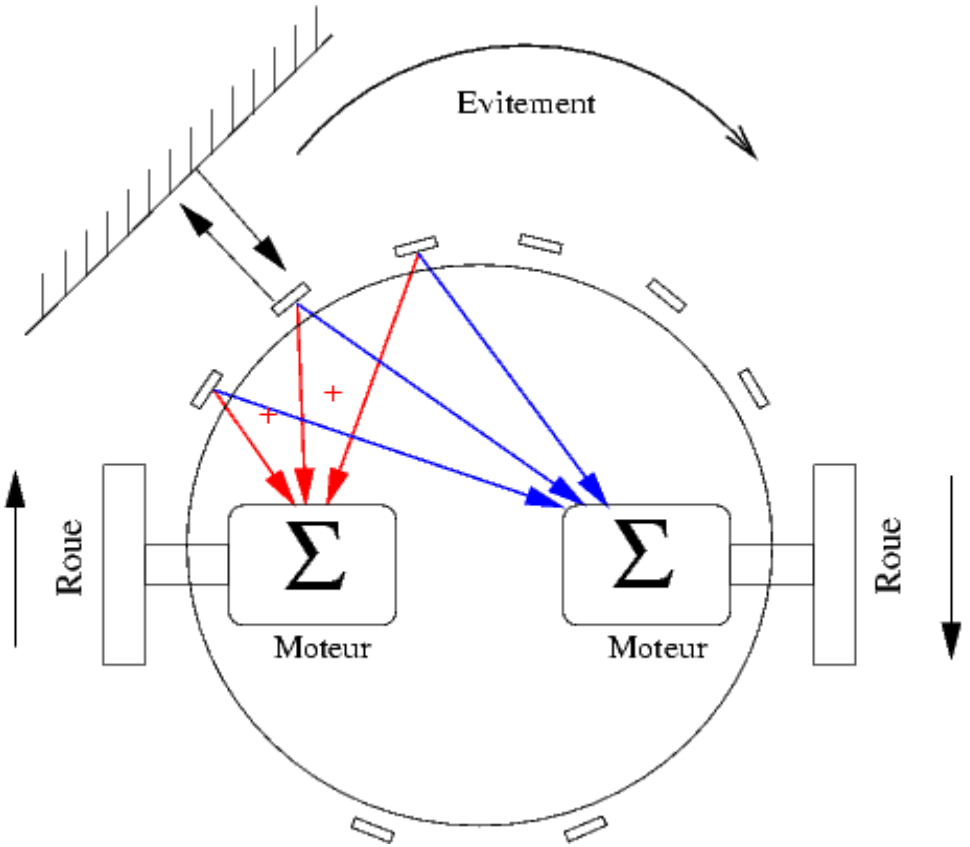
Véhicules de Braitenberg

Evitement d'obstacle



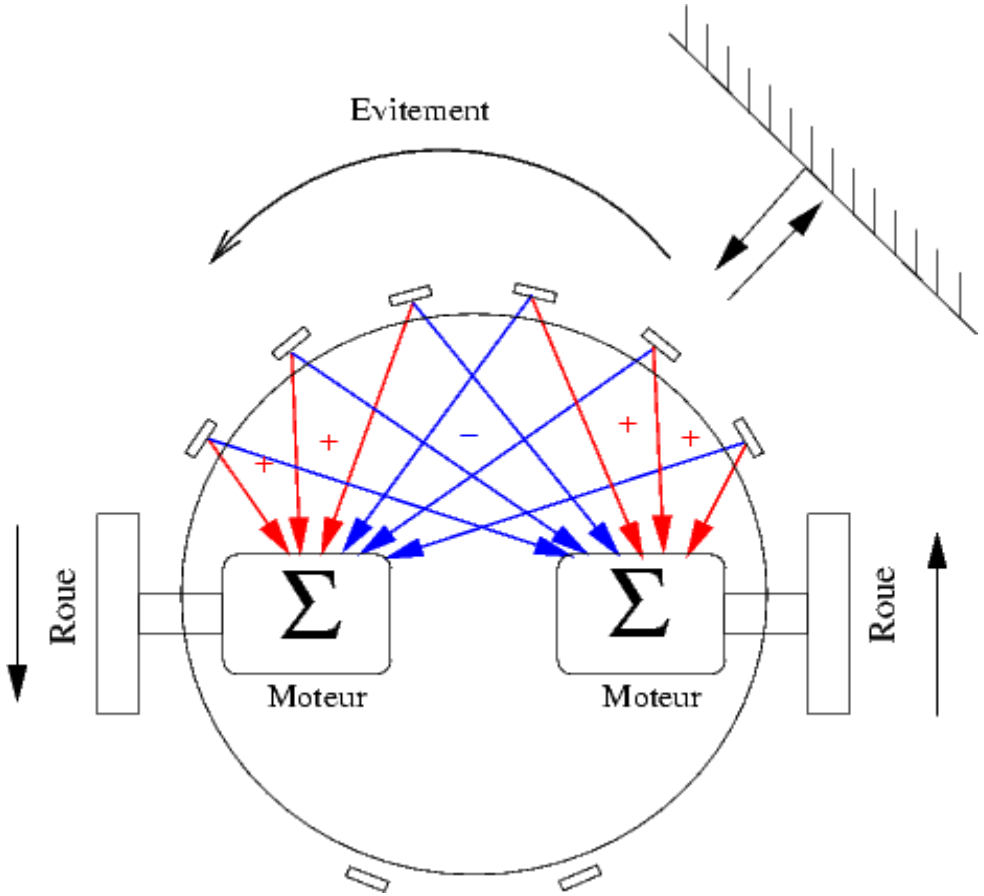
Véhicules de Braitenberg

Evitement d'obstacle



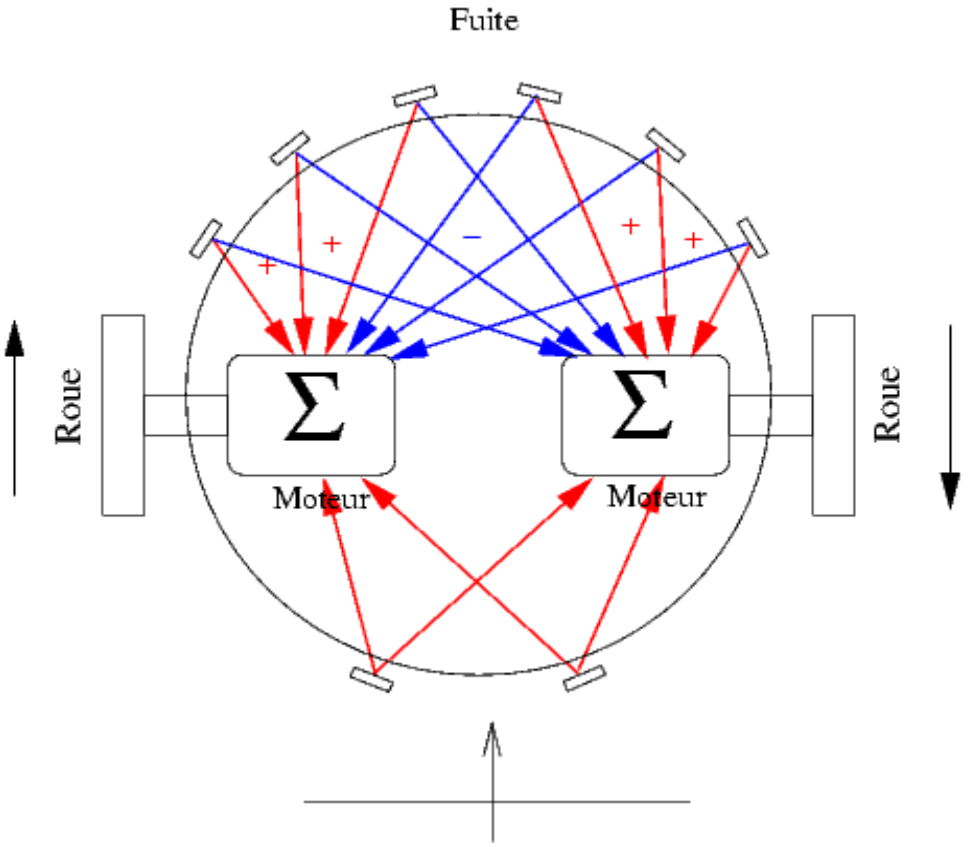
Véhicules de Braitenberg

Evitement d'obstacle



Véhicules de Braitenberg

Ajout d'une capacité à fuir



Fabrication de tas

Etude des fourmilières (Denebourg 92)

Situation initiale

1. Mouvements aléatoires
2. Evitement d'obstacles
3. Prise objet
4. Dépos objet

web site: www.etis.ensea.fr/~neurocyber/Videos/

Fabrication de tas

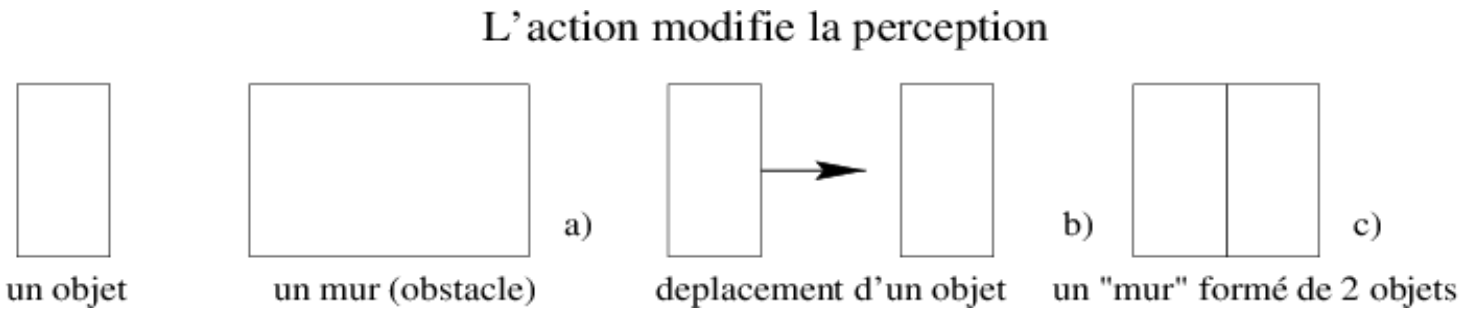
Le comportement n'est pas inscrit dans le réseau...

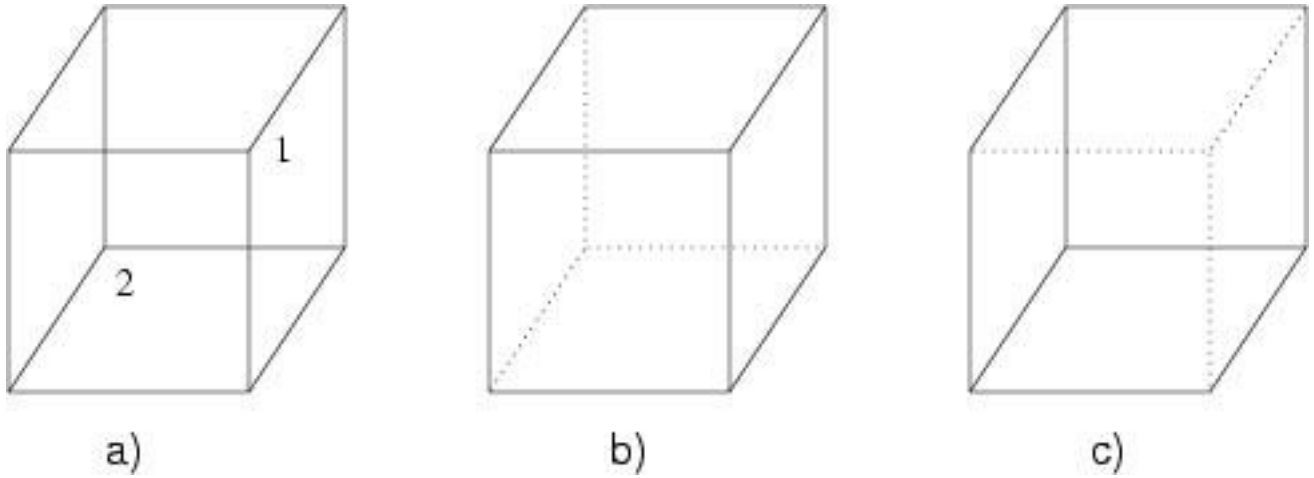
Situation après 30min

web site: www.etis.ensea.fr/~neurocyber/Videos/

L'action modifie la perception

Ambiguité fondamentale de la perception



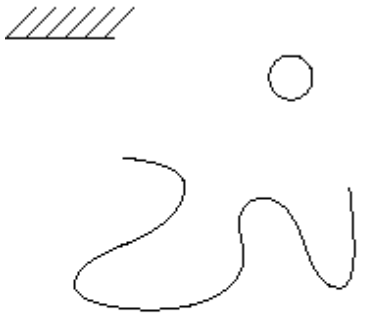


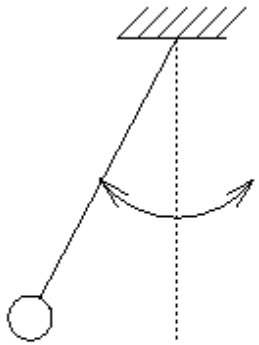
Propriétés émergentes

Théorie de la Gestalt :

« Le tout est plus que la somme de ses parties »

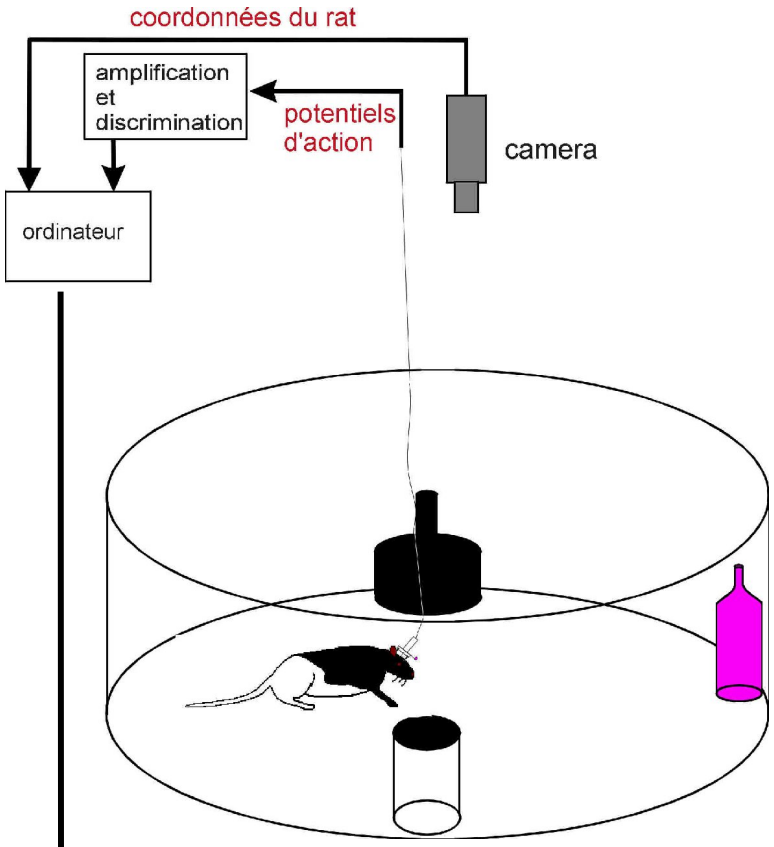
Notion de propriétés émergentes
(importance de la dynamique des interactions entre éléments)

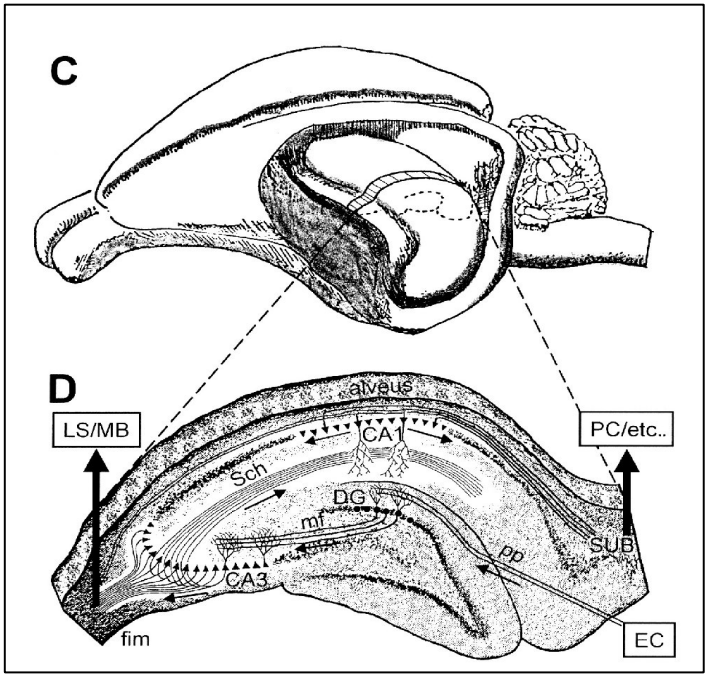


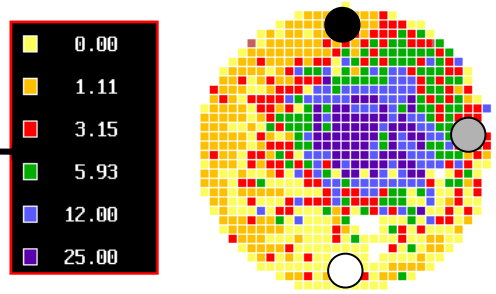


[K. Lorenz73]

Généralisation: Reconnaissance de lieux

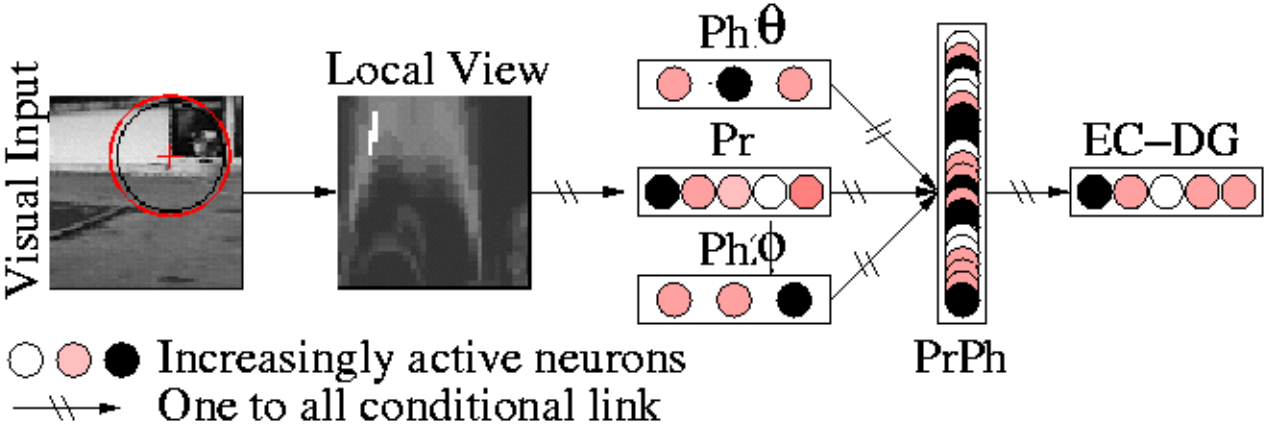




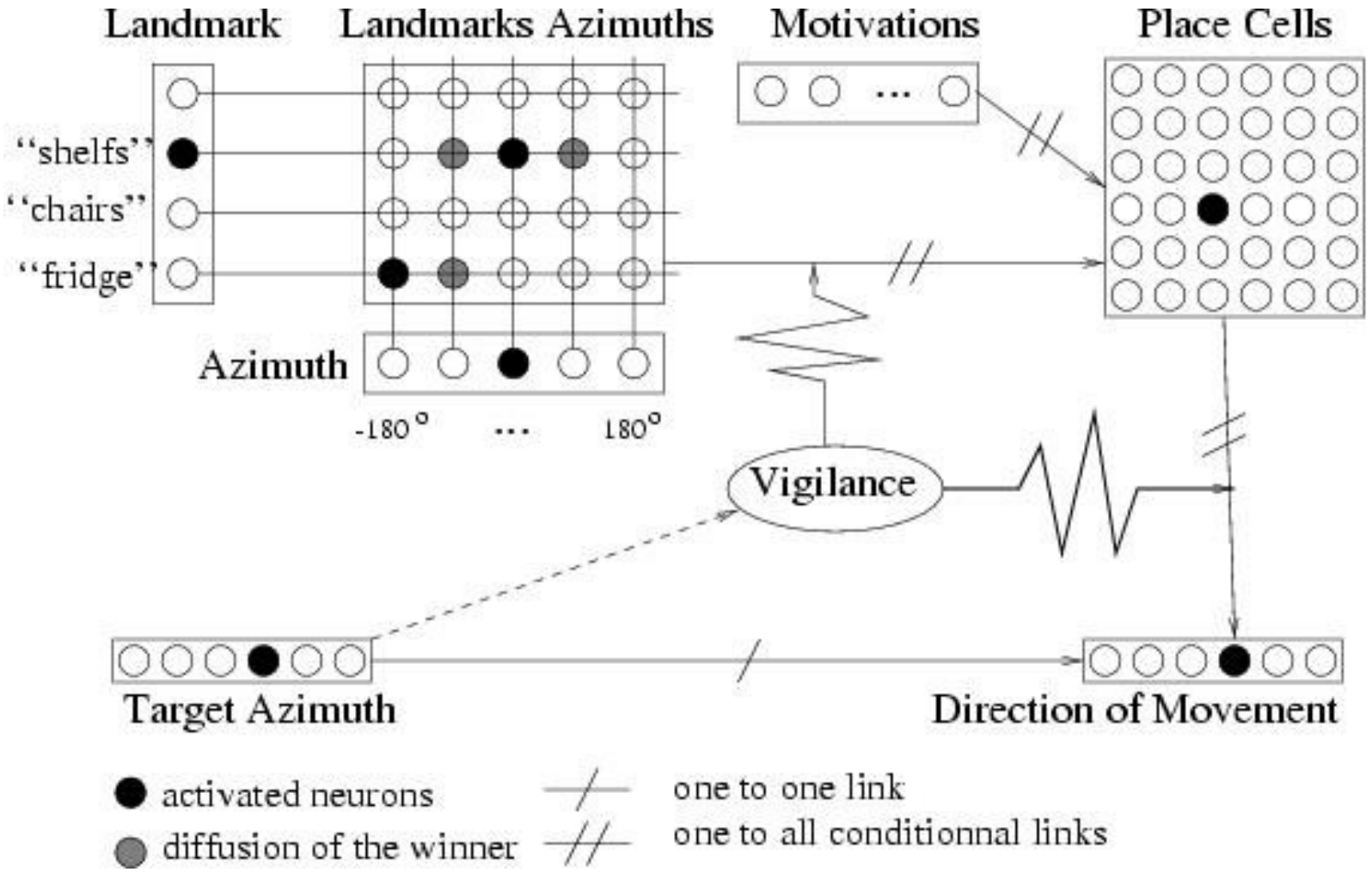


Les cellules de lieu
de l'hippocampe chez le rat
(équipe B. Poucet – Marseille)

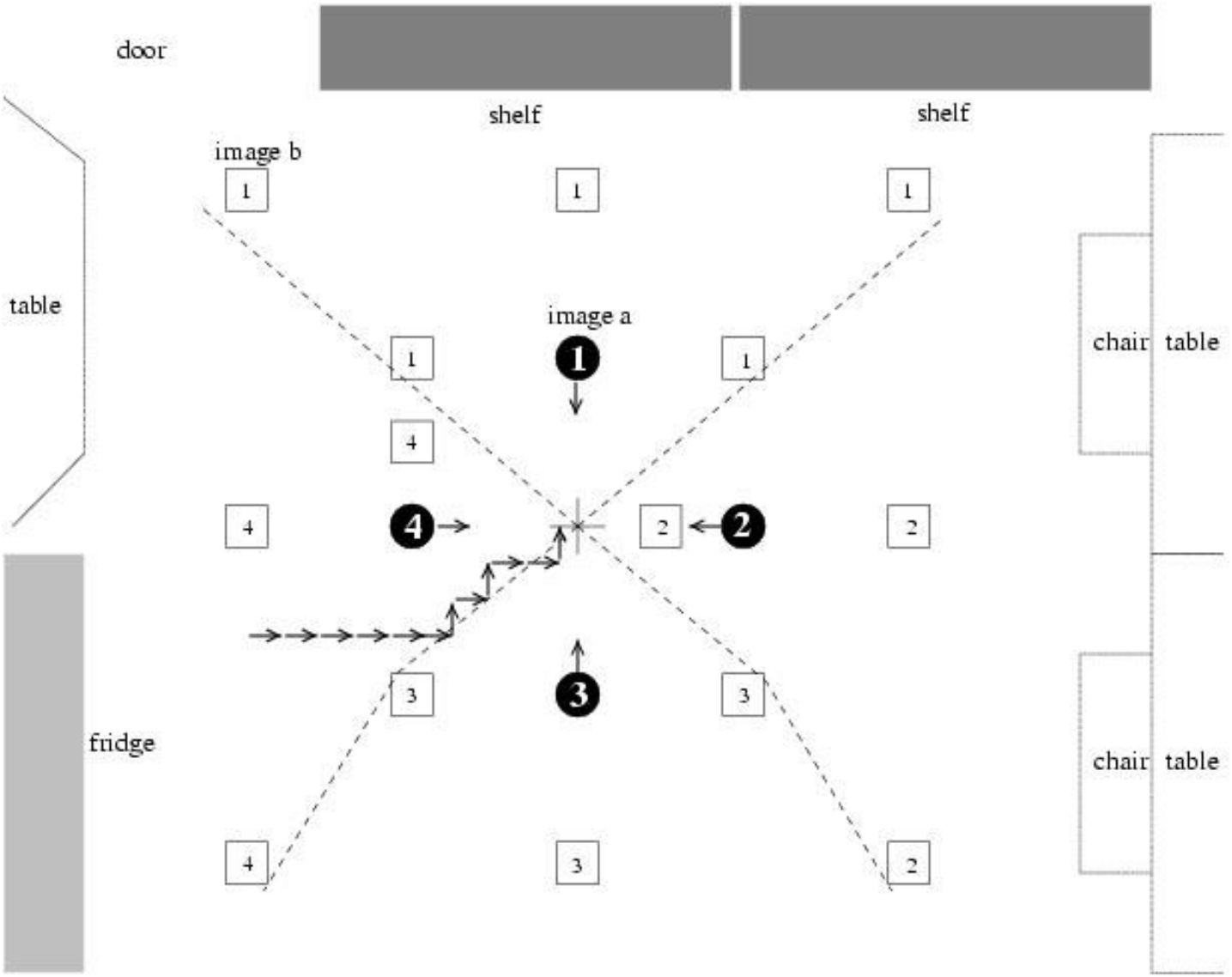
θ = 37°	θ = 49°	θ = 87°	θ = 106°	θ = 109°	θ = 113°	θ = 121°	θ = 128°
1 : 0.9615	3 : 0.9589	24 : 0.9096	4 : 0.9130	9 : 0.9358	10 : 0.9151	15 : 0.9033	0 : 0.9382
10 : 0.9246	5 : 0.9249	17 : 0.9089	21 : 0.9114	16 : 0.9304	19 : 0.9146	0 : 0.8934	2 : 0.9166
25 : 0.9221	6 : 0.9190	7 : 0.9073	32 : 0.9059	29 : 0.9301	25 : 0.9040	26 : 0.8934	22 : 0.9116
11 : 0.9056	2 : 0.8937	37 : 0.8830	13 : 0.9022	14 : 0.8980	2 : 0.9029	12 : 0.8912	12 : 0.9096



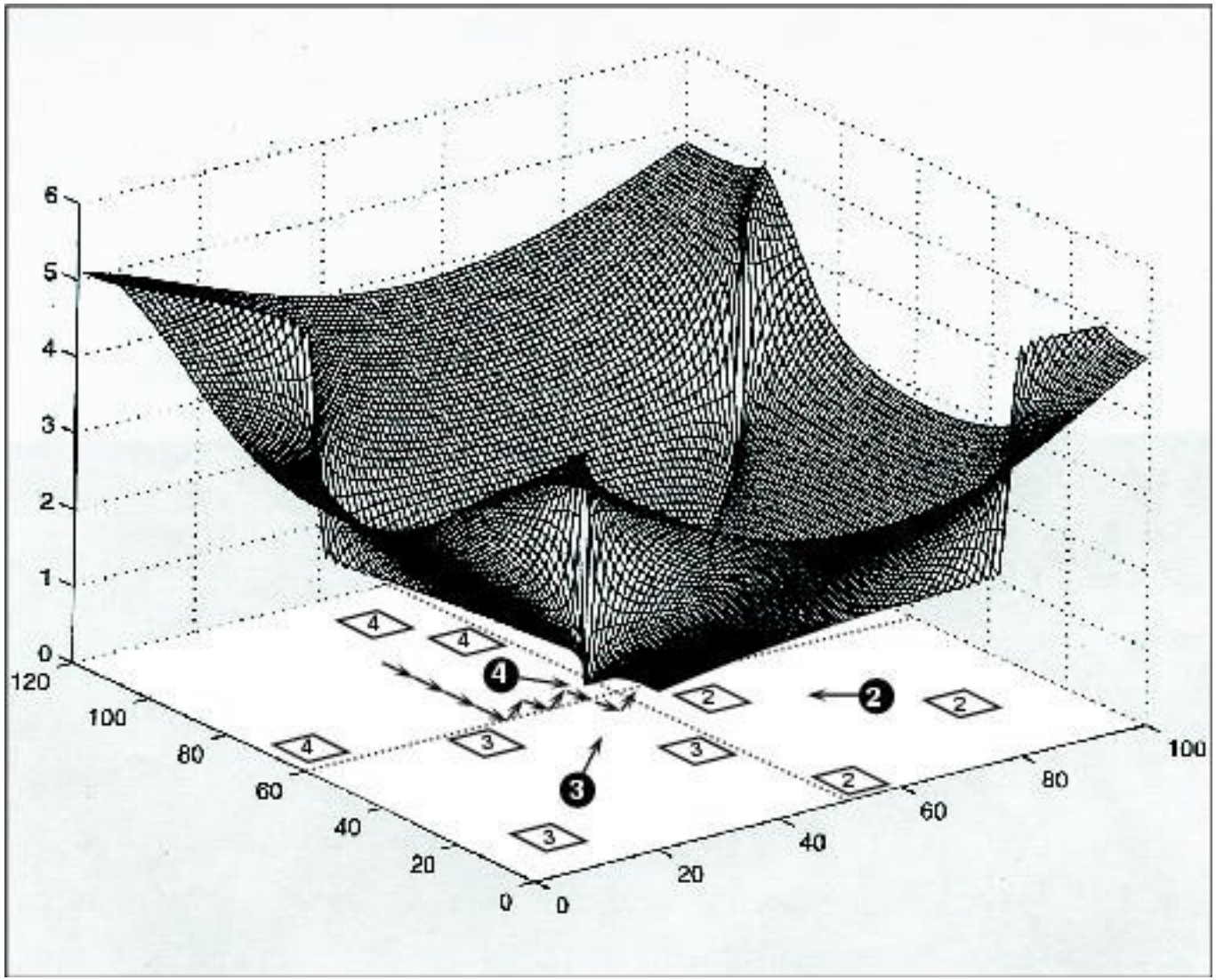
Comment atteindre un lieu?



Navigation avec PerAc



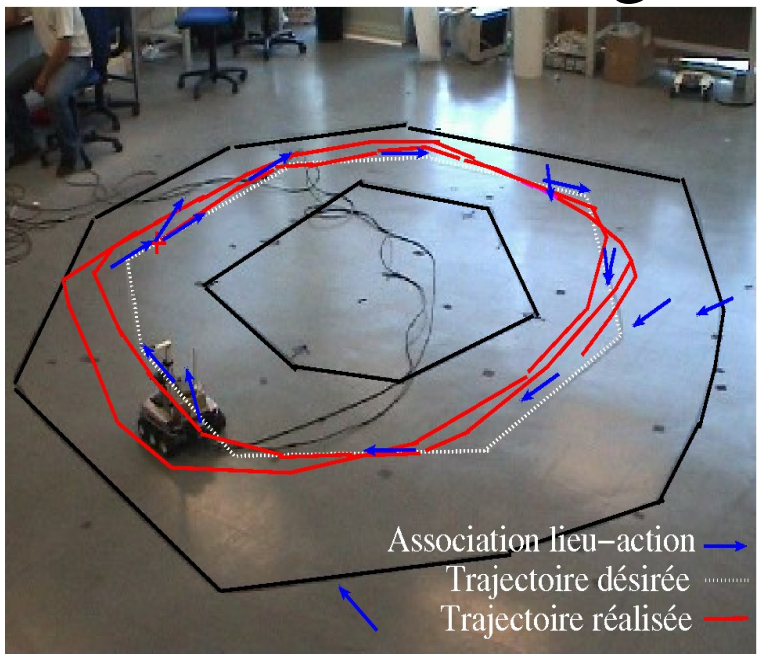
Effet de l'apprent. sensori-moteur



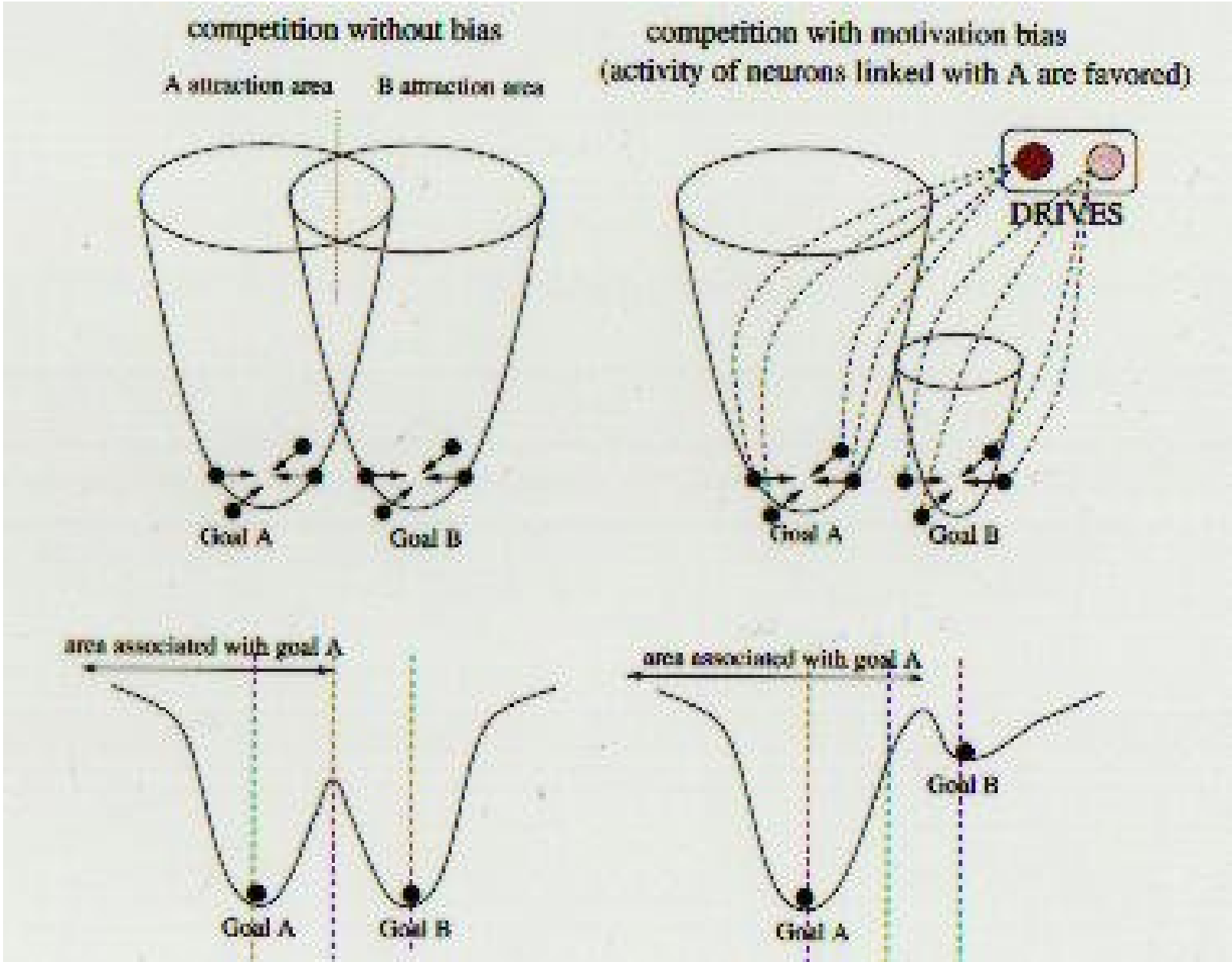
Création d'un bassin d'attraction

Apprendre une trajectoire

[Giovannangeli05,06]



Biais motivationel



C. Giovannangeli (IROS 06, EPIROB 06)

Définition de la Perception

La perception doit être considérée comme un attracteur dynamique permettant un ensemble cohérent d'actions en fonction des sensations (attracteur sensori-moteurtractor)

Nous définissons la Perception *Per* comme une fonction scalaire telle que :

$$\mathbf{Ac} = -m\ \overrightarrow{grad}\ Per(\mathrm{p})$$

Definition de la Perception

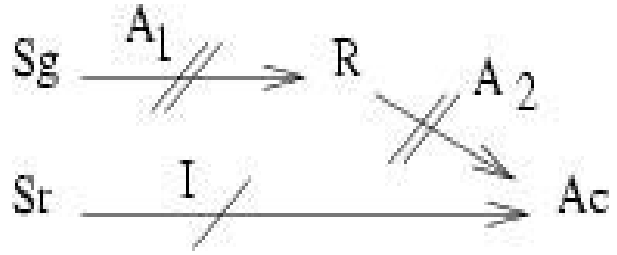
$$\mathbf{Ac} = -m\ \overrightarrow{grad}\ Per(\mathrm{p})$$

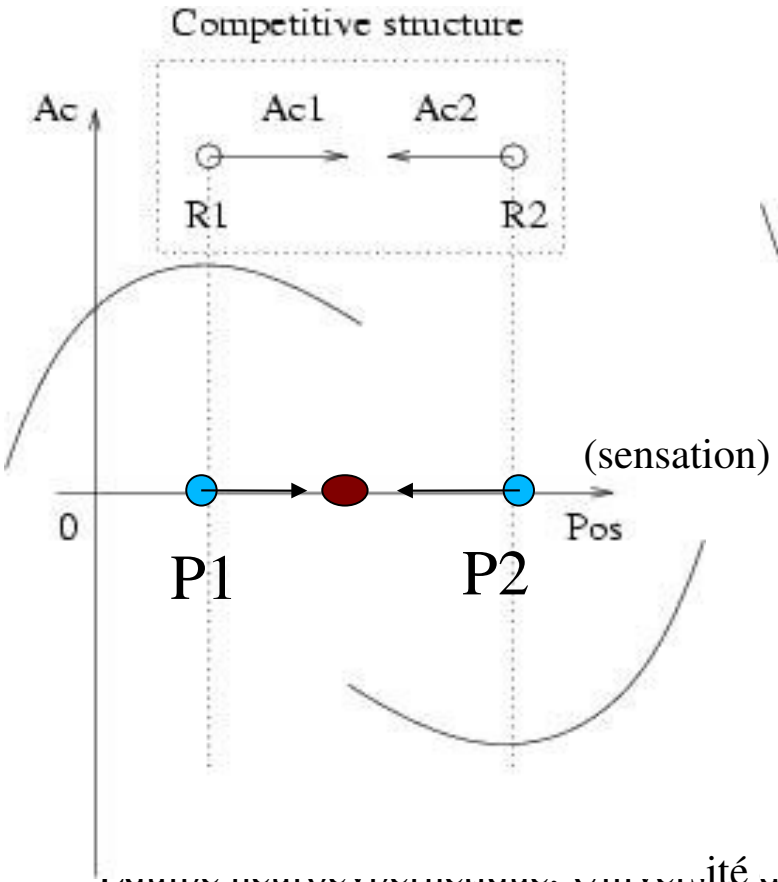
- **p** : vecteur caractérisant l'état de l'agent s(variables internes et/ou externes)
- *m* : un facteur caractérisant « l'embodiment » (une masse virtuelle)
- **Ac** : vecteur action (interne et/ou externe...)

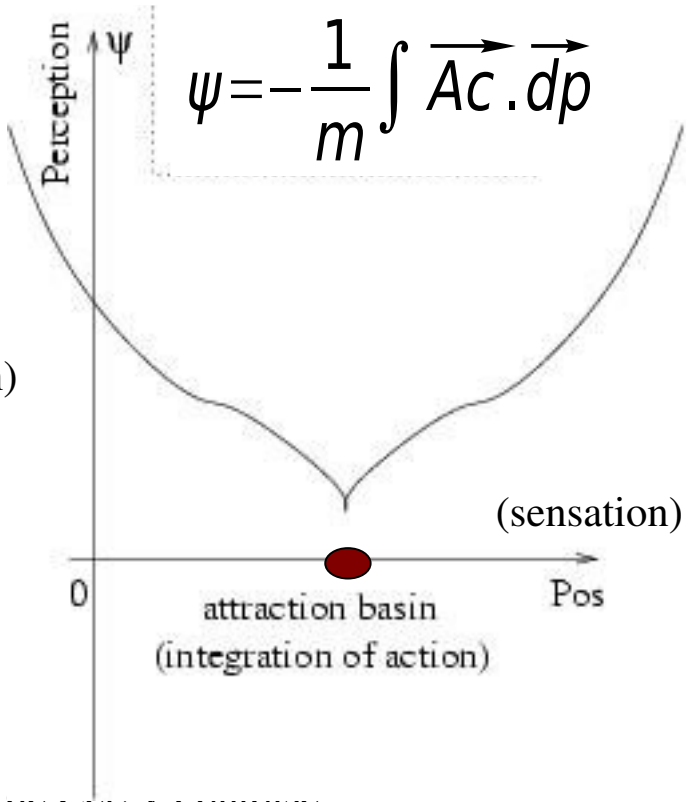
The PerAc architecture

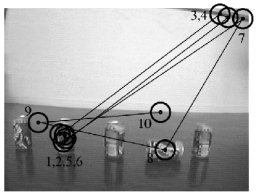
Associative pathway

Reflex pathway

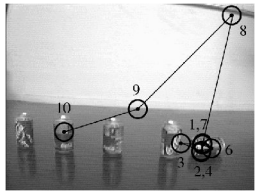








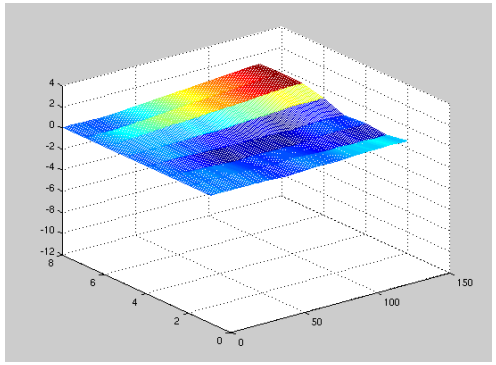
Perception

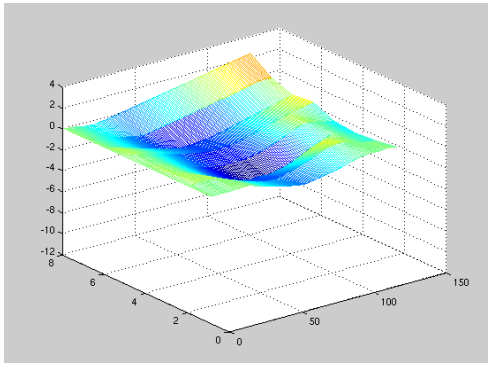


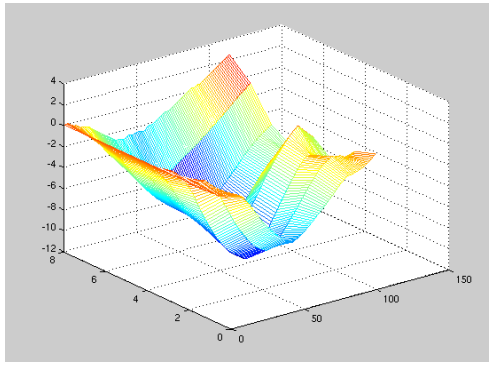
Perception : behavioral attraction basin
Learning sensori-motor invariants
(affordances/recognition)

Ac=-m.grad(Per)

[Maillard05]







Considered as recognition for the observer ?

Comment généraliser notre approche bottom up ?

Problèmes liés aux très “gros” systèmes:

· L’apprentissage d’un ensemble d’associations sensori-motrices est en général NP complexe

· Apprendre seul n’est plus possible!

➔ Nécessité d’introduire des capacités d’imitation

Qu’elles peuvent être les bases neurobiologiques de l’imitation?
Comment amorcer l’imitation? (bootstrap)

PARTIE 2

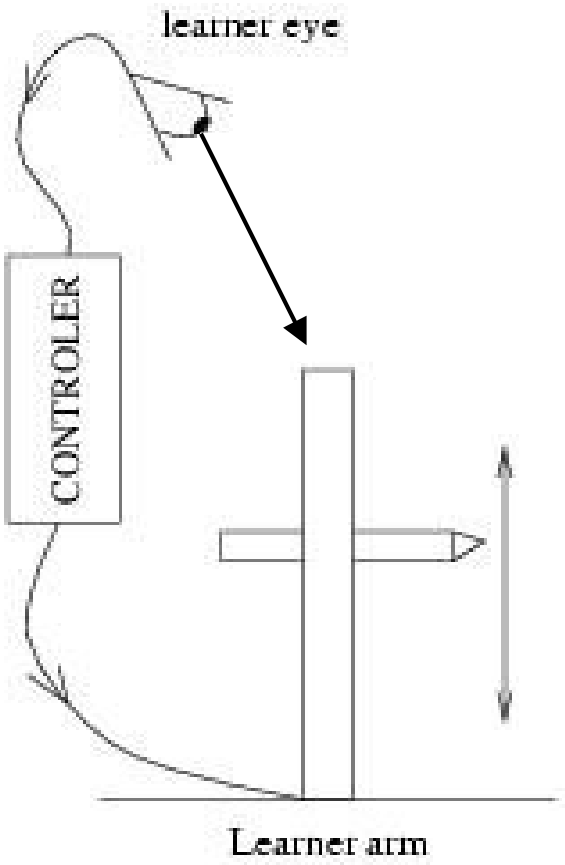
L’imitation…

Définitions de l'imitation

``**True**" imitation: [Whiten&Byrne82, Mitchell87]
Apprendre un nouveau comportement et reproduire les actions permettant d'atteindre le **but** de ce comportement:
- Imitation immediate vs différée
- imitation au niveau de l'action vs au niveau du programme

D'autres types d'interactions:
- stimulus enhancement [Spense37]
- emulation (obtenir la même récompense) [Tomassello87]
- Facilitation de la réponse [Byrne94]

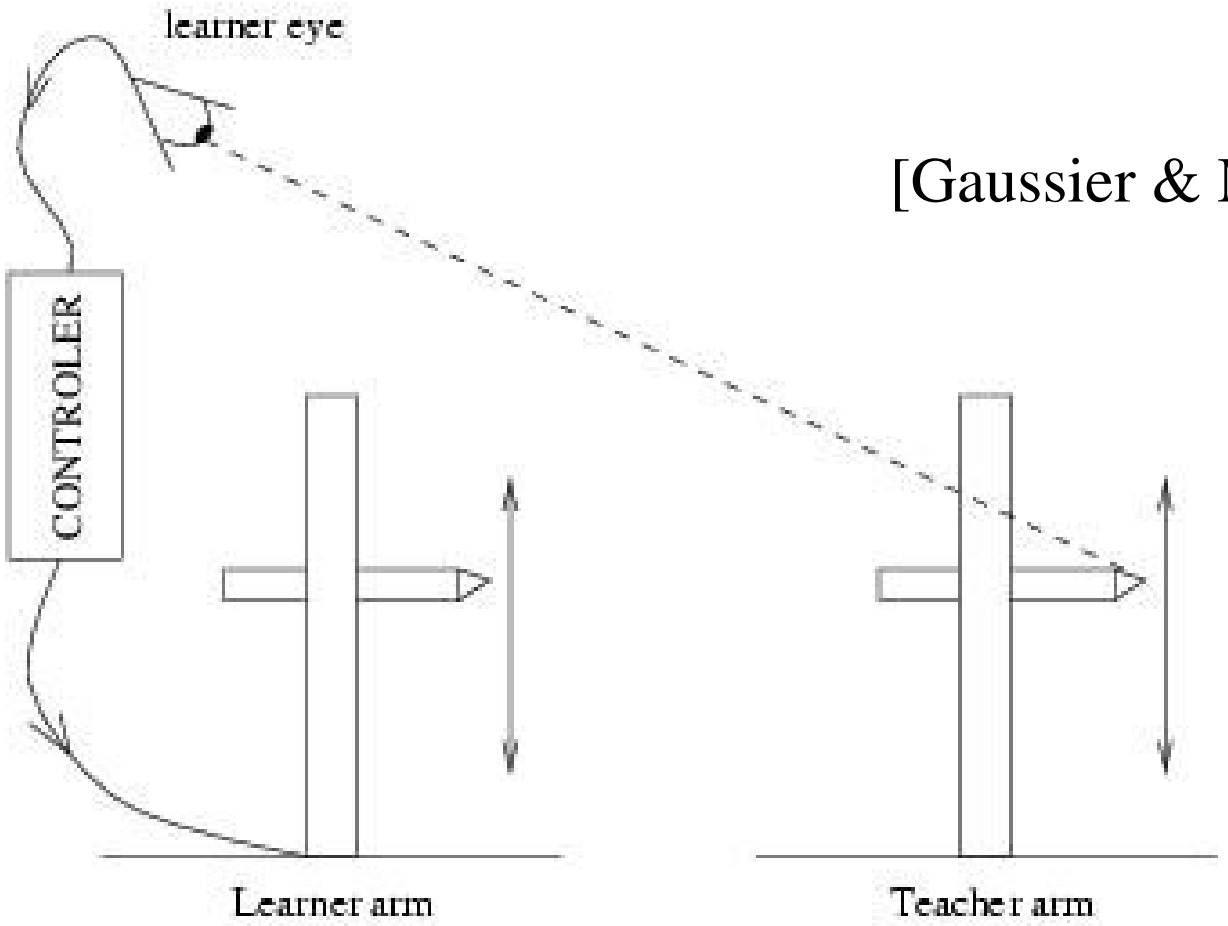
Bootstrap pour l'imitation



[Gaussier & Moga 98]

Apprendre un comportement homéostatique

Bootstrap pour l'imitation

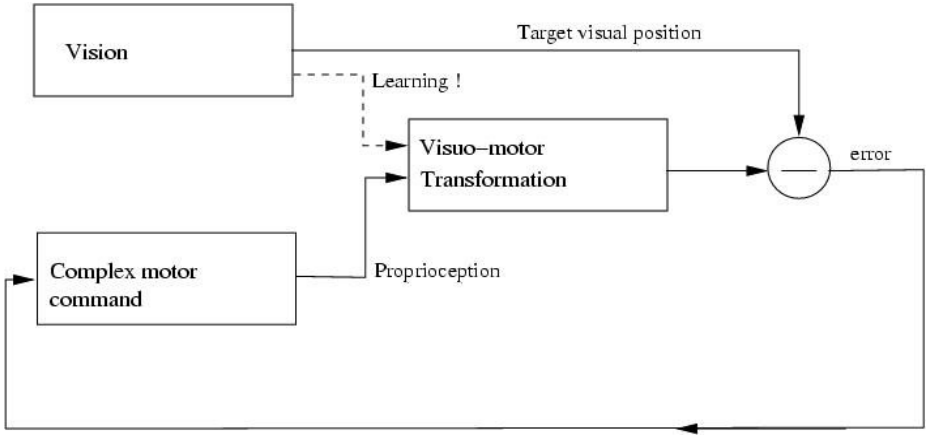


[Gaussier & Moga 98]

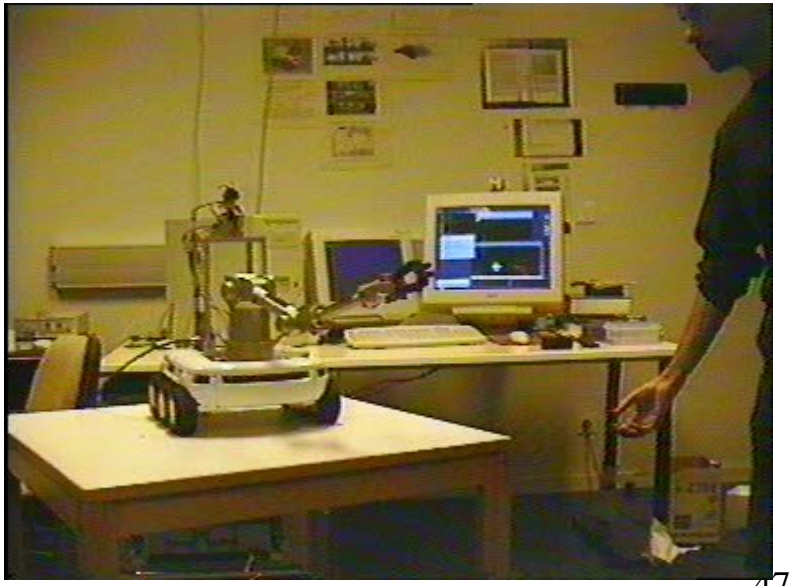
Proto-imitation peut être un effet de bord d'un homéostat (ambiguité de la perception)

Setup experimental

Simple système homéostatique + ambiguïté de la perception

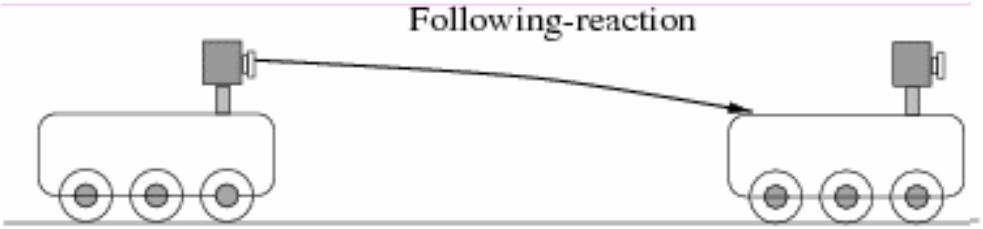


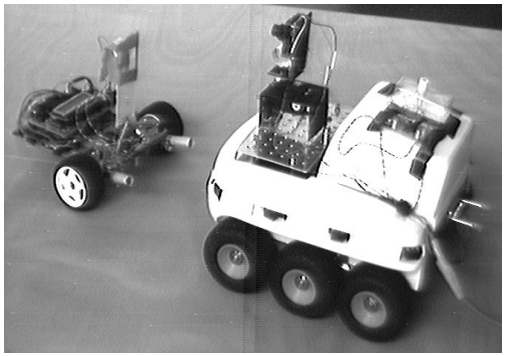
[Andry et al 2002]



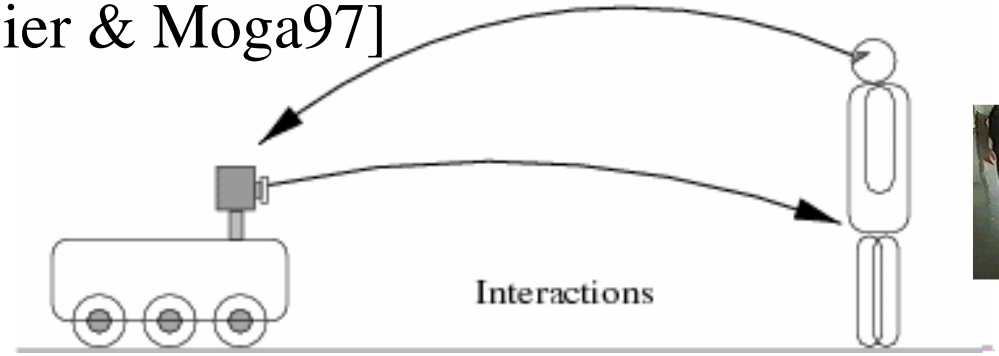
System limitations:

- No synchronisation capabilities between agents
- Need of an explicit reward or adhoc mechanism to decide if given sequence must be learned
- Need of an explicit signal to specify the beginning and the end of the expriment





[Gaussier & Moga97]



3rd part

- Issues in human-robot interactions
  - ***Learning via imitation***
    - ***Avoid combinatorial explosion of learning by an isolated individual***
  - ***Interaction as a reinforcement signal***
    - ***Exploit dynamics of interaction (communication)***

Imitation et interactions sociales

Emotional value of interactions

Inspiration from mother-baby face to face interactions:

« still-face » [Tronick 78]:

- Moving to still face
- Negative effect on the children

double video [Threvarten 85, Nadel 99]:

- Mother and child communicate via a double video system
- Introduction of a temporal delay
- Contingency is essential to maintain the interaction

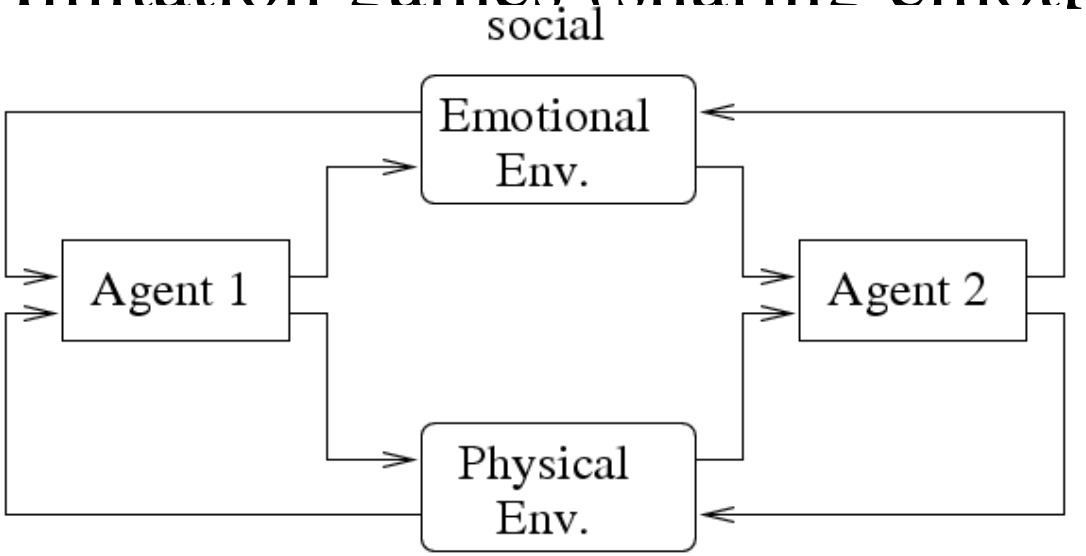
→ Rhythm and synchrony are important elements for the interaction [Andry, Gaussier and Nadel 01]

Emotional value of interactions

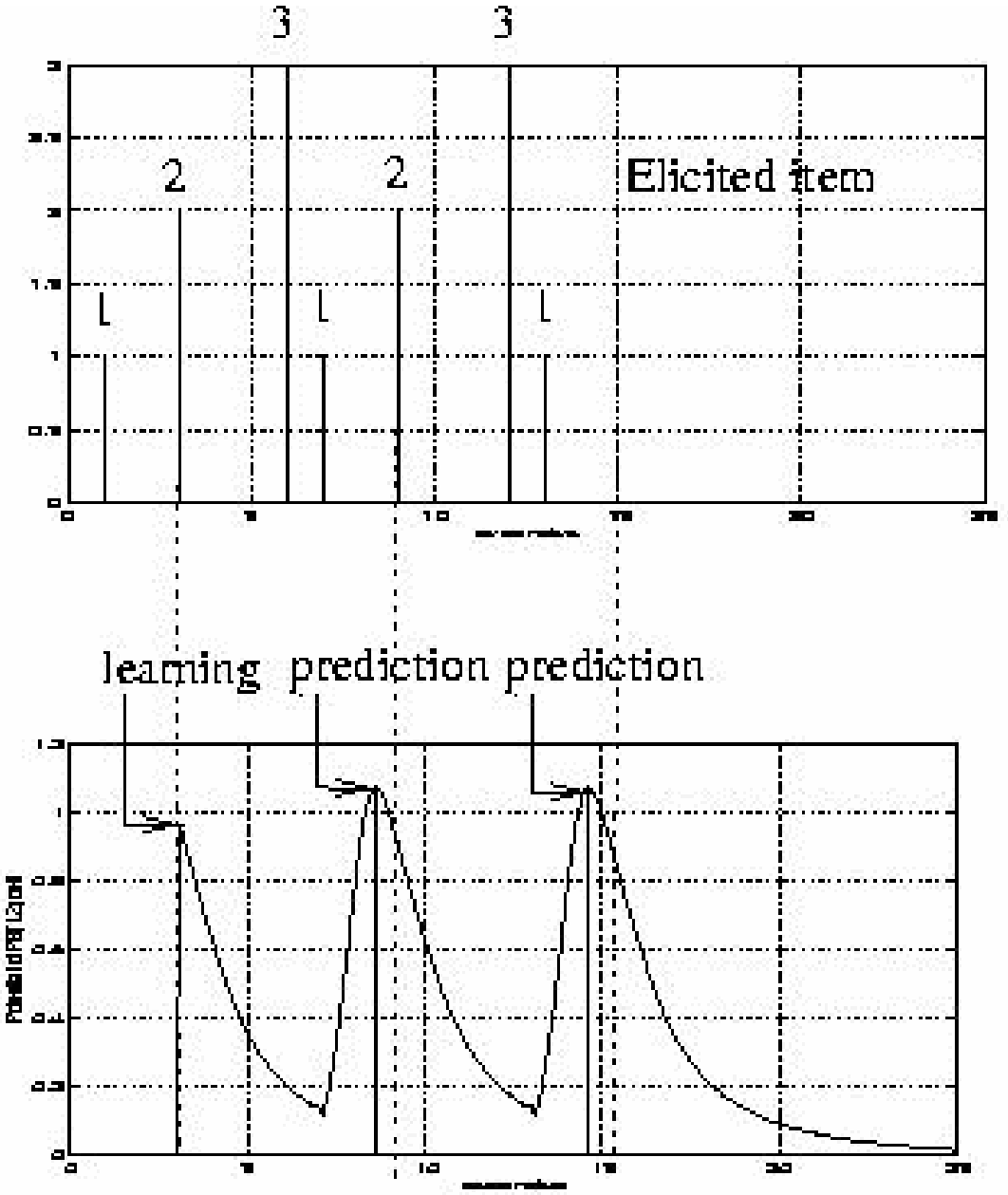
Emotional resonance or contagion (bootstrap **empathy**)

Capability to predict the rhythm of the interaction (associated to a positive reward for ex.)

Imitation games (sharing emotions?)



Prédiction du rythme (Hipp)



Imitation and social interactions

Double function of imitation:
- Learning
- Communication

Capability to predict the rythm of the exchange can be used as an internal reward

Interest of displaying the internal state induced by reward (second order interaction)
How to express it quickly?

4th part

- Artefacts et emotions

Modeling emotions for social interactions

Conveying intentionality

- Coherent explanation for observed behavior
- Emotions and personalities as sources of intentions

Eliciting/controlling emotions

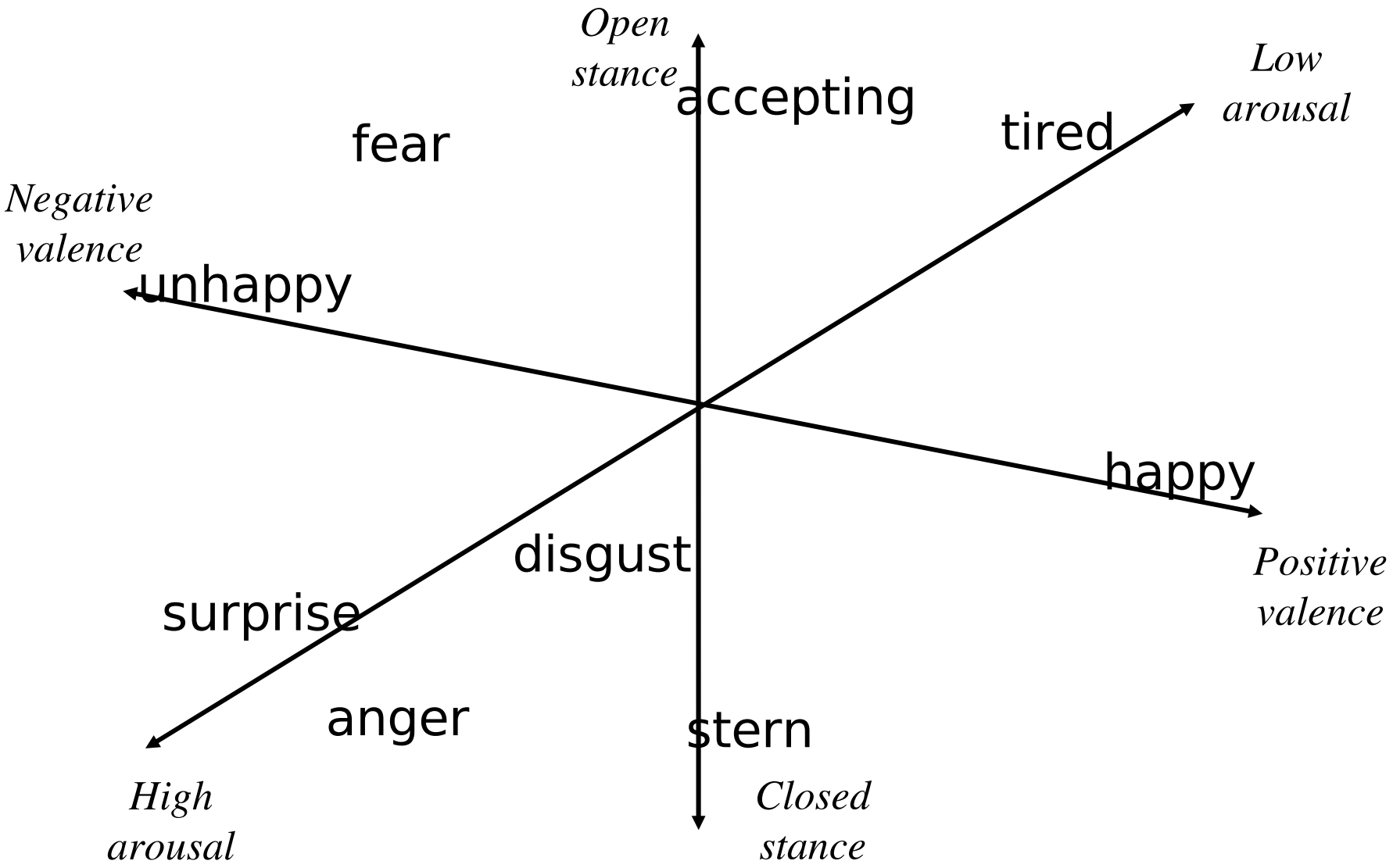
Making humans **feel comfortable** about the interaction

- Tailor interactions to meet human needs
- Artifact more believable, “closer” to human (in autism?)

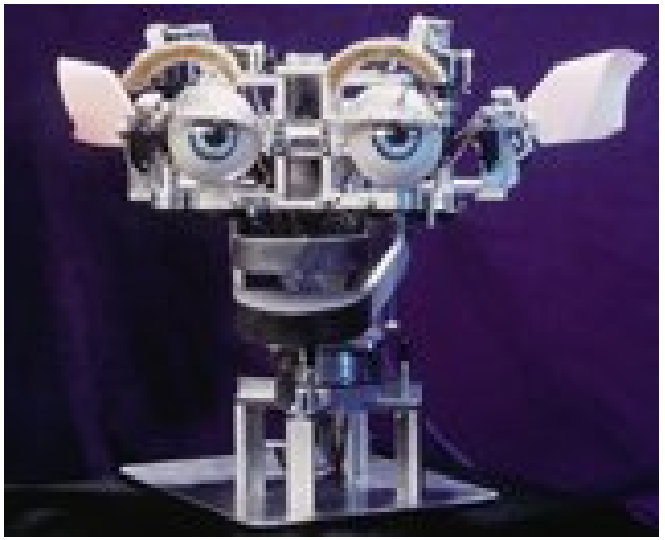
Enhanced communication

- Non-verbal communication
- “deeper” understanding (what we *mean*, not what we say)

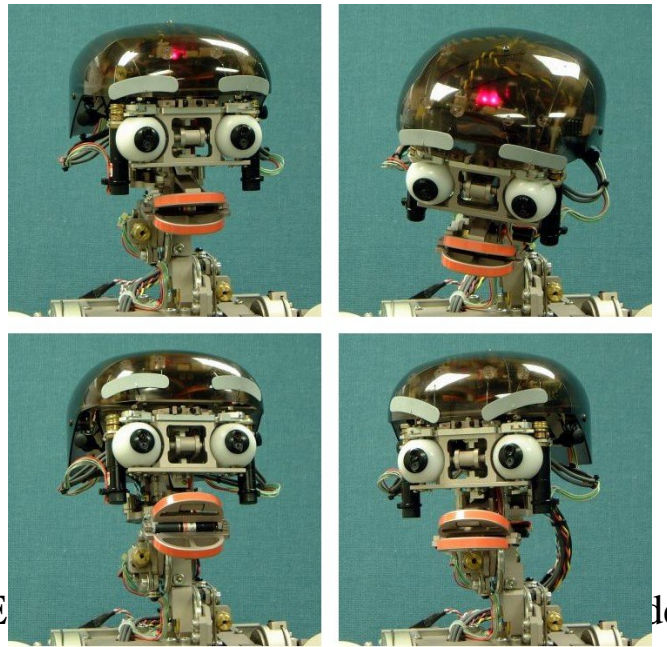
Choice of model: dimensions?



Sophisticated communicative/emotional robots



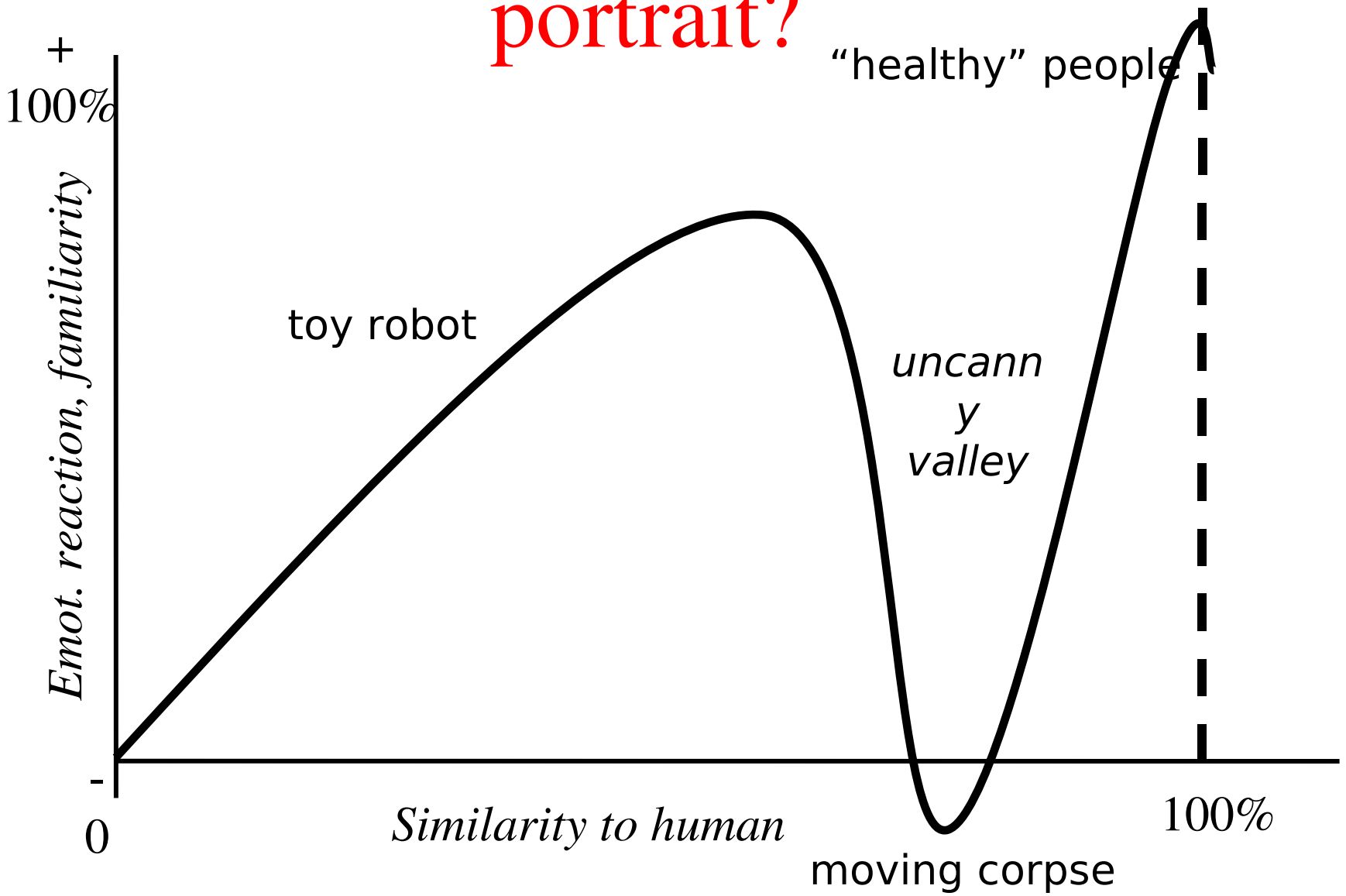
Repliee (Ishiguro)



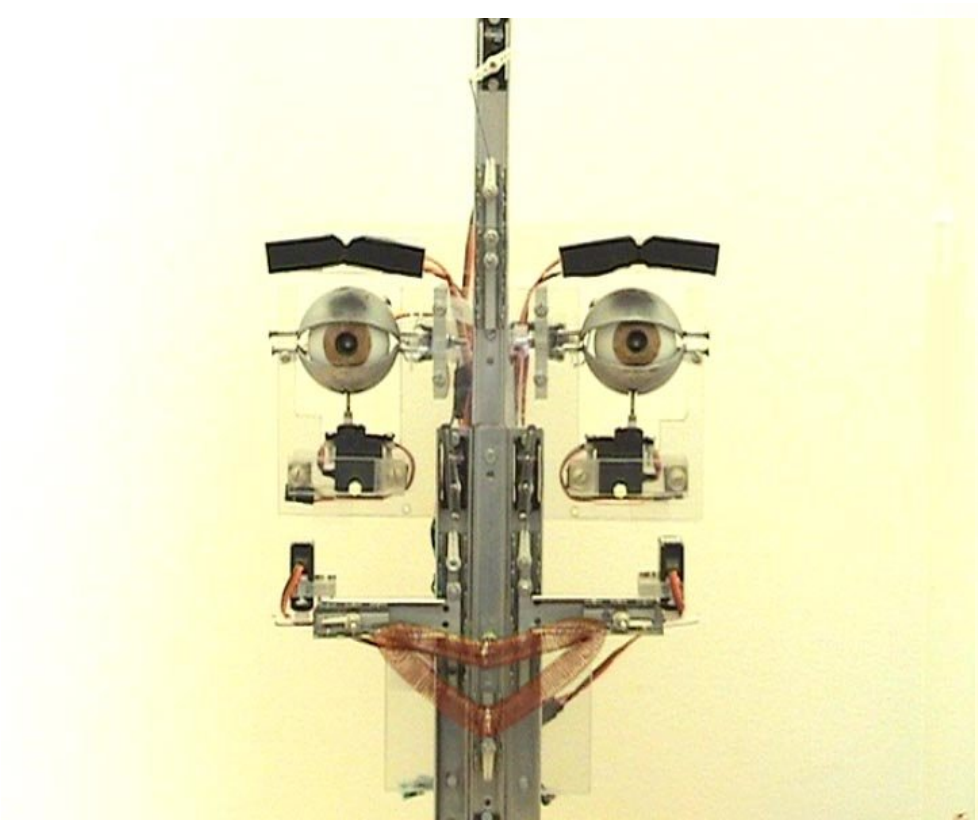
Kismet (S. Breazel)

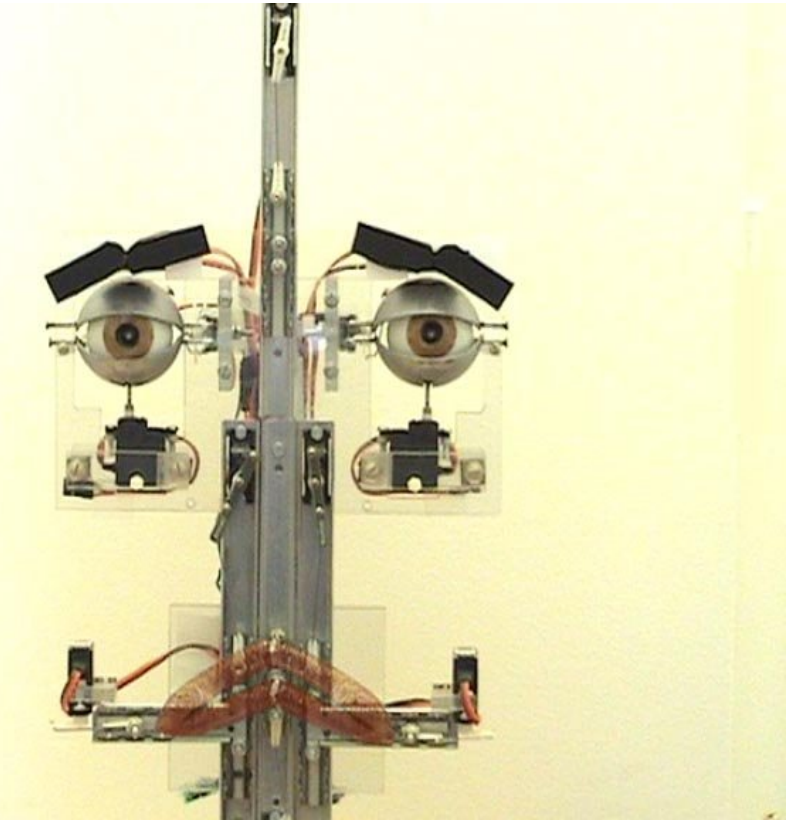
Infanoid (I. Kozima)

Complexity: caricature or portrait?



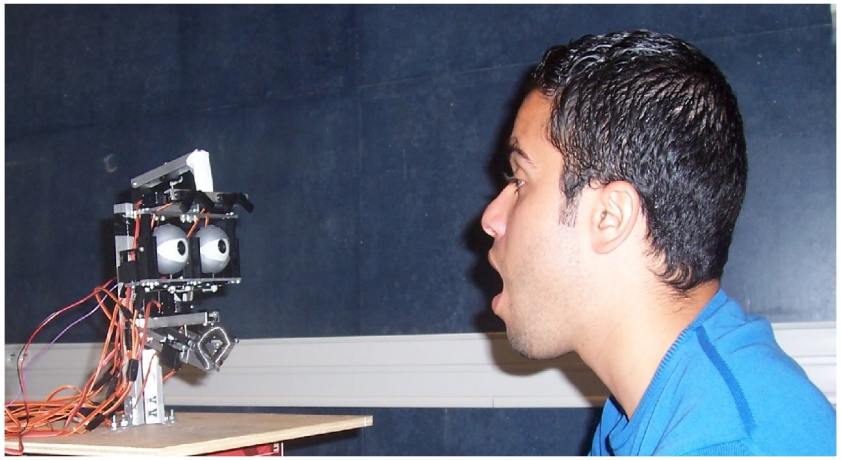
Emotions and communication

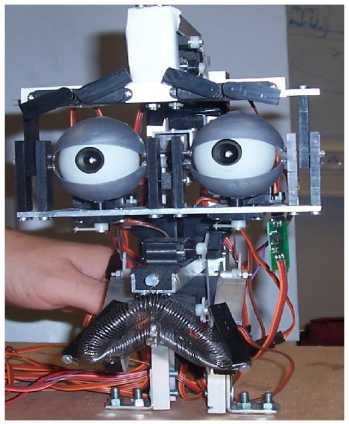


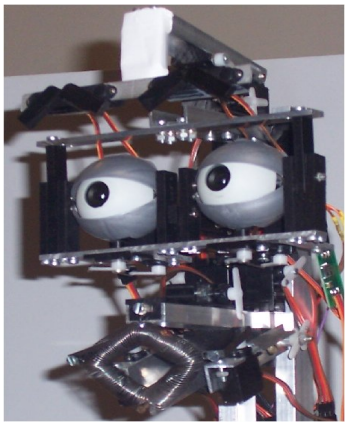


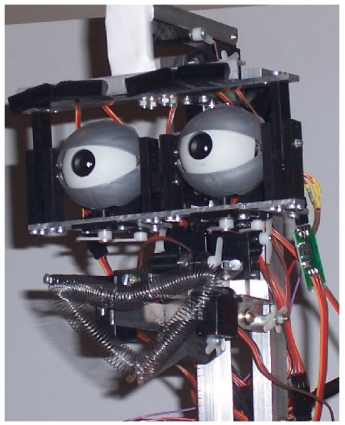
See M. Simon & J. Nadel works

Développement de la capacité à reconnaitre des expressions faciales









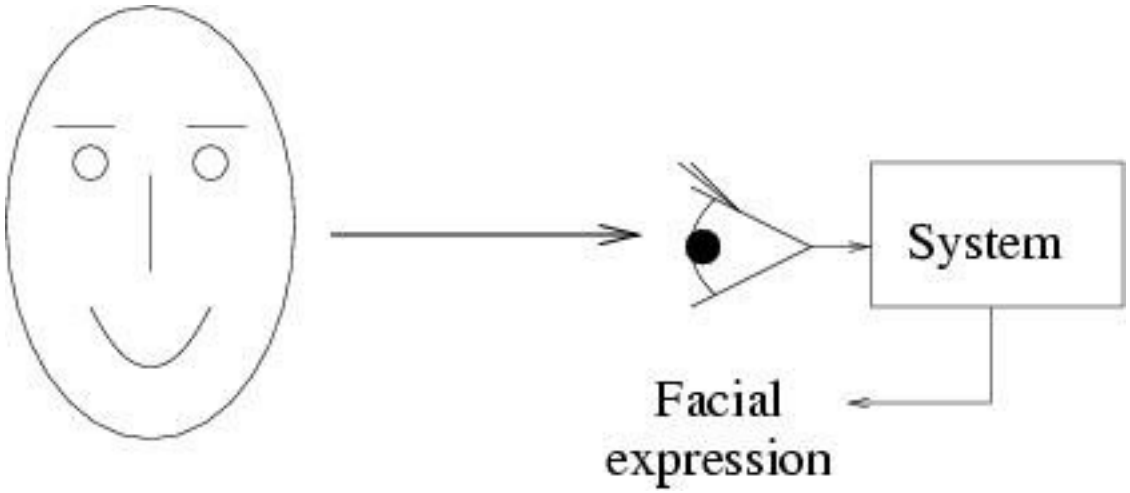
Theoretical studies of interacting systems

How to compare different models?
Do their belong to the same family?

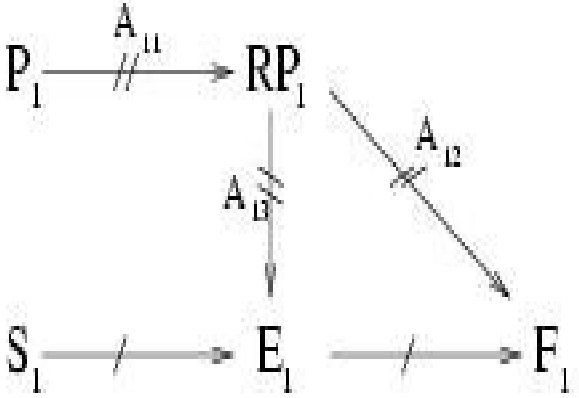
I will try to show you on an example that:

It is possible to create a mathematical model to analyze a computation architecture and to predict its behavior
(learning in an interaction game)

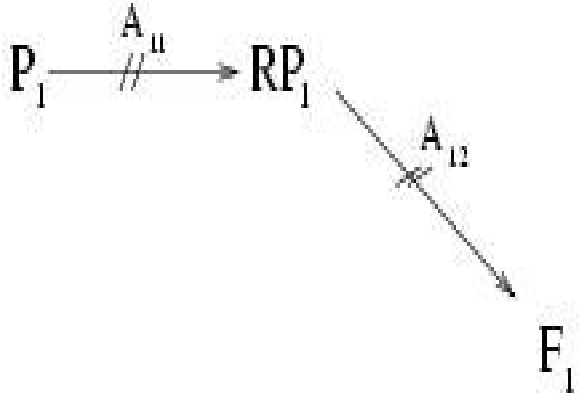
How to model baby learning?

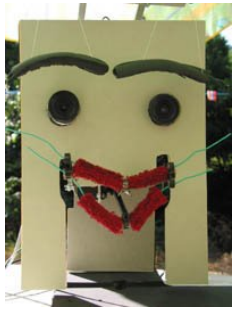


One possible architecture:



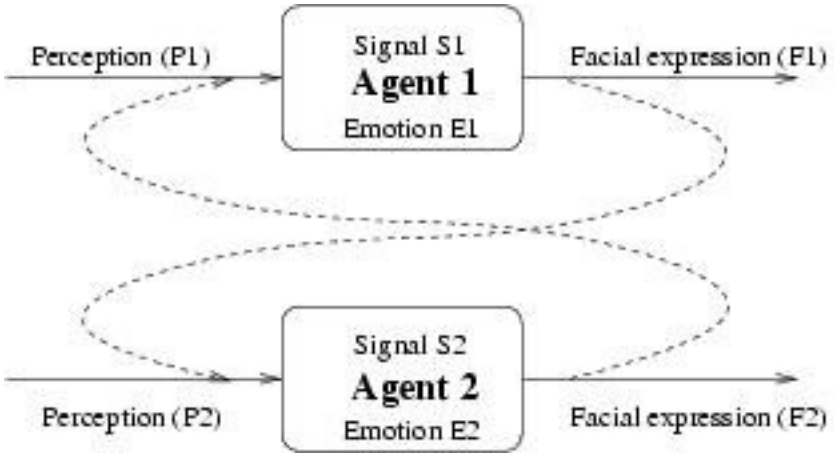
Desired solution:



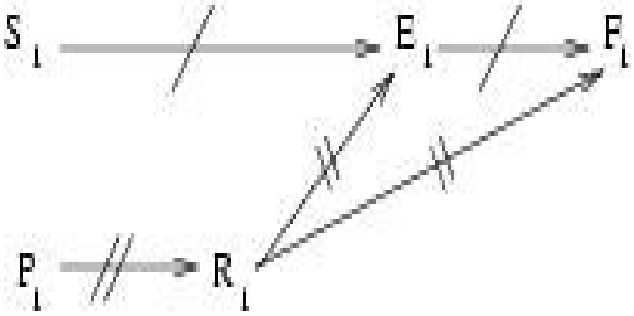


(based only on sensori-motor loops)

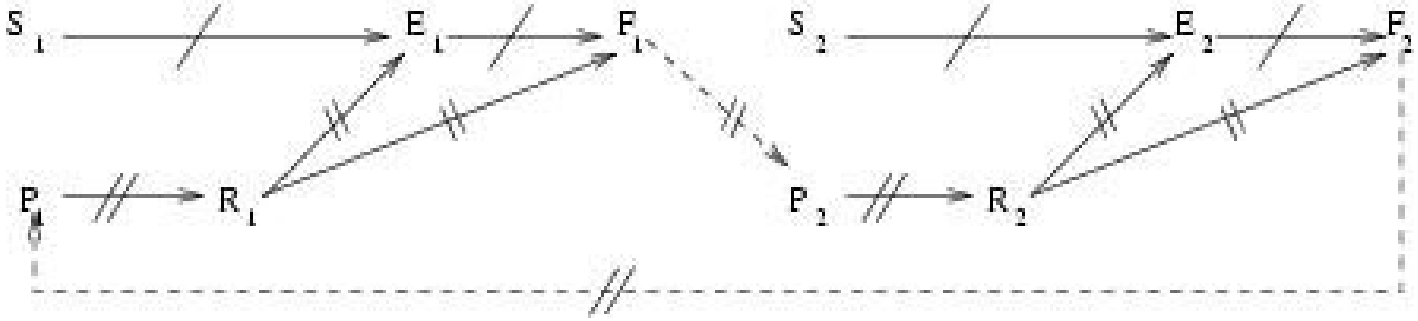
Study of a dynamical interaction

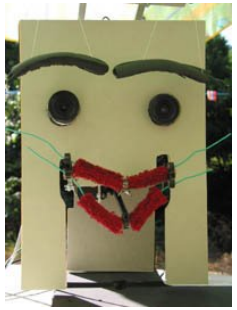


Agent architecture

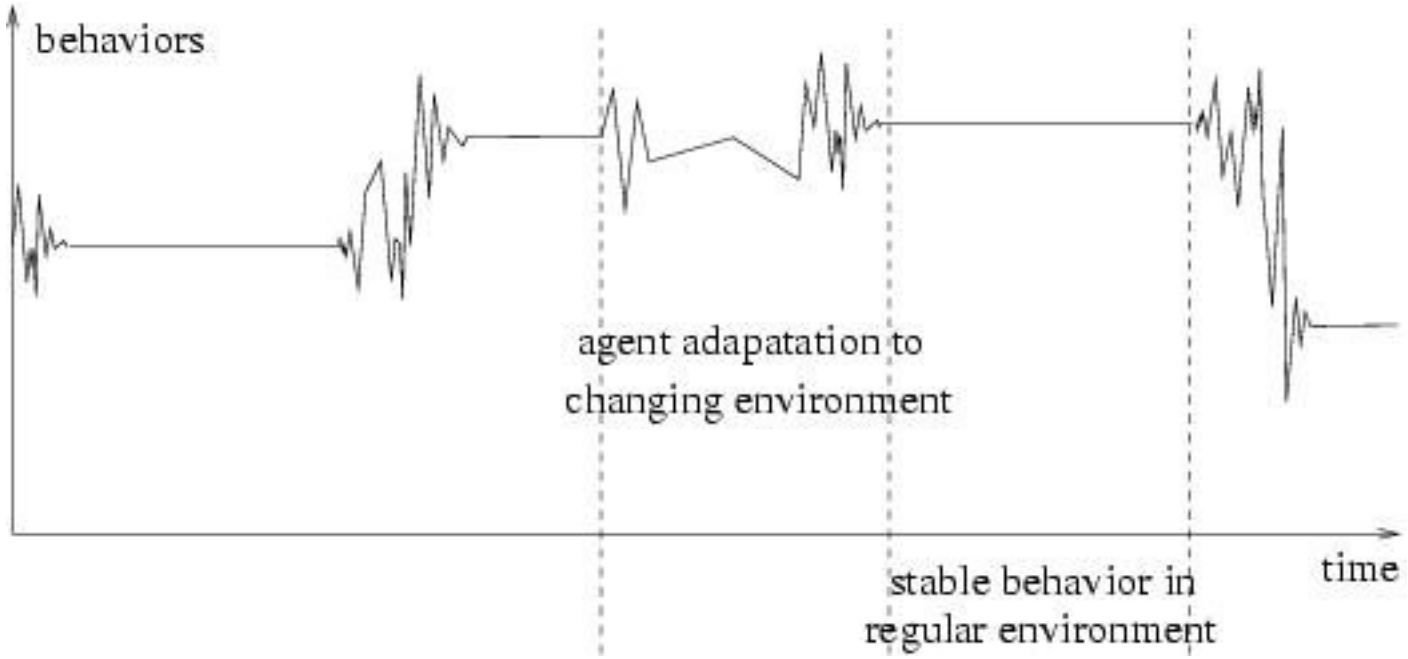


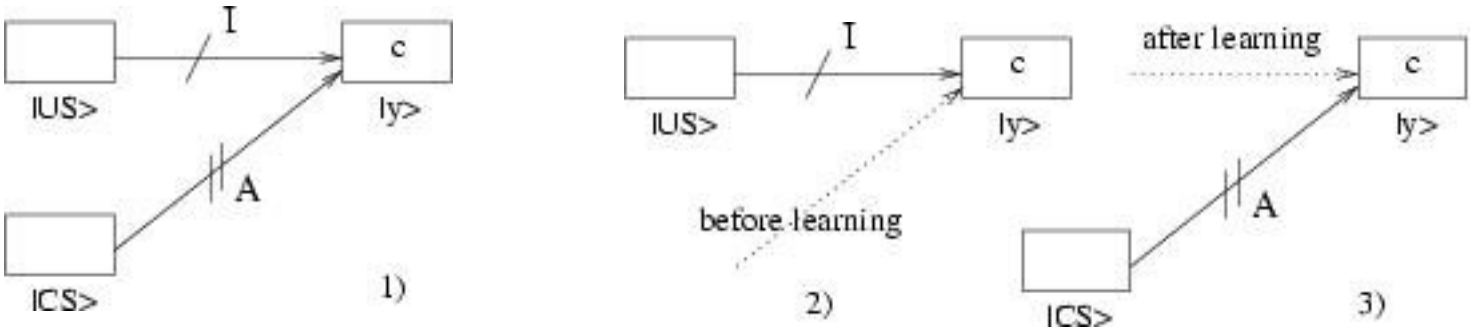
Global system (both agents) :

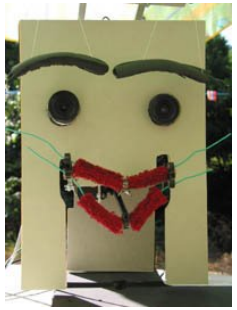




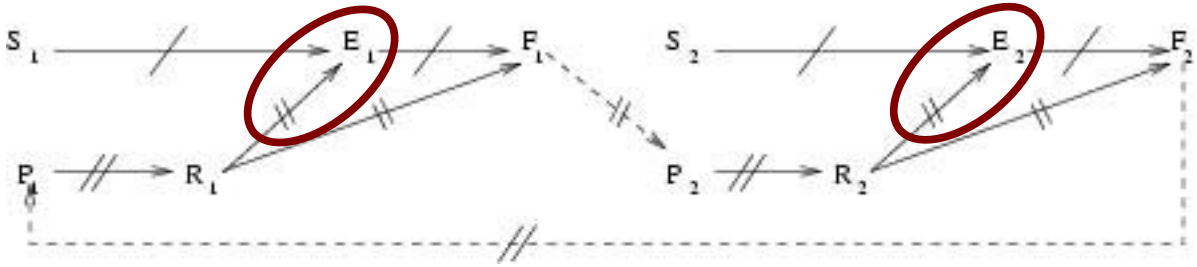
Stable state of “perception”



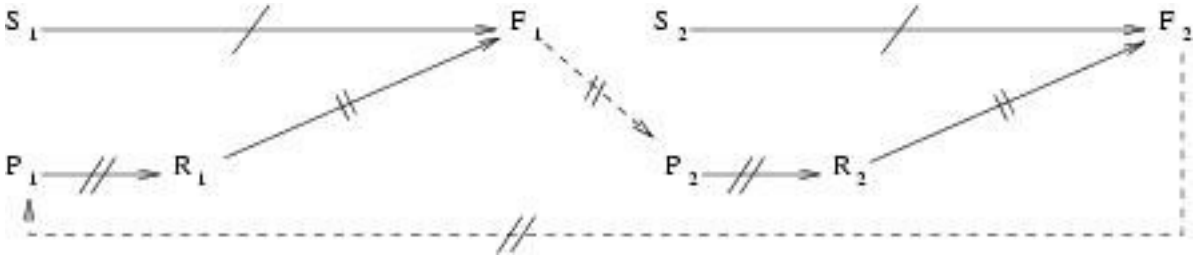


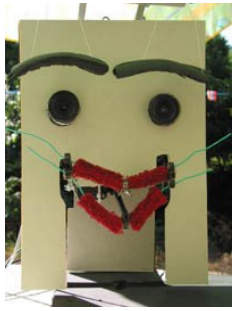


System simplification

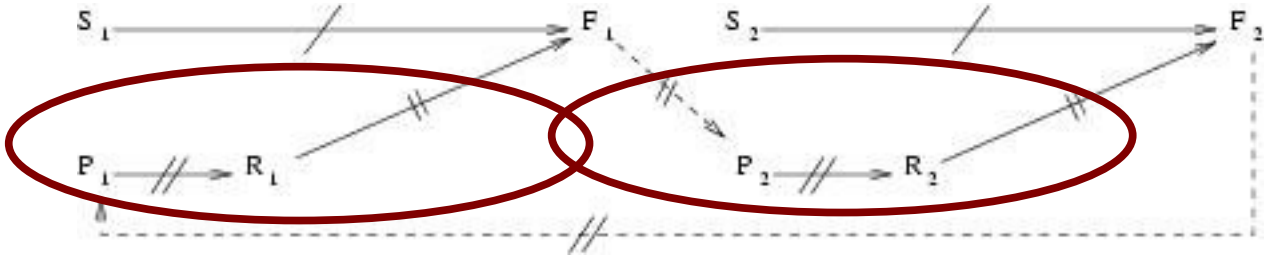


First simplification if learning is possible:

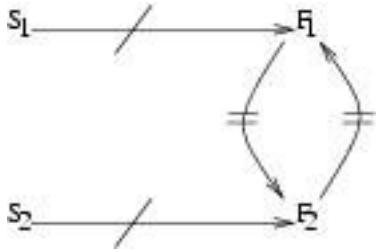


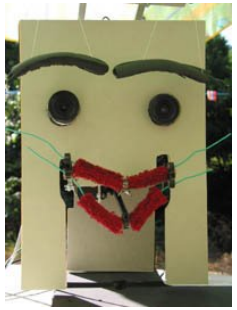


System simplification

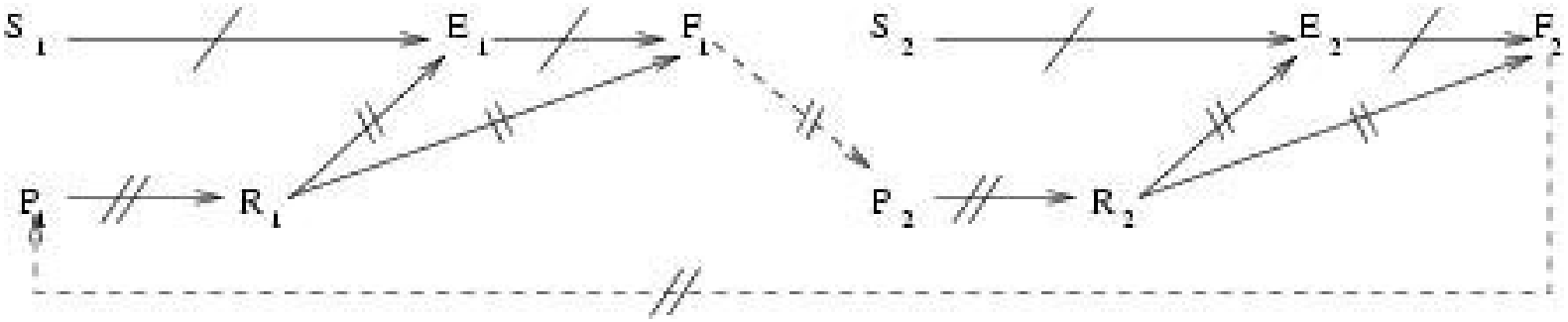


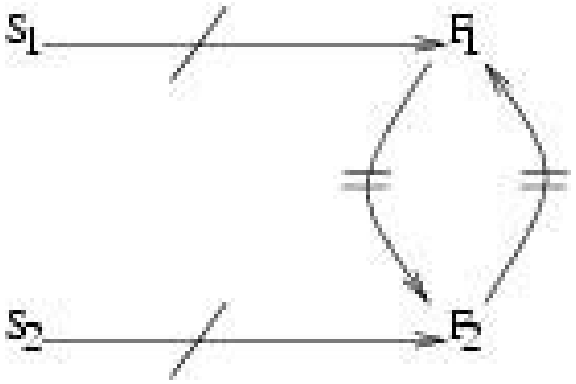
Second simplification:



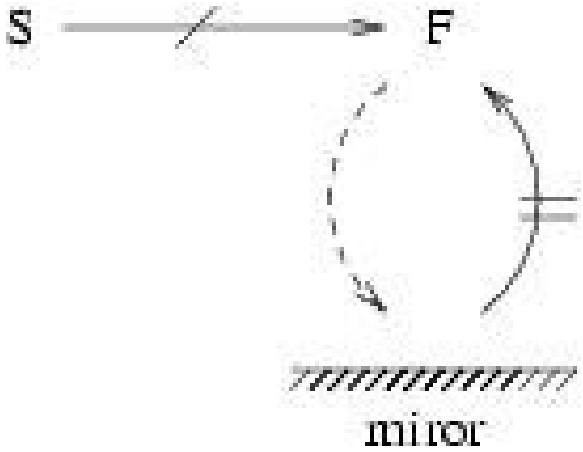


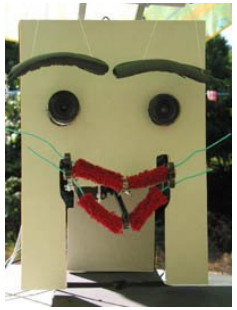
Stability condition



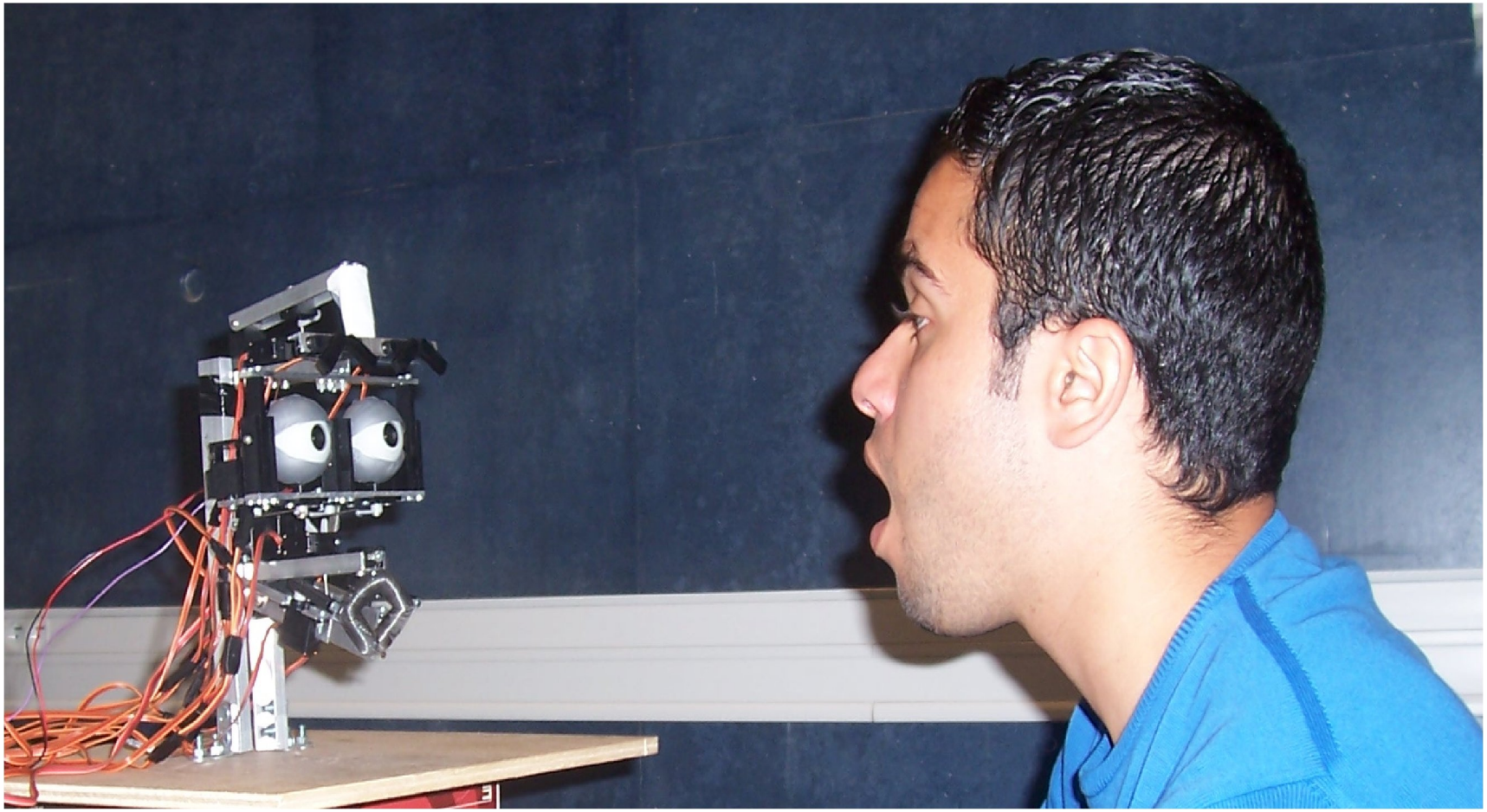


Condition for a stable association?





Development of facial expression recognition



[Boucenna08]

First computational models

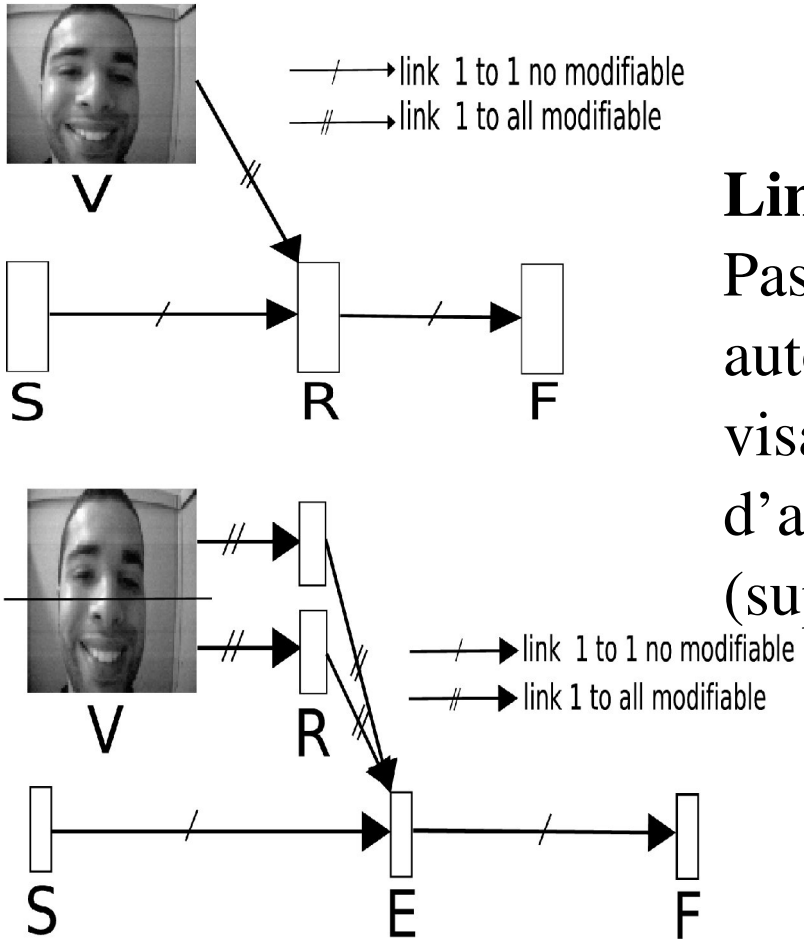
Principle of the classical algorithms for facial expression recognition:

Find the face in the image...

Build a **frame** around the face

Recognition of the normalized image (eigenvalues, supervised NN...)

Stratégies neuronales “Classiques”

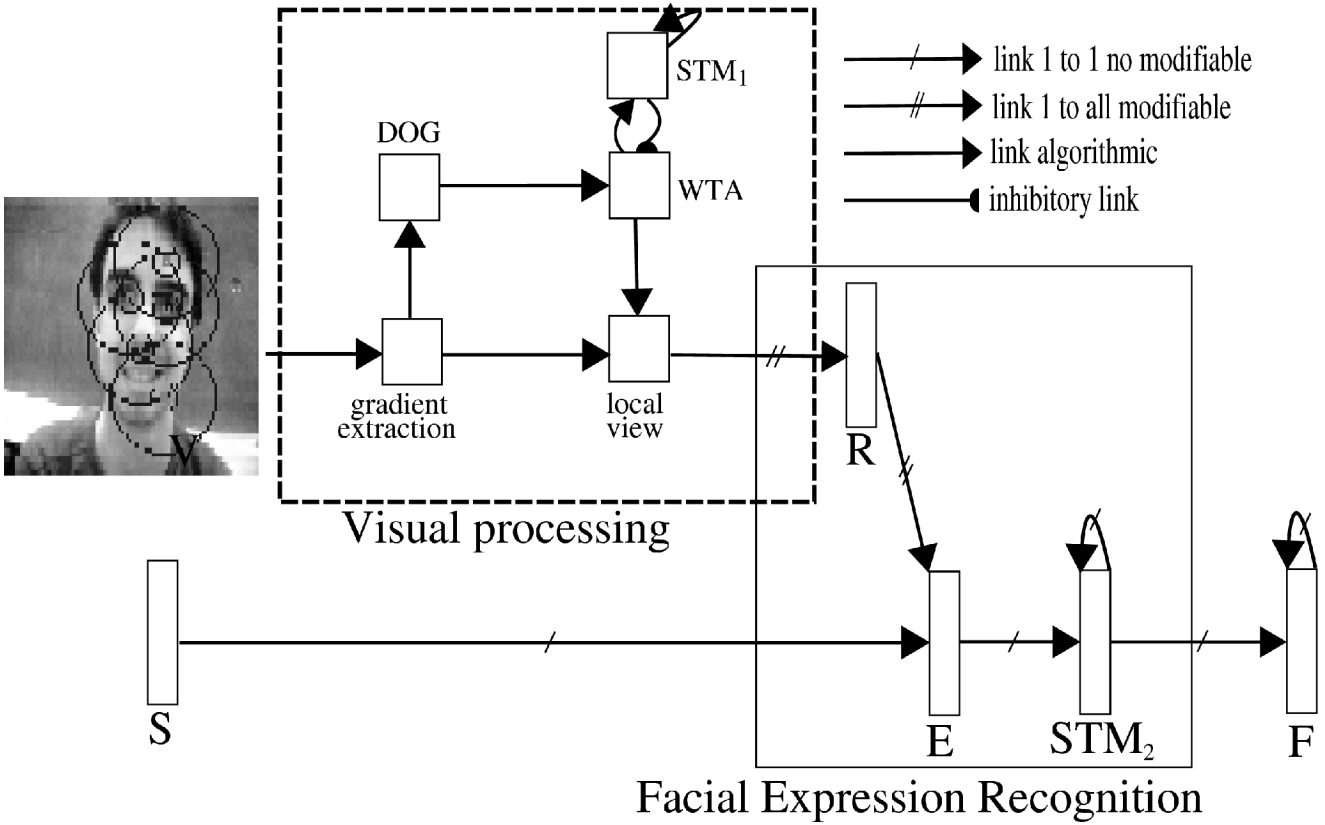


Limitation:

Pas d’apprentissage réellement autonome car la reconnaissance visage/non visage nécessite un signal d’apprentissage externe (supervision)!

Facial expression recognition without face detection

Idea: math. model does not suppose a first step of face detection.



Success rate: happiness: 86 %, anger: 66 %, surprised: 51 %, sadness: 48 %, neutral: 36 %

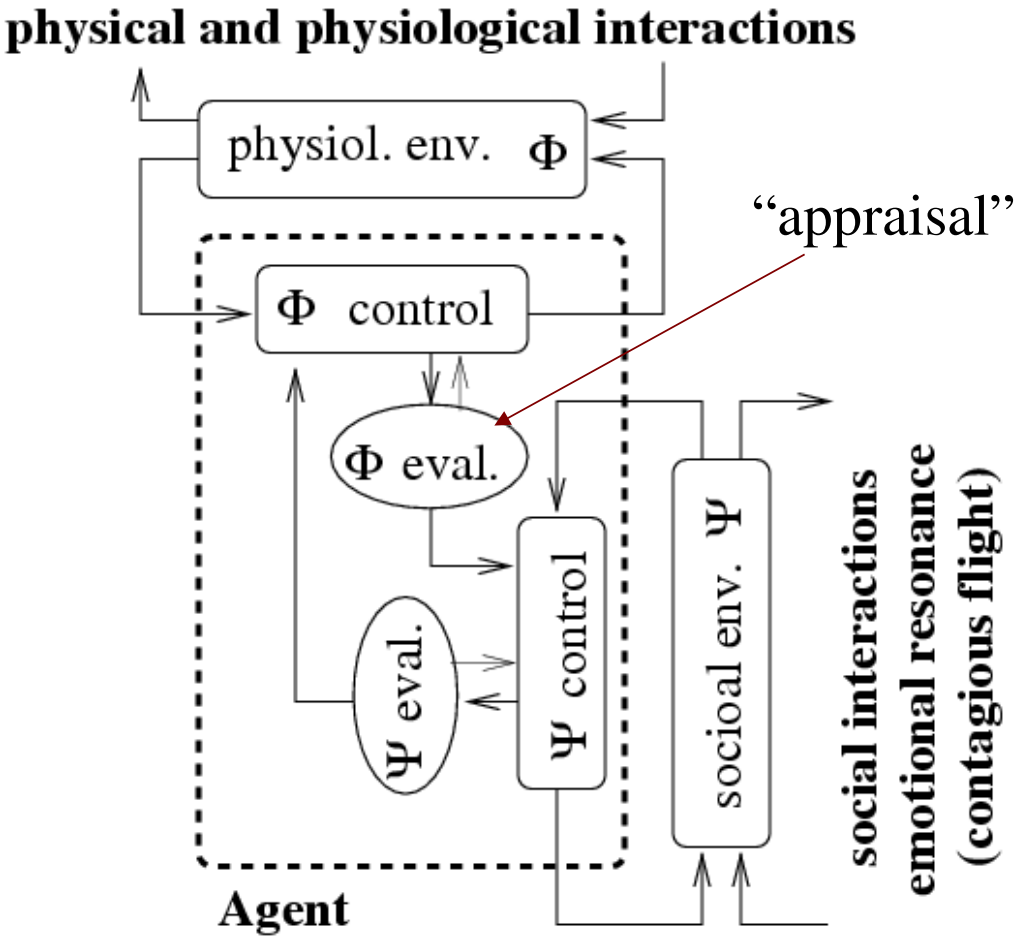
Les émotions comme moyen de structurer l'apprentissage

- La reconnaissance d'une expression peut précéder la reconnaissance visage/non visage !

- Prendre en compte le développement émotionnel ouvre de nouvelles voies pour l'apprentissage autonome
- Les émotions peuvent être utilisées comme moyen de structurer et déclencher des apprentissages de plus en plus complexes quand aucun renforcement explicite ne peut être utilisé.

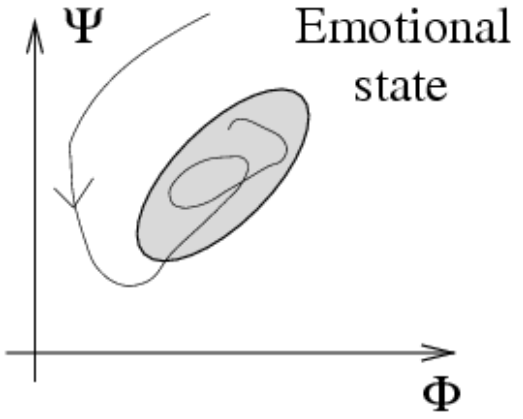
Les émotions, un système dynamique ?

(STREP FEELIX Growing)



Pas de centre

Pour les "états émotionels"?

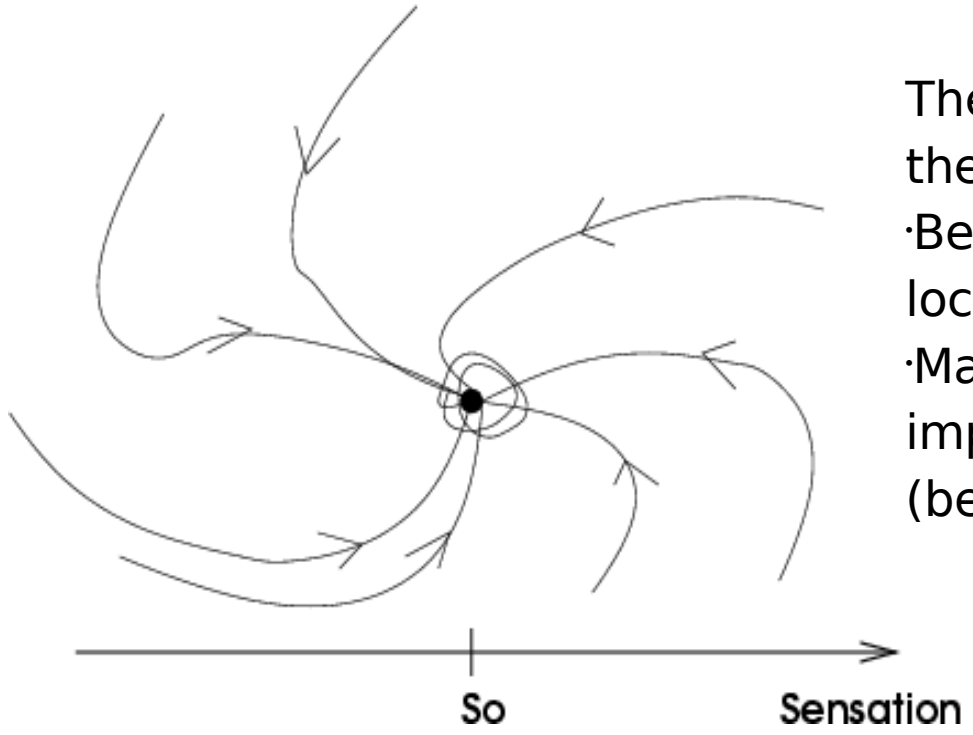


Sous structures partagées entre les 2 controlleurs

→Emotions complexes construites aux travers des interactions

Limitations of simple conditioning

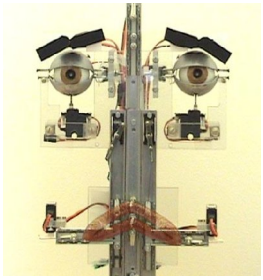
Dynamics of the interaction (and its perception) collapses to a fixed point attractor



The demonstrator controls the interaction :

·Be sure of the visual locking ,

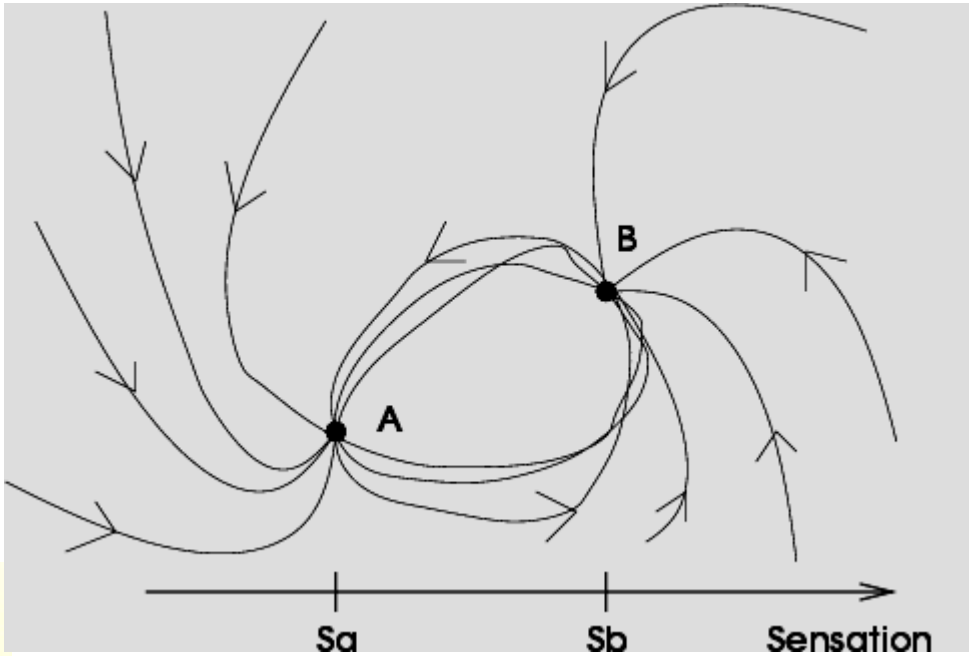
·Manage some explicit / implicit signals (begin/end of the exp.)



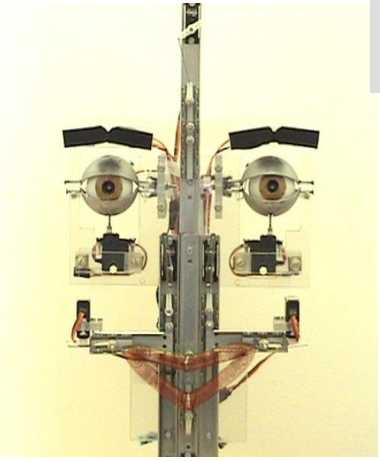
The innovation only comes from the other!

More complex Resonances

Need to introduce at least cyclic attractors:

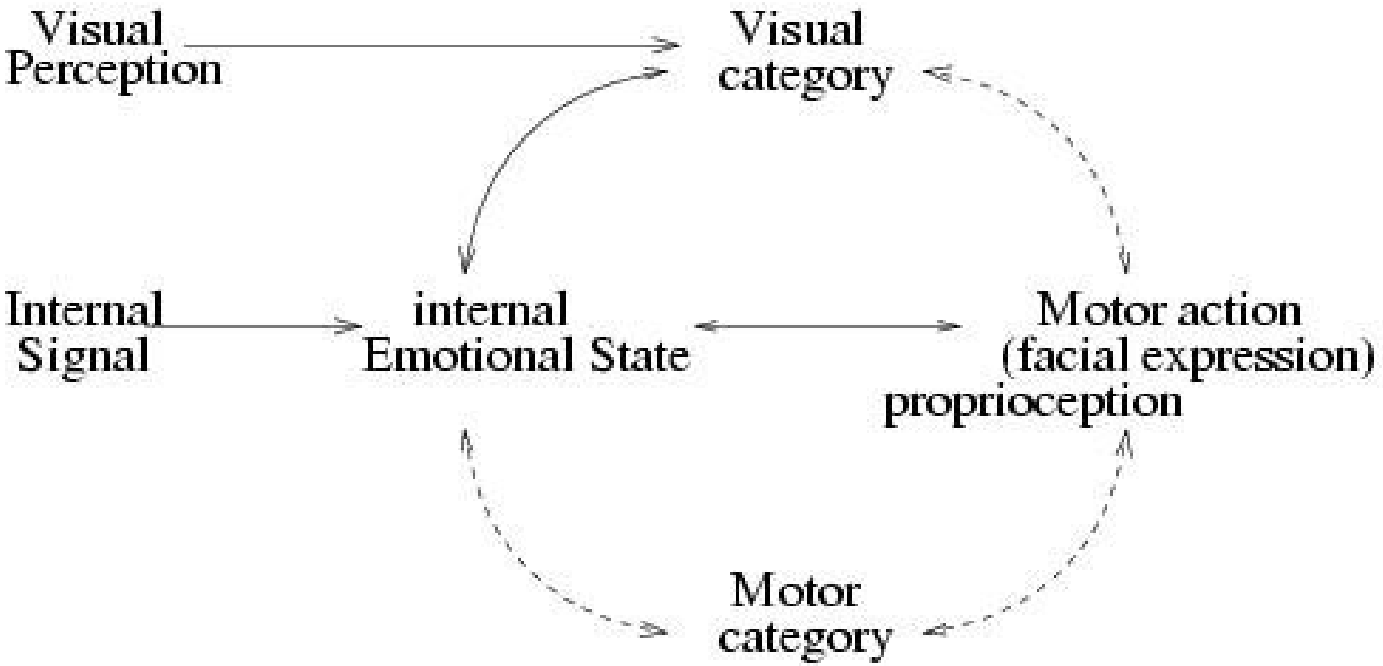


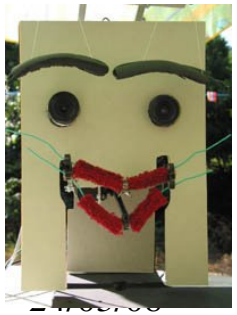
Different levels:
- turn taking
- role switching



"Will" of interaction:
a simple internal oscillator circuit?

More realistic architecture





Conclusion

Possible mathematical analysis of embodied brain models (development, interactions…)

➔ New cybernetics

Need of an holistic approach to cognition :

Go from simple to more and more complex tasks to take into account the NL effects of the dynamics of the interactions with env.

Impossibility to decouple perception and action

Perception can be seen as a dyn. attractor

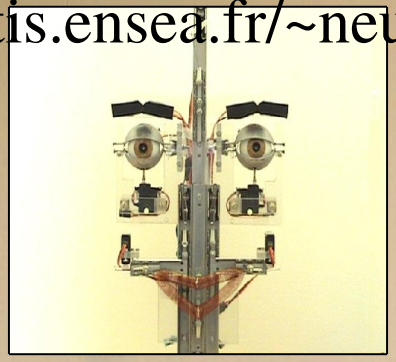
Conclusion

Le robot un artefact et un modèle
Le robot: une IHM et un moyen de comprendre les IHMs!

Les robots en tant qu'artefacts doivent être capable
de créer des couplages pour leur propre bon fonctionnement!

Interet d'artefacts pouvant interagir sur le registre émotionel
(résonance avec l'humain)
➔ Prégnance du couplage

web site: www.etis.ensea.fr/~neurocyber/Videos/



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