Robots should not be Robinson Crusoes

A plea for enculturated intelligent systems

Tony Belpaeme
Artificial Intelligence Laboratory
Vrije Universiteit Brussel

Robots today…

- Have pre-programmed or pre-trained representations.
  - Useful for industrial robots.
  - Less than useful for cognitive robots.
- Have little interaction with humans or other robots.
  - If they do, they do not learn or adapt from these interactions.
- Are expected to have full functionality out-of-the-box.

The Robinson robot

The Robinson robot

- Most robots are still as isolated from others as Shakey (SRI, 1966).

- AIBO is full of gimicks, but takes no advantage from social interaction.

Humans however…

- Acquire concepts through interacting with their environment and with other humans.
- Communicate using complex language.
- Need long ontogenetic development.

Out-of-the-box functionality?

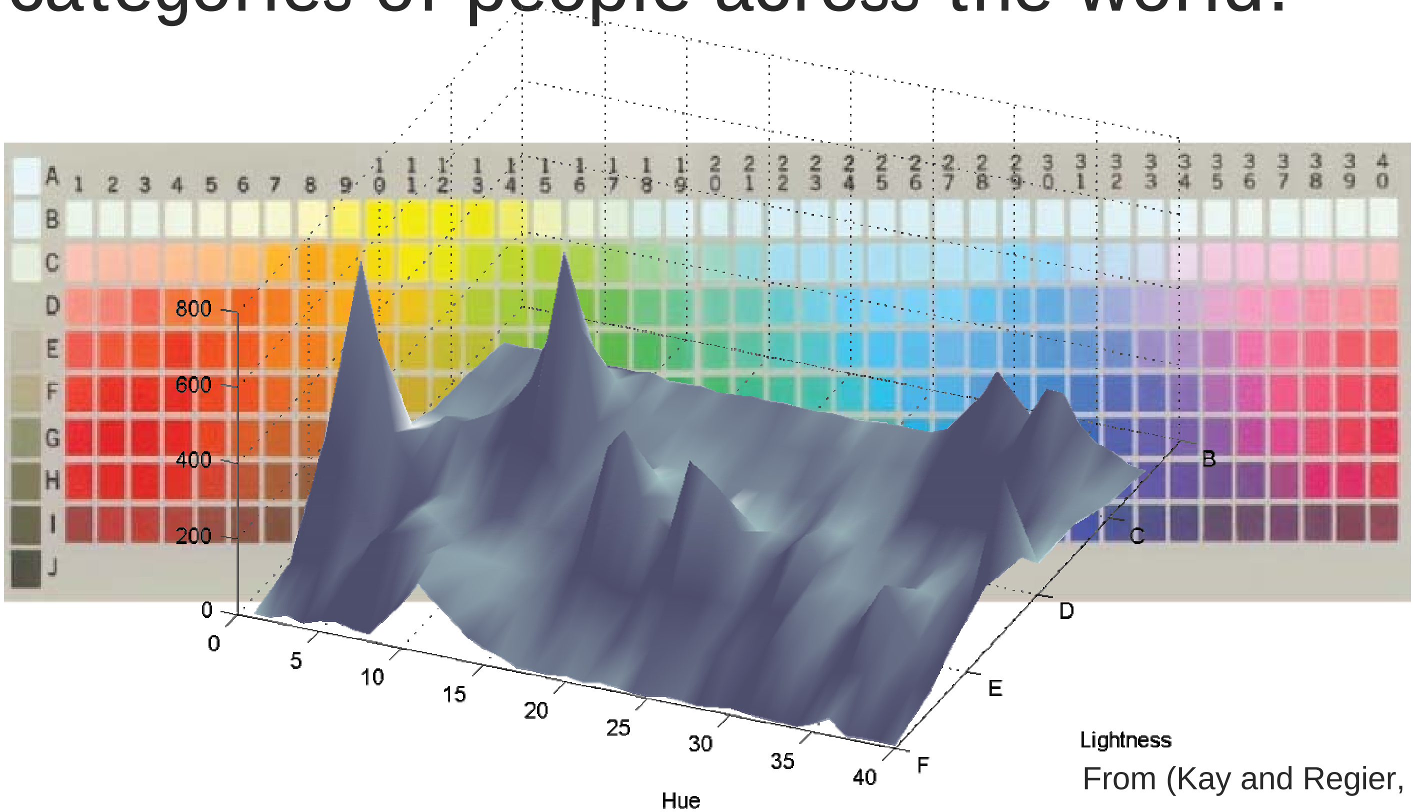
Colour categories

- The inspiration and justification of this talk.

- Colour categories provide us a look in the human mind:
  - How do we form categories and concepts?

Colour categories are universal

- There is a certain regularity in colour categories of people across the world.



From (Kay and Regier, 2003)

The trouble with universality

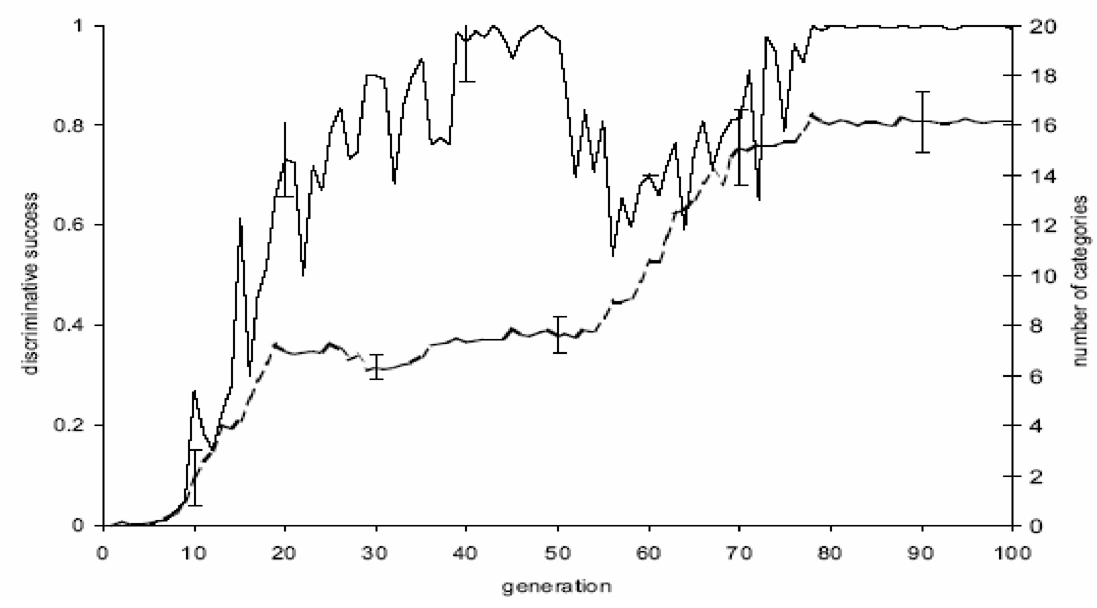
- Three positions
  - **Genetic determinism**: directly or indirectly our categories are specified by our genetic make-up.
  - **Empiricism**: categories are shaped through interacting with the environment.
  - **Culturalism**: categories are the product of cultural and linguistic interactions.

Genetic determinism

- Very plausible, but recently received some critique.
- Problems
  - Genes of colour opsins vary.
  - Doesn’t not explain all the data.
  - Genetic evolution is slow and undirected.

Genetic determinism

- Simulations using a model of computational evolution confirm this last point.



From (Steels and Belpaeme, 2005)

Empiricism

- We extract colour categories by interacting with our environment.
  - Our visual perpection is adapted to viewing our world.
  - Our ecology contains a certain chromatic structure which is reflected in our colour categories.

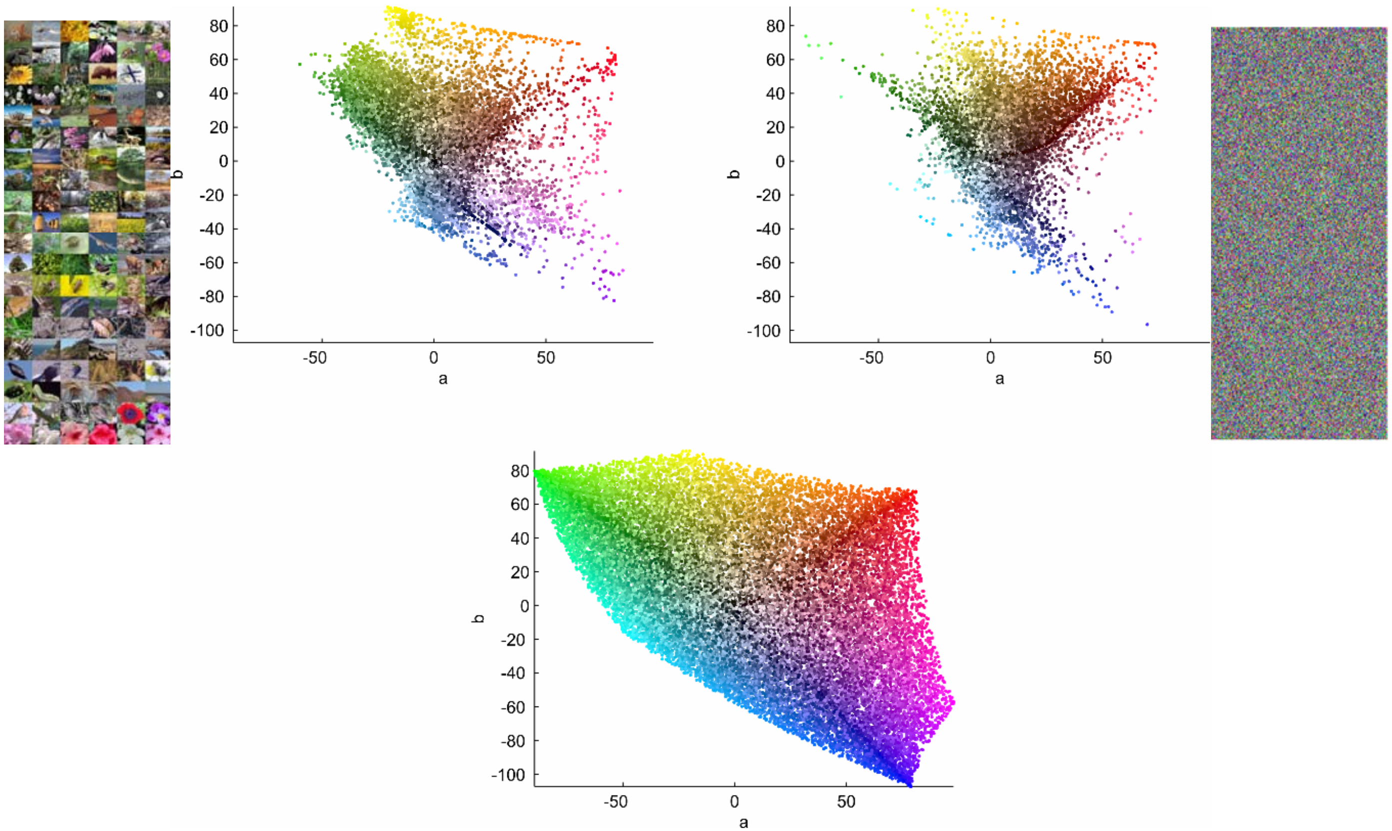
- Problems
  - People experience different ecologies.

Studying empiricism

- Procedure
  - Collect chromatic data.
  - Extract colour categories. For this we use a k-nearest neighbour clustering algorithm.
  - Compare extracted categories with each other and with human colour categories.
- If empiricism holds, we would expect a high correlation between the extracted categories and human categories.

Studying empiricism

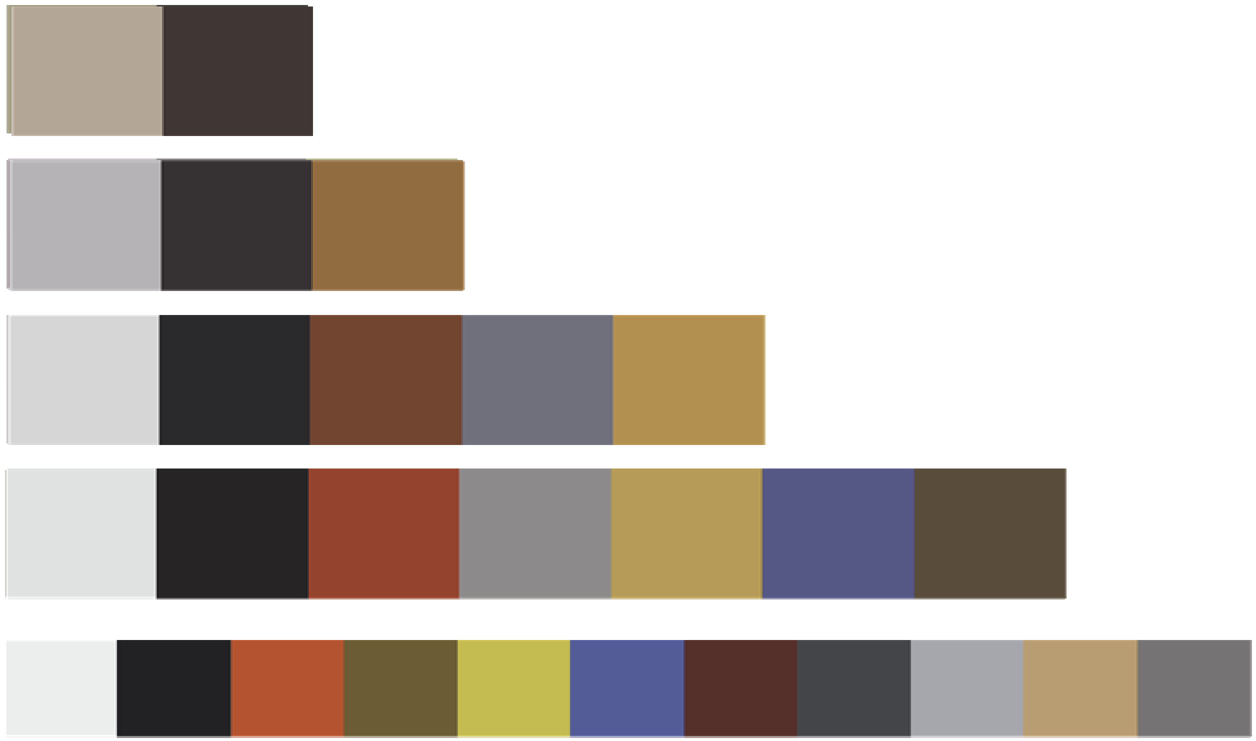
- Input data



Studying empiricism

Categories from urban data:

Categories from natural data:



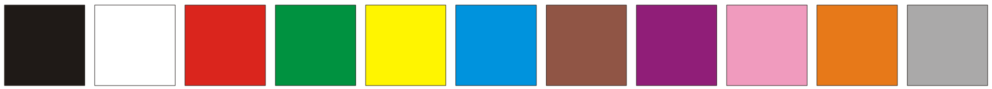
k=2

k=3

k=5

k=7

k=11



Studying empiricism

- Correlation between extracted clusters and human categories.

11 categories	L*	a^*	b^*	C^*_{ab}	H_{ab}
NATURAL	0.785*	0.200	0.745*	0.709*	0.636*
URBAN	0.935*	0.382	0.745*	0.491*	0.345
RANDOM	0.411	0.309	0.782*	0.600*	0.709*

* Correlation is significant at the 0.05 level.

- No significant higher correlation compared to **random** input.
- Empiricism does not explain the nature of colour categories.
  - However, there seems to be an influence of the colour space and of the properties of categorisation.

From (Belpaeme and Bleys, in prep.)

Culturalism

- Categories are culturally determined: we learn what colours mean through our peers.
- Problems
  - If so, one would expect much more variability between different cultures. **Every culture divides the rainbow at will.**
  - How can something as random as culture explain such uniform colour categories?

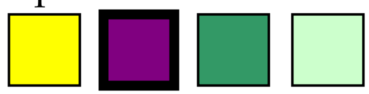
Studying culturalism

- **Needed**: A model for learning concepts through linguistic experience.

- Language game (Steels, Belpaeme, et al)
  - Agent-based model.
  - Agent can perceive, categorise and lexicalise.
  - They are forced to communicate.
  - Simultaneous acquisition of lexicon and categories.

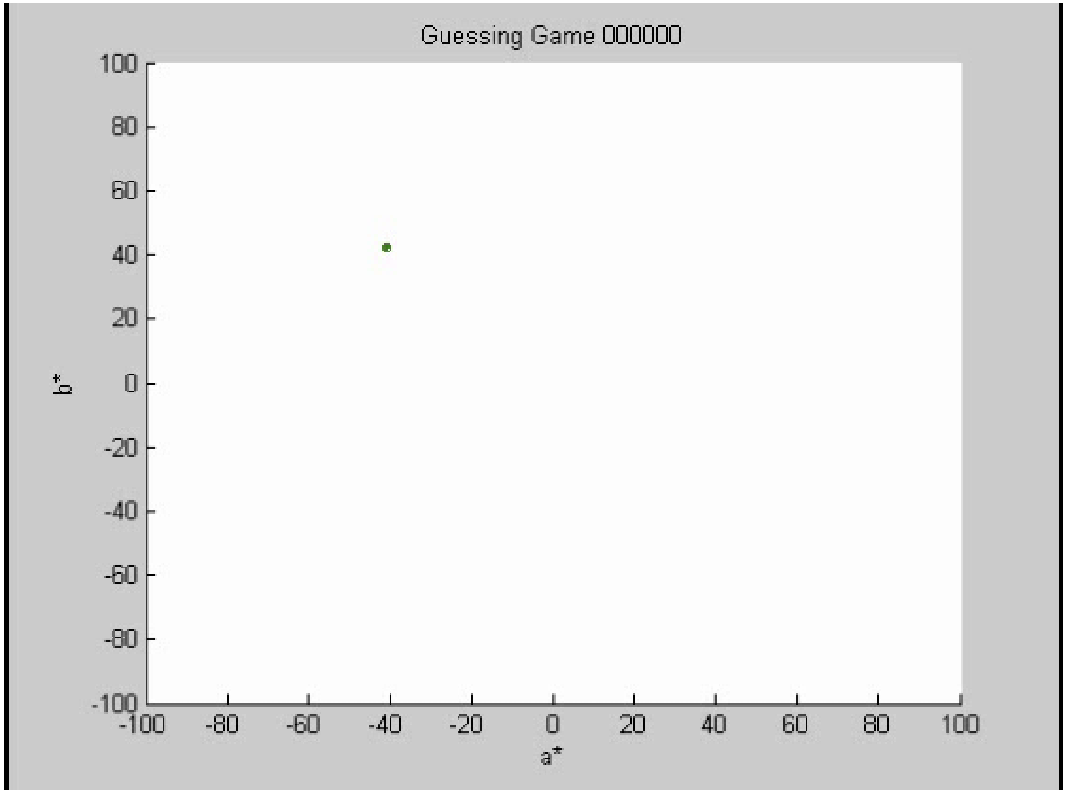
Studying culturalism

- Guessing game

Speaker	**Hearer**
Choose topic from context	
	
Can topic be distinguished from other?	
Find word associated with category	
Utter word to hearer	Hear word
	Find category which best matches word
	Find object which best matches category, point at it
If hearer points at topic, then **success**	
Adapt associations between word and category.	Adapt associations between word and category.

Studying culturalism

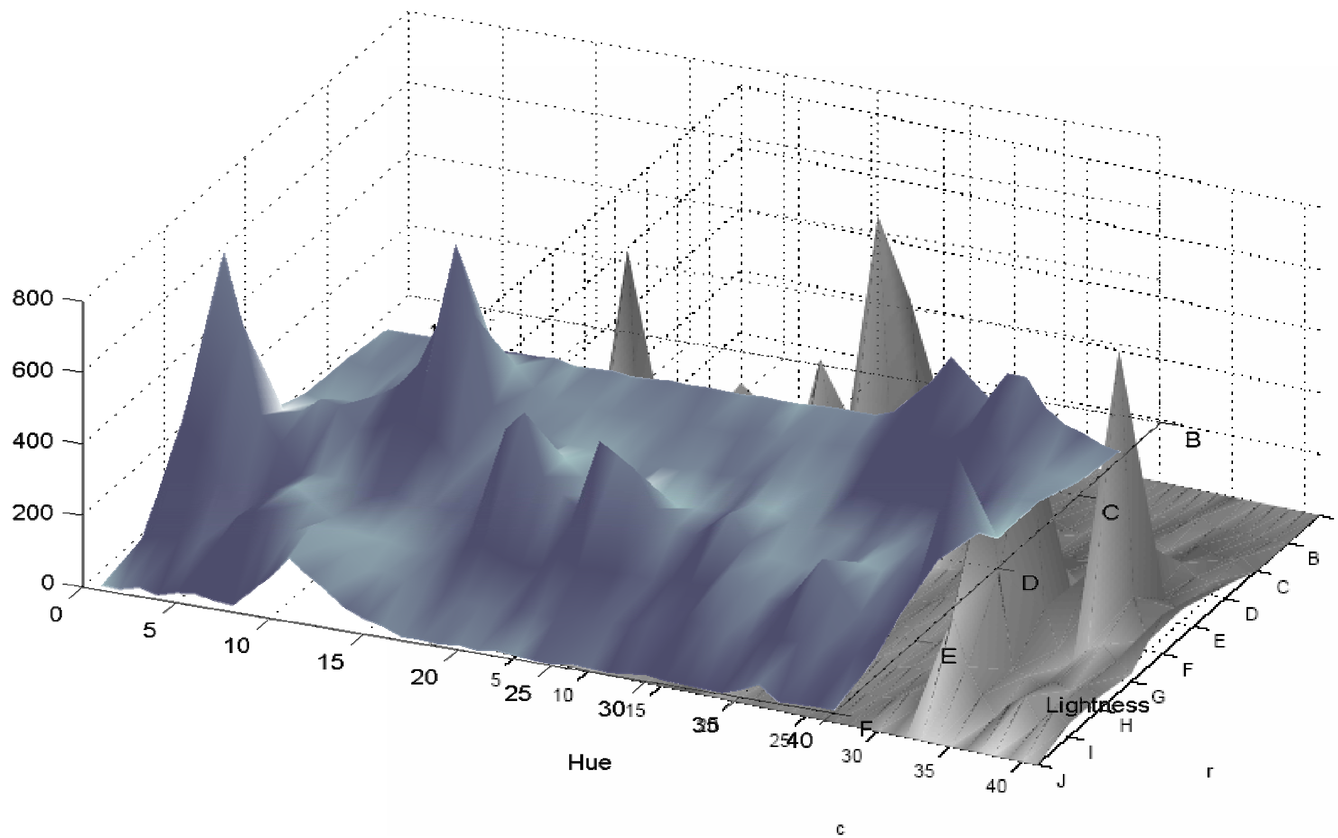
- Result of a guessing game



(Courtesy of Joris Bleys)

Studying culturalism

- Can we replicate the universalist results?



Cultural propagation

- Works well for perceptual categories, but… should even work better for other categories and concepts.
  - Perceptual categories could be pre-programmed, complex concepts can not.
  - Cultural learning does not assume concepts to fixed, instead they are **adaptable**.

Example of concepts

From (French, B. et al, 2004)

Robots picking your brain

- Intelligent systems have no way to access your concepts.
  - No telepathic access, no brain scans.

- The only way into the human brain is through language.
  - Through **active** linguistic interactions with the robot, the robot can extract meaning.

The robot body

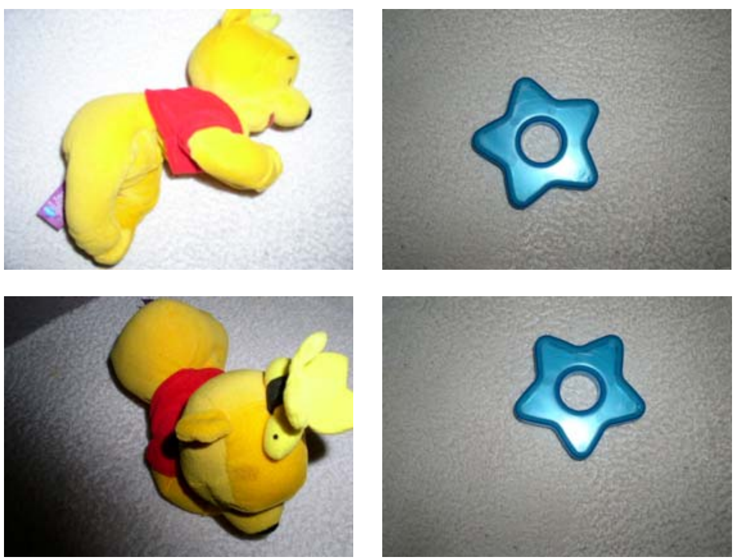
- Sensory modalities need not be the same.
  - The robot can perceive the world through its own sensors.
- The robot needs to be **grounded** in the world the human is grounded in.
  - The context about which robots and humans communicate needs to be shared.

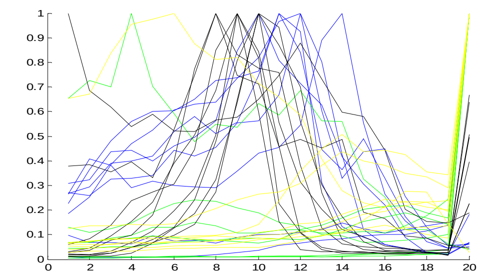
Time scale

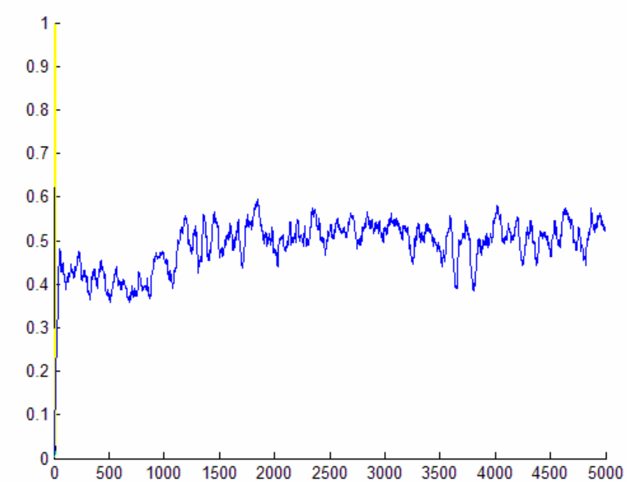
- Emerging field of **developmental robotics.**
- Time scale on which robots learn concepts will be huge.
  - Could be fix the robot with a basic repertoire of concepts and words?
  - Even better... Hook robots up to network and let them exchange sensory and linguistic experiences.

Preliminary experiments

- Robotic system learns concepts for toys.

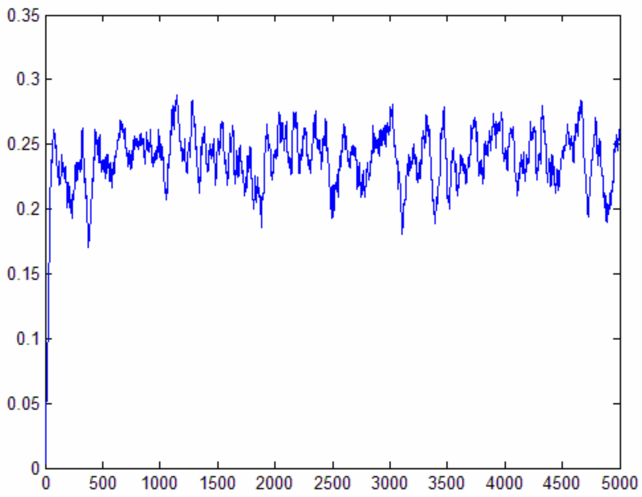






Preliminary experiments

- Robotic system learns concepts for rooms in a house.



Cultural propagation in other domains

- Imitation of actions and goals. (Jansen, B.)
- Construction of meaning between agents. (Vogt, P.; Roy, D.; Kaplan, F.; Steels, L.; De Vylder, B.)
- Self-organisation of speech sounds. (de Boer, B.; Oudeyer, PY.)
- Emergence of grammatical structure in artificial languages. (de Beule, J.; Steels, L.)

Conclusion

Further reading

- Interesting people (in no particular order): Luc Steels, Paul Vogt, Deb Roy, Frédéric Kaplan, Bart Jansen, Bart de Boer…
- Interesting dead trees
  - Steels, L. & Belpaeme, T. (2005) Coordinating perceptual categories through language. A case study for colour. *Behavioral and Brain Sciences.* In press.
  - Belpaeme, T. & Bleys, J. (2005) Does the world hand us color categories? In preparation, draft available.
  - Belpaeme, T., de Boer, B. and Jansen, B. (2005) The role of population dynamics in imitation. In Dautenhahn, K. and Nehaniv, C.L. (eds.) Imitation and Social Learning in Robots, Humans and Animals: Behavioural, Social and Communicative Dimensions. Cambridge University Press. Cambridge, UK. To appear.