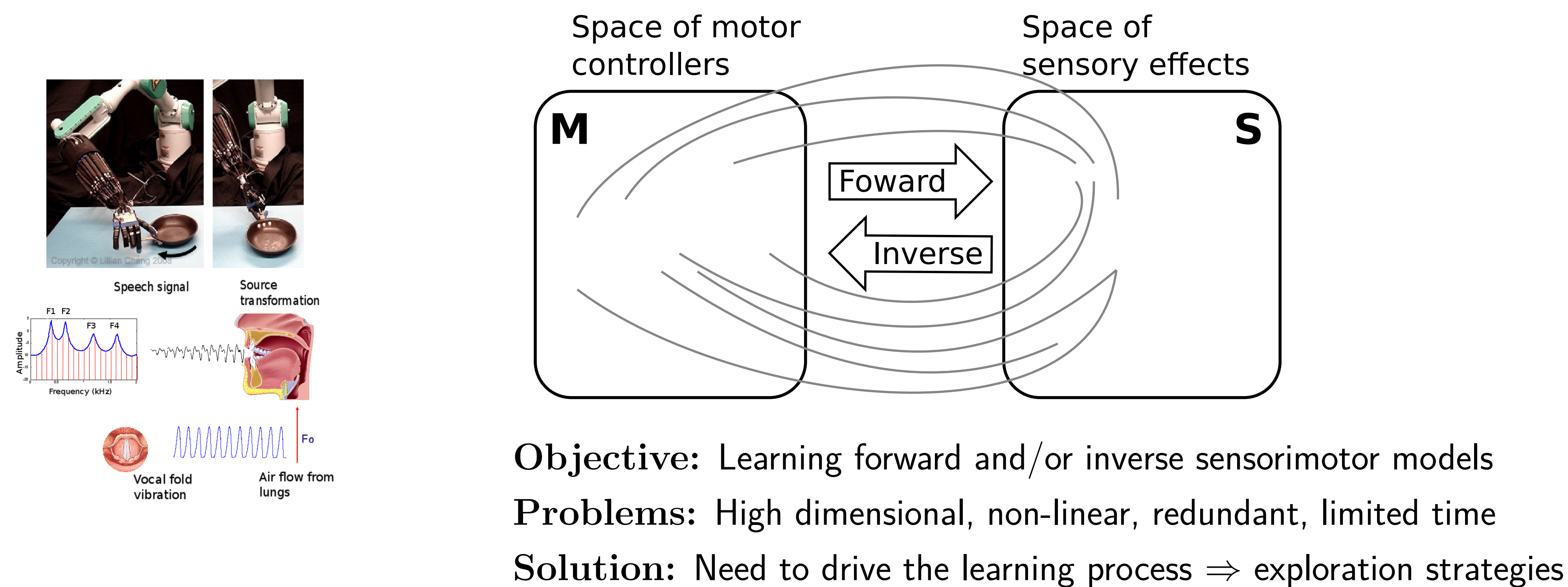


Exploration strategies in developmental robotics: a unified probabilistic framework

Clément Moulin-Frier and Pierre-Yves Oudeyer
Flowers Team — Inria / ENSTA-ParisTech / Bordeaux, France

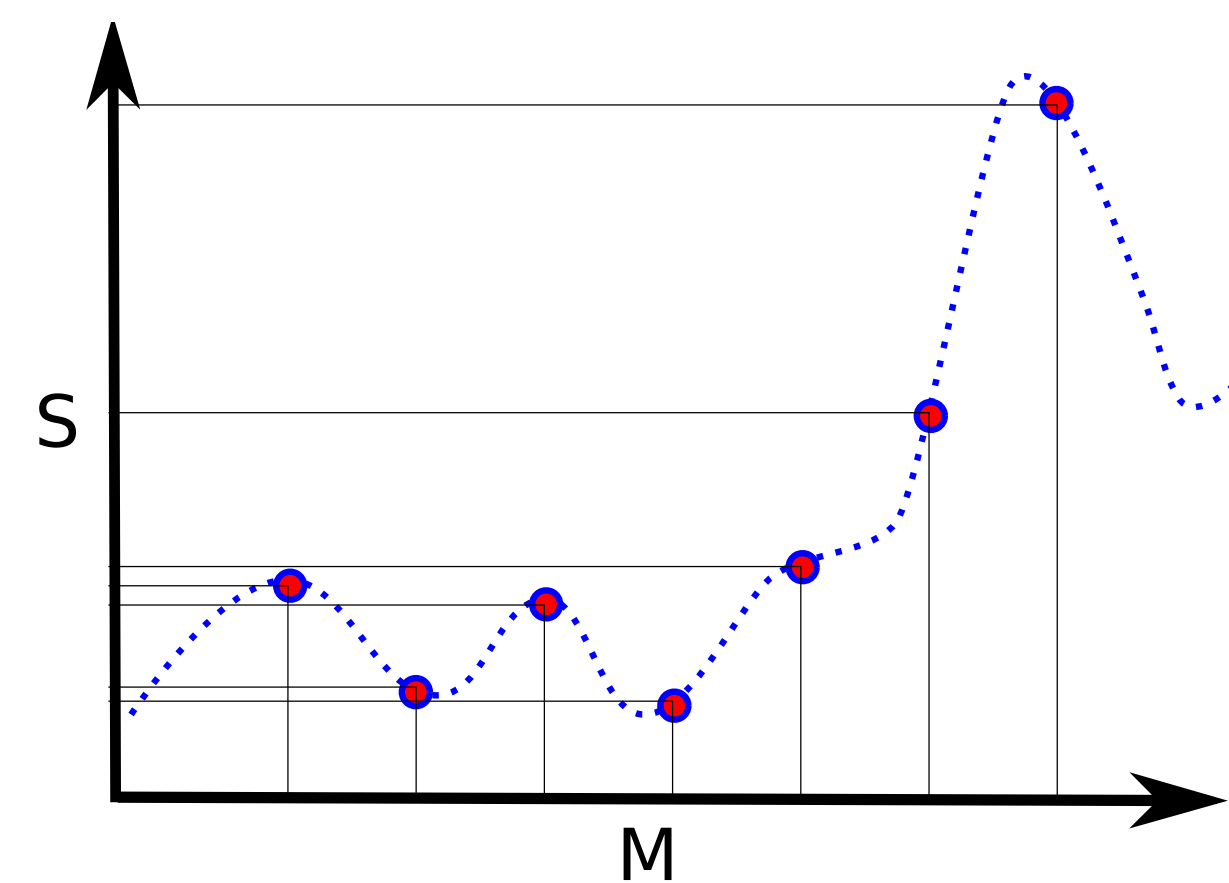
1. Why exploration strategies?



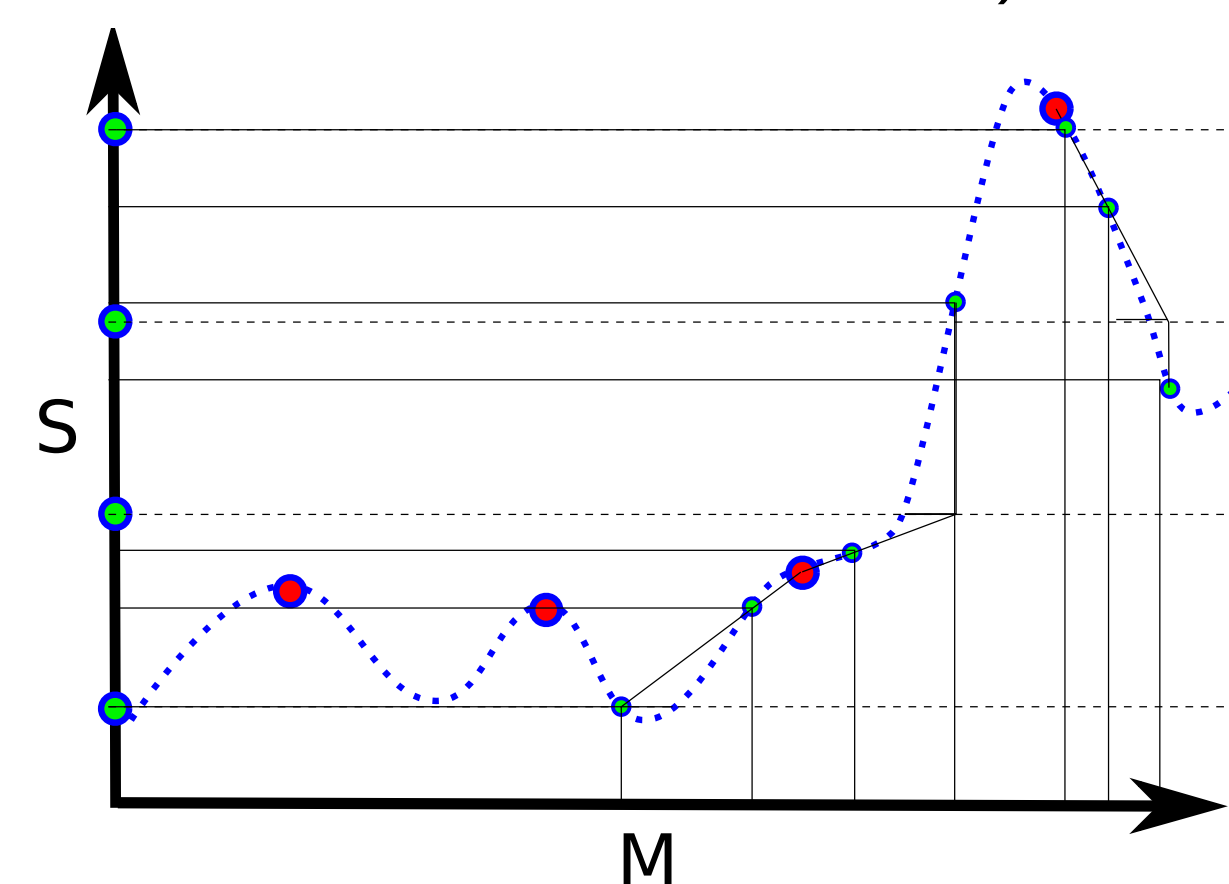
2. Two important principles

• In which space to sample

- Motor babbling (sample in M , observe in S)



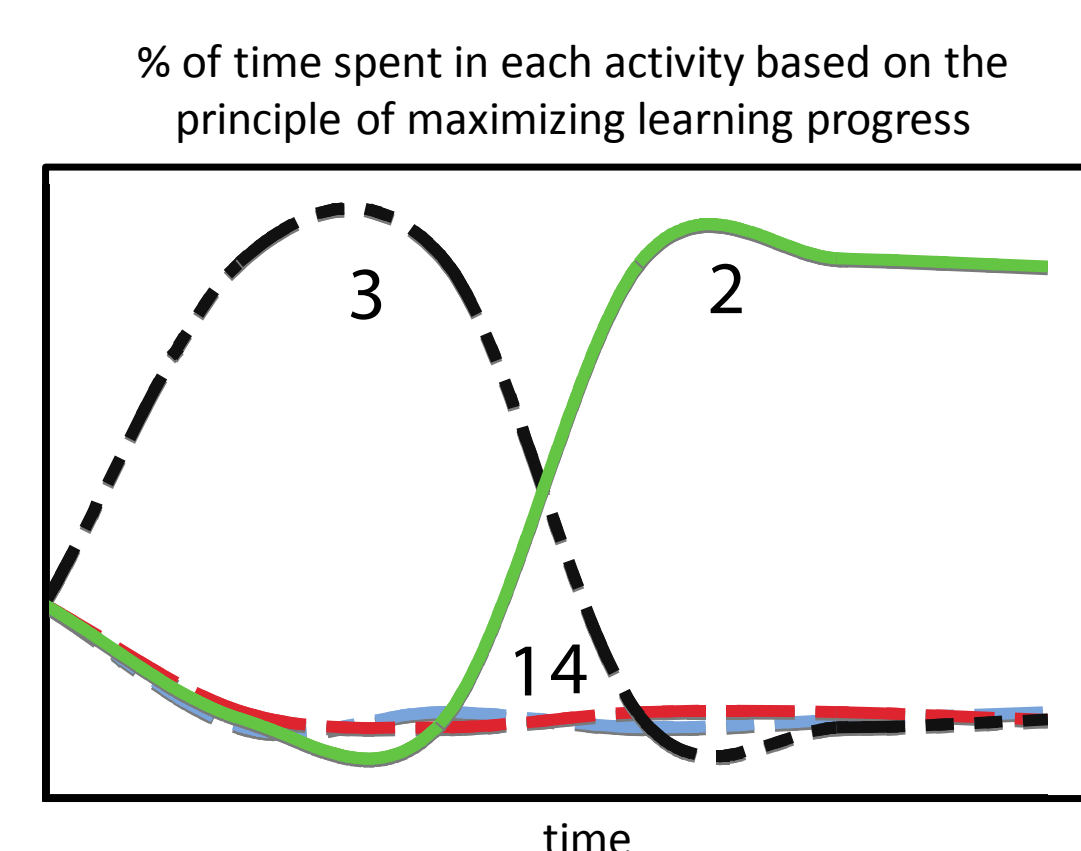
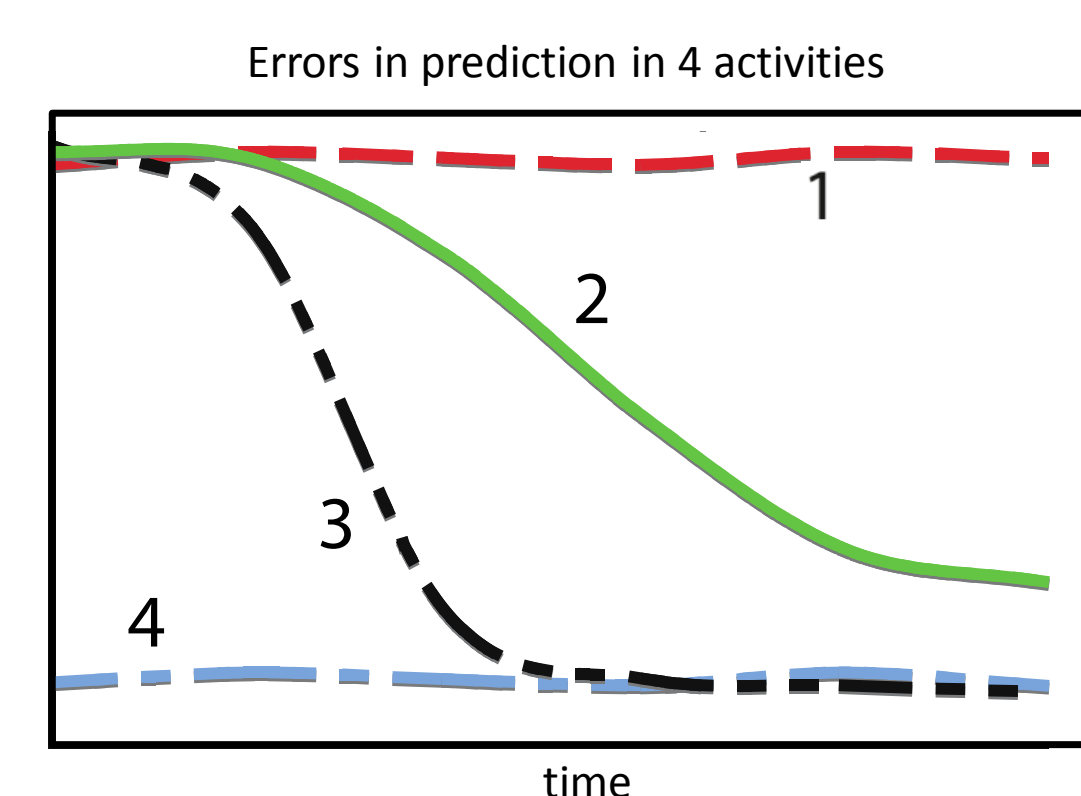
- Goal babbling (sample in S , attempt to reach trough M , observe in S)



\Rightarrow Goal babbling collects data more uniformly distributed on S than motor babbling

• Where in the space to sample

- Random exploration
- Active exploration maximizing the learning progress



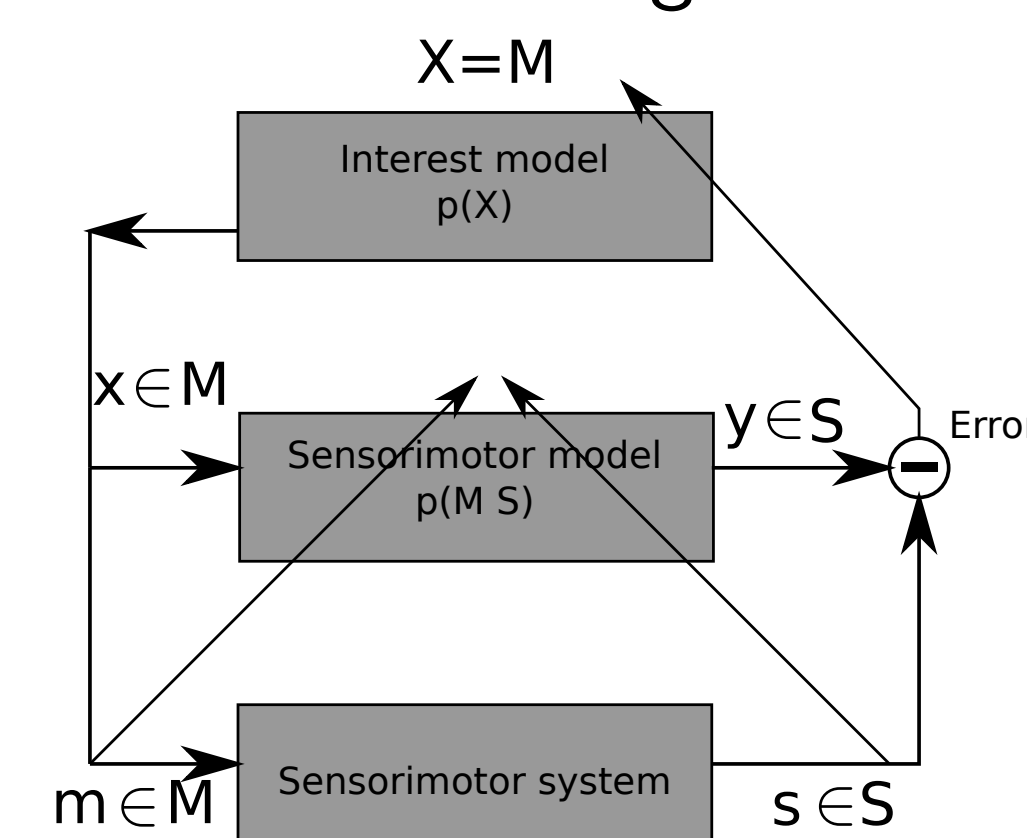
\Rightarrow Active exploration focuses on tasks of increasing complexity

3. A generic exploration algorithmic architecture

Choice space X	Interest distribution $p(X)$		
	Random exploration		Active exploration
Motor babbling	Random motor exploration (ACTUATOR-RANDOM)	Active motor exploration (ACTUATOR-RIAC)	
Goal babbling	Random goal exploration (SAGG-RANDOM)	Active goal exploration (SAGG-RIAC)	

(Baranes and Oudeyer, 2010, 2013)

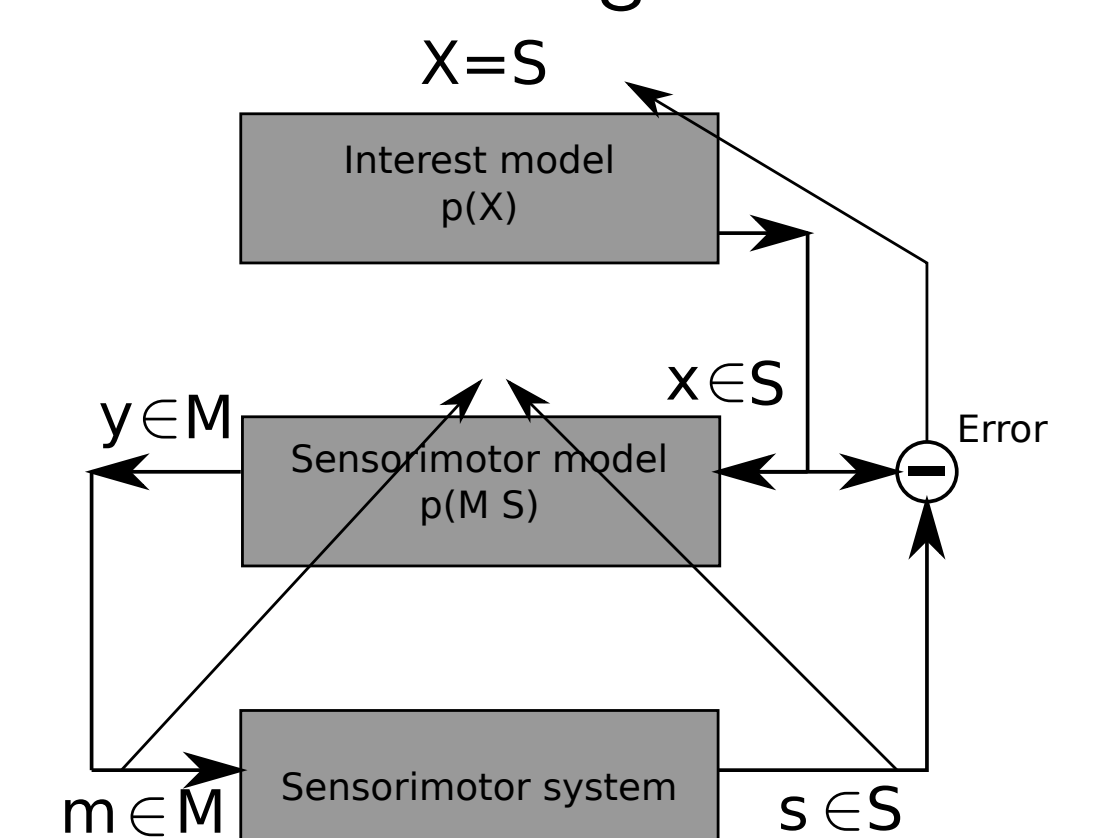
• Motor babbling



1: while true do

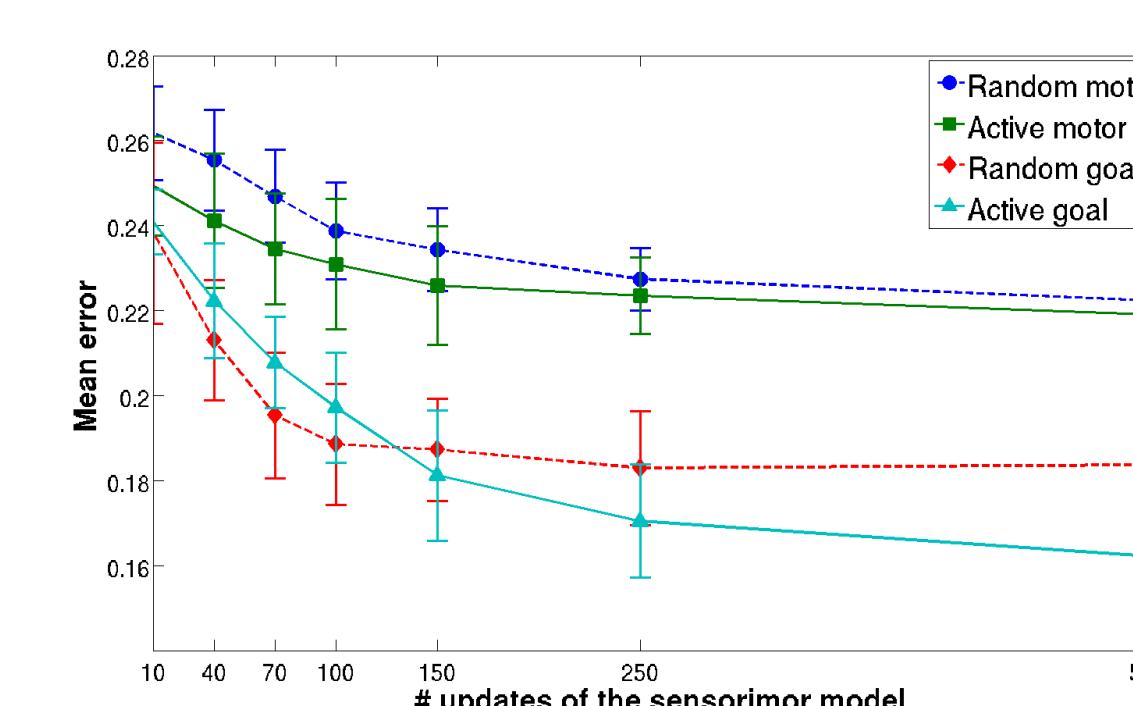
- 2: $x \sim p(X)$
- 3: $y \sim p(Y | x)$
- 4: $m = M((x, y))$
- 5: $s = f(m) + \epsilon$
- 6: $e = \text{distance}(S(x, y), s)$
- 7: $\text{update}(p(M|S), (m, s))$
- 8: $\text{update}(p(X), (x, e))$
- 9: end while

• Goal babbling

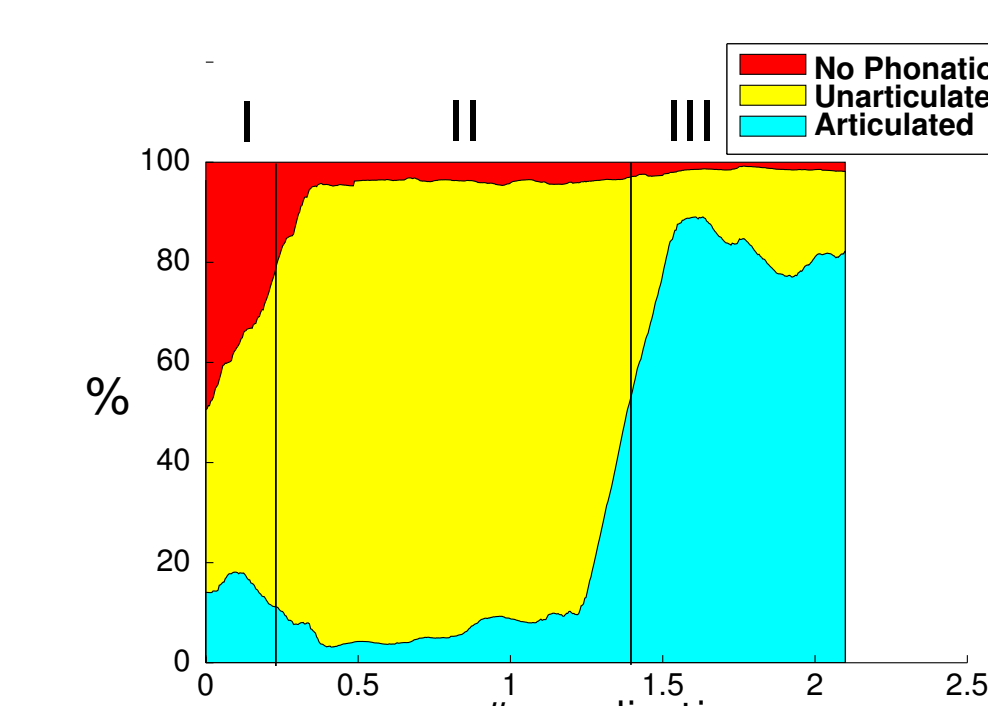


4. Results: a case study on articulatory-acoustic spaces

- Performance comparison on uniformly distributed acoustic goals



- Self-organization of a developmental sequence (active goal strategy)



5. Conclusion

- Goal babbling drives efficiently the collection of learning data of an inverse model
- Active exploration based on the maximization of the learning progress enables the self-organization of a developmental sequence

6. Related paper

Clément Moulin-Frier and Pierre-Yves Oudeyer (2013). Exploration strategies in developmental robotics: a unified probabilistic framework. In *International Conference on Development and Learning, Epirob, Osaka, Japan*.