Active Interaction Between Robots and Humans for Automatic Curriculum Learning and Assistive Robotics

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AFIA
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Thème INTERACTIONS : HUMAINS, ROBOTS, ENVIRONNEMENT.
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ENSTA IP PARIS

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Lab-STICC

1. Robot Coach for Rehabilitation

1. A robot Coach for Physical Rehabilitation

http://keraal.enstb.org

1. A robot Coach for Physical Rehabilitation

LEARNING THE EXERCISE SPECIFICATIONS
Gaussian Mixture Model on Riemannian manifolds

DEMONSTRATION

Gaussian Mixure Regression & Gaussian Process

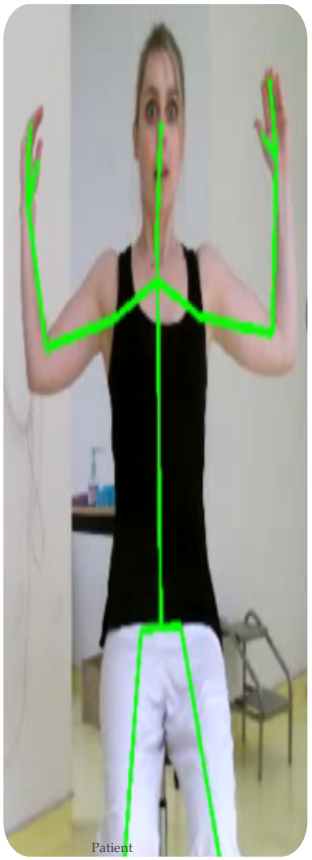
MOVEMENT ANALYSIS

Body part & Temporal

Likelihood estimation

FEEDBACK

Svm to classify errors



http://keraal.enstb.org

1. A robot Coach for Physical Rehabilitation

- Clinical trials:
  - **30 patients**
  - **30 minutes/day**
  - **3 weeks**
- Results:
  - **Medical evaluation: Non inferiority of the robotic coach**
- Goal:
  - **increase the time patients spend exercising**
  - **alleviate the lack of time a physiotherapist can spend monitoring a patient**
  - **reduce difficulties of transport to the rehabilitation center**
- Proposition:
  - **Embodied training companion to entice motivation through advice understandable by humans**

2. Computational Model of Motivation

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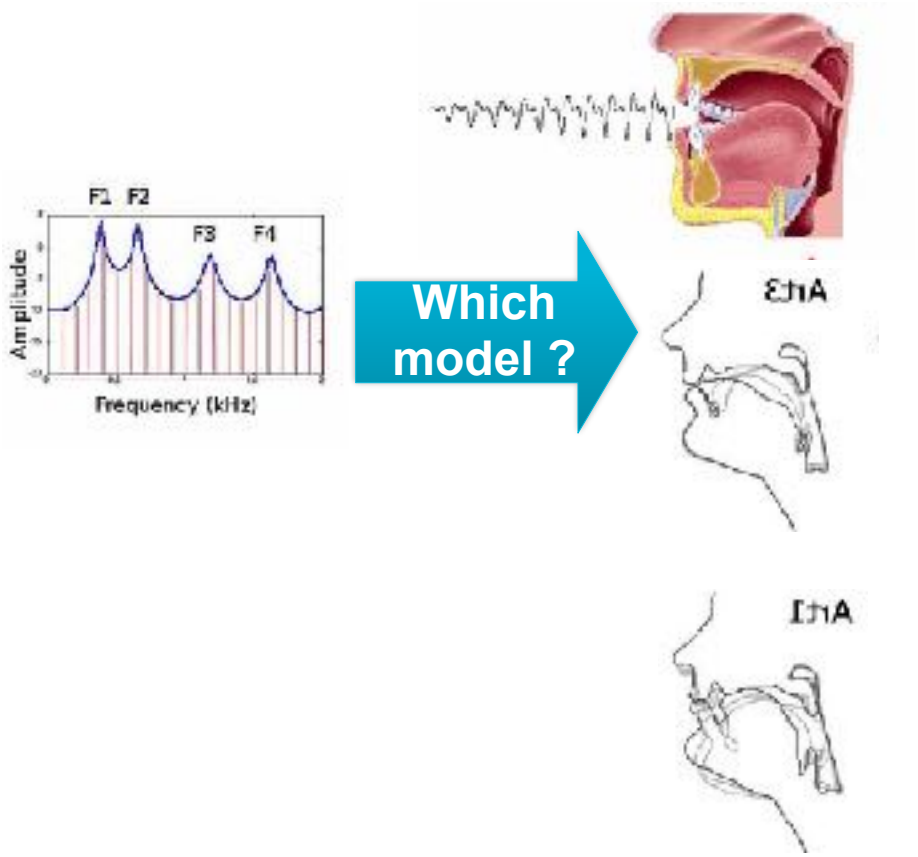
Infant development of vocalisation



Multi-task learning

Model to learn : G_{SM} : S → M

Sound ⟼ Motor control of mouth, vocal tract, lungs

Goal-oriented exploration : G_{IM} : history ⟼ Sound s_g

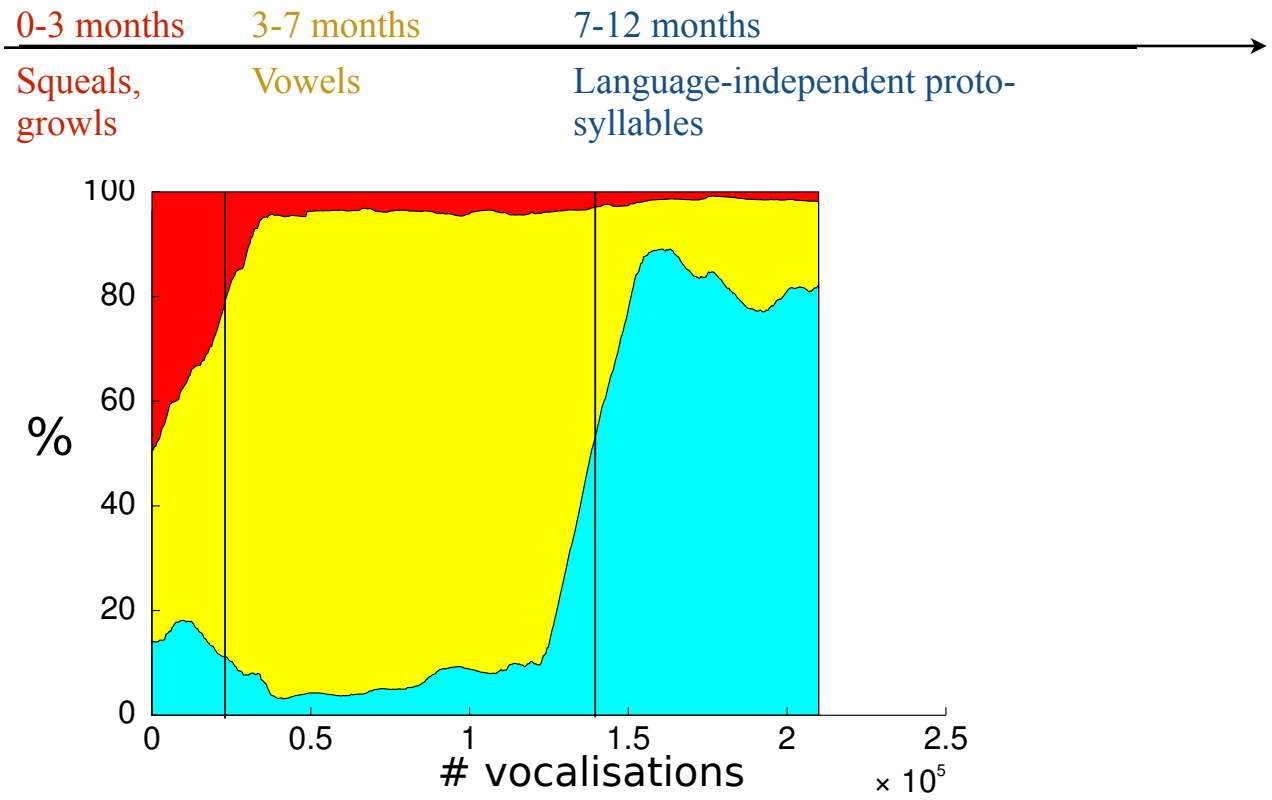
Algorithm 1 | Self-exploration with active goal babbling (stochastic SAGG-RIAC architecture).

1: initialise G_{SM} and G_{IM}
2: **while** true **do**
3: $s_g \sim G_{IM}(S)$
4: $m \sim G_{SM}(M \mid s_g)$
5: $s = f(m) + \epsilon$
6: $c = comp(s_g, s)$
7: $update(G_{SM}, (m, s))$
8: $update(G_{IM}, (s_g, c))$
9: **end while**

Moulin-Frier et al., 2014

2. Computational Model of Motivation

Infant development of vocalisation



Moulin-Frier et al., 2014

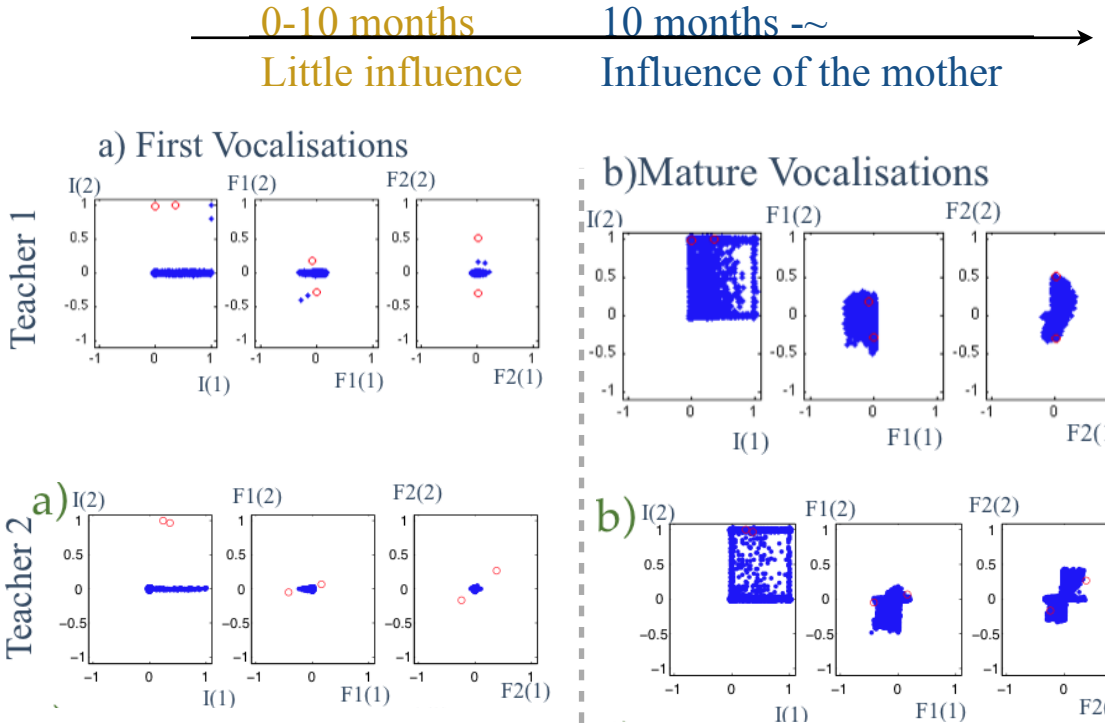
2. Computational Model of Motivation

Infant development of vocalisation

With Social Guidance

Algorithm 2 | Strategic active exploration (active goal babbling and imitation with stochastic SGIM-ACTS architecture).

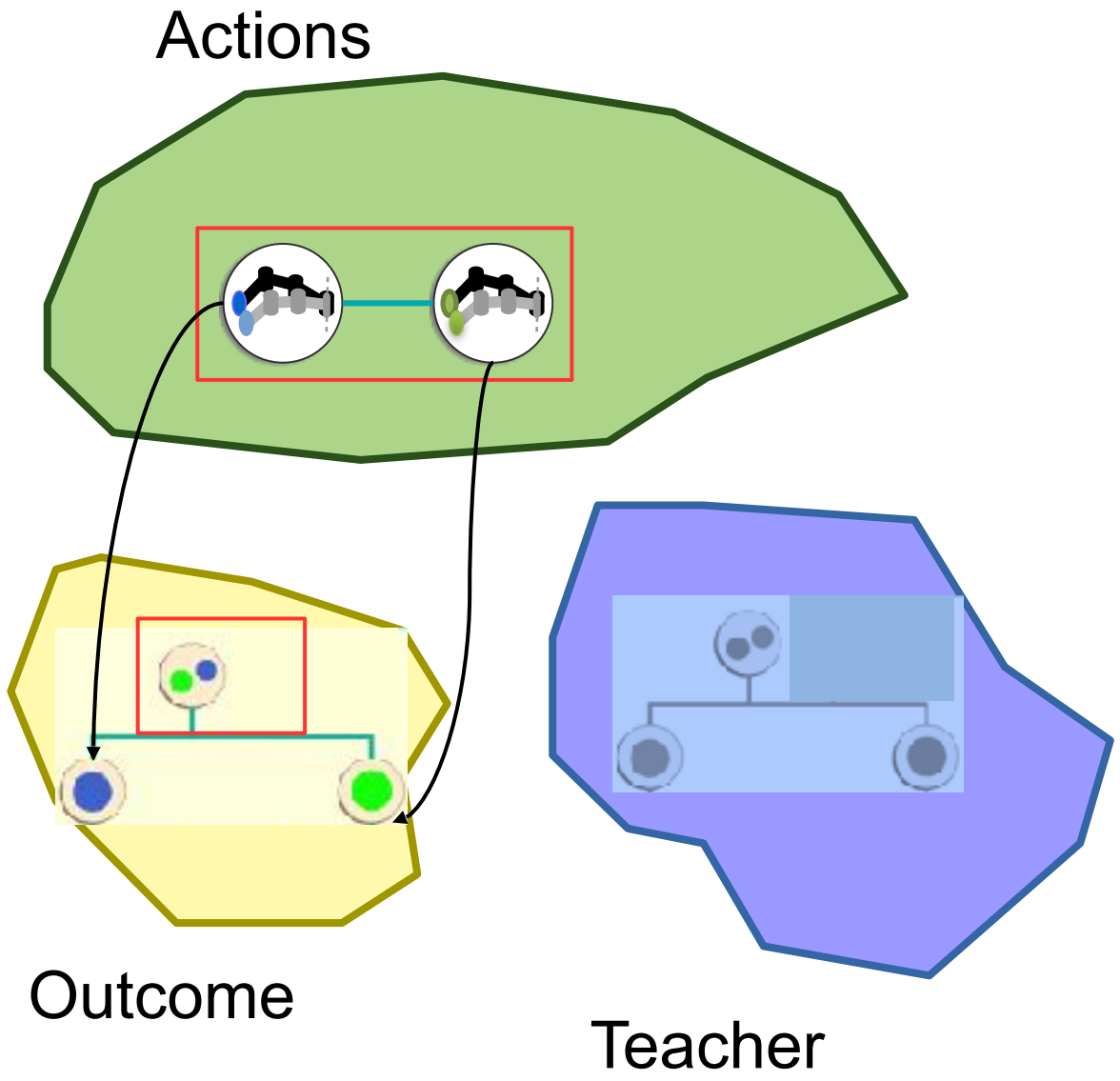
1: Initialize G_{SM} and G_{IM}
2: **while** true **do**
3: $(str, s_g) \sim G_{IM}(StrS)$
4: **if** $(str = social\_guidance)$ **then**
5: $s_g \leftarrow$ random auditory demonstration from the ambient language
6: **end if**
7: $m \sim G_{SM}(M \mid s_g)$
8: $s = f(m) + \epsilon$
9: $c = comp(s_g, s)$
10: $update(G_{SM}, (m, s))$
11: $update(G_{IM}, (str, s_g, c))$
12: **end while**



Moulin-Frier et al., 2014

3. Intrinsic Motivation for Hierarchical Learning

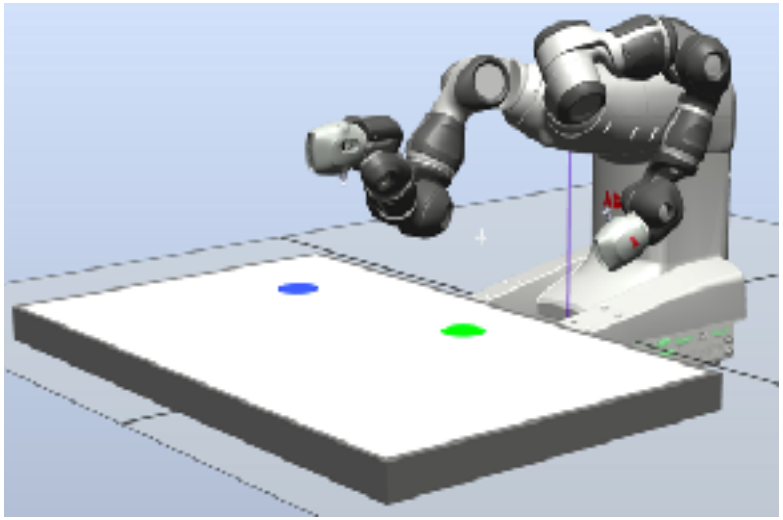
3. Intrinsic Motivation for Hierarchical Learning Intuition

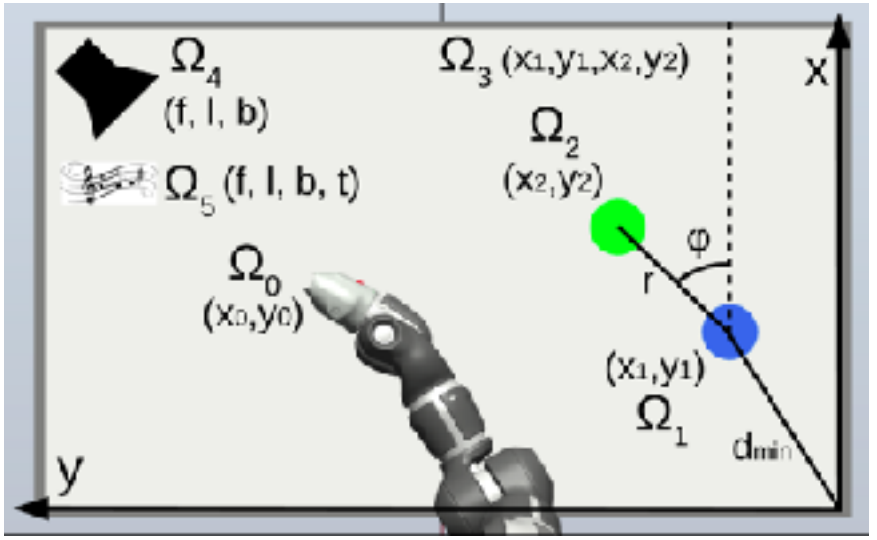


3. Intrinsic Motivation for Hierarchical Learning

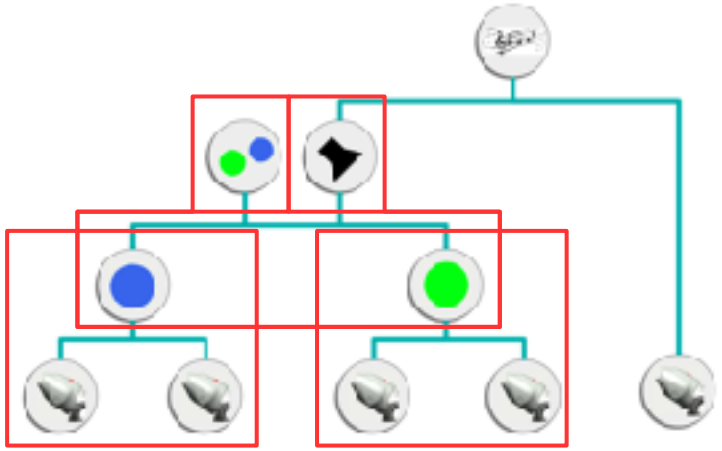
Experimental setup

Duminy et al, 2018





- 7 joints controlled by DMP
- 14 parameters primitives: $(\mathbb{R}^{14})^{\mathbb{N}}$
- Outcome space: $\Omega = \cup_{i=0}^{5} \Omega_i$



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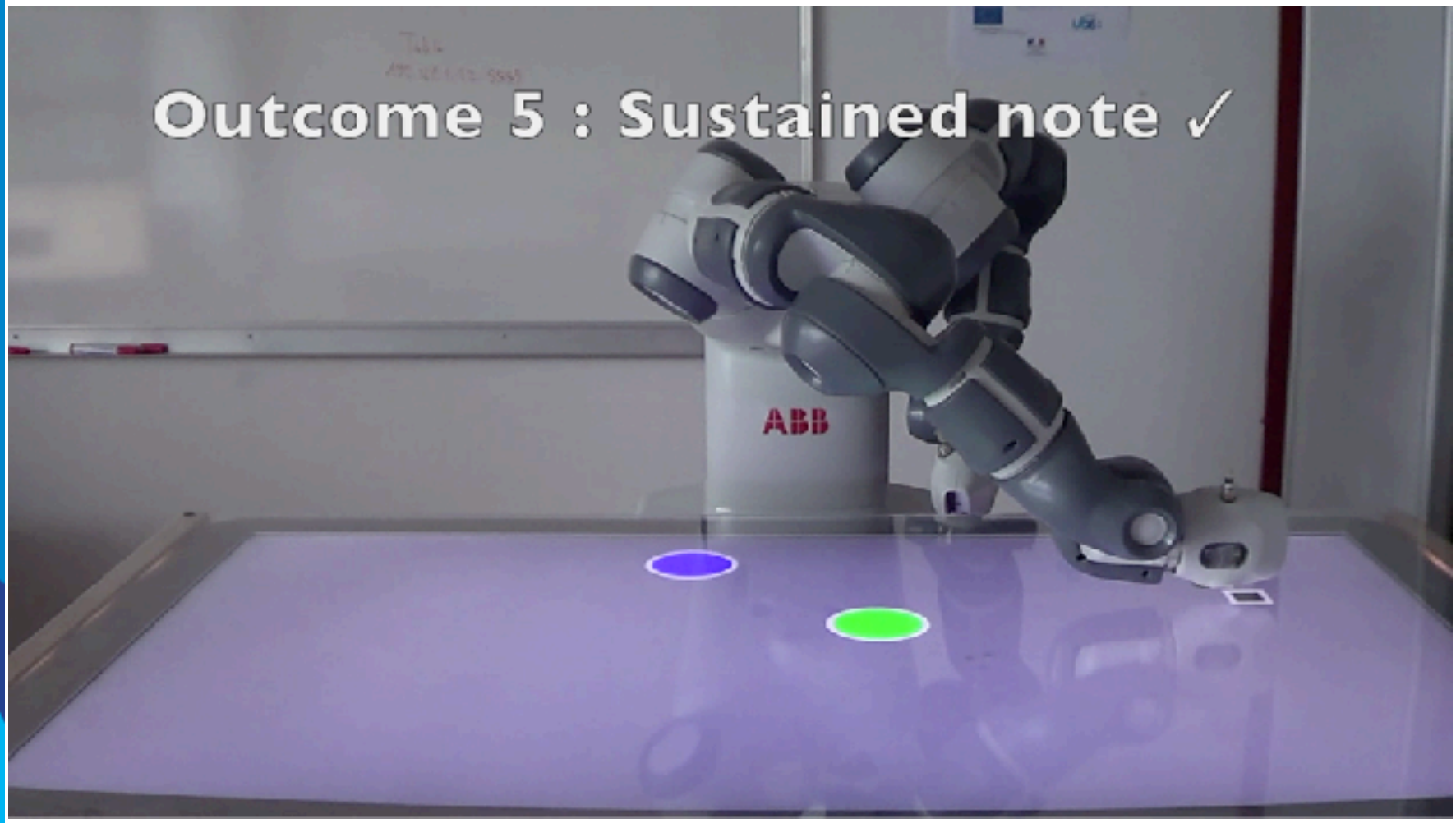


Evaluation

3. Intrinsic Motivation for Hierarchical Learning

Learning compound actions using task hierarchy

Duminy et al, 2018

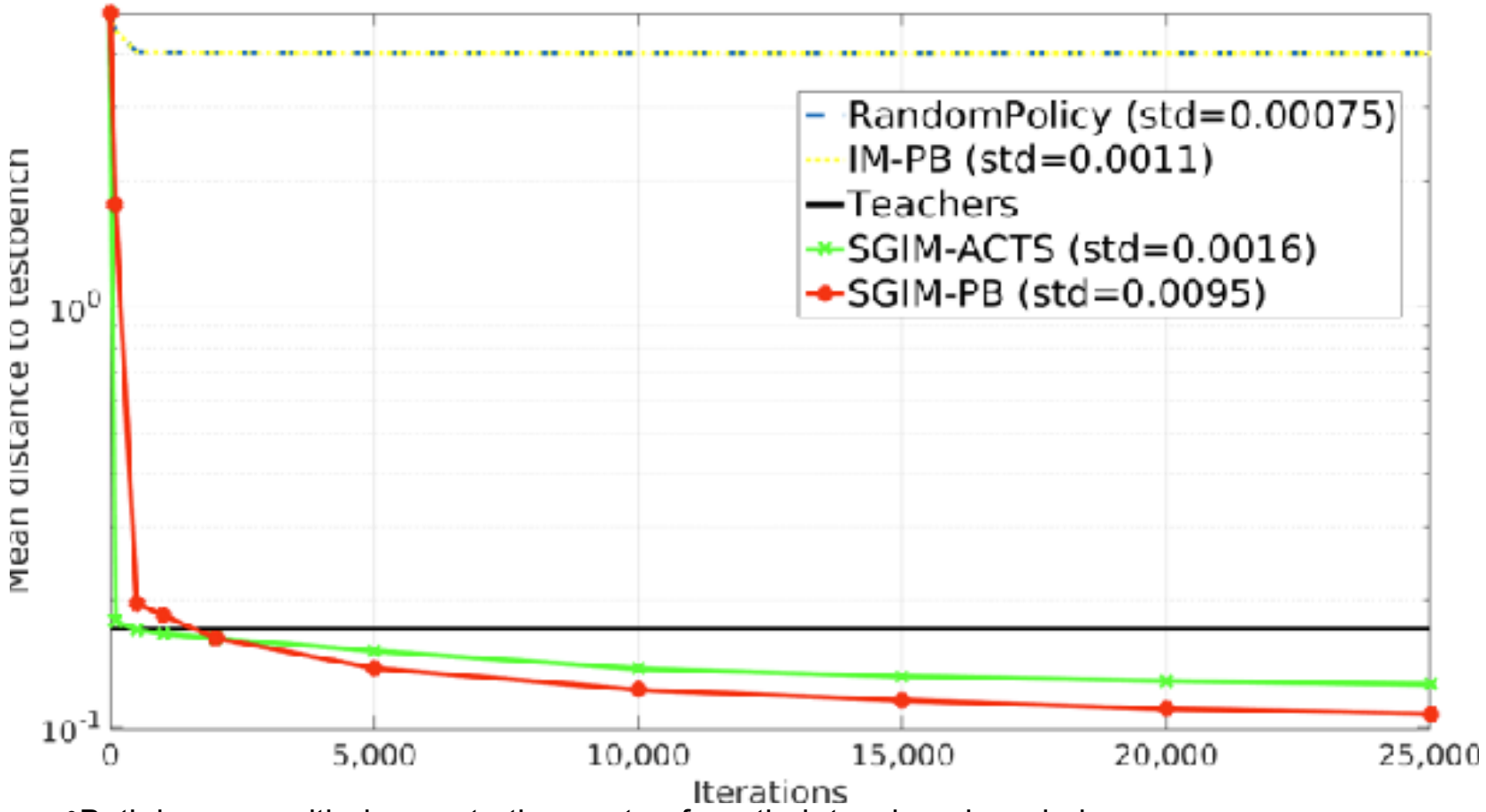
- Multi-task Learning : policies of different complexities
  - **Compound actions = sequences of primitive actions of adapted size**
- Discover and exploit the task hierarchy
  - **Task-oriented combination of skills**
- Automatic Curriculum Learning
  - **Goal Babbling**
  - **Active Imitation of several teachers**

Socially-Guided Intrinsic Motivation with Procedure Babbling (SGIM-PB)

3. Intrinsic Motivation for Hierarchical Learning

Results: Evaluation performance

Duminy et al, 2018



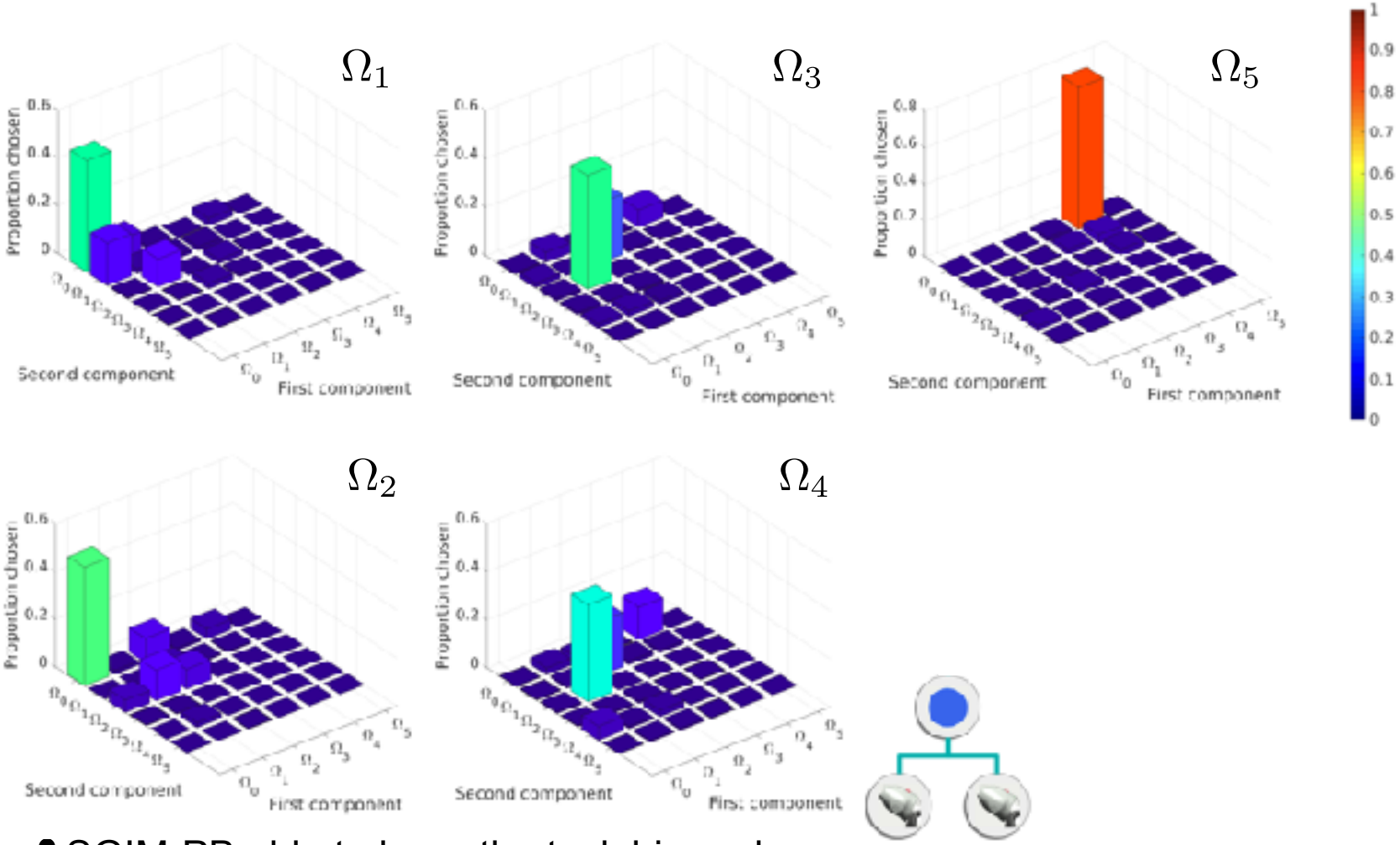
- Both learners with demonstrations outperform their teachers knowledge
- SGIM-PB outperforms SGIM-ACTS showing the potency of procedural teachers

3. Intrinsic Motivation for Hierarchical Learning

Results: Procedures learned

Duminy et al, 2018

Which subgoals are associated to each task ?

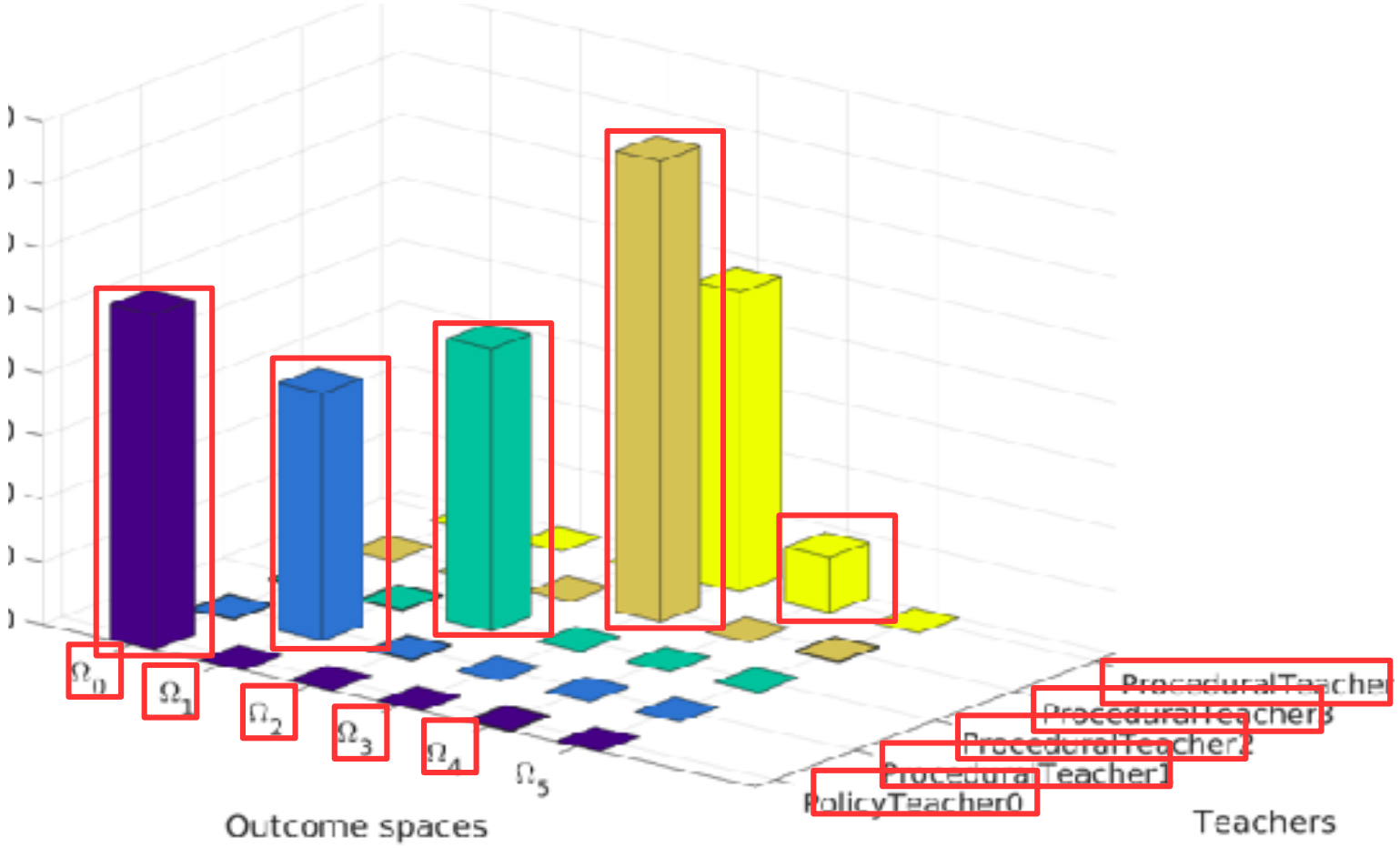


- SGIM-PB able to learn the task hierarchy
- Even without teacher to help it for

3. Intrinsic Motivation for Hierarchical Learning

Duminy et al, 2018

- ## Results: Strategic choices

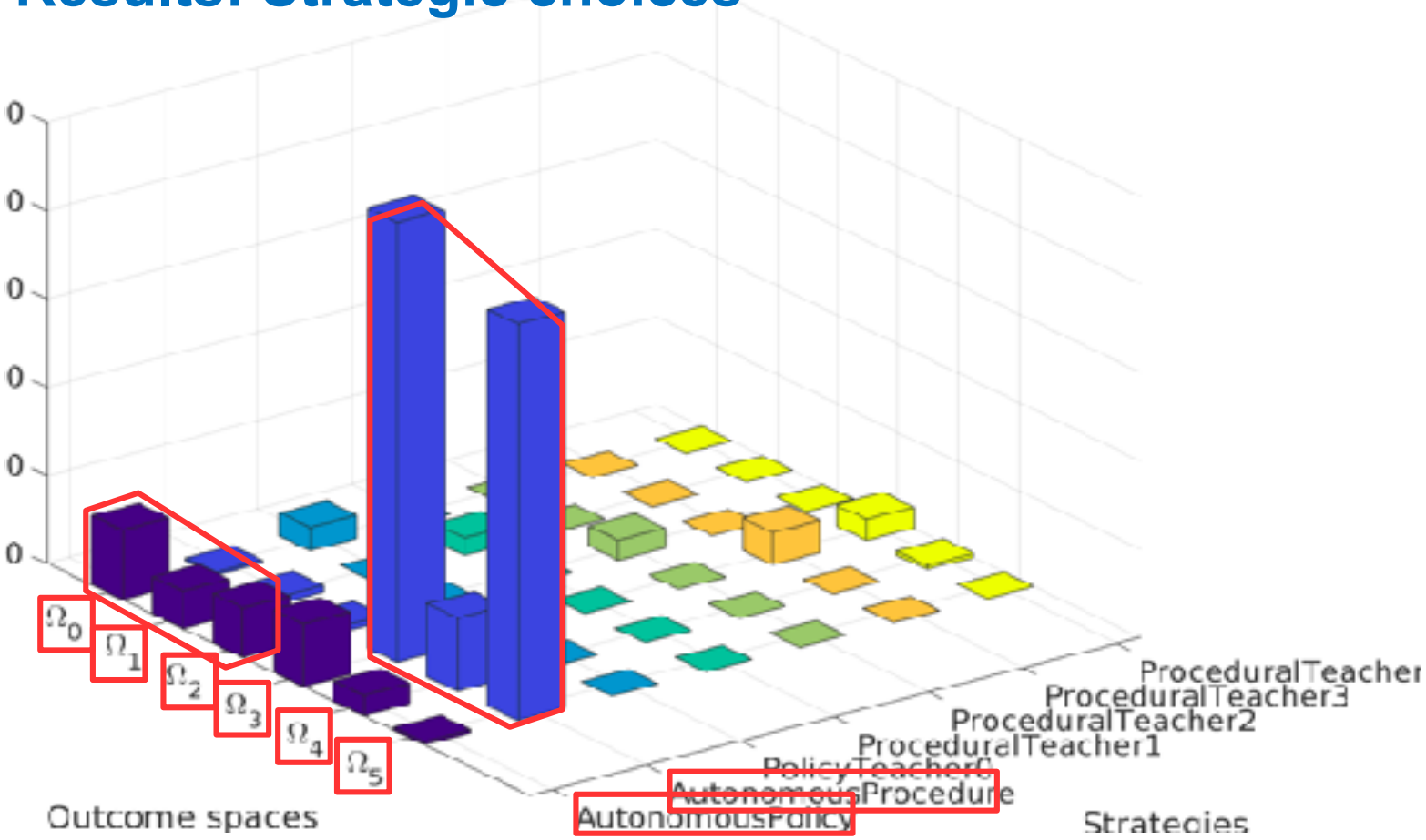


- SGIM-PB able to self-organize its learning process

3. Intrinsic Motivation for Hierarchical Learning

Results: Strategic choices

Duminy et al, 2018



- Use mainly policies for simple tasks and procedures for most hierarchical

Contributions

Duminy et al, 2018

- Multi-task learning:
  - Procedures enable the discovery of task hierarchy
  - Transfer knowledge from easy tasks to complex tasks
- Curriculum learning:
  - Choose easy tasks first
  - Choose the most adapted teachers for each task

- Human demonstrations bootstrap learning
  - Policies for the simplest tasks
  - Procedures for the highest hierarchical and complex tasks
  - **What, When, How, Whom to imitate ?**

References

- M. Devanne, S. M. Nguyen, O. Remy-Neris, B. Le Gales-Garnett, G. Kermarrec, and A. Thepaut, A co-design approach for a rehabilitation robot coach for physical rehabilitation based on the error classification of motion errors, *IEEE IRC workshop on Collaboration of Humans, Agents, Robots, Machines and Sensors,* 2018.
- C. Moulin-Frier, S. M. Nguyen, and P.-Y. Oudeyer, Self-organization of early vocal development in infants and machines: The role of intrinsic motivation. Frontiers in Psychology (Cognitive Science), 4(1006), 2014.
- N. Duminy, S. M. Nguyen, and D. Duhaut, "**Effects of social guidance on a robot learning sequences of policies in hierarchical learning**", in *IEEE International Conference on Systems, Man and Cybernetics (SMC2018)*, 2018.
- N. Duminy, S. M. Nguyen, and D. Duhaut. "**Learning a Set of Interrelated Tasks by Using a Succession of Motor Policies for a Socially Guided Intrinsically Motivated Learner**". In: *Frontiers in Neurorobotics* 12 (2019), p. 87. issn: 1662-5218. doi: 10.3389/fnbot.2018.00087. url: https://www.frontiersin.org/article/10.3389/fnbot.2018.00087.

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