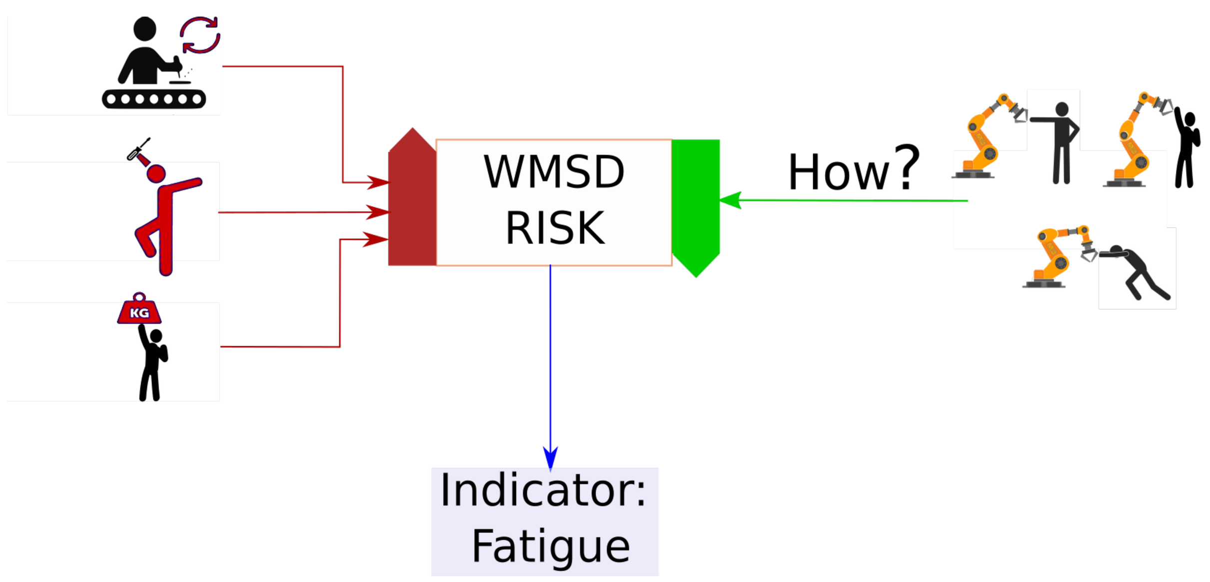
# Probabilistic Planning for Cobots to Mitigate Fatigue in Repetitive Comanipulation

**Aya Yaacoub**, Vincent Thomas, Francis Colas, Pauline Maurice
Université de Lorraine, CNRS, Inria, LORIA, Nancy

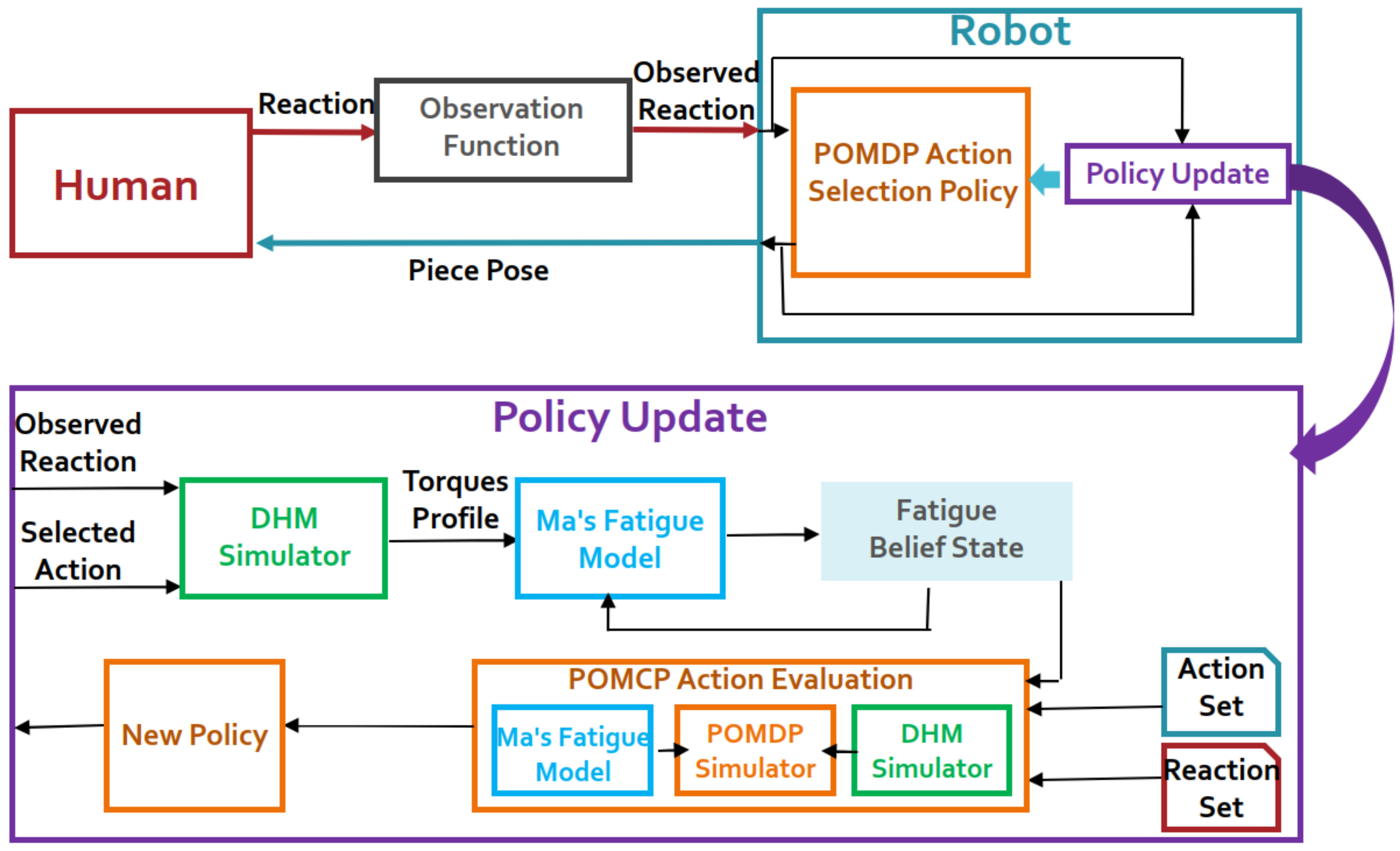
## Introduction

- Repetitive work, awkward postures, and forceful work lead to work related musculoskeletaldisorders (WMSD) [1].
-Cobots End Effector(E.E) pose can influence human reaction.

**How can we use cobots to mitigate fatigue in repetitive co-manipulation?**



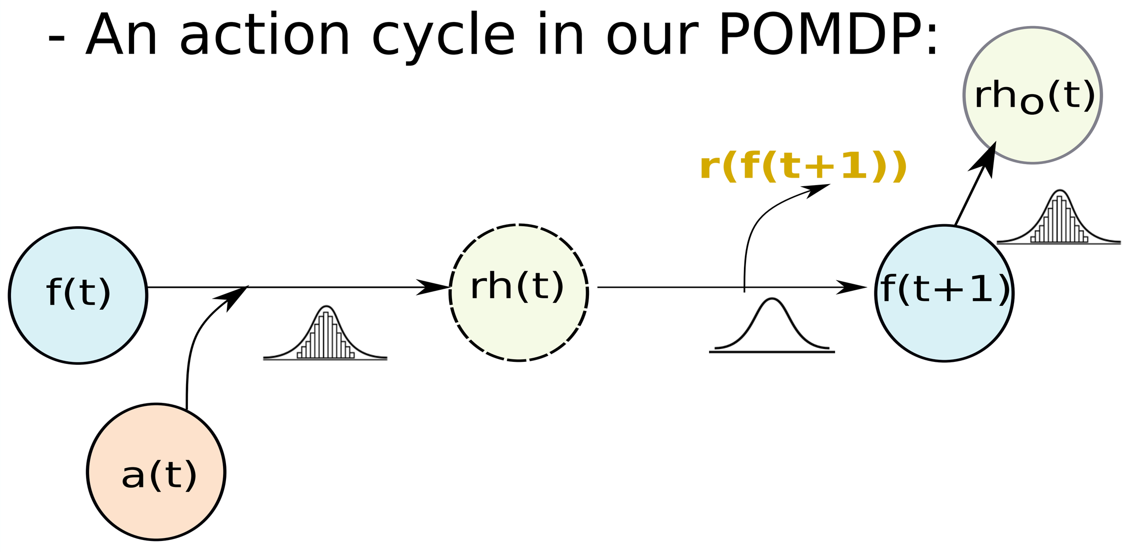

## General Approach




## POMDPs

- Partially Observable Markov Decision Processes

- An action cycle in our POMDP:




- f(t) : human fatigue at time t
- a(t) : robots action or E.E pose selected at t
- rh(t) : human's reaction at t
- rho(t) : observed human reaction at t
- f(t+1) : human fatigue at end of reaction
- r(f(t+1)) : the reward obtained as a function of new fatigue

- Partially observable Monte Carlo Planning (POMCP) is used to generate the action selection policy of the POMDP.

## Fatigue Model:

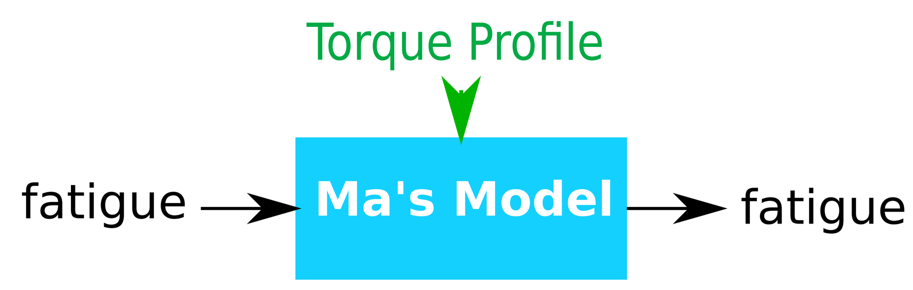
- Ma's Dynamic Fatigue Model based on joints torques [2]:

$$\frac{d\Gamma^i_{cem}}{dt} = \begin{cases} -k \frac{\Gamma^i_{cem}}{\Gamma^i_{max}} \Gamma^i_{load} & \Gamma^i_{load} > \Gamma^i_{threshold} (fatiguing) \\ -R(\Gamma^i_{max} - \Gamma^i_{cem}) & \Gamma^i_{load} < \Gamma^i_{threshold} (recovering) \end{cases}$$

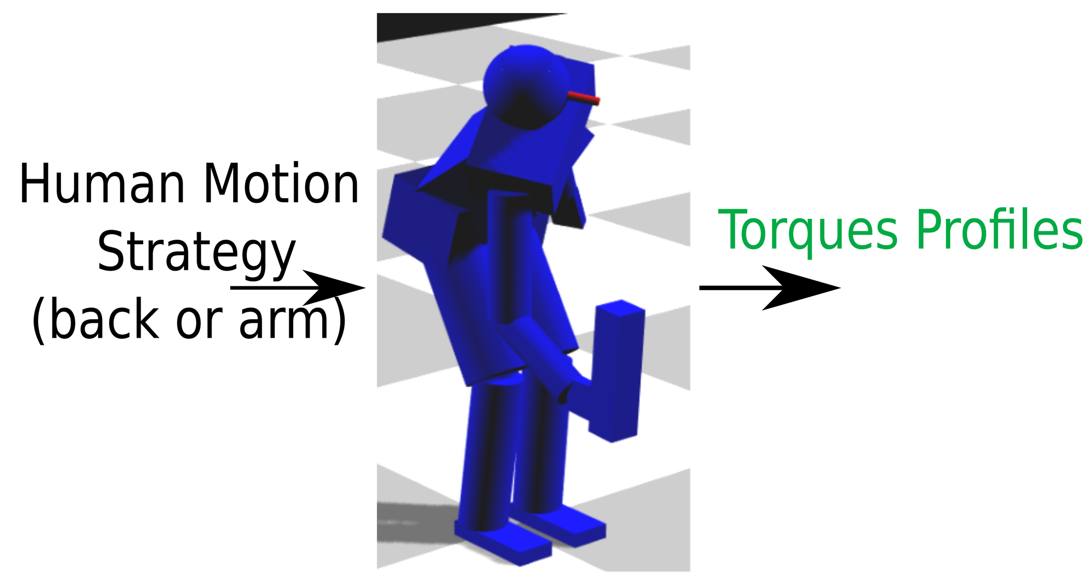
- $\Gamma^i_{cem}$ : current maximum exertable torque of joint i
- $\Gamma^i_{max}$ : maximum exertable torque of joint i
- $\Gamma^i_{load}$ : load torque at joint i
- k, R : Relatively the fatigue and recovery coefficient of the model

- Fatigue considered as a loss in torque generation capacity:

$$f^i(t) = 1 - \frac{\Gamma^i_{cem}(t)}{\Gamma^i_{max}}$$




## Digital Human Model:




Humans Equations of Motion
+ Linear Quadratic Programming (LQP) Controller
[3]

- LQP Controller [4]:

$$\arg\min_{trajectories} \sum weight_k Task_k$$

Subject to:
- Dynamic Equations
- Joints actuation limits

- The LQP finds the best trajctory (including torque profile) that minimuizes the wighted sum of tasks costs.

- The tasks and their weights determine the human strategy.

## Results

| | | Policies | | | |
|---|---|---|---|---|---|
| | | Random | Fixed | Greedy | POMCP |
| Expected Cost | 5 cycles | 0.01089 | 0.01076 | 0.00295 | 0.00294 |
| | 20 cycles | 0.10608 | 0.10451 | 0.10068 | 0.10115 |
| | 100 cycles | 0.23320 | 0.22974 | 0.22777 | 0.22857 |

- For an expert individual, POMCP provides the best action selection policy.
- Further testing is needed to draw conclusions for non experts.
- Planning should be tested in scenarios with more robot actions.

## References

[1] European Agency for Safety and Health at Work., “E-fact 9 - Work-related musculoskeletal disorders (MSDs): an introduction | Safety and health at work EU-OSHA,” 2007
[2] L. Ma et al., International Journal of Industrial Ergonomics, 2009
[3] P. Maurice et al., Elsevier, 2019
[4] J. Salini et al., Advances in Robot Kinematics: Motion in Man and Machine, Springer,

This work was funded by the French ANR under Grant No. ANR-20-CE33-0004