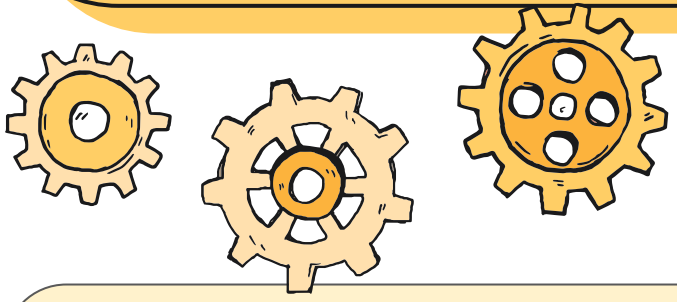
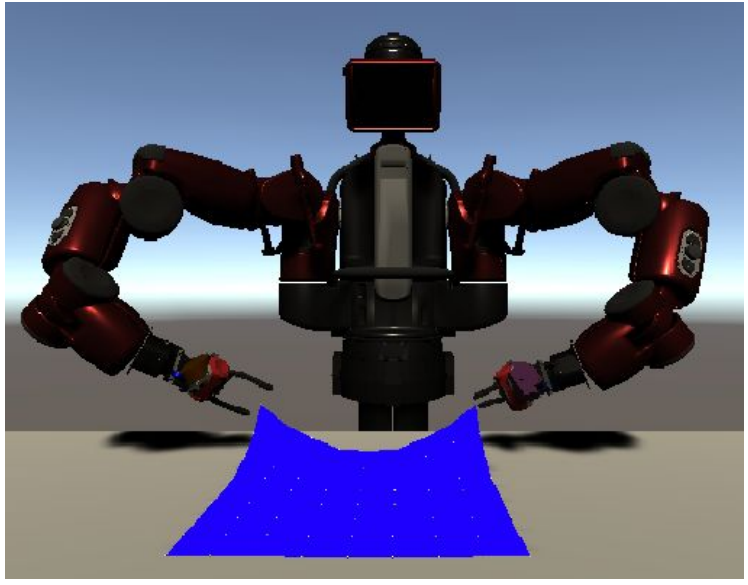
Robotic folding with CURL in simulation



Vicent Roig Server

Francis wyffels, Andreas Verleysen,
Victor-Louis De Gusseme



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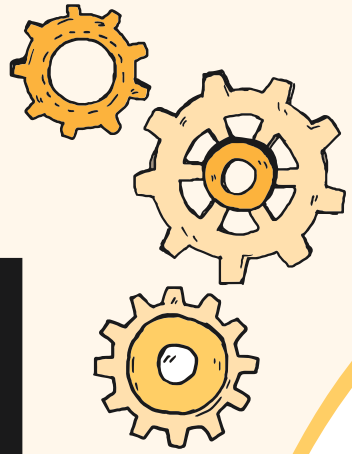


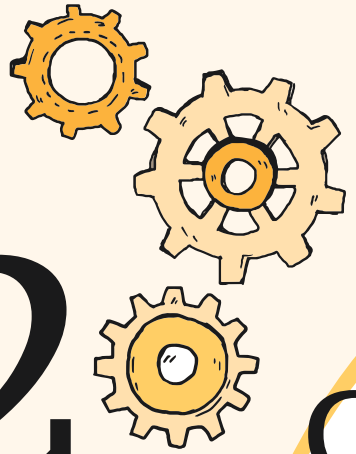
01 Introduction

Task problem

Task problem: Cloth folding

Infinite types of cloth.

With visual observations the robot has to recognise and fold the cloth.



02 Cloth simulation

2.1 Model
2.2 Timeline

Cloth simulation: Mass-Spring model

Structural

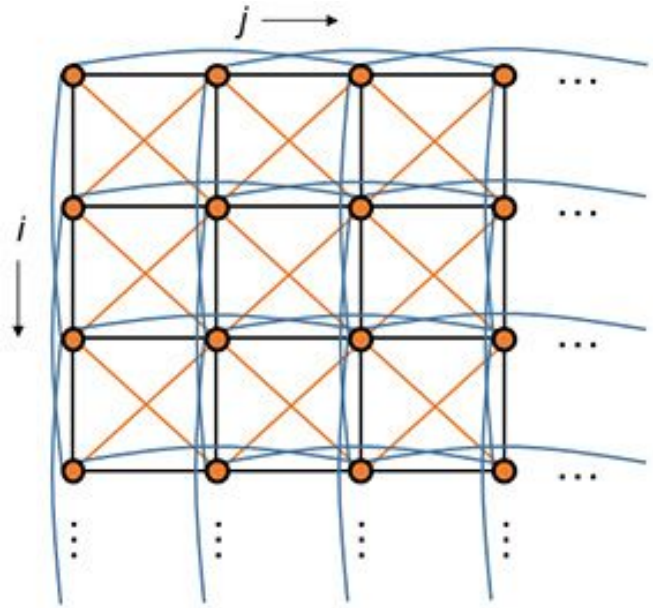
$[i, j]$—$[i, j + 1]$; $[i, j]$—$[i + 1, j]$

Shear

$[i, j]$—$[i + 1, j + 1]$; $[i + 1, j]$—$[i, j + 1]$

Bend

$[i, j]$—$[i, j + 2]$; $[i, j]$—$[i + 2, j]$



Cloth simulation in four steps

1 **Calculate forces**

- External and Internal forces
  - Elastic force
  - Viscous force
  - Gravity force
  - Wind force

2 **Integrator**

- Verlet Integrator
  - Fast
  - Position based

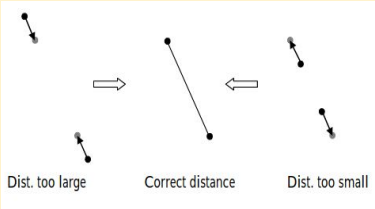
$$x(t + \Delta t) = 2x(t) - x(t - \Delta t) + a(t)\Delta t^2$$

3 **Collisions**

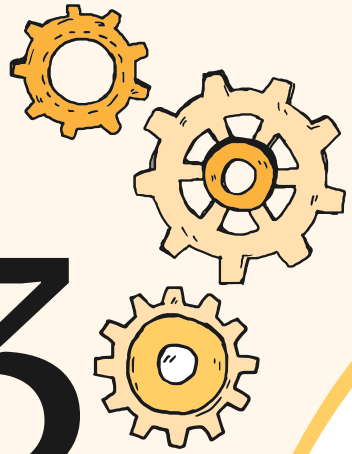
- Correction
  - Interpenetration
  - Friction
  - Impact

4 **Constraints**

- Superelasticity
  - Fix unrealistic behavior



03



CURL

Contrastive Unsupervised Representation for Reinforcement Learning

CURL: Contrastive Unsupervised Representations for Reinforcement Learning

Problem

Reinforcement learning from high dimensional observations such as raw pixels is inefficient.

Solution

CURL: Extract information from the images to help the RL algorithm.

CURL

Original

No crop, original image

Query observation

Central crop of the original image

NN encode: **q**

Contrastive Learning

q **W** k-

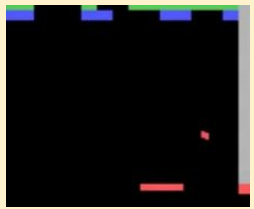
q **W** K+

NN encode: **k+**

NN encode: **k-**

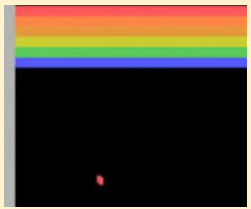
Positive observation

Random crop of the original image



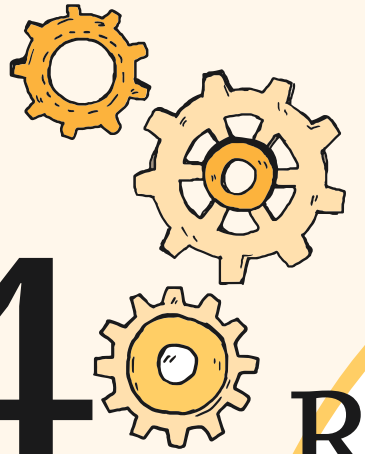
Negative observation

Random crop of other image



Reinforcement Learning Algorithm

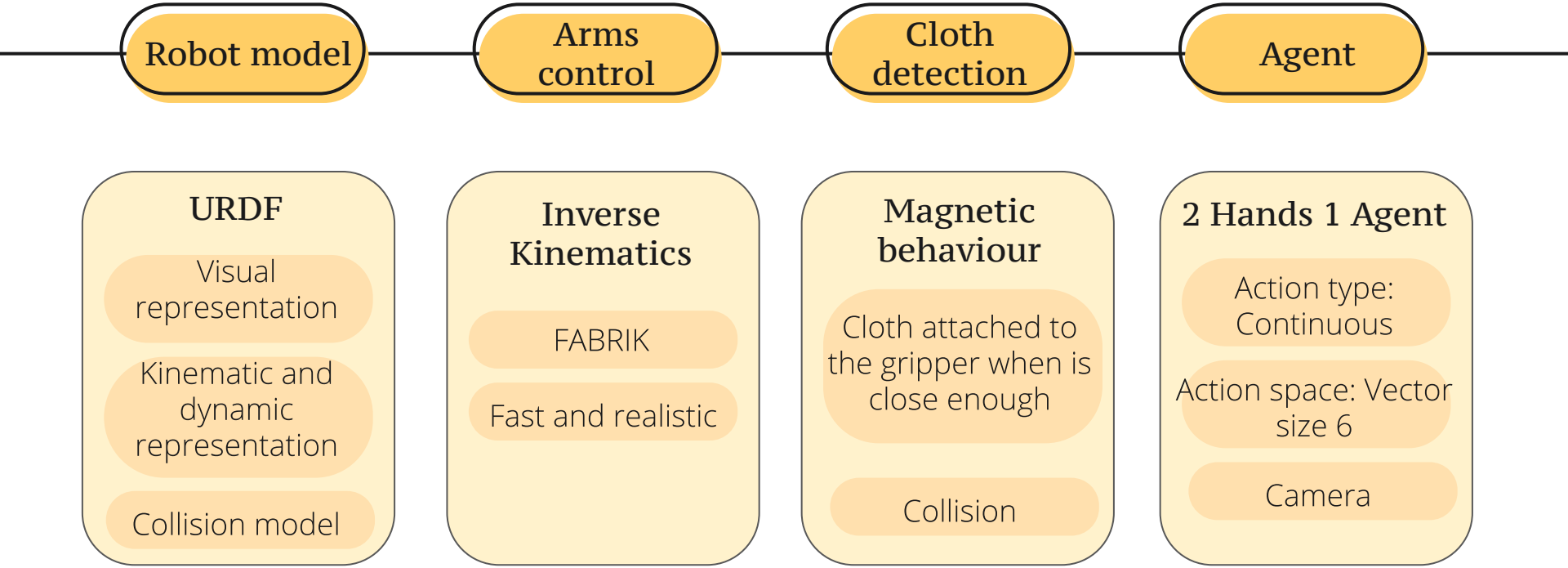
Reinforcement learning algorithm will receive as a input the **q** representation extracted



04 Robot simulation

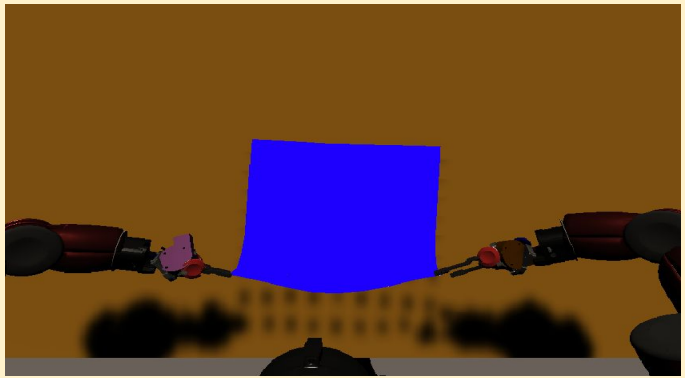
4.1 Simulation environment
4.2 Folding task
4.3 Reward function
4.4 Experimental framework

Robot simulation: Simulation environment

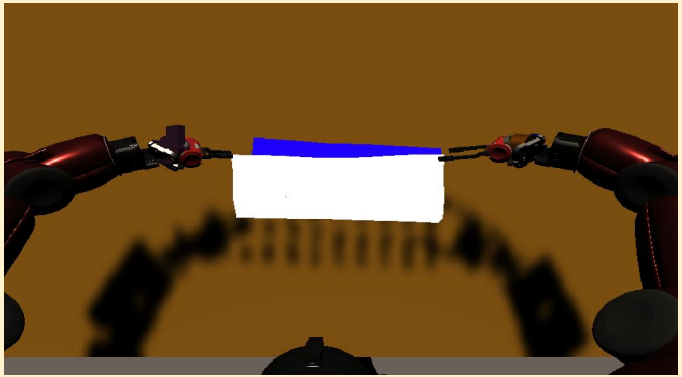


Folding task

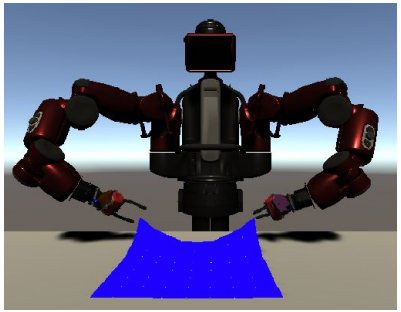
First step

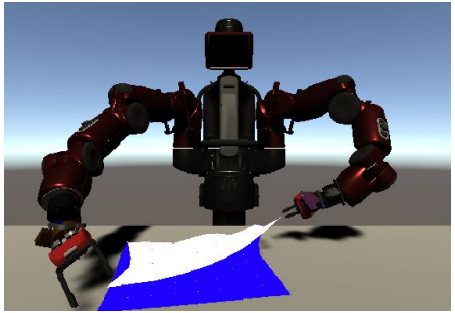


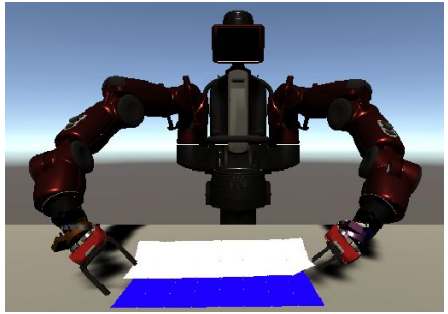
Second step

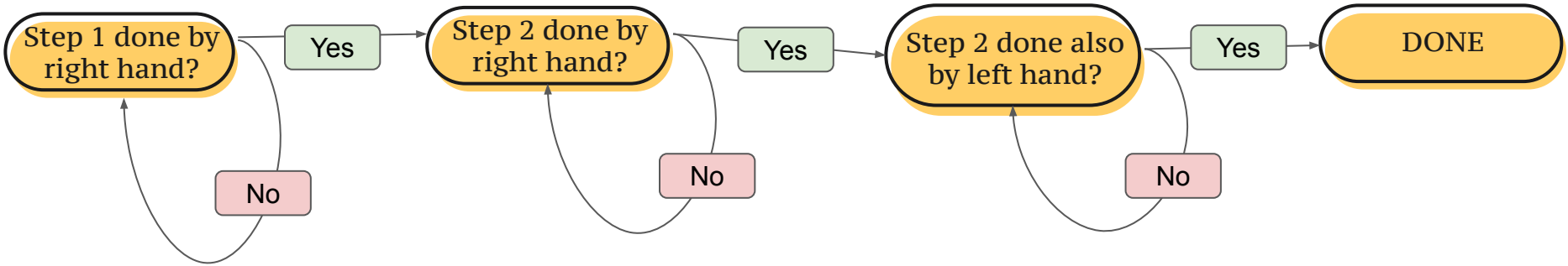


Reward function

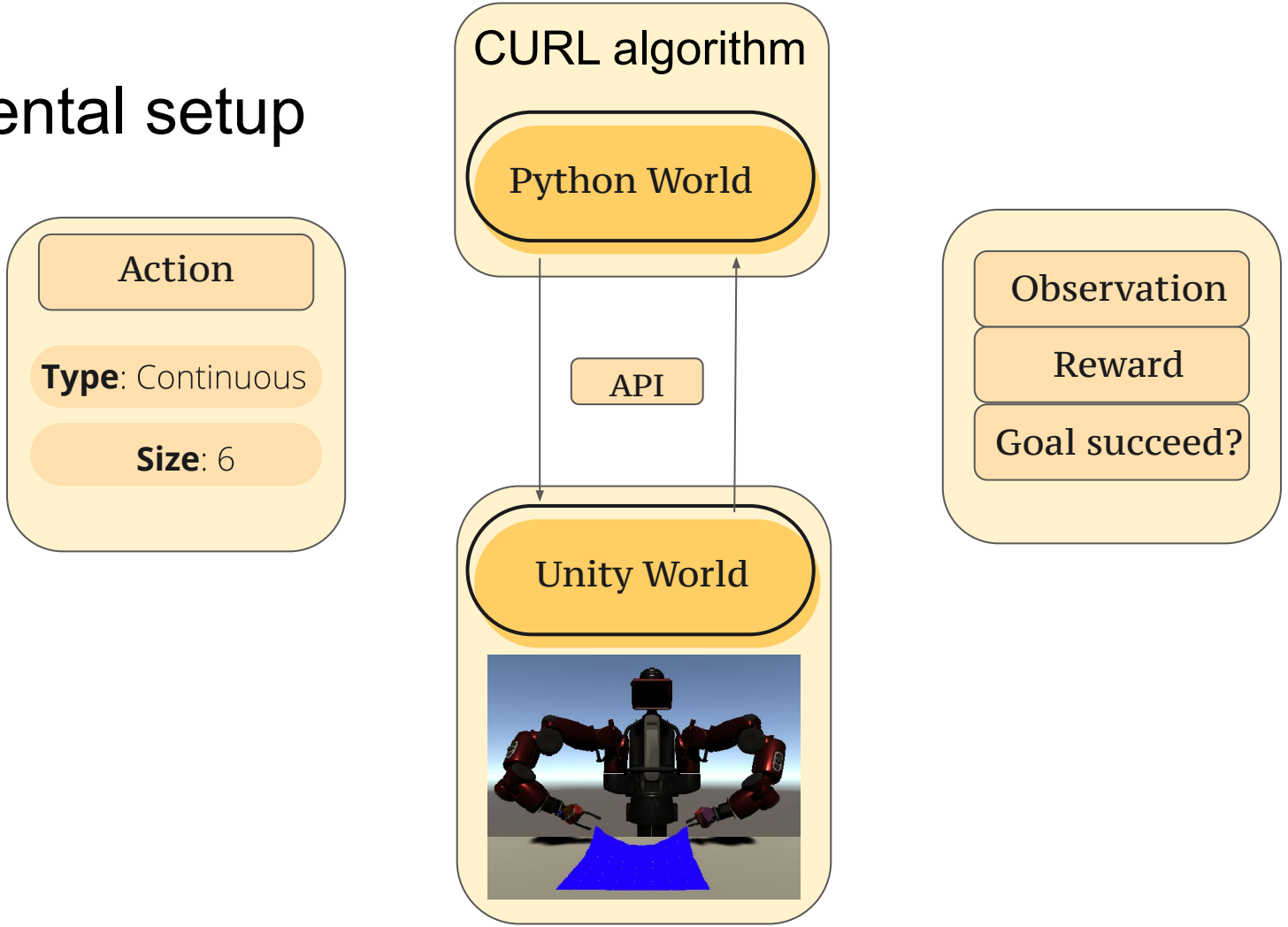


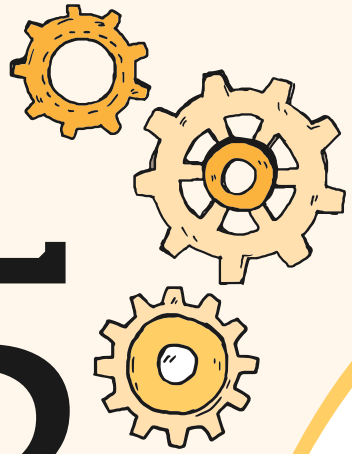






Experimental setup

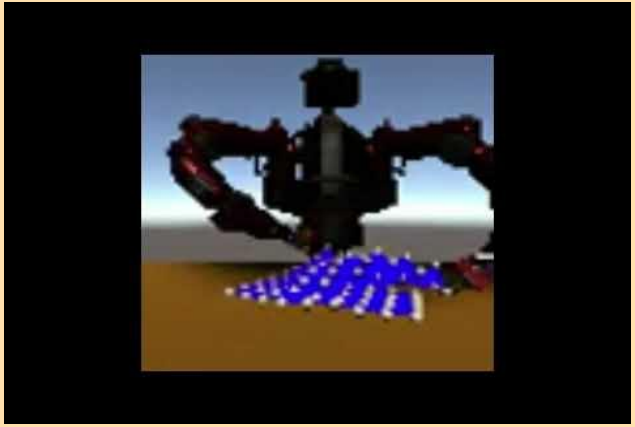


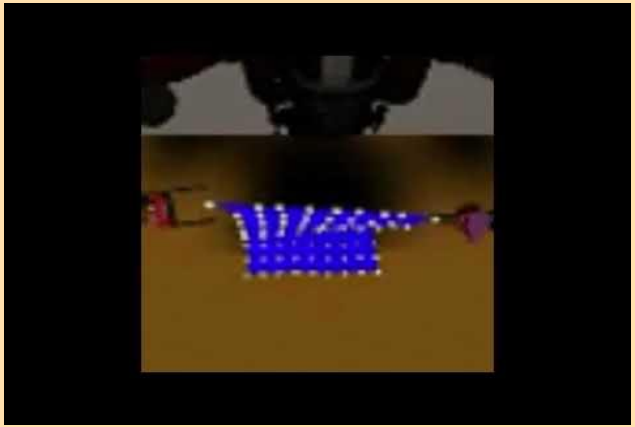


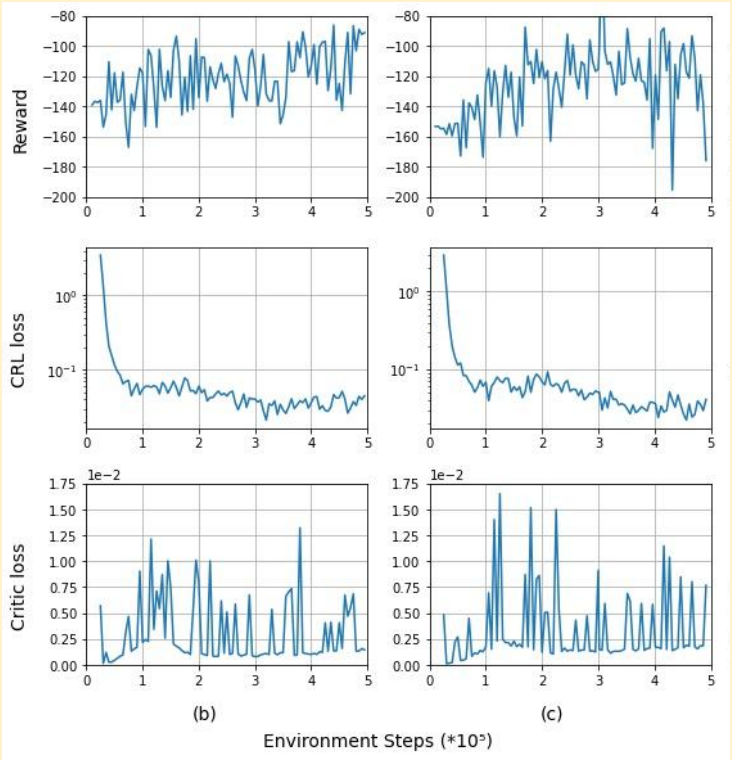
05 Results

5.1 Results

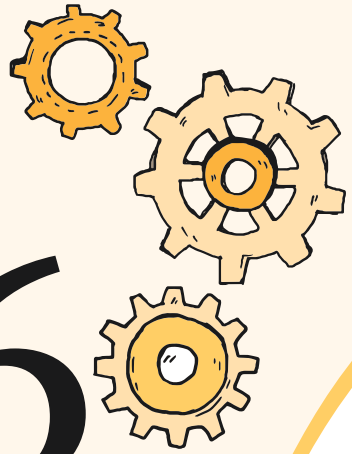
Results






Reward
CRL loss
Critic loss
1e−2
1e−2
(b)
(c)
Environment Steps (*10⁵)

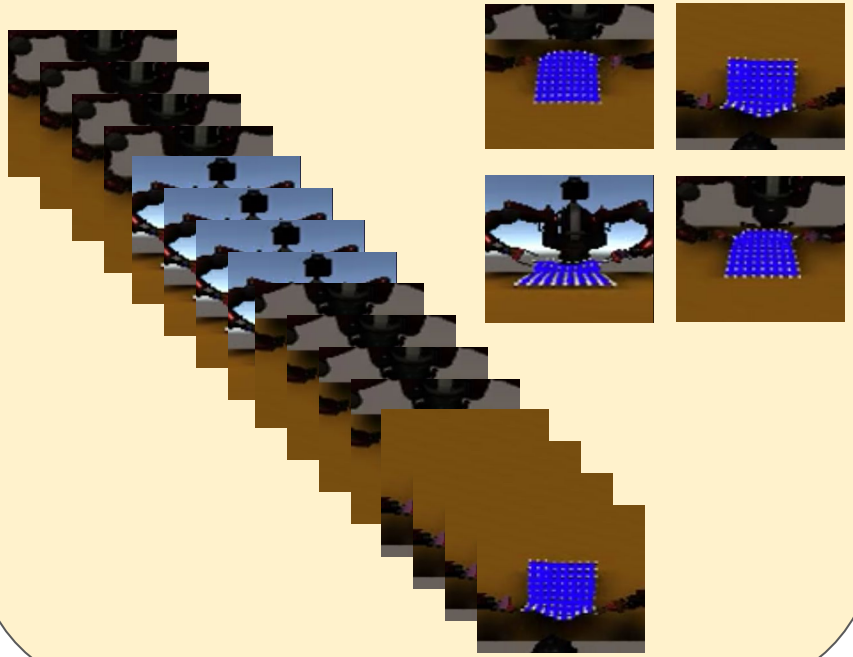
06



Conclusions

Conclusions

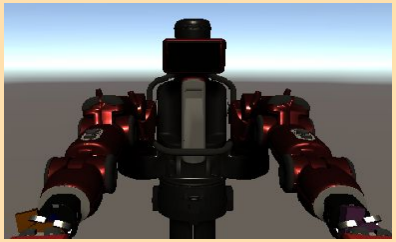
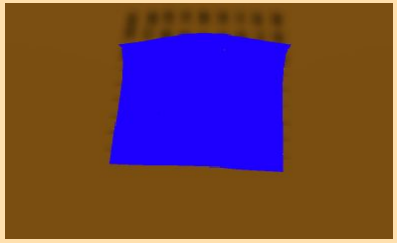
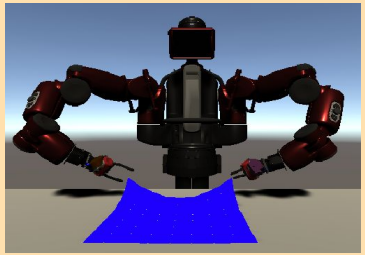
Increase the dimension of the observations



Cloth simulation problems

$$\vec{F}^{e}_{ij} = k_{ij}\left(\left\|\vec{r_{ij}}\right\| - l_{ij}\right)\frac{\vec{r_{ij}}}{\left\|\vec{r_{ij}}\right\|}$$

$$\vec{F}^{d}_{ij} = d_{ij}\left(\vec{v_i} - \vec{v_j}\right)$$

Conclusions

Different simulation time step