Increasing the Human Likeness of Robot Movements

The Persistent Autonomy and Robot Learning (PeARL) Lab - Dr. Reza Ahmadzadeh

Hoang Nguyen

MOTIVATION

Robot are primarily used for aiding human in task completion, and we are more comfortable around human-like movements. Also, when comparing human and robot movements, human movements are always thought to be more efficient.Therefore, increasing the human likeness of the robot's movements will theoretically increase the movements' efficiency and the quality of the robot's assistance.

APPROACH

Define the necessary equations and the equation that represent the human likeness factor

↓

2D testing on the computer

↓

3D testing on the computer

↓

Test on the real robotic arm

1. Record the robot demonstration.
2. Create the 3D reproduction on the computer.
3. Run the reproduction on the robotic arm.

METHODS/ RESULTS

1. Equations:

- The mathematical equation for human movements factor can be created by:
  - The instantaneous velocity of movement function: V(t) = $k_V r(t)^{\frac{1}{3}}$
  - The radius of curvature: $r(t) = \left|\frac{(1+x'(t)^2)^{\frac{3}{2}}}{x''(t)}\right|$
- **The required equation:**

$$U_H = \left\|\left|x'(t) - k_V\left|\frac{(1+x'(t)^2)^{\frac{3}{2}}}{x''(t)}\right|^{\frac{1}{3}}\right|\right\|^2$$

- Elastic map, a method for robot learning from demonstration:
  - The approximation energy function:

$$U_Y = \frac{1}{\sum_{g_j} w_j}\sum_{i=1}^{N}\sum_{g_j\in K_i} w_j\|\boldsymbol{g}_j - \boldsymbol{y}_i\|^2$$

  - The stretching energy:

$$U_E = \sum_{i=1}^{P}\lambda_i\|e_i(1) - e_i(0)\|^2$$

  - The bending energy:

$$U_R = \sum_{i=1}^{S}\mu_i\|r_i(0) - 2r_i(1) + r_i(2)\|^2$$

- The equations that will be using to generate the reproductions:
  - Y = minimize $U_Y + U_E + U_R$
  - Y = minimize $U_Y + U_H$

V(t) = $k_V r(t)^{\frac{1}{3}}$

- K_V: a constant that depends on movement characteristics.
- r(t): the radius of curvature as a function of time (t).

$r(t) = \left|\frac{(1+x'(t)^2)^{\frac{3}{2}}}{x''(t)}\right|$

- x'(t): the velocity as a function of time (t).
- x''(t): the acceleration as a function of time (t).

$U_Y = \frac{1}{\sum_{g_j} w_j}\sum_{i=1}^{N}\sum_{g_j\in K_i} w_j\|\boldsymbol{g}_j - \boldsymbol{y}_i\|^2$

- K_i: the set of data points clustered around a node y_i
- w_j: the weight corresponding to the approximation stiffness of data point g_j.

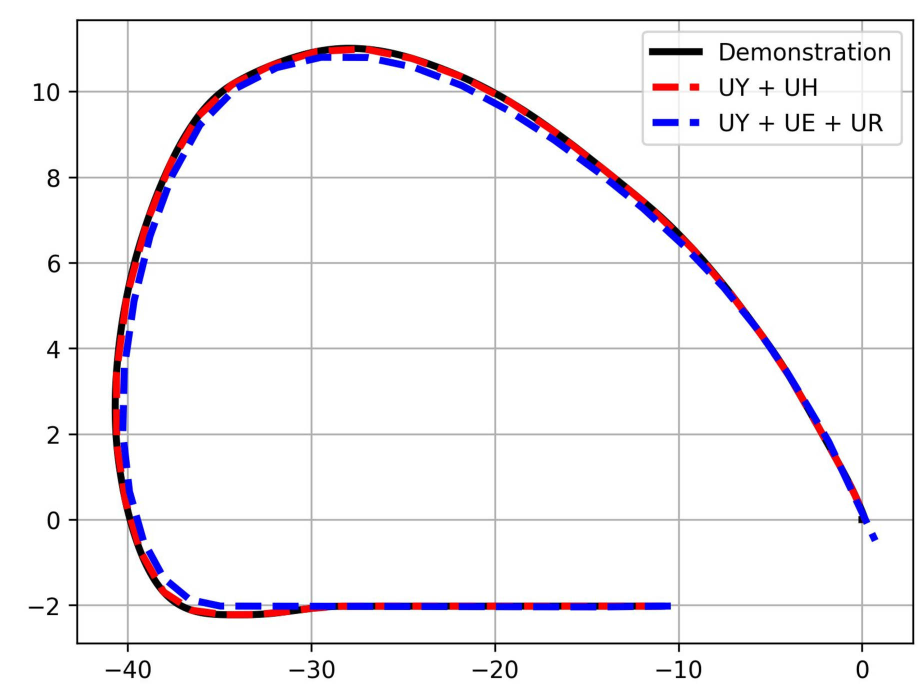
$U_E = \sum_{i=1}^{P}\lambda_i\|e_i(1) - e_i(0)\|^2$

- λ_i: the weight representing the resistance to stretching of edge e_i.

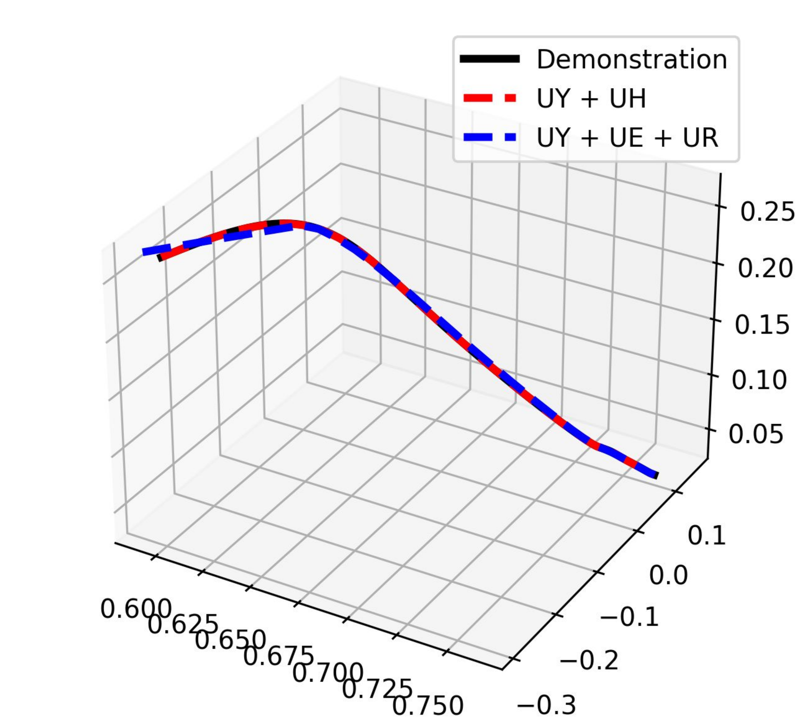
$U_R = \sum_{i=1}^{S}\mu_i\|r_i(0) - 2r_i(1) + r_i(2)\|^2$

- μ: the weight representing the bending resistance of rib r_i.

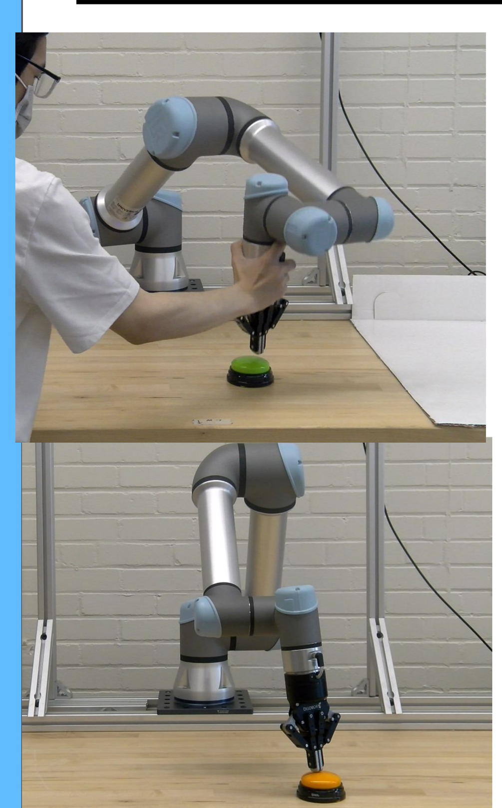
2. 2D testing:

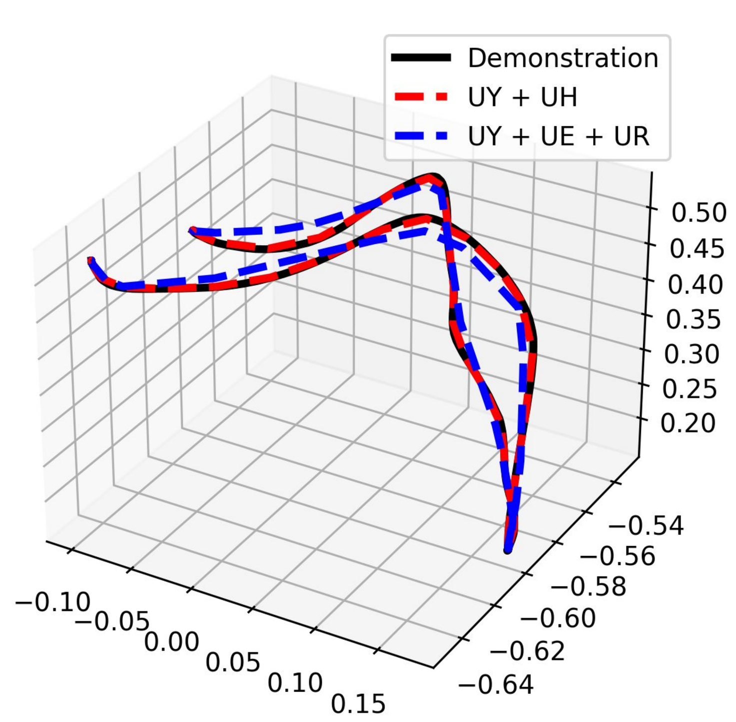


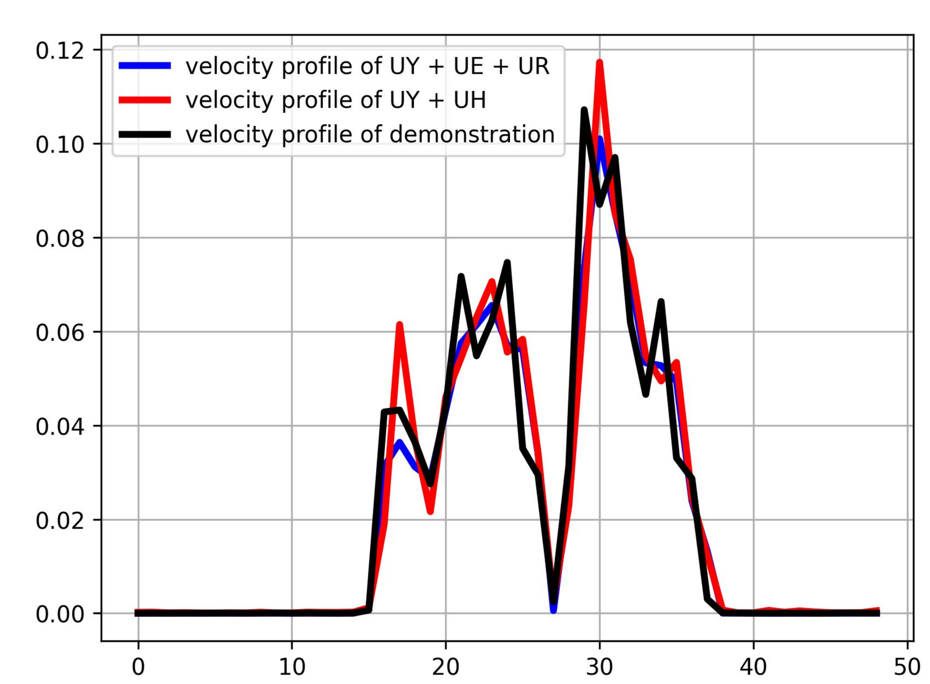
3. 3D testing:



4. Test on the real robotic arm:







CONCLUSIONS

- We were able to create the equation that represents the human likeness factor, and it successfully increases the efficiency of robot movements in 2D, 3D, and real-life testing.
- We could not run the reproduction on the robot smoothly but as each segment at a time until it pressed the button. There might be a technical error along the way.
- In the future, we would look at other laws governing human movements as well as record human demonstrations and replicate joint movements.

	$U_Y + U_H$	$U_Y + U_E + U_R$
Frechet	0.0237	0.0271
SSE	2.2027×10^{-9}	0.0215
Angular	0.0008	0.0409
Jerk	4.9105	4.756

ACKNOWLEDGEMENTS / REFERENCES

- Brendan Hertel, research assistant at University of Massachusetts Lowell.
- Dr. Reza Ahmadzadeh, advisor and director at PeARL Lab.
- Hertel, Brendan, et al. "Robot Learning from Demonstration Using Elastic Maps." 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2022.
- Miranda, Jose Garcia, et al. "Complex Upper-Limb Movements Are Generated by Combining Motor Primitives That Scale with the Movement Size." Scientific Reports, vol. 8, no. 1, 2018.