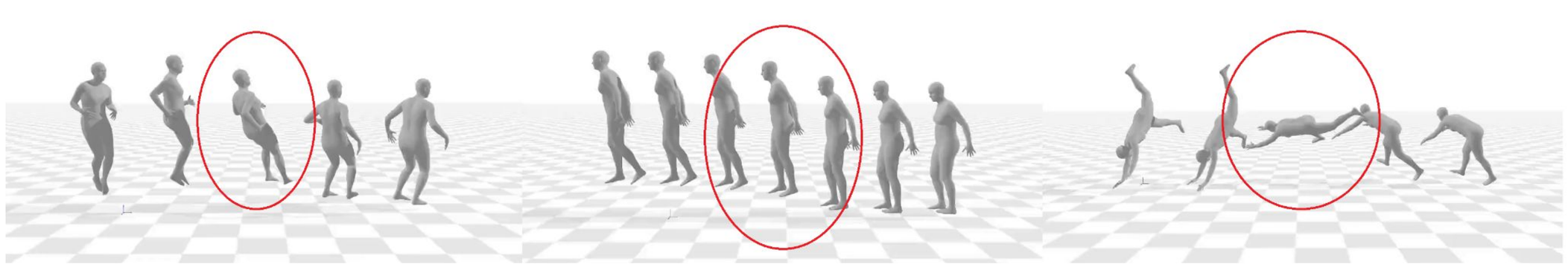
Improving Human Motion Plausibility with Body Momentum

CODE RELEASED!

Ha Linh Nguyen, Tze Ho Elden Tse and Angela Yao
National University of Singapore

BMVC 2025

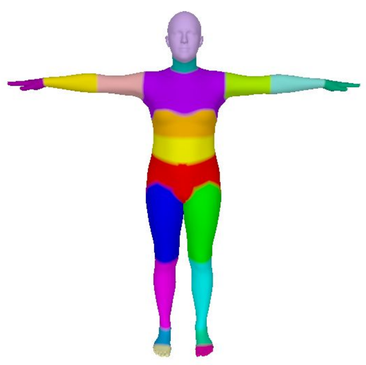
Motivation



Failure to capture the **physical relationship** between local joint configuration and global dynamics leads to implausible motion prediction. We observe that whole-body **linear and angular momentum** provides a constraint to relate local joint behavior to global displacement.

Approach

- Partition the body into P=20 parts



- Compute linear and angular momentum of the predicted pose sequences in world frame

$$\mathrm{LMo}(R,T,\theta) = \sum_{i=1}^{P} m_i \dot{c}_i{}^{W}$$

$$\mathrm{AMo}(R,\theta) = \sum_{i=1}^{P} I_i \dot{\theta}_i + m_i c_i^B \times \dot{c}_i{}^{B}$$

- During training, match the momentum of prediction with ground truth in **both time and frequency domain** by minimizing

$$\lambda_{\mathrm{AMo}}\mathcal{L}_{\mathrm{AMo}} + \lambda_{\mathrm{LMo}}\mathcal{L}_{\mathrm{LMo}} + \lambda_{\mathrm{Freq}}\mathcal{L}_{\mathrm{Freq}}$$

where

$$\mathcal{L}_{\mathrm{AMo}} = \|\Delta_{\mathrm{AMo}}\|_2 + \|\Delta'_{\mathrm{AMo}}\|_2$$
$$\mathcal{L}_{\mathrm{LMo}} = \|\Delta_{\mathrm{LMo}}\|_2 + \|\Delta'_{\mathrm{LMo}}\|_2$$
$$\mathcal{L}_{\mathrm{Freq}} = \left\|\mathcal{F}(\mathrm{AMo}(\hat{R},\hat{\theta})) - \mathcal{F}(\mathrm{AMo}(R,\theta))\right\|_2$$

Δ difference between prediction and ground truth signals

Δ' time derivative of Δ

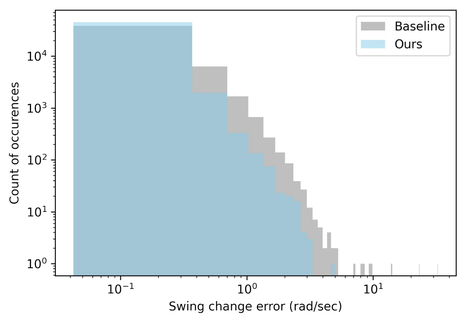
$\mathcal{F}$ discrete Fourier transform

Results

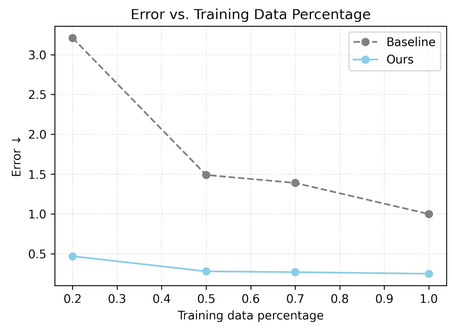
- Improve motion plausibility while preserving accuracy in global motion recovery task

	EMDB 2			RICH		
	RTE↓	Jitter↓	FS↓	RTE↓	Jitter↓	FS↓
TRACE	17.7	2987.6	370.7	610.4	1578.6	230.7
SLAHMR	10.2	31.3	14.5	28.9	34.3	5.1
GLAMR†	6.5	19.9	5.7	8.8	17.9	4.0
GLAMR† + $\mathcal{L}_{\mathrm{TMo}}$	5.6	**15.1**	**3.6**	8.6	**13.4**	**2.4**
WHAM	4.1	21.0	4.4	**4.1**	19.7	3.3
WHAM + $\mathcal{L}_{\mathrm{TMo}}$	4.3	19.7	3.7	4.4	17.9	3.2

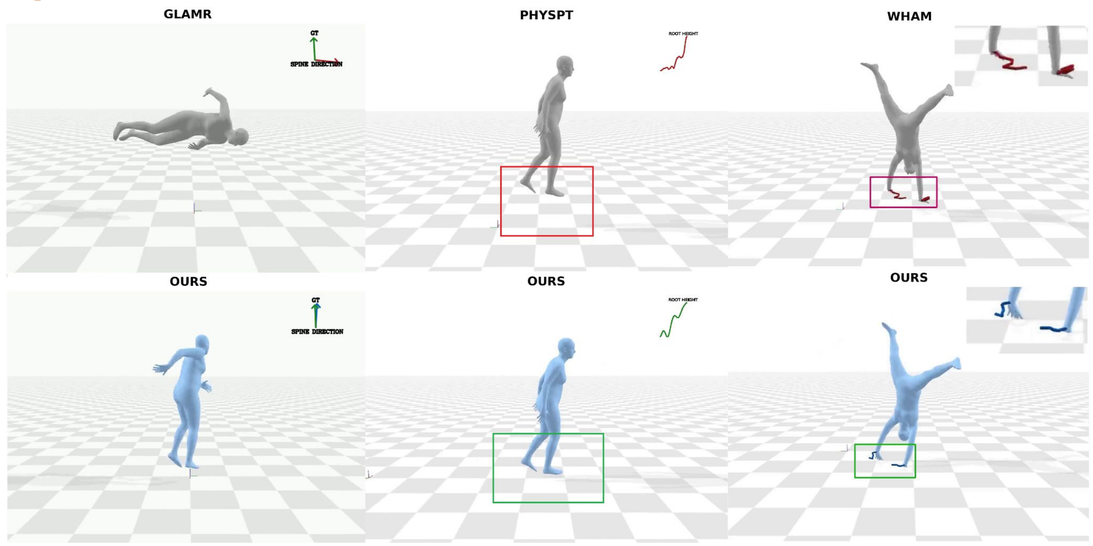
- Increase body stability



- Data-efficient



Qualitative results



Takeaways

- Body momentum **matters** for motion realism
- Physical plausibility goes **beyond ground contact**: consistent body momentum profiles can capture **whole-body realism** missed by contact-only methods