

March 21-25.2022 San Francisco,CA



#### Al Animator : **A Real Time Motion Completion System**

#### Yinglin Duan NetEase Games AI Lab

#GDC22 **#NetEase Games** 

### Overview

- Background
- Methodology
- Experiments
- Application
- Q & A







## Why we are here?

#### Discussion

- Paper of motion completion state-of-art 0
- Details and tips in our paper 0
- Take a guess
  - 3D computer animation 0
  - Application of deep learning



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#### **A Unified Framework for Real Time Motion Completion**

#### Yinglin Duan<sup>1</sup>, Yue Lin<sup>1</sup>, Zhengxia Zou<sup>2\*</sup>, Yi Yuan<sup>3</sup>, Zhehui Qian<sup>3</sup>, Bohan Zhang<sup>3</sup>

Model from <a href="https://www.mixamo.com">https://www.mixamo.com</a>, only for illustrations

# **Traditional animation workflows**

- Artists / animators
  - drawing key-frames are a burden on animators 0
- Linear interpolation, IK, searching-based can't generate high-quality and long animations
- State machines
  - require a lot of manpower to build and maintain









Blue: Input Key-frames

> White: Interpolation results

#### Linear interpolation

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### Recently

- Al assisted workflow
  - RNN-based
  - Convolution-based
  - Ours



#### Linear interpolation & Our results





### **Our motivations**

- We need a simple but effective method:
  - familiar to animators and enthusiasts
  - handling a massive scope of datasets
  - real-time high quality animation generation



## **Our motivations**

- A unified framework
  - In-betweening
  - In-filling
  - Blending









## Architecture

- Backbone:
  - Bidirectional Encoder Representation
    from Transformers
- Input:
  - known frames + unknown frames
- Output:
  - Predict ones







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# Frame in details

- Input :
  - Known frames: Key frame(s)
  - unknown frames : Interpolation
  - Target frames : Key frame(s)
- Output :
  - Generation frames

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- •Input & Output poses details:
  - joint positions coordinate matrix
  - joint rotations quaternion matrix





#### Linear interpolation & Our in-betweening results



# Mixture embeddings

- Position embedding:
  - time sequence
  - each one for a single time step
- Keyframe embedding:
  - annotates a keyframe

				_
Positional Embedding		1	2	3
	_	Pas	st Keyfram	es
	(			
Kovframo		Keyframe	1	
Embedding		U	nknown fra	nme
		Keyf	rames	1
l		(Curren	t motion)	







### **Transformer in details**





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#### **Reconstruction Loss**

Loss function

$$\mathcal{L}_{\text{rec}} = \frac{1}{NT} \sum_{n=1}^{N} \sum_{t=1}^{T} (\|\boldsymbol{p}_{n}^{t} - \widehat{\boldsymbol{p}}_{n}^{t}\| + \|\boldsymbol{p}_{n}^{t} - \widehat{\boldsymbol{p}}_{n}^{t}\|)$$

#### Known frames + Interpolation frames



Input



#### **Reconstruction Frames**



#### Output

# **Kinematics Loss**

- Forward Kinematics loss
  - follow Harvey et al.[1]
  - in local coordinate system
- Inverse Kinematics loss
  - in global coordinate system



#### Our in-betweening results with IK loss

[1] Harvey F G, Yurick M, Nowrouzezahrai D, et al. Robust motion in-betweening[J]. ACM Transactions on Graphics (TOG), 2020, 39(4): 60: 1-60: 12.



# Motion perceptual loss

- Ground contact constraints
  - reduce foot-skate in human motion 0
- Discrete wavelet transformation capturing of high-frequency information









#### Our blending results with perceptual loss

### **Implementation Details**

ltem	Setting
Backbone	BERT
Depth	8 transformer layers
Bandwidth	256-dimension
Attention Heads	8
Optimizer	ADAM
Learning Rate	1e-3
Framework	PyTorch







		L2Q			L2P		
Length	5	15	30	5	15	30	5
Zero-Vel	0.56	1.10	1.51	1.52	3.69	6.60	0.0053
Interp	0.22	0.62	0.98	0.37	1.25	2.32	0.0023
Harvey et al. (LSTM-based)	0.17	0.42	0.69	0.23	0.65	1.28	0.0020
Kaufmann et al. (Conv-based)	0.49	0.60	0.78	0.84	1.07	1.53	0.0048
Ours (local w/ ME)	0.18	0.47	0.74	0.27	0.82	1.46	0.0020
Ours (local w/ ME & FK loss)	0.17	0.44	0.71	0.23	0.74	1.37	0.0019
Ours (global w/ ME)	0.14	0.36	0.61	0.21	0.57	1.11	0.0016
Ours (global w/ ME & IK loss)	0.14	0.36	0.61	0.22	0.56	1.10	0.0016
Ours (global transformer only)	0.16	0.37	0.63	0.24	0.61	1.16	0.0018
Ours (global full)	0.18	0.37	0.61	0.23	0.56	1.06	0.0018
Ours (noisy training data - 30 db)	0.19	0.39	0.63	0.27	0.59	1.11	0.0020

#### Experimental results on LaFAN1 dataset





#### NPSS

15	30
0.0522	0.2318
0.0391	0.2013
0.0258	0.1328
0.0345	0.1454
0.0307	0.1487
0.0291	0.1430
0.0238	0.1241
0.0234	0.1222
0.0243	0.1284
0.0238	0.1218
0.0248	0.1259

		L2P	
Length	5	15	30
Zero-Vel	2.34	5.12	6.73
Interp	0.94	3.24	4.68
Kaufmann <i>et al</i> .	3.57	3.69	3.93
Ours (full)	0.84	1.46	1.64

In-filling results on Anidance dataset







	L2Q			L2P				NPSS		
Length	8 16		32	8	16	32	8	16	32	
Zero-Vel	0.93	1.41	1.89	2.71	4.08	5.73	0.0221	0.1003	0.4875	
Interp	0.40	0.92	1.44	1.16	2.34	3.70	0.0122	0.1095	0.4726	
Kaufmann et al.	1.36	1.35	1.35	3.64	3.63	3.64	0.0392	0.1223	0.3944	
Ours	0.35	0.60	0.98	0.79	1.35	2.32	0.0122	0.0631	0.3124	
Ours (enhanced)	0.29	0.51	0.89	0.62	1.12	2.12	0.0098	0.0529	0.2817	

Blending results of our new dance dataset







#### Blending results of our new dance dataset





# Application

- Easy to use
  - Unified framework: mocap data / raw animation data / dance cards at any length
  - Embed in animation pipeline: polish and editing (e.g. Maya Plugin)
  - High performance: real-time inference on CPU

Method	1 x 30	10 x 30	CPU info
Harvey et al.	0.31s	0.40s	E5-1650
Kaufmann <i>et al</i> . Ours(global full)	0.066s <b>0.025s</b>	0.33s 0.083s	I7-8700K I7-8700K

• CPU inference time is\* recorded in different batch sizes (1 & 10), where in-betweening length is set to 30 frames (i.e. 1 second).



#### nce cards at any length a Plugin)



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EndFrame	0	8
Key Interval	0	8
Target Frame	0	8









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#### Clip



#### Model from the Netease Game The World 3





NeteaseGames





#### Retargeting to our model



#### Model from the Netease Game The World 3

#### Polish and editing













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#### Model from the Netease Game The World 3

#### Different missing frames









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#### Model from the Netease Game The World 3



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