Emotionally Expressive Motion Controller for Virtual Character Locomotion Animations

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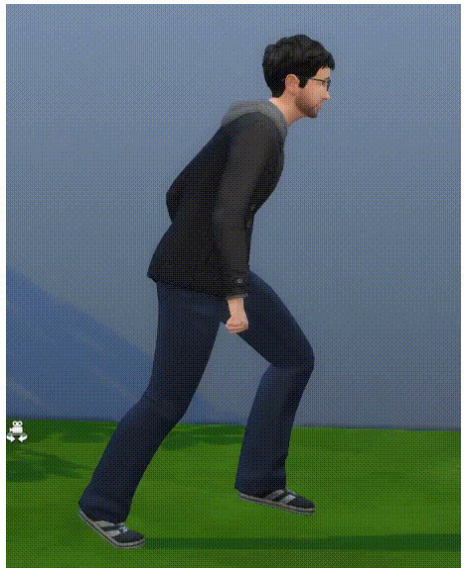
TÉCNICO LISBOA

MOTIVATION

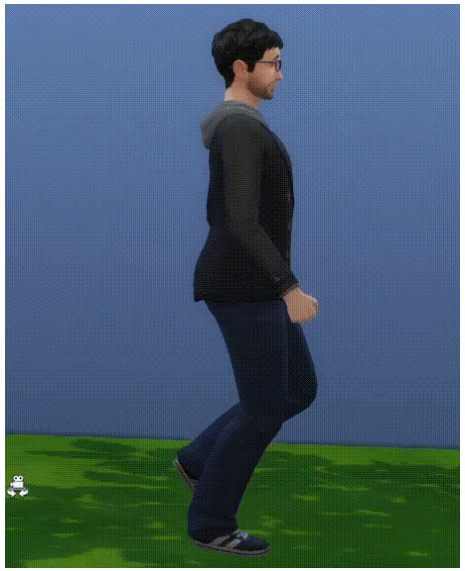
"Neutral"

[The Sims 4, Maxis, 2014]



"Angry"

"Confident"



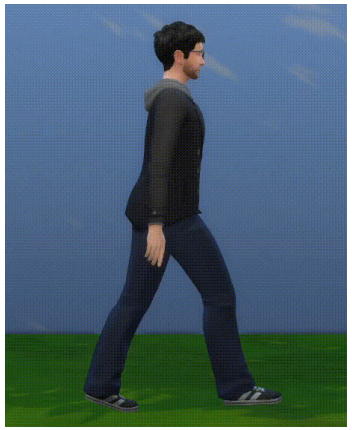
"Energized"

"Sad"

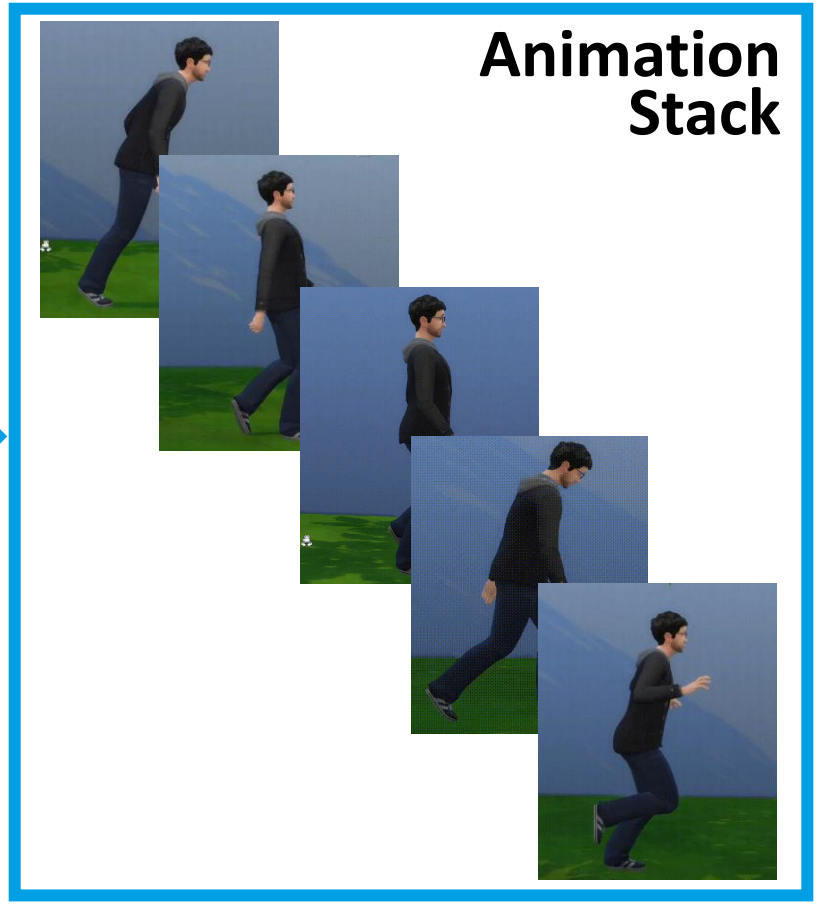
"Afraid"

PROBLEM

- New Animation for each Emotion
- Variants of Baseline
- Repeat Process for each Motion
- Time Consuming & Expensive

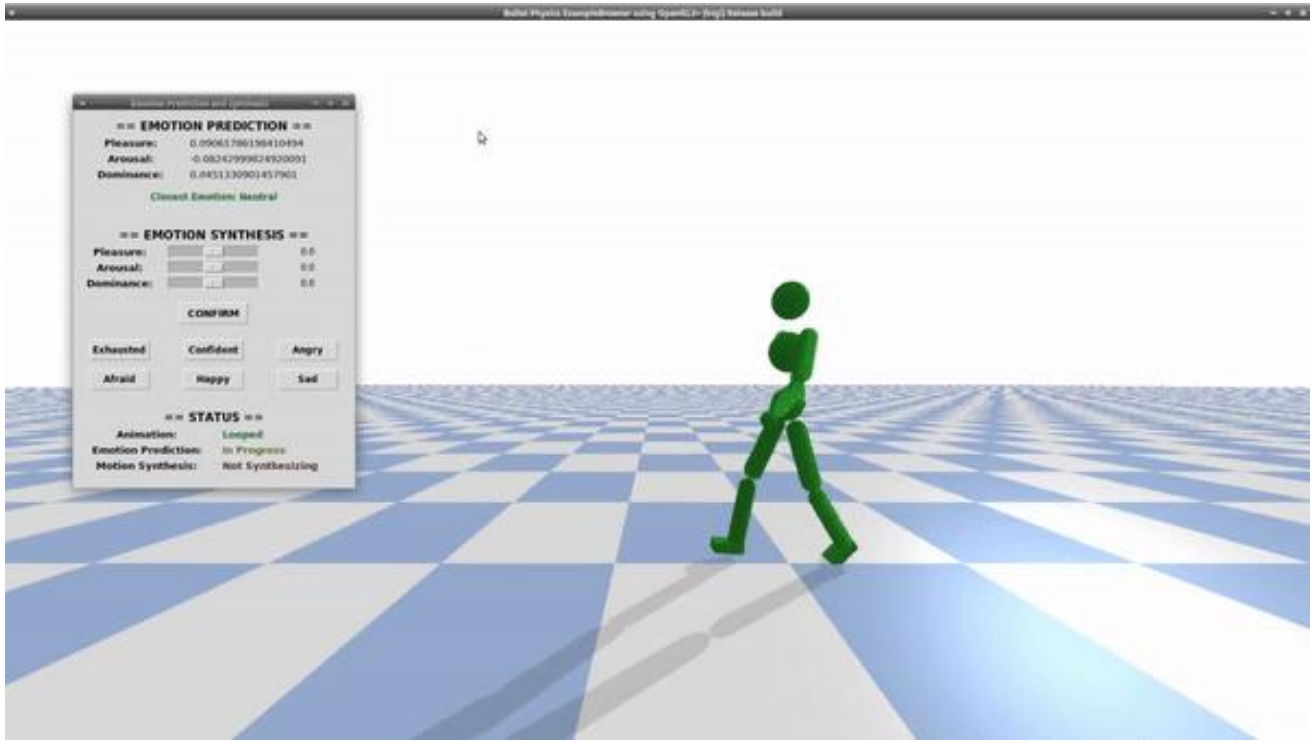


[The Sims 4, Maxis, 2014]



SOLUTION

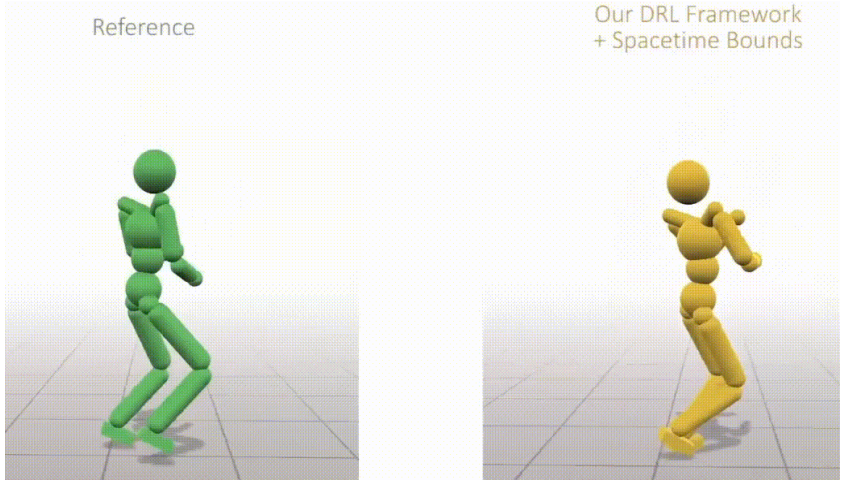
- Automatic
- Real-Time
- No Additional Data or Training Required
- Works with both Kinematic and Policy-Based Physics-Enabled characters



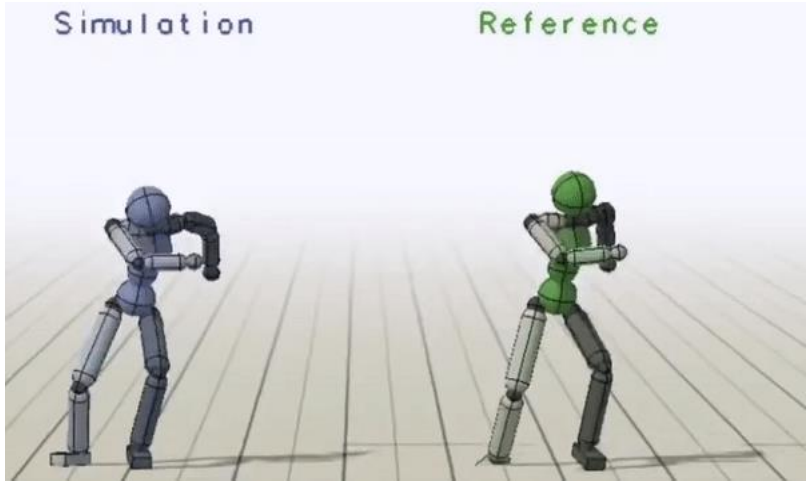
Emotionally Expressive Motion Controller

RELATED WORK – DeepMimic & Spacetime Bounds

[Bandai-Namco Research Inc., 2022]



[DeepMimic, Li-Ke Ma et al., 2021]



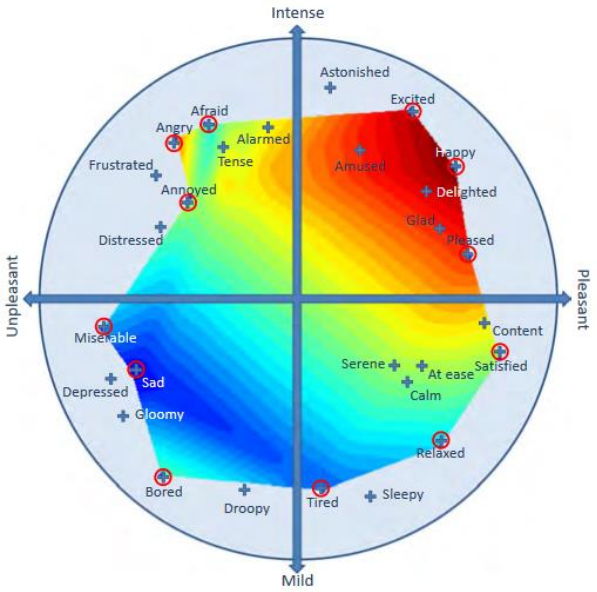
[Spacetime Bounds, Xue Bin Peng et al., 2018]

[https://youtu.be/GuBEup_90EQ?t=350, 2020]

Problems:

- No way to explicitly audit the outcome animation
- No way to tweak a character's motion after training

RELATED WORK – Emotion Control of Dance Movements



		Basic LMA Features f^i	Derived Features $\tilde{f}^i$			
		Description	*max*	*min*	*std*	*mean*
BODY	f^1	Left foot-hip distance	$\tilde{f}^1$	$\tilde{f}^2$	$\tilde{f}^3$	$\tilde{f}^4$
	f^2	Right foot-hip distance	$\tilde{f}^5$	$\tilde{f}^6$	$\tilde{f}^7$	$\tilde{f}^8$
	f^3	Left hand-shoulder distance	$\tilde{f}^9$	$\tilde{f}^{10}$	$\tilde{f}^{11}$	$\tilde{f}^{12}$
	f^4	Right hand-shoulder distance	$\tilde{f}^{13}$	$\tilde{f}^{14}$	$\tilde{f}^{15}$	$\tilde{f}^{16}$
	f^5	Hands distance	$\tilde{f}^{17}$	$\tilde{f}^{18}$	$\tilde{f}^{19}$	$\tilde{f}^{20}, \tilde{f}^1$
	f^6	Left hand-head distance	$\tilde{f}^{21}$	$\tilde{f}^{22}$	$\tilde{f}^{23}$	$\tilde{f}^{24}$
	f^7	Right hand-head distance	$\tilde{f}^{25}$	$\tilde{f}^{26}$	$\tilde{f}^{27}$	$\tilde{f}^{28}$
	f^8	Left hand-hip distance	$\tilde{f}^{29}$	$\tilde{f}^{30}$	$\tilde{f}^{31}$	$\tilde{f}^{32}, \tilde{f}^2$
	f^9	Right hand-hip distance	$\tilde{f}^{33}$	$\tilde{f}^{34}$	$\tilde{f}^{35}$	$\tilde{f}^{36}, \tilde{f}^3$
	f^{10}	Hip-ground distance	$\tilde{f}^{37}$	$\tilde{f}^{38}$	$\tilde{f}^{39}$	$\tilde{f}^{40}, \tilde{f}^4$
	f^{11}	Hip-ground minus feet-hip	$\tilde{f}^{41}$	$\tilde{f}^{42}$	$\tilde{f}^{43}$	$\tilde{f}^{44}$
	f^{12}	Feet distance	$\tilde{f}^{45}$	$\tilde{f}^{46}$	$\tilde{f}^{47}$	$\tilde{f}^{48}, \tilde{f}^5$
	f^{13}	Left hand and chest	$\tilde{f}^{113}$	$\tilde{f}^{114}$	$\tilde{f}^{115}$	$\tilde{f}^{116}, \tilde{f}^{30}$
	f^{14}	Right hand and chest	$\tilde{f}^{117}$	$\tilde{f}^{118}$	$\tilde{f}^{119}$	$\tilde{f}^{120}, \tilde{f}^{31}$
EFFORT	f^{15}	Deceleration peaks				$\tilde{f}^{49}, \tilde{f}^6$
	f^{16}	Pelvis velocity	$\tilde{f}^{50}$		$\tilde{f}^{51}$	$\tilde{f}^{52}, \tilde{f}^7$
	f^{17}	Left hand velocity	$\tilde{f}^{53}$		$\tilde{f}^{54}$	$\tilde{f}^{55}, \tilde{f}^8$
	f^{18}	Right hand velocity	$\tilde{f}^{56}$		$\tilde{f}^{57}$	$\tilde{f}^{58}, \tilde{f}^9$
	f^{19}	Left foot velocity	$\tilde{f}^{59}$		$\tilde{f}^{60}$	$\tilde{f}^{61}, \tilde{f}^{10}$
	f^{20}	Right foot velocity	$\tilde{f}^{61}$		$\tilde{f}^{61}$	$\tilde{f}^{64}, \tilde{f}^{11}$
	f^{21}	Pelvis acceleration	$\tilde{f}^{65}, \tilde{f}^{12}$		$\tilde{f}^{66}$	
	f^{22}	Left hand acceleration	$\tilde{f}^{67}, \tilde{f}^{13}$		$\tilde{f}^{68}$	
	f^{23}	Right hand acceleration	$\tilde{f}^{69}, \tilde{f}^{14}$		$\tilde{f}^{70}$	
	f^{24}	Left foot acceleration	$\tilde{f}^{71}, \tilde{f}^{15}$		$\tilde{f}^{72}$	
	f^{25}	Right foot acceleration	$\tilde{f}^{73}, \tilde{f}^{16}$		$\tilde{f}^{74}$	
	f^{26}	Jerk	$\tilde{f}^{75}, \tilde{f}^{17}$		$\tilde{f}^{76}$	
SHAPE	f^{27}	Volume (5 joints)	$\tilde{f}^{77}$	$\tilde{f}^{78}$	$\tilde{f}^{79}$	$\tilde{f}^{80}, \tilde{f}^{18}$
	f^{28}	Volume (All joints)	$\tilde{f}^{81}$	$\tilde{f}^{82}$	$\tilde{f}^{83}$	$\tilde{f}^{84}, \tilde{f}^{19}$
	f^{29}	Torso height	$\tilde{f}^{85}$	$\tilde{f}^{86}$	$\tilde{f}^{87}$	$\tilde{f}^{88}, \tilde{f}^{20}$
	f^{30}	Hands level				$\tilde{f}^{89}, \tilde{f}^{91}, \tilde{f}^{21}, \tilde{f}^{23}$
	f^{31}	Volume (upper body)	$\tilde{f}^{97}$	$\tilde{f}^{98}$	$\tilde{f}^{99}$	$\tilde{f}^{100}, \tilde{f}^{26}$
	f^{32}	Volume (lower body)	$\tilde{f}^{101}$	$\tilde{f}^{102}$	$\tilde{f}^{103}$	$\tilde{f}^{104}, \tilde{f}^{27}$
	f^{33}	Volume (right side)	$\tilde{f}^{105}$	$\tilde{f}^{106}$	$\tilde{f}^{107}$	$\tilde{f}^{108}, \tilde{f}^{28}$
	f^{34}	Volume (left side)	$\tilde{f}^{109}$	$\tilde{f}^{110}$	$\tilde{f}^{111}$	$\tilde{f}^{112}, \tilde{f}^{29}$
SPACE	f^{35}	Total distance				$\tilde{f}^{92}, \tilde{f}^{24}$
	f^{36}	Area per second	$\tilde{f}^{93}$	$\tilde{f}^{94}$	$\tilde{f}^{95}$	$\tilde{f}^{96}, \tilde{f}^{25}$
	f^{37}	Total volume				$\tilde{f}^{121}$

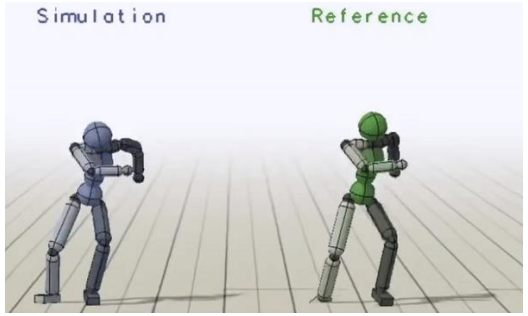
[Emotion Control of Unstructured Dance Movements, Andreas Aristidou et al., 2017]

Problems:

- Does not work with learned Policy-Based Physics-Enabled Controllers
- Changes take time to apply
- Focuses on non-generic dance animations

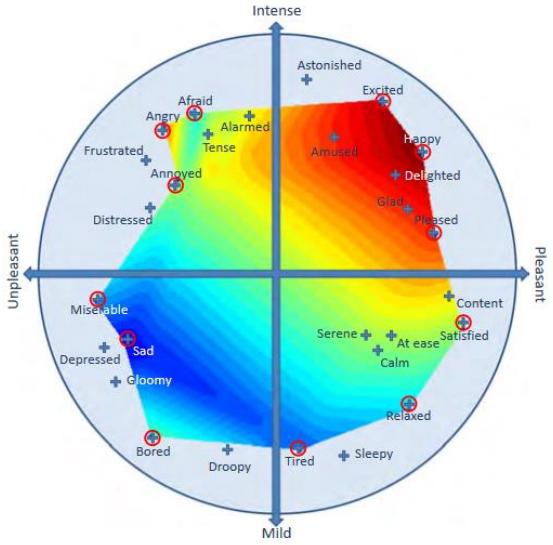
RELATED WORK – Emotion Control of Dance Movements

[DeepMimic, Li-Ke Ma et al., 2021]



[Spacetime Bounds, Xue Bin Peng et al., 2018]

RCM Emotional Model

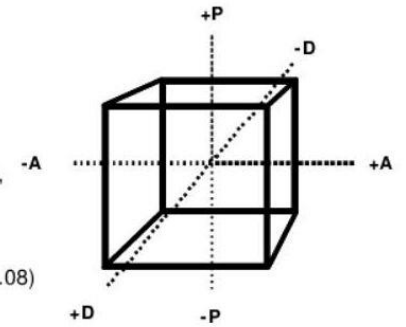


[Emotion Control of Unstructured Dance Movements, Andreas Aristidou et al., 2017]

PAD Emotional Model

The following sample ratings illustrate definitions of various emotion terms when scores on each PAD scale range from -1 to +1:

angry (-.51, .59, .25)
bored (-.65, -.62, -.33)
curious (.22, .62, -.01)
dignified (.55, .22, .61)
elated (.50, .42, .23)
hungry (-.44, .14, -.21)
inhibited (-.54, -.04, -.41),
loved (.87, .54, -.18)
puzzled (-.41, .48, -.33)
sleepy (.20, -.70, -.44)
unconcerned (-.13, -.41, .08)
violent (-.50, .62, .38).



The emotional state "angry" is a highly unpleasant, highly aroused, and moderately dominant emotional state. The "bored" state implies a highly unpleasant, highly unaroused, and moderately submissive state.

[Joost Broekens et al., 2004]

Problems:

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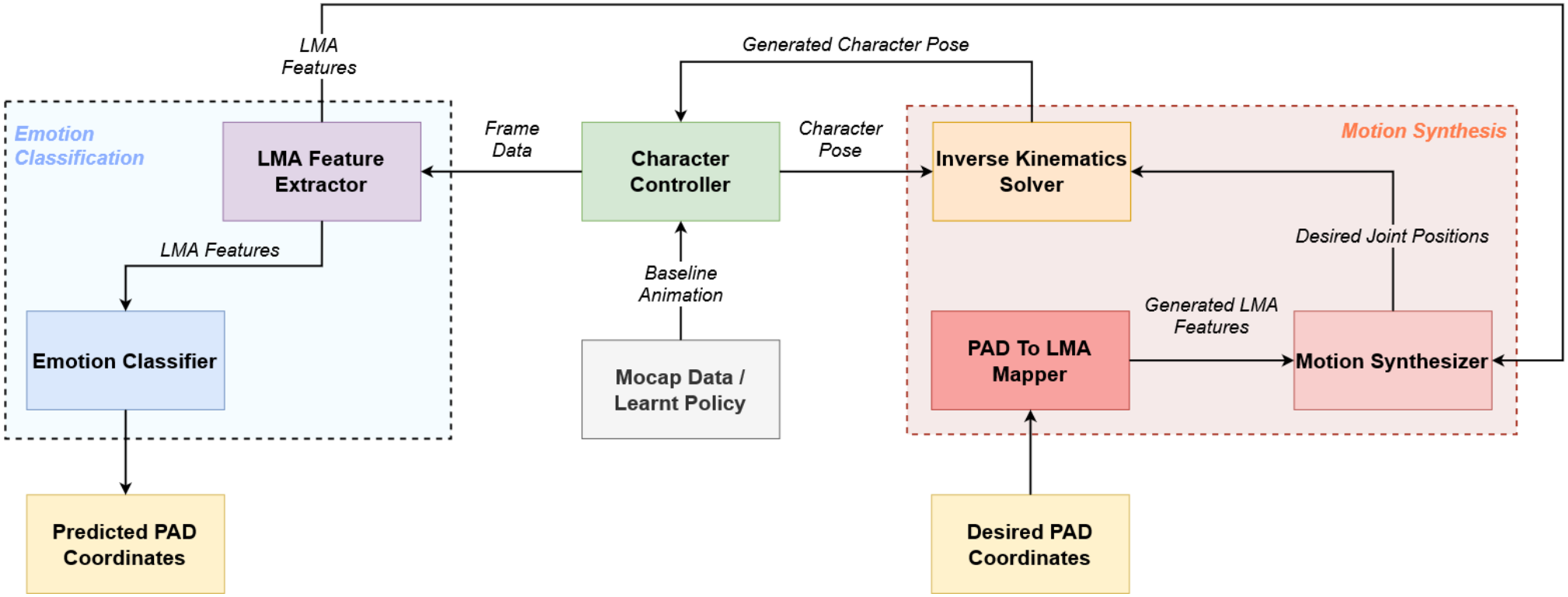
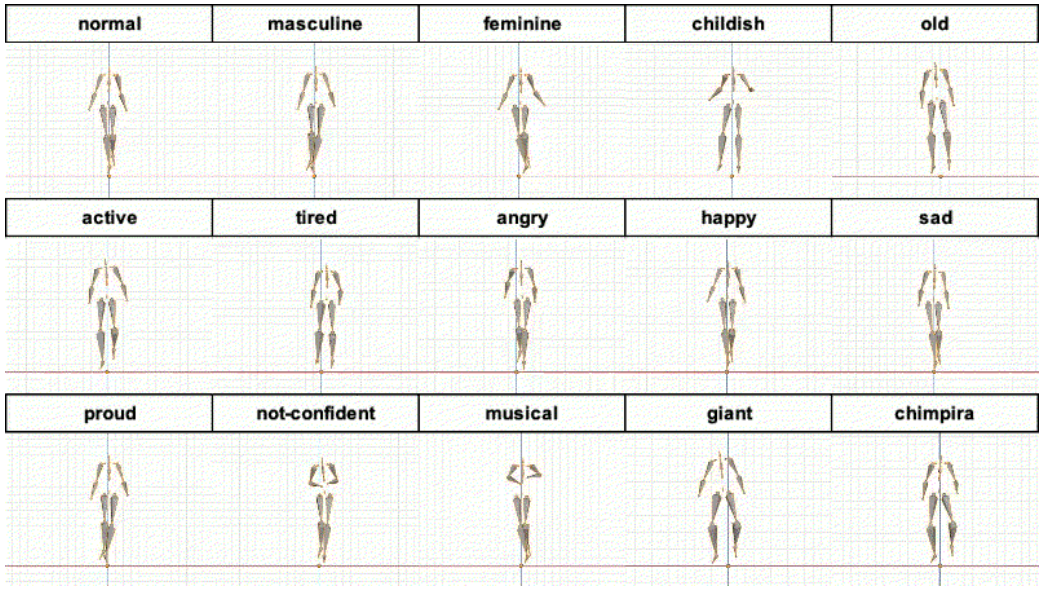
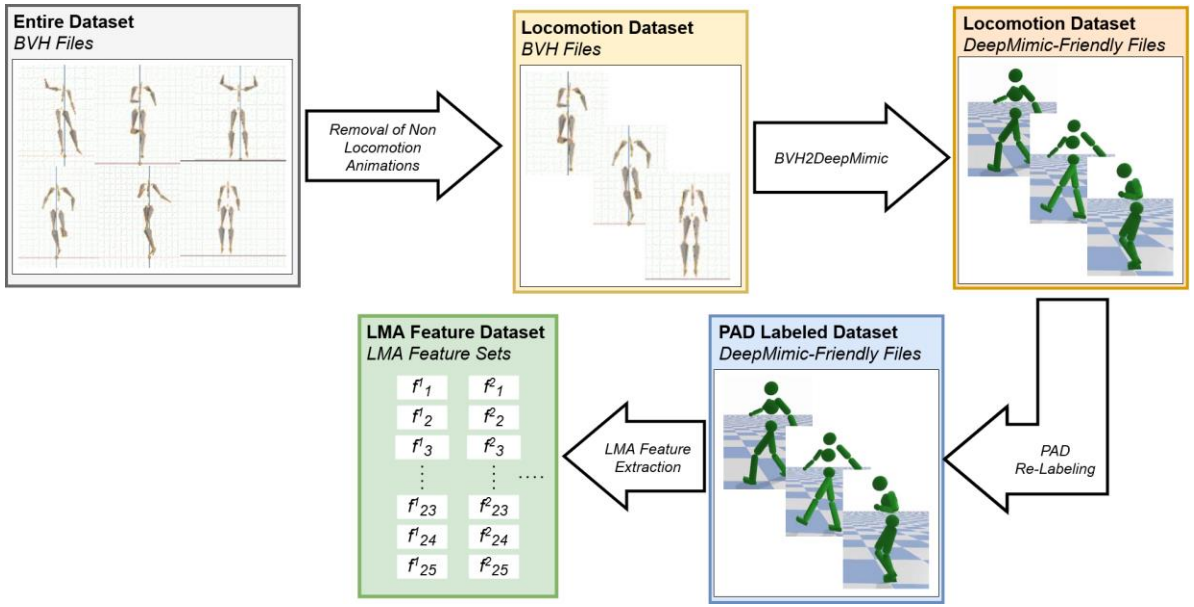
EMOTIONALLY EXPRESSIVE MOTION CONTROLLER



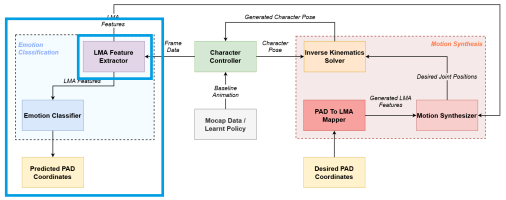
DATASET

- Various Motions in different Emotional Styles
- Only Locomotion Animations were kept
- 78551 LMA Feature Sets in 14 different Emotional Styles





LMA FEATURE EXTRACTOR



LMA Feature	f	LMA Category
Max Hand Distance	f_1	Body
Avg. Left Hand - Hip Distance	f_2	Body
Avg. Right Hand - Hip Distance	f_3	Body
Max Stride Length	f_4	Body
Avg. Left Hand - Chest Distance	f_5	Body
Avg. Right Hand - Chest Distance	f_6	Body
Avg. Left Elbow - Hip Distance	f_7	Body
Avg. Right Elbow - Hip Distance	f_8	Body
Avg. Chest - Pelvis Distance	f_9	Body
Avg. Neck - Chest Distance	f_{10}	Body
Avg. Total Body Volume	f_{11}	Shape
Avg. Lower Body Volume	f_{12}	Shape
Avg. Upper Body Volume	f_{13}	Shape
Avg. Area between Hands and Neck	f_{14}	Shape
Avg. Area between Feet and Hip	f_{15}	Shape
Left Hand Speed	f_{16}	Effort
Right Hand Speed	f_{17}	Effort
Left Foot Speed	f_{18}	Effort
Right Foot Speed	f_{19}	Effort
Neck Speed	f_{20}	Effort
Left Hand Acceleration Magnitude	f_{21}	Effort
Right Hand Acceleration Magnitude	f_{22}	Effort
Left Foot Acceleration Magnitude	f_{23}	Effort
Right Foot Acceleration Magnitude	f_{24}	Effort
Neck Acceleration Magnitude	f_{25}	Effort

```
{
    "frame_counter": index of the frame at which LMA features were computed,

    "label": PAD Emotional Coordinates (3D),

    "lma_features": [
        max hand_distance (1D),
        average l_hand_hip_distance (1D),
        average r_hand_hip_distance (1D),
        max stride length (distance between left and right foot) (1D),
        average l_hand_chest_distance (1D),
        average r_hand_chest_distance (1D),
        average l_elbow_hip_distance (1D),
        average r_elbow_hip_distance (1D),
        average chest_pelvis_distance (1D),
        average neck_chest_distance (1D),
        average total_body_volume (1D),
        average lower_body_volume (1D),
        average upper_body_volume (1D),
        triangle area between hands and neck (1D),
        triangle area between feet and root (1D),
        l_hand speed (1D),
        r_hand speed (1D),
        l_foot_speed (1D),
        r_foot_speed (1D),
        neck speed (1D),
        l_hand acceleration magnitude (1D),
        r_hand acceleration magnitude (1D),
        l_foot acceleration magnitude (1D),
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        neck acceleration magnitude (1D)
    ]
}
```
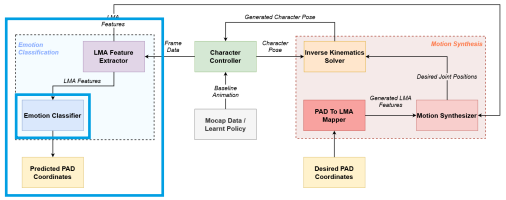
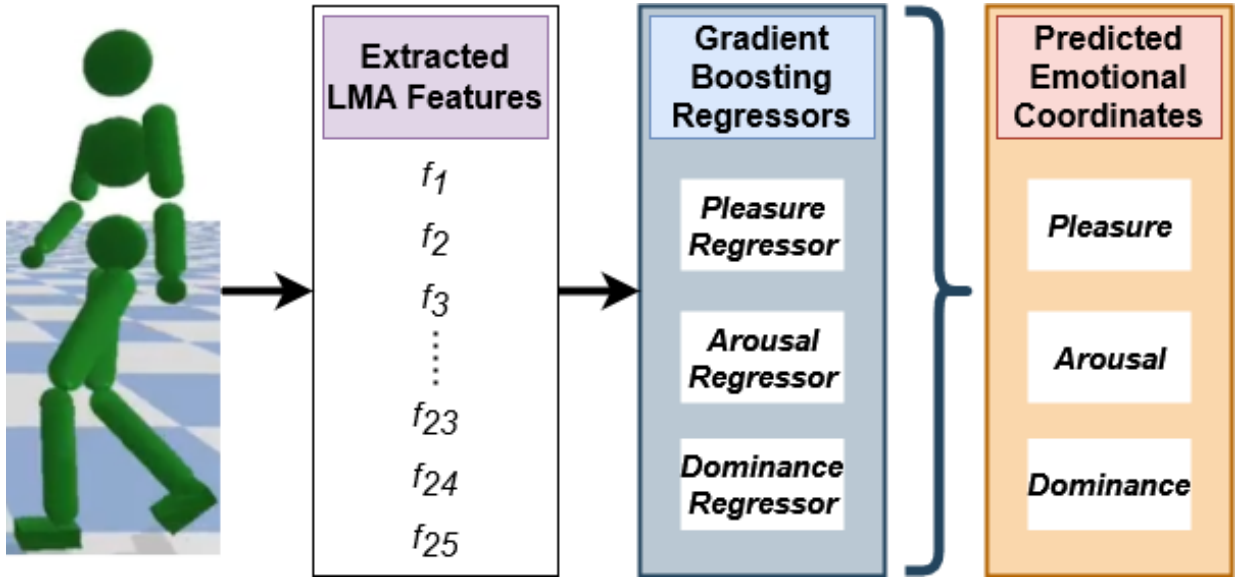
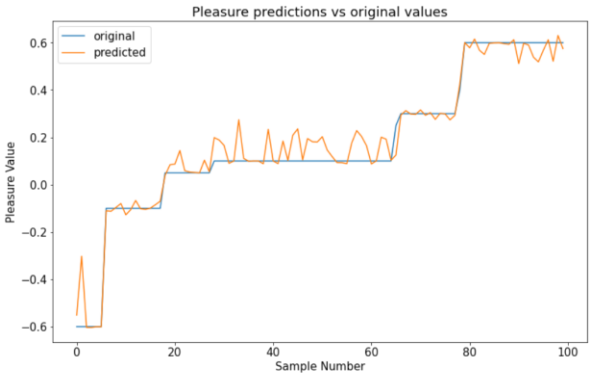
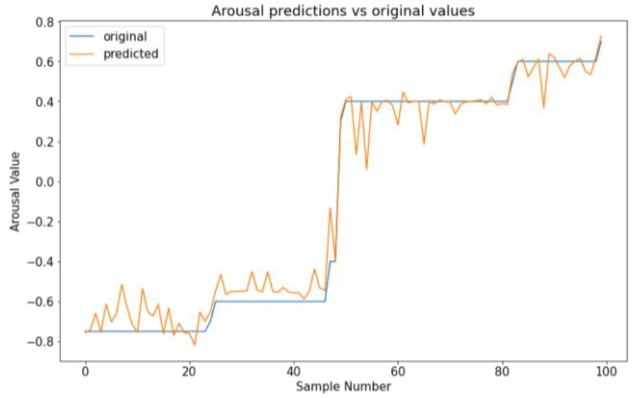
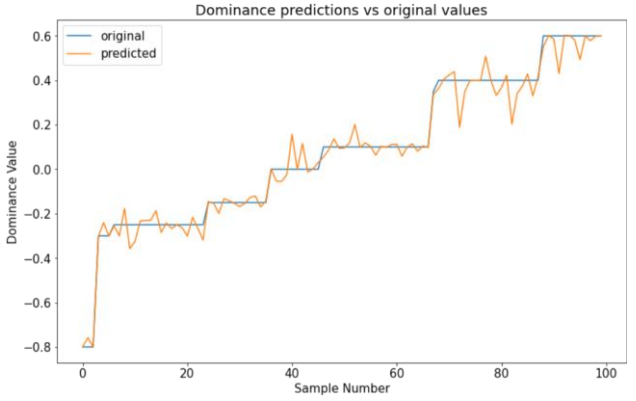

LMA TO PAD REGRESSION

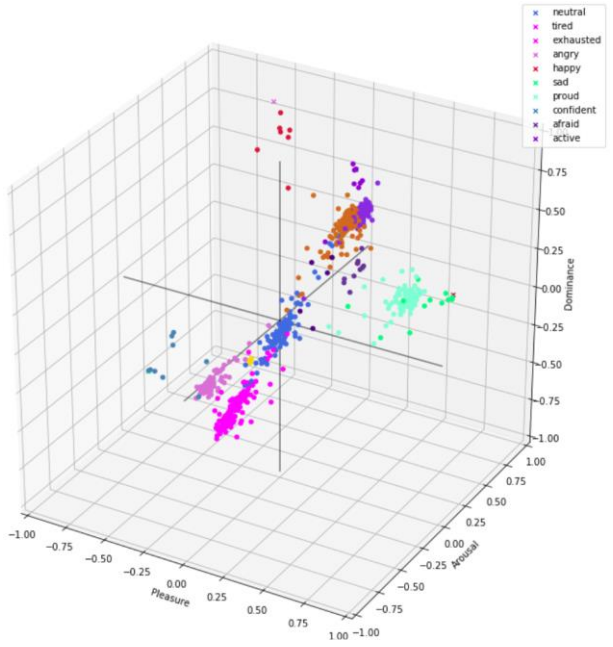




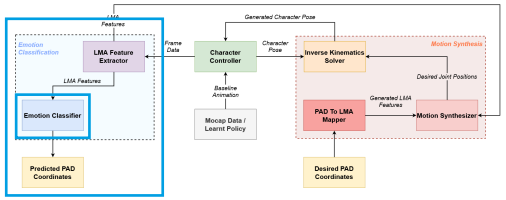


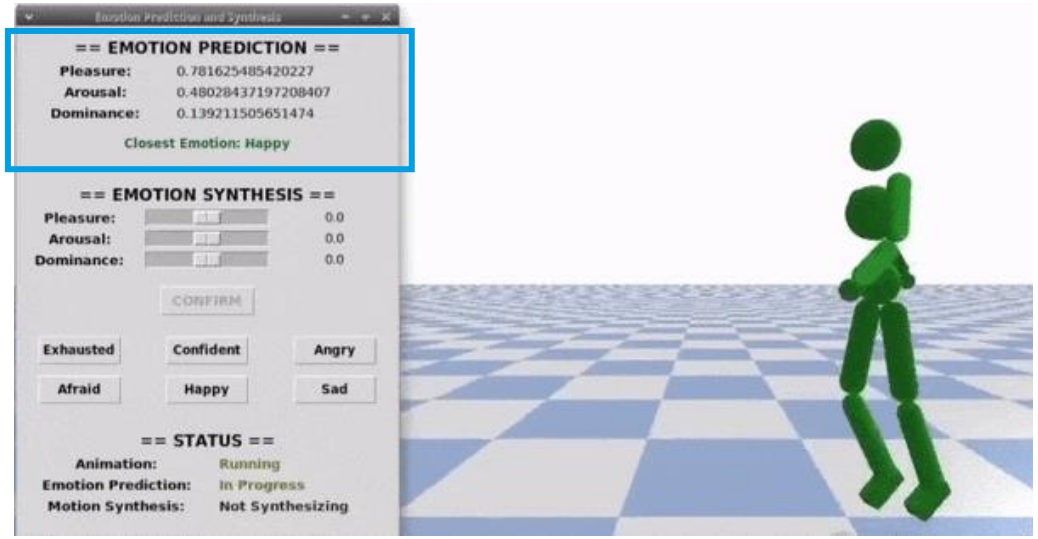


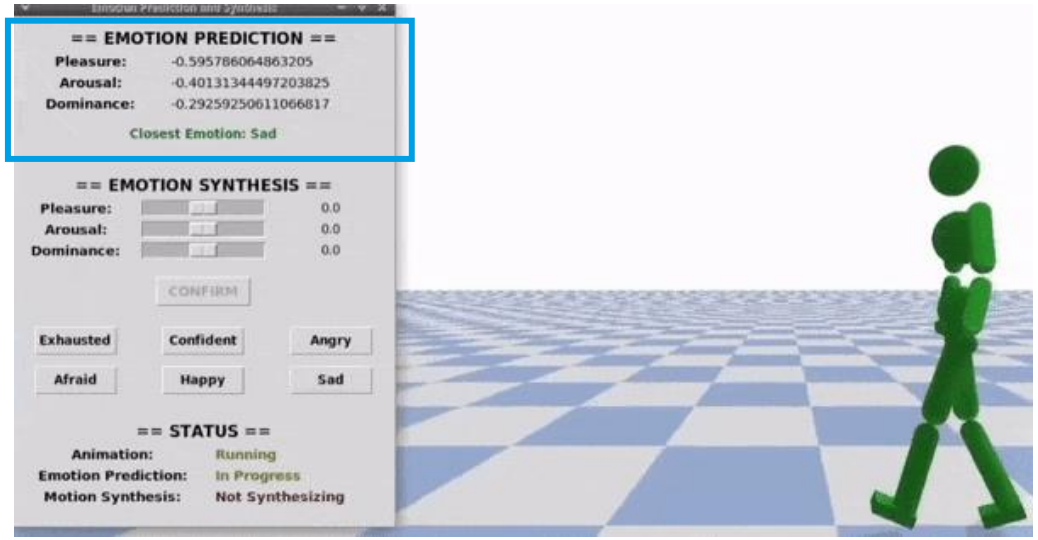


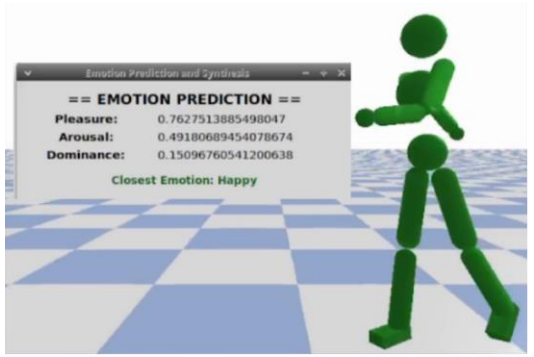


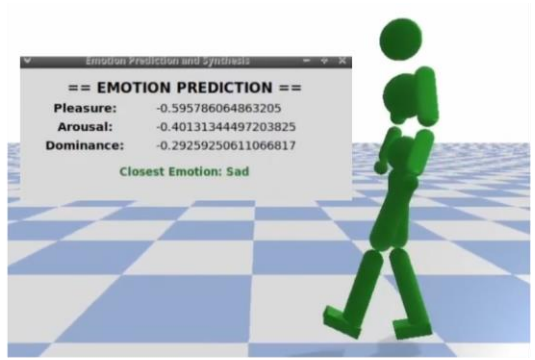
EMOTIONAL CLASSIFICATION

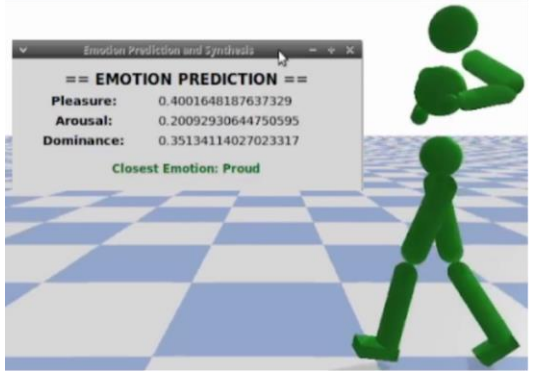


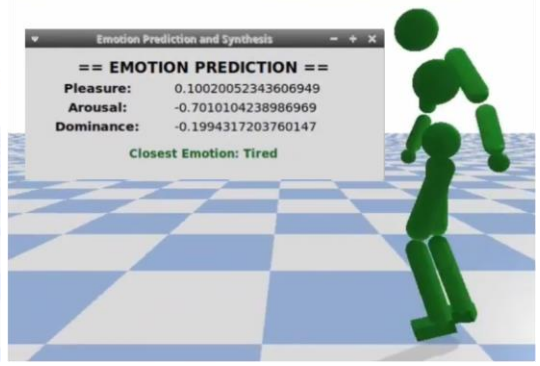


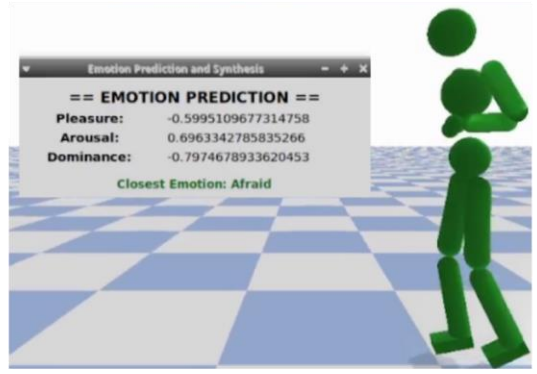




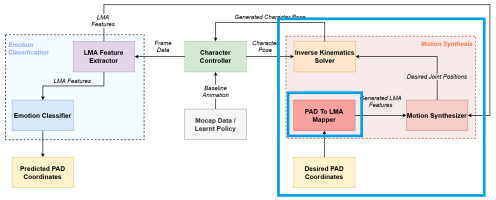


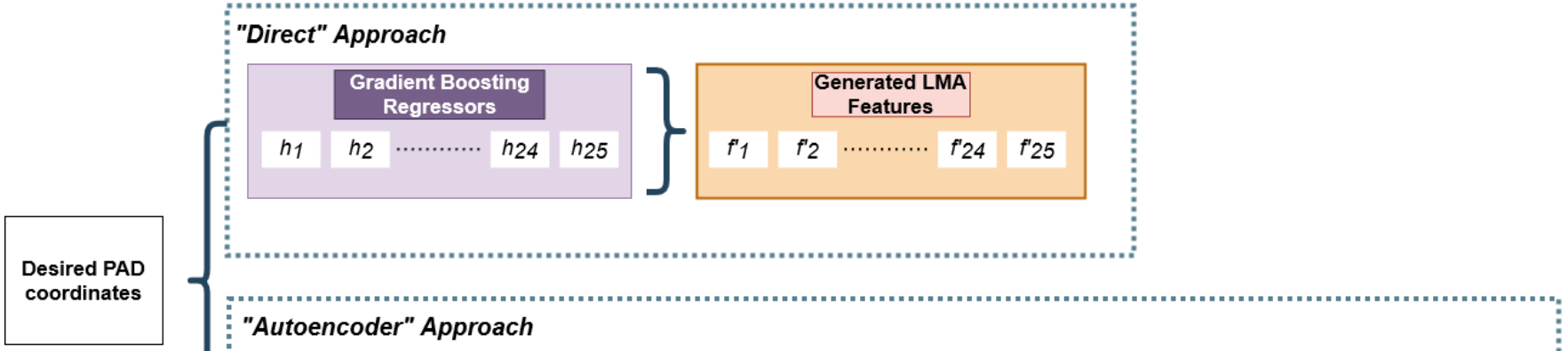


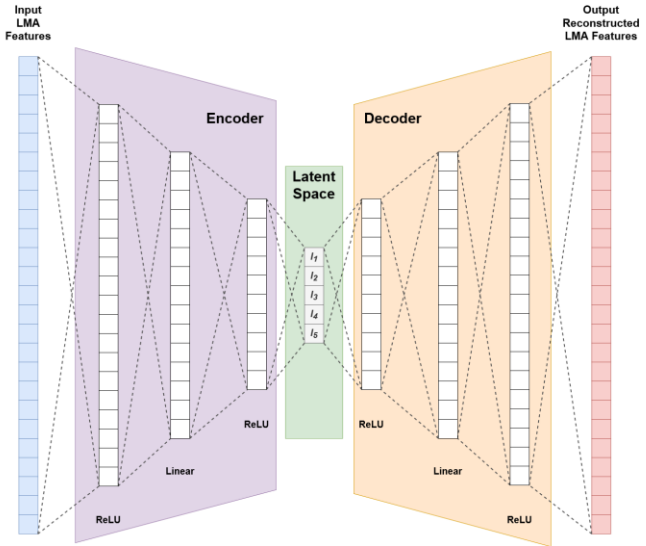




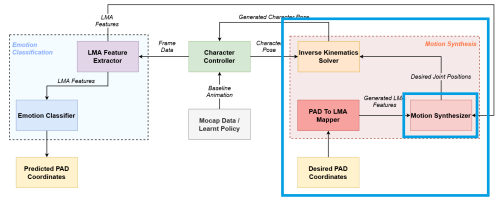
PAD TO LMA REGRESSION







MOTION SYNTHESIS

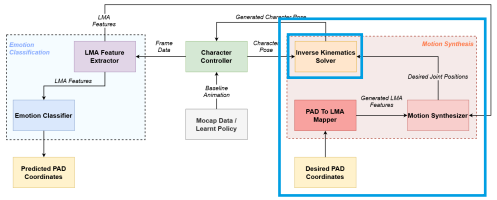


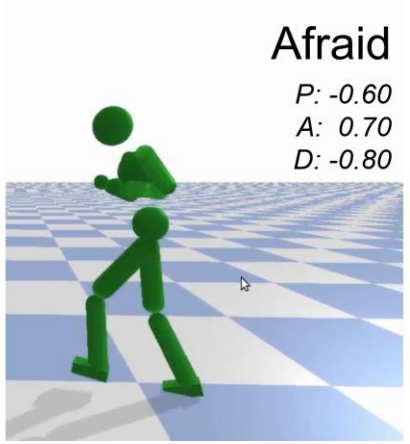
- Compute new desired positions/rotations for core joints
- 6 Heuristic Rules
- Coefficients to represent the difference between Baseline's and Generated LMA Features

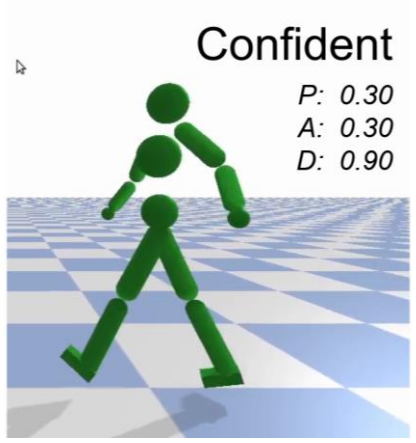
$$\sum_{t} \parallel \hat{f} - f_t c \parallel^2$$

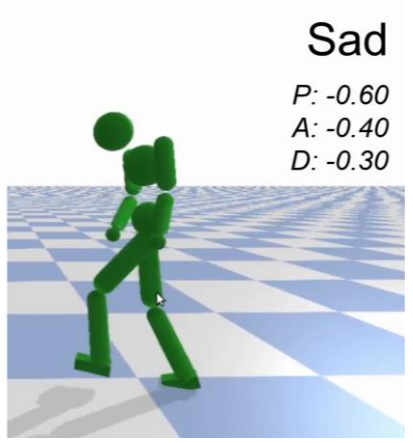
Rule	Associated LMA Features
g1: Modifies Hip Height *Raises or lowers the character's Hip, changing the body volume.*	Avg. Chest-Pelvis Distance (f_8) ; Avg. Total Body Volume (f_{10}) ; Avg. Lower Body Volume (f_{11}) ; Avg. Area Feet-Hips Triangle (f_{14}) ;
g2: Modifies the Chest's Position *Raises or lowers the character's Chest, making their back appear slumped over or straight.*	Avg. Chest-Pelvis Distance (f_8) ; Avg. Total Body Volume (f_{10}) ; Avg. Upper Body Volume (f_{12}) ;
g3: Modifies the Hands' Positions *Pulls each Hand towards or away from the character's body. Also raises or lowers each Hand towards the character's chest.*	Max Hand Distance (f_0) ; Avg. Left Hand-Hip Distance (f_1) ; Avg. Right Hand-Hip Distance (f_2) ; Avg. Left Hand-Chest Distance (f_4) ; Avg. Right Hand-Chest Distance (f_5) ; Avg. Total Body Volume (f_{10}) ; Avg. Upper Body Volume (f_{12}) ; Avg. Area Hands-Neck Triangle (f_{13}) ;
g4: Modifies Elbows Positions *Pulls each Elbow towards or away from the character's body, changing their upper volume.*	Avg. Left Elbow-Hip Distance (f_6) ; Avg. Right Elbow-Hip Distance (f_7) ; Avg. Total Body Volume (f_{10}) ; Avg. Upper Body Volume (f_{12}) ;
g5: Modifies the Feets' Positions *Increases or decreases the distance between each Foot, changing the stride length.*	Max Stride Length (f_3) ; Avg. Total Body Volume (f_{10}) ; Avg. Lower Body Volume (f_{11}) ; Avg. Area Feet-Hips Triangle (f_{14}) ;
g6: Modifies Neck Tilt *Tilts the character's Neck towards or away from their chest.*	Avg. Neck-Chest Distance (f_9) ; Avg. Total Body Volume (f_{10}) ; Avg. Upper Body Volume (f_{12}) ;

INVERSE KINEMATICS

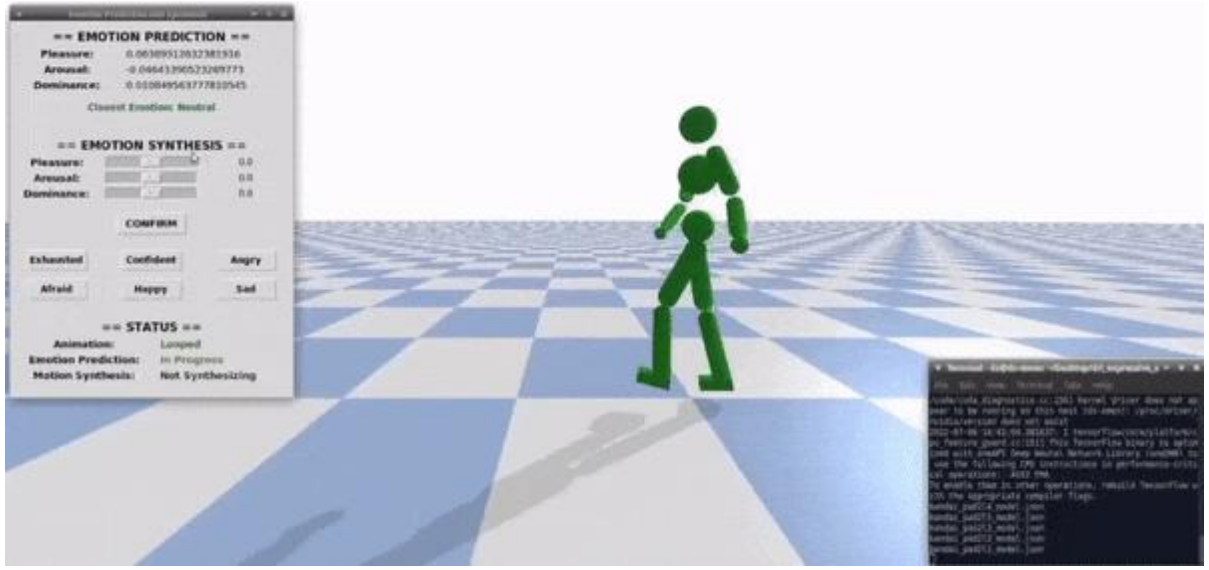


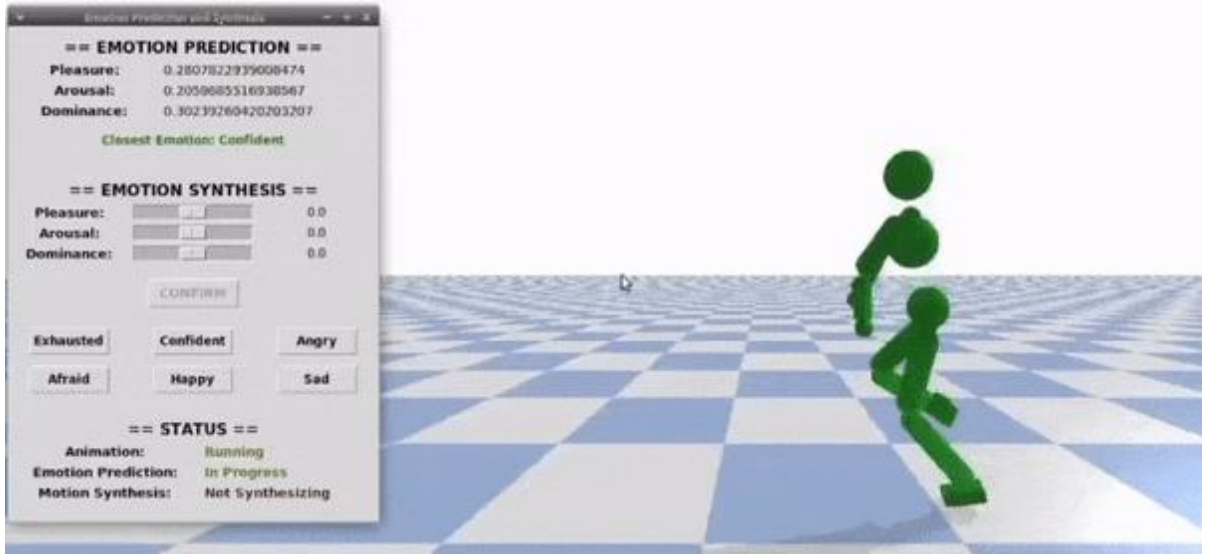






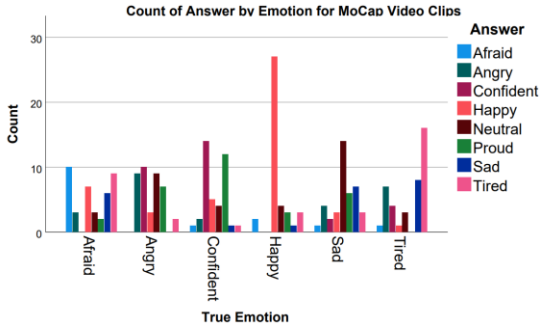
EMOTIONALLY EXPRESSIVE MOTION CONTROLLER

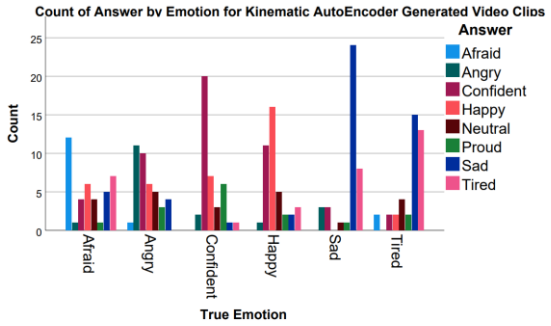


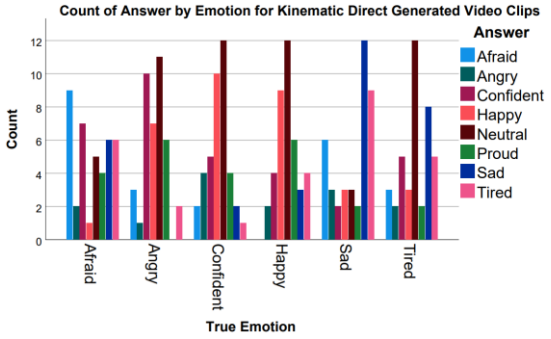


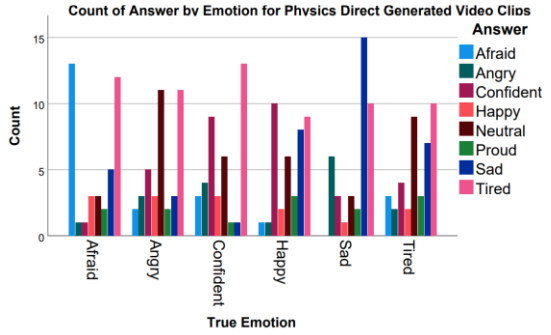
USER TESTS

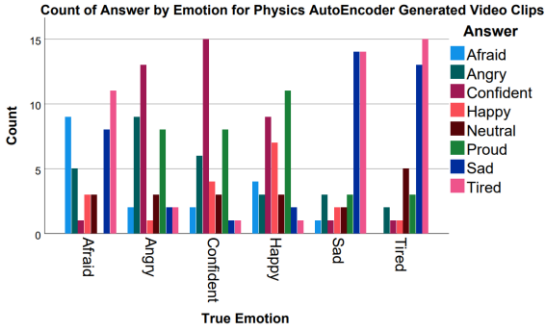
Emotional Selection Task



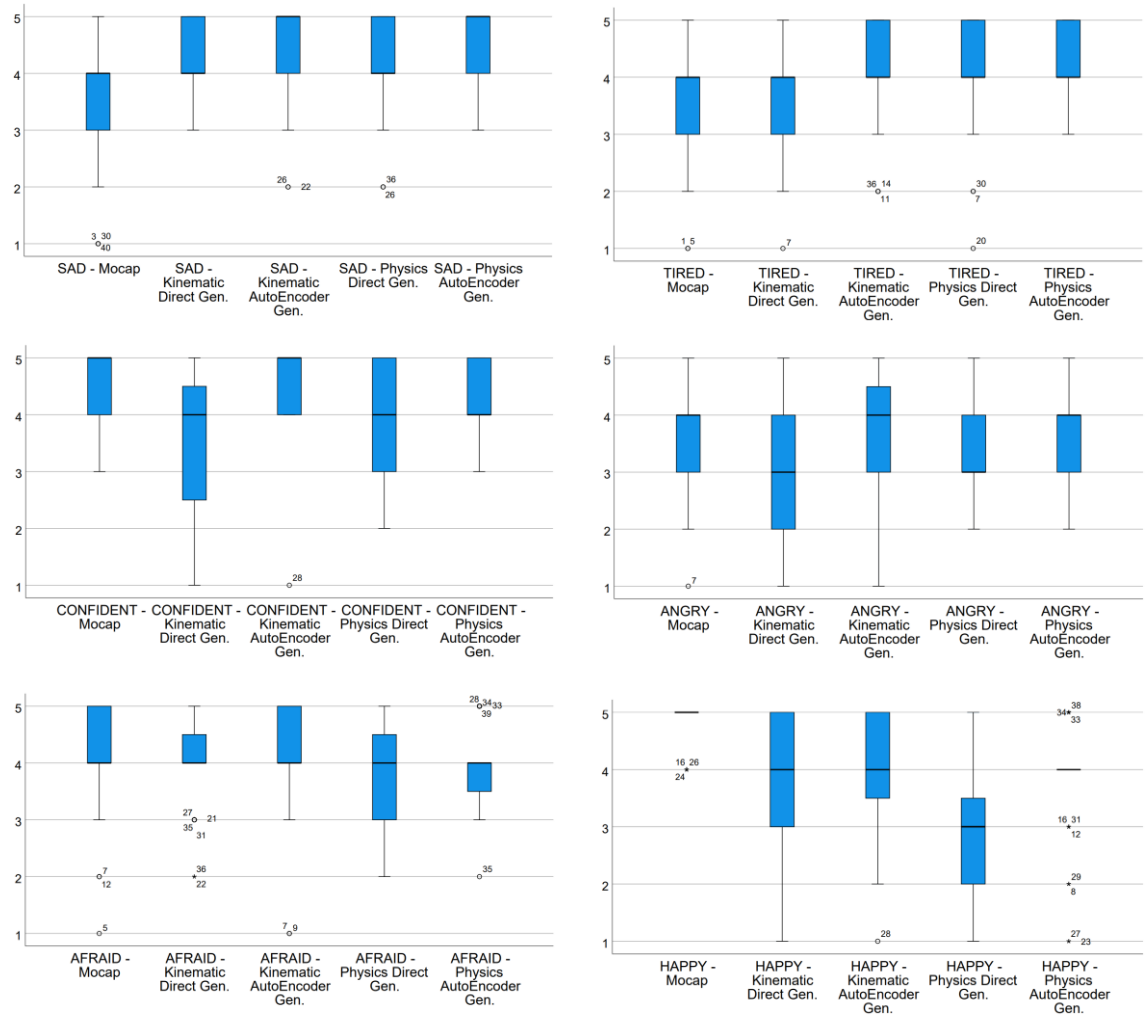






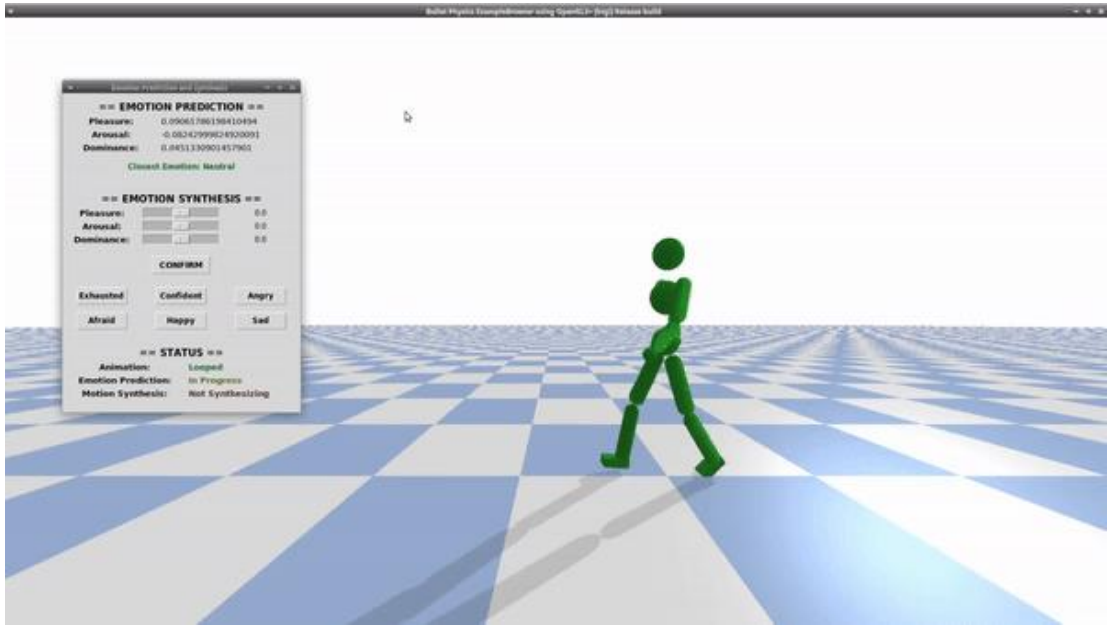


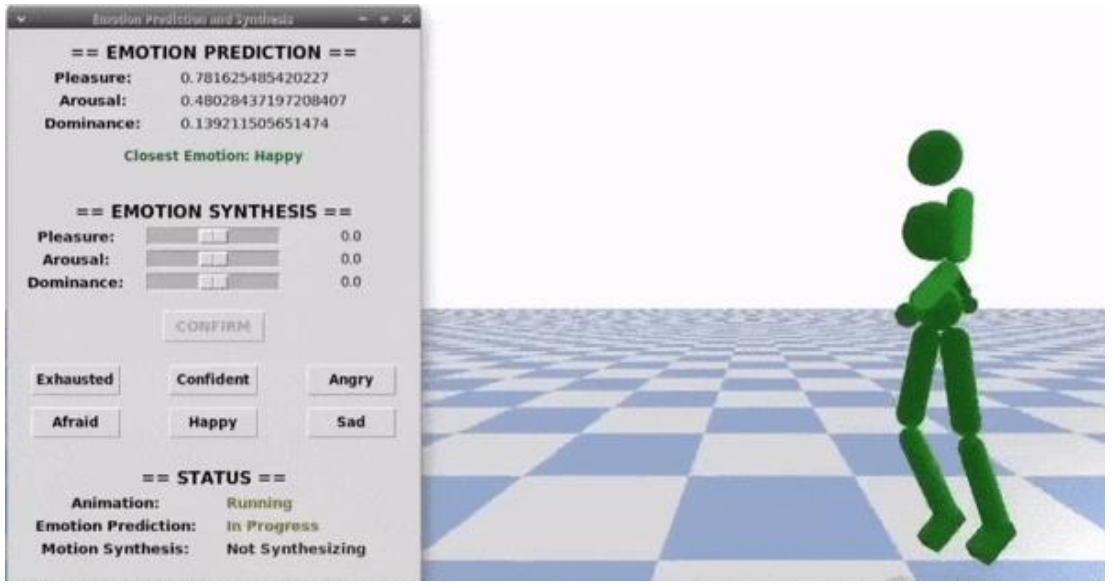
Primed Emotional Agreement Task



CONCLUSION

- Automatic System for Emotionally Expressive Motion Synthesis of Locomotion Animations
- Works with both Kinematic and Policy-Based Physics-Enabled Character Controllers
- Emotions specified using the PAD Model
- Emotional Prediction and Motion Synthesis in Real Time
- No need for extra data or training
- Quality of synthesized motions validated through User Tests
- Work accepted for publishing in IEEE ISM 2022





Thank you for listening!

INDEX

- Motivation
- Related Work
- Emotionally Expressive Motion Controller
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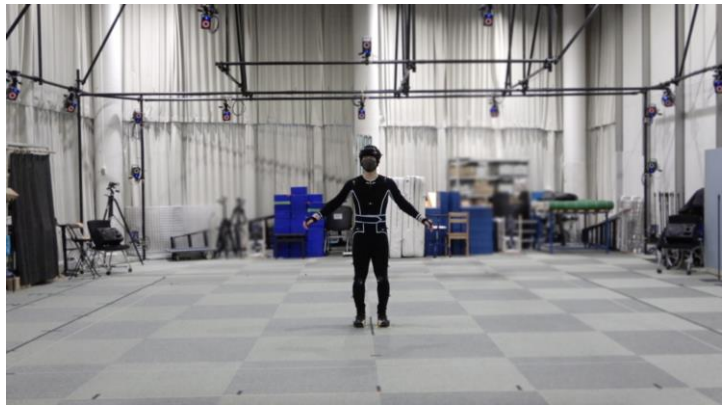
BACKGROUND – Computer Animation

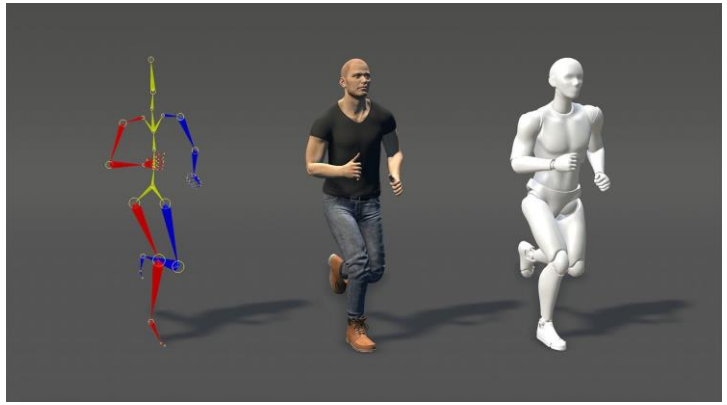
Kinematic Controllers



[Bandai-Namco Research Inc., 2022]

[Blender, 2022]

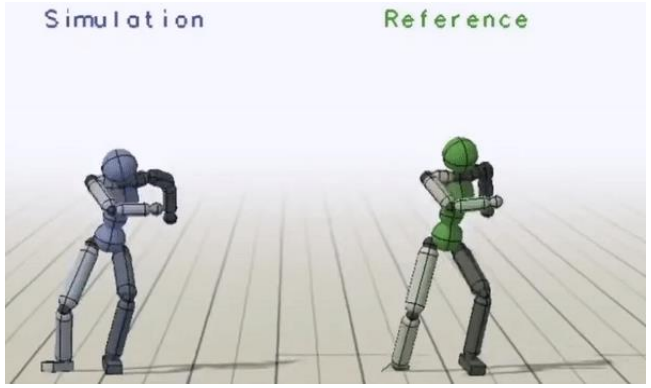
[https://youtu.be/GuBEup_90EQ?t=350, 2020]



[https://youtu.be/z93e5_7P54g, 2020]

[DeepMimic, Li-Ke Ma et al., 2021]

Physics Controllers



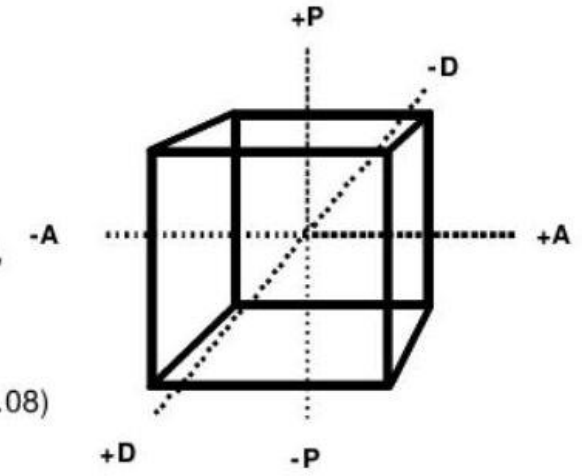
[Spacetime Bounds, Xue Bin Peng et al., 2018]

BACKGROUND – Emotional Models & Laban Movement Analysis

PAD Emotional Model

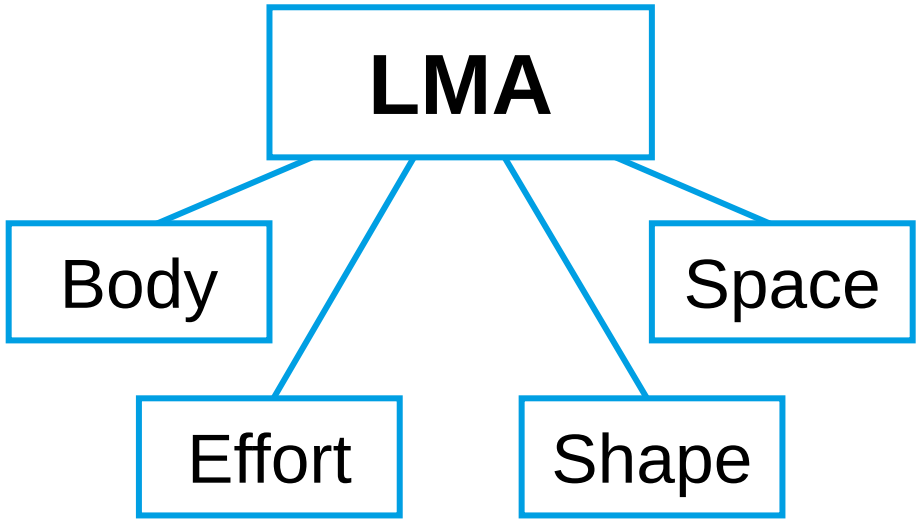
The following sample ratings illustrate definitions of various emotion terms when scores on each PAD scale range from -1 to +1:

angry (-.51, .59, .25)
bored (-.65, -.62, -.33)
curious (.22, .62, -.01)
dignified (.55, .22, .61)
elated (.50, .42, .23)
hungry (-.44, .14, -.21)
inhibited (-.54, -.04, -.41),
loved (.87, .54, -.18)
puzzled (-.41, .48, -.33)
sleepy (.20, -.70, -.44)
unconcerned (-.13, -.41, .08)
violent (-.50, .62, .38).



The emotional state "angry" is a highly unpleasant, highly aroused, and moderately dominant emotional state. The "bored" state implies a highly unpleasant, highly unaroused, and moderately submissive state.

[Joost Broekens et al., 2004]



Feature	Category
Hands Distance	Body
Hip-Ground Distance	Body
Left Foot Velocity	Effort
Pelvis Acceleration	Effort
Volume (All joints)	Shape
Torso Height	Shape
Total Distance	Space
Area Per Second	Space