



Emotionally Expressive Motion Controller for Virtual Character Locomotion Animations

Diogo Silva

Coordinated by: Prof. Pedro A. Santos & Prof. João Dias



MOTIVATION



"Neutral"

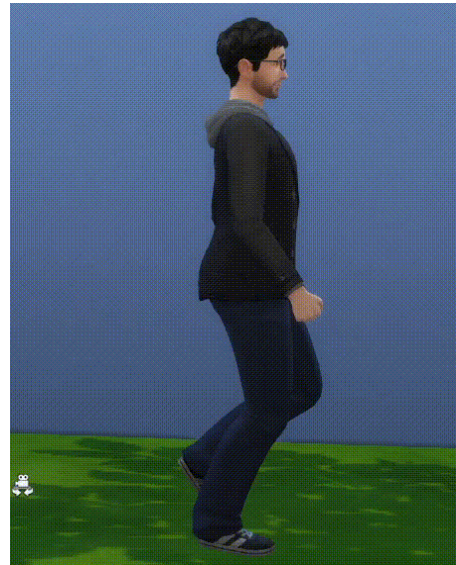
[The Sims 4, Maxis, 2014]



"Angry"



"Confident"



"Energized"



"Sad"



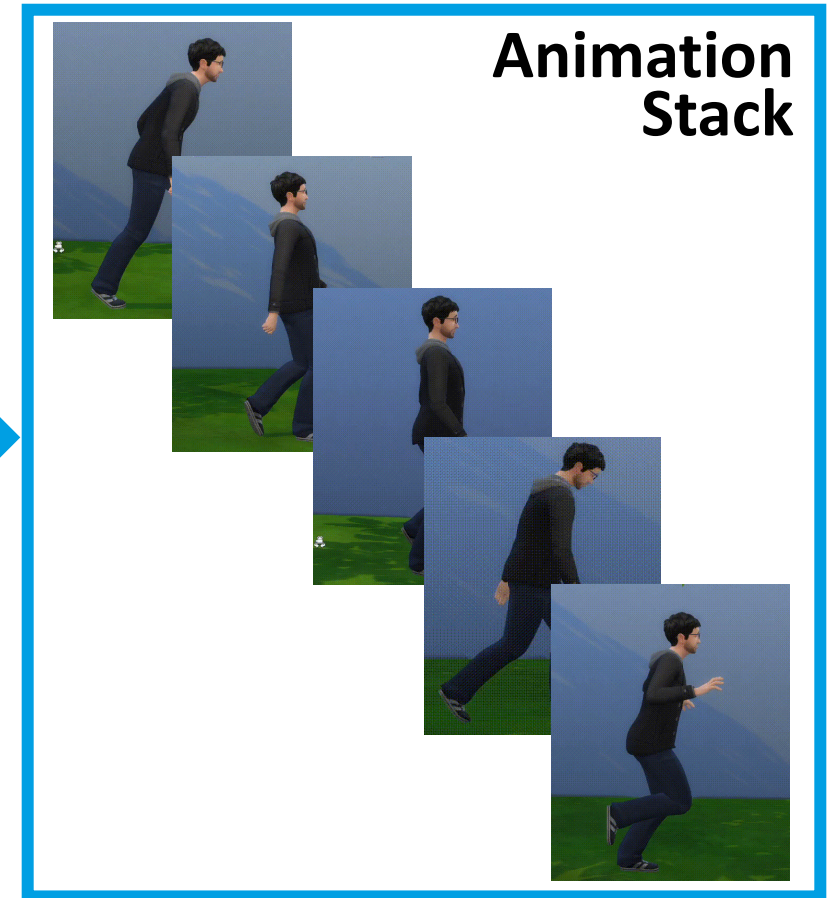
"Afraid"

PROBLEM

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

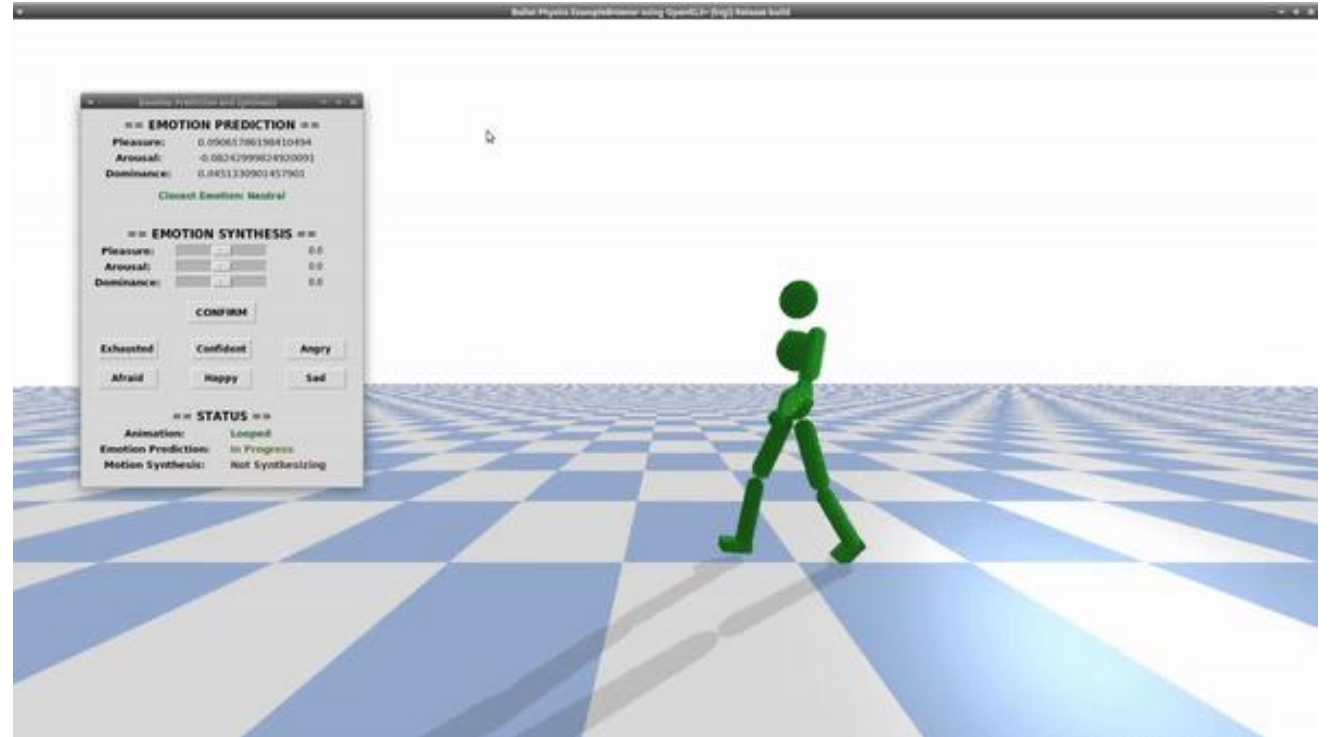


[The Sims 4, Maxis, 2014]



SOLUTION

- Automatic
- Real-Time
- No Additional Data or Training Required
- Works with both Kinematic & Policy-Based Physics-Enabled characters
- Focused on Locomotion
- Based on Machine Learning & Laban Movement Analysis

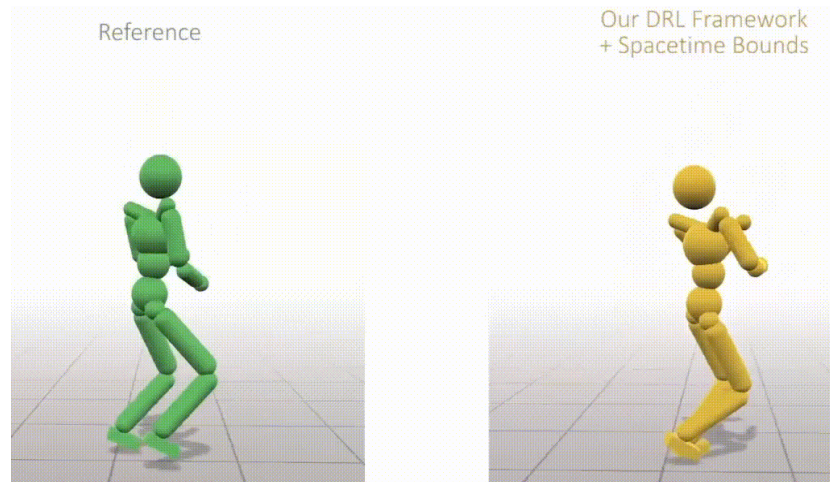


Emotionally Expressive Motion Controller

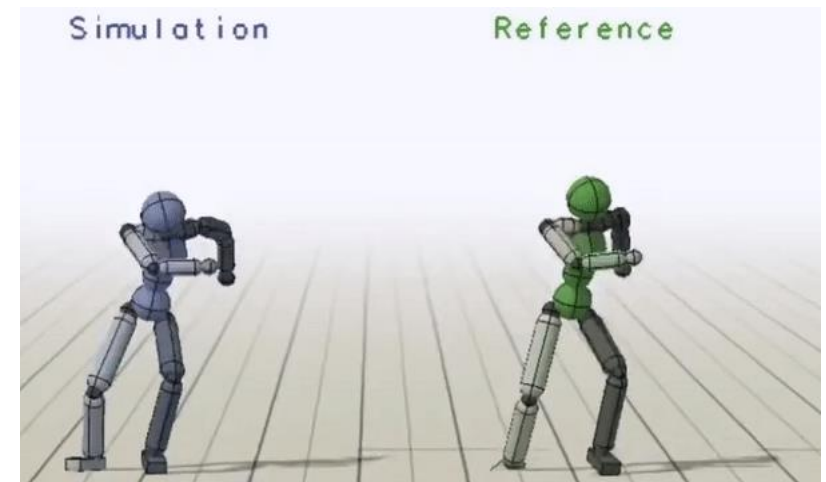
RELATED WORK – DeepMimic & Spacetime Bounds



[Bandai-Namco Research Inc., 2022]



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



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

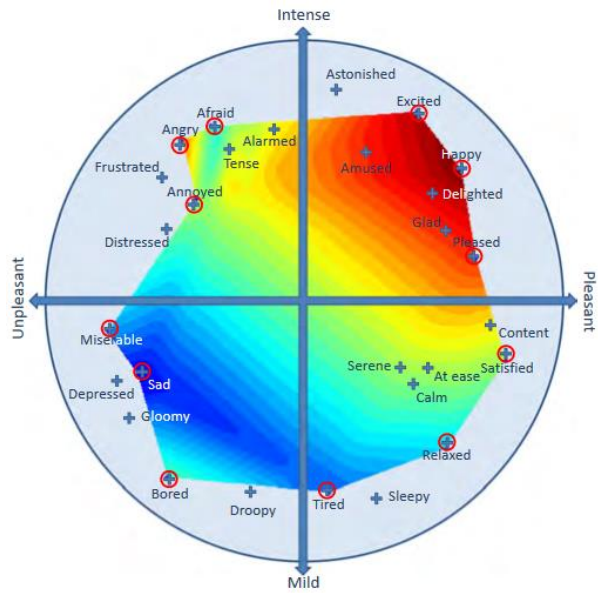


[https://youtu.be/GuBEup_90EQ?t=350, 2020]

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 \hat{f}^i | | | |
|-----------------------------|------------------------------------|------------------------------|------------------------------|------------------|----------------------------------|--------------------|
| | Description | max | min | std | mean | |
| BODY | f^1 Left foot-hip distance | f^1 | f^2 | f^3 | f^4 | |
| | f^2 Right foot-hip distance | f^5 | f^6 | f^7 | f^8 | |
| | f^3 Left hand-shoulder distance | f^9 | f^{10} | f^{11} | f^{12} | |
| | f^4 Right hand-shoulder distance | f^{13} | f^{14} | f^{15} | f^{16} | |
| | f^5 Hands distance | f^{17} | f^{18} | f^{19} | f^{20}, f^{21} | |
| | f^6 Left hand-head distance | f^{21} | f^{22} | f^{23} | f^{24} | |
| | f^7 Right hand-head distance | f^{25} | f^{26} | f^{27} | f^{28} | |
| | f^8 Left hand-hip distance | f^{29} | f^{30} | f^{31} | f^{32}, f^{33} | |
| | f^9 Right hand-hip distance | f^{33} | f^{34} | f^{35} | f^{36}, f^{37} | |
| | f^{10} Hip-ground distance | f^{37} | f^{38} | f^{39} | f^{40}, f^{41} | |
| | f^{11} Hip-ground minus feet-hip | f^{41} | f^{42} | f^{43} | f^{44} | |
| EFFORT | f^{12} Feet distance | f^{45} | f^{46} | f^{47} | f^{48}, f^{49} | |
| | f^{13} Left hand and chest | f^{113} | f^{114} | f^{115} | f^{116}, f^{117} | |
| | f^{14} Right hand and chest | f^{117} | f^{118} | f^{119} | f^{120}, f^{121} | |
| | f^{15} Deceleration peaks | | | | f^{49}, f^{50} | |
| | f^{16} Pelvis velocity | f^{50} | | f^{51} | f^{52}, f^{53} | |
| | f^{17} Left hand velocity | f^{53} | | f^{54} | f^{55}, f^{56} | |
| | f^{18} Right hand velocity | f^{56} | | f^{57} | f^{58}, f^{59} | |
| | f^{19} Left foot velocity | f^{59} | | f^{60} | f^{61}, f^{62} | |
| | f^{20} Right foot velocity | f^{61} | | f^{62} | f^{64}, f^{65} | |
| | f^{21} Pelvis acceleration | f^{65}, f^{66} | f^{67} | | f^{66} | |
| | f^{22} Left hand acceleration | f^{67}, f^{68} | | f^{68} | | |
| SHAPE | f^{23} Right hand acceleration | f^{69}, f^{70} | | f^{70} | | |
| | f^{24} Left foot acceleration | f^{71}, f^{72} | | f^{72} | | |
| | f^{25} Right foot acceleration | f^{73}, f^{74} | | f^{74} | | |
| | f^{26} Jerk | f^{75}, f^{76} | | f^{76} | | |
| | f^{27} Volume (5 joints) | f^{77} | f^{78} | f^{79} | f^{80}, f^{81} | |
| | f^{28} Volume (All joints) | f^{81} | f^{82} | f^{83} | f^{84}, f^{85} | |
| | f^{29} Torso height | f^{85} | f^{86} | f^{87} | f^{88}, f^{89} | |
| | f^{30} Hands level | | | | $f^{89}, f^{91}, f^{92}, f^{93}$ | |
| | f^{31} Volume (upper body) | f^{97} | f^{98} | f^{99} | f^{100}, f^{101} | |
| | f^{32} Volume (lower body) | f^{101} | f^{102} | f^{103} | f^{104}, f^{105} | |
| | SPACE | f^{33} Volume (right side) | f^{105} | f^{106} | f^{107} | f^{108}, f^{109} |
| f^{34} Volume (left side) | | f^{109} | f^{110} | f^{111} | f^{112}, f^{113} | |
| f^{35} Total distance | | | | | f^{92}, f^{24} | |
| f^{36} Area per second | f^{93} | f^{94} | f^{95} | f^{96}, f^{25} | | |
| f^{37} Total volume | | | | f^{121} | | |



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

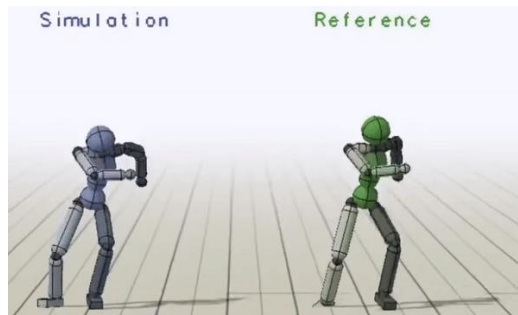
Problems:

- 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

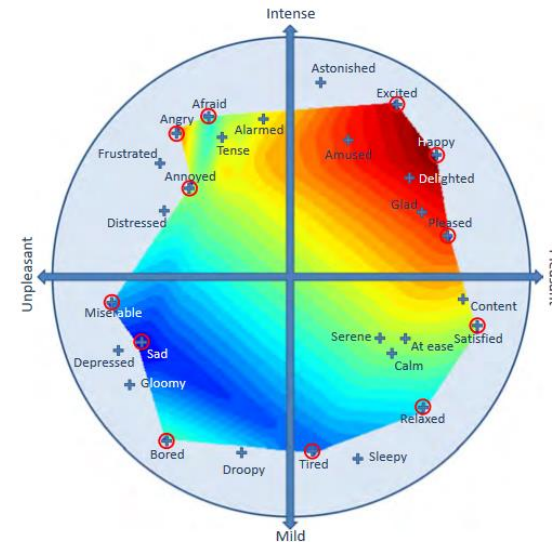


[DeepMimic, Li-Ke Ma et al., 2021]



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

RCM Emotional Model

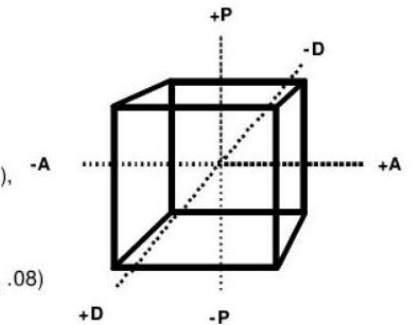


[Emotion Control of Unstructured Dance Movements, Andreas Aristidou et al., 2017]

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).



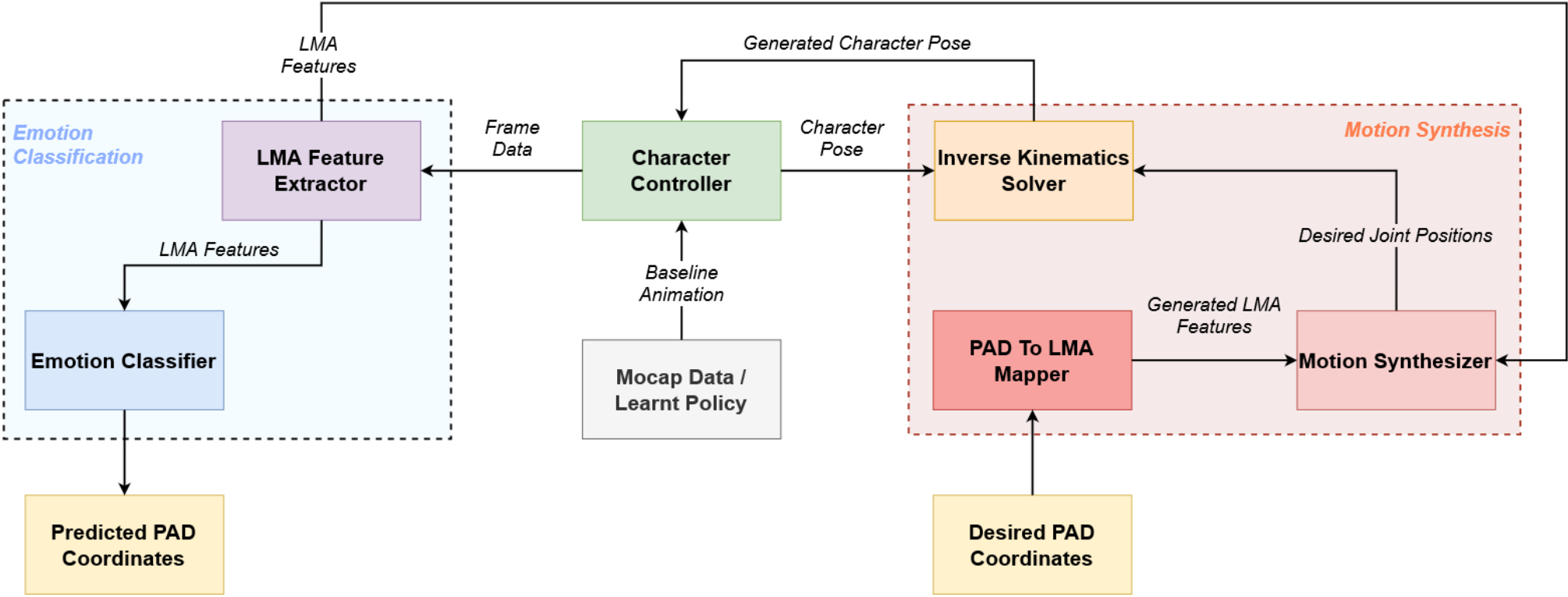
The emotional state "angry" is a highly unpleasant, highly aroused, and moderately dominant emotional state. The "bored" state implies a highly unpleasant, highly unaroused, and moderately submissive state.

[Joost Broekens et al., 2004]

Problems:

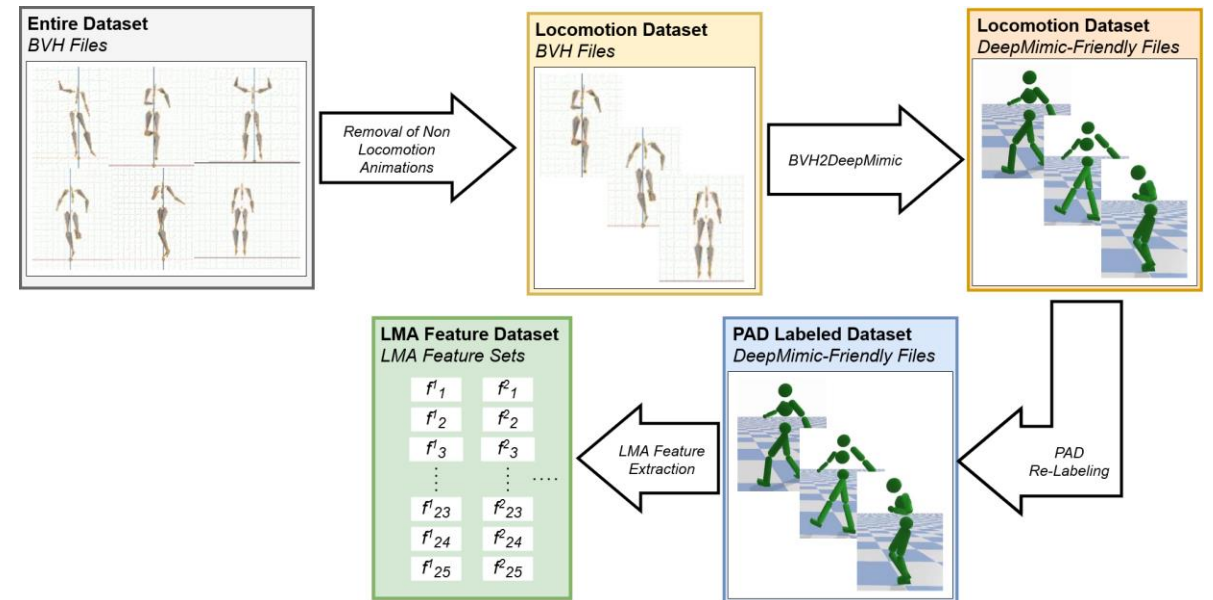
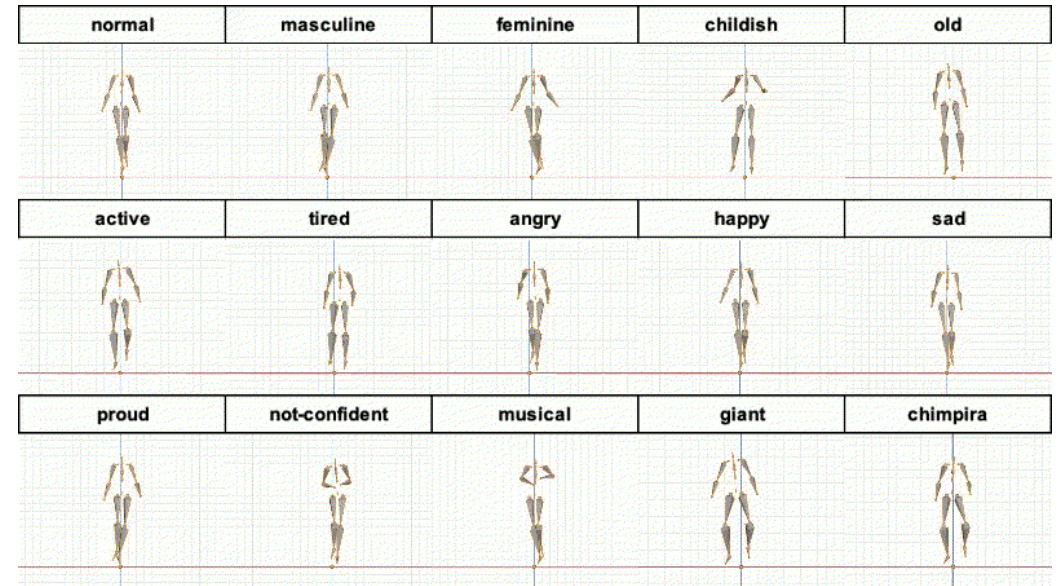
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EMOTIONALLY EXPRESSIVE MOTION CONTROLLER

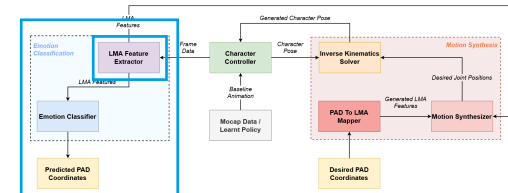


DATASET

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



LMA FEATURE EXTRACTOR



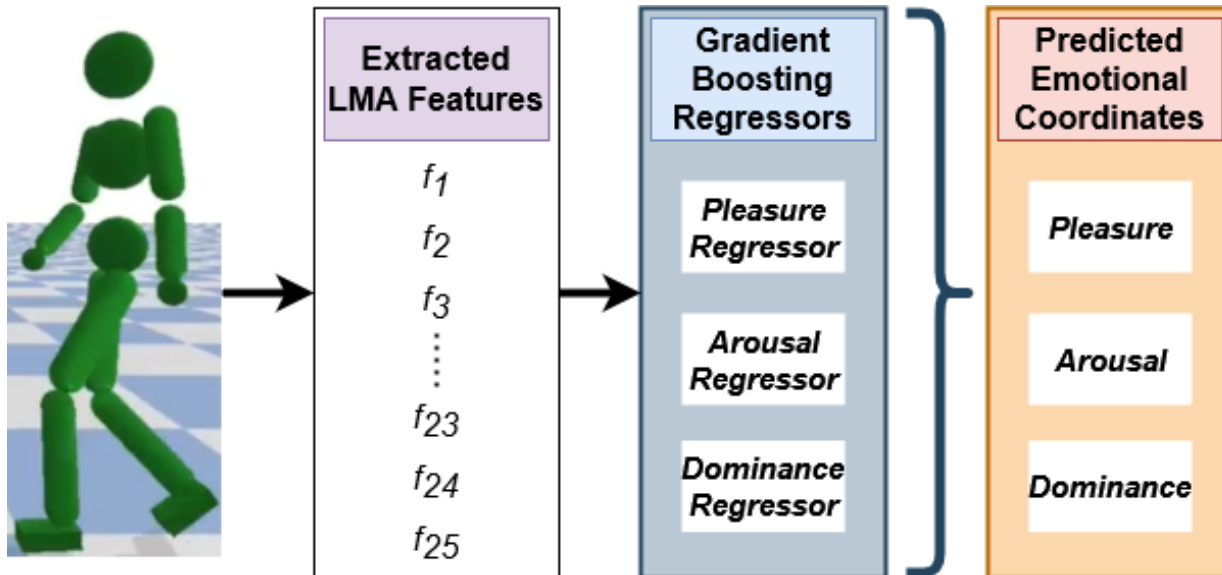
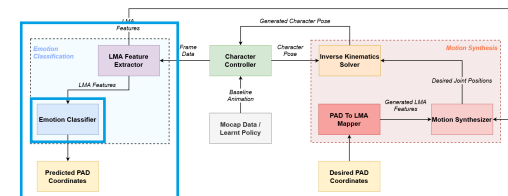
| LMA Feature | f | LMA Category |
|-----------------------------------|----------|--------------|
| Max Hand Distance | f_1 | Body |
| Avg. Left Hand - Hip Distance | f_2 | Body |
| Avg. Right Hand - Hip Distance | f_3 | Body |
| Max Stride Length | f_4 | Body |
| Avg. Left Hand - Chest Distance | f_5 | 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 |

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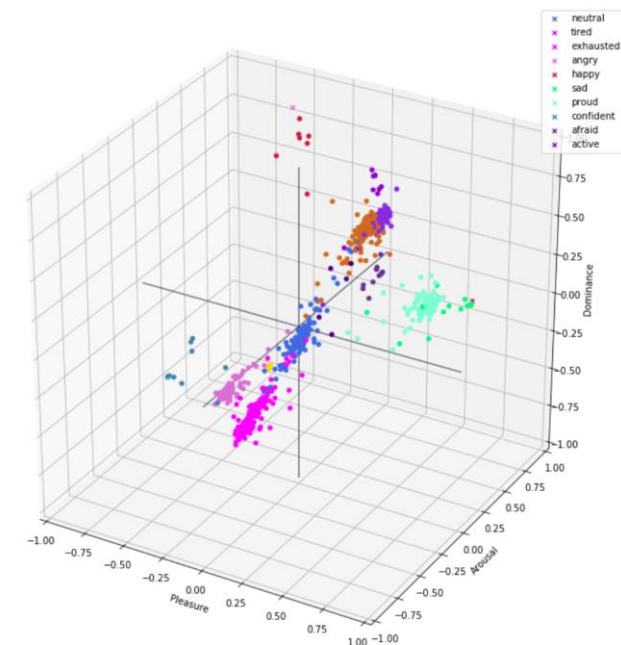
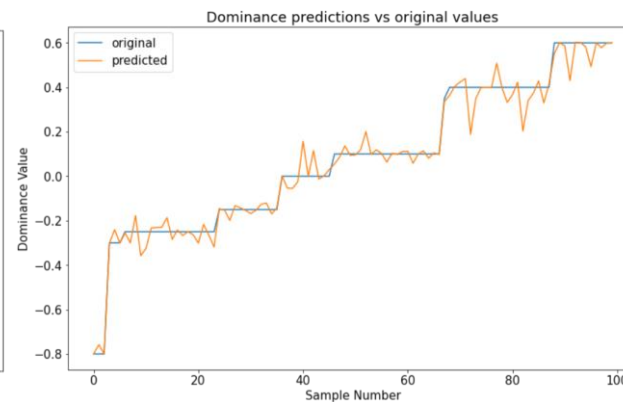
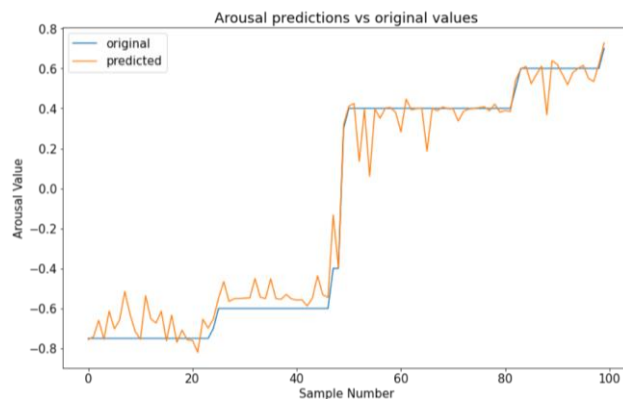
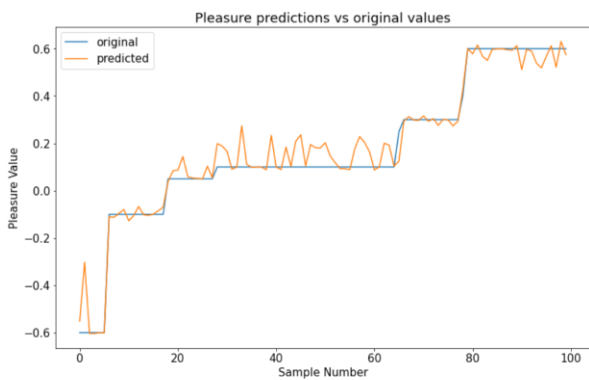
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3   "label": PAD Emotional Coordinates (3D),
4   "lma_features": [
5     max hand_distance (1D),
6     average l_hand_hip_distance (1D),
7     average r_hand_hip_distance (1D),
8     max stride length (distance between left and right foot) (1D),
9     average l_hand_chest_distance (1D),
10    average r_hand_chest_distance (1D),
11    average l_elbow_hip_distance (1D),
12    average r_elbow_hip_distance (1D),
13    average chest_pelvis_distance (1D),
14    average neck_chest_distance (1D),
15    average total_body_volume (1D),
16    average lower_body_volume (1D),
17    average upper_body_volume (1D),
18    triangle area between hands and neck (1D),
19    triangle area between feet and root (1D),
20    l_hand speed (1D),
21    r_hand speed (1D),
22    l_foot_speed (1D),
23    r_foot_speed (1D),
24    neck speed (1D),
25    l_hand acceleration magnitude (1D),
26    r_hand acceleration magnitude (1D),
27    l_foot acceleration magnitude (1D),
28    r_foot acceleration magnitude (1D),
29    neck acceleration magnitude (1D)
30  ]
31 }
32
33

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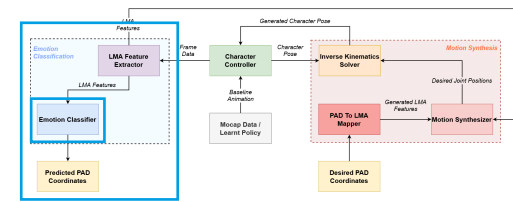
LMA TO PAD REGRESSION



| Regressor | MAE |
|-----------|------|
| Pleasure | 0.02 |
| Arousal | 0.06 |
| Dominance | 0.03 |



EMOTIONAL CLASSIFICATION



== EMOTION PREDICTION ==
 Pleasure: 0.781625485420227
 Arousal: 0.48028437197208407
 Dominance: 0.139211505651474
 Closest Emotion: Happy

== EMOTION SYNTHESIS ==
 Pleasure: 0.0
 Arousal: 0.0
 Dominance: 0.0

CONFIRM

Exhausted Confident Angry
 Afraid Happy Sad

== STATUS ==
 Animation: Running
 Emotion Prediction: In Progress
 Motion Synthesis: Not Synthesizing

== EMOTION PREDICTION ==
 Pleasure: 0.7627513885498047
 Arousal: 0.49180689454078674
 Dominance: 0.15096760541200638
 Closest Emotion: Happy

== EMOTION PREDICTION ==
 Pleasure: -0.595786064863205
 Arousal: -0.40131344497203825
 Dominance: -0.29259250611066817
 Closest Emotion: Sad

== EMOTION PREDICTION ==
 Pleasure: 0.4001648187637329
 Arousal: 0.20092930644750595
 Dominance: 0.35134114027023317
 Closest Emotion: Proud

== EMOTION PREDICTION ==
 Pleasure: 0.10020052343606949
 Arousal: -0.7010104238986969
 Dominance: -0.1994317203760147
 Closest Emotion: Tired

== EMOTION PREDICTION ==
 Pleasure: -0.595786064863205
 Arousal: -0.40131344497203825
 Dominance: -0.29259250611066817
 Closest Emotion: Sad

== EMOTION SYNTHESIS ==
 Pleasure: 0.0
 Arousal: 0.0
 Dominance: 0.0

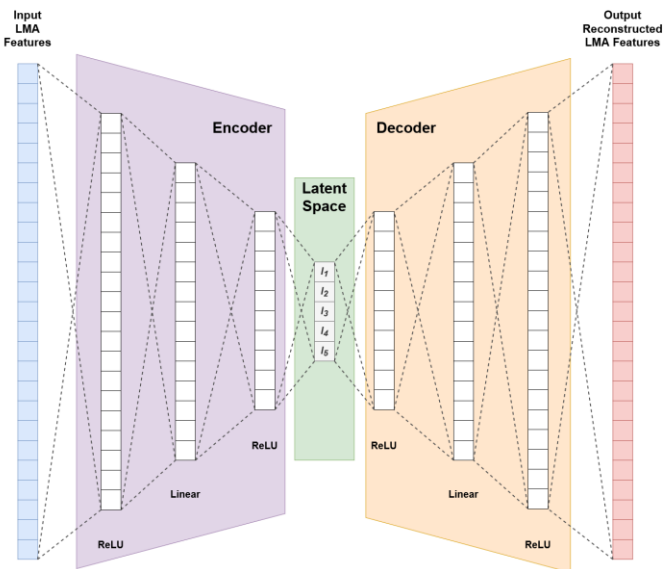
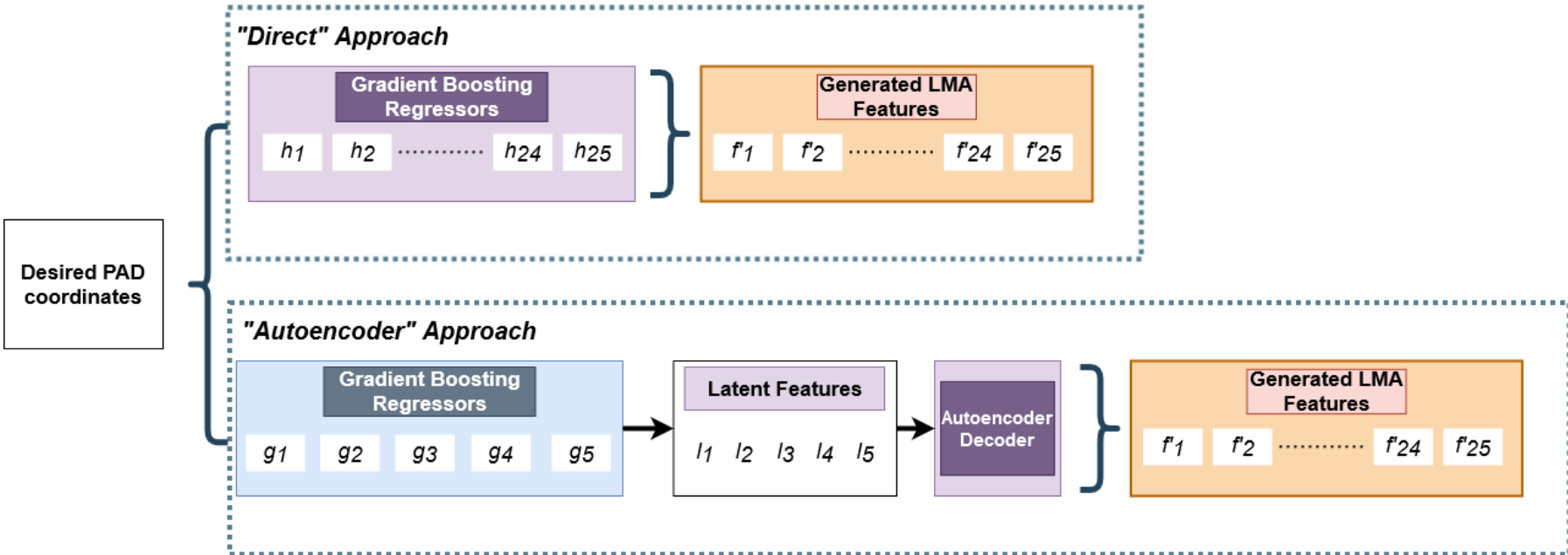
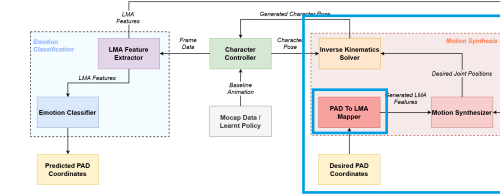
CONFIRM

Exhausted Confident Angry
 Afraid Happy Sad

== STATUS ==
 Animation: Running
 Emotion Prediction: In Progress
 Motion Synthesis: Not Synthesizing

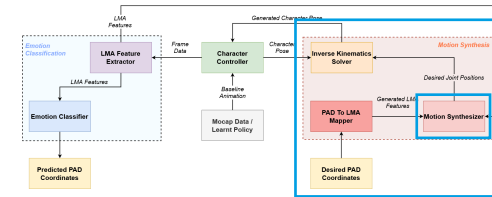
== EMOTION PREDICTION ==
 Pleasure: -0.5995109677314758
 Arousal: 0.6963342785835266
 Dominance: -0.7974678933620453
 Closest Emotion: Afraid

PAD TO LMA REGRESSION



| MAE | Direct | AutoEncoder |
|-----------|--------|-------------|
| Pleasure | 0.20 | 0.19 |
| Arousal | 0.30 | 0.24 |
| Dominance | 0.18 | 0.14 |

MOTION SYNTHESIS

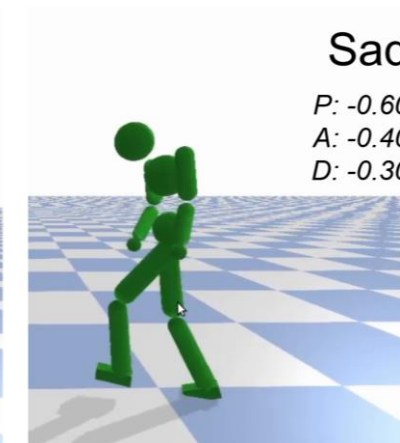
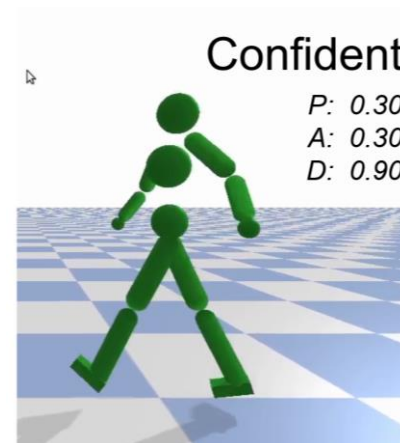
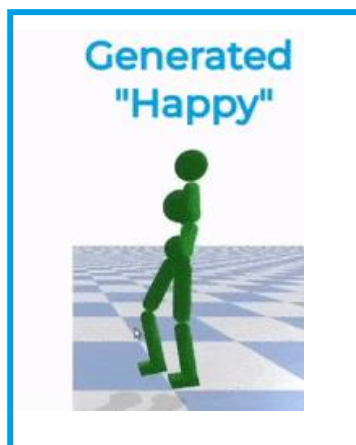
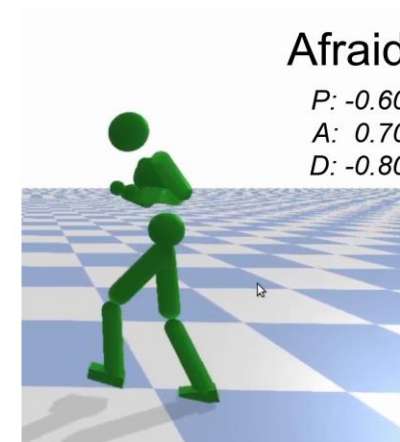
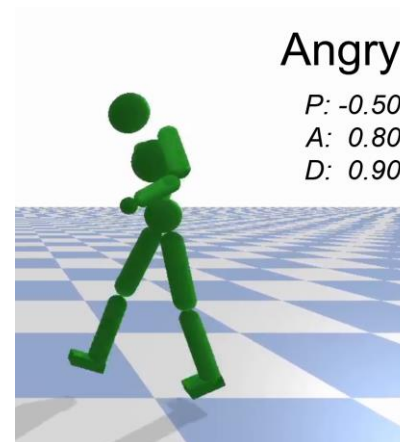
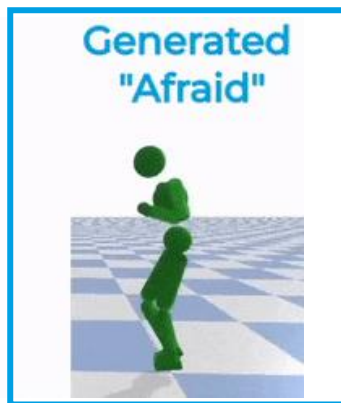
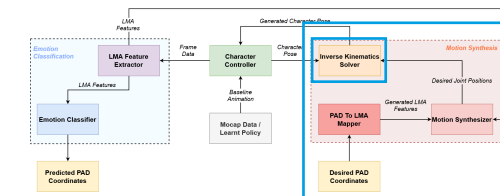


- Compute new desired positions/rotations for core joints
- 6 Heuristic Rules
- Coefficients to represent the difference between Baseline's and Generated LMA Features

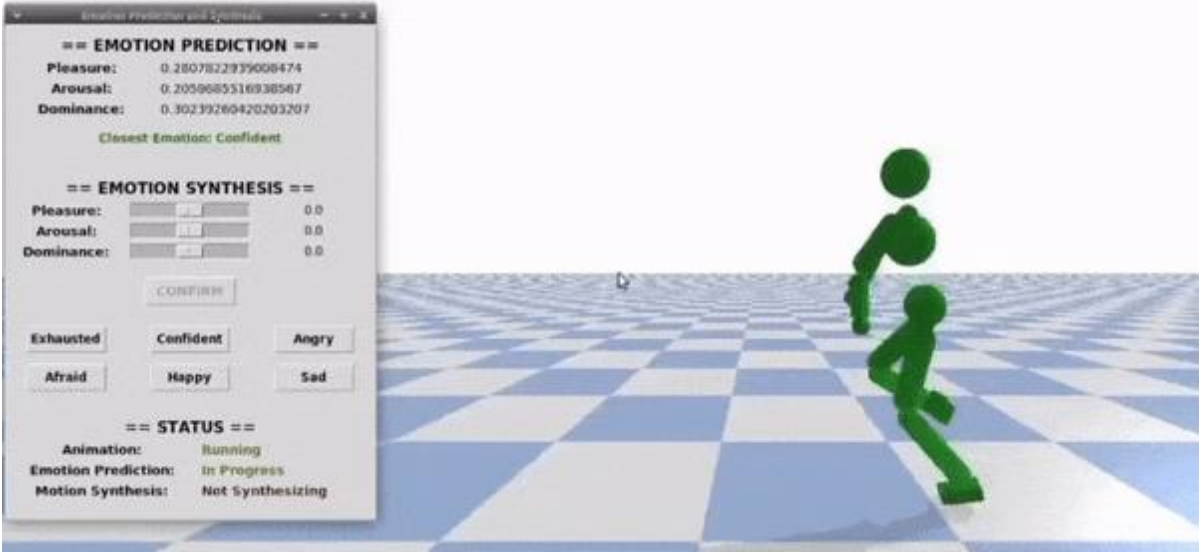
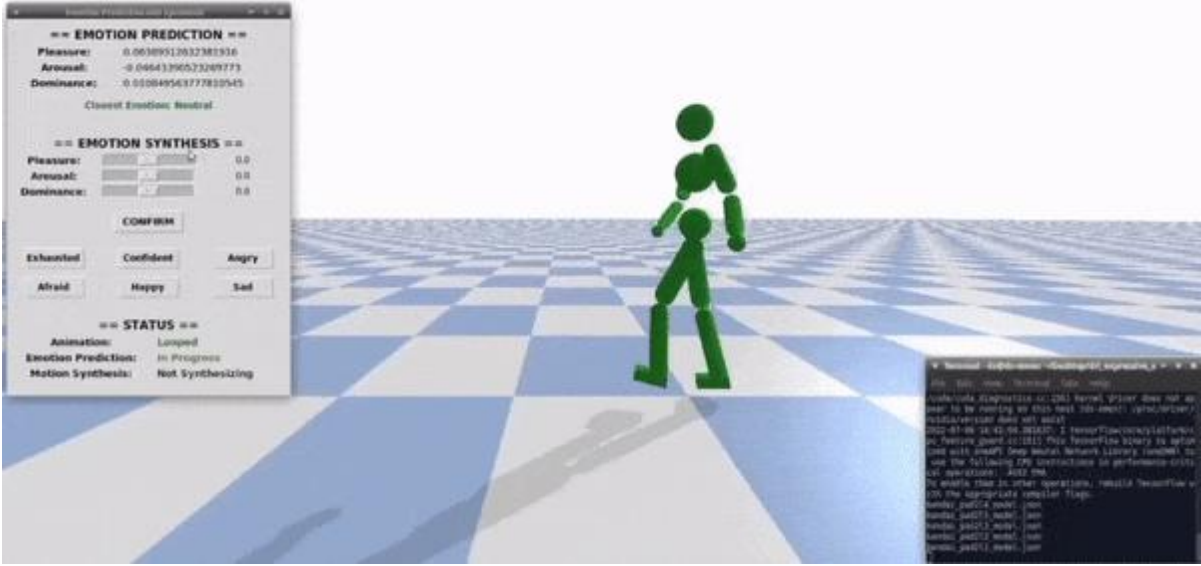
$$\sum_t \| \hat{f} - f_{tc} \|^2$$

| Rule | Associated LMA Features |
|--|---|
| g1: Modifies Hip Height <i>Raises or lowers the character's Hip, changing the body volume.</i> | 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 <i>Raises or lowers the character's Chest, making their back appear slumped over or straight.</i> | Avg. Chest-Pelvis Distance (f_8) ; Avg. Total Body Volume (f_{10}) ; Avg. Upper Body Volume (f_{12}) ; |
| g3: Modifies the Hands' Positions <i>Pulls each Hand towards or away from the character's body. Also raises or lowers each Hand towards the character's chest.</i> | 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 <i>Pulls each Elbow towards or away from the character's body, changing their upper volume.</i> | 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 <i>Increases or decreases the distance between each Foot, changing the stride length.</i> | 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 <i>Tilts the character's Neck towards or away from their chest.</i> | Avg. Neck-Chest Distance (f_9) ; Avg. Total Body Volume (f_{10}) ; Avg. Upper Body Volume (f_{12}) ; |

INVERSE KINEMATICS

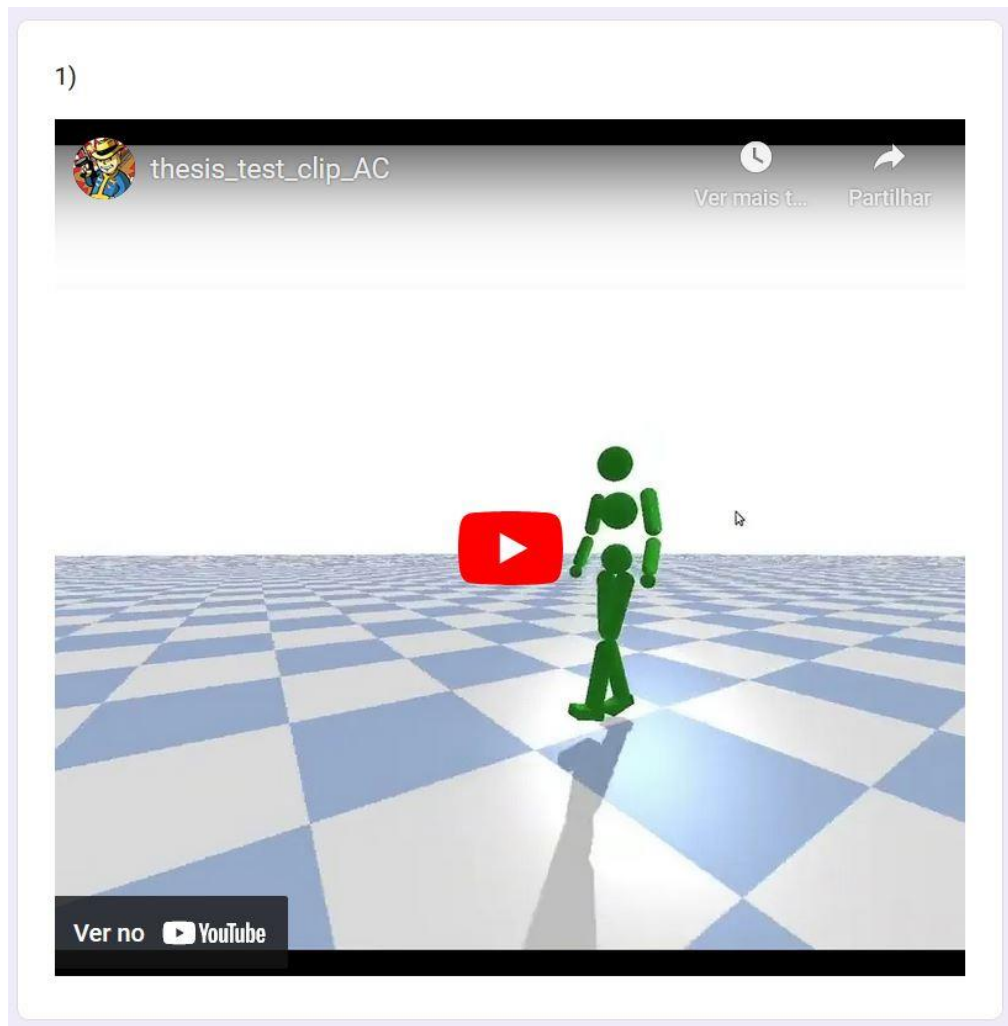


EMOTIONALLY EXPRESSIVE MOTION CONTROLLER



USER TESTS

Emotional Identification Task



1) What do you think the Emotional State of the character is? *

- Neutral
- Happy
- Sad
- Tired
- Angry
- Afraid
- Confident
- Proud

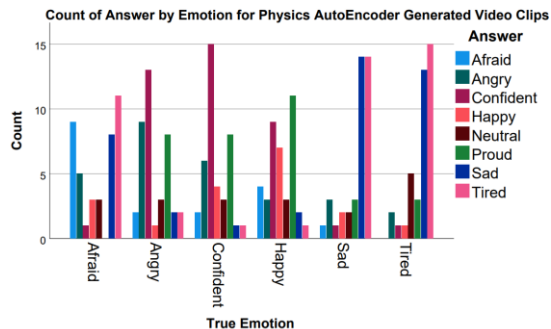
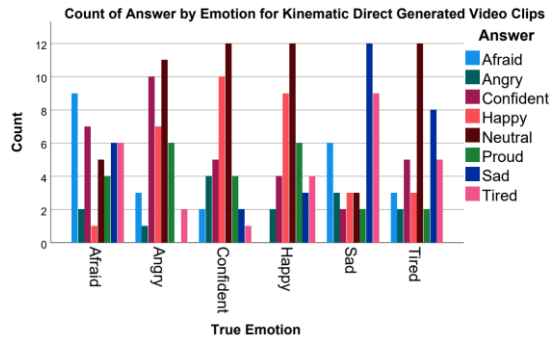
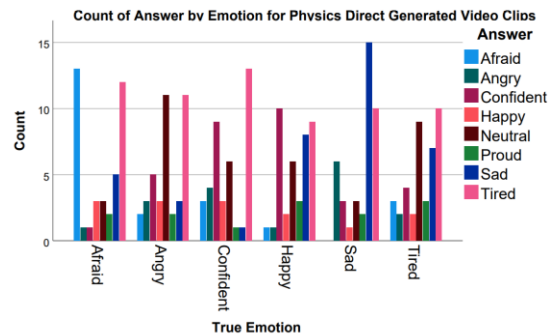
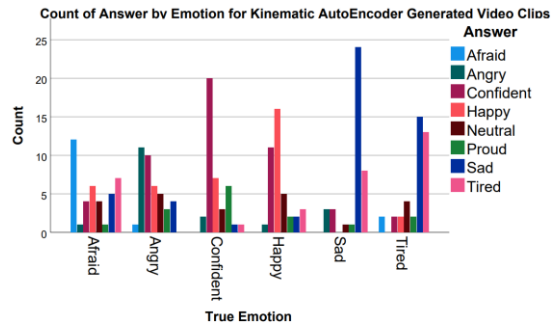
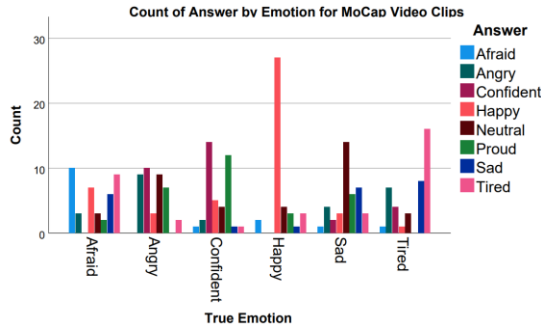
1) The character is feeling "Sad" *

- 1 2 3 4 5
- Completely Disagree Completely Agree

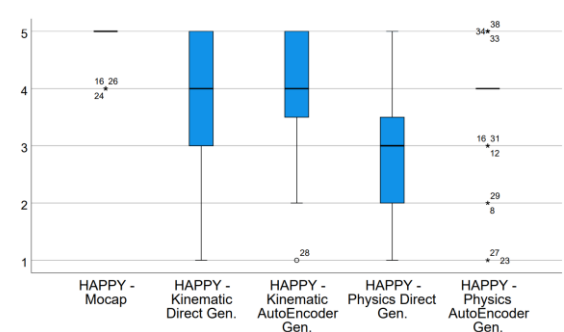
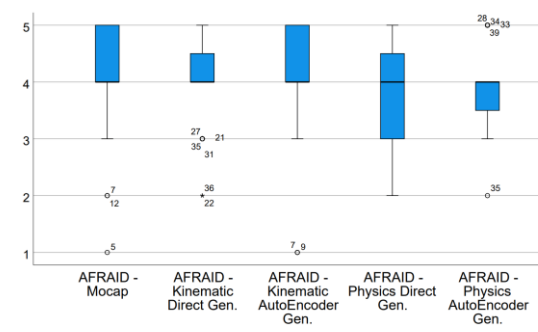
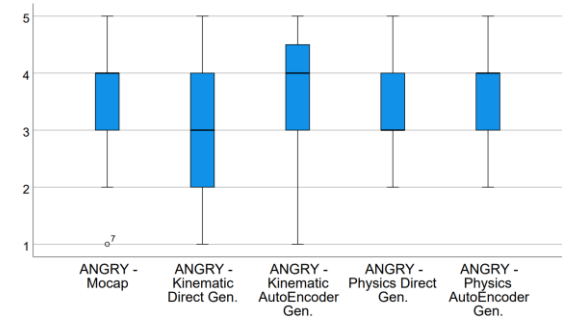
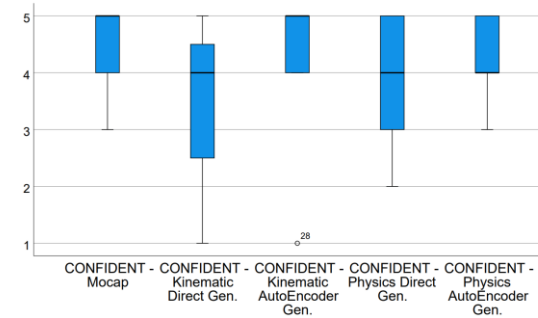
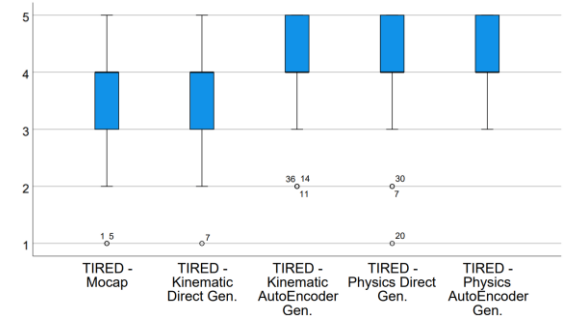
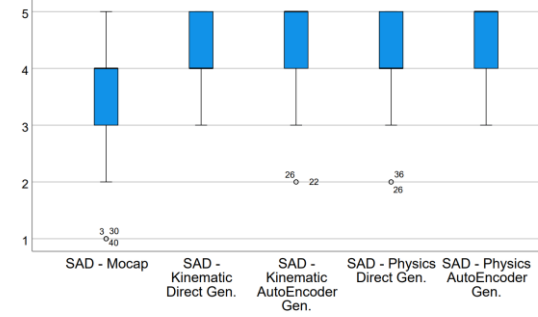
Primed Emotional Agreement Task

USER TESTS

Emotional Identification Task

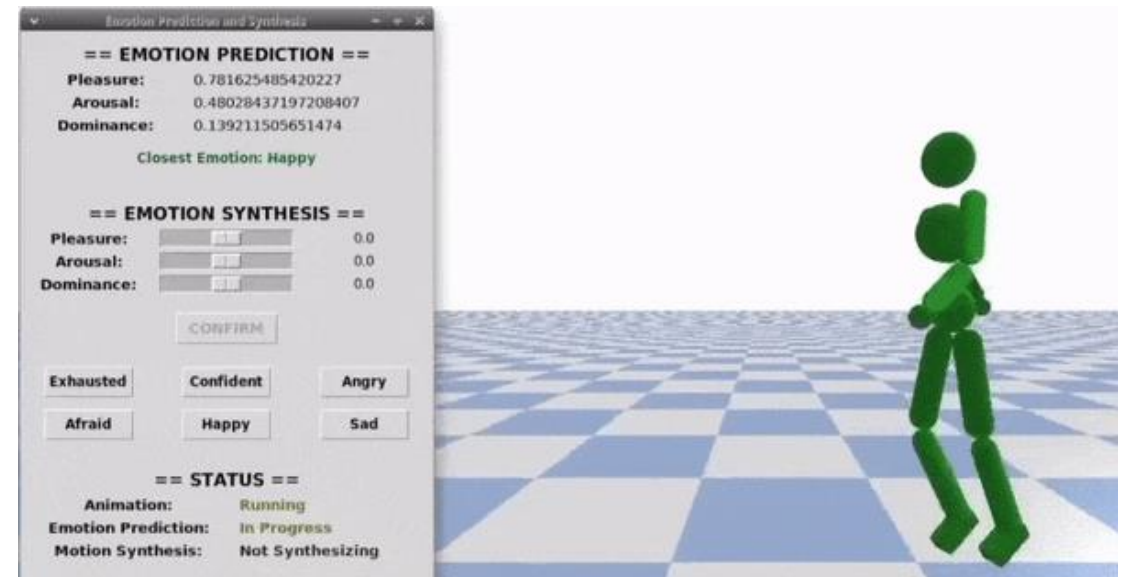
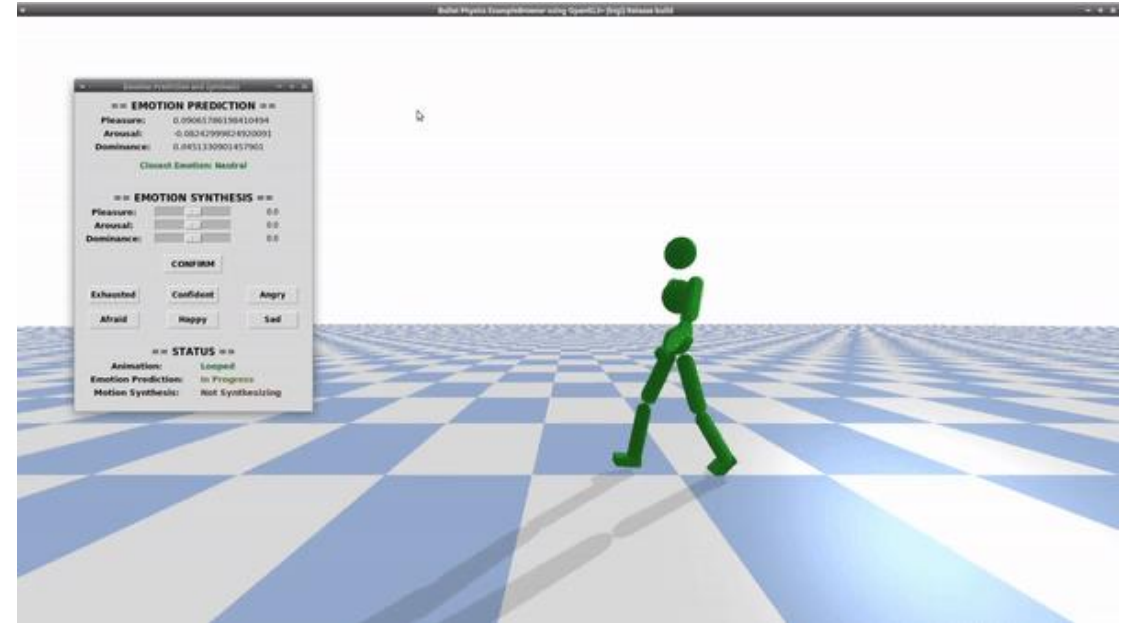


Primed Emotional Agreement Task



CONCLUSION

- Automatic System for Emotionally Expressive Motion Synthesis of Locomotion Animations
- No need for extra data or training
- 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
- Quality of synthesized motions validated through User Tests
- Work accepted for publishing in IEEE ISM 2022





Thank you for listening!

More Info at: https://heroufenix.github.io/expressive_animations_web/



INDEX

- Motivation
- Related Work
- Emotionally Expressive Motion Controller
- User Testing
- Conclusion

BACKGROUND – Computer Animation

Kinematic Controllers



[Bandai-Namco Research Inc., 2022]



[Blender, 2022]



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

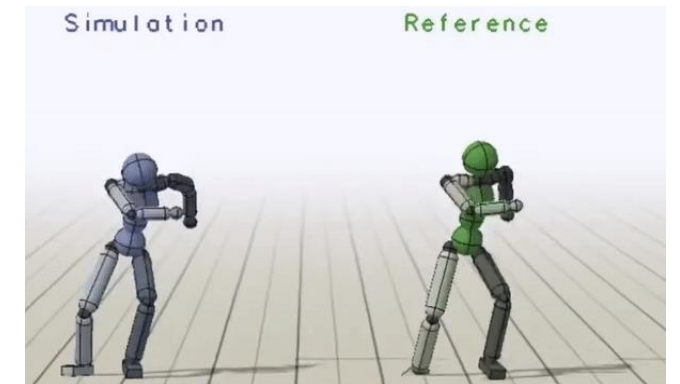


[https://youtu.be/z93e5_7P54g, 2020]



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

Physics Controllers



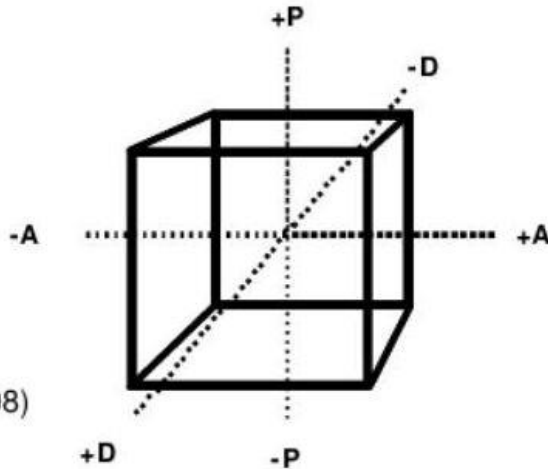
[Spacetime Bounds, Xue Bin Peng et al., 2018]

BACKGROUND – Emotional Models & Laban Movement Analysis

PAD Emotional Model

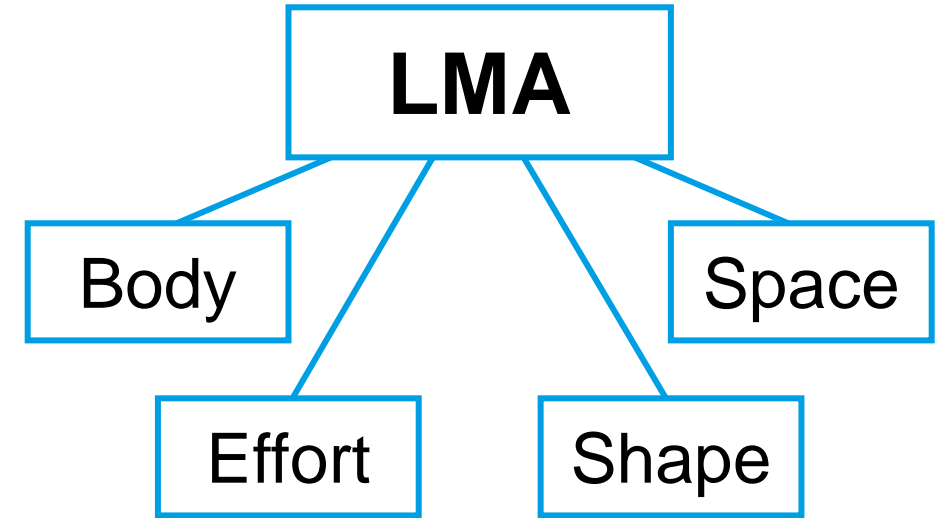
The following sample ratings illustrate definitions of various emotion terms when scores on each PAD scale range from -1 to +1:

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 |