Expressive Motion Synthesis for Humanoid Robot

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Agenda

- Motivation and Problem Statement
- Introduction
- Related Works on Expressive Humanoid Robots
- Proposed Motion Synthesis Method
- Experiments and Results
- Conclusion
- Future Work

”Imagine the automatic movements of a machine; the impulse of force is purely physical. Without the mental component it is devoid of any human, expressive quality.” - L. Bishko

Motivation and Problem Statement

- Motivation:
  - The most human-like android/humanoid robots still awkward to most people.
    - Looks and behaviors do not match expectations.
  - Emotions can be effectively expressed through motions and gestures.
  - Many research in computer animation on emotional expressions through motion, but few applied in robotics.
  - I love animations.

Motivation and Problem Statement

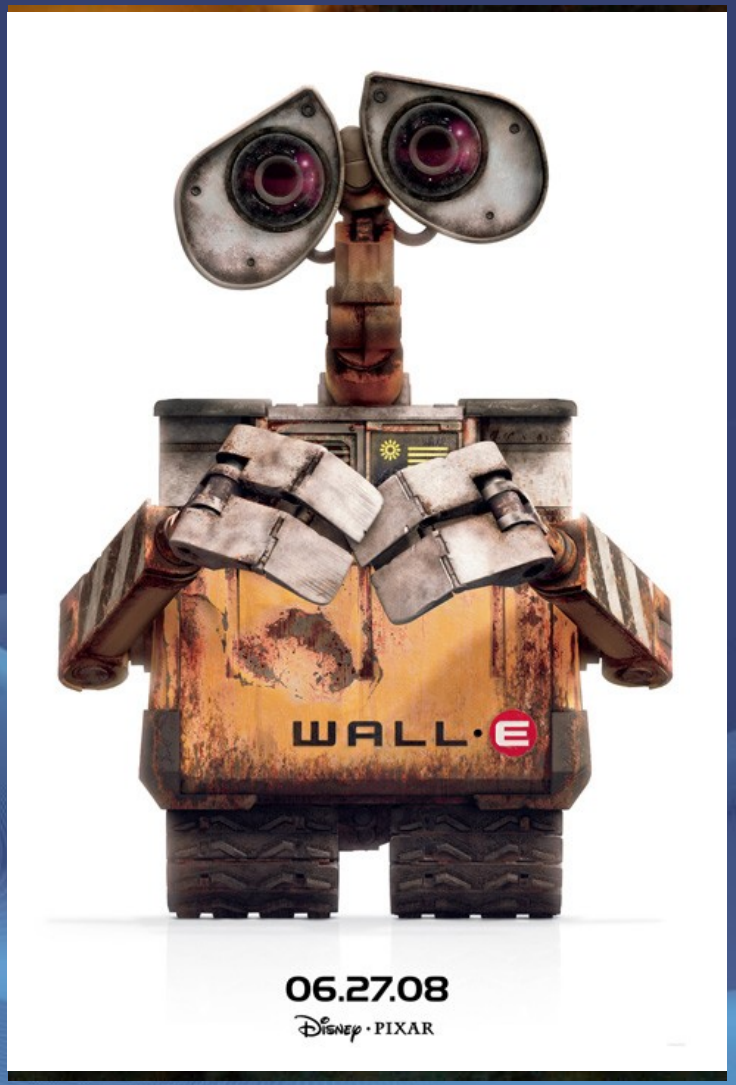
- Problem Statement:
  - How to effectively enable a (humanoid) robot to autonomously show emotional expressions through its motions, in such a way that the expressions enhance the intuitiveness of the human-robot interaction.

Thesis

We can create and modify the emotional or physical expressions of a motion of a humanoid robot using a set of signal processing methods.

Introduction

- Fictional humanoid robots:
  - Terminator
  - C3PO & R2D2
  - Wall-E
  - Etc.
- Gestures, voice, movement very human-like
- Audience easily empathize with the robots



Introduction (cont'd)

- Real humanoid robots:
  - Asimo
  - Hubo
  - HRP-4C
  - WE-4R II
  - Ishiguro's androids
  - Kismet
- Human-like looks
- Audience often feels the robot eerie, creepy
- Uncanny Valley problem

Introduction (cont'd)

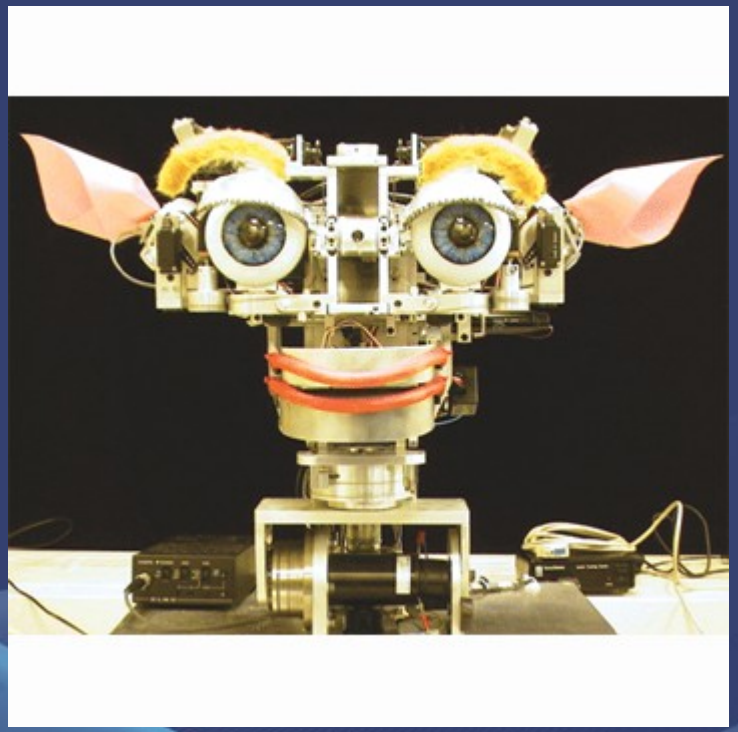
- Jim Henson's Muppets and Sesame Street puppets
  - Yes, human-controlled
  - Audience easily empathize with the *characters*
  - How do the puppets able to show emotions without changing facial expressions?

Introduction (cont'd)

- Human-robot Interaction:
  - Classical:
    - Control peripherals (e.g. joystick, consoles)
    - Programming language/syntaxes/codes
  - Modern:
    - Vision
    - Speech/sound
    - Gestures
    - Touch

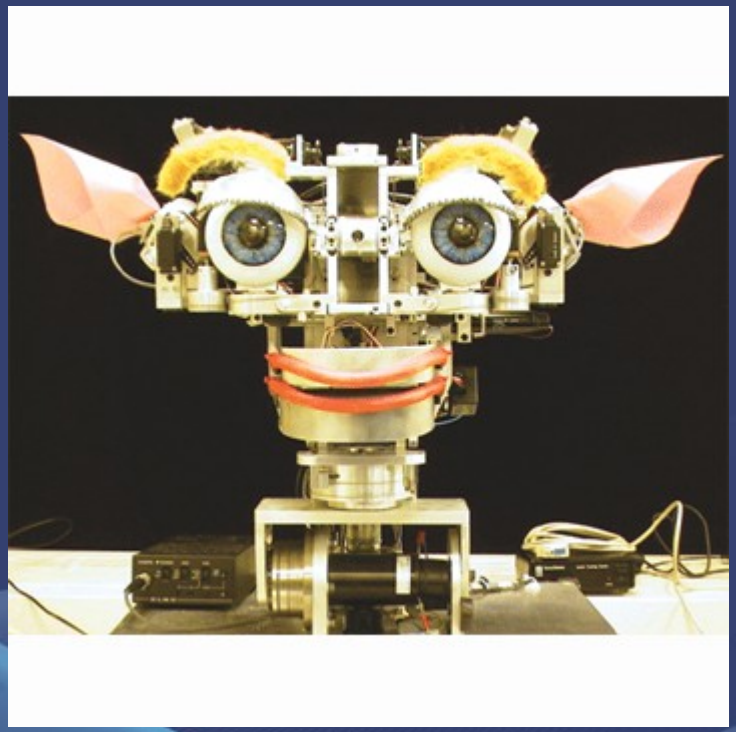
Related Works on Expressive Humanoid Robots

- Kismet (Breazeal, MIT):
  - Social interaction norms
  - Child-like mental model
  - 14 Degree of Freedom (DOF)
  - Sensing:
    - Face/presence of person
    - Voice (w/ triangulation)
    - Object tracking
    - Touch
  - Response:
    - Voice (prosody)
    - Facial expressions



Related Works on Expressive Humanoid Robots

- Kismet (Breazeal, MIT):
  - Motion:
    - Pre-programmed facial expressions
    - Eyes and neck move to track face and objects



Related Works on Expressive Humanoid Robots

- WE-4R II (Waseda Univ.):
  - Complex emotional model
  - Artificial 'lungs'
  - 59 DOFs
  - Sensing:
    - Vision
    - Voice (w/ triangulation)
    - Object tracking
    - Touch
  - Response:
    - Voice
    - Facial expressions
    - Body gestures

Related Works on Expressive Humanoid Robots

- WE-4R II (Waseda Univ.):
  - Motion:
    - Pre-programmed emotional expressions (facial and body)
    - Body and head moves for object tracking
    - Reaching for objects
    - Moves according to direction of stimuli (voice & touch)

Related Works on Expressive Humanoid Robots

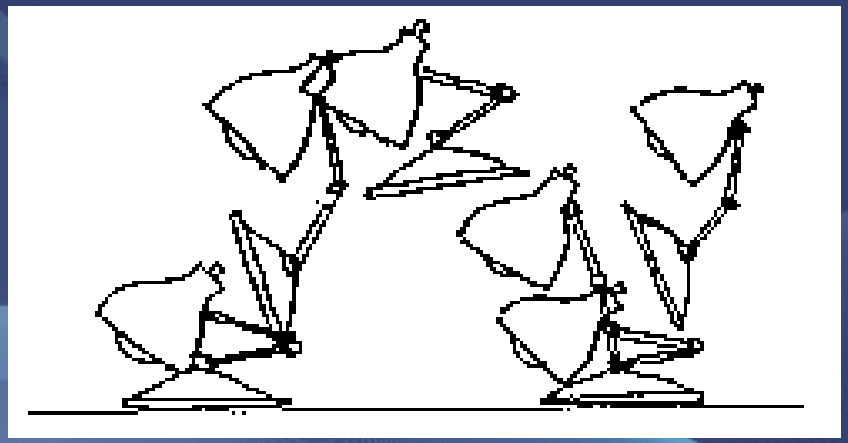
- Summary:
  - Classic video game problem: repetitive/limited responses.
  - Expressions of robot are limited by the number of programmed expressions.
  - Quality of (programmed) animation/movement/ expression depends on animator's skill.

What's Missing?

- Anatomy... check
- Looks... check
- Interaction... check
- Appeal... check (with exceptions)
- Autonomy... check (with limitations)
- Personality/character... a little
- Empathy... no

Animation

- Lasseter:
  - Applying principles of traditional 2D animation on 3D models (rigid bodies)



Laban Movement Analysis

- Badler, et. al:
  - Using LMA parameters as motion control parameters on computer animation (EMOTE)
- Zhao:
  - Extraction of LMA parameter values from motion capture data
- Bishko:
  - Applying LMA knowledge to create 3D computer animation

Motion Signal Processing

- Bruderlin, Williams:
  - Introduced the concept of treating motions as a set of signals.
  - Thus, motions can be processed using common signal processing techniques to achieve different animation expressions.
- Unuma:
  - Using Fourier analysis to extract 'emotion characteristics' (as Fourier coefficients) in motion.
  - The extracted 'emotion characteristics' can be applied to different motions and still exhibit similar characteristics.
- Huang, Boulic, and Thalmann:
  - Blending motions using multiresolution filtering.

Proposed Motion Synthesis Method

- Follows guidelines from Disney Animation Principles (DAP) and Laban Movement Analysis (LMA)
  - What kind of motion produces what kind of expressions?
- Motion Signal Processing (Bruderlin, Williams) approach
  - Use a set of signal processing methods: interpolation, resampling, multiresolution filtering

Proposed Motion Synthesis Method

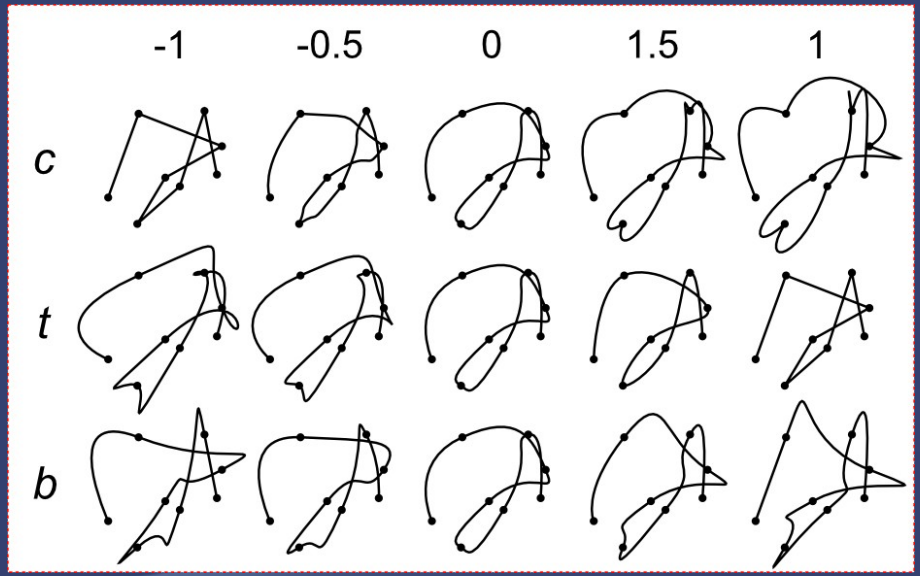
- DAP
  - Anticipation
  - Stretch & Squash
  - Follow-through & Overlapping
  - Slow-in/Slow-out
  - Exaggeration
  - Timing
- LMA
  - Effort:
    - Weight (sensing physical force/gravity)
    - Space (direction)
    - Time (urgency)
    - Flow (continuity)
  - Relationship between Effort values and intention/ psychological state of the actor

Proposed Motion Synthesis Method

- Need to control four motion parameters:
  - Speed
  - Acceleration/deceleration
  - Range of motion
  - (Direction)

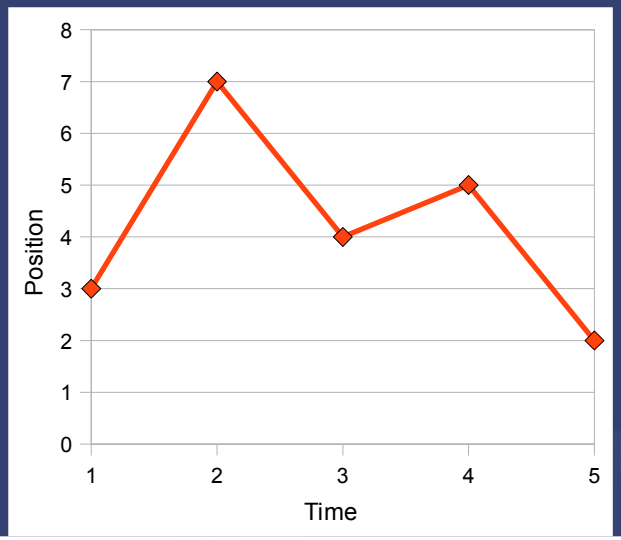
Proposed Motion Synthesis Method

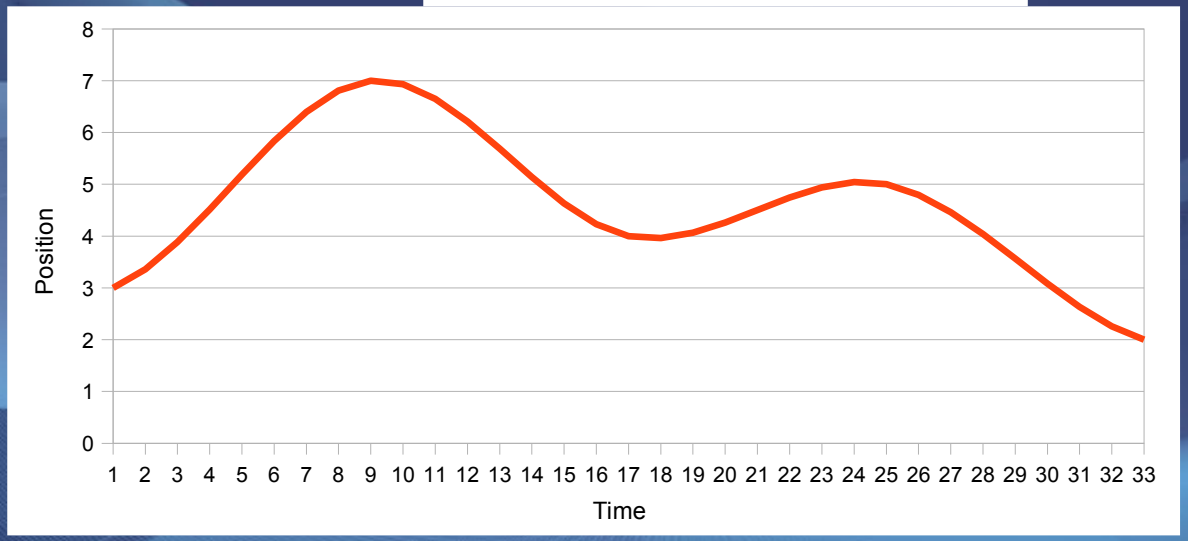
- Interpolation:
  - Kochanek-Bartels Spline Interpolation (Hermite)
    - 3 parameters:
      - Bias
      - Tension
      - Continuity
  - Used to control:
    - Acceleration/deceleration
    - Exaggeration
    - Overshoots
    - Transitions between movements



Proposed Motion Synthesis Method

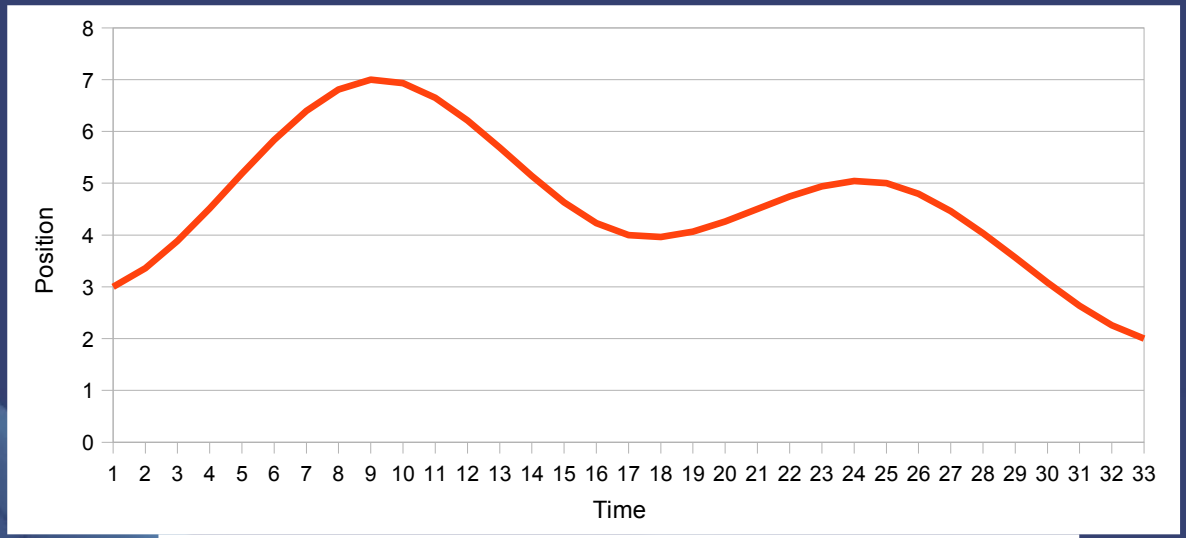
- Kochanek-Bartels interpolation
  (shown: bias=0, tension=0, continuity=0)

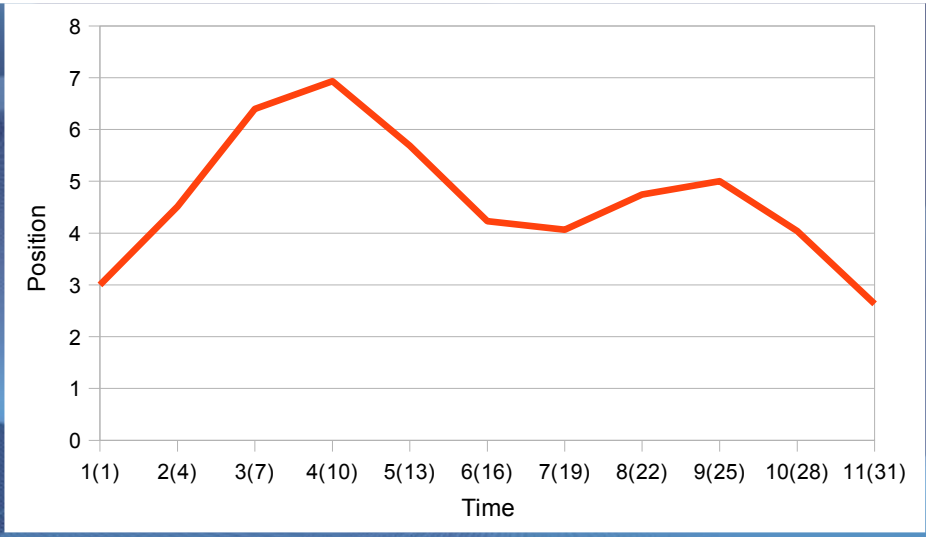




Proposed Motion Synthesis Method

- (Re)Sampling:
  - User-definable sampling rate
  - Used to control:
    - Speed
    - Duration of movement



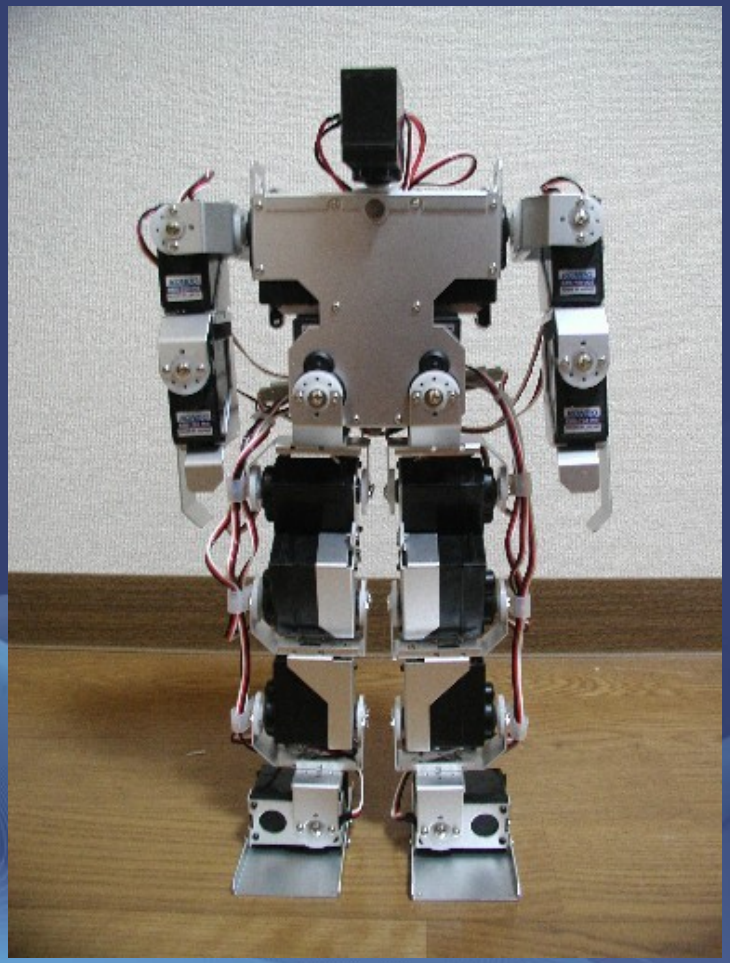


Proposed Motion Synthesis Method

- Multiresolution filtering:
  - Manipulate gains of each frequency band of the movement
  - Used to control:
    - Removing noise/smoothness of motion
    - Increase/decrease range of motion

Experiments

- KHR-1
  - 17 DOFs
  - 2 servo controller boards (RCB-1)
  - 128kbits on-board EEPROM
  - RS-232



Experiments

Proposed Motion Synthesis Method

- Why DAP and LMA?
  - Both were developed to explain the relationship between motion and physiological/psychological expressions.
  - Both have been successfully used in animation and entertainment industry to convey the actor's psychological messages to the audience.
- Not all aspects can be implemented
  - Rather, relevant aspects are used as guidelines to identify what motion qualities must be considered to create effective expressions.
  - Realization of these aspects must be automated (not relying on animator's involvement)