Modeling human behavior in virtual humans

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Background

Computational Models of Human Behavior

* Cognitive and Emotional processes
* Social Interaction & Theory of Mind
* Nonverbal behavior (Facial Expressions, gesture, posture, gaze…)

Applications

Virtual Humans, Social Simulation, Interactive Drama

Tools

PsychSim/Thespian, SmartBody, NVBG
Outline

- Emotion and it’s impact on human behavior
- Why model emotion computationally?
  - Application: Virtual Humans for Serious Games
- How we model it
  - EMA
- Validation: Can the model predict human behavior in a game?
- Example of how we use it in Virtual Humans
  - Listener feedback
Why study emotion?

“Reason is, and ought to be, only the slave of the passions”

David Hume, 1711-1776
What is emotion?

- **Functions associated with individual autonomy**
  - Rapid, continually adjusting assessment of significant events
  - Interruption of behaviors and changing of goals
  - Action preparation: energizes body, changes physical orientation

- **Functions associated with social interaction**
  - Signaling: broadcast information about mental state
  - Coordination: orient and coordinate group response

- Immersion and contagion
Why Study Emotion?

Emotion influences cognitive processes

- **Emotions change perception & decision-making**
  - Angry people blame others/outgroups (Keltner et al 93; Mackie et al 00)
  - Quicker to perceive threats (DeSteno et al 2000/2004)
  - Underestimate risk (Lerner & Keltner 2000/2001)

- **Emotions impact memory**
  - Mood Congruent Recall & Learning (Bower, 91)
Why Study Emotion?

Emotion influences human behavior

- **Emotions change behavior**
  - Anger primes aggressive responses (Keltner & Haidt 1999)
  - Characteristic displays (Spoor & Kelly 04, Parkinson 01, Darwin, Ekman)
Why Study Emotion?

Emotion influences social behavior

- **Emotions impact social interaction**
  - Distress elicits helping *(Eisenberg et al. 89)*
  - Anger elicits fear *(Dimberg & Ohman 96)*
  - Negotiators concede more to angry partner *(van Kleef et al. 2007)*
  - Emotion communicates information to other social actors *(Darwin; Parkinson 01)*
  - Emotion expression as signal

- **Emotions impact social systems**
  - Improves group utility *(Darwin; Frank, 1988)*
Why model emotion?
Claim: emotion research has important benefits:

- **Study human behavior**
  - Inform theory development (Marsella et al. 2010)

- **Inform general theories of intelligence**
  - Provide insights to expanding general theories
  - Simon, 67; Minsky, 85; Scheutz, & Sloman, 2001

- **Enhance human computer interaction**
  - Recognize and respond to human’s emotional influences
  - Modeling Player, User, Student (Lisetti & Schiano, 2000; Conati & MacLaren, 2004)
  - Emotional Virtual Humans for Education & Training
Virtual Humans

Intelligent agent that supports face-to-face social interactions with human users in virtual reality

Characters with a brain
- Reason about environment
- Understand and express emotion
- Communicate through speech & gesture
- Play the role of teachers, peers, adversaries
Social Skills Training
Health Communication and Intervention

Persuasive Interfaces

Seek Mental Health Help (Rizzo et al.)

Medical adherence / outpatient procedures (Bickmore)

Coping Skills and Empathy Training

Anti-Bullying (Aylett et al)

Deal with child's illness (Marsella et al)

Intervention and Prevention

Autism (Tartaro & Cassell)

AIDS Prevention (Miller et al.)
Entertainment

Common Theme: Central Role of Emotion
- User immersed in emotional scenario
  - Talking to a patient with a serious illness
  - Confronting a gunfighter
- Virtual human must convey emotion
  - Clinician’s compassion for patient
  - Bartender having a gun pointed at him
Research & Technology of Virtual Humans

Perception
• Morency

NLP
• DeVault, Hovy, Traum

Emotion/Cognition
• Gratch, Marsella, Pynadath

Behavior Generation
• Lee & Marsella

Animation
• Chiu, Marsella & Shapiro
EMA: Computational Model of Emotion

- How do we computationally model emotion?
  - Both the causes and cognitive/behavioral consequences of emotion?

- How do we evaluate/validate these models?
  - Can it predict human behavior?
  - And model users?

- How do we use the model in virtual humans?
Theoretical Perspective:
Appraisal Theory

(Arnold, Lazarus, Frijda, Scherer, Ortony et al.)

• Emphasizes cognitive antecedents of emotion
  – Emotion arises from an evolving subjective interpretation of person’s relation to their environment
  – Well-suited to computational realization
    • Emotion arises from inference over representations
Theoretical Framework: Appraisal Theory
(Arnold, Lazarus, Frijda, Scherer, Ortony et al.)

- Environment
- Appraisal
  - Emotion
    - Action Tendencies
      - Problem-Focused
        (act on world)
  - “Affect”
  - Physiological Response
    - Emotion-Focused
      (act on self)
- Goals/Beliefs/Intentions

Coping Strategy
Theoretical Framework: Appraisal Theory

(Arnold, Lazarus, Frijda, Scherer, Ortony et al.)

Environment → Desirability → Goals/Beliefs/Intentions

Environment → Expectedness → Goals/Beliefs/Intentions

Environment → Controllability → Goals/Beliefs/Intentions

Environment → Causal Attribution → Goals/Beliefs/Intentions

Environment → Emotion

Emotion: Action Tendencies, "Affect", Physiological Response

Emotion: Take action, Seek support

Emotion: Coping Strategy

Coping Strategy: Resignation, Distancing, Wishful Thinking
Appraisal Theory as Architectural Specification

To derive a computational model need to model:

• Representation of Person-Environment relation

• Derivation of appraisal values.

• Map from appraisals to emotions.

• Behavioral, cognitive consequents of emotion
  – Coping

• **EMA: EMotion & Adaptation**
  – (Gratch & Marsella 2005; Marsella & Gratch 2009)
Causal Interpretation
Working memory of plans, beliefs, desires, intentions

Past Events
Past Act
Cause: Other
Intend: yes
Prob: 100%

Goal
Utility: 50
Probability: 100%
Belief: False

Present
Inhibits

Future Plans
Future Act
Cause: self
Intend: yes
Probability: 50%

Facilitates
Goal
Utility: 50
Probability: 50%
Intend-that: True

Planning
Perception
Dialogue
Action

Cognitive Operations (inference)
EMA: Appraisal Derivation Model

- **Appraisal as evaluation of the causal interpretation**
  - Define appraisal variables in terms of features
  - Fast, parallel pattern matching

- **Appraisal Variables**
  - *Desirability*: Does proposition facilitate/inhibit agent’s utility
  - *Expectedness*: Could truth value of a state be predicted.
  - *Controllability*: Can the outcome be altered by agent
  - *Changeability*: Can outcome be altered by other causal agent
  - *Causal Attribution*: what agent is blameworthy/praiseworthy

- **Scope**
  - Blueprint for a social agent
EMA: Coping Model

- Sequential, deliberate, mediated by focus of attention
- Problem-focused → Take Action, Make Plans
- Emotion-focused → Alters Attention, Beliefs & Desires:
  - Attention
    - Avoidance → Take action that alters attention
  - Beliefs
    - Wishful Thinking → Change belief / likelihood
    - Shift blame → Change causal attribution
  - Desires
    - Distancing → Lower utility of desired, threatened state
    - Find silver lining → Change utilities
  - Intentions
    - Resignation → Drop intention to achieve a desired state
- Key: Finding ecological niche
  - Concretize Coping Theory: Framework for modeling emotion’s impact
Future Act
Cause: self
Intend: yes
Probability: 50%

Goal
Utility: 50
Probability: 50%
Intend-that: True

Past
Past Act
Cause: Other
Intend: yes
Prob: 100%

Inhibits

Present
Goal
Utility: 50
Probability: 100%
Belief: False

Future
Future Act
Cause: self
Intend: yes
Probability: 50%

Threat
Desirability: -50
Likelihood: 100%
Causal Attribution: Other
Control: moderate
Emotion: Anger(50)

Challenge
Desirability: 50
Likelihood: 50%
Causal Attribution: self
Control: Moderate
Emotion: Hope(25)

Facilitates
Past Act

Cause: Other
Intend: yes
Prob: 100%

Goal
Utility: 50
Probability: 100%
Belief: False

Inhibits

Future Act

Cause: self
Intend: yes
Probability: 50%

Challenge
Desirability: 50
Likelihood: 50%
Causal Attribution: self
Control: Moderate
Emotion: Hope(25)

Threat
Desirability: -50
Likelihood: 100%
Causal Attribution: Other
Control: moderate
Emotion: Anger(50)

Resignation
(abandon goal)

Coping
Validity & Application

• Does the model predict human emotional reactions?

• How can such models drive Virtual Human behavior and influence HCI?
Validation: Coping

- **Human tendency to alter mental beliefs and commitments in response to emotion**
  - Often characterized as irrational

- **But argued to serve important adaptive functions**


- **Questions:**
  - Can EMA predict such “distortions”
  - How do they differ from “rational” models
- **Rational models decouple preferences and beliefs**
  - Desires shouldn’t change beliefs (and vice versa)
    - e.g., Just wanting something shouldn’t make it true
  - Preferences *fixed* over time

![Diagram](attachment:image.png)
• Coping serves to “confound” beliefs and desires
  • Emotion-biases on decision making (Loewenstein & Lerner, 2003)
  • Cognitive dissonance (Festinger57)
  • Motivated inference (Kunda87)
    – Few attempts to model computationally (Marsella&Gratch; Dias)
Coping Study (Marsella, Gratch et al., ACII09)

Can EMA predict human behavior in experimental games

Does success/failure during game alter
Desire to win?
Intention to play?
Perceived likelihood of winning?

Model Driven Experimentation Paradigm
- Use EMA to generate task specific predictions
- Evaluate predictions through human subject experiments
Build Model

Simulate some games
- “Winning” vs. “Losing”
- Developed and validated in 2 pilot studies

Note EMA predictions
- Automatically derives emotion and coping tendencies
- Appraisals and coping tendencies constitute a set of predictions that can be tested against data
EMA’s Coping Predictions (subset)

Emotion will “irrationally” change

- **Desires** (distancing)
  - H1: Subjective utility of winning will drop as player loses
    - H1a: Magnitude of subjective utility predicts intensity of effect

- **Intentions** (resignation)
  - H2: Intention to play will drop as player loses
    - H1a: Magnitude of subjective utility predicts intensity of effect

- **Beliefs** (wishful thinking)
  - H3: Losing interacts with utility to predict probability bias
    - Players that want to win will perceive higher win probability in lose condition
Human subjects study 100 participants (2 conditions)*

- Prior Expectations
  - Time 0
  - Time 1
  - Time 2

- Winning condition
  - WINNING
  - WON GAME

- Losing condition
  - LOSING
  - LOST GAME

Assess emotions and coping

Confederate

Participant

Hidden Camera
Instruments

– Measured Emotions and Appraisals
  – Self-Report: based on Ellsworth and colleagues’ appraisal questionnaire (e.g., Treynor, Ellsworth, & Gonzalez, in preparation; also see Smith & Ellsworth, 1985)

– Measured coping
  – Self-Report: Computer Coping Questionnaire (based on SCPQ; Perrez & Reicherts, 1992)
  – Behaviorally: Response time
Subjects find experience to be emotional

- Emotions change predictably throughout game
- Appraisals of utility and probability predict emotion intensity
Coping

- Rationality assumption: desire should be independent of probability
- Emotion distorts desires and intentions
  - H1 and H2 supported: losers distance and resign (sour grapes)
  - But also “coping” with winning observed
    - EMA implementation makes no prediction
Individual differences: Impact depends on initial preferences

- H1a and H2a also supported: strength of an individual’s desire predicts strength of coping response
  - In Lose condition: Subject’s with initial high desire to win distanced and resigned more
  - In Win condition: Subject’s with initial low initial desire to win became more engaged (EMA makes no prediction)
**Discussion**

- **Overall, results suggest that coping moves subjects toward more positive emotional states**
  - Distancing and resignation of losing, high motivated subjects reduces negative emotionality of threat to high utility goal
  - Increased engagement of winning, low motivated subjects enhances positive emotions from previously unattainable goal

- **HCI: Suggests appraisal theory as a tool for understanding and influencing user’s desires and intentions**

- **Directions:**
  - Different Win-Loss Trajectories
  - Hard fought close battle; Come from behind; Total rout
The Expression of Affective Information
Functions of Nonverbal Behavior

AFFECTIVE/COGNITIVE
- Express Emotion, Attitude
- Reveal Traits, Culture
- Engender Trust, Rapport

INTERACTIONAL
- Convey Awareness/Recognition
- Initiate/Break contact
- Take/Hold/Give turns

PROPOSITIONAL
- Emphasize/Contrast
- Refer
- Depict feature
- Change topic
- Request/Give feedback

PHYSICAL
- Tired, Alive/Homeostasis, Health

- Raise eyebrows
- Gaze / Gaze Posture
- Nod
- Smile
- Shake head
- Beat
- Point/Deictics
- Gesture
- Move eyebrows
- Toss head
- Body orientation
- Pause
- Breathing
- Drop Jaw
- Walk Style
- Postural Shifts
Issues for Nonverbal Behavior Generation

• **Model when behavior occurs and its influence**
  – What is the context in which a behavior used?
  – How does the Behavior/Context impact its influence?

• **Realize the appearance & dynamics**
  – The appearance and dynamics impacts its interpretation/influence.
  – e.g., Smile dynamics influences trust, Krumhuber et al. 2007

• **Bringing virtual humans into life**
  – Encode into virtual humans
  – Evaluating its impact on human – virtual human interaction
Approaches to Modeling Nonverbal Knowledge

**Science & Arts**
- Benefits: Centuries of research to leverage
  - Excellent place to start
- Limitations: Gaps
  - Little sufficiently precise data on appearance & dynamics
  - Sparse coverage of when behavior is exhibited
  - Individual and Cultural differences

**Data-driven, machine learning**
- Benefits: Fill the Gaps
  - Can capture data on actual behavior
  - Including Individual and Cultural differences
- Limitations: Getting Data
  - Especially difficult if data needs to be annotated
Example: Responsive listening

- **Challenge of Listening Behavior**
  - Powerful impact on interaction
  - Traditionally Virtual Humans used idle, bobble-head behaviors to suggest active listening
Types of Listener Feedback

- **Generic feedback**
  - Low-level feedback tied to shallow features of speaker behavior
  - **Attendance:** gaze toward speaker, head nod
  - **Mimicry:** speaker’s head nods, gaze direction, facial expression, etc.

- **Specific feedback**
  - Related to comprehension of and reaction to the utterance
  - Through various nods, facial expressions, gaze movements
  - **Comprehension:** partial understand, confusion
  - **Valenced reactions:** Anger, surprise, like, dislike, interested, agree

- **Tied to role and goals**
  - Role: Addressee, bystander, eavesdropper
  - E.g., Bored Listener wanting to leave conversation

Beyond the Bobble-head  (Wang, Lee & Marsella  2011)

Nonverbal Behavior Generator

Listener’s
- Goals/Roles
- Unfolding understanding
- Emotional Reaction
- Perception of Speaker’s NVB & Prosodic Features

Cognition
Dialog
Emotion
Perception

Function Rules
NVB Rules
Behavior Description
NVBG’s Listening Behavior (Wang, Lee & Marsella 2011)

Generic feedback:
• Show attention
• Mimic speaker’s gaze and head nods
• Track speaker gestures

Analysis → Behavior Suggestion → Behavior Selection

Function Rules → NVB Rules → Behavior Description

Cognition
Dialog
Emotion
Perception

Nonverbal Behavior Generator Analysis Behavior Suggestion Animation System

Challenges NVBG SmartBody
NVBG’s Listening Behavior (Wang, Lee & Marsella 2011)

Nonverbal Behavior Generator

Cognition
- Dialog
- Emotion
- Perception

Analysis → Behavior Suggestion → Behavior Selection

Specific feedback:
- Comprehension feedback
  - e.g. think, gather info, confused
- Affective feedback
  - e.g. joy, anger, dislike
NVBG’s Listening Behavior (Wang, Lee & Marsella 2011)

Nonverbal Behavior Generator

Analysis ➔ Behavior Suggestion ➔ Behavior Selection

Function Rules ➔ NVB Rules ➔ Behavior Description

Cognition

Dialog

Emotion

Perception

Challenges NVBG SmartBody

Conflict Resolution:
• Specific Feedback Dominates Generic
Gunslinger: Utah reacting to User’s offer of a job
Summary

- **Emotion has a powerful impact on human behavior**
  - Both one's own and others' emotion

- **Value for modeling and predicting human behavior**
  - EMA predicts change in desires & intentions in competitive game

- **Value for shaping human computer interaction**
  - Give insight into user behavior
  - Key component in virtual humans