Measuring and Optimizing Player Satisfaction

Tutorial on "Measuring and Optimizing Player Satisfaction"

Computational Intelligence and Games '08

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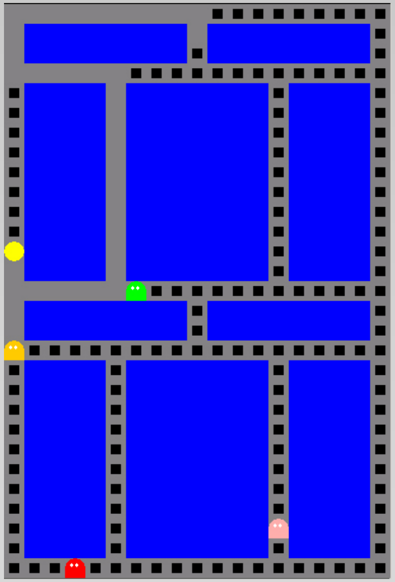

Why a Tutorial on Player Satisfaction?

- Increasing interest (different disciplines)
- Growing Community
- High quality publications (more)
- Game developers believe is hot!
- Organization:
  - IEEE Task force (game.itu.dk/PSM/)
  - 2 Workshops: SAB'06, AIIDE'07
  - Special Session at CIG'08
- Time for more CIG people to see the potential
- That's essentially our "objective function"
- Goal of the whole game design process (?)

Who is this tutorial for…?

- People
  - With CI backgrounds and/or
  - Using games as their domain
- People thinking…
  - …it's too early for such a direction
  - …that sounds cool! Can I really capture "fun"?
- That's CIG people.. but also
- Psychologists/Usability testers/evolutionary & emergent design researchers/ game experience researchers
- Game Developers

Tutorial Structure

- PART I – NPC Behavior (Georgios)
  - Introduction
  - What is Fun? Review on Entertainment Capture
  - Modeling Player Satisfaction
    - Custom-designed metrics
    - Machine Learning
      - Data Source: Keyboard, Physiology
  - Optimizing Player Satisfaction
  - GamePlay – Test-beds:
    - Screen-Based Games
    - Physical Interactive Games
  - Open Research Questions

Tutorial Structure

- PART II – Game design (Julian)
  - Static vs. Dynamic Predictors
  - Environments
  - Narratives
  - Rules and parameters
  - Open questions

Introduction

Human Experience and Fun

- Play Modes: Screen-based, physical interactive, mixed–reality..
- Several experiences emerge during HCI
- Why entertainment, fun, player satisfaction?
  - The most essential part of play!
  - Fun is a term easily interpretable by humans
  - The more the fun – the more the learning – the higher the quality of the interaction!
- Definition of Fun?
  - No way!
  - Approximation of human response instead
  - Non-linear!

Human Experience and Fun

- Challenges towards capturing "fun"? …. many!
  - Complicated mental process
  - Unique (subjectivity)
  - Augmented experimental (report, hardware) noise
  - …
- Ways of modeling fun?... Some (ideas are welcome)
- Overall purpose?
  - Make something useful with all this data/exploit multimodality
  - Richer HCI
  - Personalized HCI systems
  - Better understanding of humans (and games)
  - …

"Fun" and commercial Game Development

- Intelligence can be generated easily through FSMs!
- CI in game development?
  - Not much…but why?
    - Unpredictable behaviors
    - Debugging issues
    - Emergence – Wow, can you repeat that?
    - Expressiveness – Wow, how did he do that?
    - Game engine (h-FSM) compatibility
    - …
    - …

"Fun" and commercial Game Development

- However, need for believability and more fun in real-time… how?
- CI is here to provide
  - Believable Characters
  - More Fun in Real-time
  - That's the purpose of this tutorial!

"Fun" and academia

- Emerging research direction
- Optimizing **performance** of NPCs (intelligence)
  - That is implicitly more "fun"
- Optimizing for **"fun"** is a hard and interesting problem
  - Answers the key question of AI in Games

After this tutorial...

Some answers to the following

- Which are the features/criteria that collectively determine enjoyment (in games).
- How to quantitatively **measure** the player's satisfaction (entertainment, fun) in real-time.
- How to **increase** a game's low entertainment value and/or how to maintain a high value of entertainment.

What is “Fun”?

Entertainment Capture

What is "fun" and how to measure?

G. N. Yannakakis, "**How to Model and Augment Player Satisfaction: A Review**," in *Proceedings of the 1st Workshop on Child, Computer and Interaction (WOCCI)*, 2008.

- Qualitative
  - Malone, 1981 → Challenge, Curiosity, Fantasy
  - Kline and Alridge, 2003; Lazzaro, 2004 → Malone + Socialization
  - Read et al., 2002 → Expectations, Engagement, Endurability
  - Vorderer *et al.*, 2003 → Entertainment is all about competition
  - Koster, 2005 → Theory of Fun
  - Sweetser and Wyeth, 2005 → GameFlow (*theory of flow*)
  - Pagulayan et al., 2007 → extensive outline of *game testing* methods for effective user-centered game design.
  - Ijssellstein et al., 2007, → challenges of measuring game experiences and highlight the concepts of *immersion* and *flow*
  - Ryan et al., 2006 → perceived in-game autonomy and competence are associated with game enjoyment.
  - ...

Entertainment Capture

What is “fun” and how to measure?

G. N. Yannakakis, "**How to Model and Augment Player Satisfaction: A Review**," in *WOCCI Proceedings*, 2008.

- Limitations of Qualitative Approaches
  - Based on
    - empirical observations or
    - linear correlations of user input (interaction and physiological data) with reported emotions
  - Likert scale questionnaires are used
- We get inspiration from those
- Focus on quantifying “fun”

Entertainment Capture

What is "fun" and how to measure?

G. N. Yannakakis, "**How to Model and Augment Player Satisfaction: A Review**," in *WOCCI Proceedings*, 2008.

- Quantitative
  - Player-Game Interaction Data (Focus on Player-NPC Interaction)
    - Iida, 2003 → Entertainment Metrics for Board games
    - Yannakakis and Hallam, 2004 → Entertainment Custom-Designed Metrics for Prey/Predator games (match human entertainment)
    - Yannakakis and Hallam, 2006 → ANNs and Fuzzy-NN models get closer to human notion of entertainment (Prey/Predator games)
    - Yannakakis and Hallam, 2007 → Accurate ANN models of fun preference (physical interactive games)
  - Introduction of *comparative fun analysis*, opposed to Likert scale methodology

Entertainment Capture

What is “fun” and how to measure?

G. N. Yannakakis, "**How to Model and Augment Player Satisfaction: A Review**," in *WOCCI Proceedings*, 2008.

- Quantitative (cont.)
  - Physiological Data
    - Mandryk et al., 2006 → Correlations between GSR, jaw EMG, respiration, cardiovascular measures and reported experiences
    - Fuzzy model indicates high arousal and positive valence (i.e. possibly `fun') when a smiling (jaw EMG) player has high HR and GSR (Mandryk et al., 2007).
    - Hazlett (2006) → use of facial EMG to distinguish positive and negative emotional valence during interaction with racing video games.
    - Rani et al. (2006) → player anxiety detection which adjusts the level of challenge (e.g. speed) in the game of `Pong'.
    - Yannakakis et al, (2007, 2008) → Identification of physiological features corresponding to “fun” in physical interactive games; construction of very accurate “fun” models

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Optimize Player Satisfaction

A brief review

G. N. Yannakakis, "**How to Model and Augment Player Satisfaction: A Review**," in *WOCCI Proceedings*, 2008.

- Implicit
  - Challenge-based entertainment modeling through:
    - RL (Andrade et al., 2005): Dynamic game balance;
    - GAs (Verma and McOwan, 2005);
    - Probabilistic models (Hunicke and Chapman, 2004);
    - Dynamic Scripting (Spronck et al., 2004)
    - rtNEAT: Dynamic Game Balance in RTS games (Olesen et al., CIG'08)

    Not cross-validated against human players yet (?).

Optimize Player Satisfaction

A brief review

G. N. Yannakakis, "**How to Model and Augment Player Satisfaction: A Review**," in *WOCCI Proceedings*, 2008.

- Explicit
  - Yannakakis and Hallam, 2007 → Real-time Neuro-Evolution for optimizing an "interest" value (prey/predator games)
  - Player Modeling + Neuro-Evolution (Yannakakis and Maragoudakis, 2005)
  - Gradient-search: adaptive physical interactive games (Yannakakis and Hallam, CIG'08)

How to Capture Fun?

Custom-Designed "Fun" Metrics

Custom-Designed "Fun" Metric

Step-by-step

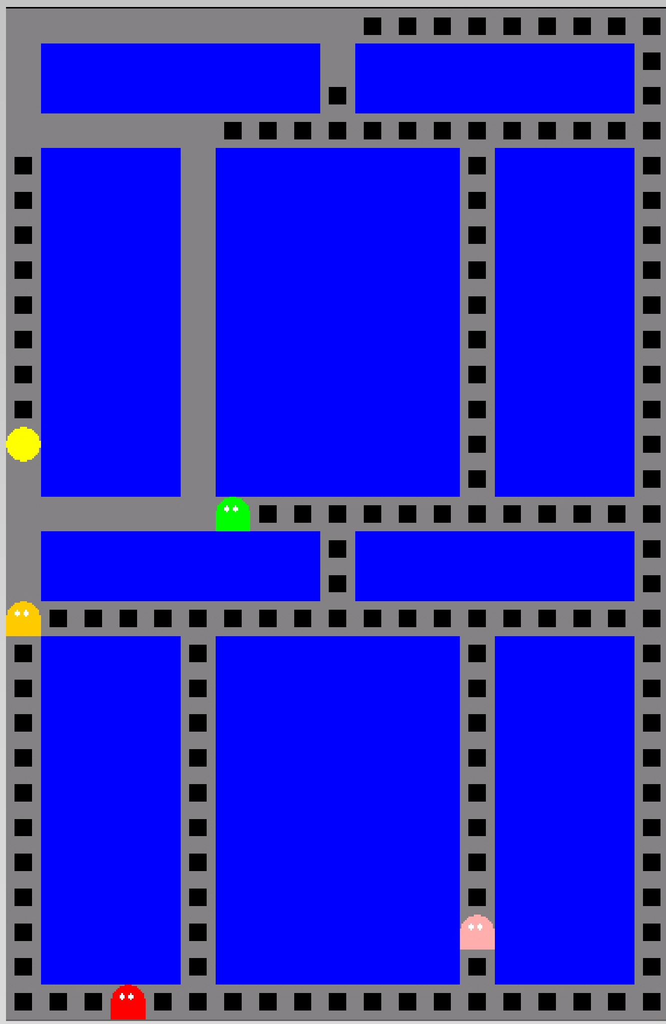
G. N. Yannakakis, and J. Hallam, "**Towards Optimizing Entertainment in Computer Games**," *Applied Artificial Intelligence*, 21:933-971, 2007.

- Collect criteria features
  - Ask players, visit game forums
  - **NPCs**, Storyline, Graphics, Mechanics…? What?
- Quantify criteria and combine them into a "fun" formula
- Adjust formula for meaningful "fun" values
- Devise survey experiment
  - Cross-Validate your formula against human preferences of fun
    - Does it work? → Use it as your objective function
    - It doesn't… → Get feedback, go back to your criteria

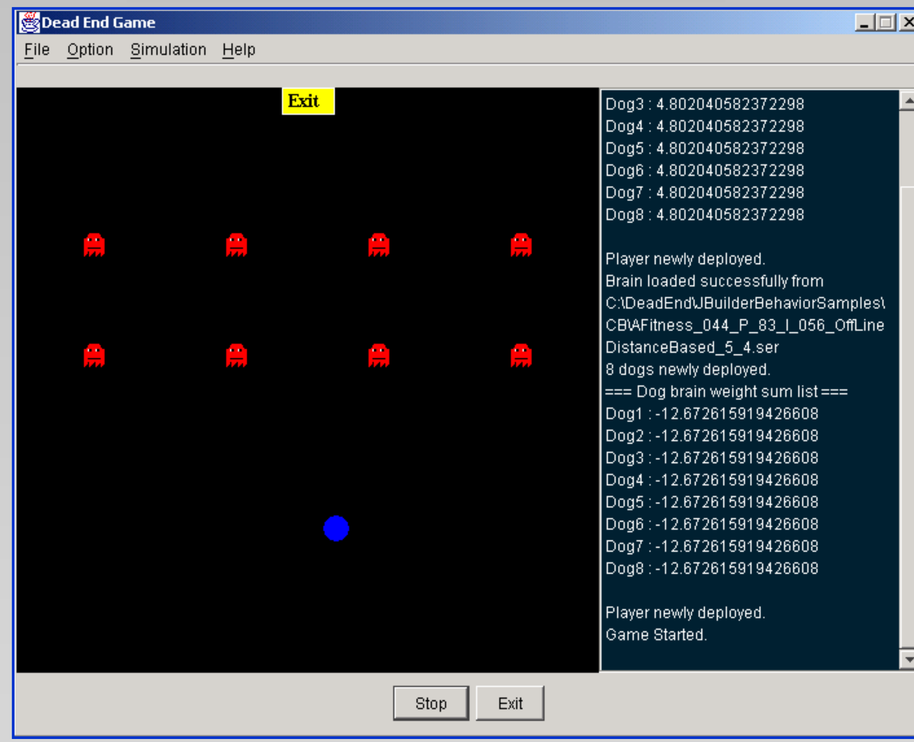
Case Study: Prey/Predator Games

G. N. Yannakakis, and J. Hallam, "**Towards Optimizing Entertainment in Computer Games**," *Applied Artificial Intelligence*, 21:933-971, 2007.

PacMan



DeadEnd



Case Study: Prey/Predator Games

G. N. Yannakakis, and J. Hallam, "**Towards Optimizing Entertainment in Computer Games**," *Applied Artificial Intelligence*, 21:933-971, 2007.

"Interesting" (Fun) refers (qualitatively) to interest primarily generated by **opponent** behavior

Graphics, Physics, Sound, Storyline,… etc.?

T to measure **appropriate level of challenge**

S to measure **behavior diversity**

H to measure **spatial diversity**

Real-Time Interest Metric (Cross-validated against Humans; $r = 0.4444$, p-value = $1.17 \cdot 10^{-8}$):

$$I = \frac{\gamma T + \delta S + \varepsilon H}{\gamma + \delta + \varepsilon}$$

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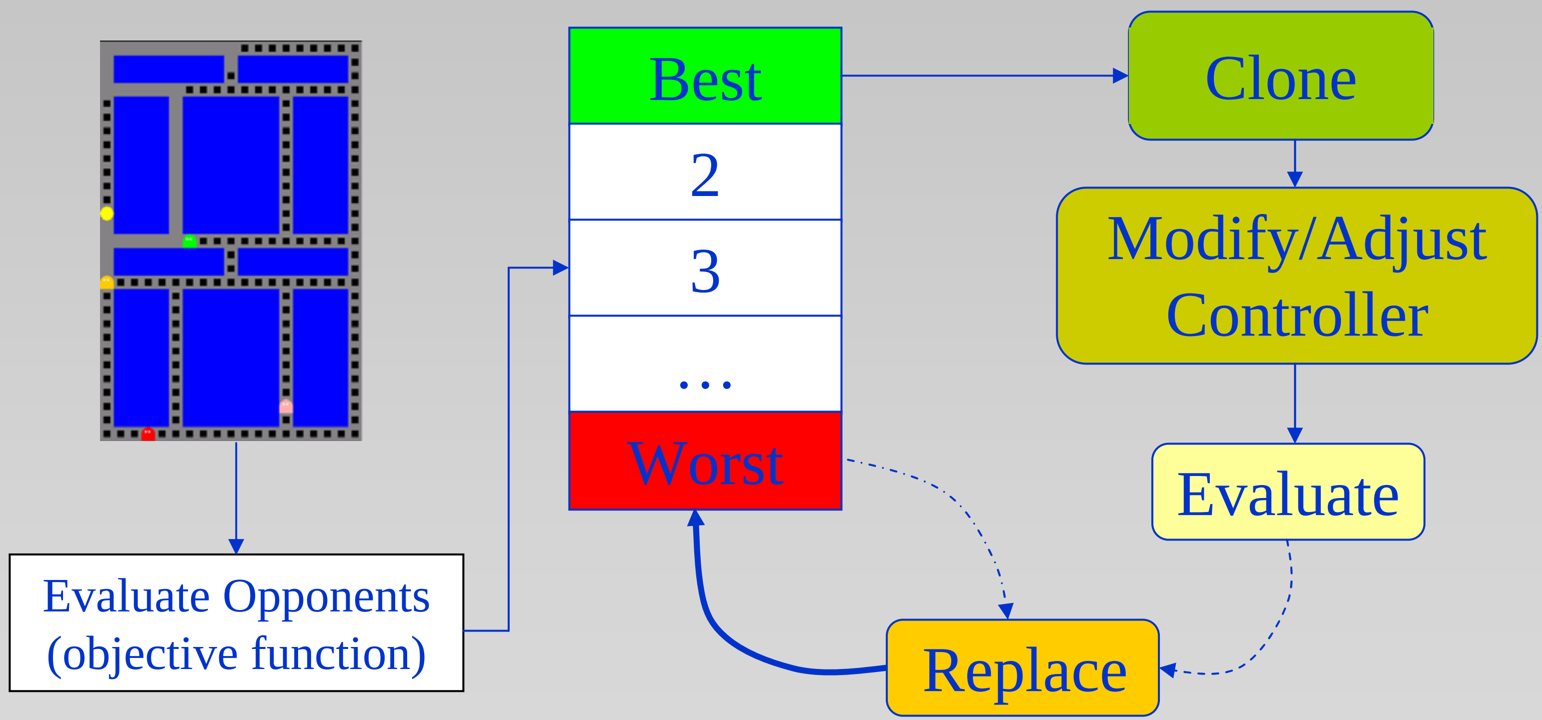
Learning in Real-Time

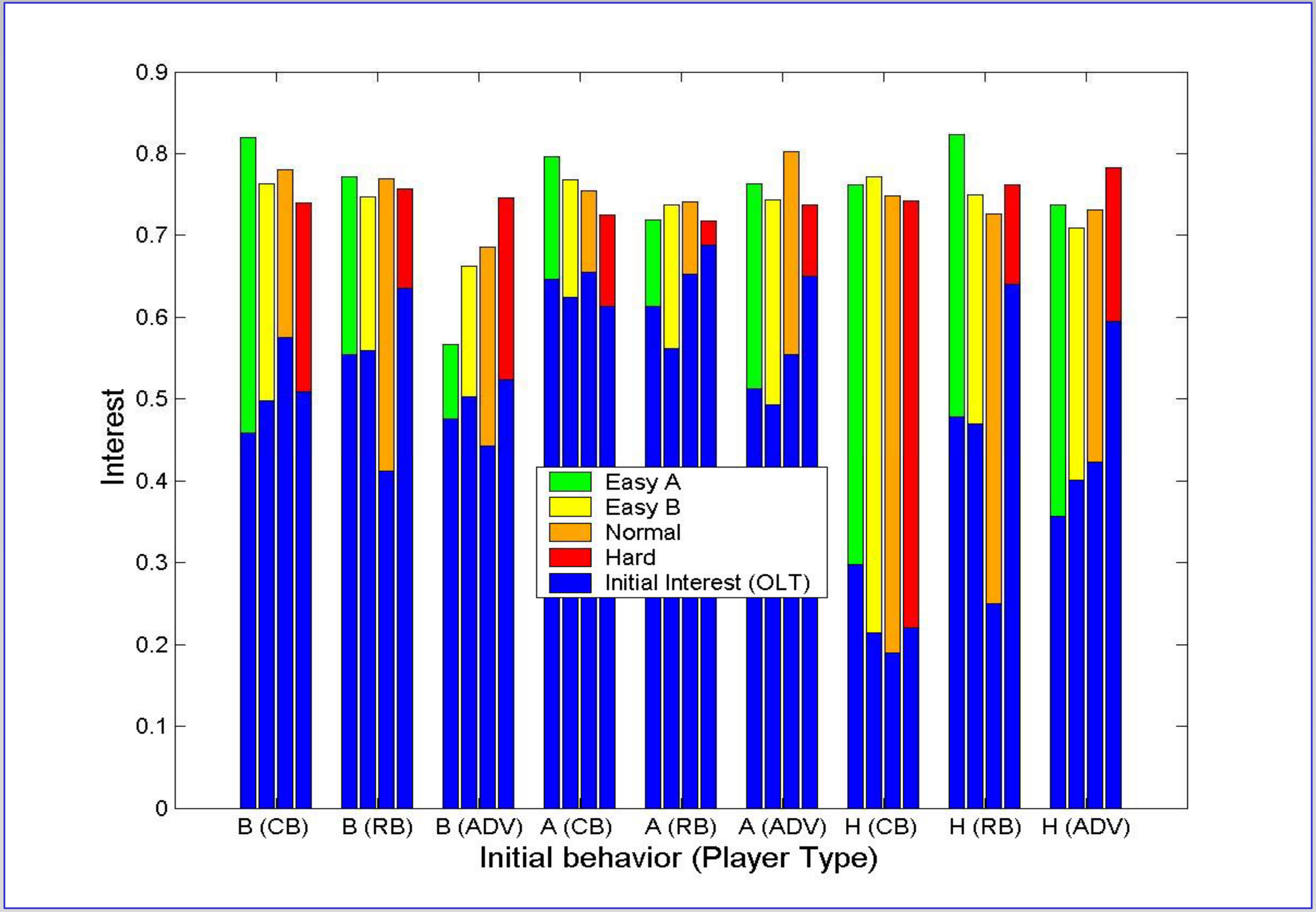
G. N. Yannakakis, and J. Hallam, "**Towards Optimizing Entertainment in Computer Games**," *Applied Artificial Intelligence*, 21:933-971, 2007.

Every *n* ticks – While the game is Played



Learning in Real-Time: Pac-Man

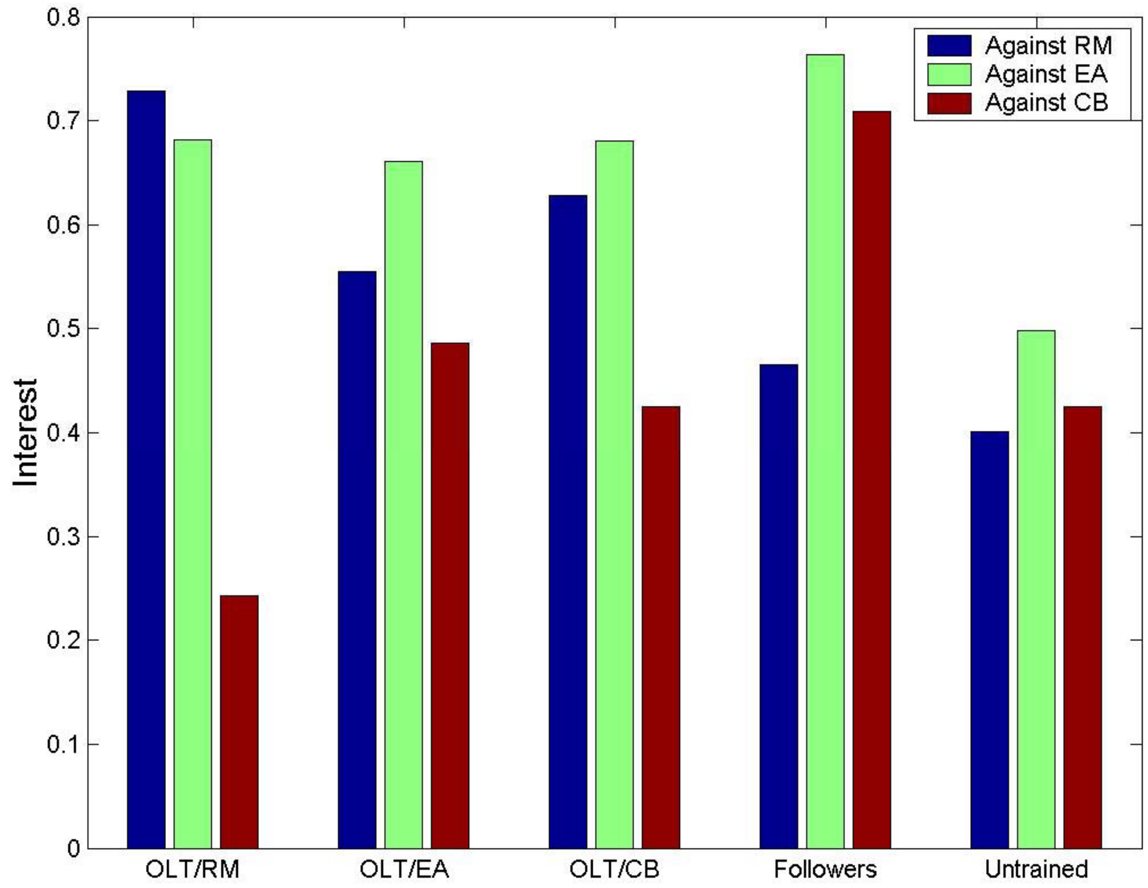
G. N. Yannakakis, and J. Hallam, “**A Generic Approach for Obtaining Higher Entertainment in Predator/Prey Computer Games**," *Journal of Game Development*, vol. 1, issue 3, 23-50, 2007.



Learning in Real-Time: Dead-End

G. N. Yannakakis, and J. Hallam, “**A Generic Approach for Obtaining Higher Entertainment in Predator/Prey Computer Games**," *Journal of Game Development*, vol. 1, issue 3, 23-50, 2007.

Learning Off-Line



Learning in Real-Time: Dead-End

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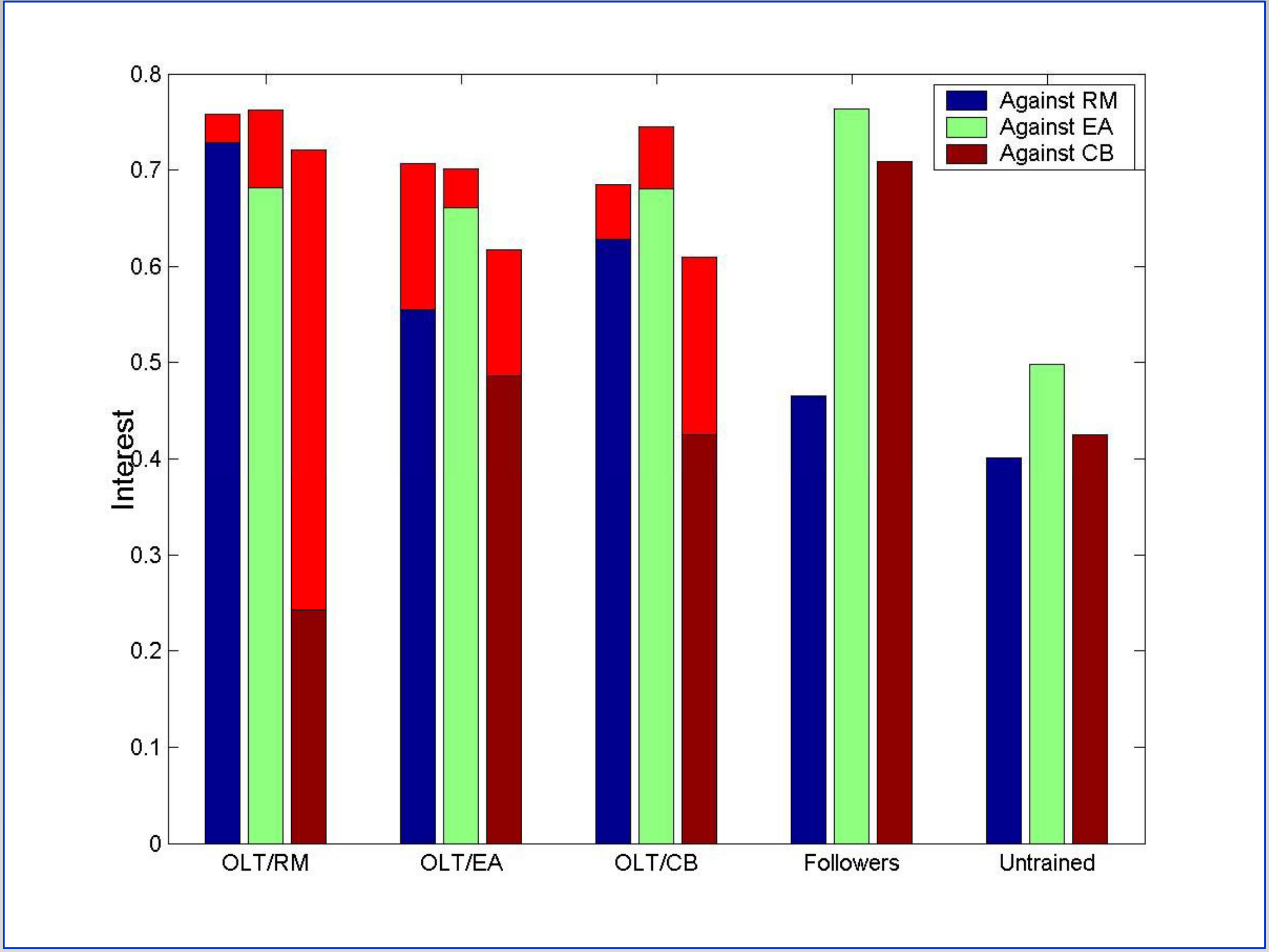
Learning On-Line



How to Capture Fun?

Machine Learning

Machine Learning Approach

Step by step guidelines for Entertainment Modeling

- Before you even start…
  - Go through psychological/qualitative fun approaches
  - Provide quantitative measurements of entertainment for qualitative factors (e.g. Malone's **Challenge** and **Curiosity**)
  - Generate game variants
  - Devise survey experiment for effective and "clean" data collection
    - Be aware of all those experiment effects (cultural, day-dependency, order of play)

Machine Learning Approach

Step by step guidelines for Entertainment Modeling

- Within your survey experiment
  - Extract player features (as many as possible) through
    - Game-player interaction
    - Physiology
    - Speech
    - …
  - Question subject preferences on game variants (remember: **always compare** for reliable cognitive models!)

Machine Learning Approach

Step by step guidelines for Entertainment Modeling

- After your experiment
  - Feature Selection
  - Preference Learning
    - **Neuro-evolution**
    - Large Margin classifiers
    - Bayesian Learning
  - Built a model (function) of user/game characteristics and user preferences of fun
  - Enhance/Optimize entertainment value in real-time based on that model

Tools

Which Features though? → Feature Selection

- What does feature selection do ?

  → appropriate input vector of the model

- Selection methods
  - n-Best feature selection (nBest)
  - Sequential Forward Selection (SFS)
  - Fisher Projection
  - …

Tools

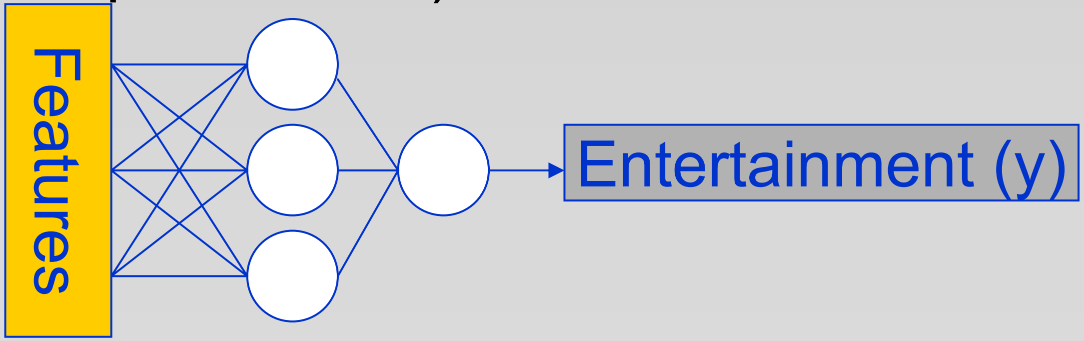
Preference Learning

Preference Learning

Learn the mapping between selected feature subset and entertainment preferences.

(Assumption: *y* of a given game is an unknown function of player features-characteristics)

- **Neuro-Evolution: GA** shapes
  - **ANNs** (connection weights)
  - **Fuzzy-NN** (rule weights and membership function parameters)



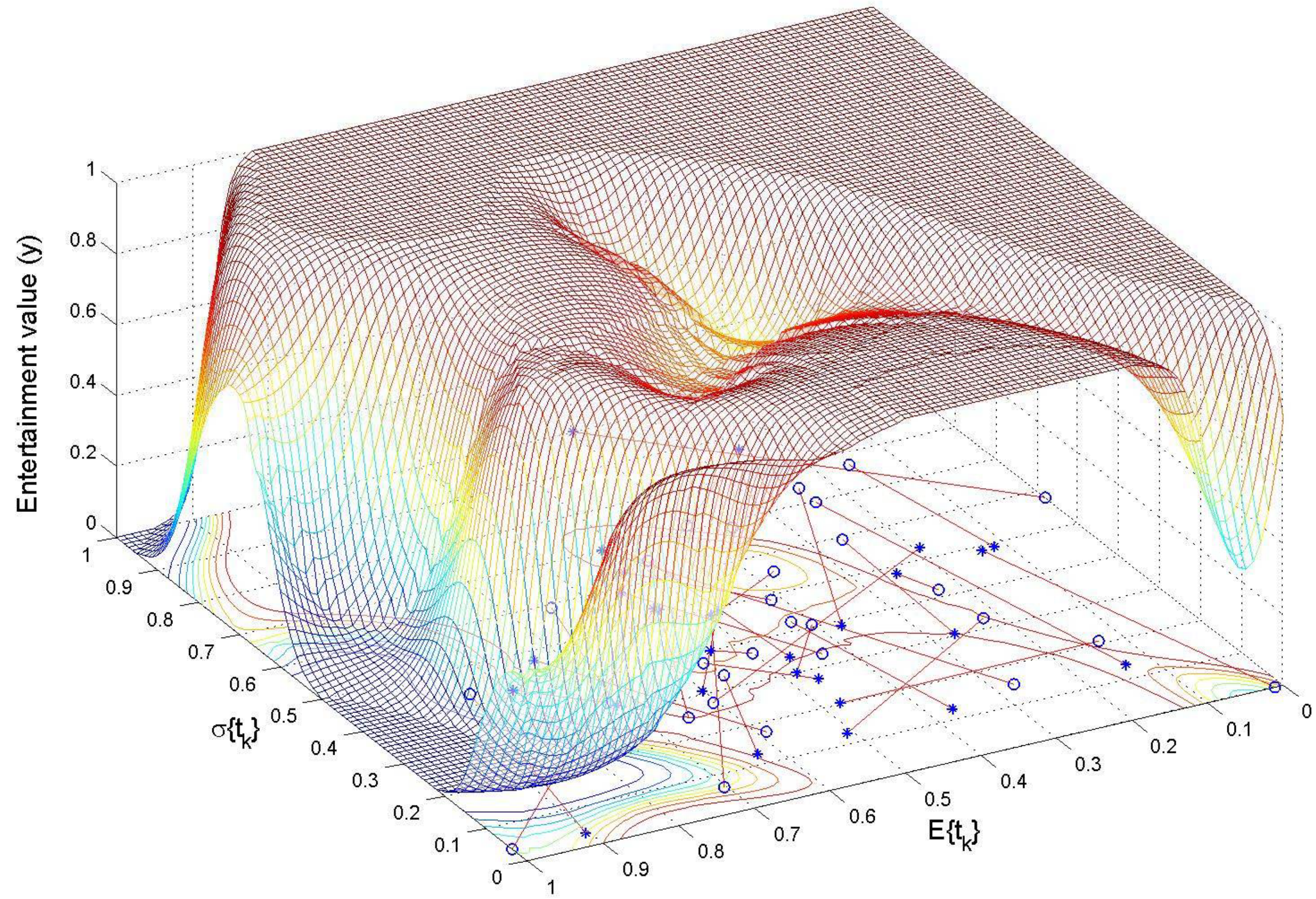
Case Study: Pac-Man

G. N. Yannakakis, and J. Hallam, "**Modeling and Augmenting Game Entertainment through Challenge and Curiosity**," *International Journal on Artificial Intelligence Tools,* vol. 16, issue 6, pp. 981-999, December 2007.

- 30 subjects (44% female, 56% male; 90% Danish, 10% Greek)
- Each subject plays two variants of the game (*A* and *B*)
- Each subject is asked which on of the two (A or B) was more ***fun*** to play (2-alternative forced choice).

Case Study: Pac-Man

G. N. Yannakakis, and J. Hallam, "**Modeling and Augmenting Game Entertainment through Challenge and Curiosity**," *International Journal on Artificial Intelligence Tools,* vol. 16, issue 6, pp. 981-999, December 2007.



Conclusions

G. N. Yannakakis, and J. Hallam, "**Modeling and Augmenting Game Entertainment through Challenge and Curiosity**," *International Journal on Artificial Intelligence Tools,* vol. 16, issue 6, pp. 981-999, December 2007.

- Modelling and Enhancement of Player Satisfaction:
  - **Possible** for **simple** 2D arcade games
- Better use ML rather than custom-design of "fun"
  - The ANN model gets closer to the human notion of entertainment (r = 0.5432, p-value = $3.89 \cdot 10^{-12}$)

From Screen to Physical Interaction

Physical Interactive Games

Computer Games: Rich form of Interactivity, roles in a virtual (fantasy) world

Traditional play: physical activity, socialization, freedom: new games and rules.

Exertainment: Advantages from both worlds, play out of screen, partly solve reported health (obesity) problems..?

Georgios N. Yannakakis (yannakakis@itu.dk) and Julian Togelius (julian@togelius.com), December 15, 2008

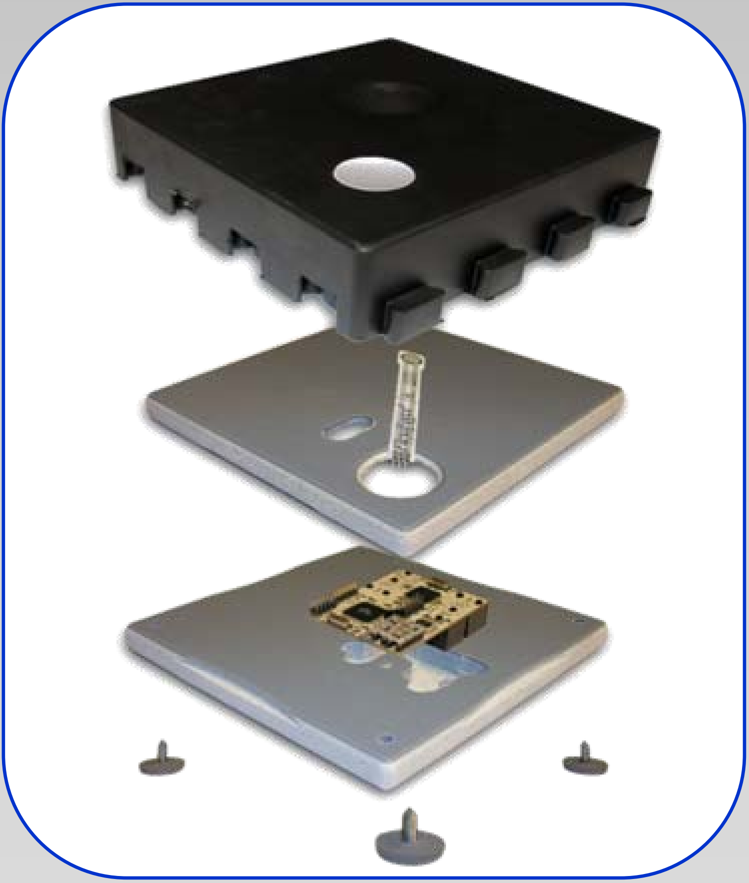
Playware Playground

What is it?

New game generation: adaptive, intelligent interactive physical playground (augmented-reality)

Theoretical background: Embodied AI (Brain-Body)

Plastic Tiles (Building blocks): CPU, input (FSR sensor), output (LEDs, sound), communication



Test-bed games

Bug-Smasher / Space-Invaders

- Bug-Smasher

Topology: 6 x 6

- Space-Invaders

Topology: 10 x 5

Experiment

Protocol

- 72 Danish, normal-weighted children (Age Group: 8-10)
- Each child plays a pair of game variants (*A* and *B*).
- The child is asked whether *A* or *B* was more "***fun***"

Naive interviewer, no interviewed questions → minimization of interviewing effects.

Order of play effects? No!

Features Extracted

- **Game** (controllable) Features [2]:
  - Challenge (*S*)
  - Curiosity (*H*)
- **Player** (personalized) Features [9]:
  - Based on 3 measurable features (child-game interaction):
    - **State** (position and LEDs color) of a pressed tile
    - **Time** that a tile-press event took place
    - **Pressure force** on a pressed tile

Results

G. N. Yannakakis and J. Hallam, "**Game and Player Feature Selection for Entertainment Capture**," in *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, pp. 244-251, Hawaii, USA, 2007.

n-Best Feature Selection		Sequential Forward Selection	
Feature Subset	Validation (%)	Feature Subset	Validation (%)
Average response time	62.22	**Average response time**	62.22
Variance of response times	58.88	**Variance of pressure forces**	67.77
Variance of pressed tile-bugs distances	44.44	**Curiosity (*H*)**	68.88
No. of interactions	46.67	**No. of interactions**	**77.77**
Curiosity	52.22	Variance of response times	63.33

p-value=0.0019

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Real-time Entertainment Augmentation

G. N. Yannakakis, and J. Hallam, "**Real-time Adaptation of Augmented-Reality Games for Optimizing Player Satisfaction**," in *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, Perth, December, 2008.

- **Use this model to…**
- **…adjust** opponents (e.g. bugs) according to the playing style/preferences of each player:
  - Gradient-ascent $\partial y / \partial H$
  - Adaptive game: Simple rule-based system for adjusting *H* every 15''
  - 24 Subjects
  - "Fun" Comparison between static and adaptive game variants
  - Children prefer the adaptive over the static game in **76%** of game comparisons

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Entertainment Modeling: Going physiological

Measuring and Optimizing Player Satisfaction

Physiology of Entertainment…?

Entertainment is a complex mental process. However, some of its elements (sympathetic arousal) can be measured through physiological indices:

- Heart Rate
- Skin Conductance
- Blood Volume Pulse/Photoplethysmography
- Skin temperature
- Jaw-Electromyography
- …

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Physiology of Entertainment

Heart Rate Experiment

G. N. Yannakakis, J. Hallam and H. H. Lund, "**Entertainment Capture through Heart Rate Activity in Physical Interactive Playgrounds**," *User Modeling and User-Adapted Interaction, Special Issue on Affective Modeling and Adaptation,* vol. 18, no. 1-2, pp. 207-243, February 2008.

- Extracted features from **56** children
  - Games: Bug-Smasher + Space Invaders
  - Heart Rate (HR)

14 features in total..

Results

Heart Rate Experiment

G. N. Yannakakis, J. Hallam and H. H. Lund, "**Entertainment Capture through Heart Rate Activity in Physical Interactive Playgrounds**," *User Modeling and User-Adapted Interaction, Special Issue on Affective Modeling and Adaptation,* vol. 18, no. 1-2, pp. 207-243, February 2008.

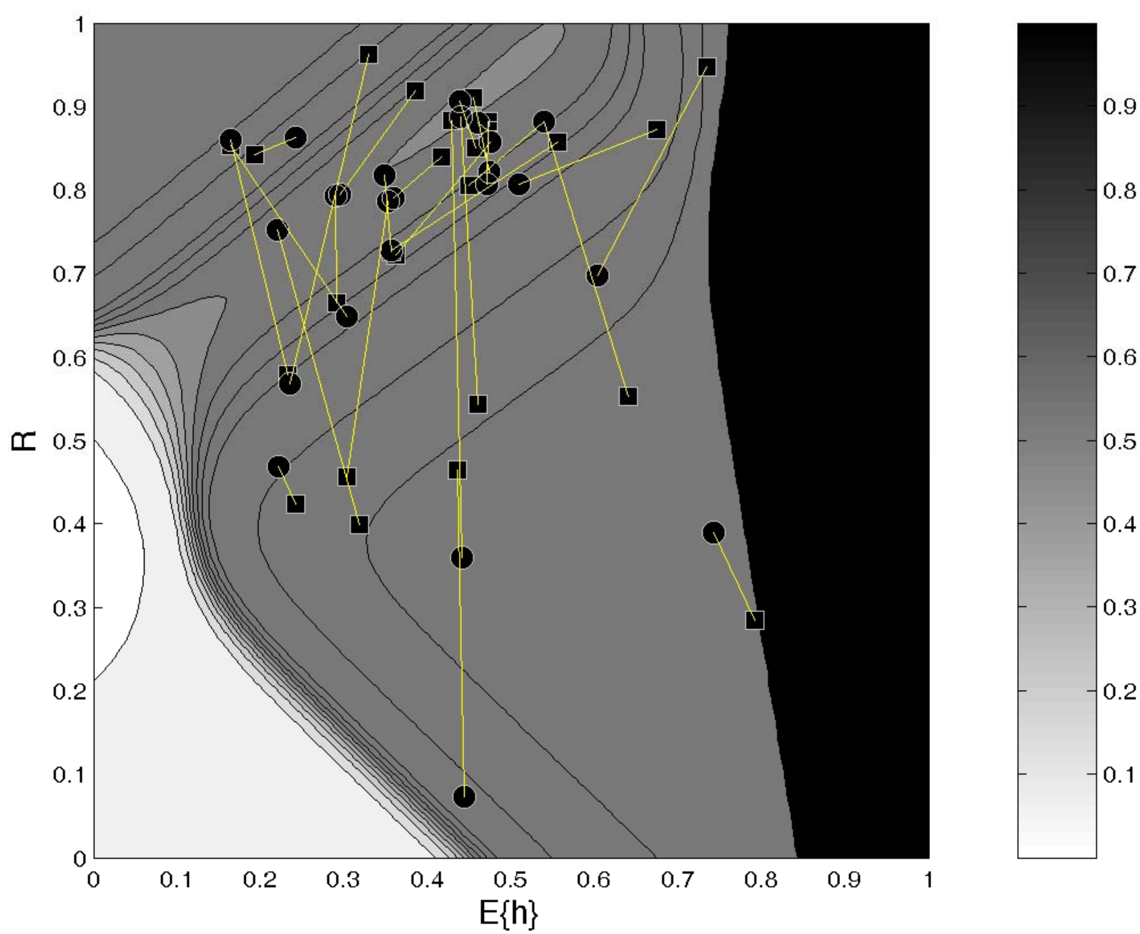
n-Best Feature Selection		Sequential Forward Selection	
Feature Subset	Validation (%)	Feature Subset	Validation (%)
Correlation (R)	72.00	**Correlation (R)**	72.00
Linear slope	70.66	**Average HR (E{h})**	**76.00**
Average HR	72.00	Max{HR}-min{HR}	74.66

p-value=0.0014

Results

Hear Rate Experiment

G. N. Yannakakis, J. Hallam and H. H. Lund, "**Entertainment Capture through Heart Rate Activity in Physical Interactive Playgrounds**," *User Modeling and User-Adapted Interaction, Special Issue on Affective Modeling and Adaptation,* vol. 18, no. 1-2, pp. 207-243, February 2008.



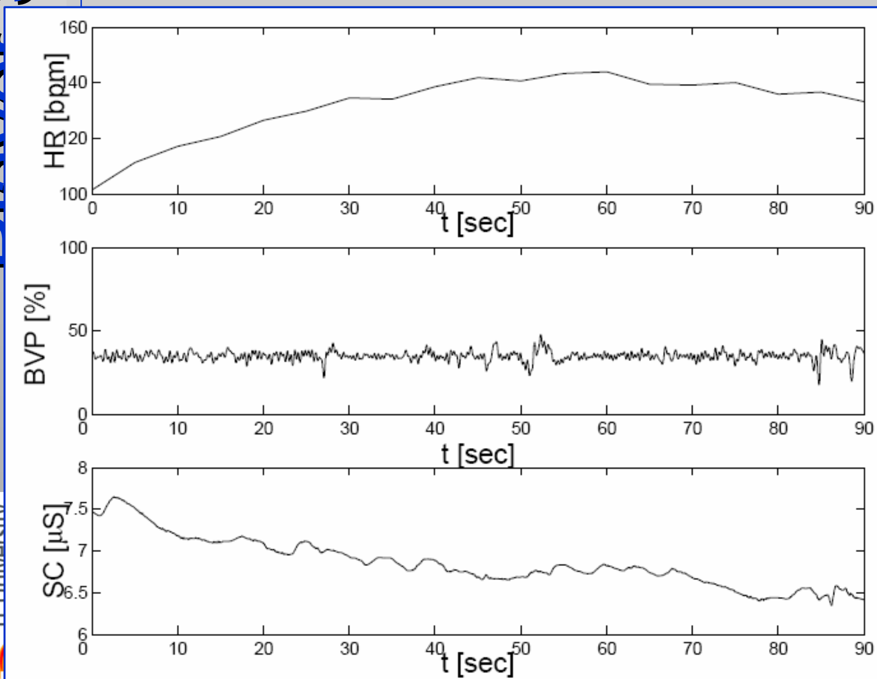
More Physiological Signals?

G. N. Yannakakis, and J. Hallam, "**Entertainment Modeling through Physiology in Physical Play**," *International Journal of Human-Computer Studies* (to appear)

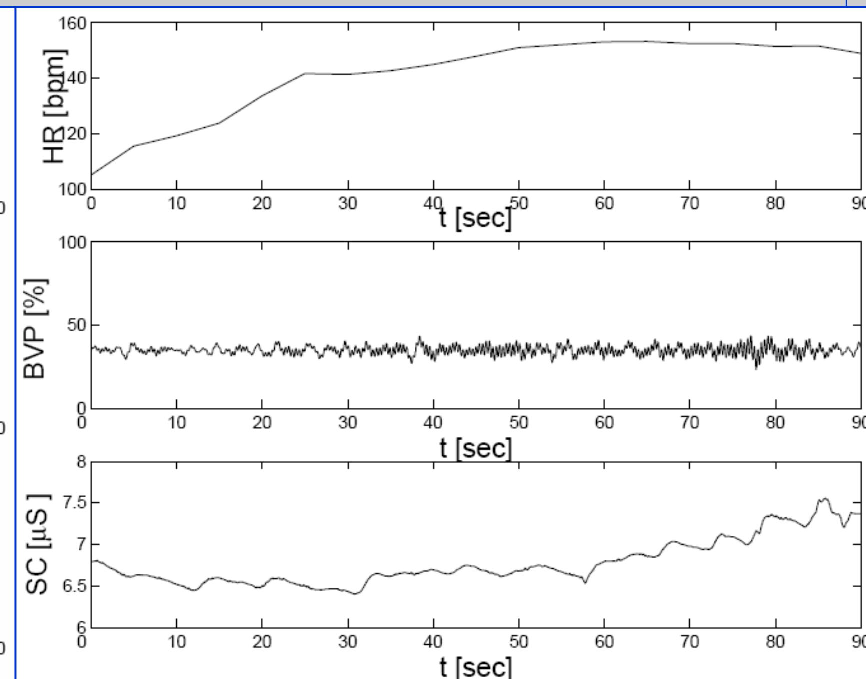
- Extracted features from **72** children
  - Heart Rate (HR), Blood Volume Pulse (BVP), Skin Conductance (SC)

  44 features in total…

Non-preferred game



Preferred Game



Results

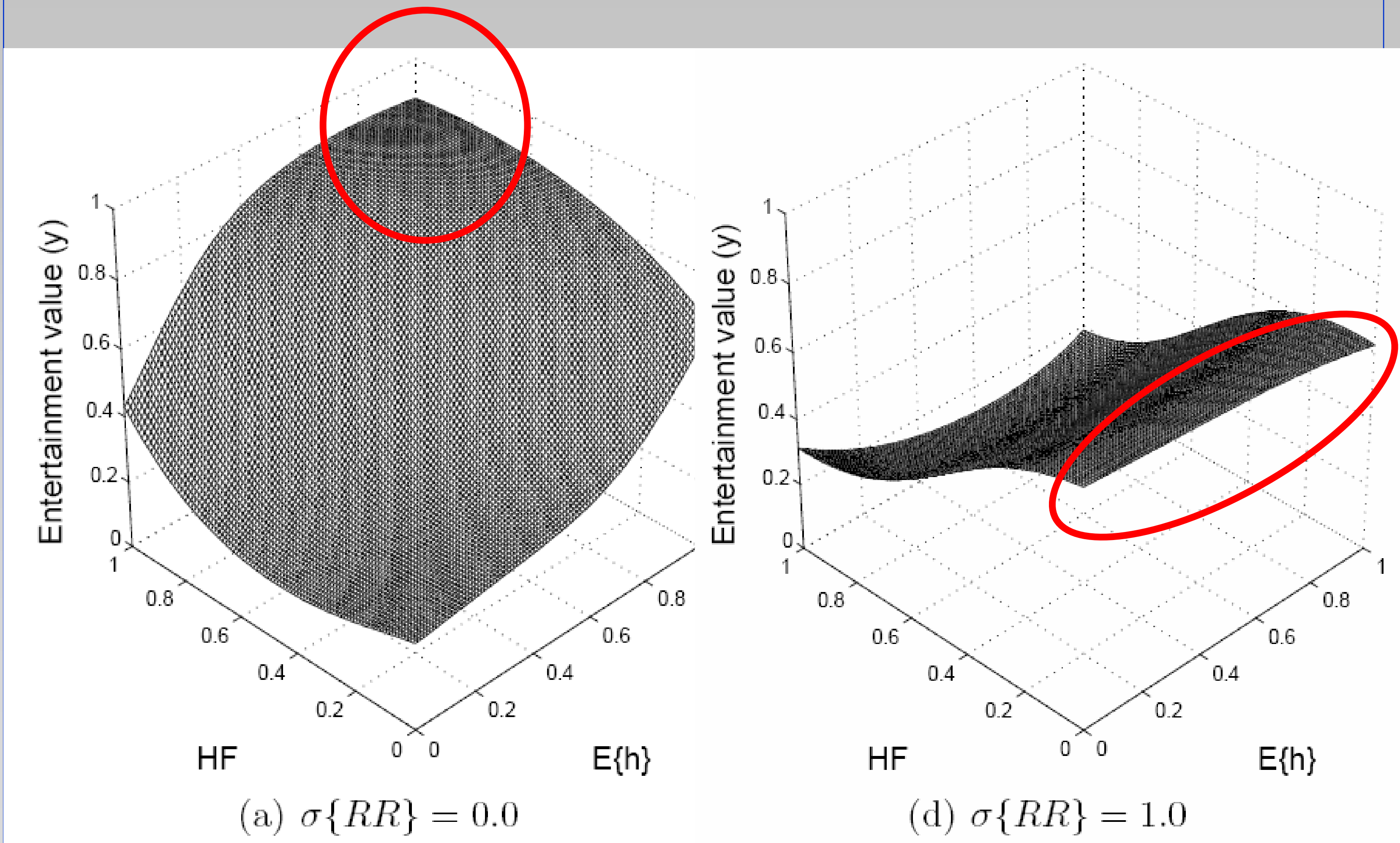
G. N. Yannakakis, and J. Hallam, "**Entertainment Modeling through Physiology in Physical Play**," *International Journal of Human-Computer Studies* (to appear)

- Selected features:
  - High frequency energy of HRV (HF): mental or emotional load/effort (parasympathetic CNS)
  - average heart rate ($E\{h\}$): physical effort
  - standard deviation of *RR* intervals ($\sigma\{RR\}$): uniformity of heart pulses
- Model's accuracy: **79.76%** (3-fold CV)

Measuring and Optimizing Player Satisfaction

Results

G. N. Yannakakis, and J. Hallam, "**Entertainment Modeling through Physiology in Physical Play**," *International Journal of Human-Computer Studies* (to appear)



Conclusions

Child-Platform Interaction Data

G. N. Yannakakis and J. Hallam, "**Game and Player Feature Selection for Entertainment Capture**," in *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, pp. 244-251, Hawaii, USA, 2007.

G. N. Yannakakis, and J. Hallam, "**Real-time Adaptation of Augmented-Reality Games for Optimizing Player Satisfaction**," in *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, Perth, December, 2008 (to appear).

- **ANN:** 3-fold cross-validation accuracy **77.77%** due to experimental noise (questionnaires, hardware failure).
- Indications that even simple gradient-ascent augments “fun” in real-time
- **Generality…**
  - **Results:** Playware action games
  - **Approach:** any computer game

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Conclusions

Physiology

G. N. Yannakakis, and J. Hallam, "**Entertainment Modeling through Physiology in Physical Play**," *International Journal of Human-Computer Studies* (to appear)

- ANNs: successful predictors of children's reported entertainment grounded on physiology
- There exist features (E{*h*}, HF) corresponding to physical activity that can effectively capture entertainment
- Isolation of those features is **possible** in physical games

Key/Open Research Questions

- Strong evidence already exist; however…
  - **Generalization (different scales):** More complex environments – commercial-standard computer games.
  - **Generalization (different modes):** Design and implementation of adaptive human-centered systems of rich HCI (exertainment, edutainment, adaptive Web).
  - **Real-time augmentation** of 'entertainment value' of HCI systems by adjusting ***opponents:***
    - Various levels of NPC control
    - Content creation
    - Storyline/Narrative
    - Game/interface design
    - …

Part II: Game Design

Part II: Game Design

- Overview:
  - Why should we try to design (aspects of) games automatically?
  - How can we create predictors of player satisfaction?
    - Static approaches
    - Dynamics approaches
  - Which aspects of games can we optimize?
    - Environments
    - Narratives
    - Rules and parameters

Why automate game design?

- It's an interesting research problem
  - interdisciplinary: optimization, supervised learning, game studies, psychology...
  - not much research done yet!
- Could save game developers money
  - Large parts of game budgets go into creating environments, tuning parameters
- Could enable new types of games
  - adaptive content creation
  - evolution might be a radical designer

Automatic content creation / game design: general idea

- Use optimization algorithms (e.g. evolution) to optimize some aspect of a game, not necessarily the agent
  - keep the rest of the game similar, while changing the aspect that's being optimized
- Objective: make the game more fun
  - we need a measure of fun

Predicting player satisfaction

- The big problem: we want to optimize (aspects of) games to be fun, but how do we know what is fun?
  - i.e. where's our fitness function?
- Using human players? (interactive)
  - takes too much time (during optimization)
  - humans don't want to play boring games (low-fitness solutions)
- Need a predictor of fun/satisfaction

Criteria for a predictor

- Accurate, i.e.
  - theoretically well-founded or understood
  - or empirically validated
- Fast!
- Personalizable (preferably)
- Generalizable over different types of games and content (preferably)

Player satisfaction prediction: overall idea

- Create a game-playing agent (NPC AI)
  - hard-coded, or
  - through some learning algorithm
  - maybe as a model of a human player
- Let the agent play a game
  - judge how much "fun" the agent had according to some theory of fun, and the behaviour of the agent
  - if the theory is right, and if the agent plays like a human, the predictor is accurate

Approaches to predictor design: Static fun predictors

- Assume the agent (player model) does not learn
- Based on e.g. Malone's factors
- Very often focuses on challenge - the game should not be too easy (too hard?)
  - i.e. how well does the agent play the game?
- Many similar measures possible:
  - variation in performance
  - diversity in behavior, locations visited etc.
- Georgios' model for Pacman (slide 20)

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Approaches to predictor design: Dynamic fun predictors

- Assume the agent learns, measure learning progress / learnability
- Raph Koster: learning = fun
  - A game is fun to the extent you learn while playing
- Juergen Schmidhuber: curiosity = prediction progress
  - a curious agent chooses to explore areas which it can learn about

What's in a game?

- Agent controllers (NPC AI)
  - this is what most CIG research is about, though usually not with an *explicit* player satisfaction perspective
- Environments
  - levels, tracks, maps, cities...
- Narrative
- Rules and parameters
- Artwork

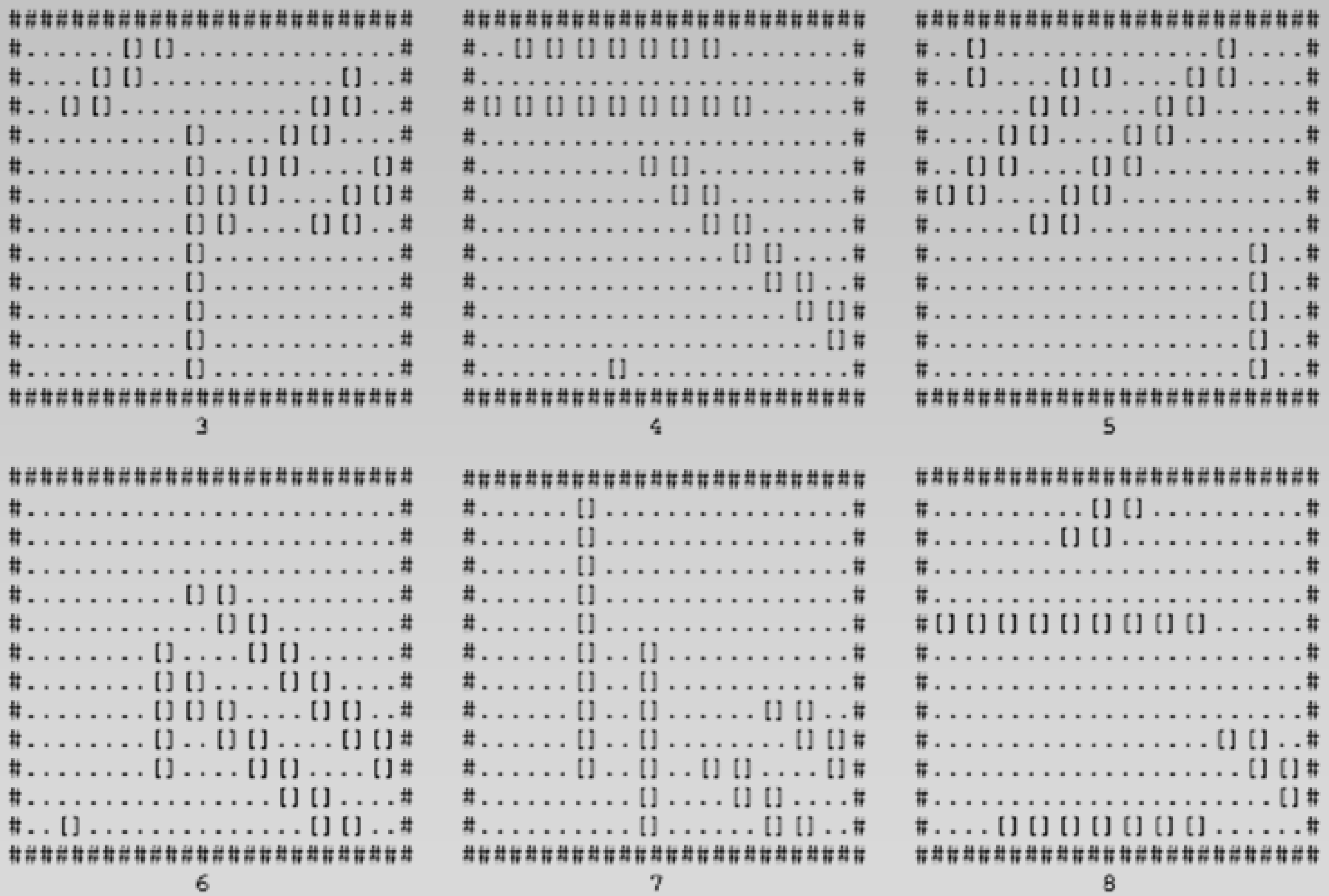
Criteria for a representation

- Expressive (should be able to express good content / rules)
- Adaptive (induces a smooth search space, so can be used with evolution)
- Human-readable (can be further edited by humans)

Environments: mazes

- Representation: placement, orientation and lengths of walls in a grid world
- Static fitness function: maximize minimum number of turns and path length taken by agent (as determined by dynamic programming) in order to reach goal from start
  - D. Ashlock, T. Manikas and K. Ashenayi, *Evolving A Diverse Collection of Robot Path Planning Problems*. CEC 2006

Environments: mazes



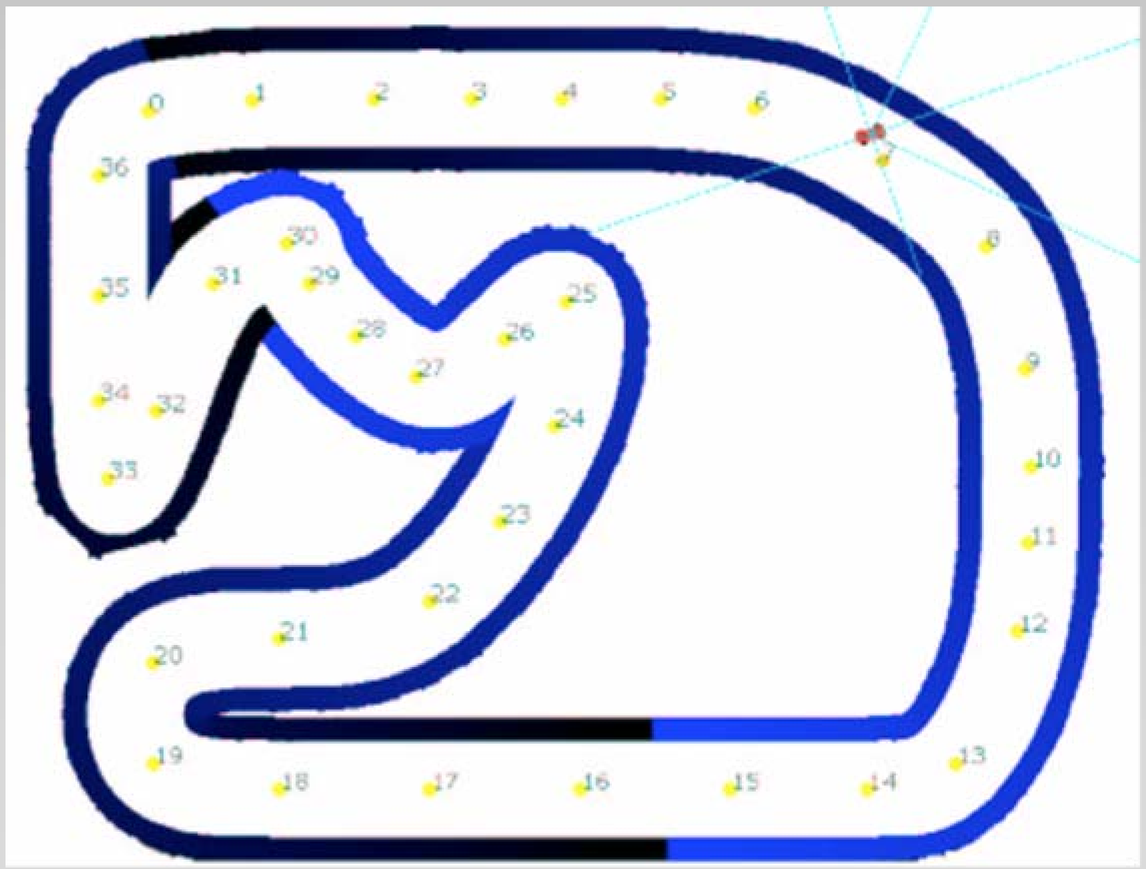
Environments: racing tracks

- Static fitness function:
  - loosely based on Malone
  - right amount of progress on track, maximize variation in progress, maximize difference between max and mean speed
- Representation:
  - b-splines (sequences of Bezier curves)

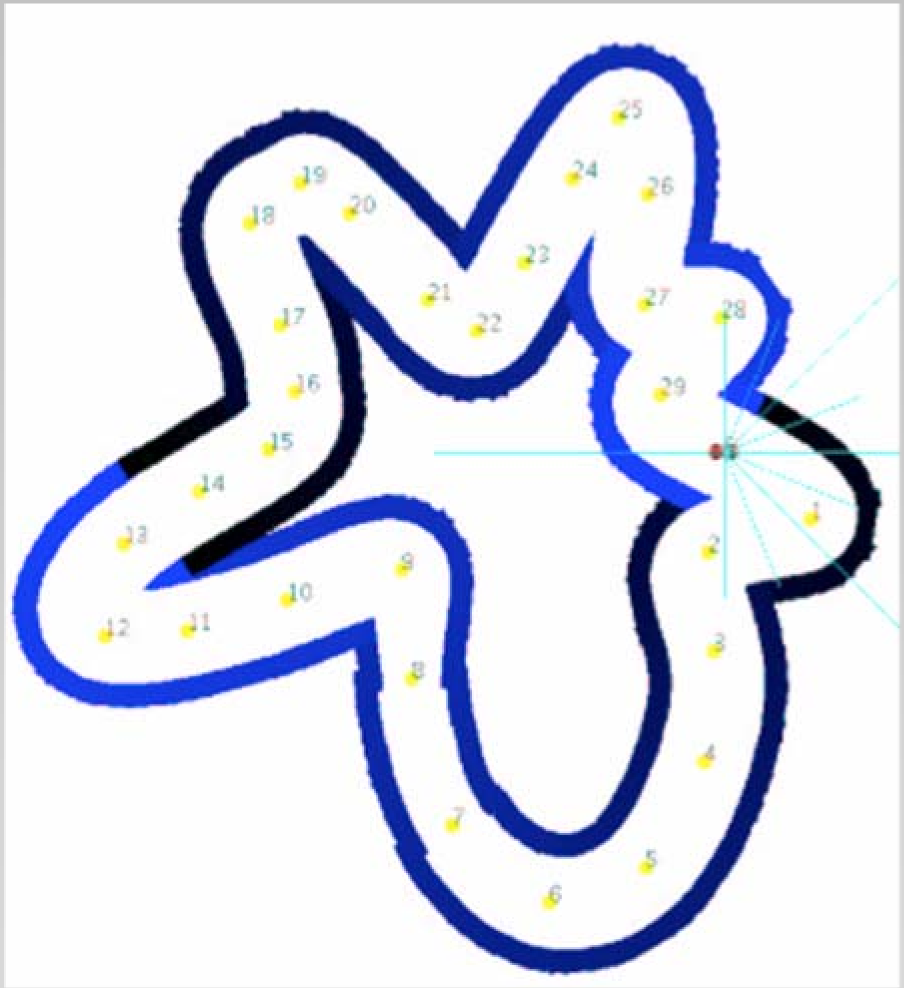
—Julian Togelius, Renzo De Nardi and Simon Lucas. *Towards automatic personalized content creation for racing games*. CIG 2007

Environments: racing tracks

- First, create a player model through letting a human drive on a test track, and evolving a controller that mimics the driving style of the human

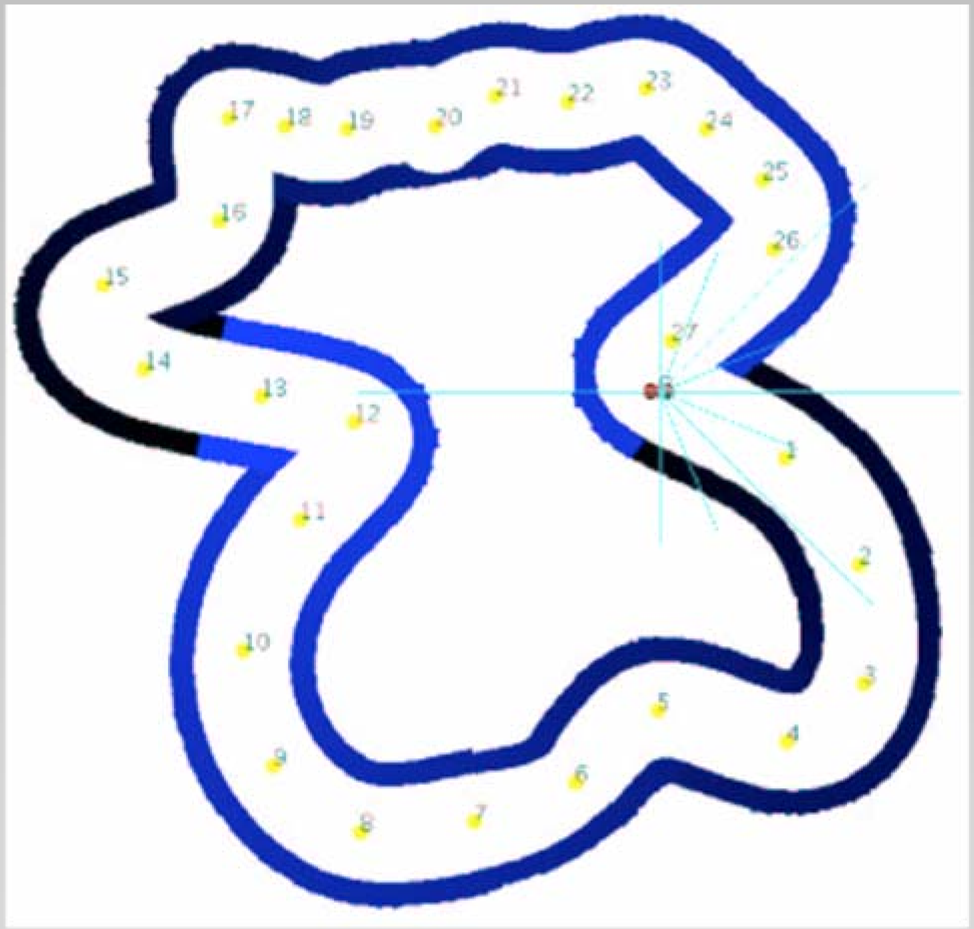


Environments: racing tracks



Track evolved for me

Environments: racing tracks



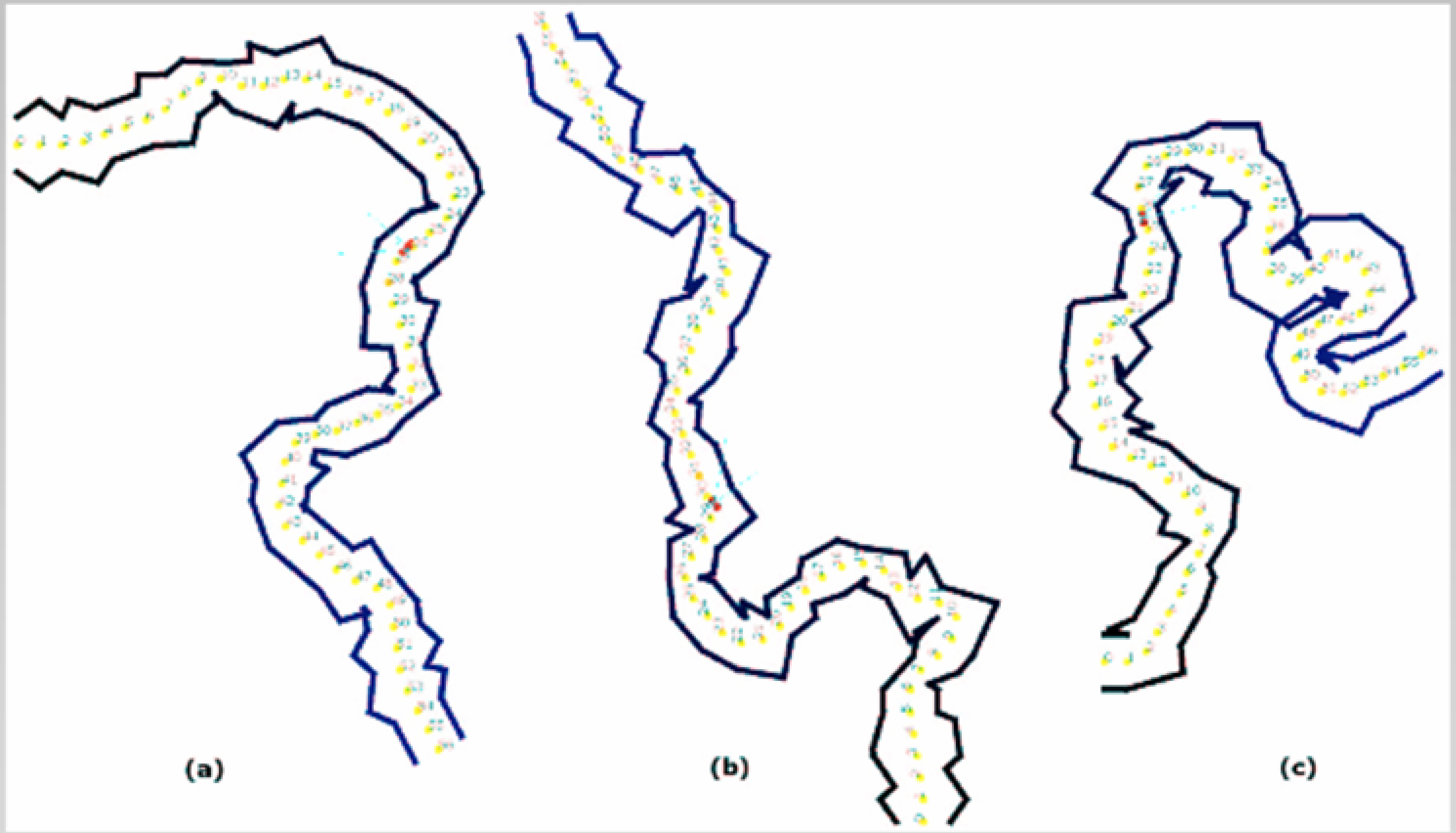
Track evolved for Renzo

Measuring and Optimizing Player Satisfaction

Environments: racing tracks

Track evolved with random initialization

Environments: racing tracks



Tracks evolved with segment representation

Environments: cities

- Fitness function: none! (not used for player satisfaction optimization yet)
  - but imagine escape routes from a bank robbery in GTA...
- Representation: recipe for building the city procedurally
  - procedural representation needed to keep search space manageable (cities are big!)
    - » George Kelly, Hugh McCabe. *Citygen: An Interactive System for Procedural City Generation*. GDTW 2007

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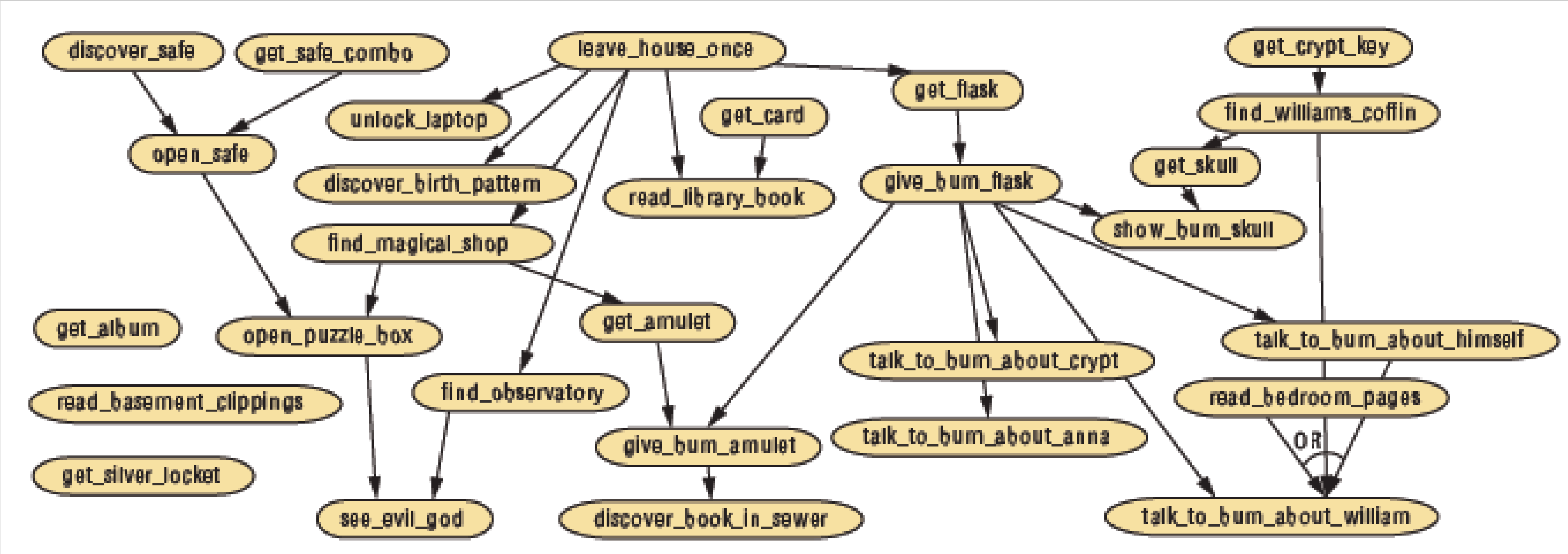
Narrative

- Fitness function: measures of the behaviour of an e.g. random agent
  - location flow (successive events at the same place)
  - thought flow (events related conceptually)
  - motivation (related causally)
    - » Mark Nelson, Michael Mateas, David Roberts and Charles Isbell, "*Declarative Optimization-Based Drama Management in the Interactive Fiction Anchorhead.*" IEEE Computer Graphics and Applications, vol 26, number 3, 2006, pp 32-41.

Narrative

- Representation:
  - deniers, causers, hints and game endings that affect a player's progression through a story



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Rules and parameters: Board games

- Static fitness function: results of playing game with Alfa-beta search
  - Completion: most games reach a conclusion
  - Balance: no advantage to either player
  - Advantage: no first move advantage
  - Duration: games end in a reasonable number of moves
  - Additional “aesthetic measurements”
    - » Cameron Browne, *Automatic Generation and Evaluation of Recombination Games* (PhD Thesis), Queensland University of Technology 2008

Rules and parameters: Board games

- Representation: The *Ludi* game description language

```
(ludeme TicTacToe
    (players White Black
    (board
        (tiling square i-nbors)
        (shape square)
        (size 3 3)
    )
    (end (All win (in-a-row 3) ) )
)
```


Georgios N. Yannakakis (yannakakis@itu.dk) and Julian Togelius (julian@togelius.com), December 15, 2008

Rules and parameters: Agent-based games

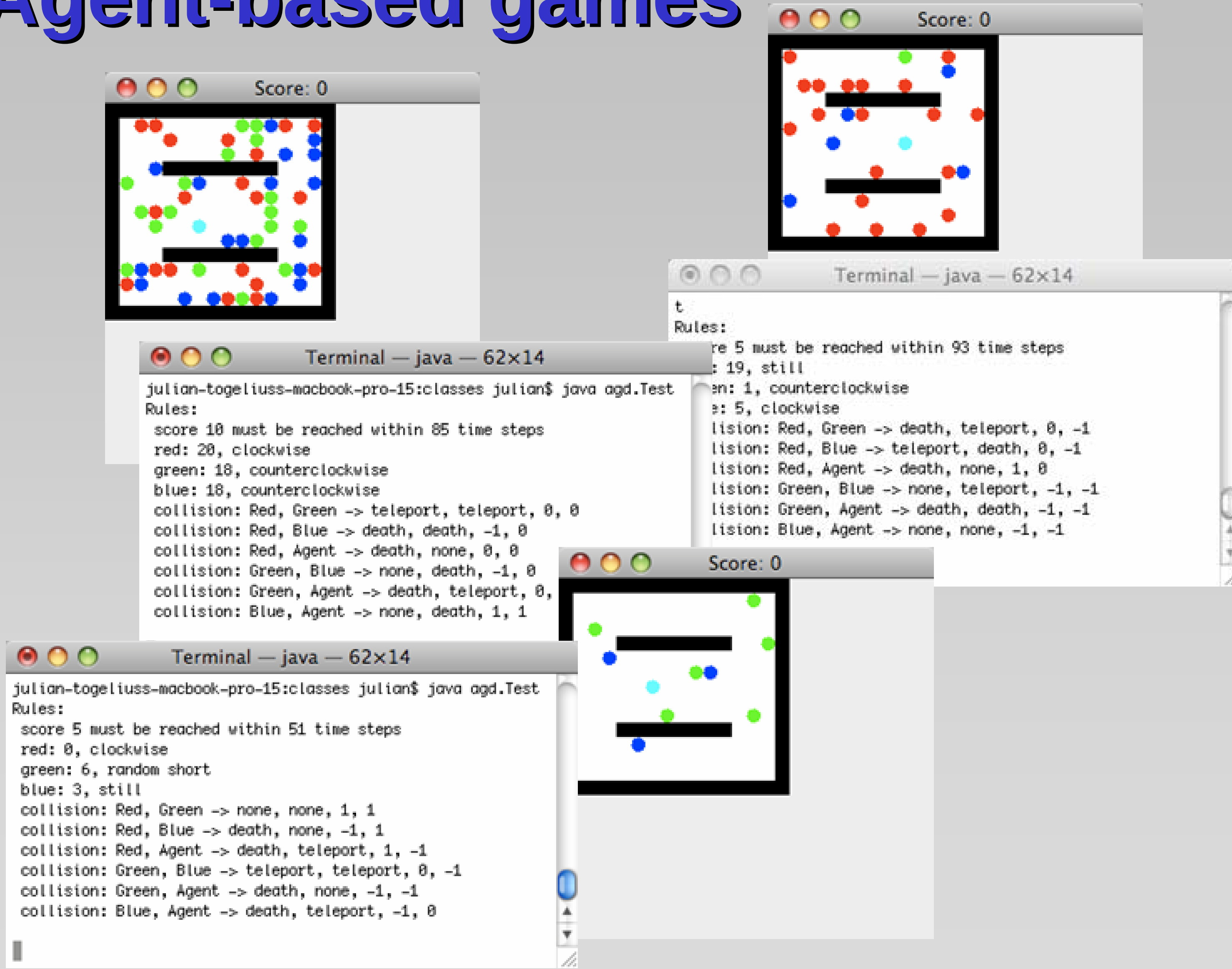
- Dynamic fitness function: learnability of game rules
  - the game should not be too easy (winnable by a random game agent)
  - an "inner" evolutionary process should be able to learn to play the game satisfactorily
  - inspired by Koster, Schmidhuber
    - – Julian Togelius and Juergen Schmidhuber. *An Experiment in Automatic Game Design.* This symposium!

Rules and parameters: Agent-based games

- Representation: game rules
  - number of red, green, blue things
  - movement logic for things
  - effects on things or agent when things or agents collide with each other (death, teleport etc.)
  - ending conditions (time, score)

Georgios N. Yannakakis (yannakakis@itu.dk) and Julian Togelius (julian@togelius.com), December 15, 2008

Rules and parameters: Agent-based games



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Open research questions

- Pretty much everything!
- Does it work?
  - need empirical validation with human players
- Does it scale?
  - only relatively small spaces searched so far, for relatively simple games
- Variations: online / offline, static / dynamic, personalized / generic, invention / fine tuning etc.

Some obvious ideas

- Multi-objectivity
  - fun can be measured in many ways, maybe we want to optimize different experiences
  - MOEAs can explore trade-offs
- Model learning
  - dynamic predictors are based on learnability; we need a learning process that learns like a human player
- Parameters for games

Questions…?

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IEEE Task Force on Player Satisfaction Modeling
game.itu.dk/PSM/

References

–G. Andrade, G. Ramalho, H. Santana, and V. Corruble. Extending reinforcement learning to provide dynamic game balancing. In *Proceedings of the Workshop on Reasoning, Representation, and Learning in Computer Games, 19th International Joint Conference on Artificial Intelligence (IJCAI)*, pages 7-12, August 2005.

–N. Beume, H. Danielsiek, C. Eichhorn, B. Naujoks, M. Preuss, K. Stiller, and S. Wessing. Measuring Flow as Concept for Detecting Game Fun in the Pac-Man Game. In *Proc. 2008 Congress on Evolutionary Computation (CEC'08) within Fifth IEEE World Congress on Computational Intelligence (WCCI'08)*. IEEE, 2008.

–D. Choi, H. Kim, and J. Kim. Toward the construction of fun computer games: Differences in the views of developers and players. *Personal Technologies*, 3(3):92-104, September 1999.

–B. Cowley, D. Charles, M. Black, and R. Hickey. Toward an Understanding of Flow in Video Games. *ACM Computers in Entertainment*, 6(2), July 2008.

–M. Csikszentmihalyi. *Flow: The Psychology of Optimal Experience*. New York: Harper & Row, 1990.

–M. Csikszentmihalyi. *Beyond Boredom and Anxiety: Experiencing Flow in Work and Play*. San Francisco: Jossey-Bass, 2000.

–R. L. Hazlett. Measuring emotional valence during interactive experiences: boys at video game play. In *CHI '06: Proceedings of the SIGCHI conference on Human Factors in computing systems*, pages 1023-1026, New York, NY, USA, 2006. ACM Press.

–R. Hunicke and V. Chapman. AI for Dynamic Difficulty Adjustment in Games. In *Proceedings of the Challenges in Game AI Workshop, 19th Nineteenth National Conference on Artificial Intelligence (AAAI'04)*, 2004.

–H. Iida, N. Takeshita, and J. Yoshimura. A metric for entertainment of boardgames: its implication for evolution of chess variants. In R. Nakatsu and J. Hoshino, editors, *IWEC2002 Proceedings*, pages 65-72. Kluwer, 2003.

–W. A. Ijsselsteijn, Y. A. W. de Kort, K. Poels, A. Jurgelionis, and F. Belotti. Characterising and measuring user experiences. In *ACE 2007 International Conference on Advances in Computer Entertainment Technology*, 2007.

–R. Koster. *A Theory of Fun for Game Design*. Paraglyph Press, 2005.

–N. Lazzaro. Why we play games: Four keys to more emotion without story. Technical report, XEO Design Inc., 2004.

Measuring and Optimizing Player Satisfaction

References

–T. W. Malone. What makes computer games fun? *Byte*, 6:258{277, 1981.

–R. L. Mandryk and M. S. Atkins. A Fuzzy Physiological Approach for Continuously Modeling Emotion During Interaction with Play Environments. *International Journal of Human-Computer Studies*, 65:329-347, 2007.

–R. L. Mandryk, K. M. Inkpen, and T. W. Calvert. Using Psychophysiological Techniques to Measure User Experience with Entertainment Technologies. *Behaviour and Information Technology (Special Issue on User Experience)*, 25(2):141-158, 2006.

–S. McQuiggan, S. Lee, and J. Lester. Predicting User Physiological Response for Interactive Environments: An Inductive Approach. In *Proceedings of the 2nd AIIDE Conference*, pages 60-65, 2006.

–R. J. Pagulayan and K. Keeker. *Handbook of Formal and Informal Interaction Design Methods*, chapter Measuring Pleasure and Fun: Playtesting. San Francisco: Morgan Kaufmann Publishers, 2007.

–P. Rani, N. Sarkar, and C. Liu. Maintaining optimal challenge in computer games through real-time physiological feedback. In *Proceedings of the 11th International Conference on Human Computer Interaction*, 2005.

–N. Ravaja, T. Saari, M. Turpeinen, J. Laarni, M. Salminen, and M. Kivikangas. Spatial Presence and Emotions during Video Game Playing: Does It Matter with Whom You Play? *Presence Teleoperators & Virtual Environments*, 15(4):381{392, 2006.

–J. Read, S. MacFarlane, and C. Cassey. Endurability, engagement and expectations. In *Proceedings of International Conference for Interaction Design and Children*, 2002.

–D. L. Roberts, C. R. Strong, and C. L. Isbell. Estimating player satisfaction through the author's eyes. In G. N. Yannakakis and J. Hallam, editors, *Proceedings of the AIIDE'07 Workshop on Optimizing Player Satisfaction, Technical Report WS-07-01*, pages 31-36. AAAI Press, 2007.

–P. Spronck, I. Sprinkhuizen-Kuyper, and E. Postma. Difficulty Scaling of Game AI. In *Proceedings of the 5th International Conference on Intelligent Games and Simulation (GAME-ON 2004)*, pages 33{37, 2004.

–P. Sweetser and P. Wyeth. GameFlow: A Model for Evaluating Player Enjoyment in Games. *ACM Computers in Entertainment*, 3(3), July 2005.

–D. Thue, V. Bulitko, M. Spetch, and E. Wasylishen. Learning player preferences to inform delayed authoring. In *Papers from the AAAI'07 Fall Symposium on Intelligent Narrative Technologies*. AAAI Press, 2007.

Measuring and Optimizing Player Satisfaction

References

–J. Togelius, R. De Nardi, and S. M. Lucas. Making racing fun through player modeling and track evolution. In G. N. Yannakakis and J. Hallam, editors, *Proceedings of the SAB Workshop on Adaptive Approaches to Optimizing Player Satisfaction*, pages 61-70, Rome, 2006.

–J. Togelius, R. De Nardi, and S. M. Lucas. Towards automatic personalised content creation for racing games. In *Proceedings of the IEEE Symposium on Computational Intelligence and Games*, pages 252-259, Hawaii, USA, April 2007. IEEE.

–J. Togelius and J. Schmidhuber. An Experiment in Automatic Game Design. This symposium.

–M. A. Verma and P. W. McOwan. An adaptive methodology for synthesising Mobile Phone Games using Genetic Algorithms. In *Congress on Evolutionary Computation (CEC-05)*, pages 528-535, Edinburgh, UK, September 2005.

–P. Vorderer, T. Hartmann, and C. Klimmt. Explaining the enjoyment of playing video games: the role of competition. In D. Marinelli, editor, *ICEC conference proceedings 2003: Essays on the future of interactive entertainment*, pages 107-120, Pittsburgh. Carnegie Mellon University Press.

–G. N. Yannakakis and J. Hallam. Evolving Opponents for Interesting Interactive Computer Games. In S. Schaal, A. Ijspeert, A. Billard, S. Vijayakumar, J. Hallam, and J.-A. Meyer, editors, *From Animals to Animats 8: Proceedings of the 8th International Conference on Simulation of Adaptive Behavior (SAB-04)*, pages 499-508, Santa Monica, LA, CA, July 2004. The MIT Press.

–G. N. Yannakakis and J. Hallam. A Generic Approach for Obtaining Higher Entertainment in Predator/Prey Computer Games. *Journal of Game Development*, 1(3):23-50, December 2005.

–G. N. Yannakakis and J. Hallam. A generic approach for generating interesting interactive pac-man opponents. In *Proceedings of CIG'05*, pages 94-101, 2005. IEEE

–G. N. Yannakakis and J. Hallam. Game and Player Feature Selection for Entertainment Capture. In *Proceedings of CIG'07*, pages 244-251, Hawaii, USA, April 2007. IEEE.

–G. N. Yannakakis and J. Hallam. Modeling and augmenting game entertainment through challenge and curiosity. *International Journal on Artificial Intelligence Tools*, 16(6):981-999, December 2007.

–G. N. Yannakakis and J. Hallam. Towards Optimizing Entertainment in Computer Games. *Applied Artificial Intelligence*, 21:933-971, 2007.

–G. N. Yannakakis and J. Hallam. Entertainment Modeling through Physiology in Physical Play. *International Journal of Human-Computer Studies*, 66:741-755, October 2008.

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References

–G. N. Yannakakis and J. Hallam. Real-time Adaptation of Augmented-Reality Games for Optimizing Player Satisfaction. In *Proceedings of CIG'08,* Perth, Australia, December 2008. IEEE.

–G. N. Yannakakis, J. Hallam, and H. H. Lund. Entertainment Capture through Heart Rate Activity in Physical Interactive Playgrounds. *User Modeling and User-Adapted Interaction, Special Issue: Affective Modeling and Adaptation*, 18(1-2):207{243, February 2008.

–G. N. Yannakakis and M. Maragoudakis. Player modeling impact on player's entertainment in computer games. In *Proceedings of the 10th International Conference on User Modeling; Lecture Notes in Computer Science*, volume 3538, pages 74-78, Edinburgh, July 2005. Springer-Verlag.