Evolutionary Computation in Games: Dealing With Uncertainty

Paolo Burelli - Aalborg University Copenhagen
pabu@create.aau.dk - www.paoloburelli.com

Me

- Research in Artificial Intelligence and Computer Graphics (Intelligent User Interfaces)
- Focus on Virtual Cinematography and Player Modelling

Tutorial

- Evolutionary Computation in Games
- Uncertainty
- Uncertainty in Games
- Examples

Evolutionary Computation In Games

Generate optimal player/game

- Objective functions
  - Player: performance/human likeness
  - Game: player experience, balance, duration...
- Domain
  - Player: controller/strategy
  - Game: content configuration

Galactic Arms Race

- Evolving weapons
- Interactive Evolutionary Computation
  - Objective function is human evaluation
- Compositional Pattern-Producing Networks

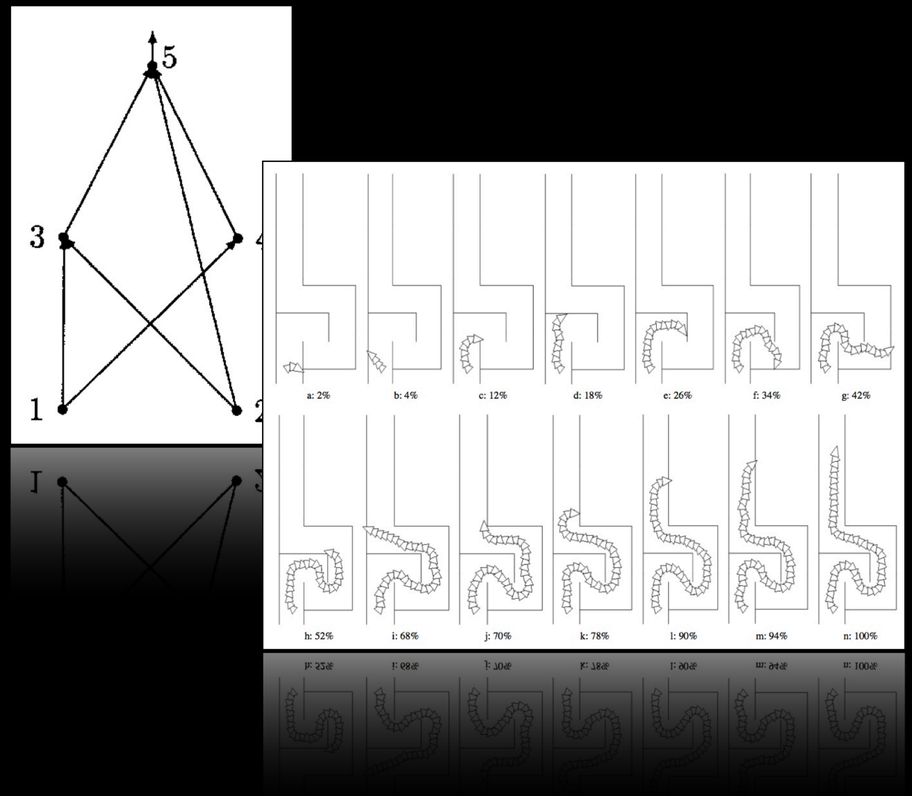
E. J. Hastings, R. K. Guha and K. O. Stanley. Automatic Content Generation in the Galactic Arms Race Video Game. IEEE Transactions on Computational Intelligence and AI in Games, 2009.

Uncertainty

- Noise
- Robustness
- Approximation
- Dynamic Problem

Noise

- Noisy objective function evaluation
- **Same** evaluation, **different** values
  - Genotype v.s. phenotype
  - Environment/Sensor noise

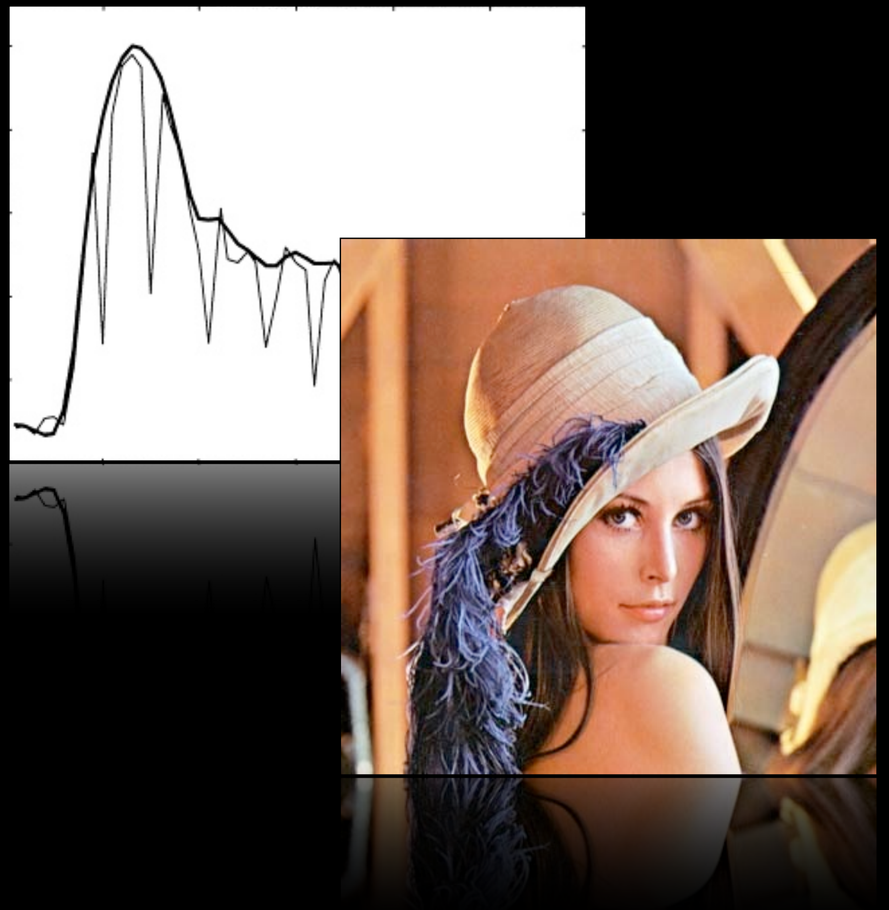


Robustness

- Variations of the **design variables**
- Variations of the **environment**

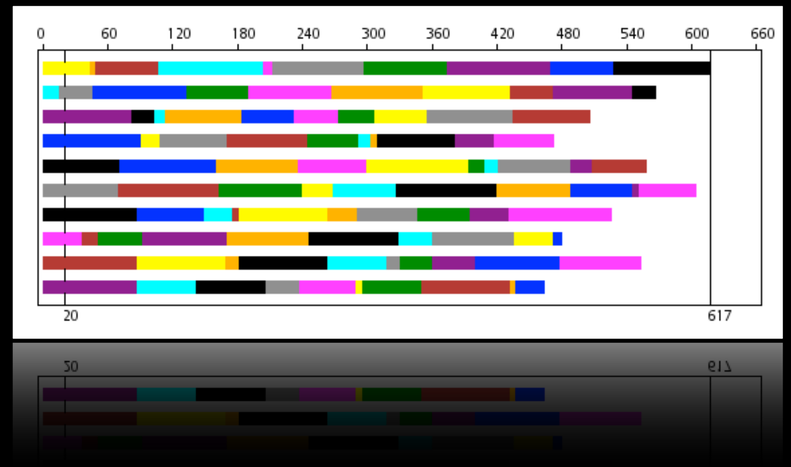
Approximation

- Objective function is an **approximation** of the real problem
- Evaluation is time-consuming
- No real fitness available
- Additional evaluation necessary
- Rugged fitness landscape



Dynamic Problem

- Optimum moves **during** optimization
  - Environment
  - Objectives
  - Representation
- Linear/non-linear motion
- Oscillation
- Random jumps



Uncertainty in Games

- Affects the quality of content/agent
- Sources?

Uncertainty in Games

- Affects the quality of content/agent
- Sources:
  - Player
  - Sensors
  - Dynamic virtual environment
  - Complex virtual environment
  - Slow execution

Examples

- Automatic Camera Control
- Experience Driven Procedural Content Generation
- Simulation Based Optimization

Example 1: Automatic Camera Control

Virtual Camera

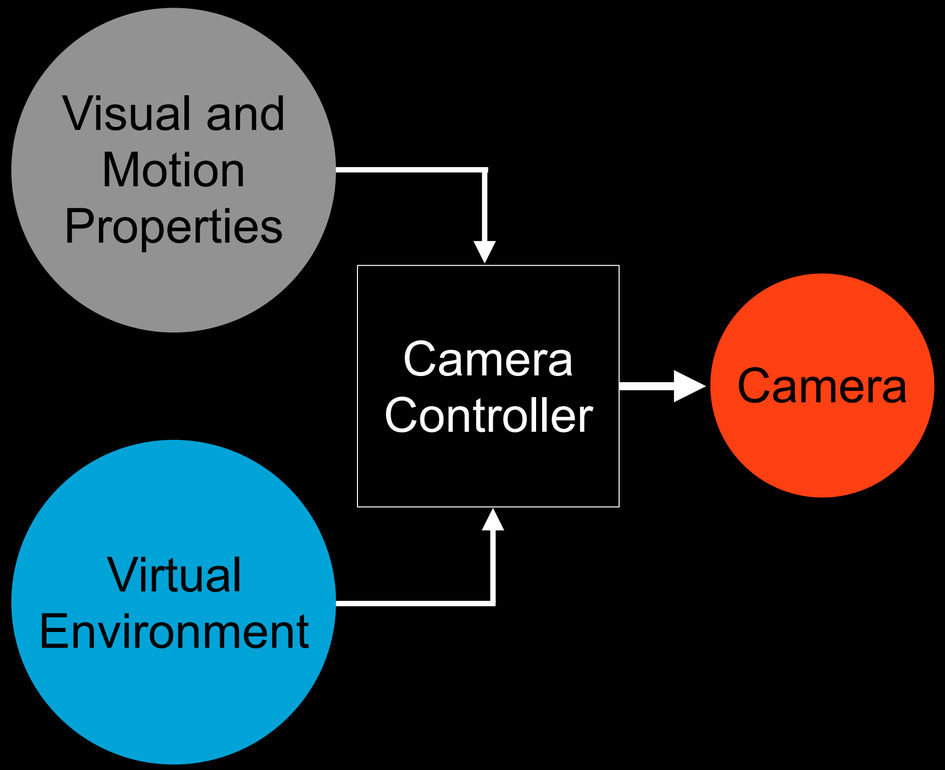
Camera

Action

Frame

Automatic Camera Control

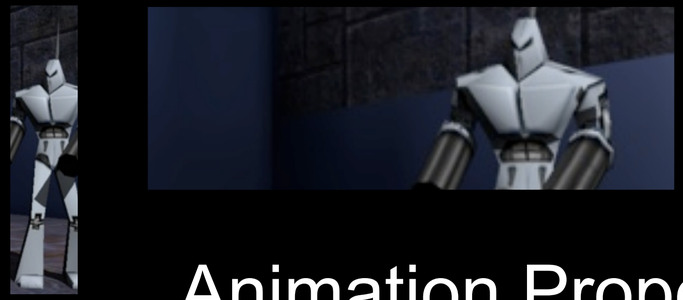
- **Abstraction** Layer
- High Level **Properties**
- Automatic **Configuration**
- Automatic **Animation**



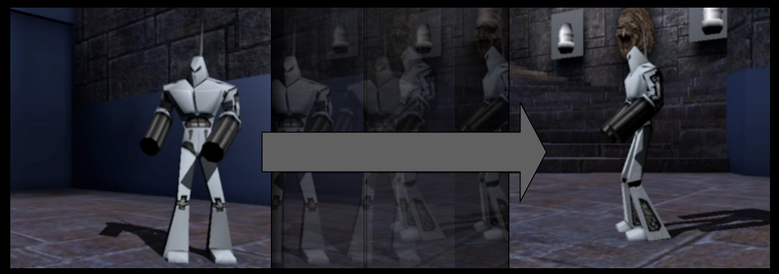
Inputs

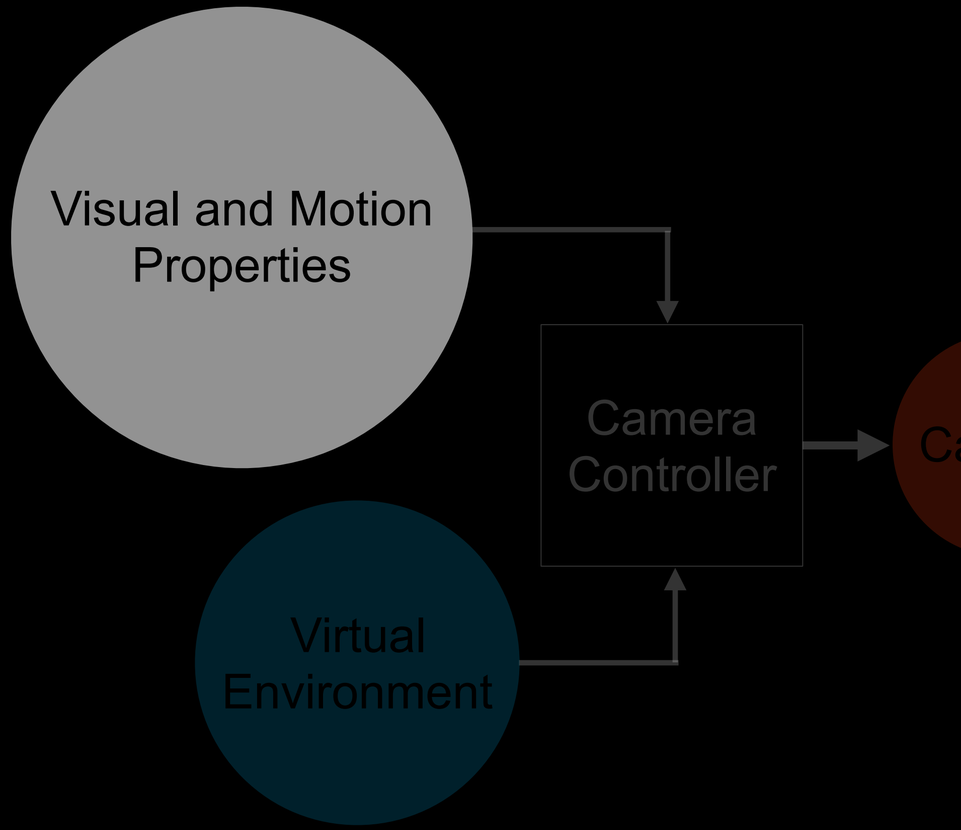
Composition Properties

Camera Properties



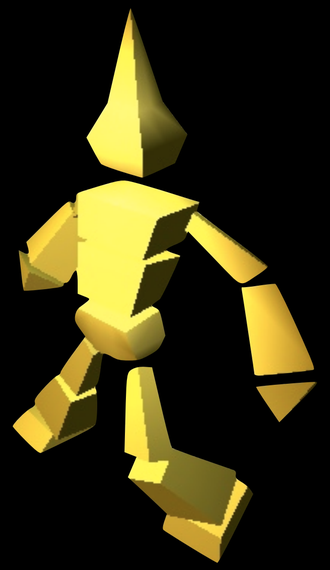
Animation Properties



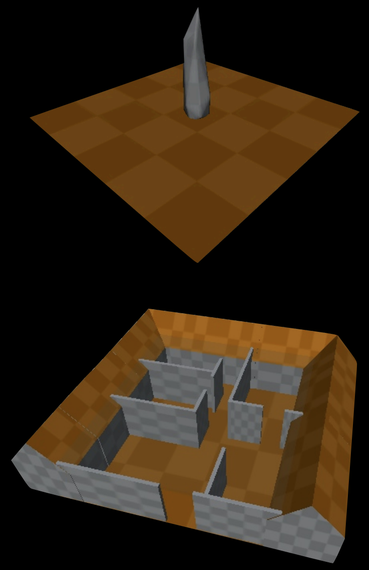


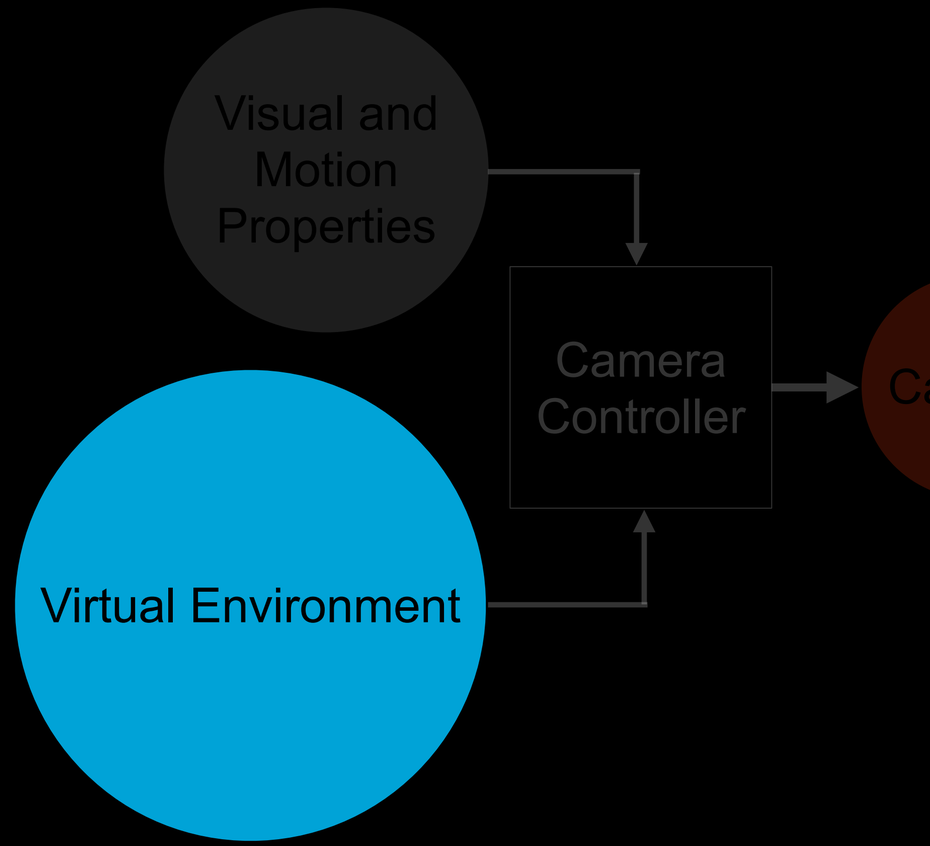
Inputs

Subjects

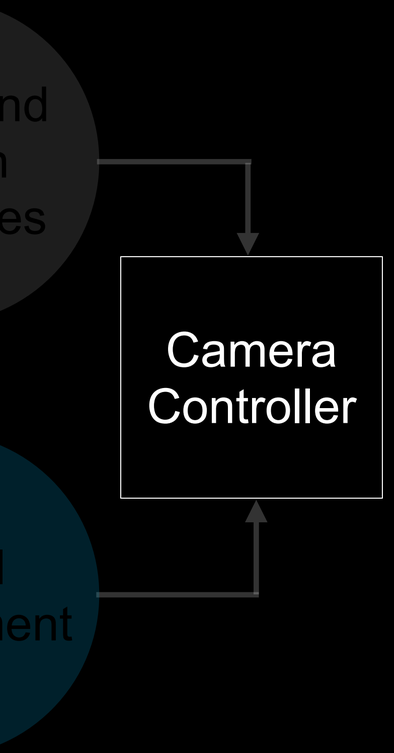


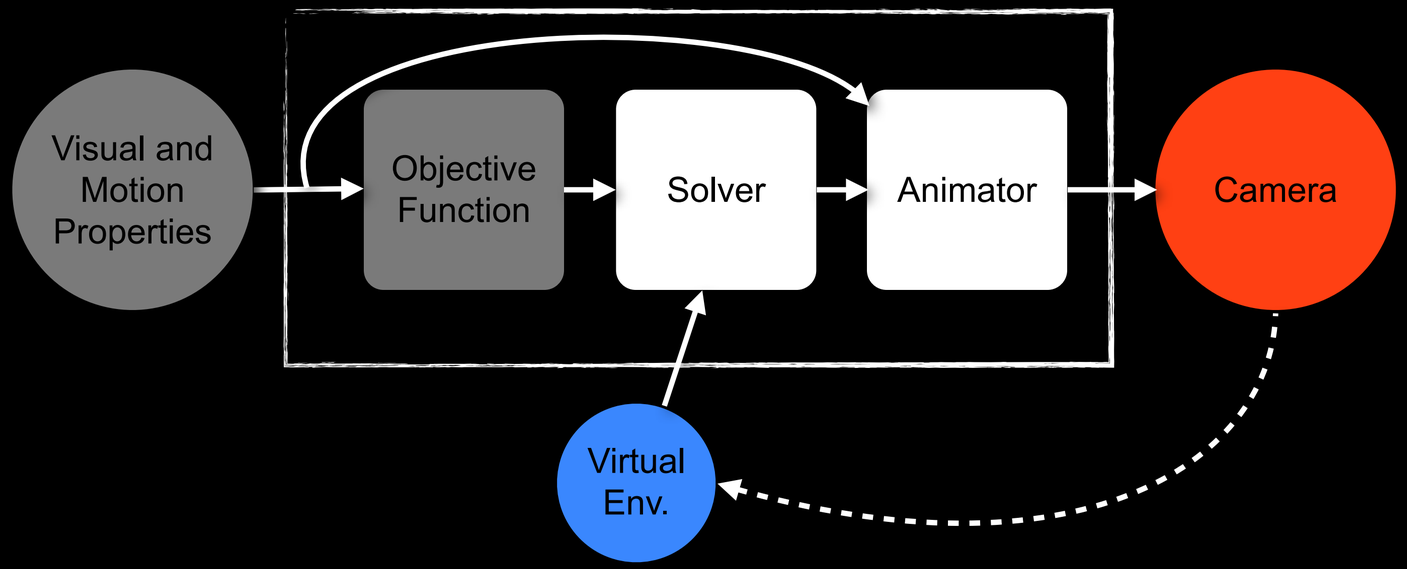
Environment Geometry



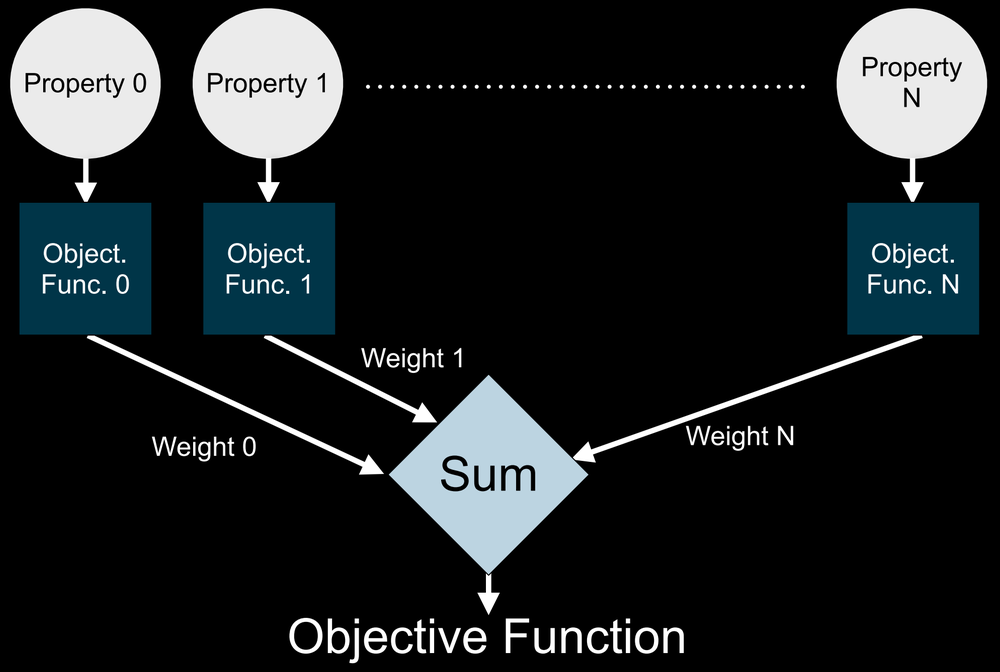


CamOn


Camera
Controller


Visual and
Motion
Properties
Objective
Function
Solver
Animator
Camera
Virtual
Env.

Objective Function



Objective Function: Properties

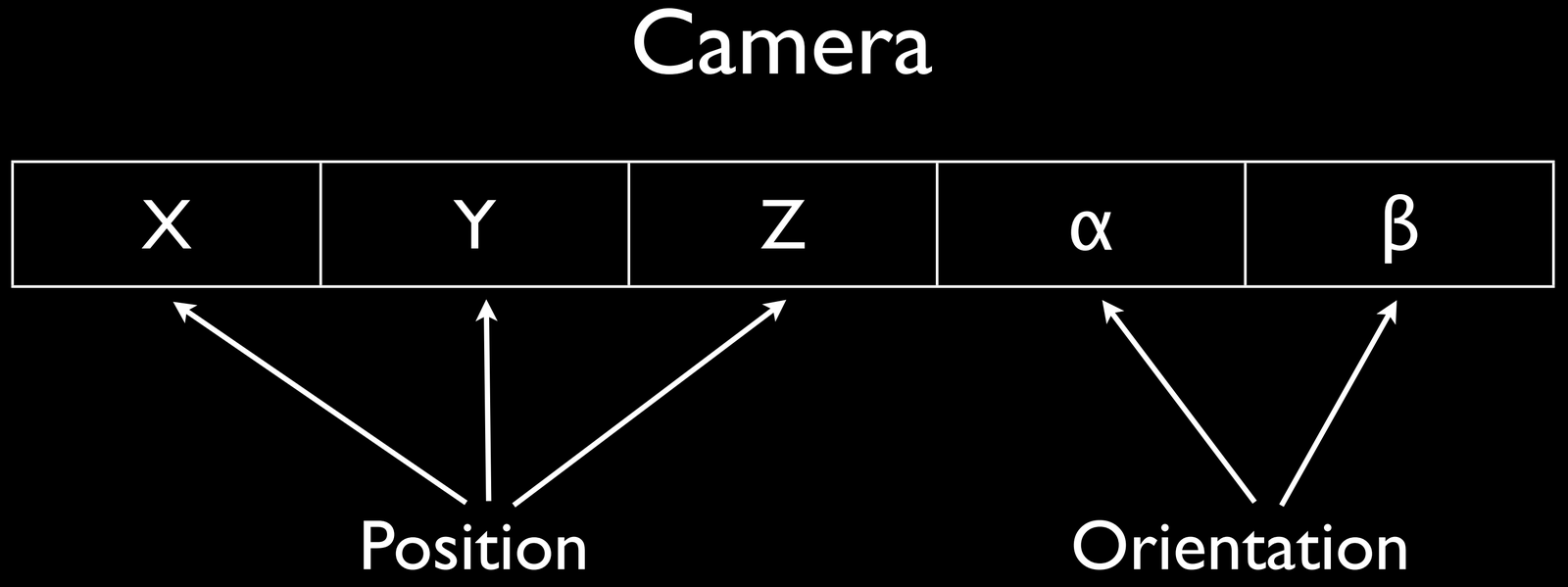
Visibility

Vantage Angle

Projection Size

Frame Position

Objective Function: Domain



Main source of uncertainty?

Main source of uncertainty: Dynamic Problem

Dynamic Problem

- Subjects and other objects move in the virtual space
- The frame properties might change
- The geometry of the subjects might change

Possible Solution

- **Restart**

Possible Solution

- **Restart**
- Simple

Possible Solution

- **Restart**
- Simple
- No time

Possible Solution

- **Restart**
- Simple
- No time
- Waste of information

Possible Solution

- **Restart**
- Simple
- No time
- Waste of information
- Might be the only solution

Challenges

Information Reuse

how to store and reuse information about the landscape?

Population Diversity

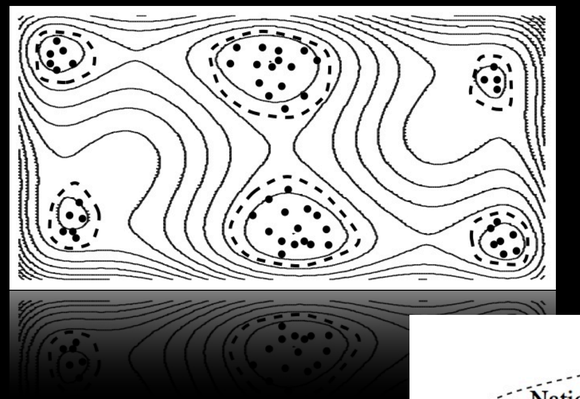
how to avoid premature population convergence?

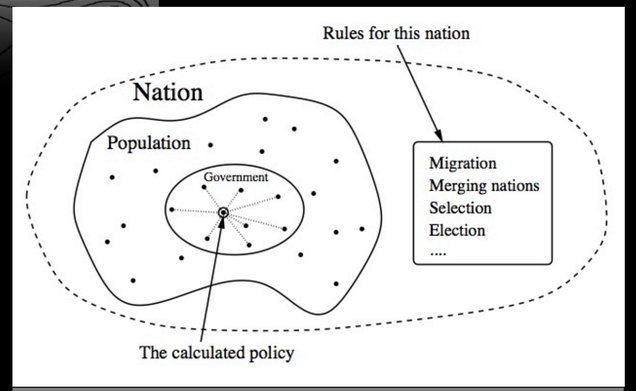
Information Reuse

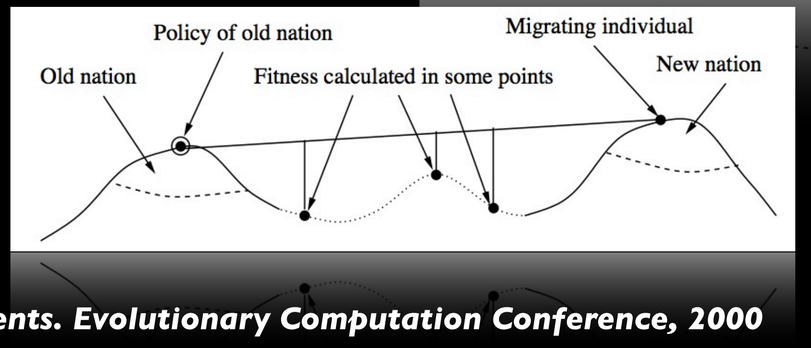
- Explicit memory
  - Data structure: landscape fingerprint, optima
  - Ruse part of the population
- Implicit memory
  - Multiploidy/Diploidy
- Information validity
  - Generational

Population Diversity

- Diversity after change
  - Hypermutation
  - Variable local search
- Diversity throughout the optimization
  - Random immigrants
- Multiple populations



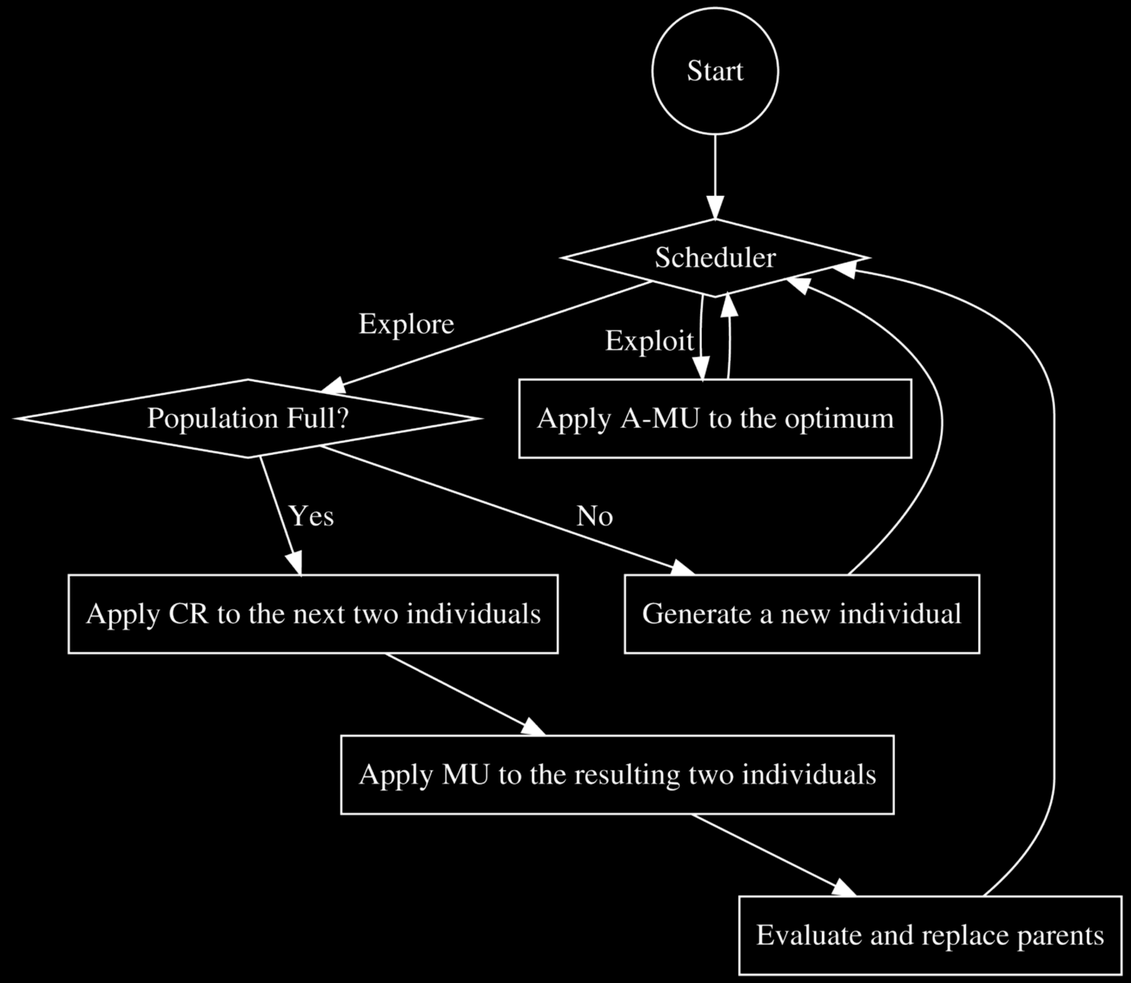




Rasmus K. Ursen. Multinational GAs: Multimodal optimization techniques in dynamic environments. Evolutionary Computation Conference, 2000

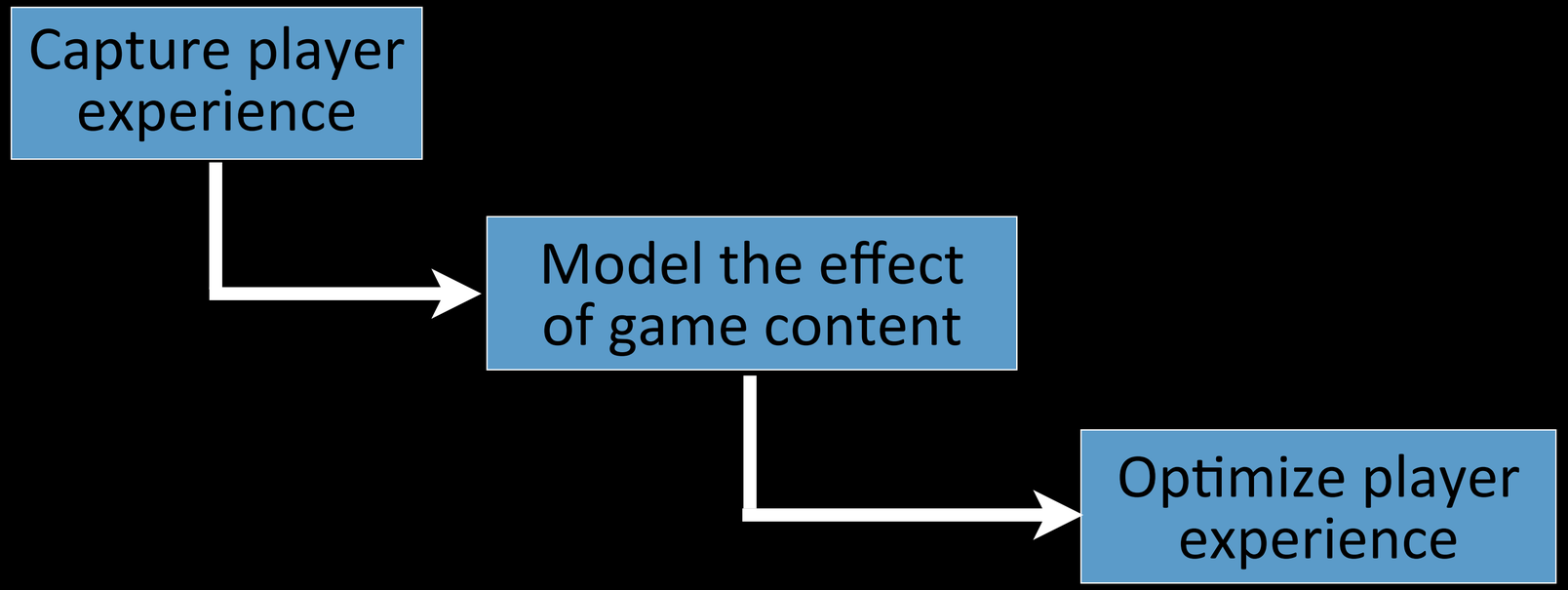
Hybrid Genetic Algorithm

- Hybrid Lamarckian-Darwinian evolution
- Explore if early convergence
- Early convergence if:
  - No improvement for one frame
  - Complete occlusion



Example 2: Experience Driven Procedural Content Generation

EDPCG



Georgios N. Yannakakis and Julian Togelius. Experience-driven procedural content generation. IEEE Transactions on Affective Computing, 2011.

Challenges

- How to capture **Player Experience**?
- How to evaluate the **quality** of content?
- How to **optimize** game content for Player Experience?

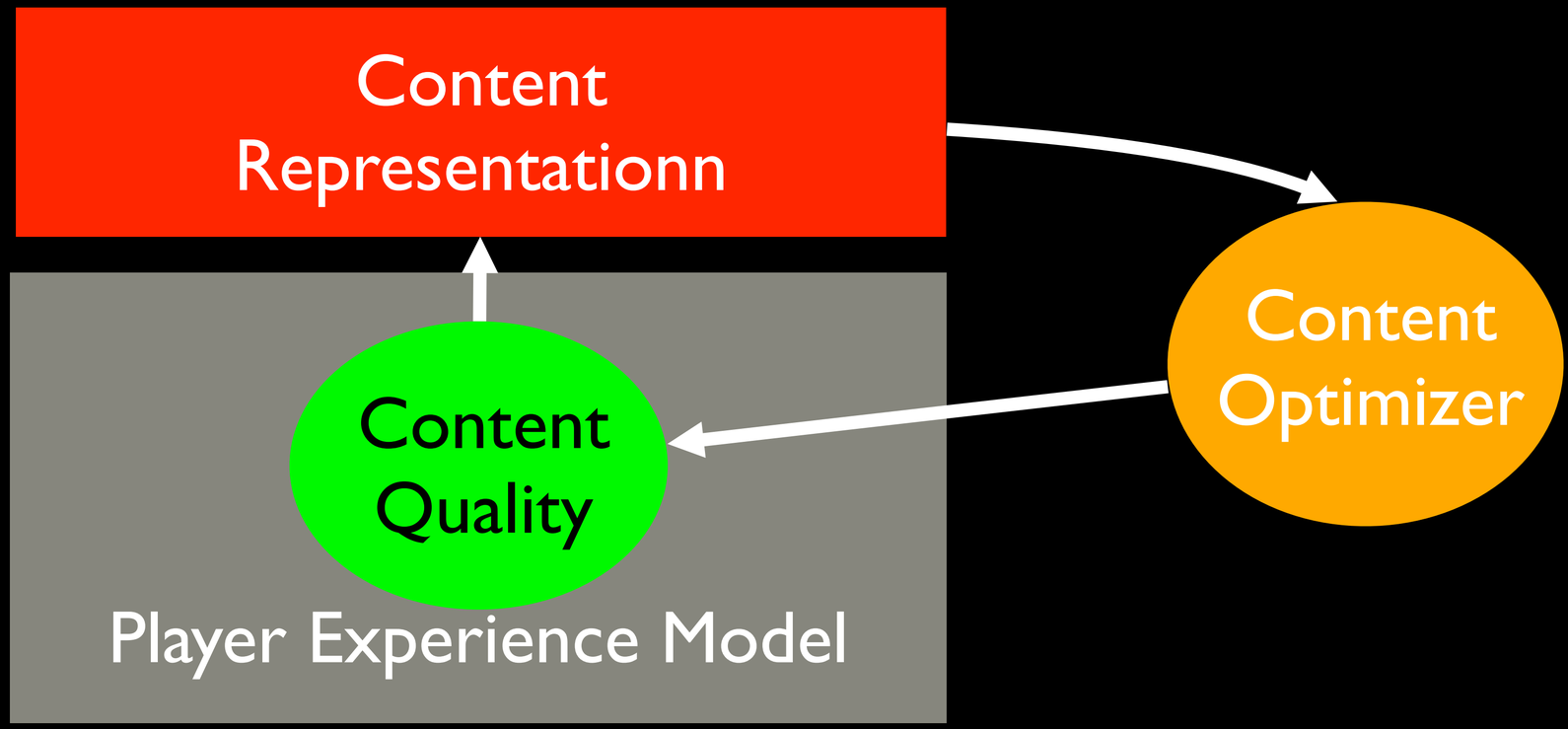
Capturing Player Experience

- Subjectively
  - Asking players: self-report questionnaires (ranking, preferences)
- Objectively
  - Physiology (GCR, EEG, EMG, BVP,…); eye-tracking; facial expression; speech
- GamePlay-Based
  - Player game preferences (what players do relates to their experience)

Content Quality

- Direct utility/fitness
  - A direct mapping between content and quality; e.g. number of jumps in a platform game
- Simulation-based
  - An AI agent (human-like?) plays the game for a while and content is evaluated through playing style
- Interactive fitness
  - Real-time evaluation via a player or players

Optimize Content



Main sources of uncertainty?

Main sources of uncertainty: Noise, Robustness

Noise

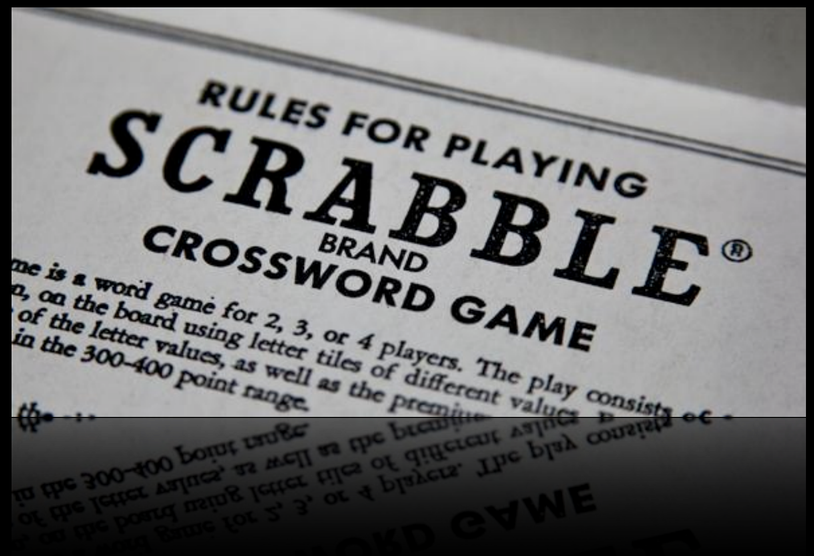
Dealing with Noise

- Explicit average
  - Multiple samples per evaluation
  - Average with neighborhud
  - Interpolation
- Implicit average
  - Increase population size
- Selection scheme
  - Threshold for selection
- Noise might be useful...

Sandor Markon, Dirk V. Arnold, Thomas Back, Thomas Beielstein and Hans–Georg Beyer. Thresholding – a Selection Operator for Noisy ES, IEEE Congress on Evolutionary Computation, 2001

Robustness

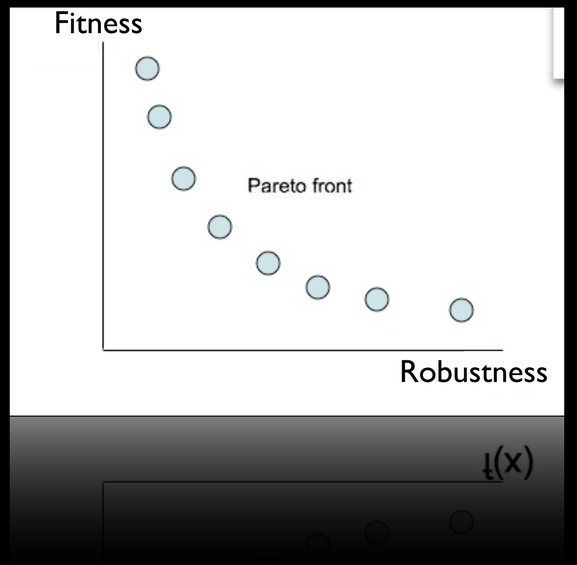

I'VE
CHANGED
MY MIND


RULES FOR PLAYING
SCRABBLE®
BRAND
CROSSWORD GAME

Dealing With Robustness

- Optimizing Expected Fitness
  - Average in the neighborhood
  - Average with similar previous values
  - Add noise and increase population
- Multi-Objective Optimization
  - Fitness v.s. Robustness
  - Measure of robustness

$$\text{Robustness measure 2: } f_j^R = \frac{\sigma_{f,j}}{\bar{\sigma}_{\boldsymbol{x},j}},$$

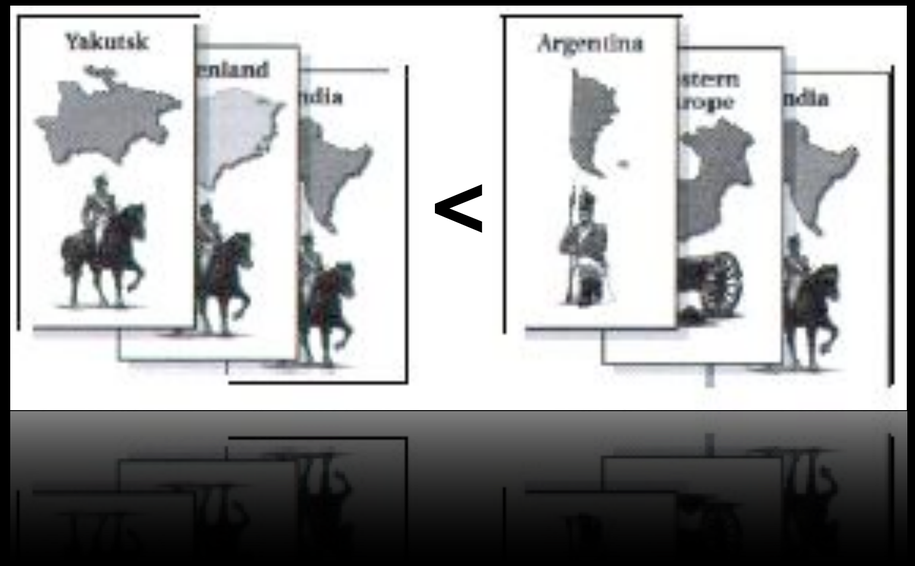


Yaochu Jin and Bernhard Sendhoff. Trade-off between Performance and Robustness: An Evolutionary Multiobjective Approach. Evolutionary Multi-Criterion Optimization, 2003

Example 3: Simulation Based Optimization

Evolving Strategy Game Units

- Objective: complementarity
- Balanced units sets stronger than unbalanced ones



Tobias Mahlmann, Julian Togelius and Georgios N. Yannakakis. Towards Procedural Strategy Game Generation: Evolving Complementary Unit Types. European Conference on Applications of Evolutionary Computation, 2011.

Problem Characteristics

- 21 attributes in the gene
- Objective function based on 6 matches player 200 times
- 1 minute per evaluation

Time Consuming Evaluation

- Long experimental time
- No possible “real-time” execution
- Applies also to agent learning

Main source of uncertainty: Approximation

Motivations

- Time consuming evaluation
- No available analytical fitness
- Noise Reduction
- Rugged landscape
- Smart population initialisation

Approximation Methods

- Simplified simulation
- Data-driven functional approximation
- Evaluations reduction
  - Fitness inheritance
  - Fitness imitation
  - Fitness assignment

Dealing With Approximation

Combine approximated function with real-function

Individual Based Control

- Random
- Best
- Most uncertain
- Most representative

Generation Based Control

Whole population every N generations

Jürgen Branke and Christian. Faster convergence by means of fitness estimation. Soft Computing, 2005

Future Work

- Experiment these techniques in games
- Use games as a benchmark for uncertainty
- Other forms of uncertainty?

References

- *Erin J. Hastings, Ratan K. Guha and Kenneth O. Stanley. Automatic Content Generation in the Galactic Arms Race Video Game. IEEE Transactions on Computational Intelligence and AI in Games, 2009.*
- *Paolo Burelli. Interactive Virtual Cinematography. IT University Of Copenhagen, 2012*
- *Rasmus K. Ursen. Multinational GAs: Multimodal optimization techniques in dynamic environments. Evolutionary Computation Conference, 2000*
- *Georgios N. Yannakakis and Julian Togelius. Experience-driven procedural content generation. IEEE Transactions on Affective Computing, 2011.*
- *Sandor Markon, Dirk V. Arnold, Thomas Back, Thomas Beielstein and Hans–Georg Beyer. Thresholding – a Selection Operator for Noisy ES, IEEE Congress on Evolutionary Computation, 2001*
- *Yaochu Jin and Bernhard Sendhoff. Trade-off between Performance and Robustness: An Evolutionary Multiobjective Approach. Evolutionary Multi-Criterion Optimization, 2003*
- *Tobias Mahlmann, Julian Togelius and Georgios N. Yannakakis. Towards Procedural Strategy Game Generation: Evolving Complementary Unit Types. European Conference on Applications of Evolutionary Computation, 2011.*
- *Jürgen Branke and Christian. Faster convergence by means of fitness estimation. Soft Computing, 2005*
- *Jürgen Branke and Yaochu Jin. Evolutionary Optimization in Uncertain Environments. IEEE Transaction on Evolutionary Computation, 2005*

EvoGAMES 2013

Bio-inspired Algorithms in Games

Submission deadline: 1 November 2012

Vienna, 3-5 April 2013

Thank you! Questions?