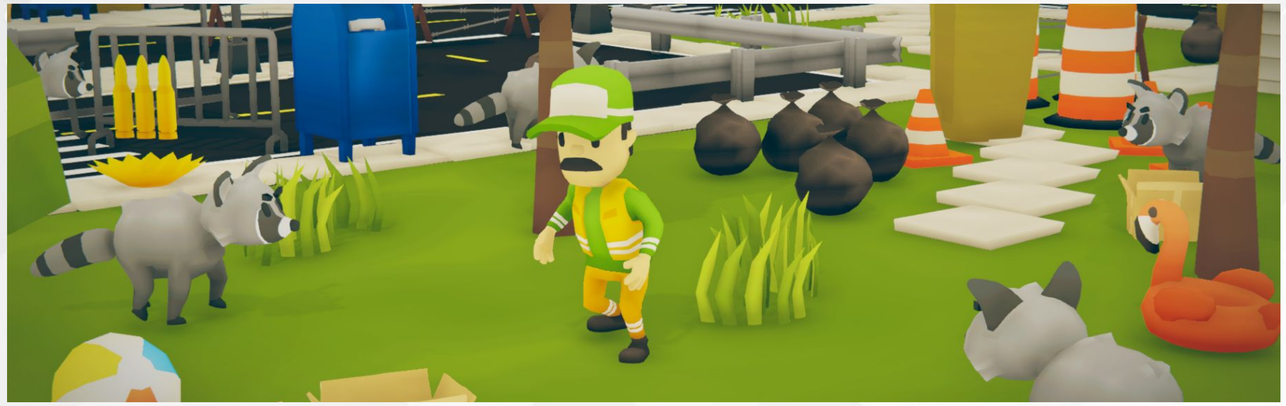


Emergent Personalized Content in Video Games

Simone Guggiari

April 17th, 2019

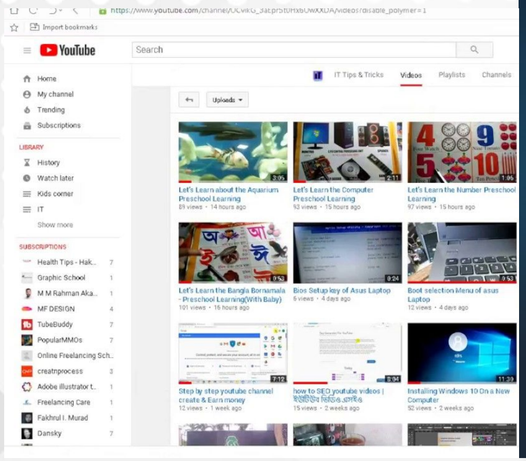
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

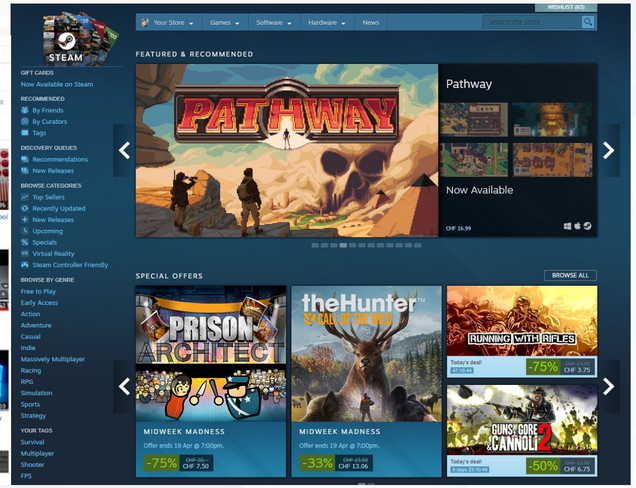
Prof. Dr. Robert W. Sumner
Dr. Fabio Zünd
Henry Raymond

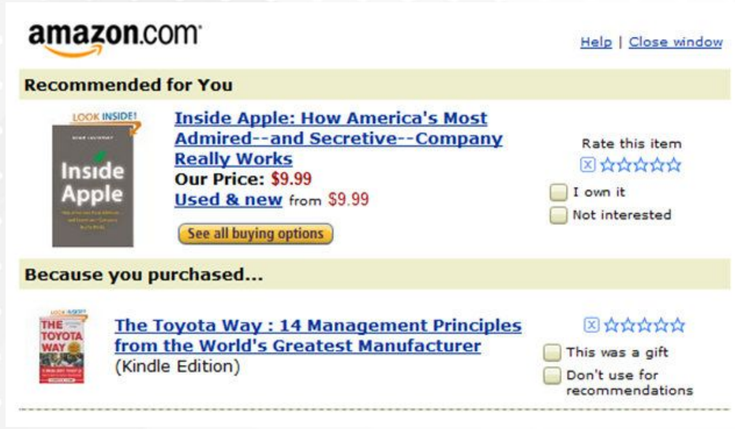
Game Technology Center

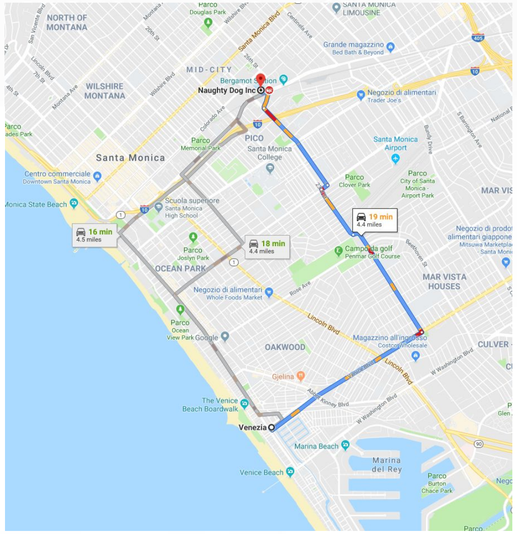
TOWARDS PERSONALIZATION

- **Data collection**
  - Amazon
  - Netflix
  - Google (e.g. maps, youtube)
  - Steam (“your” store)
- **Uses**
  - Predict purchases
  - Increase time on platform
  - Sell data
  - Enhance service
- **Content personalization**
  - Improve experience





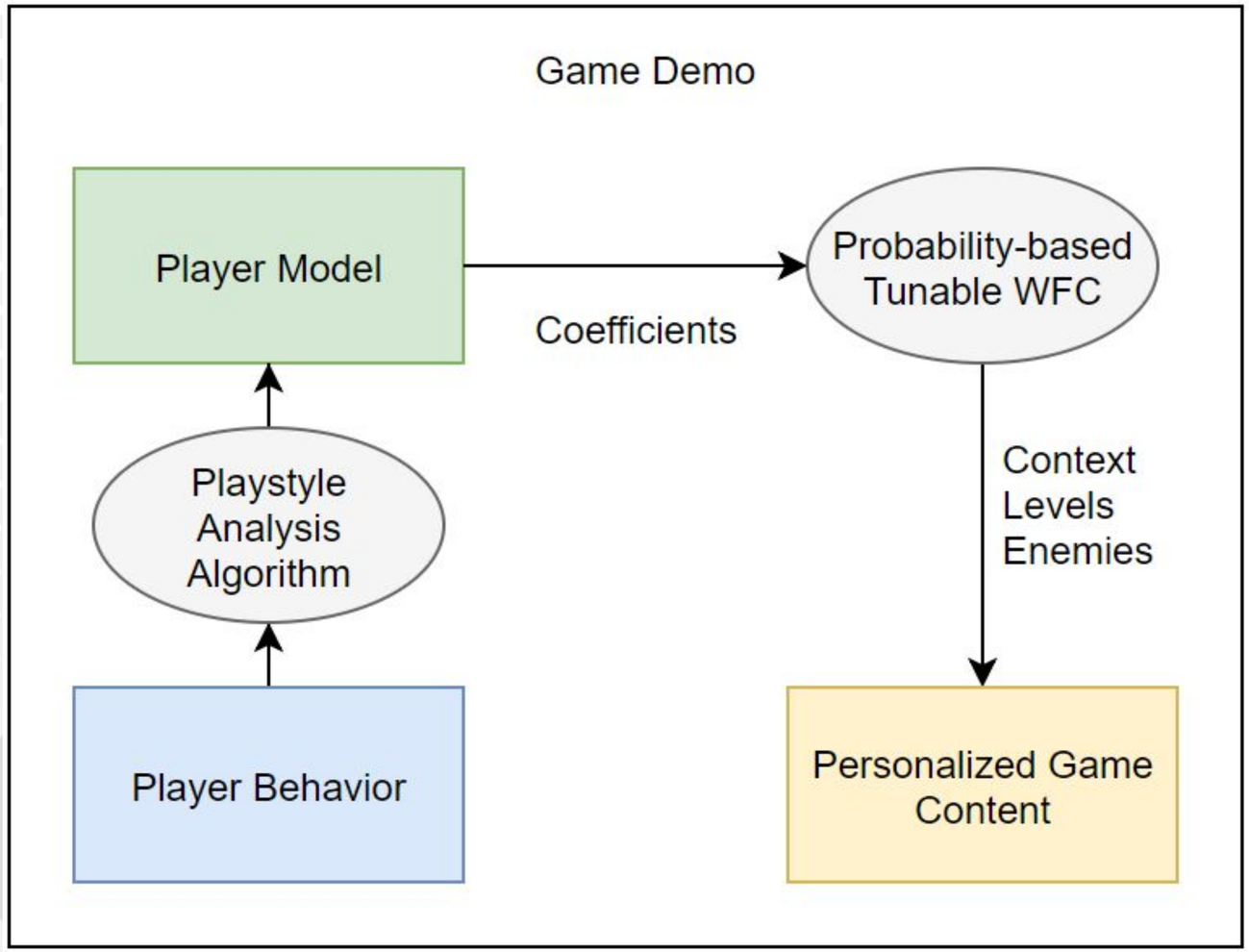




VISION

- **Video games**
  - interactive by nature
  - designers shape it
- **Use data**
  - infer models
  - improve experience
- **Adaptation**
  - Dynamic change at runtime
  - Learn preference
  - Players influence
  - Tailored
- **Examples**
  - RTS
  - Action-adventure
  - FPS

IDEA


Game Demo
Player Model
Coefficients
Probability-based Tunable WFC
Playstyle Analysis Algorithm
Context
Levels
Enemies
Player Behavior
Personalized Game Content

PROBLEM STATEMENT

Develop an algorithm embedded in a video game that *adapts* to the users by collecting information about their playstyle and uses this information to generate *procedural*, *personalized levels*.

PRESENTATION OVERVIEW

RELATED WORK

- Research
- Commercial

ALGORITHM

- Player Encoding
- Content Generation
- Adaptation

GAME

- Early Framework
- Final Game

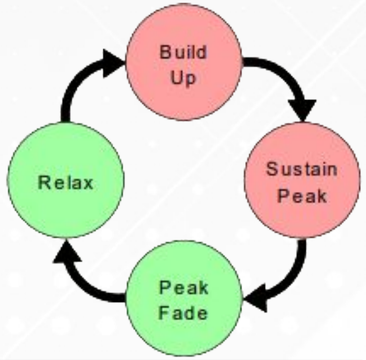
RESULTS

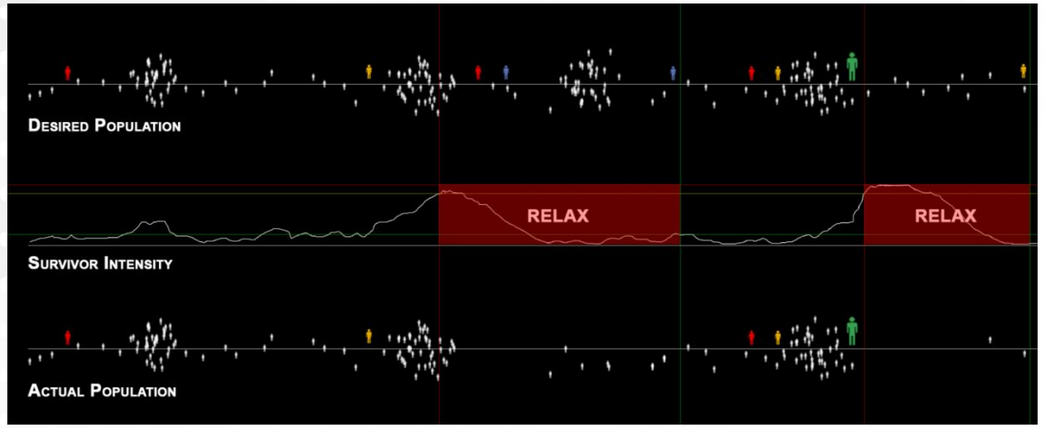
- Studies
- Insights

RELATED WORK

LEFT 4 DEAD

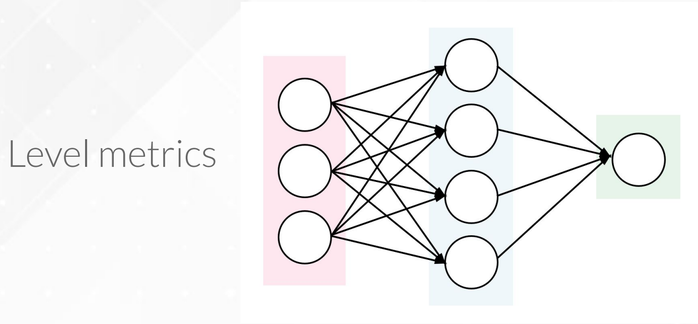
- **Goal: generate dramatic game pacing**
  - AI Director
- **Modulate action spikes**
  - Too frequent = exhausting
  - Too seldom = boring
- **Stress coefficient representation**
  - 1D value
- **Gameplay phases**
  - Build up
  - Sustain peak
  - Peak fade
  - Relax
- **Advantages**
  - Dynamic, personalized gameplay
  - Captivating, flow

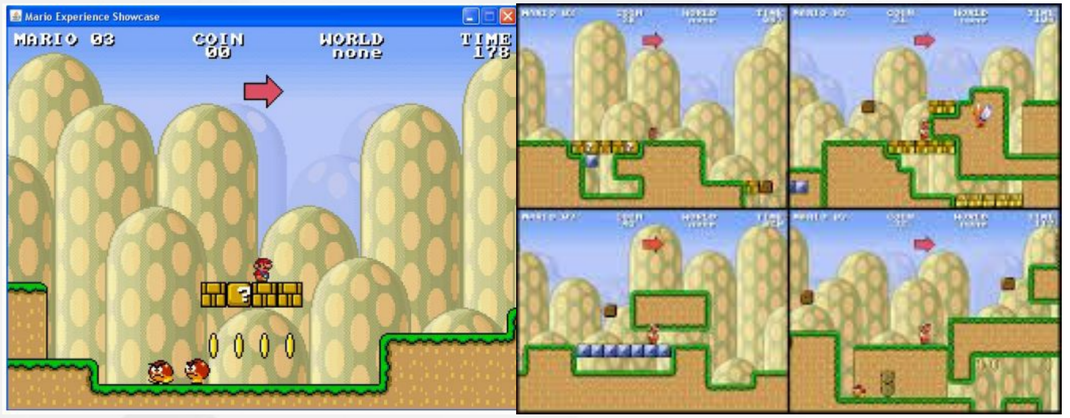


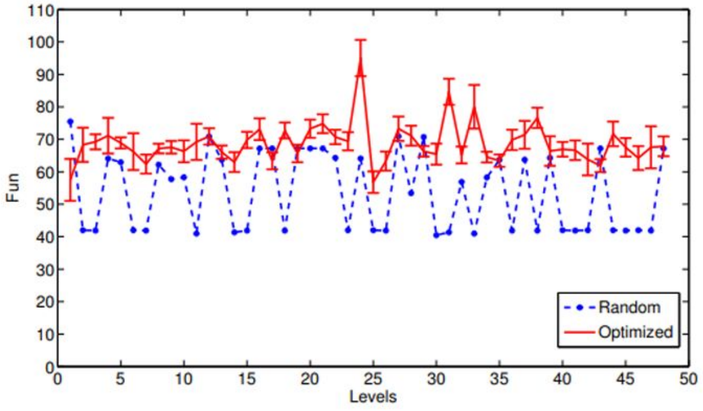


INFINITE MARIO BROS

- **Shaker, Yannakakis, Togelius (2010)**
  - Super Mario clone
  - Procedural levels
  - Adapt metrics
  - Maximize emotional state
- **Machine learning**
  - Multi-layer perceptron
- **Maximize fun**
  - Ask rating







PERSONALIZATION ALGORITHM

OVERVIEW

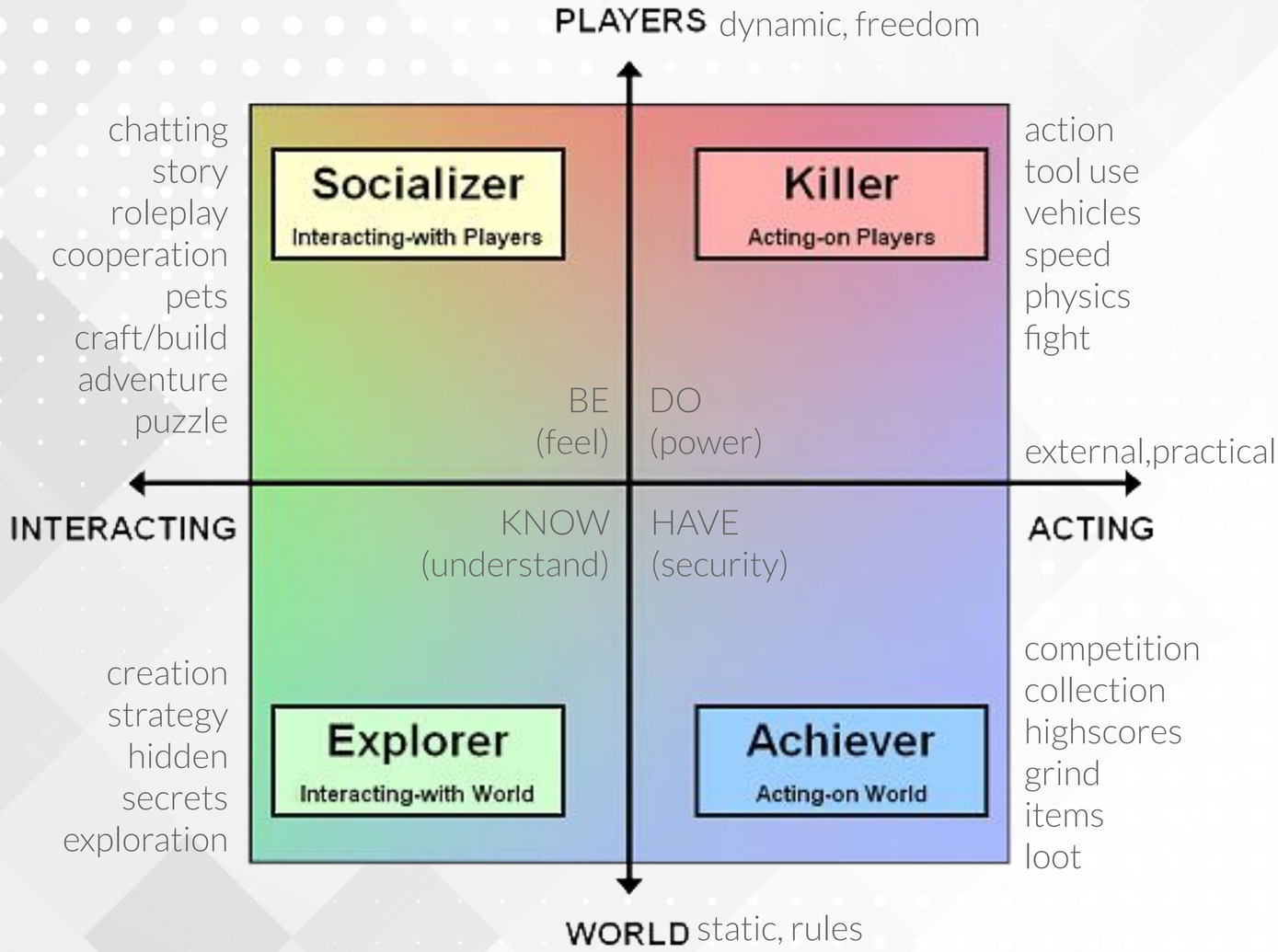
$$X \rightarrow P \rightarrow W \rightarrow L \rightarrow S$$

- Recorded metrics $x_{i,j} \in X$
- Player encoding $p_i \in P$
- Coefficients $w_j \in W$
- Level $l_j \in L$
- Satisfaction $s_j \in \mathbb{N}$

- Player model $\mathcal{C} : X \rightarrow P$
- Adaptation function $\mathcal{F} : P \rightarrow W$
- Generative algorithm $\mathrm{WFC} : W \rightarrow L$
- Rating function $\mathcal{R} : L \rightarrow S$

1 - PLAYER MODEL

BARTLE'S TAXONOMY



Music
Social
Simulation

chatting
story
roleplay
cooperation
pets
craft/build
adventure
puzzle

internal, deep,
theoretic

Adventure
Turn-based strategy
Platformer

creation
strategy
hidden
secrets
exploration

action
tool use
vehicles
speed
physics
fight

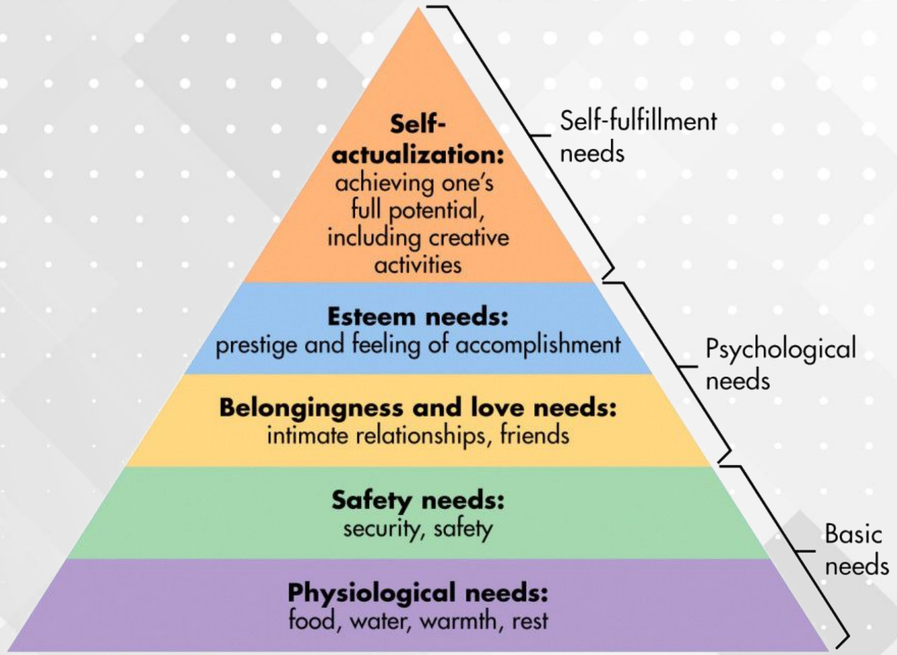
FPS
Action
Survival
RTS

MMORPG
RPG

competition
collection
highscores
grind
items
loot

GAMES AS NEEDS SATISFACTION

- Maslow's Hierarchy



Killer

Explorer

Socializer

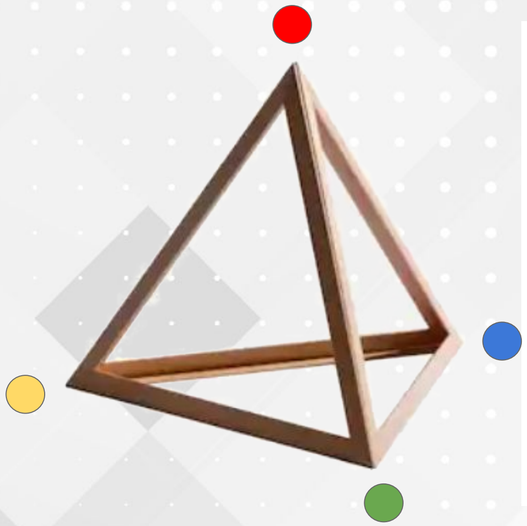
Achiever

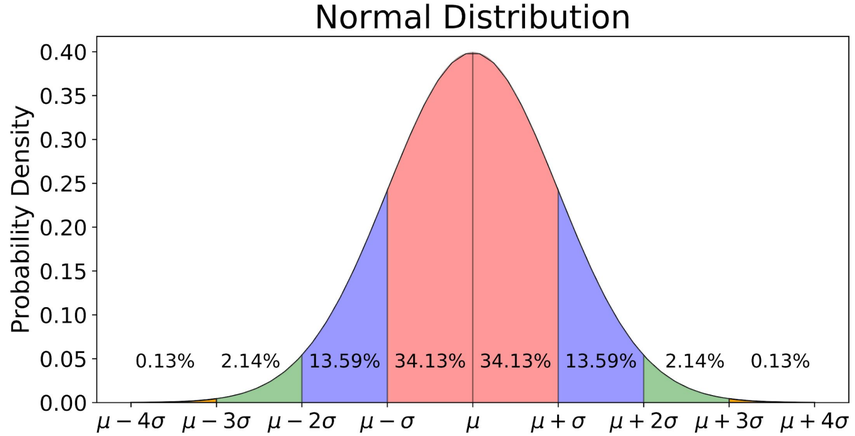
OUR MODEL

$$x_{i,j} = (k, a, e, s) \qquad X_i \subseteq X$$

- **Multi-dimensional vector**
  - Degree of membership
  - Extendible
  - Not mutually exclusive
- **Normal distribution**
  - Assumption
  - Extendible
  - Underlying game design μ
  - No direct mapping
  - Player agency
  - Deviation expressiveness σ

$$p_i = (\{-c, \frac{\mu_i - \mu}{\sigma}, c\} + c)/2c$$

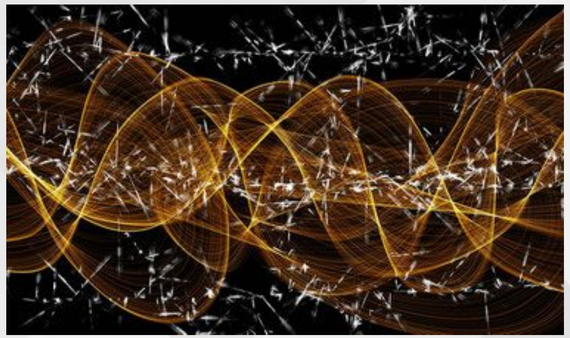




2 - CONTENT GENERATOR

CONTENT GENERATOR

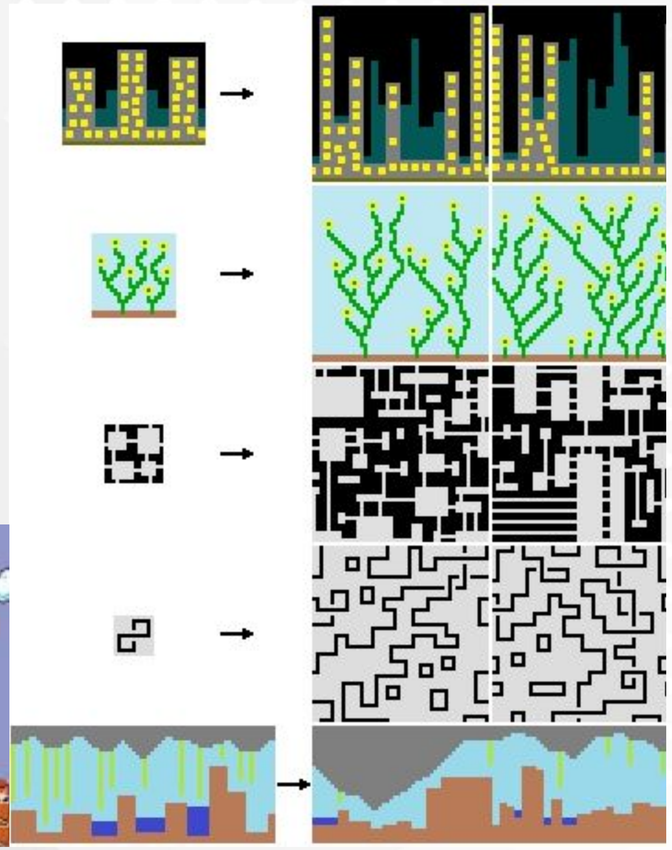
- **Procedural:**
  - Infinite content
  - Cheap
  - Adaptable
- **Constraints:**
  - General
  - Varied
  - Controllable
  - Fast
- **Wave Function Collapse**



WAVE FUNCTION COLLAPSE (WFC)

- **General-purpose content generator**
  - Maxim Gumin (2016)
  - Quantum mechanics
  - Bitmap generation
  - Wave, collapse
  - Constraint satisfaction model

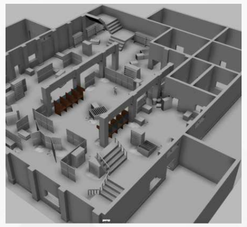
- **Locally similar bitmaps:**
  - C1: NxN patches found in input
  - C2 (weak): distribution should be similar

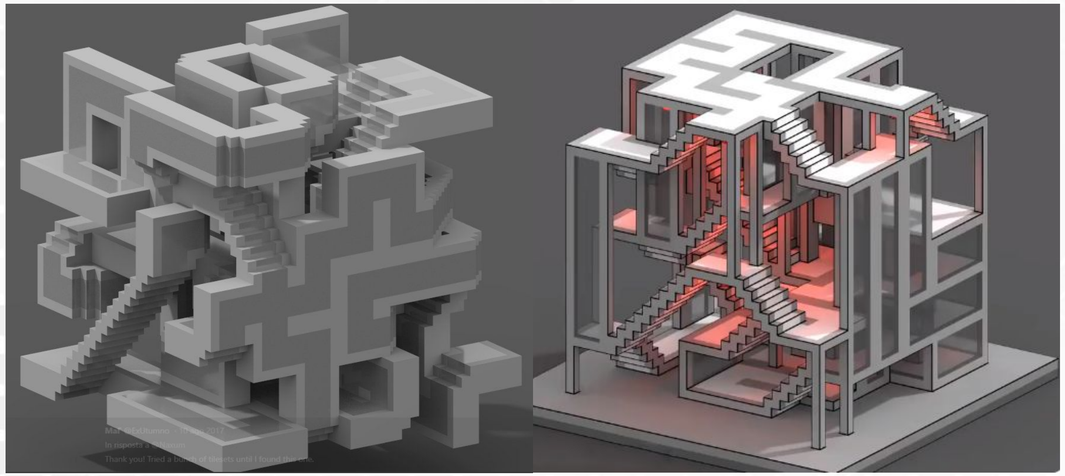


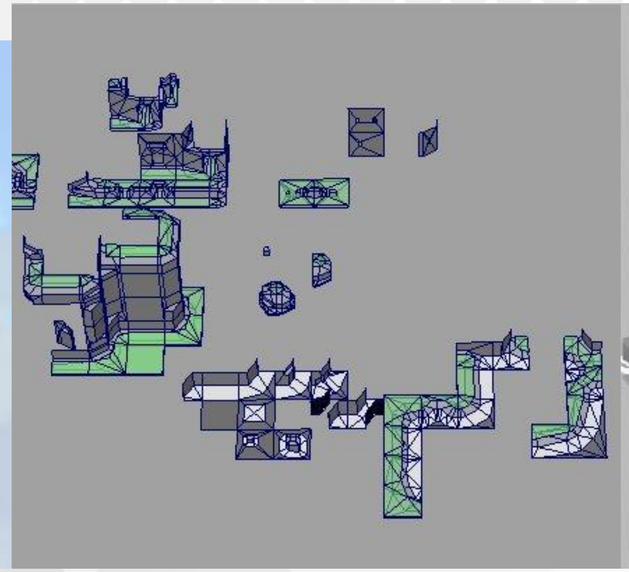
5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

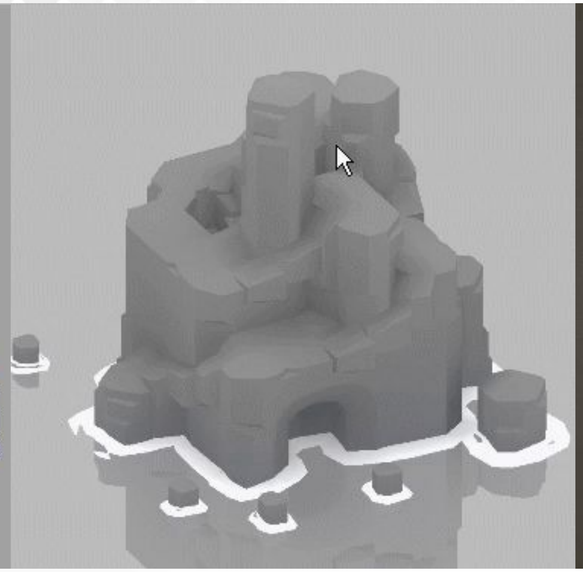
APPLICABLE TO 3D

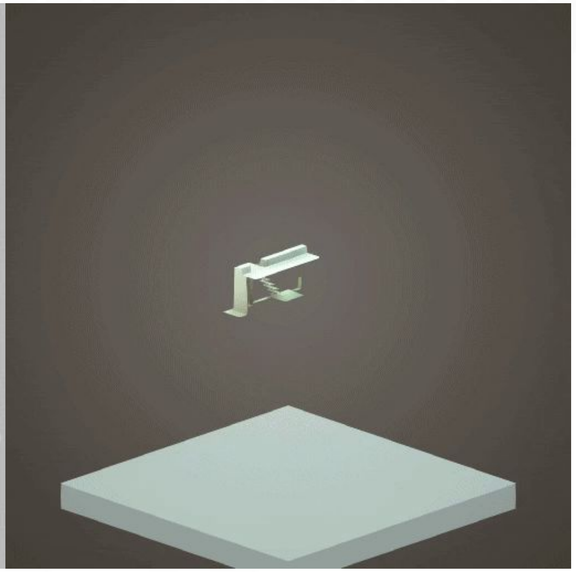
- Voxels
- Modules
  - Embed mesh in cube
- Any tileable level
  - Tileset
  - Distribution



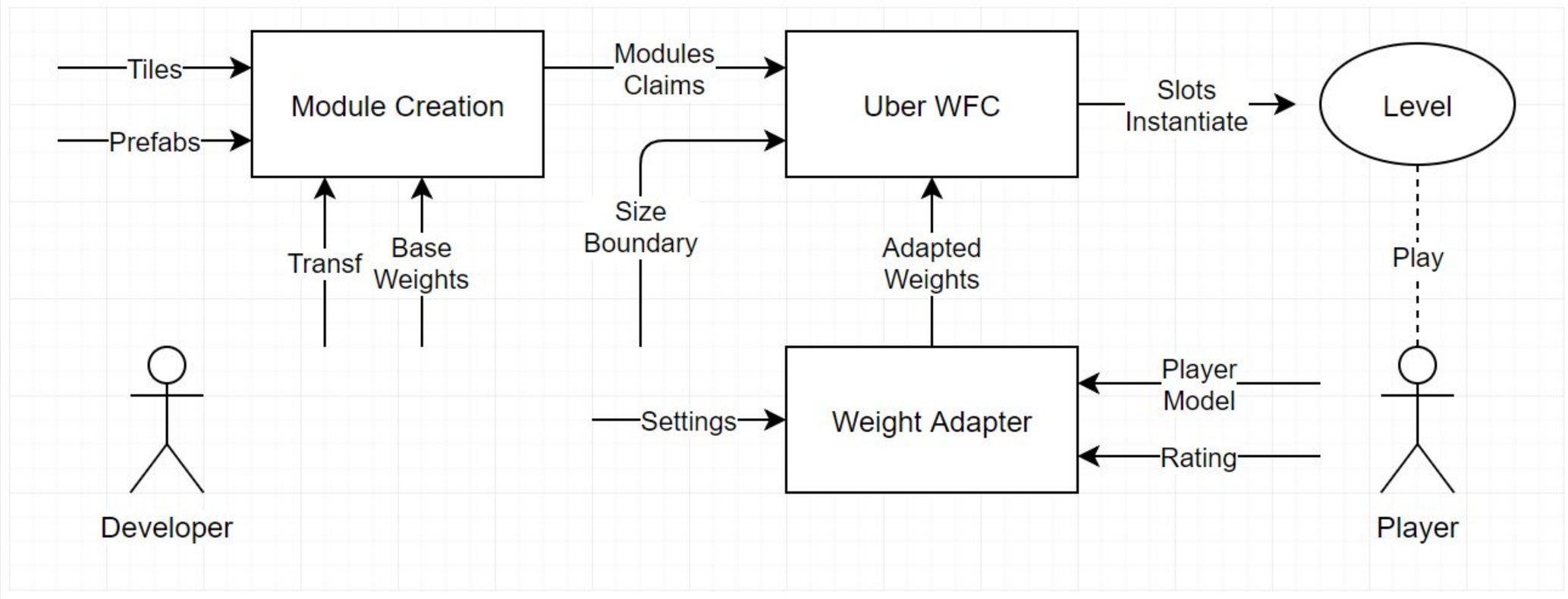






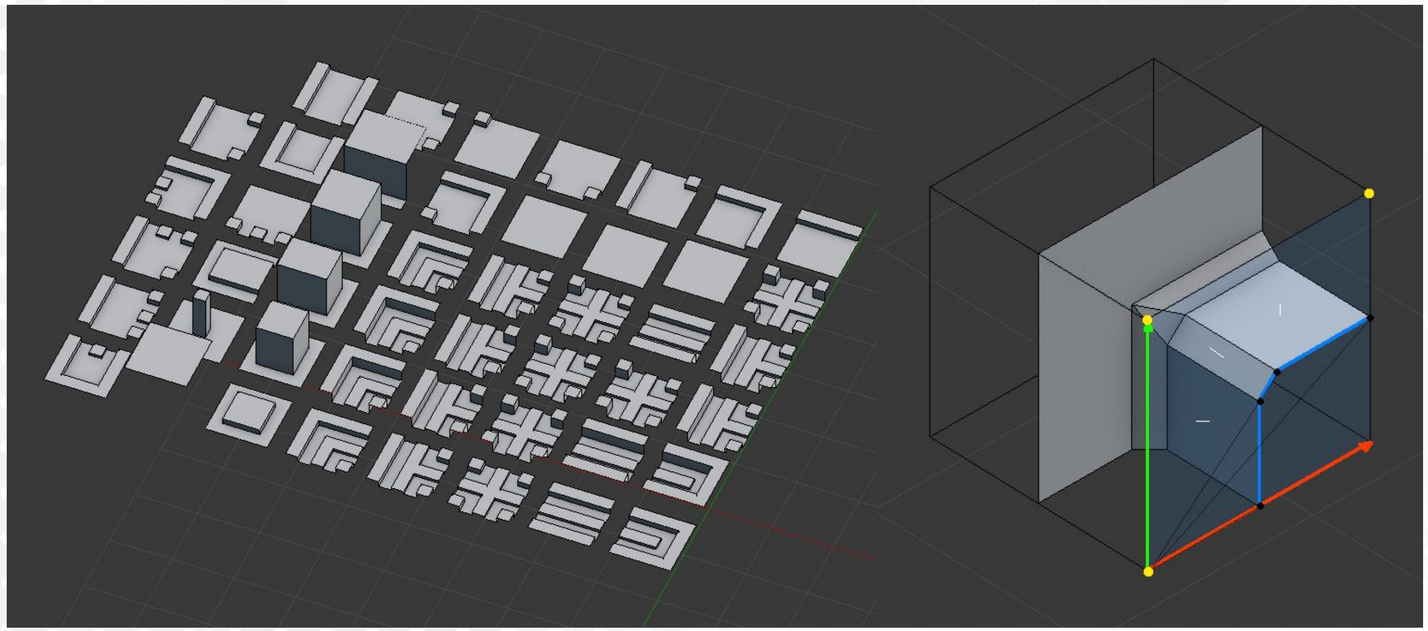


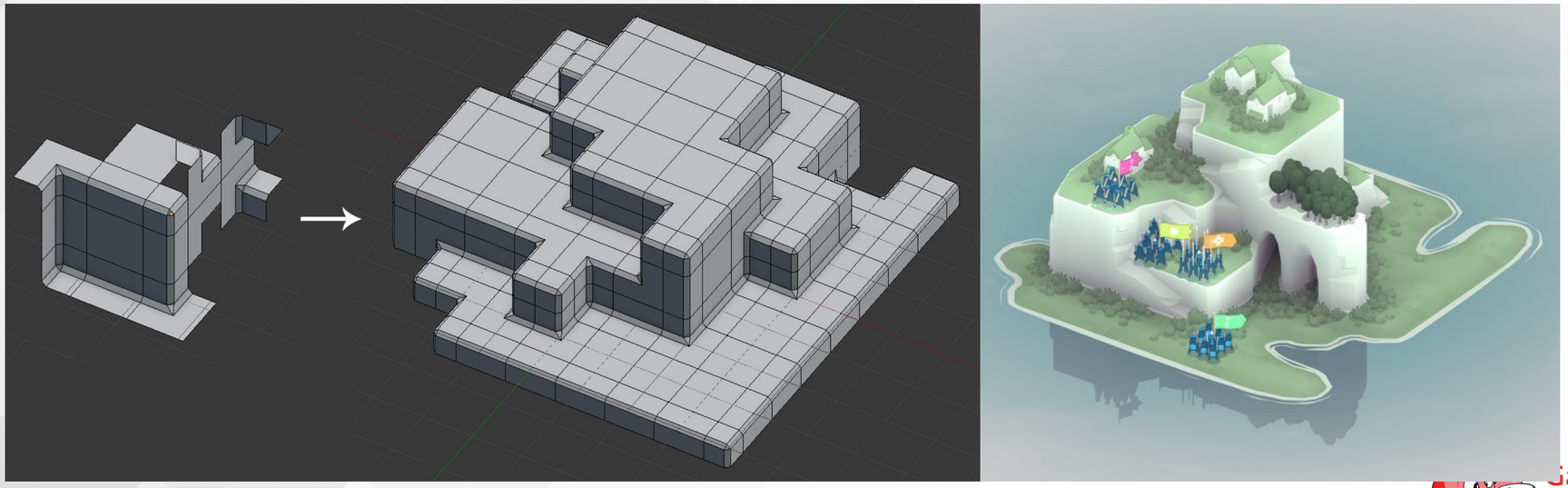
OUR GENERATIVE ALGORITHM



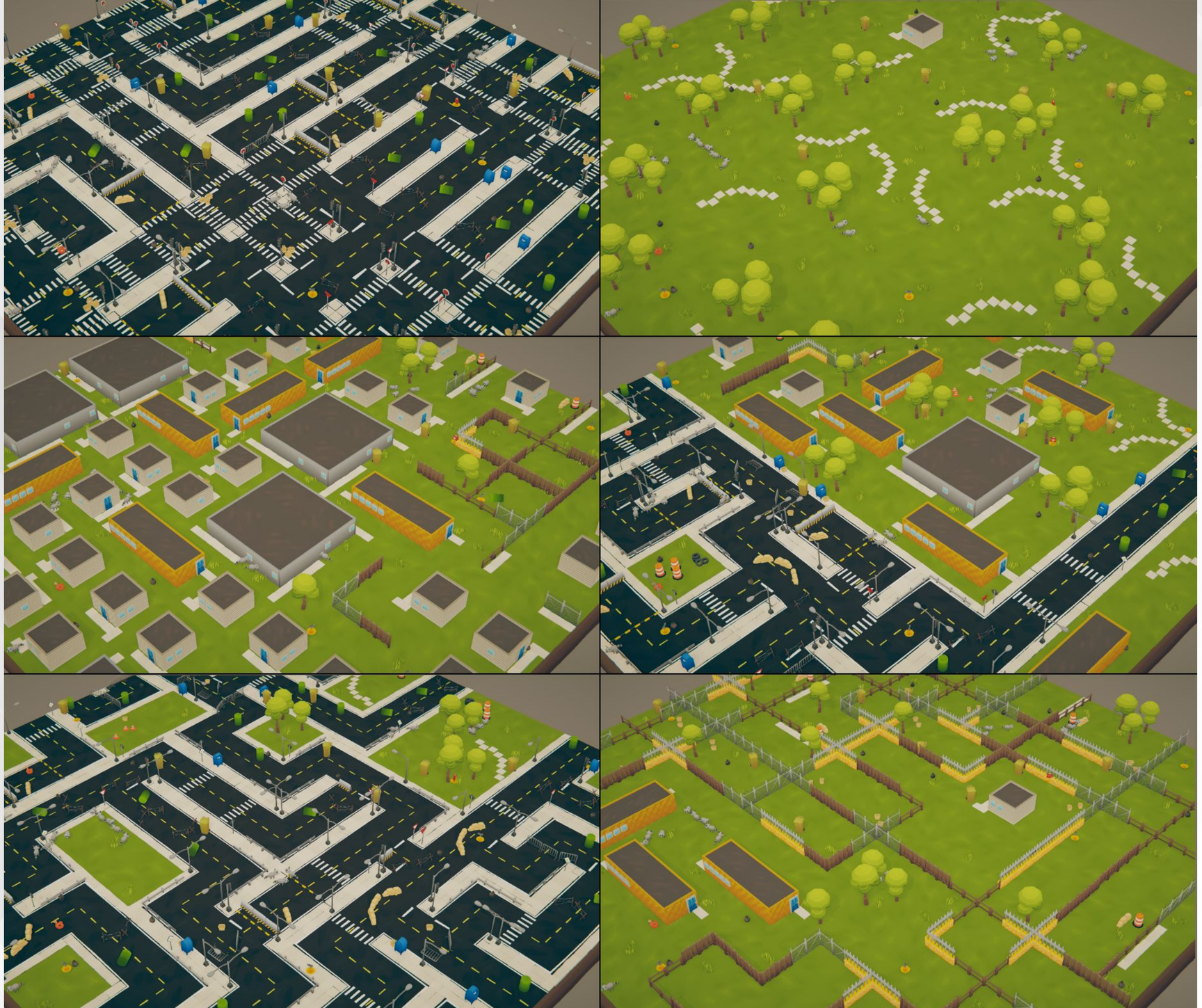
TILESETS

- **General**
  - Any tileable level
  - No code change
- **Input**
  - Tileset
  - Distribution
- **Hash**
  - Automatic
  - Boundary constraints
  - Designer friendly





GENERATION RESULTS



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Game Technology Center

GENERATION RESULTS

3 - ADAPTATION

FIND OPTIMAL COEFFICIENTS

- **Optimal parameters**
  - Maximize enjoyment
  - Leverage other players' data

$$w^* = \text{argmax}_{w \in W}(\mathcal{R}(p_i, w)) = \mathcal{F}(p_i)$$

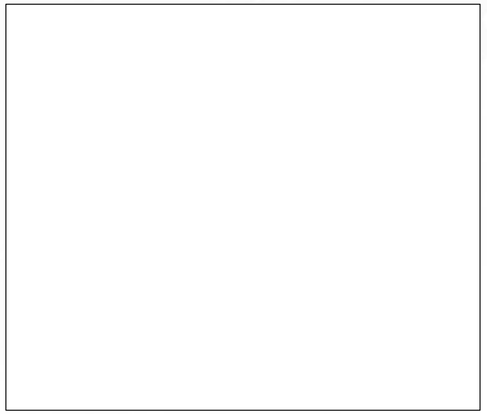
- **Assumption**
  - Similar players
  - Behavior to distinguish

- **Influence**
  - Similar players
  - Higher enjoyment

$$w_1 = \frac{1}{norm} \sum_{p_j \in N(p_i)} \delta(p_i, p_j) \cdot r(w(p_j)) \cdot w(p_j)$$

- **Search strategy**
  - Gradient
  - Step (rating dependent)

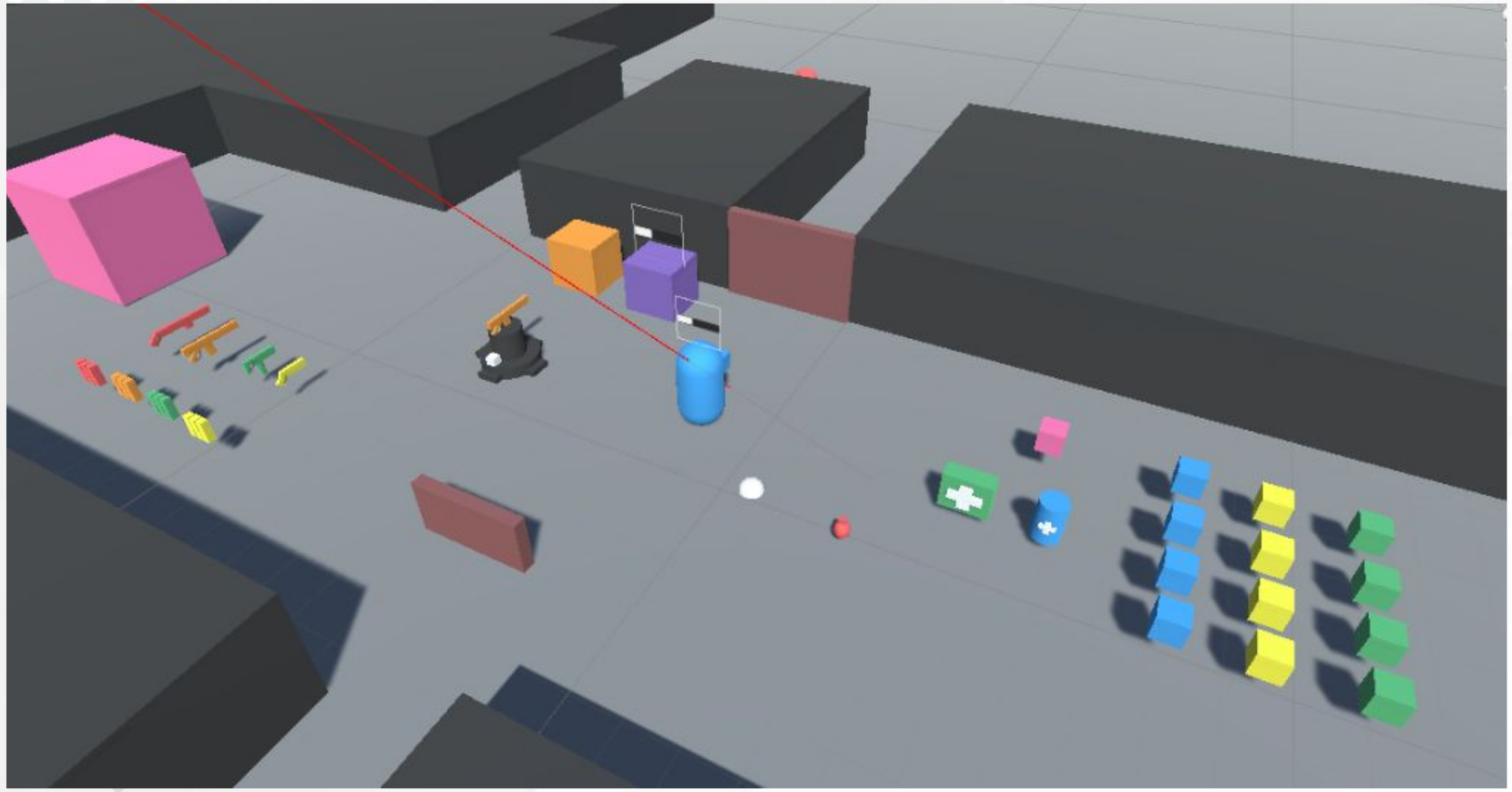
$$w_{j+1} = w_j + \eta \cdot \Delta$$



GAME

FRAMEWORK

- **General**
  - Applicable to most
  - Action-adventure
  - 3rd person avatar, top down
- **Movement**
  - Run
  - Sneak
  - Vault
- **Equipment**
  - Guns
  - Melee
  - Grenades
- **Enemy AI**
  - Patrol
  - Chase
  - Attack



FINAL GAME

- **Gianni**
  - Garbage collector
  - City of Cleanolandia
  - Defeat angry raccoons
- **Score**
  - Fighting
  - Looting
  - Exploring

GAMEPLAY

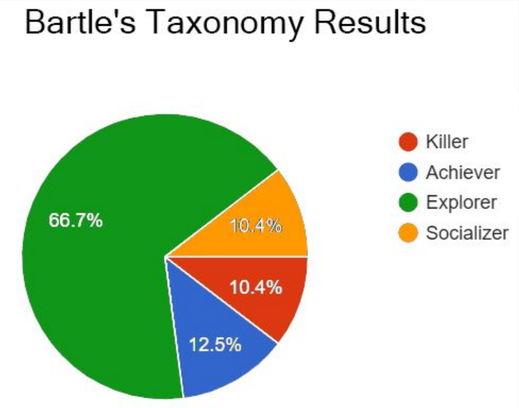
RESULTS

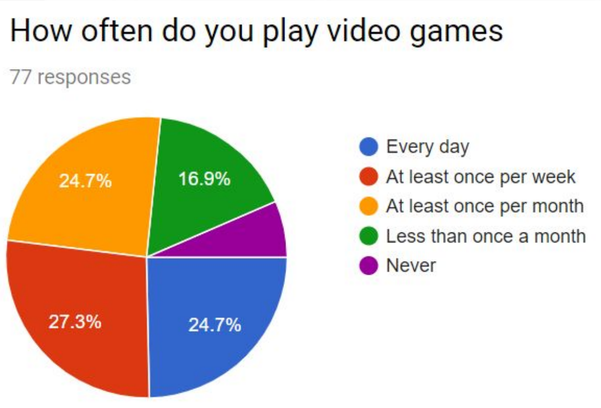
EXECUTION

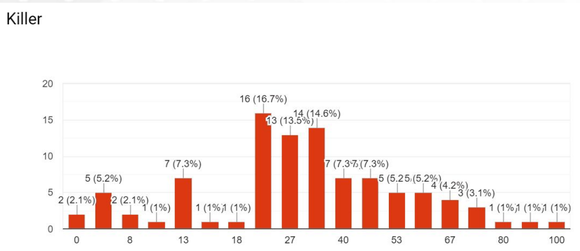
- **3 studies**
  - First - game, correlation
  - Second - balancing
  - Last - personalization
- **Goal**
  - Answer thesis
  - Does personalization algorithm increase experience enjoyment
- **Execution**
  - Questionnaire
  - Gameplay
  - Treatments
  - Rating

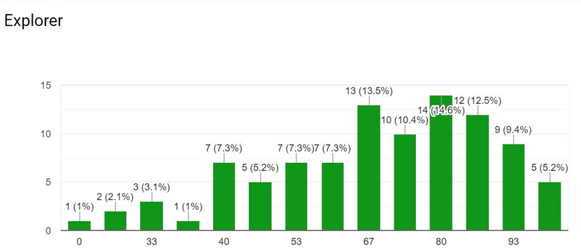
FINAL STUDY

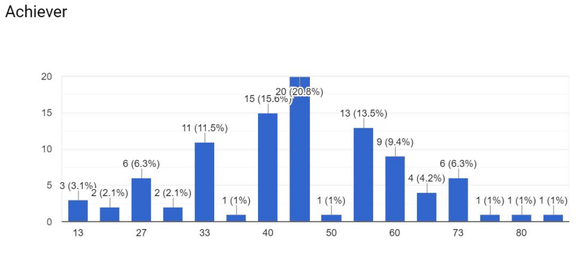
- **Participants:**
  - 96 users
  - 570 rounds
  - 40 h gameplay
- **Questionnaire results**
  - Explorer
  - Possible reasons
  - Play frequency

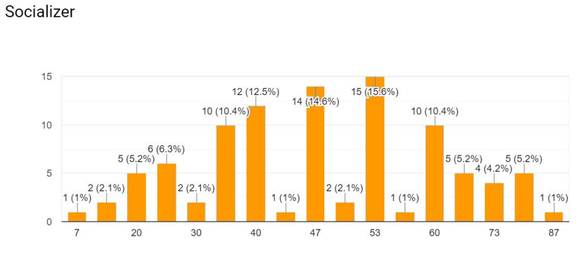








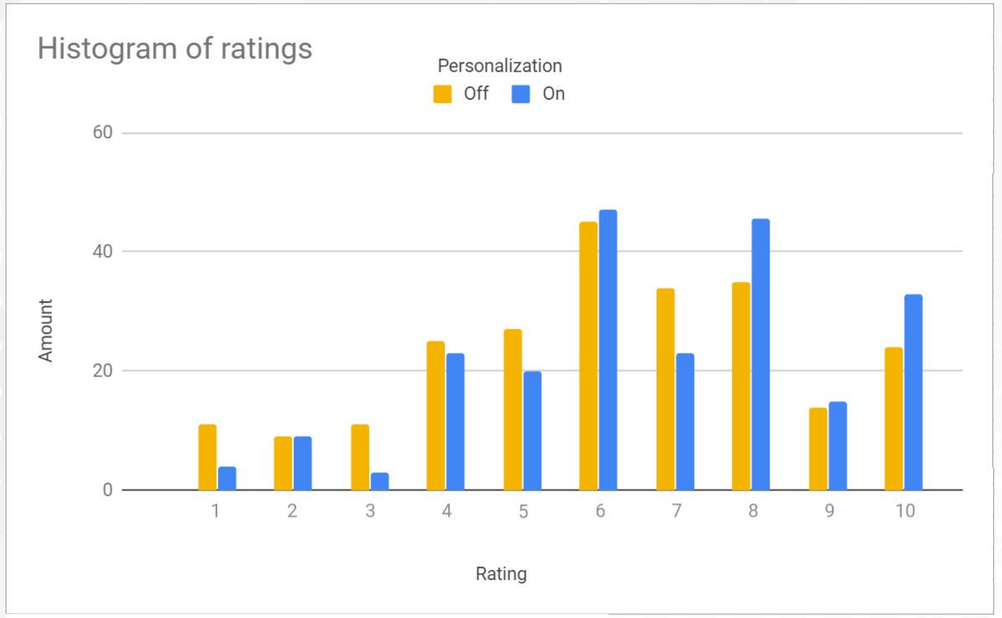


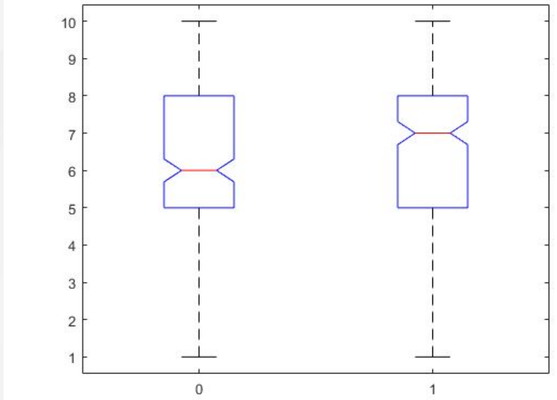


RATING RESULTS

- **Two treatments:**
  - personalization on
  - off = users' pool
- **Fit distribution**
  - increase 0.6113 stars
- **T-test**
  - p-value = 0.0078 << 0.05
- **ANOVA**
  - F-value (ratio) = 7.33
- **Mann-Whitney U-test**
  - less assumptions (no continuous, normal distr.)
  - independence only (i/d variables)
  - p-value = 0.0058

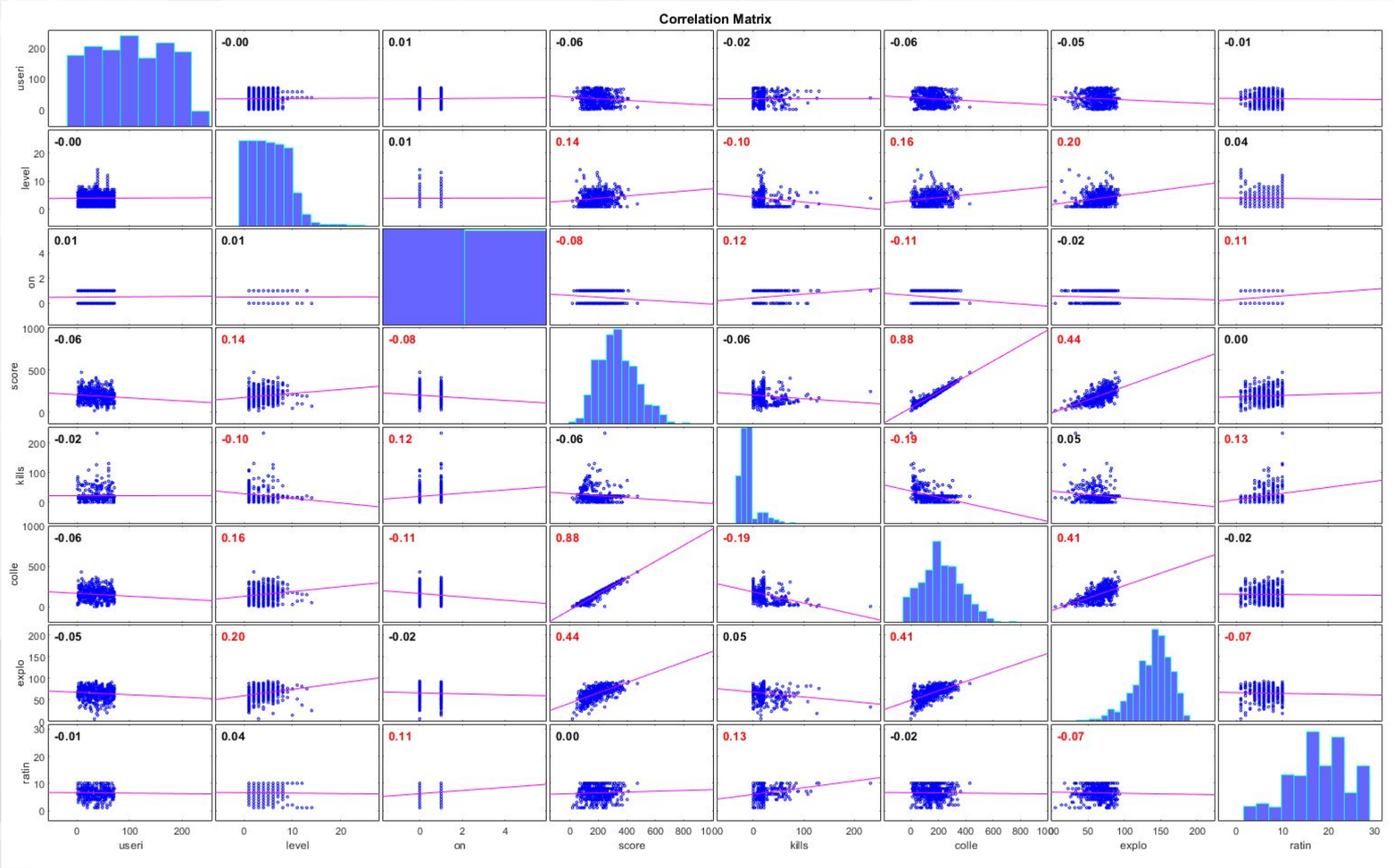
distribution	μ	σ
off	6.1441	2.3954
on	6.7554	2.2422





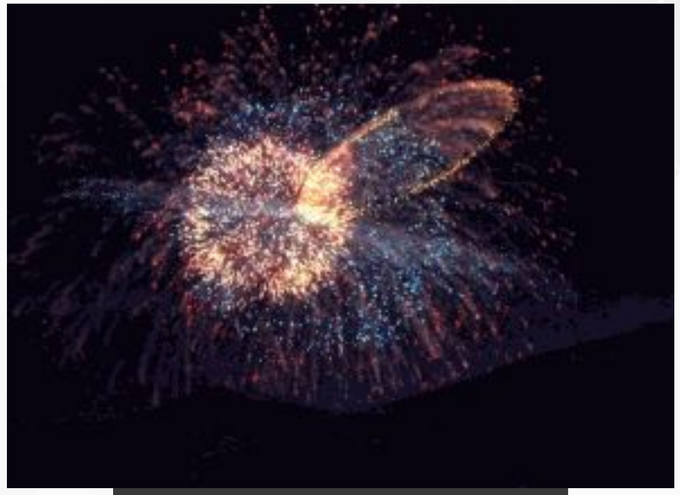
INSIGHTS

- **Correlation**
  - Level-score
  - Level-actions
  - Exploration-rating
  - Score vs enjoyment
- **Drawbacks**
  - Unbalanced game
  - Simple model
  - Too many variables
  - Focus on one research question
  - Recruitment
  - No accounting for noise



CONCLUSION

- **Future work**
  - Expanded player models
  - More complex mappings
  - Generation of other content
- **Special thanks**
  - Bob
  - Fabio
  - Henry



THANK YOU!

Questions?