

Belief-Driven Pathfinding in Videogames

Experimental Design and Validation with Real Players



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Relatore
GIUSEPPE DE GIACOMO

Correlatore
STAVROS VASSOS

Pathfinding

The origins



Labyrinth at Knossos

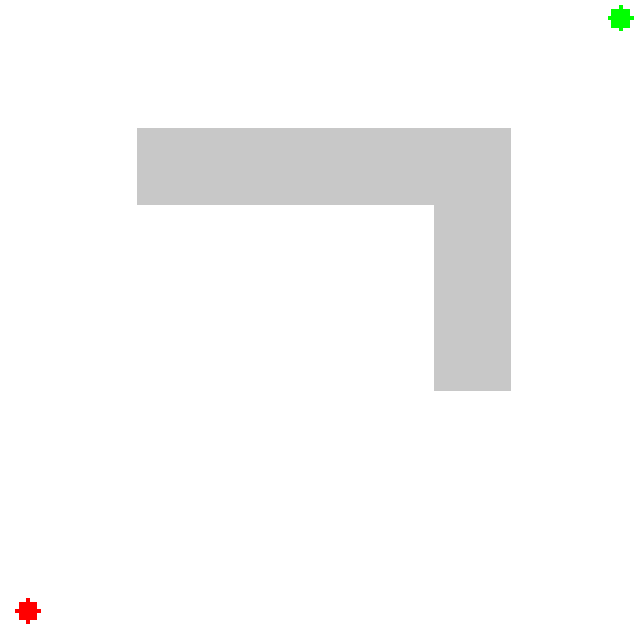
Pathfinding

Seminal work

- Leonhard Euler (1735)
- Richard Bellman and Lester Ford (1956-1958)
- Edsger Dijkstra (1959)
- Peter Hart, Nils Nilsson and Bertram Raphael (1968)

Dijkstra's algorithm

- Pathfinding from start node (lower left, red) to goal node (upper right, green)
- Open nodes represent the "tentative" set
- Filled nodes are visited ones
- Nodes in all the different directions are explored uniformly



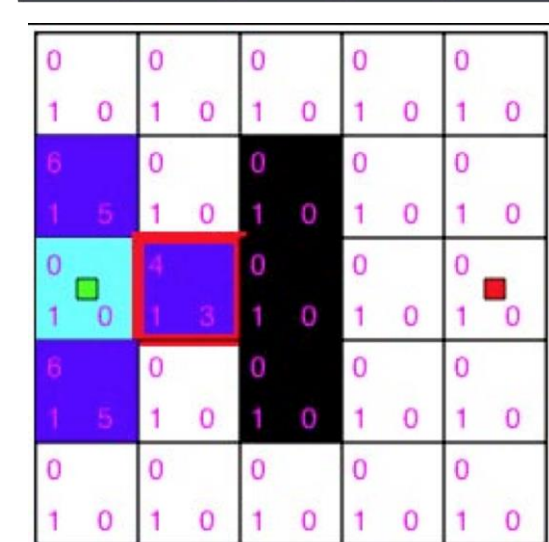
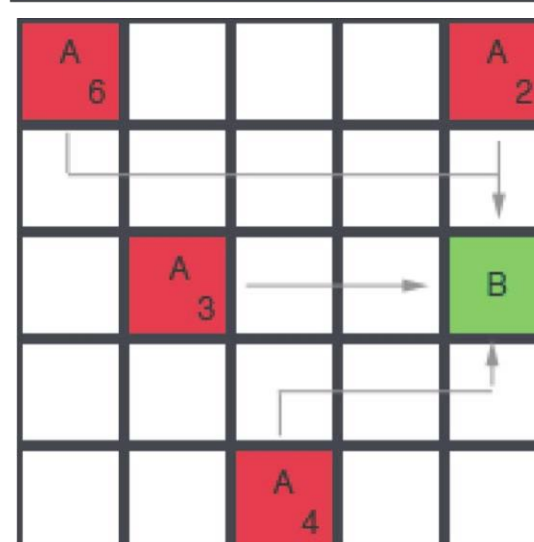
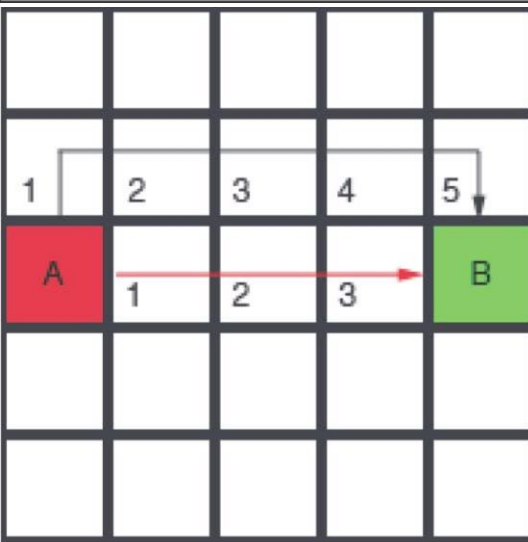
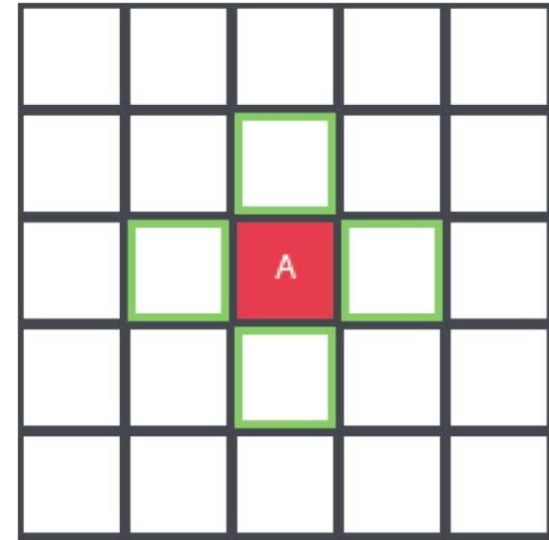
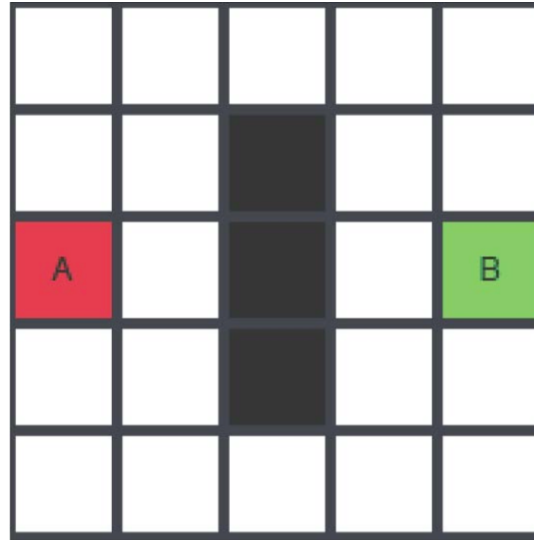
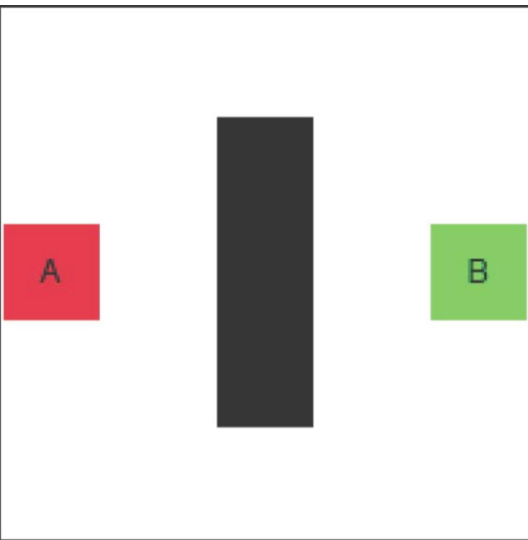
A*

The algorithm

- A* combines uniform-cost search and heuristic search to efficiently calculate optimal solutions.
- As a best-first heuristic search, it employs a function $f(n)$ that guides the selection of the next node that will be expanded.
- The order in which nodes are expanded is determined by the node evaluation function $f(n) = g(n) + h(n)$, where $g(n)$ is the cost of the best path currently known from the start node to node n , and $h(n)$ is a heuristic estimated cost to reach from this current node to the goal node.
- The behavior of A* depends in large part on the heuristic $h(n)$ that guides the search.

Manhattan length (or Taxicab geometry)

An example with A* (part 1)



An example with A* (part 2)

0	0	0	0	0
1	0	1	0	1
6	6	0	0	0
1	5	2	4	1
0	4	0	0	0
1	0	1	3	1
6	6	0	0	0
1	5	2	4	1
0	0	0	0	0
1	0	1	0	1

8	8	8	8	8
2	6	3	5	4
6	6	0	8	8
1	5	2	4	1
0	4	0	8	8
1	0	1	3	1
6	6	0	8	8
1	5	2	4	1
8	8	8	8	8
2	6	3	5	4

8	0	0	0	0
2	6	1	0	1
6	6	0	0	0
1	5	2	4	1
0	4	0	0	0
1	0	1	3	1
6	6	0	0	0
1	5	2	4	1
0	0	0	0	0
1	0	1	0	1

8	8	8	8	8
2	6	3	5	4
6	6	0	8	8
1	5	2	4	1
0	4	0	8	8
1	0	1	3	1
6	6	0	8	8
1	5	2	4	1
8	8	8	8	8
2	6	3	5	4

Variants of A*

- D* (1994)
- Field D* (FD*) (2005)
- Iterative Deepening A* (IDA*) (1985)
- Fringe Saving A* (FSA*) (2007)
- Generalized Adaptive A* (GAA*) (2008).
- Lifelong Planning A* (LPA*) (2004)
- Simplified Memory Bounded A* (SMBA*) (1992)
- Jump point search (2011)
- Theta* (2007)
- Block A* (2011)

Pathfinding in videogames

- Non-player characters (NPCs) find optimal paths on the game maps.
- Passageways, gates or doors change their statuses during gameplay.
- Game engines typically deal with these changes with *omniscient pathfinding*: NPCs **always** possess a precise view of the game maps.



Belief-Driven Pathfinding (BDP)

- Non-player characters in videogames moving under BDP assumptions *change their beliefs about the map as they explore it*, thus following in every moment the optimal path according to their present knowledge.
- The resulting gameplay should be more believable to the player and provide a more fluid gameplay.
- This is the hypothesis we tested with the developed demo and user evaluation tests.

Let's rescue the princess mini-game

Gameplay



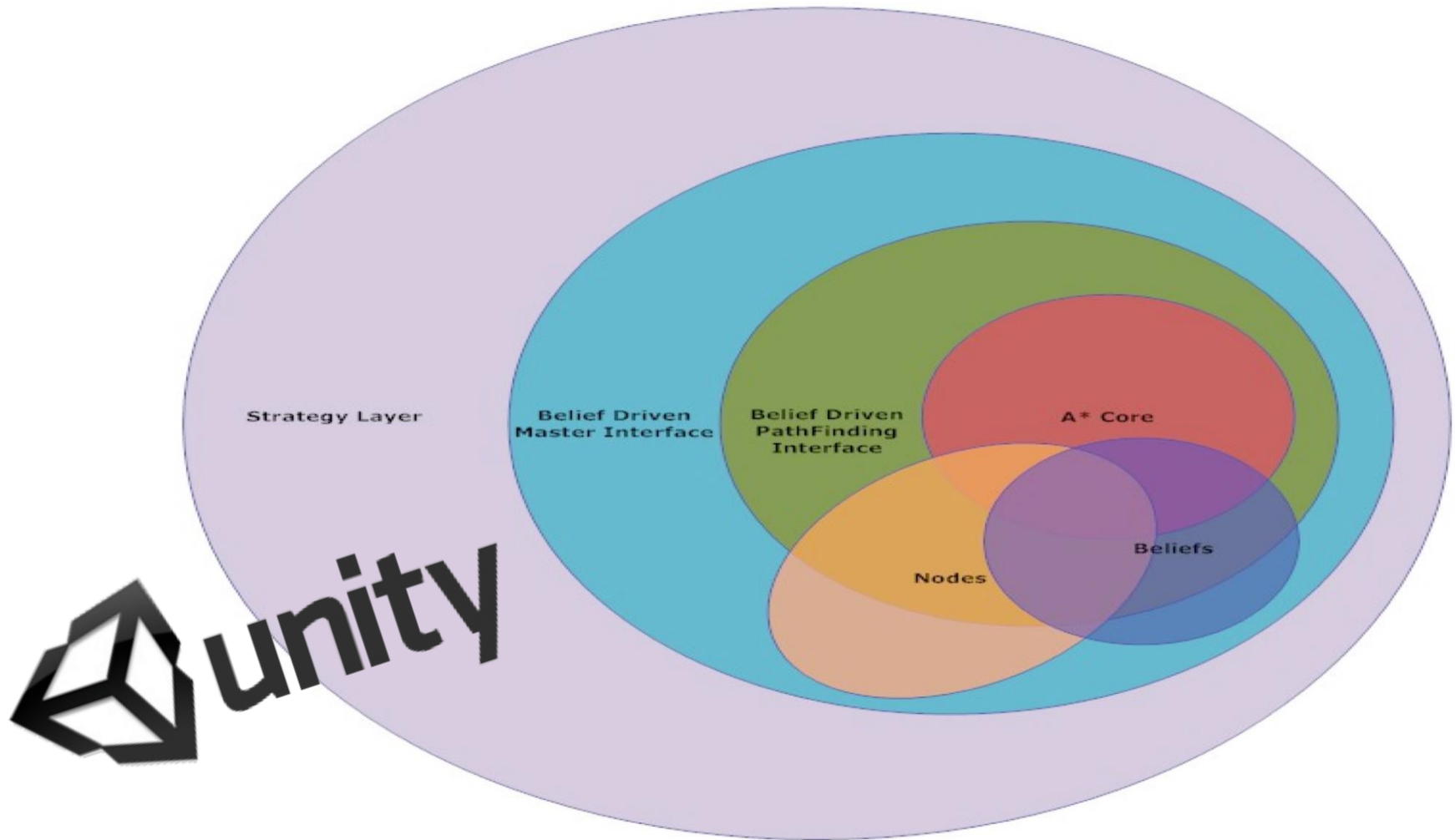
When the player closes the door in the middle...

...the **blue** omniscient opponent immediately knows and moves to the other side.

...the **red** BDP opponent continues towards the door following his beliefs.

Let's rescue the princess mini-game

Belief-Driven Pathfinding package



Belief-Driven Master Interface

Knowledge Management policies

1. Remember All
2. Remember All But No Path Forget Everything
3. Remember All But No Path Forget Latest
4. Remember All But No Path Forget Earliest
5. Refresh Before Re-path
6. Refresh After n Seconds

Belief-Driven Master Interface

Cognitions

1. Sphere
2. Ray
3. Ray Infinite Range
4. Ray Super Sight
5. Ray Super Sight Infinite Range
6. No Casting

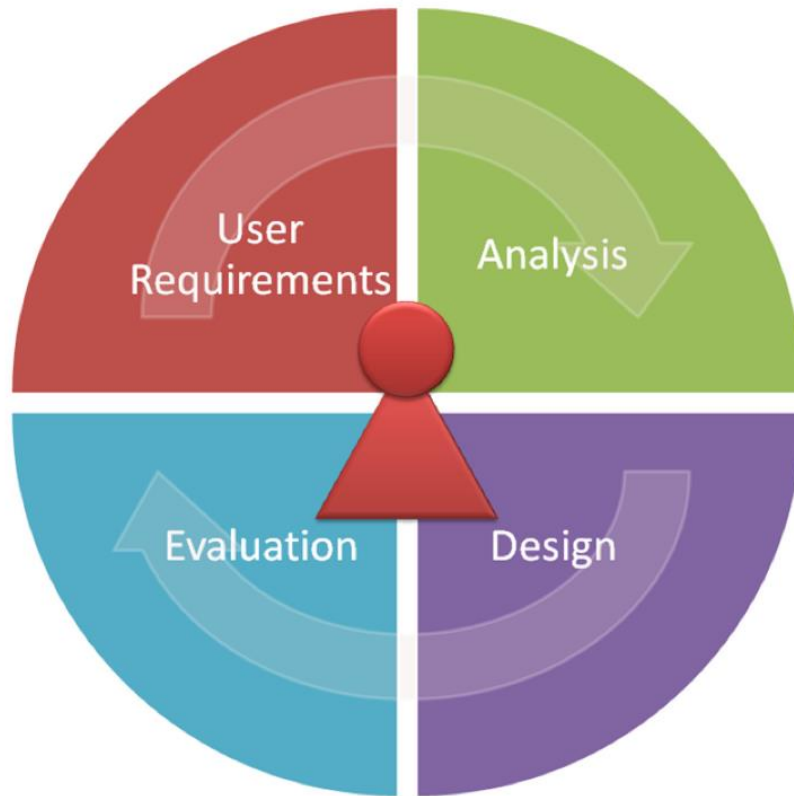
Let's rescue the princess mini-game

Other building blocks

1. Doors and switches (*animated by Unity Legacy*)
2. Characters (*animated by Mecanim Animation System*)
3. Scripts
 - player control
 - logic of choices
 - connection to parse.com
 - statistics (lives, points, time)
4. Levels
5. Menus, minimap and other minor blocks...

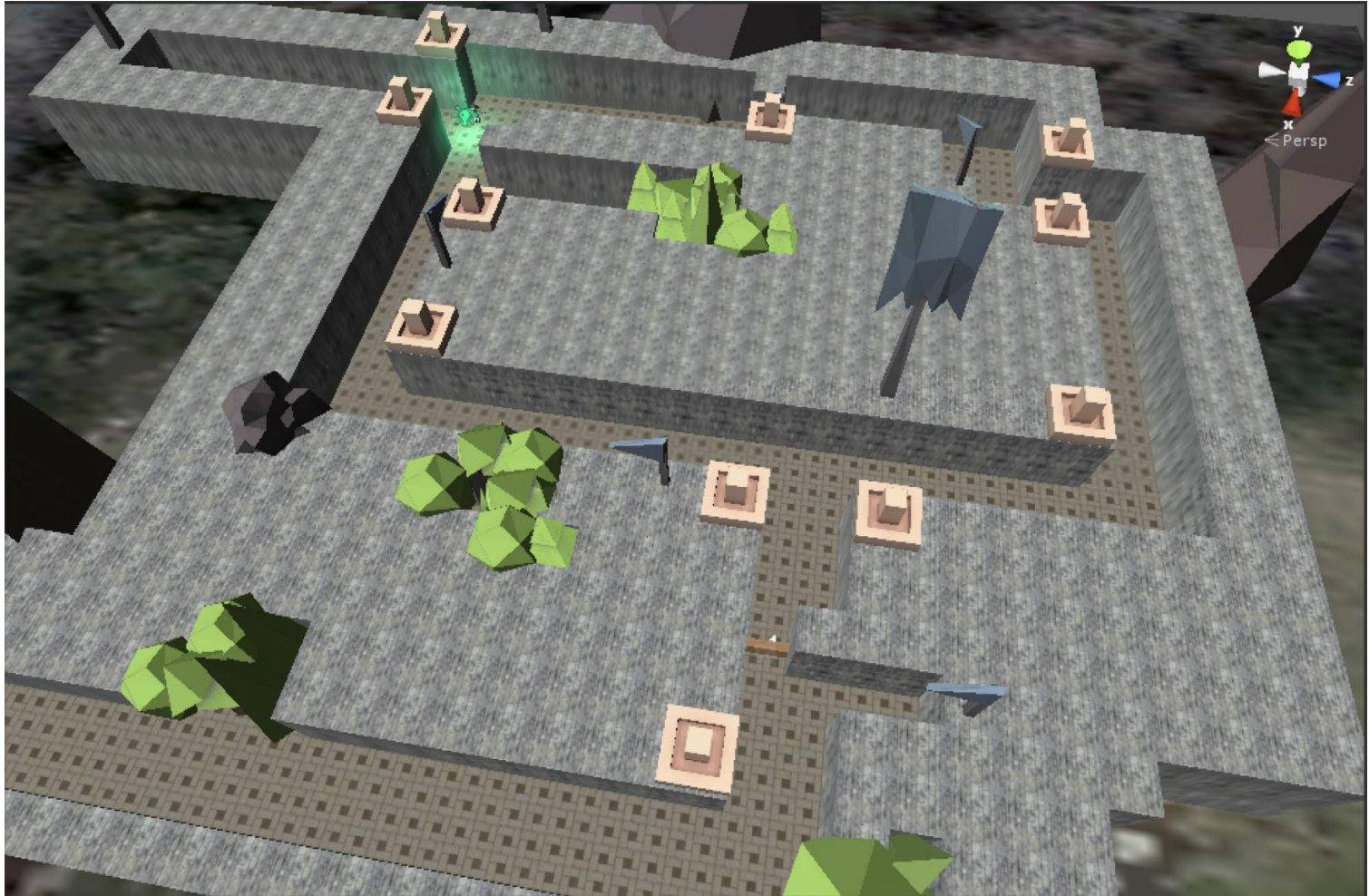
Evaluation through player participation

User Centred Design



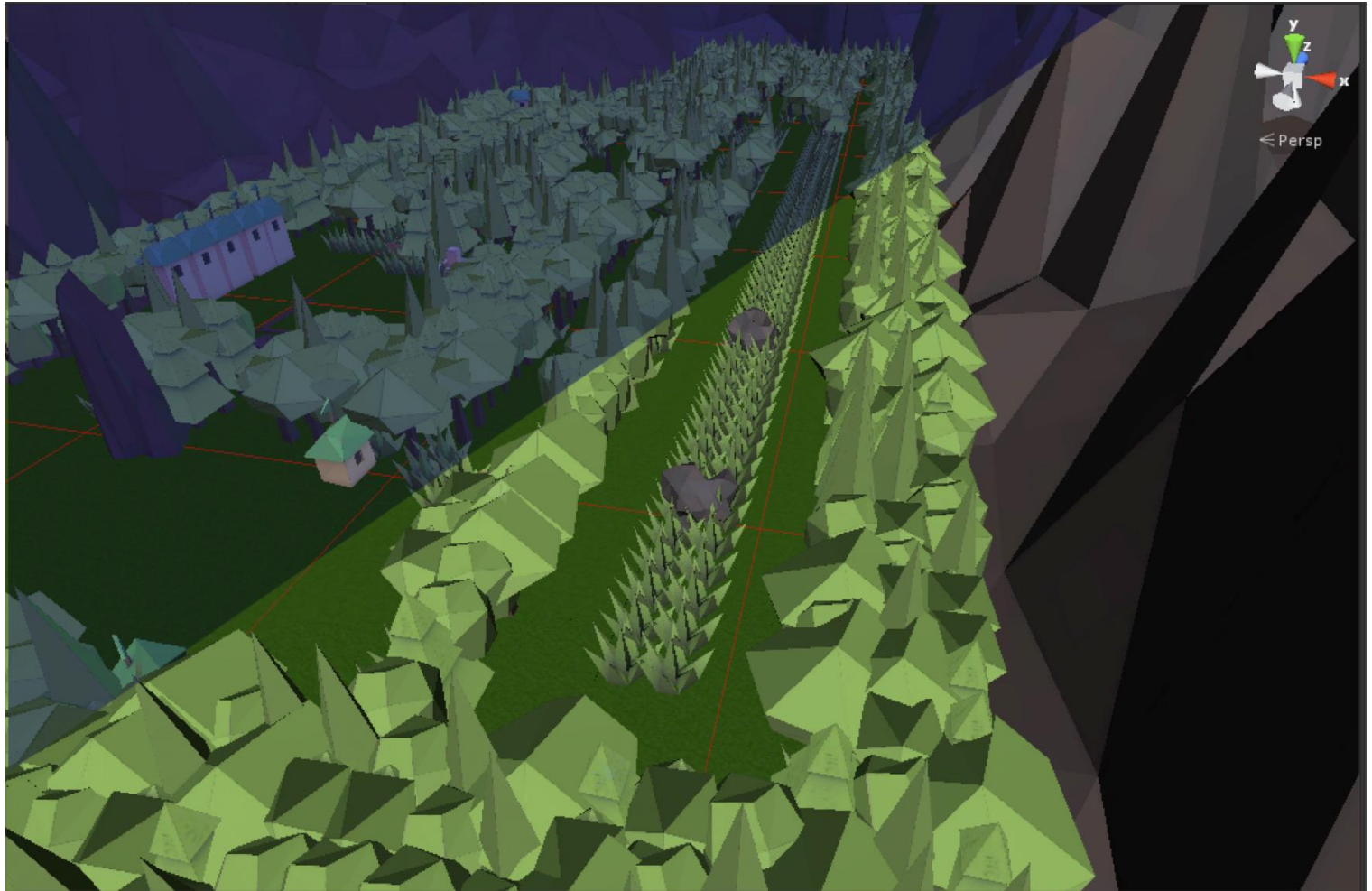
Evaluation through player participation

Demo level 1



Evaluation through player participation

Demo level 2



Evaluation through player participation

Focus groups

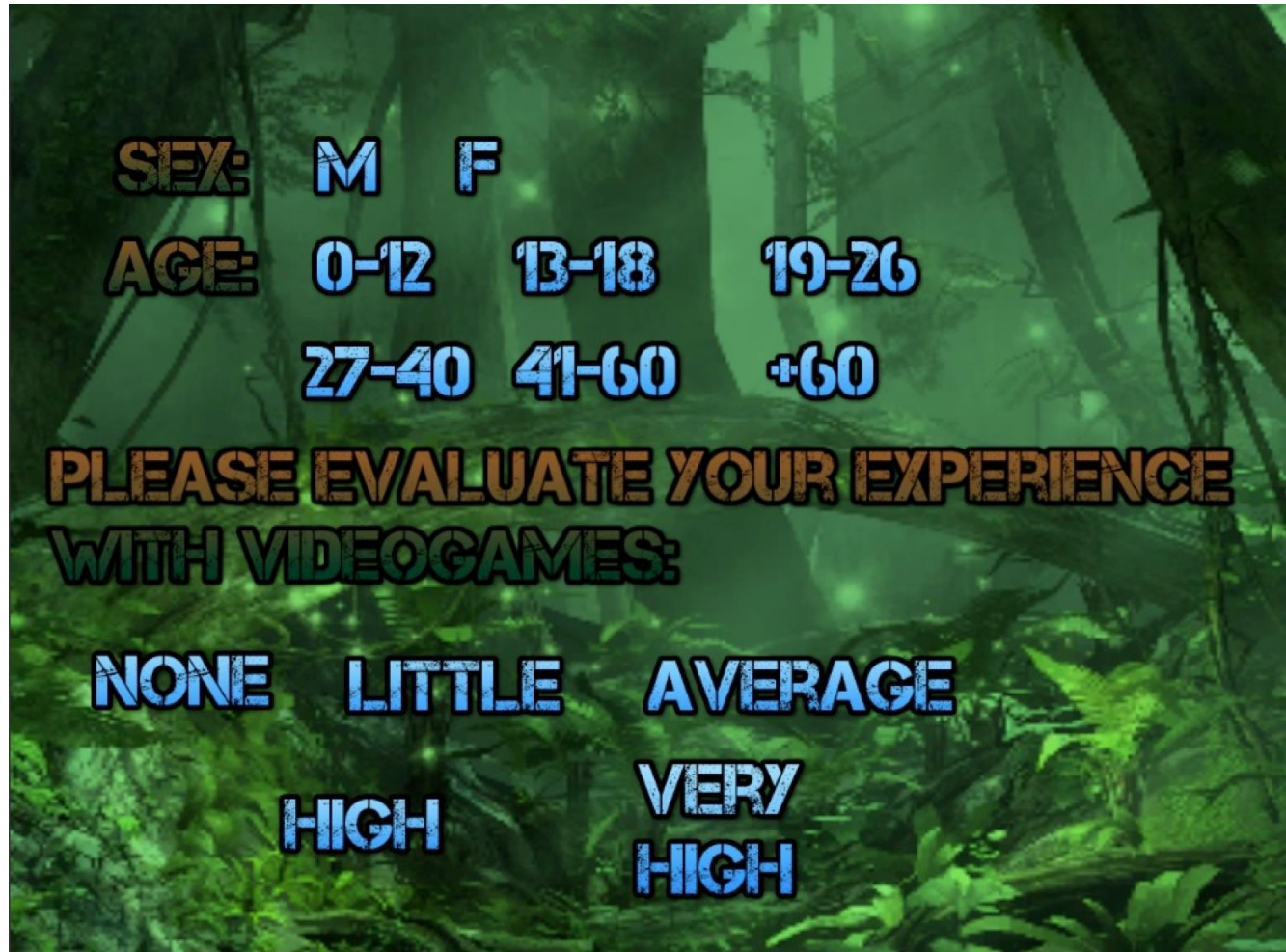
Two focus groups (in January and February 2015) were organized at Sapienza University with the Games@DIAG group.

The main results after the focus groups were:

- reduction of opponents from three to two, eliminating the purple opponent,
- implementation of a strategy layer localizing the player through the Belief-Driven Interface,
- increase of the number of lives from three to six,
- recruitment of testers among university students.

Evaluation through player participation

Demographic data



SEX: M F

AGE: 0-12 13-18 19-26
27-40 41-60 +60

**PLEASE EVALUATE YOUR EXPERIENCE
WITH VIDEOGAMES:**

NONE LITTLE AVERAGE
HIGH VERY HIGH

Evaluation through player participation

Players' opinions



Evaluation through player participation

Connection to parse.com

The mini game is connected to an account on the website parse.com, where it is possible to collect data from gameplay statistics and answers to questions.

Collected data in the demo are

- answers to questionnaires in the following format:
[Color]Opponent[Quality]Lv[NumLv]: [value 1-5]
- demographic data and autoevaluation about experience with videogames
- user name, points and difficulty level

Conclusions and further research

- The mini-game was built with the objective of checking if Belief-Driven Pathfinding methods in videogames are making the playing experience more fluid and believable.
- Preliminary qualitative evaluation seems to confirm the research hypothesis, although quantitative evaluation of user experience is needed to draw significant conclusions.
- The mini-game "Let's rescue the princess" is a ready-to-use framework to be tested with real players, opening ample spaces for future research.
- The mini-game will be used at the OpenDIAG day on March 13 to get user information about how they perceive the differences between the pathfinding approaches.

Thanks for your attention!

