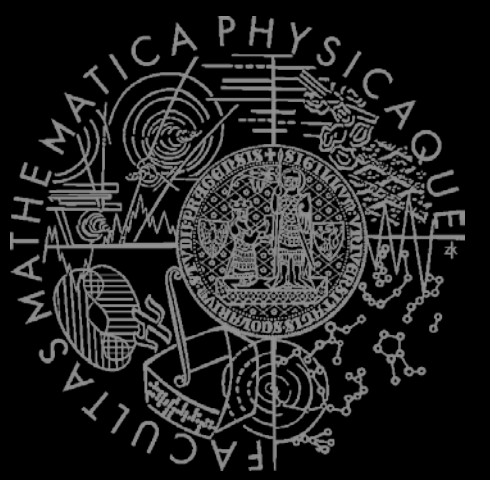
Faculty of Mathematics and Physics
Charles University in Prague
22th March 2016



Human-like Artifical Agents

Environment Awareness

NavXXX, A*, hPA*, FW, VM…

Environment Awareness

Prodiving answers/support for questions

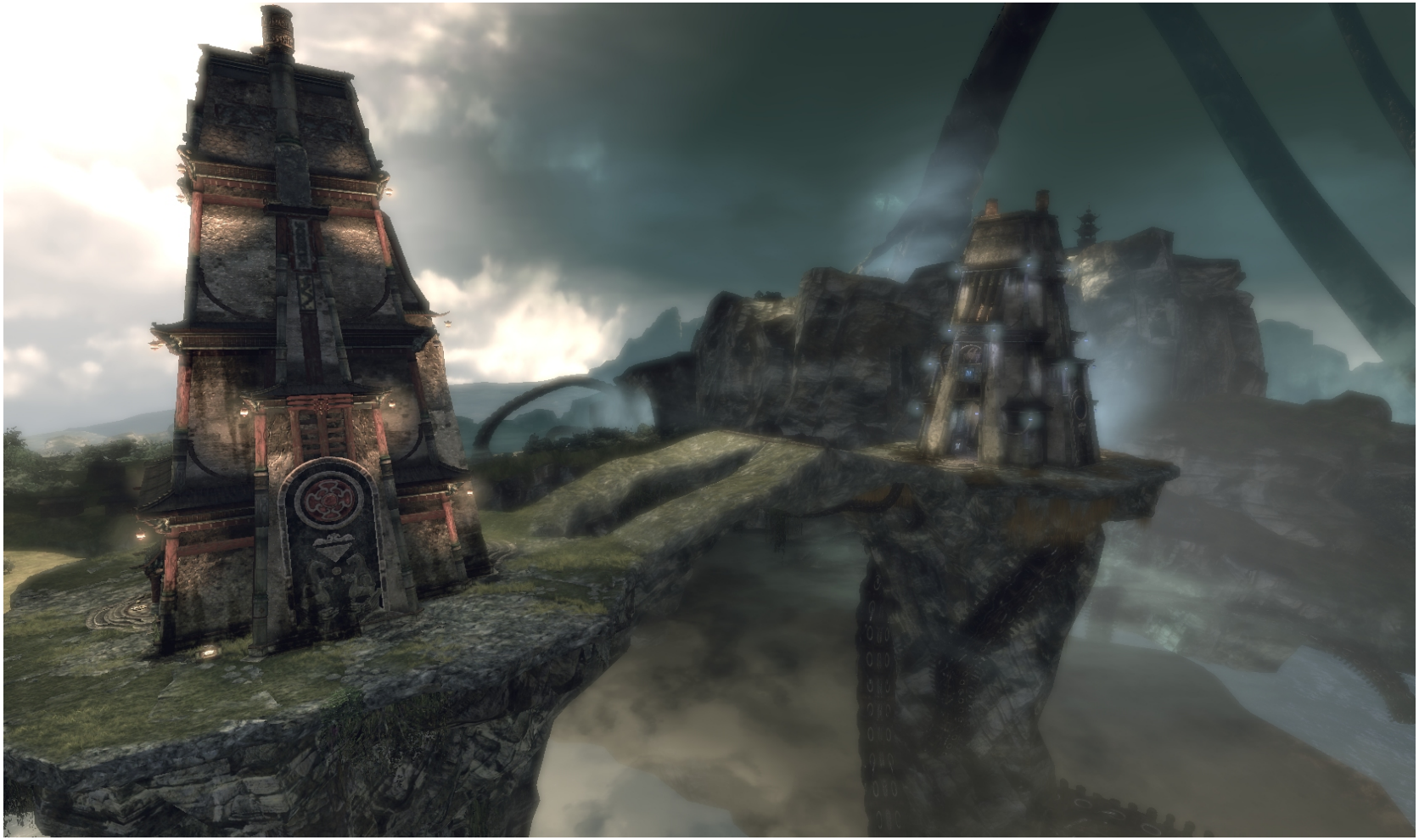
- What items are available in my vicinity / in the map?
- How do I get (to) item *x*?
- What (safe) routes are leading from my base to enemy base?
- What is a good guarding/cover/ambush spot?
- ROCKET!!! How can I dodge it? Can I fire back?
- (And others that we will cover later on…)

Environment Awareness

How do you perceive the V-World?

Environment Awareness

How do you perceive the V-World?



Environment Awareness

How does IVA reason about the virtual world?

- Floors, Walls, Pits, Obstacles, Visibility

Environment Awareness

How does IVA reason about the virtual world?

- Floors, Walls, Pits, Obstacles, Visibility
- Doors, Gates, Ladders, Stairs

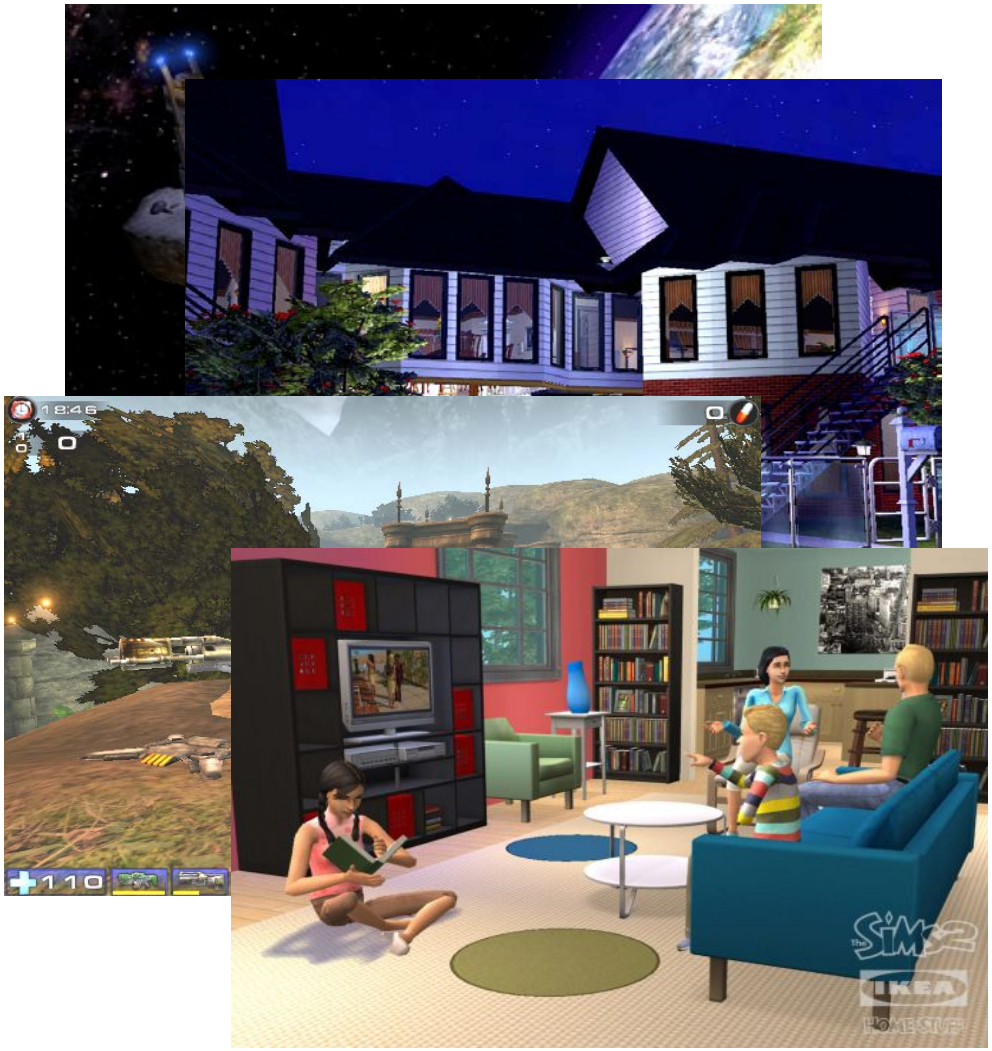
Environment Awareness

How does IVA reason about the virtual world?

- Floors, Walls, Pits, Obstacles, Visibility
- Doors, Gates, Ladders, Stairs
- Items

Environment Awareness

How does IVA reason about the virtual world?



- Floors, Walls, Pits, Obstacles, Visibility
- Doors, Gates, Ladders, Stairs
- Items
- Dynamic objects, Other IVAs

Environment Awareness

How does IVA reason about the virtual world?

- Floors, Walls, Pits, Obstacles, Visibility
  - ⇒Environment abstraction, Path-finding/following algorithms (steering)
- Doors, Gates, Ladders, Stairs
- Items
- Dynamic objects, Other IVAs

Environment Awareness

How does IVA reason about the virtual world?

- Floors, Walls, Pits, Obstacles, Visibility
- Doors, Gates, Ladders, Stairs
  - ⇒Interactive objects & Affordances
- Items
- Dynamic objects, Other IVAs

Environment Awareness

How does IVA reason about the virtual world?

- Floors, Walls, Pits, Obstacles, Visibility
- Doors, Gates, Ladders, Stairs
- Items

  ⇒ Game mechanics, Reactive plans or Learning
- Dynamic objects, Other IVAs

Environment Awareness

How does IVA reason about the virtual world?

- Floors, Walls, Pits, Obstacles, Visibility
- Doors, Gates, Ladders, Stairs
- Items
- Dynamic objects, Other IVAs

  ⇒ Steerings, IVAs coordination

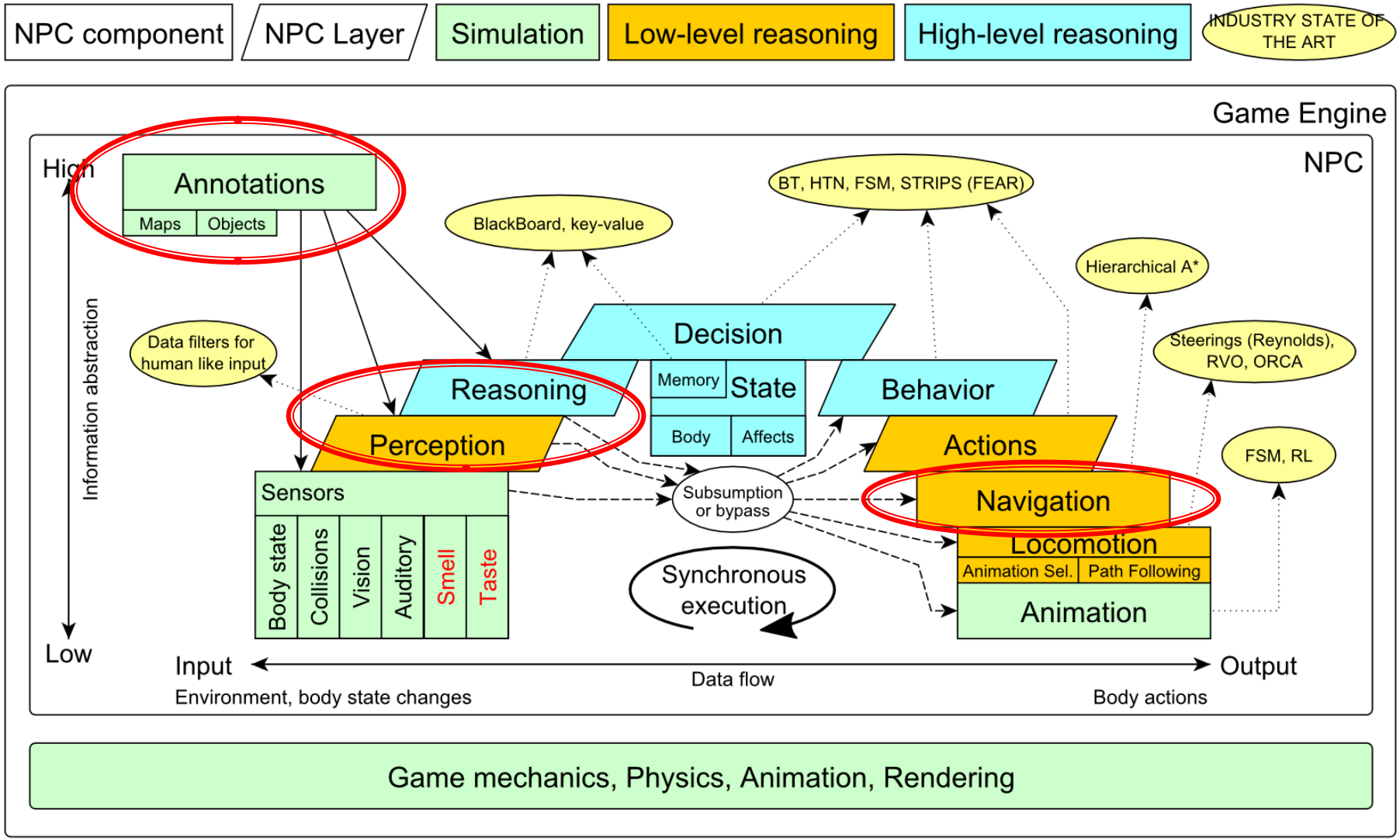
Environment Awareness

Today's Topic

1. Environment abstraction
2. Path-finding algorithms
3. *Visibility matrix [covered at workshop]*

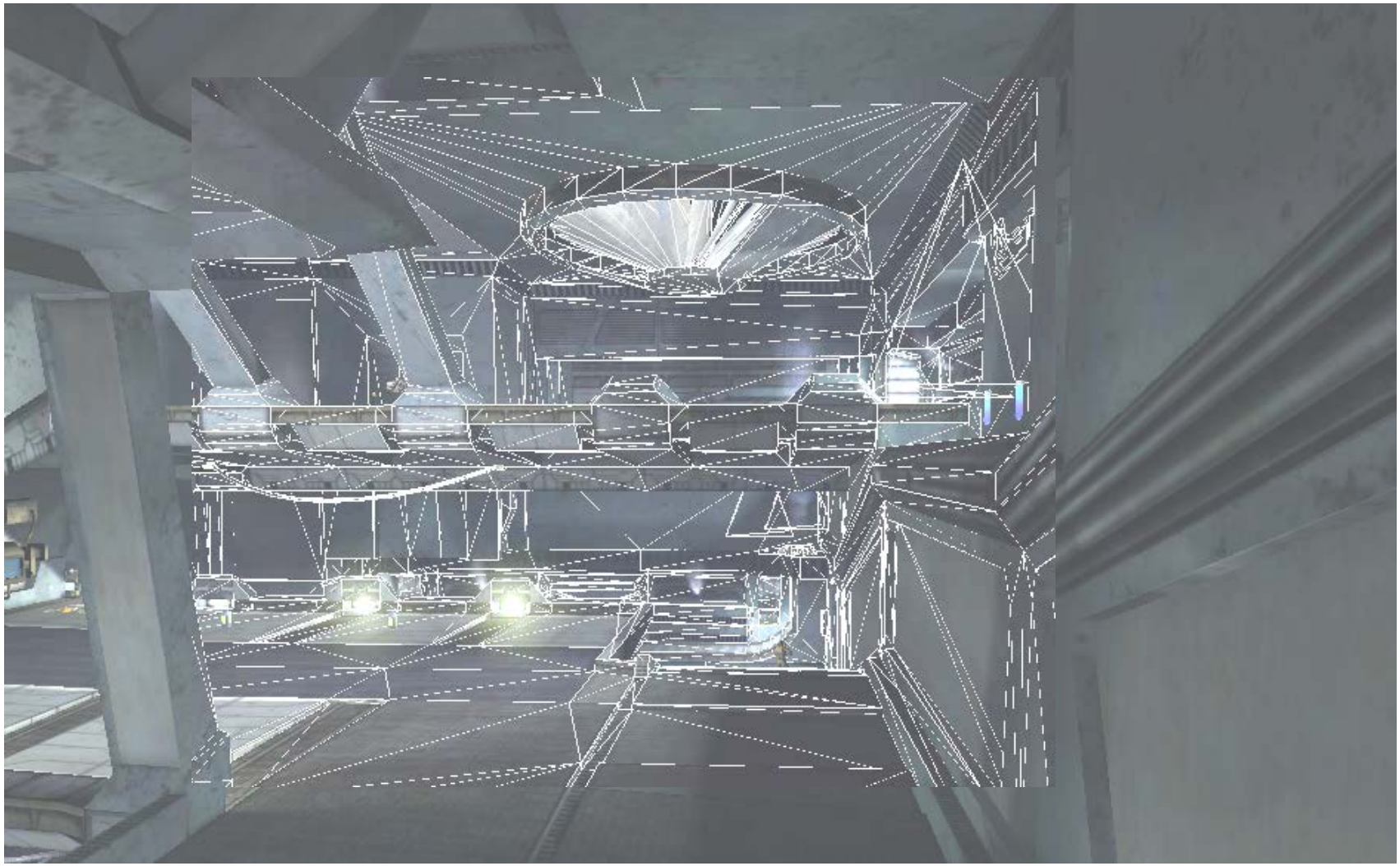
IVA in Video Games

Environment Awareness



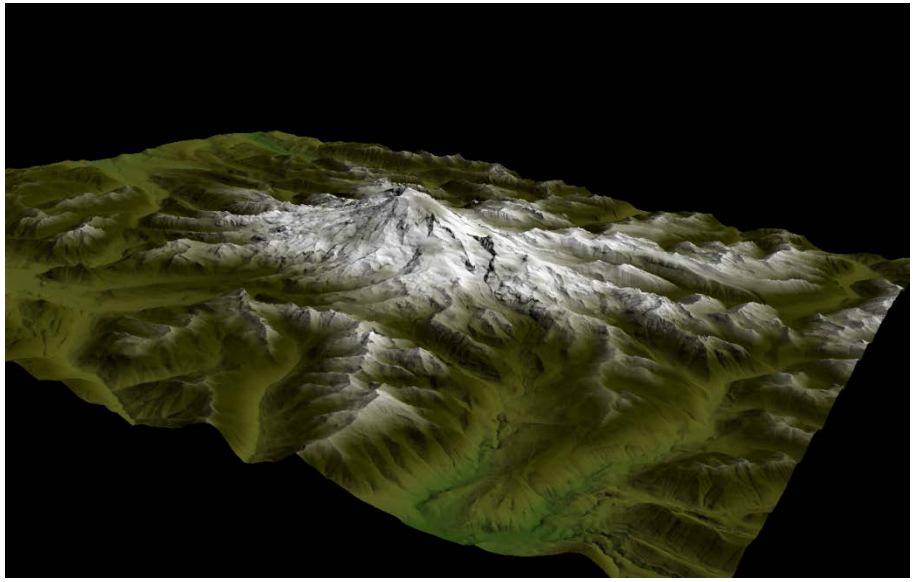
Environment Representation

Environment Representation



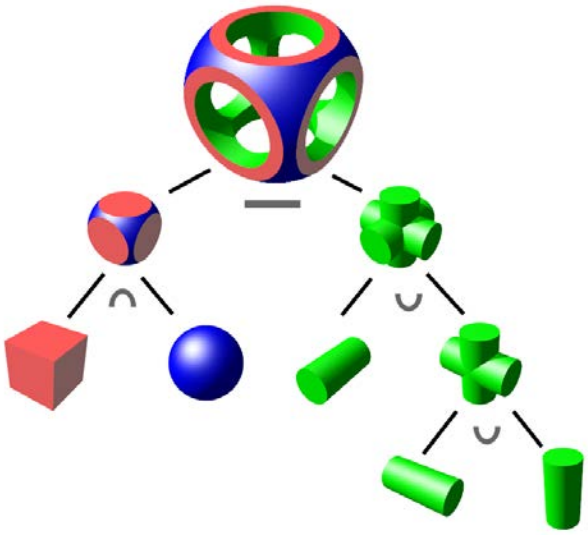
Environment Representation

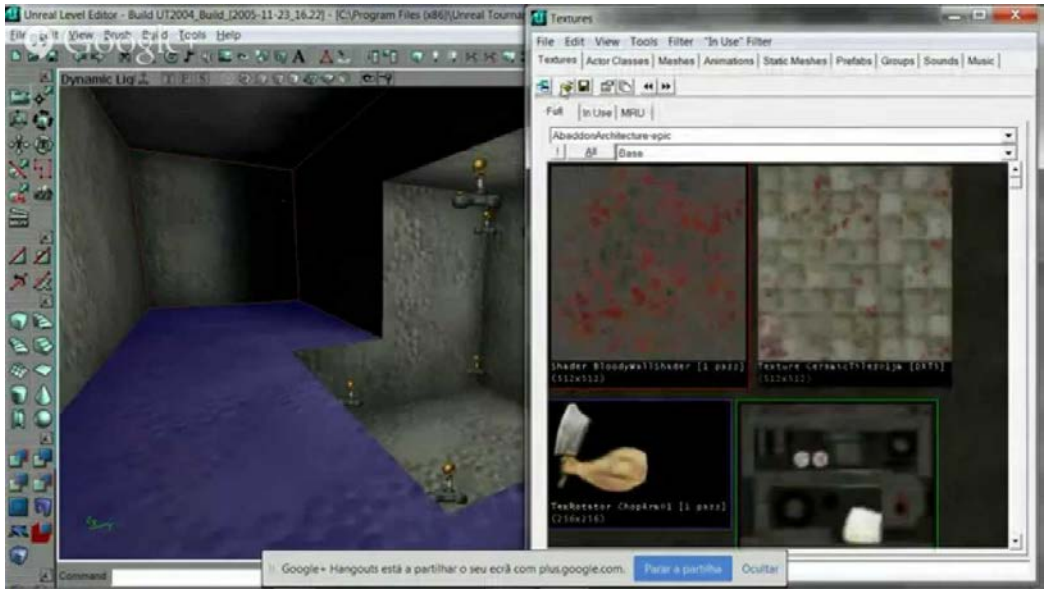
- Environment
  - Terrain (Height map)



Environment Representation

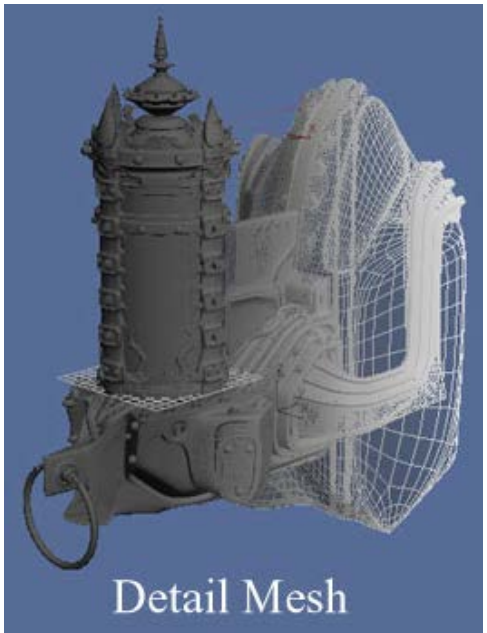
- Environment
  - Terrain (Height map)
  - Walls (Constructive Solid Geometry)

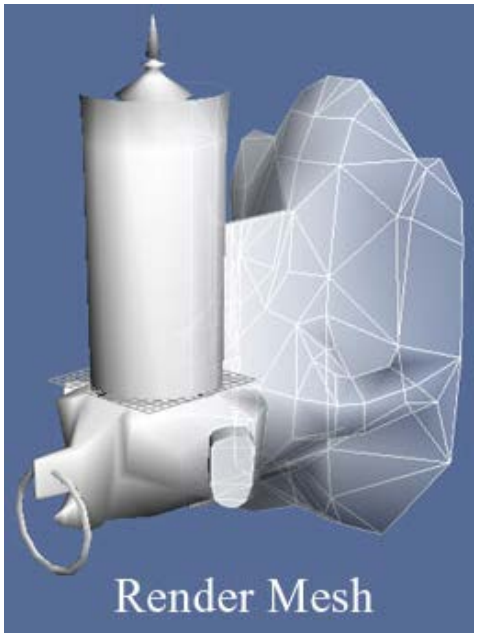




Environment Representation

- Environment
  - Terrain (Height map)
  - Walls (Constructive Solid Geometry)
  - Objects (Static Meshes, Tesselation)





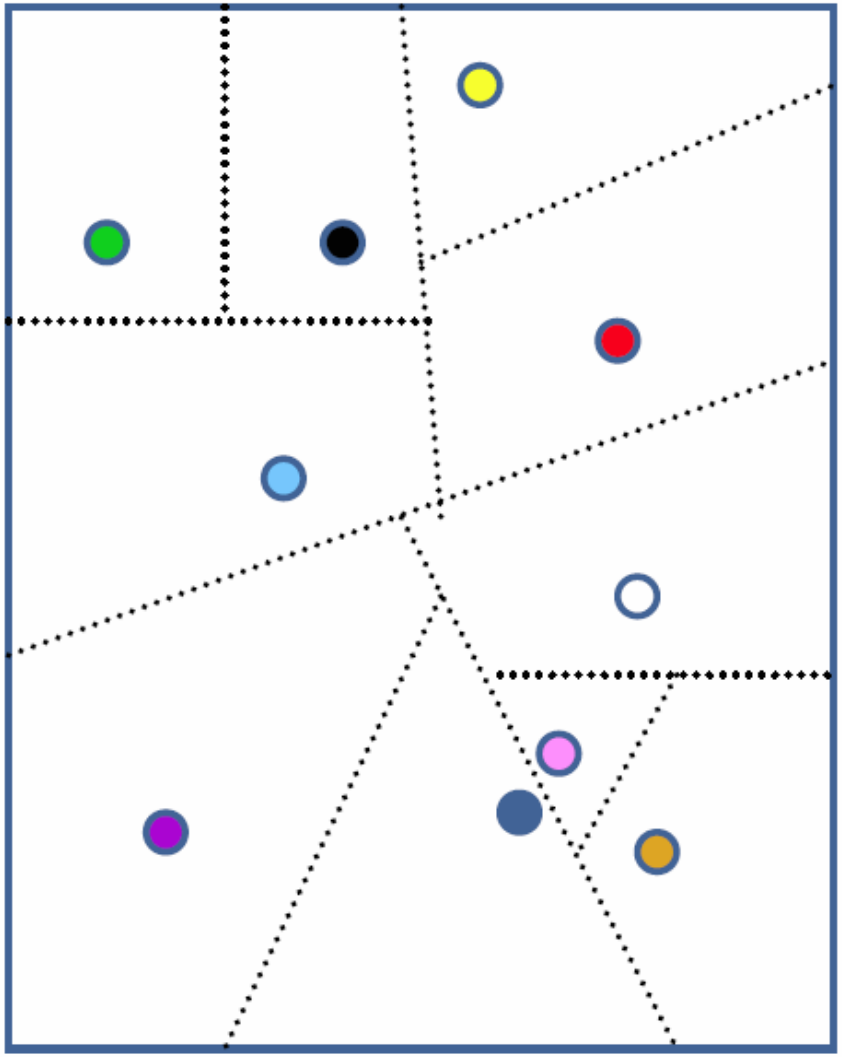
Environment Representation

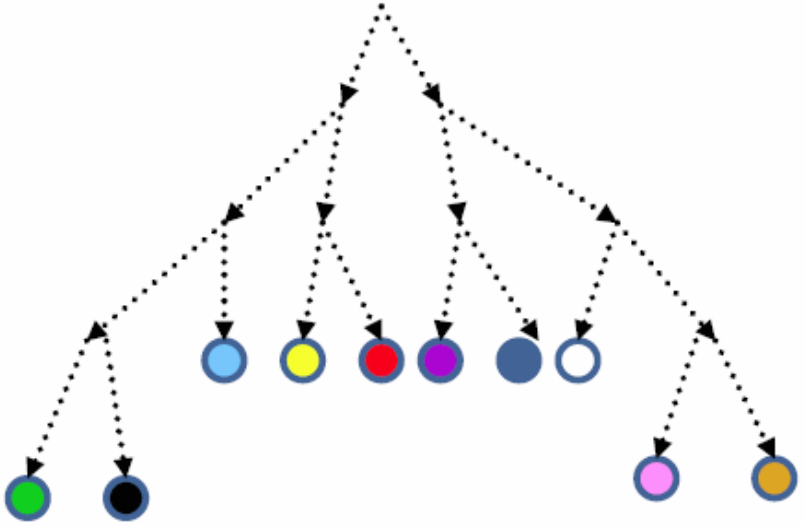
- Environment
  - Terrain (Height map)
  - Walls (Constructive Solid Geometry)
  - Objects (Static Meshes)
- Boils down to vertices/triangles

UT2004 Map	Text (XML)	Vertices	Triangles	log2(Tris)
	[MB]	[Count]	[Count]	
DM-Flux2	6	86615	63611	15,9569886
CTF-FaceClassic	10	82189	68357	16,0608015
CTF-January	30	502051	354342	18,434783
CTF-MoonDragon	60	745755	570444	19,1217257
AS-BP2-Acatana	68	830747	551456	19,0728863

Environment Representation

BSP Tree

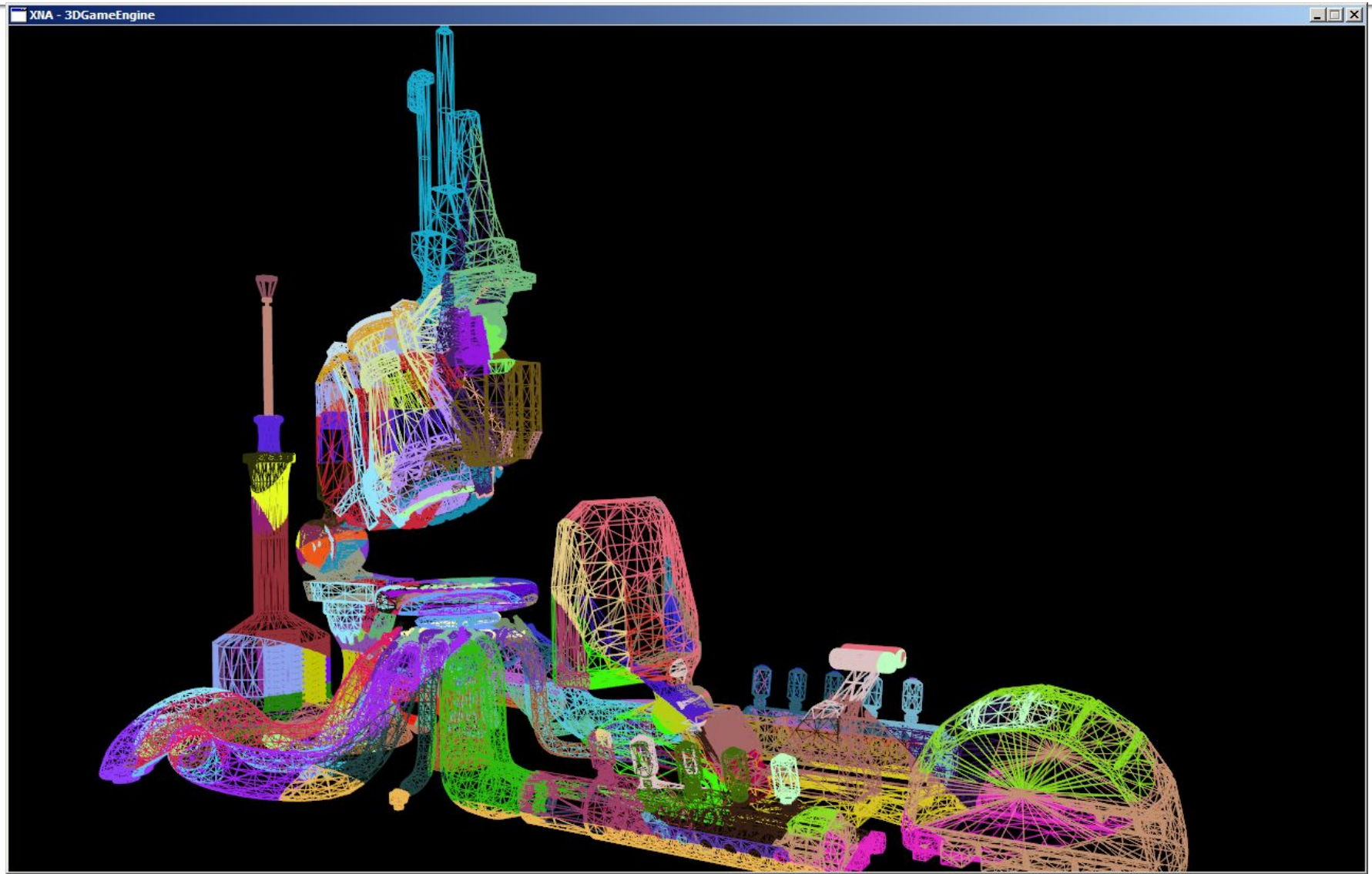




- Nodes are “lines” (2D) or “planes” (3D)
- Nodes divides the space on two parts
- Recursion

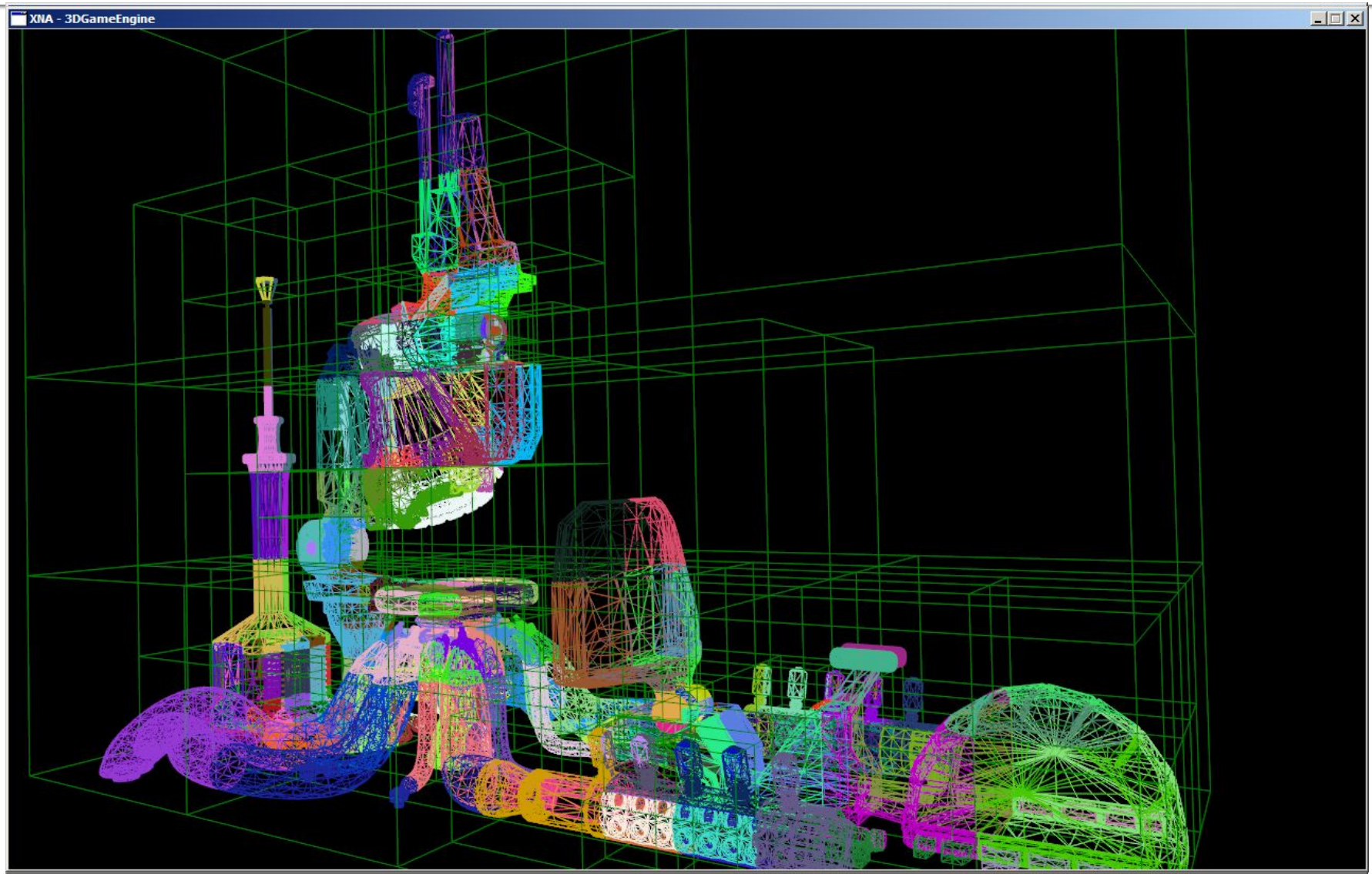
Environment Representation

BSP Tree

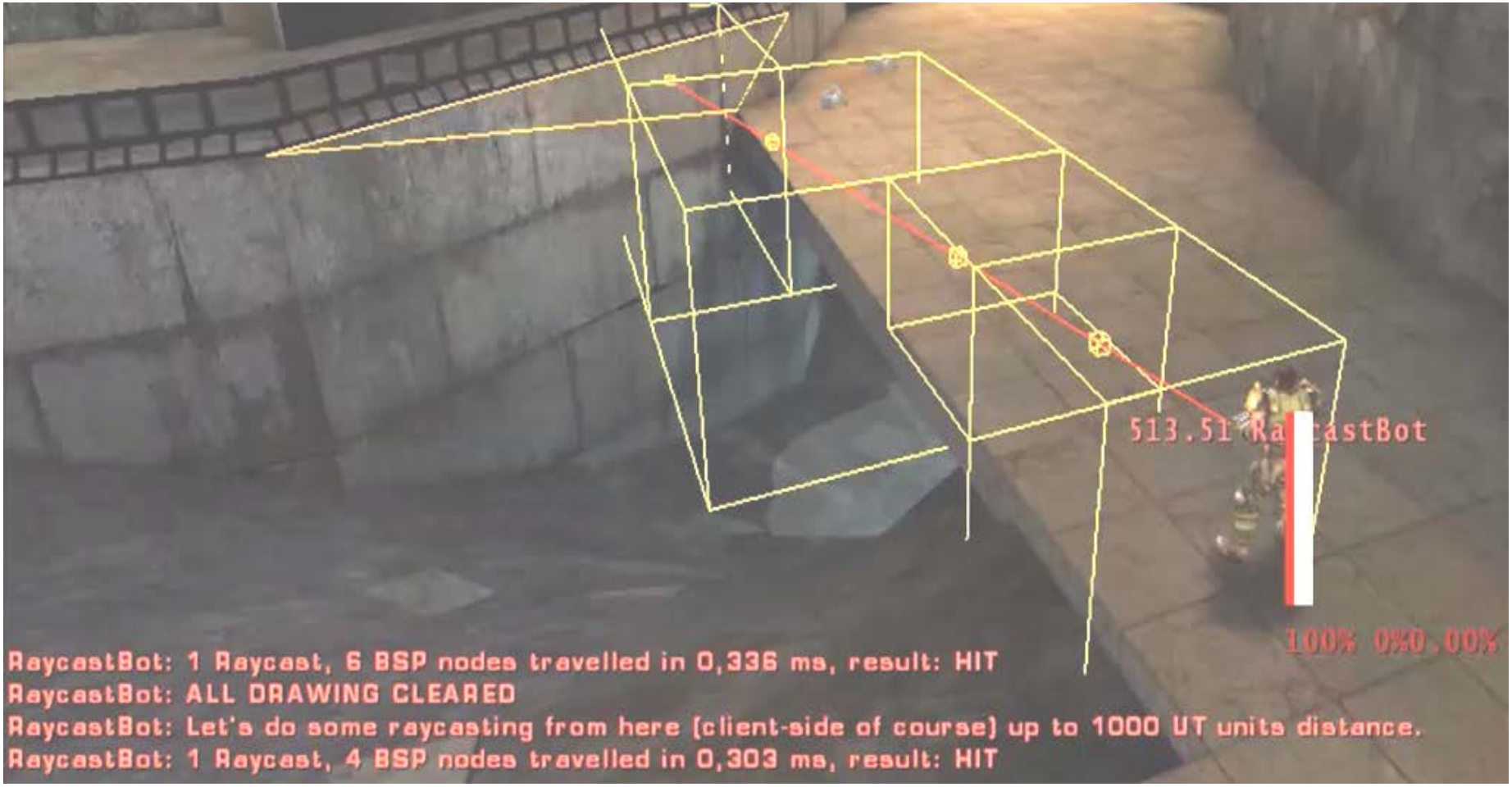


Environment Representation

BSP Tree



Environment Representation
Raycasting



=> Video [Pogamut-NavMesh, 3:06]

Environment Representation
Raycasting

Can be used to answer following questions:

- Can I see [x1,y1,z1] from [x2,y2,z2]?
  - Can I dodge "there"?
  - Is it safe to fire a rocket?
  - Is this a good cover/sniping point?

But there are problems!

- What about holes?
- Raycasting is using "1D" lines
- Multiple raycasts for volumes

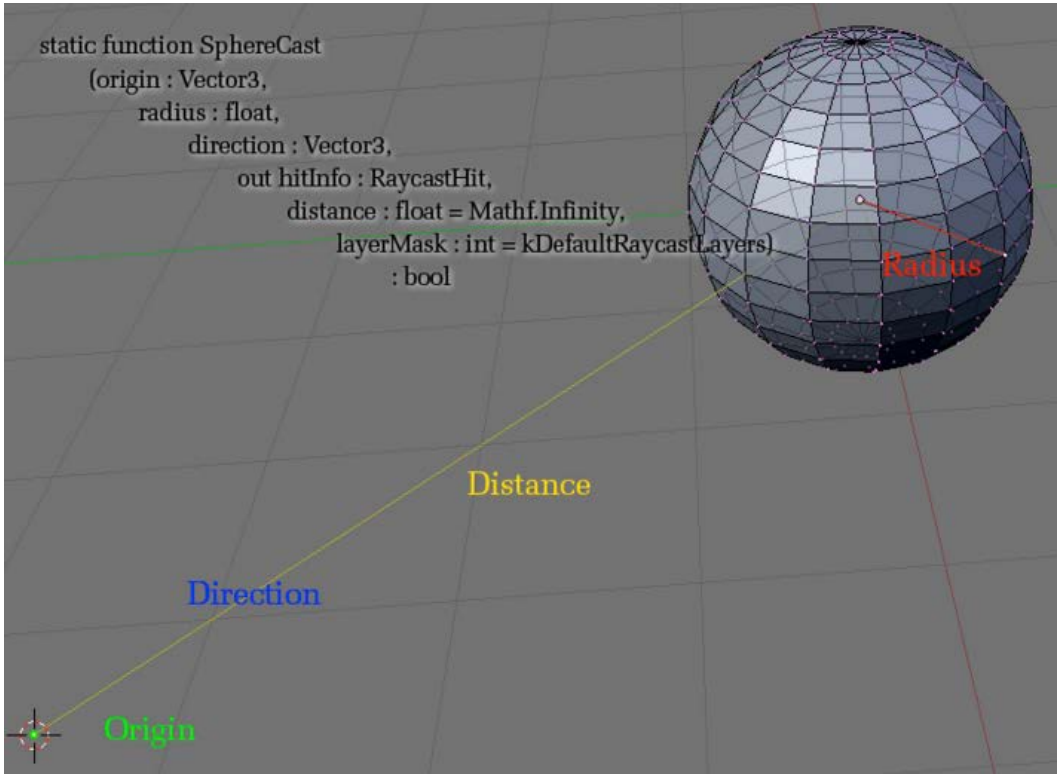
⇒ Tens bots ok … thousands KO!

⇒ Cannot be used for "path finding"!

Environment Representation
Detour: Spherecasting

Volumes can be "raycast" using spherecasting

- Uses Physics engine



Environment Representation
Raycasting

Using BSP tree for path-finding?
⇒ Certainly not …

What if we preprocess triangles, representing them in a graph (two triangles are connected in graph if they share an edge)?
⇒ … Depends on the map …

UT2004 Map	Text (XML)	Vertices	Triangles	log2(Tris)
	[MB]	[Count]	[Count]	
DM-Flux2	6	86615	63611	15,9569886
CTF-FaceClassic	10	82189	68357	16,0608015
CTF-January	30	502051	354342	18,434783
CTF-MoonDragon	60	745755	570444	19,1217257
AS-BP2-Acatana	68	830747	551456	19,0728863

Pathfinding

O(n.log n)!

Environment Abstraction
Reducing the space

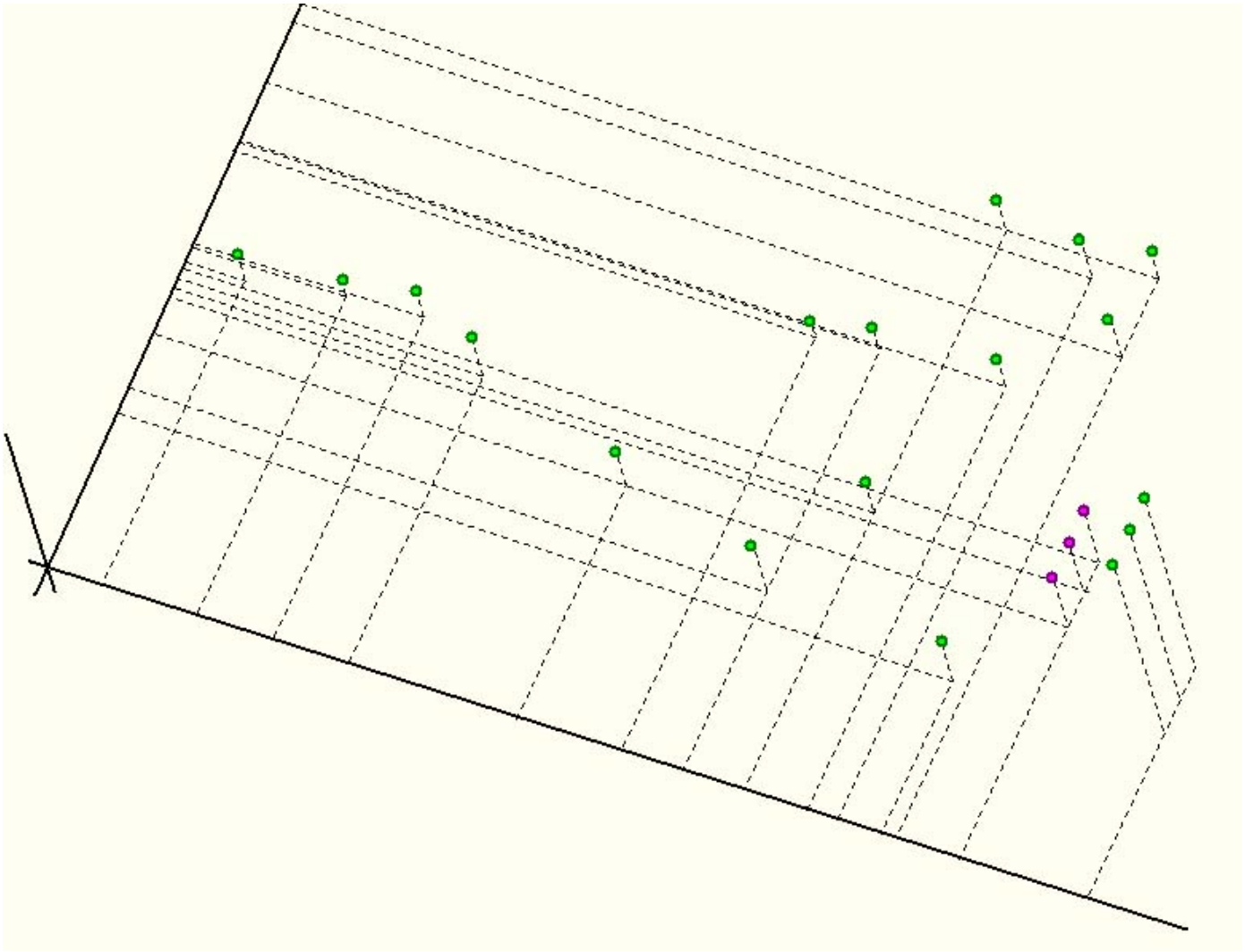
- Navigation graphs
  - „1D“ techniques
    - Using lines (segments)
  - „Pseudo 2D“ variants
    - Extra infos
- Navigation meshes
  - „2D“ techniques
    - Rectangles
    - Convex polygons
- Voxel navigation
  - 3D technique
  - Convex 3-polytops

Environment Abstraction

Navigation Graph

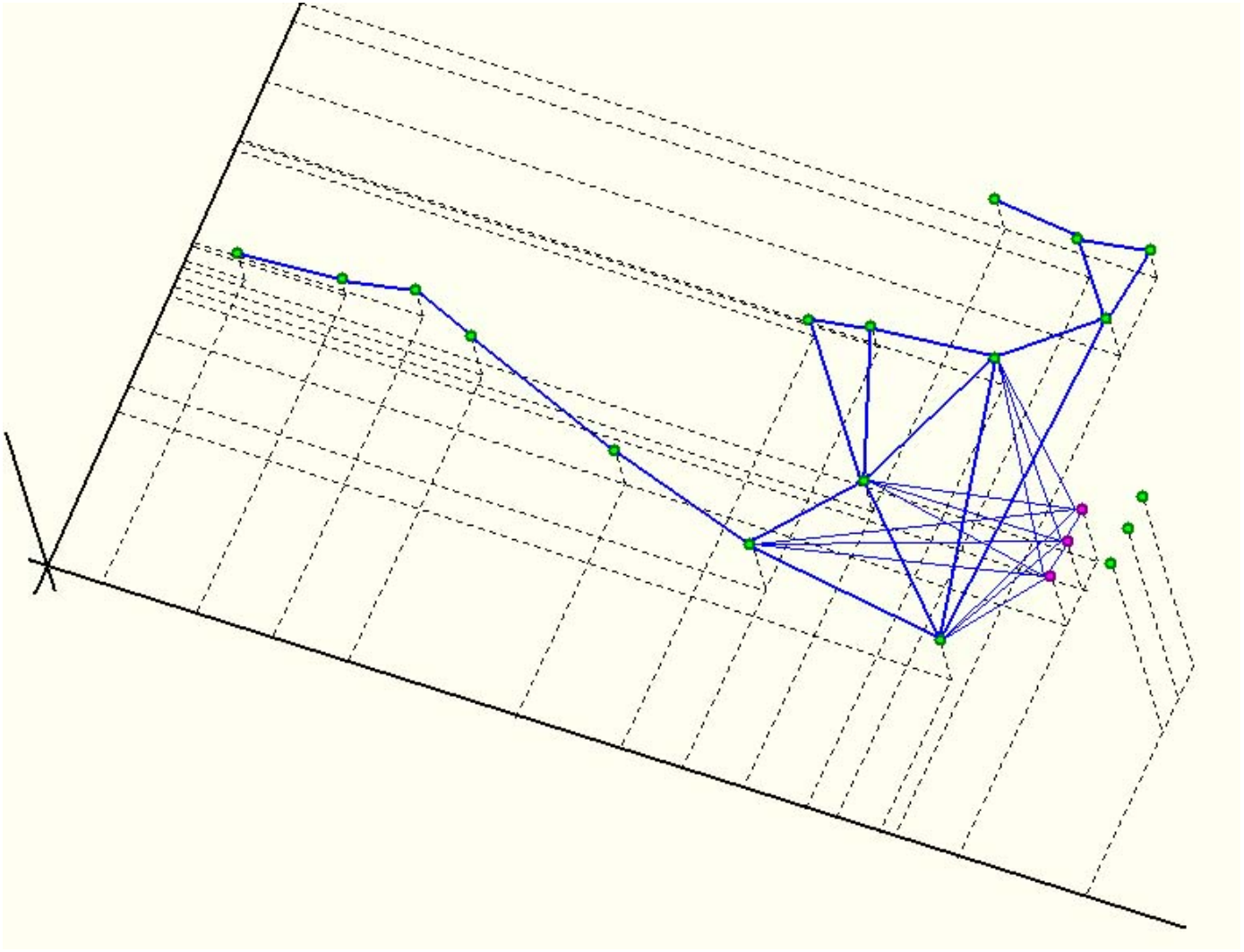
Environment Abstraction

Navigation Graph



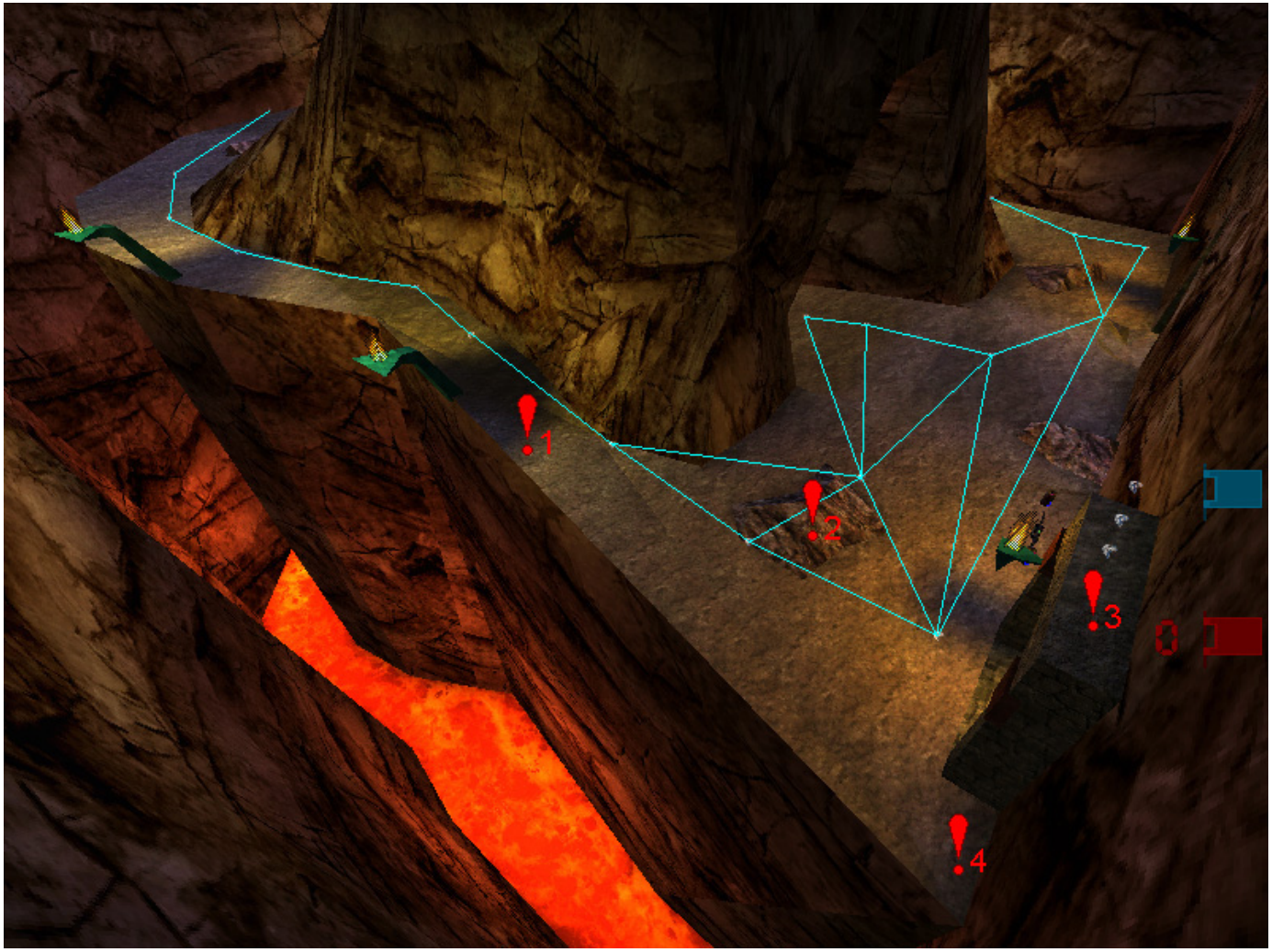
Environment Abstraction

Navigation Graph



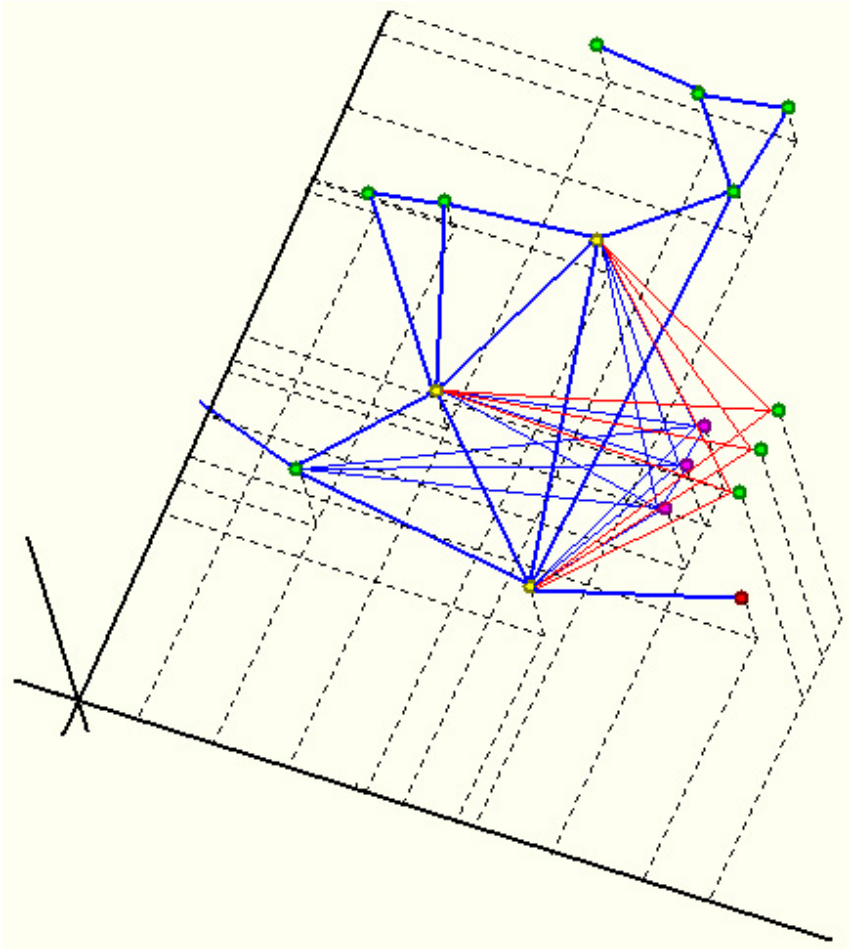
Environment Abstraction

Navigation Graph



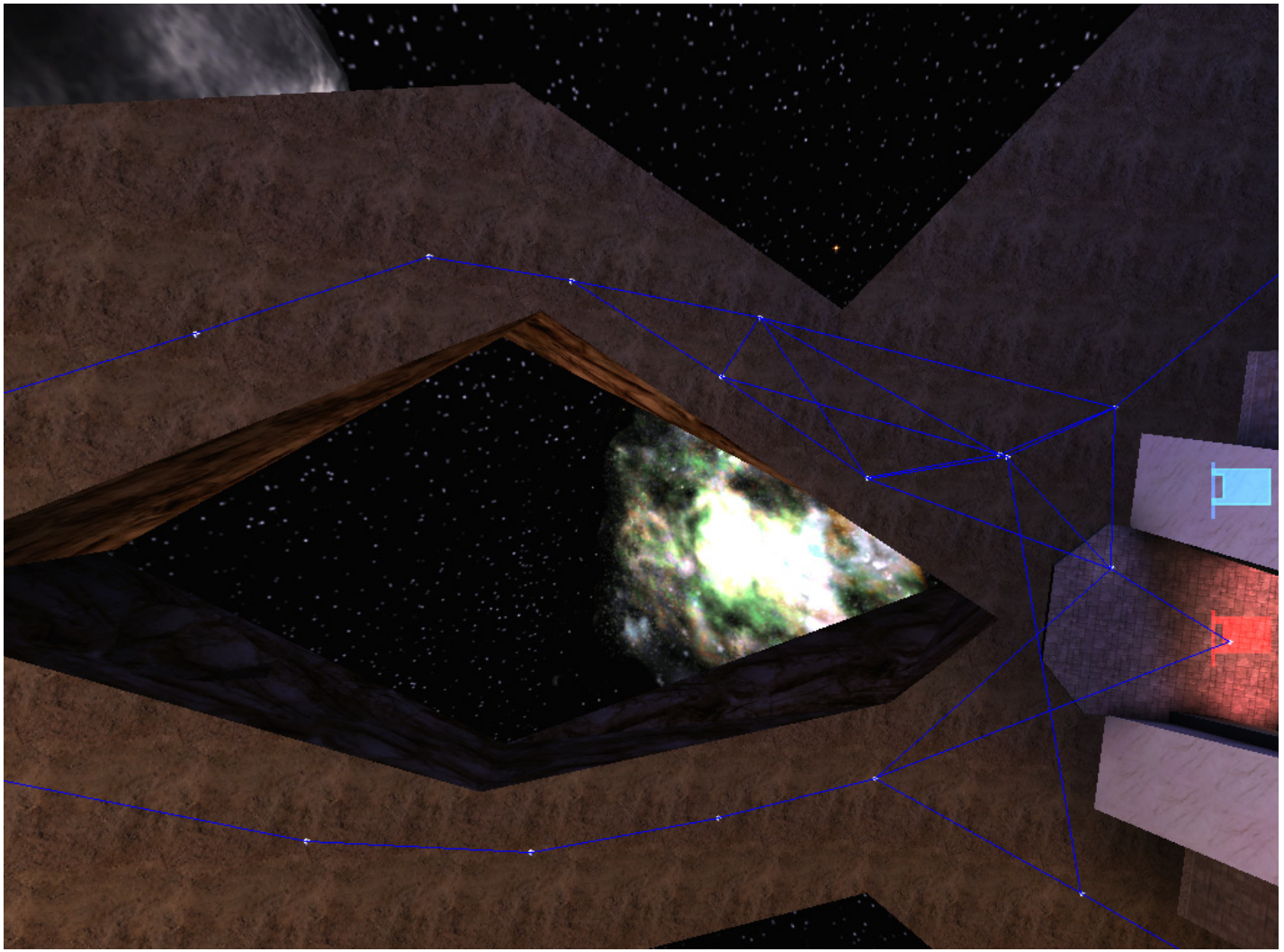
Environment Abstraction

Navigation Graph



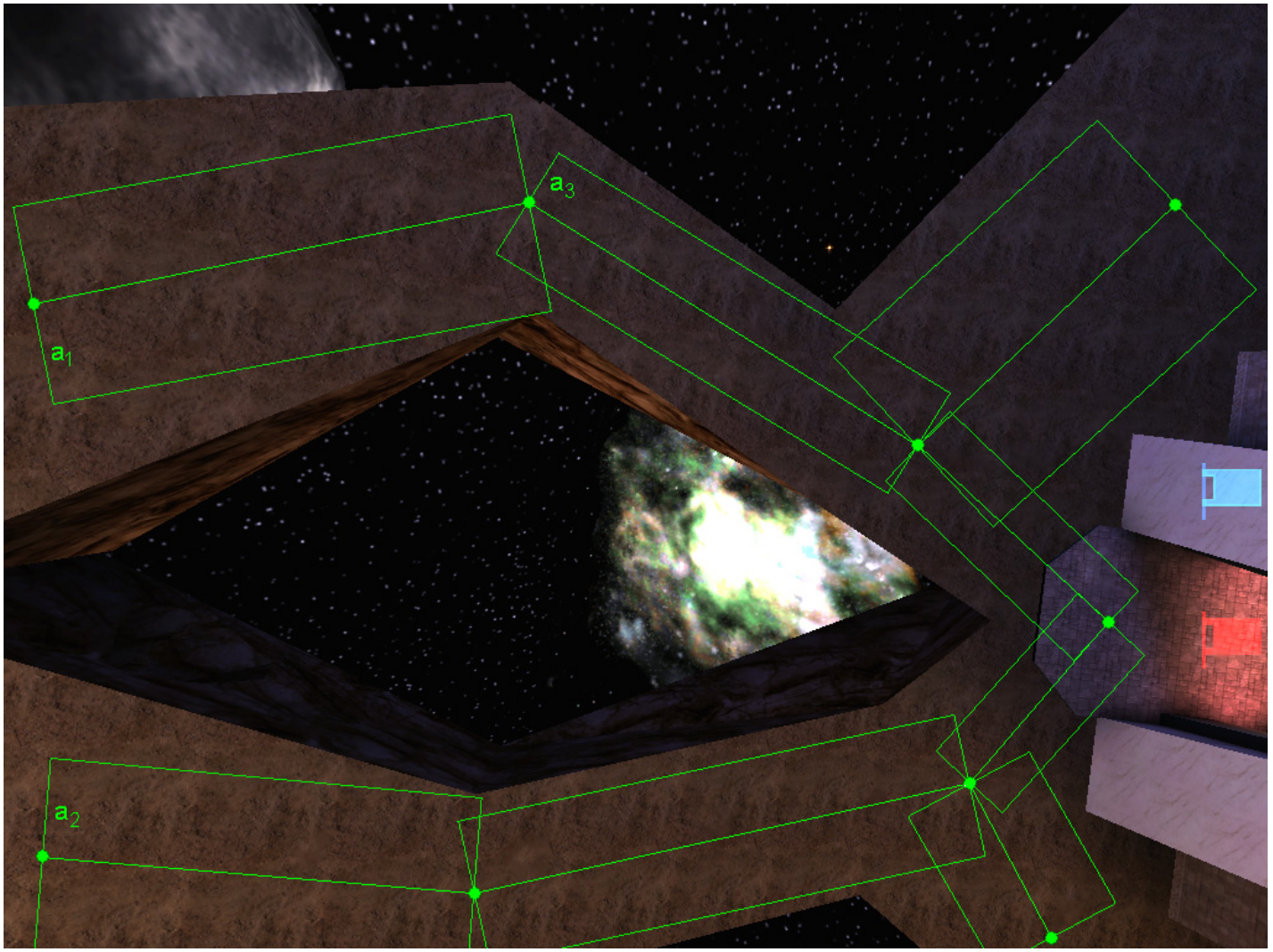
Environment Abstraction

Navigation Graph



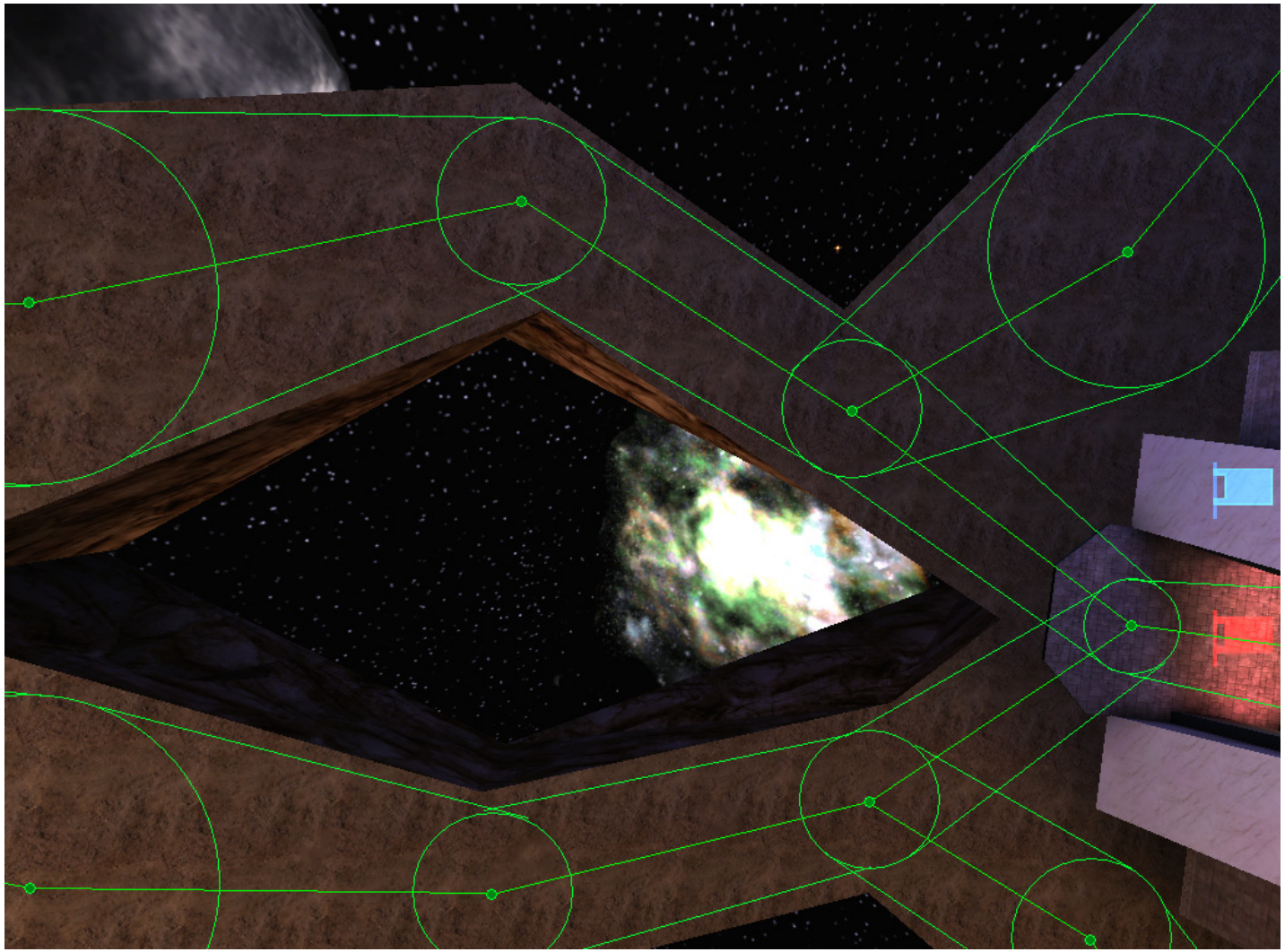
Environment Abstraction

Navigation Graph



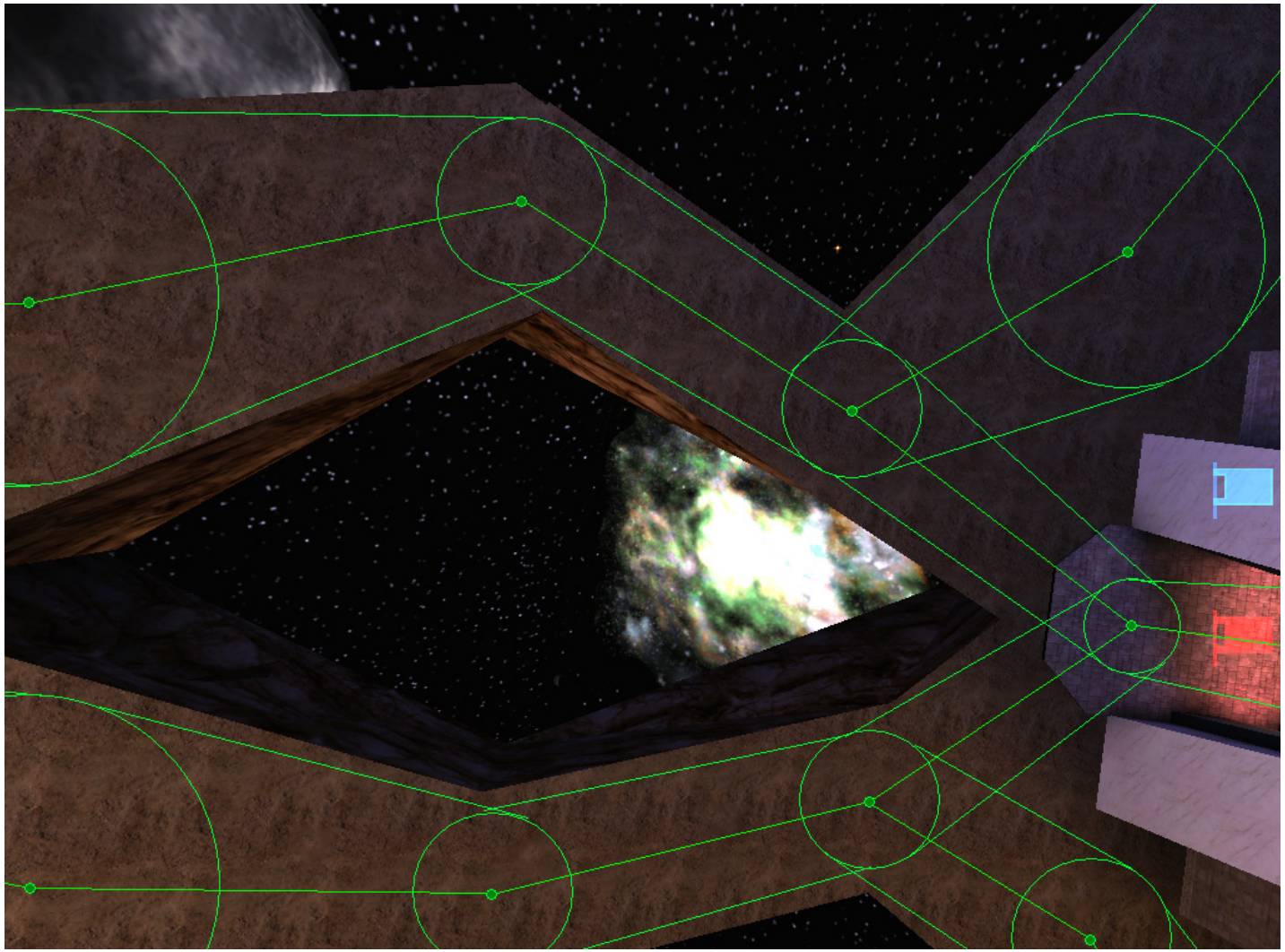
Environment Abstraction

Navigation Graph



Environment Abstraction

Navigation Graph



Environment Abstraction
Navigation Graph

- How big is the benefit of this abstraction?

UT2004 Map	Text (XML)	Vertices	Triangles	log2(Tris)	NavPoints
	[MB]	[Count]	[Count]		[Count]
DM-Flux2	6	86615	63611	15,9569886	194
CTF-FaceClassic	10	82189	68357	16,0608015	313
CTF-January	30	502051	354342	18,434783	438
CTF-MoonDragon	60	745755	570444	19,1217257	

- Key points
  - Performance wise!
  - Semi/Automatic creation/design
  - May bear extra information in nodes (cover/sniping/item spot) as well as edges (safe distance/navigation hints)
  - Movement looks “mechanic”

Environment Abstraction

Navigation Mesh

Environment Abstraction
Navigation Mesh

- How big is the benefit of this abstraction?

UT2004 Map	Text (XML)	Vertices	Triangles	log2(Tris)	NavPoints	NavMesh
	[MB]	[Count]	[Count]		[Count]	[Count]
DM-Flux2	6	86615	63611	15,95698865	194	413
CTF-FaceClassic	10	82189	68357	16,06080146	313	2492
CTF-January	30	502051	354342	18,43478295	438	3296
CTF-MoonDragon	60	745755	570444	19,12172574	498	4425

- Key points
  - Better representation of the floor
  - Fully automatic creation
  - Slower path-finding (because of extra steps)
  - Suitable for steerings, movement can be refined
  - Must be combined with navgraph - “off-mesh links”