Game Notebook
Project Magma

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PART 1 – FORMAL GAME PROPOSAL

INTRO

For reasons still being researched, volcanoes started to appear all over Antarctica, flushing resources of unprecedented value onto the earth's surface. Although the resources legally belong to the state of Antarctica, the immense value of said resources led other fractions to claim ownership. Day after day, new gatherers arrived, trying to capture as much as they could. As the situation got out of control, the world union decided to legally distribute the resources all over the planet. In a time of great decadence it was decided that shares shall be dispensed based on the outcomes of deadly robot-matches inside the volcanoes. Since then, engineers all over the world have constantly been working on improving their robots in order to be able to explore and to claim the deadly depths of Antarctica's volcanoes.

INFORMAL DESCRIPTION

OVERVIEW

The game features 2-4 players competing against each other (mainly in death match, but other modes such as control point or capture-the-flag are also conceivable) on one screen, viewed from a fixed angle (no scrolling, but automatic zoom has to be tested). The screen wraps around: if a player leaves to the right he will enter from the left and vice versa.

The competition takes place around a lake of lava. Large pillars stick out of the lava into the sky. Between the pillars, there are islands hovering on different heights. The players can stand on these islands, change the paths of the islands and go from one island to another. Islands can collide with each other and pillars, which can result in islands and/or pillars falling down and taking other objects with them. When a player stands on an island, it will slowly lose height because of the added weight. If a player leaves the island before it eventually sinks into the lava, it hovers back to its original position. Sunken islands can be replaced by new ones using a ray of cold water. Periodically, eruptions from the lava in the form of fireballs will appear and hurt players if they get hit.

GAME ELEMENTS

ENVIRONMENT

The game environment consists of a rectangular field where all the action takes place. The borders wrap around, meaning that everything disappearing on one side reappears on the other side. This battle ground basically consists of the following three different elements:

- A sea of lava covers the ground and is - of course - deadly to the players
- Rock pillars of different sizes stick out of the lava
- Rock islands hover on a specific height above the field of lava.

A more precise definition of these elements follows.

PILLARS

Pillars just stick out of the lava. Islands can collide with them and tilt them over. When a pillar falls, it can take other pillars or islands with it. On the top, the pillars are covered in ice which is constantly melting – therefore, water runs down along the pillars.

HOVERING ISLANDS

Islands hover on a specific height (Y axis) on a specific path between the pillars. When islands collide with each other or pillars, they are only deflected from their path on the XZ plane and never leave their fixed position on the Y axis. Players can stand on islands, but they will slowly lose height and eventually melt in the lava below. Islands are covered by grass and other flora. Islands in the upper heights can also be covered in ice.

PLAYER CHARACTERS

Players control characters, which have a certain amount of health and energy. A player can move between the islands and attack other players. While melee attack is free, energy is consumed if a player performs some special attack (see Indirect combat (Chicken tactics)). Health is deduced when a player gets hit by another players attack. If a player's health is zero or below, he dies and loses. A player also dies when falling into the lava.

POWER-UPS

Simple power ups for health and energy are distributed over the islands. They will randomly re-appear if collected.

PLAYER INTERACTIONS

Every player can perform the following actions without using any finite resource:

WALKING (BORING BUT NECESSARY)

Players can walk around the islands, though they cannot fall from them just by walking.

COLLECT POWER-UPS (RED BULL GIVES YOU WINGS!)

If a player gets in contact with a power-up he can collect it and will receive the power accordingly.

ISLAND ATTRACTION (USE THE FORCE, LUKE)

Islands can be attracted using some fancy force which makes them slowly move towards the island the player is standing on, so he can switch to the other island.

ISLAND JUMP (UP AND AT THEM)

The player can activate his jet pack for a very short amount of time which allows him to go from one island to another.

ISLAND REPULSION (GASSY EMISSION)

The player can change the path of an island either temporarily or completely. He does so by grasping the island and emits a burst of air using his jet pack.

DIRECT COMBAT (MANO-A-MANO)

Every player has a melee attack ability which costs no energy. A melee attack will both deduce health from his enemy as well as physically push the opponent away from the attacker. The latter one can be exploited to push an opponent over the edge of an island.

Furthermore, every player has energy as a resource. Energy will recharge itself with time and can be used to perform the following actions:

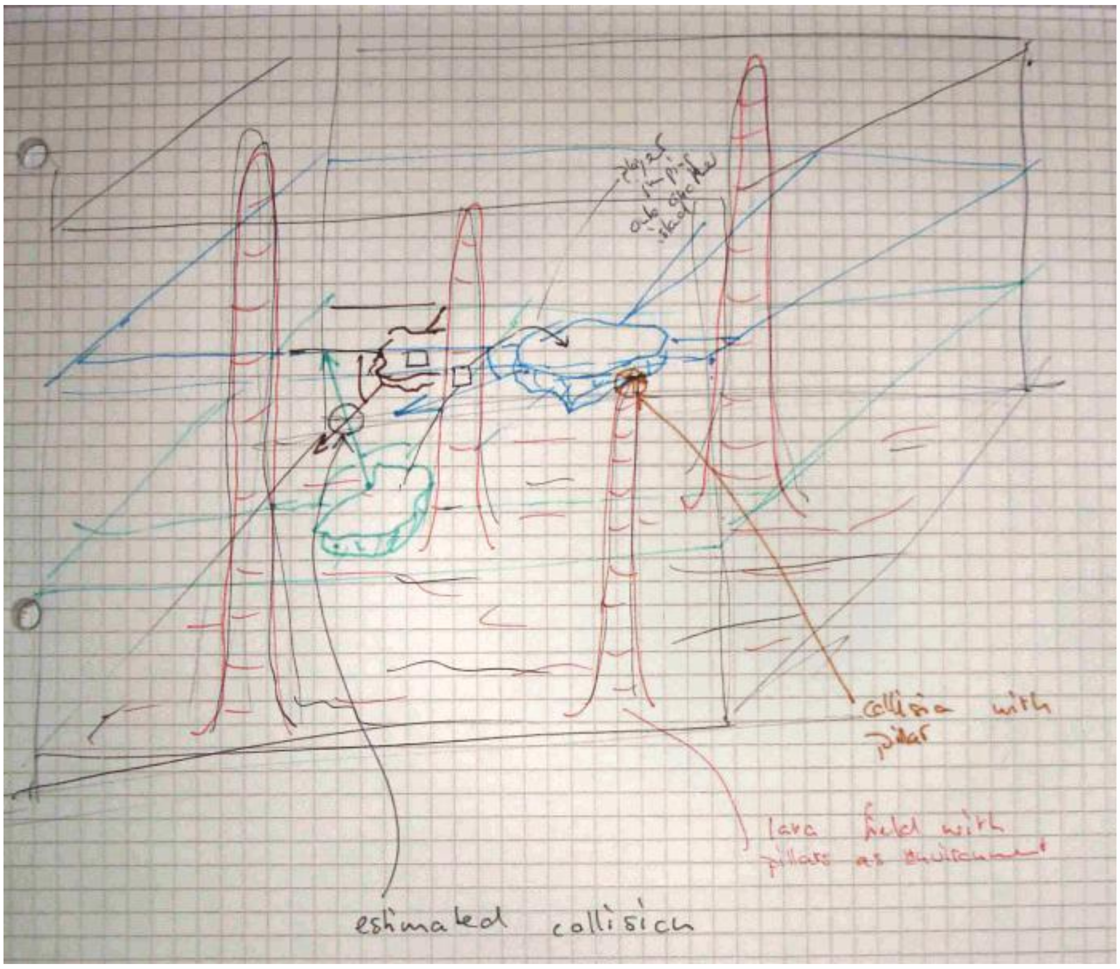
INDIRECT COMBAT (CHICKEN TACTICS)

A player has various means of indirect combat in the form of special abilities:

- **Ice spike**: The player can specify a direction in which, subsequently, a spike is sent off. If the spike hits an enemy, he will get hurt and frozen for a short period. If the spike hits lava, an island will be created.
- **Snow storm**: The player can specify a point in range; a cloud will appear and start snowing on the creatures below it, causing damage.
- **Fire wall**: The player can lighten up a fire on the floor which will remain there for a fixed amount of time. Players stepping on the fire will be hurt.
- **Small robot spawning (aka binary fission)**: The player can spawn a robot on the current island which will be there for a fixed amount of time and attack all enemies stepping on the island.

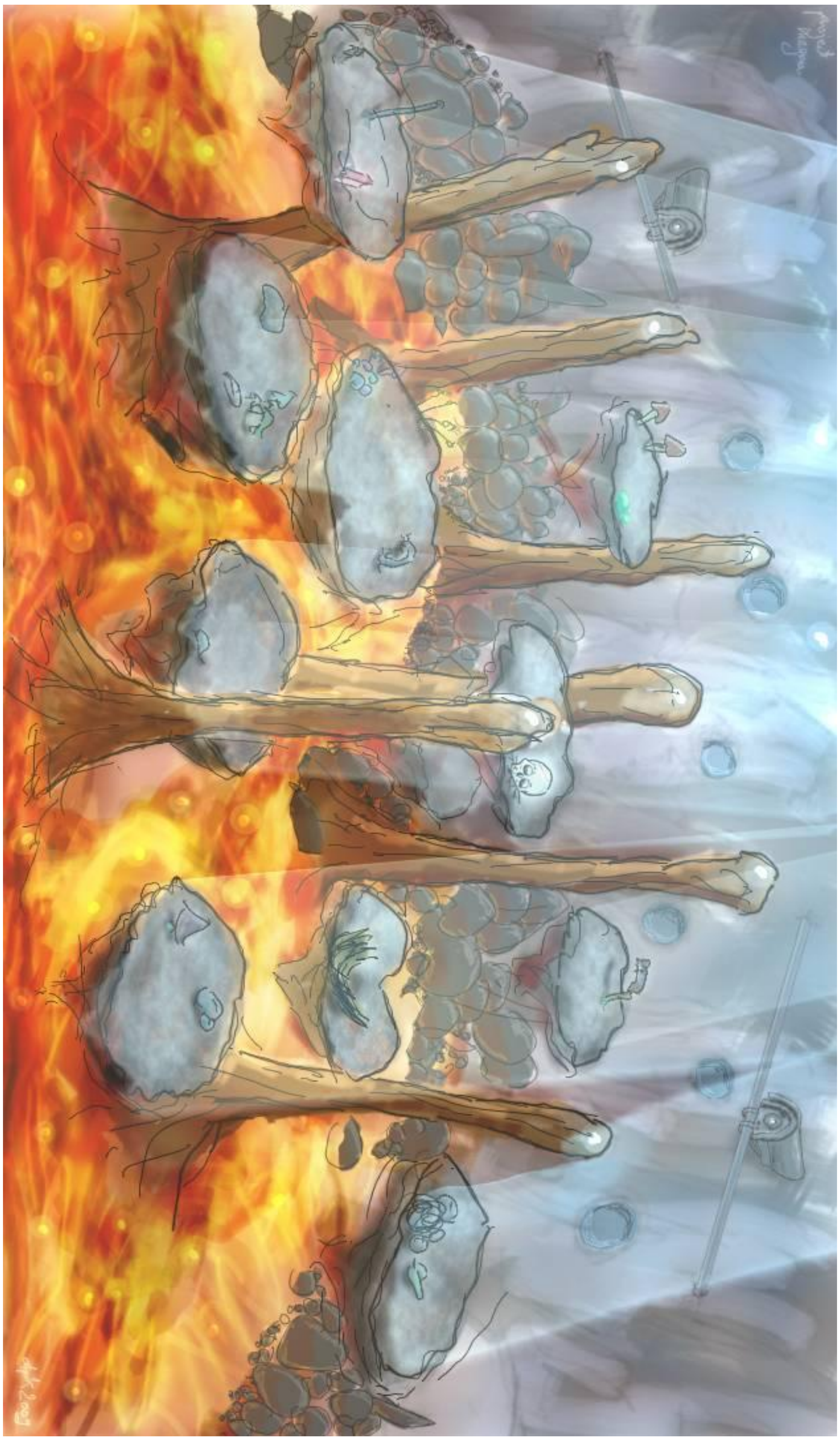
CONCEPT SKETCHES

TYPICAL IN-GAME SITUATION

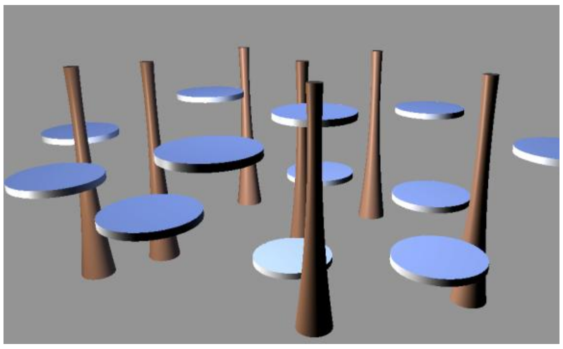

players in pos. ~~on the~~ side
collision with pillar
lava field with pillars as environment
estimated collision

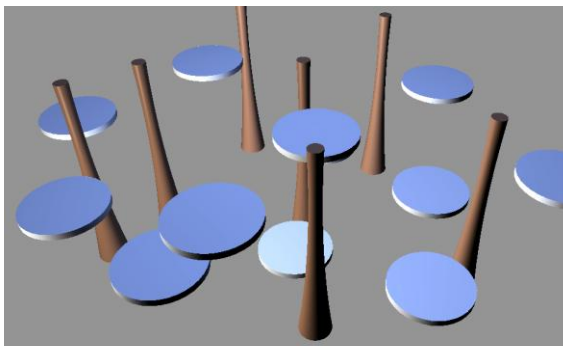
On this image one sees:

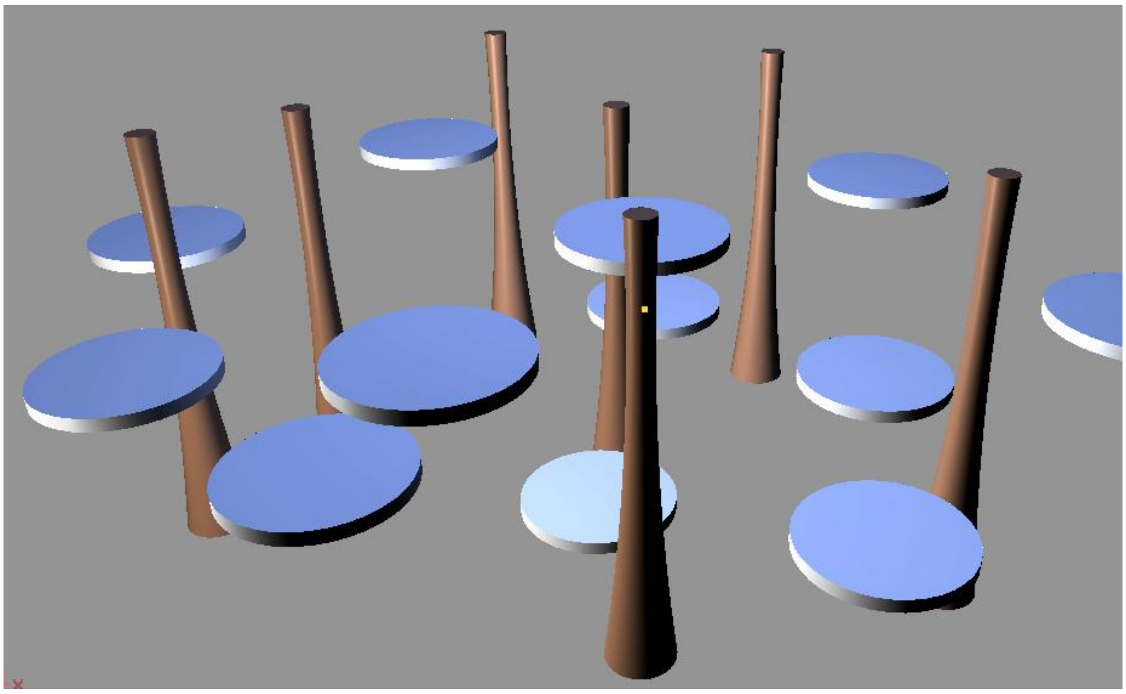
- 4 pillars
- 3 Islands floating, two of them on the same height
- Estimated collision point between the green and the brown island. After the collision, they will change their movement direction.
- Players are visualized by rectangles. Player 1 sits on the brown island waiting to shoot at player 2. Player two on the other hand flees from the crash onto the blue island.

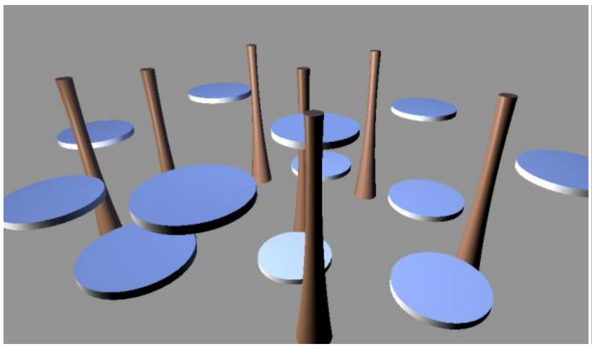


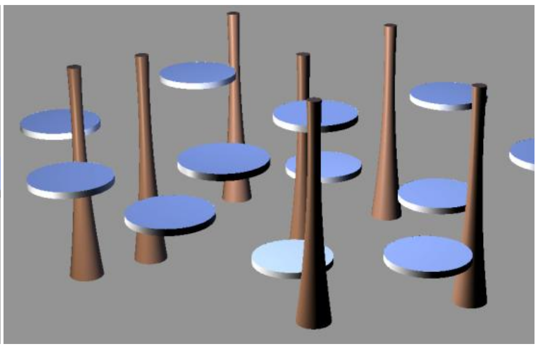
How the game could look when it is done.


An alternate view angle of 18 degrees. It is difficult here to navigate in the XZ plane.

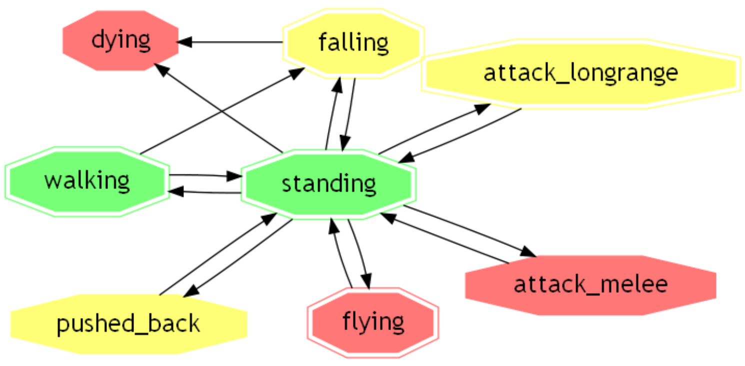

An alternate tilt angle of 38 degrees. The notion of height is difficult to grasp here.


We deemed this view to be optimal in both perspective (f=21) and tilt angle (26 degrees).


An alternate perspective, f=21. The distortion is too large, players would stay in the front.


A more orthographic perspective, f=71. There is no dramatics, the look and feel is too static.

MODEL ANIMATION STATES



A finite state automata model of player animations. Colors denote priorities of realization (green is high, red is low). Outlined states denote looping animations.

ROBOT MODELS

We particularly like the look and feel of this robot we found on the web. The head is over proportional to the body which yields a more comic look and feel. We might want to go for a longer head to make it look more aggressive, though.

A concept of little prop robots which are spawned on islands to make an island hostile (high target).

FORMAL REQUIREMENTS

GENERAL

ID	Requirement	Description
ReqG01	Basic Camera	The basic camera captures the scene from a predefined position. The whole game area is always visible.
ReqG02	Advanced Camera	The camera films the scene from a varying position. It always films from the same side, but height an zoom may vary depending on the optimal setting.
ReqG03	Basic Software Framework	Setting up a generic framework that is expandable, embeds the game logic, graphics and similar. The framework should be built as much on XNA as possible. But still every new feature should be addable as a separate component.
ReqG04	HDR Rendering	Setting up the renderer to render with high definition textures and effects. This feature significantly improves the visual appearance of the game.
ReqG05	Shadow Rendering	Rendering the scene with shadows using a state-of-the art technique.
ReqG06	Statistics	Keep track about players win and looses, their longest live, their fastest kill and their fastest death.

GUI AND HUD

ID	Requirement	Description
ReqUI01	Start Screen	There is a start screen from where one can start a new game and view the high score.
ReqUI02	High Score	The high score features statistics (defined in Req06) about past games.
ReqUI03	Text Input	Text can be entered using the controller.
ReqUI04	Player Selection	Players can select their desired character and enter their name.
ReqUI05	Map Selection	The first player can select a map to play in.
ReqUI06	Simple HUD	A HUD showing each players health and energy has to be available.
ReqUI07	Fancy HUD	A beautifully designed HUD that nicely integrates with the game environment has to be available.
ReqUI08	Intro	An intro explains the game's background story.

LAVA

ID	Requirement	Description
ReqL01	Lava Ground	The ground is covered by lava. This requirement represents the game-logic of the lava.
ReqL02	Basic Lava Effect	A basic effect to render the lava lake. A basic red rectangle is enough for a first prototype.
ReqL03	Polished Lava Effect	A polished and nice effect to render the lava lake. This includes advanced shaders.
ReqL04	Deadly Lava	If the player gets into contact with the lava he dies.
ReqL05	Fire Eruptions	At random there are fire eruptions emerging from the lake.
ReqL06	Harmful Fire Eruptions	If such a fire eruption hits a player he endures damage or dies. If the eruption hits an island it throws the island off its course.

PILLARS

ID	Requirement	Description
ReqPi01	Pillars	Pillars of different sizes stick out of the lava. This requirement

		represents the need to model pillars with respect to in-game logic.
ReqPi02	Basic Pillar Rendering	There is some model representing pillars which stick out of the lava.
ReqPi03	Sophisticated Pillar Rendering	Realistically rendered pillars stick out of the lava.
ReqPi04	Tilt Pillars	Pillars can be tilt over by islands. The resulting fall can affect other islands and pillars.
ReqPi05	Icy Pillars	Pillars have a top consisting of ice, which melts to water that runs down the pillar and drops into the lava.

FLOATING ISLANDS

ID	Requirement	Description
ReqI01	Floating Islands	Initially there is a set of floating islands of rock. The islands hover above the lake of lava in different heights.
ReqI02	Basic Island Rendering	A basic rendering such that the islands are visible and useable inside a game.
ReqI03	Sophisticated Island Rendering	A polished and nice effect to render the islands.
ReqI04	Moving Floating Islands	Islands have the ability to move. They move with a given velocity.
ReqI05	Crashing Islands	If an island crashes into another island the collision will be resolved according to physics. The resulting movement should be locked onto the x/z plane the resulting rotation only respective to the y-axis.
ReqI06	Islands and Pillars	If an island crashes into a pillar the collision will be resolved according to physics. The resulting movement should be locked onto the x/z plane the resulting rotation only respective to the y-axis.
ReqI07	Sinking Islands	If a player stands on an island it will lose height.
ReqI08	Rising Islands	If the island does not carry the player it regains its original height.
ReqI09	Melting Islands	If an island gets into contact with lava it melts.
ReqI10	Destructible Islands	If an island takes enough damage, either by a players special ability or by falling pillars it will fall apart.
ReqI11	Icy Islands	Islands hovering above a specific height are slightly or fully covered in ice.
ReqI12	Power-Ups	Power-Ups are lying on the islands.
ReqI13	Power-Up Re-spawn	Power-Ups re-spawn if consumed on a random island
ReqI14	Island Health Indication	If islands are being destroyed by heat the progress of destruction shall be indicated by an increasing glow.

PLAYER

ID	Requirement	Description
ReqP01	Player	The player has to be represented within the game-logic.
ReqP02	Basic Player Model	A model for the player is available.
ReqP03	Sophisticated Player Model	A realistic model for the player is available.
ReqP04	Island Attraction	A player can use attract an island so it floats to the side of the island the player is standing on. As soon as the island is not attracted anymore, it hovers back to its original position.
ReqP05	Island Walking	The player can walk to an island he attracted.
ReqP06	Island Jumping	A player can use the jetpack to move from one island to another.
ReqP07	Island Repulsion	A player can use the jetpack to emit bursts of air which will for a short period of time get an island to drift off its original course. If it

		collides with a pillar it could change its course completely.
ReqP08	Direct Combat 1	Every player has a melee attack ability which costs no energy. This will deduce health from his enemy.
ReqP09	Direct Combat 2	A realistic attack animation is displayed.
ReqP10	Direct Combat 3	Melee attacks will also physically push the opponent away from the attacker.
ReqP11	Energy	Every player has an energy bar which is displayed in the UI. Energy will recharge itself with time. Every used skill will use a fixed amount of energy.
ReqP12	Ice Spike	The player can specify a direction in which, subsequently, a spike is sent off. If the spike hits an enemy, he will get hurt and frozen for a short period.
ReqP13	Flame Thrower Damage	The player can use a flame thrower to cause damage to another player.
ReqP14	Flame Thrower Island Destruction	The player can use a flame thrower to target and destroy islands.
ReqP15	Building Islands with Ice Spikes	If the spike hits a rising fire ball, an island will be built.
ReqP16	Snow storm	The player can specify a point in range, a cloud will appear and start snowing on the creatures below it, causing damage.
ReqP17	Fire Wall	The player can lighten up a fire on the floor which will remain there for a fixed amount of time. Players stepping on the fire will be hurt.
ReqP18	Small Robot Spawning	The player can spawn a robot on the current island which will be there for a fixed amount of time and attack all enemies stepping on the island.
ReqP19	Aiming Aids	Visual aids for helping the player aim (during ranged combat or islands jumping) shall be implemented to simplify controlling a player.
ReqP20	Collecting Power-Ups	Players can collect power-ups and get their respective bonuses.
ReqP21	Slow Indication	If a player has been slowed, this state shall be indicated graphically.

DEVELOPMENT SCHEDULE

The development shall be divided into consecutive layers. All of the requirements defined under are classified and assigned to one of them. Those layers are:

1. **Prototype**: The prototype serves to play test the central game-logic and contains only the most minimal graphical features needed to represent the game state. If any feature is removed from this part the prototype will degrade from a game into a technical prototype.
2. **Functional minimum**: This first layer contains the set of requirements minimally required to play the game and also some first simple visuals. The functional minimum is the first milestone.
3. **Low target**: The low target is the second layer and also a milestone. Though it contains more features than the bare minimum, it is still essentially not what should be achieved during the timeframe of fourteen weeks. Still it will serve as a good indicator if the development is still inside the timeframe laid out in this chapter.
4. **Desirable target**: This layer and milestone is what the project aims at. It contains all the requirements that make up a well polished and fun to play game.

5. **High target**: The high target contains additional features that will make it into the final deliverable if the team has some free time to implement them. There is no milestone defined for it. After finishing the Desirable Target it will be decided which features of this target will make it into the gold version milestone.
6. **Extras**: This part of the schedule defines some additions to the game that would be fun but are not realistic to achieve. However in a future project they could be added.

The layers then are assigned to milestones to be reached on a specific date. Those milestones contain a detailed timetable determining when each requirement will be implemented and who is responsible for the implementation. This timetable shall be filled out iteratively during the projects development.

DELIVERABLES

PROTOTYPE

ID	Requirement
ReqG01	Basic Camera
ReqG03	Basic Software Framework
ReqL01	Lava Ground
ReqL02	Basic Lava Effect
ReqL04	Deadly Lava
ReqPi01	Pillars
ReqPi02	Basic Pillar Rendering
ReqI01	Floating Islands
ReqI02	Basic Island Rendering
ReqI04	Moving Floating Islands
ReqP01	Player
ReqP02	Basic Player Model
ReqP06	Island Jumping
ReqP08	Direct Combat 1
ReqP10	Direct Combat 3
ReqP12	Ice Spike
ReqI12	Power-Ups
ReqP20	Collecting Power-Ups

FUNCTIONAL MINIMUM

ID	Requirement
ReqI05	Crashing Islands
ReqI06	Islands and Pillars
ReqP09	Direct Combat 2
ReqI07	Sinking Islands
ReqI08	Rising Islands
ReqP13	Flame Thrower Damage
ReqP14	Flame Thrower Island Destruction
ReqP11	Energy
ReqUI06	Simple HUD
ReqP19	Aiming Aids
ReqG05	Shadow Rendering

LOW TARGET

ID	Requirement
ReqL03	Polished Lava Effect
ReqPi03	Sophisticated Pillar Rendering
ReqI03	Sophisticated Island Rendering
ReqP03	Sophisticated Player Model (may be moved)
ReqUI04	Player Selection
ReqUI07	Fancy HUD
ReqI14	Island Health Indication
ReqP21	Slow Indication
ReqP04	Island Attraction
ReqP05	Island Walking
ReqI13	Power-Up Re-spawn

DESIRABLE TARGET

ID	Requirement
ReqP07	Island Repulsion
ReqUI01	Start Screen
ReqUI05	Map Selection

HIGH TARGET

ID	Requirement
ReqG04	HDR Rendering
ReqL05	Lava Eruptions
ReqL06	Harmful Fire Eruptions
ReqPi04	Tilt Pillars
ReqPi05	Icy pillars
ReqI09	Melting Islands
ReqP15	Building Islands with Ice Spikes
ReqUI08	Intro
ReqG06	Statistics
ReqUI03	Text Input
ReqUI02	High Score
ReqG02	Advanced Camera

EXTRAS

ID	Requirement
ReqI10	Destructible Islands
ReqP16	Snow Storm
ReqP17	Fire Wall
ReqP18	Small Robot Spawning
ReqI11	Icy Islands

MILESTONES

ID	Milestone	Description	Due Date
MS01	Prototype Chapter Written	With this milestone the prototype chapter must have been written and added to the game notebook. Everyone in the team should also have installed and experimented with XNA in order to be ready for	March 16, 5pm

		development. Additionally a game prototype according to the prototype specification has been created.	
MS02	Functional Minimum	With this milestone the functional minimum must be implemented, working and tested.	March 23, 12pm
MS03	Interim Report Written	With this milestone the chapter with the interim report must have been written and added to the game notebook.	April 6, 5pm
MS04	Low Target	With this milestone the low target shall be hit.	April 13, 12pm
MS05	Desirable Target	With this milestone the team must have fulfilled the requirements for the desirable target. The prototype must be tested and in presentable order since it is needed for play testing in the week after.	May 4, 12pm
MS06	Play test Chapter Written	With this milestone the play test chapter must have been written and added to the game notebook. This concludes that to this date all the play testing must be done.	May 11, 5pm
MS07	Gold Version	With this milestone the development must have been concluded. All testing must have been finished and some of the high target functionality should be implemented.	May 25, 12pm
MS08	Conclusion and Presentation	With this milestone the conclusion chapter must have been written and added to the game notebook. In addition the public presentation of the game must be ready to be held.	May 29, 5pm

TASK ASSIGNMENTS AND WORK ESTIMATION

PROTOTYPE

ID	Requirement	Assignee	Work Estimate
ReqG01	Basic Camera	cob	2h
ReqG03	Basic Software Framework	cob	8h
ReqL01	Lava Ground	jab	3h
ReqL02	Basic Lava Effect	cob	2h
ReqL04	Deadly Lava	jab	3h
ReqPi01	Pillars	cob	3h
ReqPi02	Basic Pillar Rendering	cob	2h
ReqI01	Floating Islands	jab	2h
ReqI02	Basic Island Rendering	dpk	4h
ReqI04	Moving Floating Islands	jab	4h
ReqP01	Player	dpk	10h
ReqP02	Basic Player Model	jab	4h
ReqP06	Island Jumping	jab	4h
ReqP08	Direct Combat 1	jab	1h
ReqP10	Direct Combat 3	jab	2h
ReqP12	Ice Spike	jab	3h
ReqI12	Power-Ups	cob	2h
ReqP20	Collecting Power-Ups	cob	1h

FUNCTIONAL MINIMUM

ID	Requirement	Assignee	Work Estimate

ReqI05	Crashing Islands	cob	tbd
ReqI06	Islands and Pillars	cob	tbd
ReqP09	Direct Combat 2	jab	tbd
ReqI07	Sinking Islands	dpk	tbd
ReqI08	Rising Islands	dpk	tbd
ReqP13	Flame Thrower Damage	jab	tbd
ReqP14	Flame Thrower Island Destruction	cob	tbd
ReqP11	Energy	jab	tbd
ReqUI06	Simple HUD	jab	tbd
ReqP19	Aiming Aids	dpk	8h

LOW TARGET

ID	Requirement	Assignee	Work Estimate
ReqL03	Polished Lava Effect	dpk	
ReqPi03	Sophisticated Pillar Rendering	dpk	
ReqI03	Sophisticated Island Rendering	dpk	
ReqP03	Sophisticated Player Model		
ReqUI04	Player Selection	jab	3h
ReqUI07	Fancy HUD	jab	3h
ReqI14	Island Health Indication	cob	
ReqP21	Slow Indication	cob	
ReqP04	Island Attraction	jab	4h
ReqP05	Island Walking	jab	2h
ReqI13	Power-Up Re-spawn	jab	1h
None	Advanced Collision Detection	cob	
None	Gamplay testing	jab	4h

DESIRABLE TARGET

ID	Requirement	Assignee	Comments
ReqL03	Polished Lava Effect	dpk	performance
ReqPi03	Sophisticated Pillar Rendering	Dpk	textures
ReqI03	Sophisticated Island Rendering	Dpk	textures
ReqP03	Sophisticated Player Model	dpk /cob	
ReqUI07	(Fancy HUD)	jab	need graphics from designer
ReqI14	(Island Health Indication)	cob	depends on flamethrower
ReqP21	Slow Indication	Dpk	In player shader
ReqP07	Island Repulsion	Jab	implemented in MS03
ReqUI01	(Start Screen)		
ReqUI05	(Map Selection)		
None	Advanced Collision Detection	Cob	Performance
None	Default robot in player selection	Jab	
None	No-repeat in menu	Jab	
None	Death indication in HUD	Jab	
None	Flamethrower island selection?	Jab	
None	Improved ice spike aiming + Sphere	jab/dpk	
None	Last man standing gameplay mode	Jab	
None	Powerup and arrow animation	Dpk	
None	(Level preview in Menu)	Jab	
None	Keyboard controls for player 1	Jab	
None	Ice spike effect (particle system)	Cob	
None	Explosion effect (particle system)	Cob	
None	Fire effect (particle system)	Cob	

DEVELOPMENT TIMETABLE

WEEK 11: 9.3.-15.3. WORKING TOWARDS MS01

ID	Requirement	Assignee	Mo	Tue	Wed	Thu	Fri	Sat	Sun
ReqG01	Basic Camera	cob		2					
ReqG03	Basic Software Framework	cob	8						
ReqL01	Lava Ground	jab		3					
ReqL02	Basic Lava Effect	cob			2				
ReqL04	Deadly Lava	jab		3					
ReqPi01	Pillars	cob			3				
ReqPi02	Basic Pillar Rendering	cob			2				
ReqI01	Floating Islands	jab			2				
ReqI02	Basic Island Rendering	dpk		4					
ReqI04	Moving Floating Islands	jab				4			
ReqP01	Player	dpk		4	4	2			
ReqP02	Basic Player Model	jab				4			
ReqP06	Island Jumping	jab					4		
ReqP08	Direct Combat 1	jab			1				
ReqP10	Direct Combat 3	jab			2				
ReqP12	Ice Spike	jab				3			
ReqI12	Power-Ups	cob				2			
ReqP20	Collecting Power-Ups	cob			1				
None	Testing	jab/dpk/cob						4	4
None	Work Estimates and Plan for MS05	jab/dpk/cob						1	1

WEEK 12: 16.3.-22.3. WORKING TOWARDS MS02

ID	Requirement	Assignee	Mo	Tue	Wed	Thu	Fri	Sat	Sun
ReqG01	Basic Camera	cob		2					
ReqG03	Basic Software Framework	cob	8						
ReqL01	Lava Ground	jab		3					
ReqL02	Basic Lava Effect	cob			2				
ReqL04	Deadly Lava	jab		3					
ReqPi01	Pillars	jab			3				
ReqPi02	Basic Pillar Rendering	cob			2				
ReqI01	Floating Islands	jab			2				
ReqI02	Basic Island Rendering	dpk		4					
ReqP01	Player	jab				4			
ReqP02	Basic Player Model	dpk		4	4	2			
ReqP06	Island Jumping	jab				4			
ReqP08	Direct Combat 1	jab					4		

None	Testing	jab/dpk/cob	4	4
None	Work Estimates and Plan for MS05	jab/dpk/cob	1	1

WEEK 13: 23.3.-29.3. WORKING TOWARDS MS03 AND MS04

Exact schedule to be determined.

WEEK 14: 30.3.-05.4. WORKING TOWARDS MS03 AND MS04

Exact schedule to be determined.

WEEK 15: 06.4.-12.4. WORKING TOWARDS MS04

Exact schedule to be determined.

WEEK 16: 13.4.-19.4. WORKING TOWARDS MS05

Exact schedule to be determined.

WEEK 17: 20.4.-26.4. WORKING TOWARDS MS05

Exact schedule to be determined.

WEEK 18: 27.4.-03.5. WORKING TOWARDS MS05

Exact schedule to be determined.

WEEK 19: 04.5.-10.5. WORKING TOWARDS MS06

Exact schedule to be determined.

WEEK 20: 11.5.-17.5. WORKING TOWARDS MS07

Exact schedule to be determined.

WEEK 21: 18.5.-24.5. WORKING TOWARDS MS07

Exact schedule to be determined.

WEEK 22: 25.5.-29.5. WORKING TOWARDS MS08

Exact schedule to be determined.

ASSESSMENT

The game features various possibilities of interaction with the game world and other players. Thus, it offers a very varied game play and diverse tactics a player can employ in order to ingeniously defeat its opponent. On the other hand, it should still be simple enough for everyone to learn the controls in a matter of minutes and enjoy playing.

A game world mainly consisting of lava is a challenge, but should reward us - and the player - with a beautiful, animated environment. Additionally, there is some cool physics involved when islands collide with each other or pillars.

We regard the game to be successful if players can make real use of the floating islands - and the involved physics - to fight each other.

PART 2 – PROTOTYPE

This chapter describes a first software prototype of the main game mechanics and shows our findings based on its evaluation. The prototype already incorporates the following concepts of the final game:

- Pseudo-randomly moving islands with colliding pillar interactions.
- Players who can move in the XZ plane and jump from platform to platform using a jetpack.
- Long-range attacks of players using the ice spike skill.
- Melee attacks of players.
- Visualization aids assisting players to navigate in the 3D space using shadows.
- Power-ups which are placed on islands.

We decided to approximate all the game elements with very simple geometric primitives. Although later islands might not have a flat surface in the final game, this simplified contact and collision detection a lot. Their movement is based on two forces: First, they get attracted by all the pillars whereas the force is quadratic to the distance. Second, we add a random force in each frame to prevent them from converging at one point.

The player's movement is divided into two parts: using the gamepads left analog-stick he can move in the XZ plane, while pressing A activates the jetpack allowing him to move up the y-axis. This movement is calculated by a simple acceleration of the jetpack, which is added to the player's velocity vector in each time step. Gravity acceleration works against the jetpack and keeps a player standing on an island – and (in the worst case) falling down into the lava. If players walk into each other they receive a minor velocity-based pushback. A stronger pushback is encountered, if one player hits another.

Shadows are realized by real-time shadow maps. At the moment, they use no interpolation in the look-up stage which leads to very jagged artifacts at steep angles. However, the sole purpose of a shadow implementation at this stage was to determine whether or not shadows would serve well to support players navigating on the islands.

The ice spike implements a homing mechanism. After the spike is set off, the spike gets slightly pulled into the direction of an enemy. However, we have an upper bound for this force in order not to make aiming too easy.

For easier tracking of hits (either melee or through ice-spikes) appropriate sounds were also added.

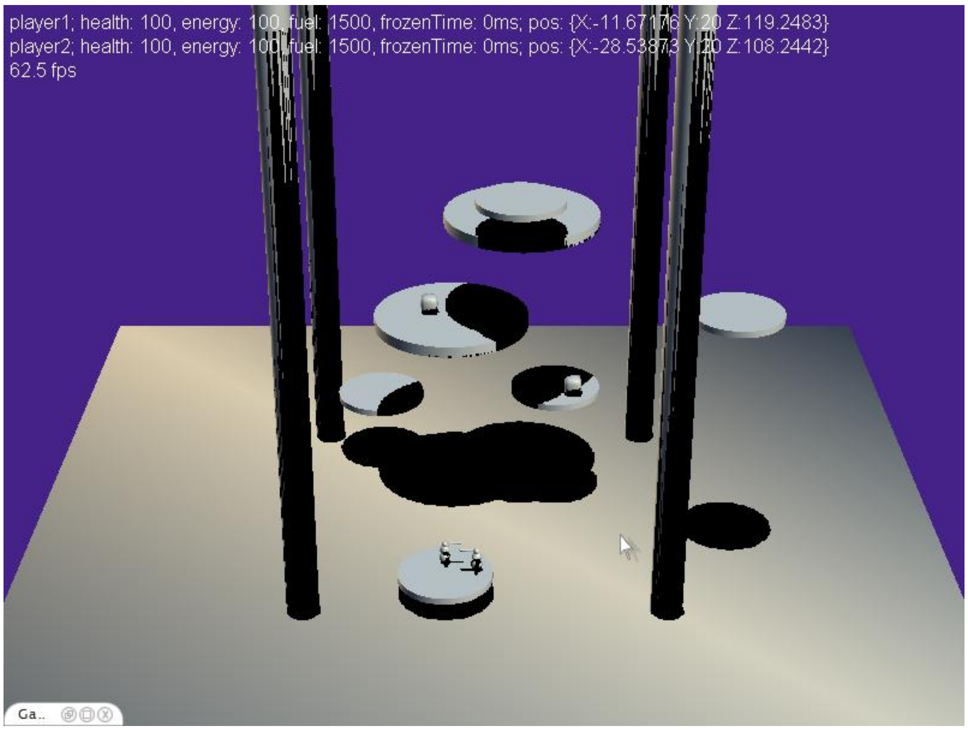
EVALUATION

We have tested the game (and will continue to do so a lot within the upcoming days) with respect to the following criteria:

- Is it easy and intuitive to move the player and perform attack actions?
- Does the core game play make fun, even after playing it for several minutes?

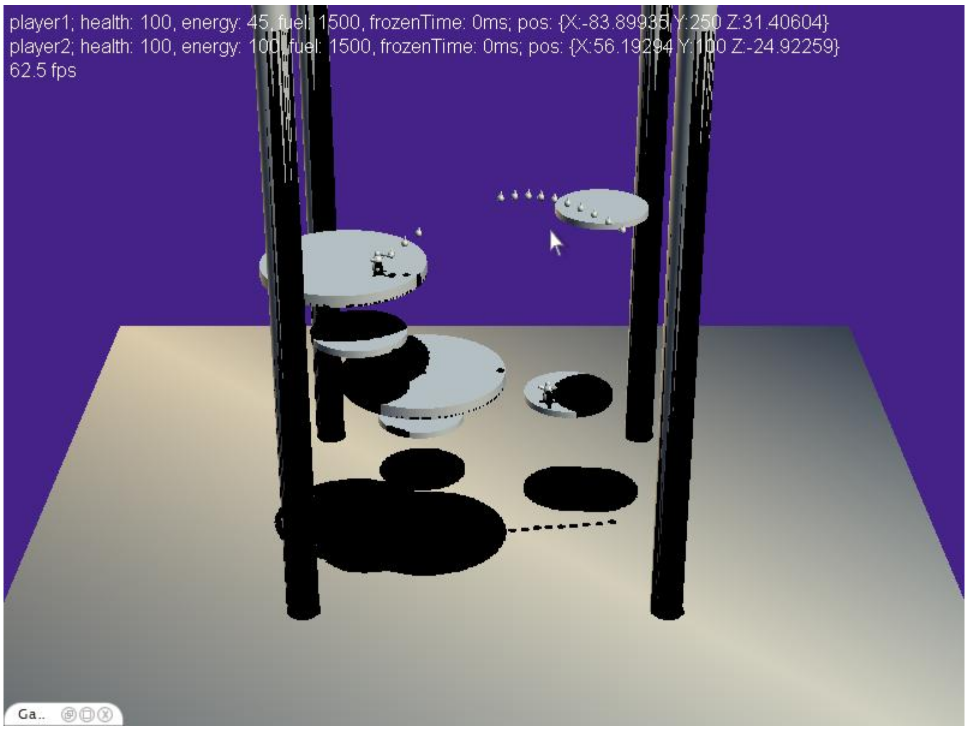
While the latter question is common and crucial for every game concept, the former one is one raised by multiple reviewers of our original concept. By testing this point in a very early phase, we want to react properly to the feedback we've got in the first stage.

GAMEPLAY SCREENSHOTS



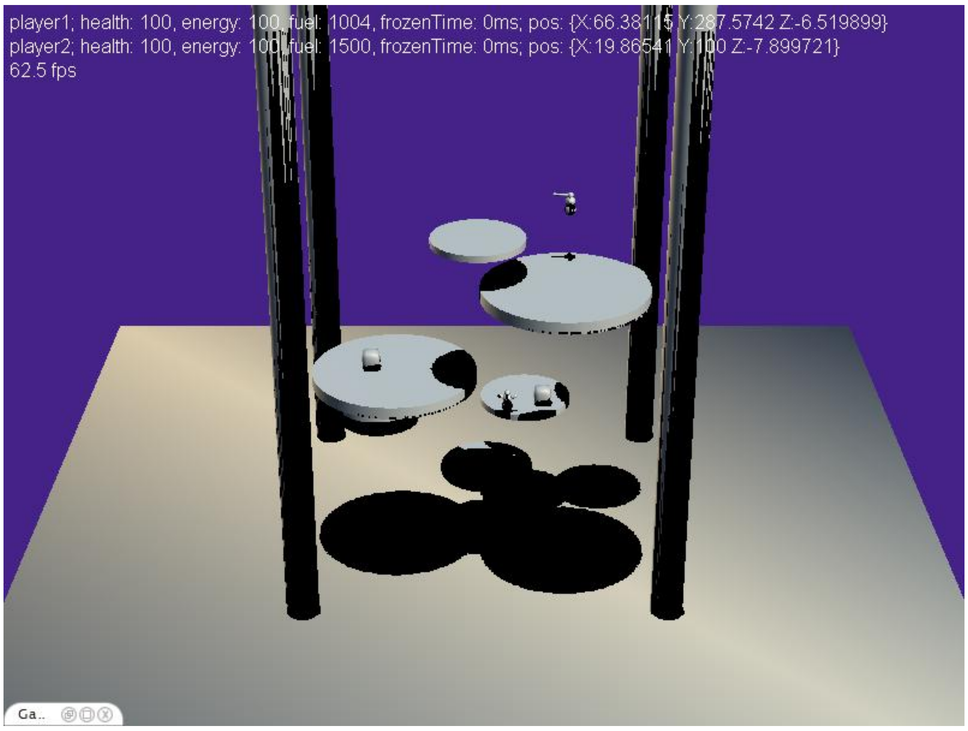
```
player1; health: 100, energy: 100, fuel: 1500, frozenTime: 0ms; pos: {X:-11.67176 Y:20 Z:119.2483}
player2; health: 100, energy: 100, fuel: 1500, frozenTime: 0ms; pos: {X:-28.53873 Y:20 Z:108.2442}
62.5 fps
```

Two players are standing on a moving island. Two collectable power-ups are on other islands. A player's health, energy and fuel level is currently shown as a text label. Later, this will be replaced by a graphical HUD.



```
player1; health: 100, energy: 45, fuel: 1500, frozenTime: 0ms; pos: {X:-83.89935 Y:250 Z:31.40604}
player2; health: 100, energy: 100, fuel: 1500, frozenTime: 0ms; pos: {X:56.19294 Y:100 Z:-24.92259}
62.5 fps
```

A player is shooting a bunch of ice-spikes, although missing his enemy.



```
player1; health: 100, energy: 100, fuel: 1004, frozenTime: 0ms; pos: {X:66.38115 Y:287.5742 Z:-6.519899}
player2; health: 100, energy: 100, fuel: 1500, frozenTime: 0ms; pos: {X:19.86541 Y:100 Z:-7.899721}
62.5 fps
```

A player is using his jetpack to move to the smaller, upper island. As visible in the text on top, using the jetpack needs fuel.

FINDINGS

POSITIONING

It is still quite tough to position yourself in the 3D environment. To make the task easier, we added shadows to enable the player to look at the projection of the island and his robot to more easily track his position. To control a player hidden behind an island or another object, we will implement some feature showing his contours projected onto such an object. This could also be combined with shadowing in a way a player gets a marker on all islands below and above him.

The addition of shadows unfortunately leads to the problem that a player is completely in the dark and not visible. Nevertheless, this can easily be solved by having the player emit his own light and adding ambient lights.

Finally, we will have to do further experiments with the angle and focal length used for the camera to reduce positioning problems.

PLAYER MOVEMENT

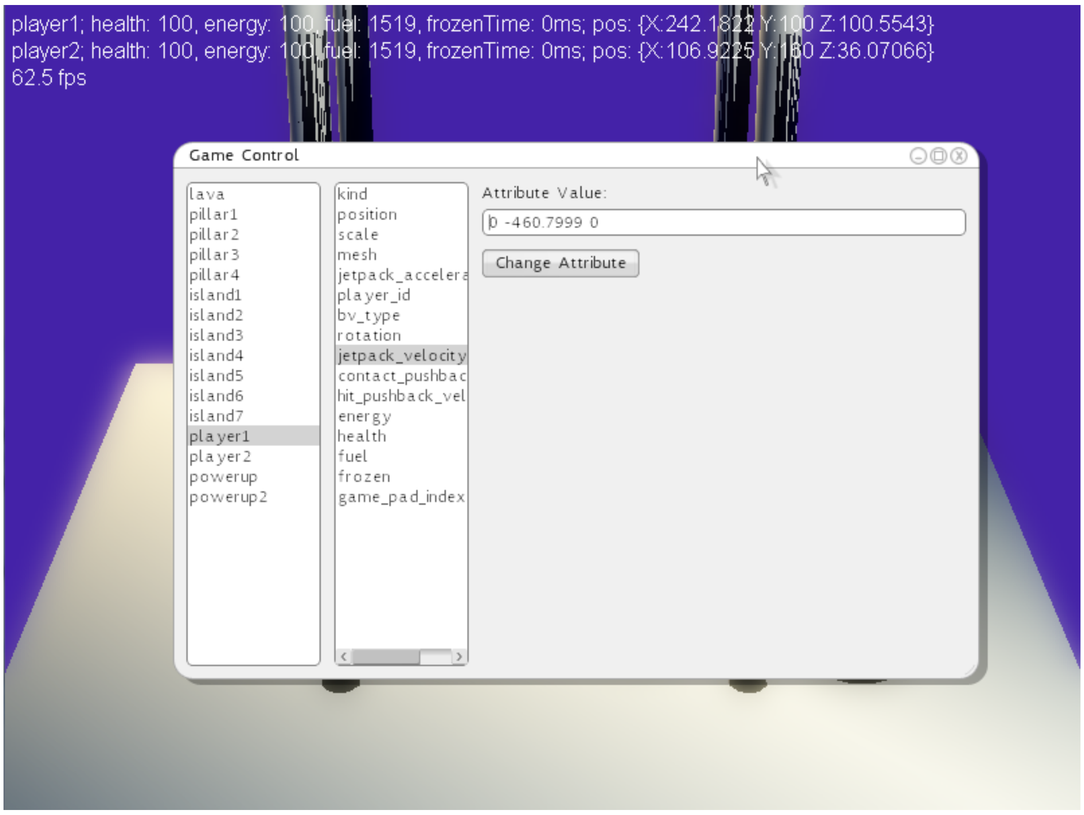
Currently, a player can walk off an island, which is a very unfortunate and leads to sudden death. It would make sense to only allow the player from falling of an island if he explicitly uses his jetpack or other means of traveling between the islands. Otherwise, He should not be able to walk beyond the edge of the island. We will implement this behavior in a further version.

ISLAND TRAVEL

Using free jetpack movement, it is nearly impossible to move between islands, because of mentioned 3D positioning and tracking problems. Therefore, a more passive approach (like selecting the island and automatic flying) should be taken. This could also have the advantage that a player can look around and shoot spikes at his opponents while flying. Additionally, the path on which an island moves should be visualized in the future (for instance by small rings of dust). Therefore the path of an island will have to be fixed or at least calculated in advanced to visualize where an island will move to some time from now.

PARAMETER TUNING

Without the need to drastically change certain implementations and aspects of the game, one can heavily improve the experience by tuning parameters (e.g. attack damage, gravity or jetpack acceleration). To simplify this task and in order to allow fast testing of different parameters, we implemented a game console which shows the state of all active entities on the screen and enables the user to directly manipulate them:



```
player1; health: 100, energy: 100, fuel: 1519, frozenTime: 0ms; pos: {X:242.1822 Y:100 Z:100.5543}
player2; health: 100, energy: 100, fuel: 1519, frozenTime: 0ms; pos: {X:106.9225 Y:160 Z:36.07066}
62.5 fps
```

An in-game console which allows the modification of parameters and attributes of all the present entities.

PART 3 – INTERIM REPORT

This chapter describes how the game developed from an early prototype to nearly the finished low target. It describes step by step the work that has been done and the changes to the original planning and schedule that have been made.

WEEK 1: FUNCTIONAL MINIMUM

CHANGES

One change as been applied to the requirements fulfilled by Milestone 2. The team agreed to delay the requirement “ReqP09 – Direct Combat 2” to the next milestone since it was not possible to implement the attack visualization without having a player model.

ACHIEVEMENTS

Compared to the prototype, the game has matured further. The major improvements that have been applied are in detail:

- ReqP13 and ReqP14: A new type of ranged weapon has been added: The flame thrower. Using the flame thrower, it is possible to either attack the opponent or to destroy islands. The flamethrower does not have the same range as the ice spike, but whatever is hit by its flames sustains heavy damage.
- ReqP12: The ice spike for which we had only a primitive implementation in the prototype has been redefined and improved. The aiming is now easier than before.
- ReqI07 and ReqI08: Islands now constantly lose height while carrying a player. As soon as a player jumps off the island it gradually regains its original height. This feature improves the dynamics of the game by making it faster.
- ReqI05: Islands can now collide with each other, allowing different islands on the same height.
- ReqUI06: The status strings have been replaced by a first and simple HUD.
- ReqP19: Failed

PROBLEMS

The game still has several shortcomings. Some of them have been mentioned in detail in chapter two. This is a short summary of the persisting problems:

- Navigation is not trivial
- Ice spike aiming could be better
- The game play is overloaded and needs to be streamlined
- The collision response has to be improved in certain places

THE PRODUCT

The working product features the moving islands in an already well fleshed-out form, but without any textures. Movement between the islands is still restricted to the jetpack, while a new gadget, the flame thrower, is available. It can be used to harm players, or islands. The ice spike aiming has been improved, but is still lacking accuracy. Collision detection is only done using simple collision primitives (cylinders and spheres).

WEEK 2: LOW TARGET PART 1

CHANGES

The realistic player model (ReqP03) has been moved to the desirable target, which further delays the direct combat animation (ReqP09). Some additional requirements were introduced, as a result of some additional play testing and findings from the prototype: ReqI14 is a new requirement for a visual indication of an island's health (it should glow when it gets damaged by the flame thrower). Similarly, ReqP21 is the visual indication of a player's frozen state (which could also be solved through the HUD). Also, ReqP04 (Island Attraction) has been extended to also include an easy way to jump from island to island.

ACHIEVEMENTS

The game made a huge step forward in terms of visuals compared to the functional minimum. Also, the problems of inter-island traveling have been addressed quite successfully in the form of island jump. The collision detection is also much finer grained compared to the simple primitives of Milestone 2. In detail, those changes are:

- ReqL03: A shader for realistic Lava rendering has been written, described in-depth in the corresponding section.
- ReqPi03: More sophisticated pillar models have been included, though they are not textured yet.
- ReqI03: Three different island models have been included.
- ReqUI04: An in-game menu has been added which will allow the selection of maps and players.
- ReqP04: Islands can be selected using the right analog stick; the closest island in the direction the stick points at is selected and the player can attract that island by pressing the right trigger. He can jump to that island by pressing the left trigger.
- ReqP05: A player can walk – or fly using the jetpack – to an attracted island.
- ReqI13: Power-ups respawn on a random island after a random amount of time after consumption.

PROBLEMS

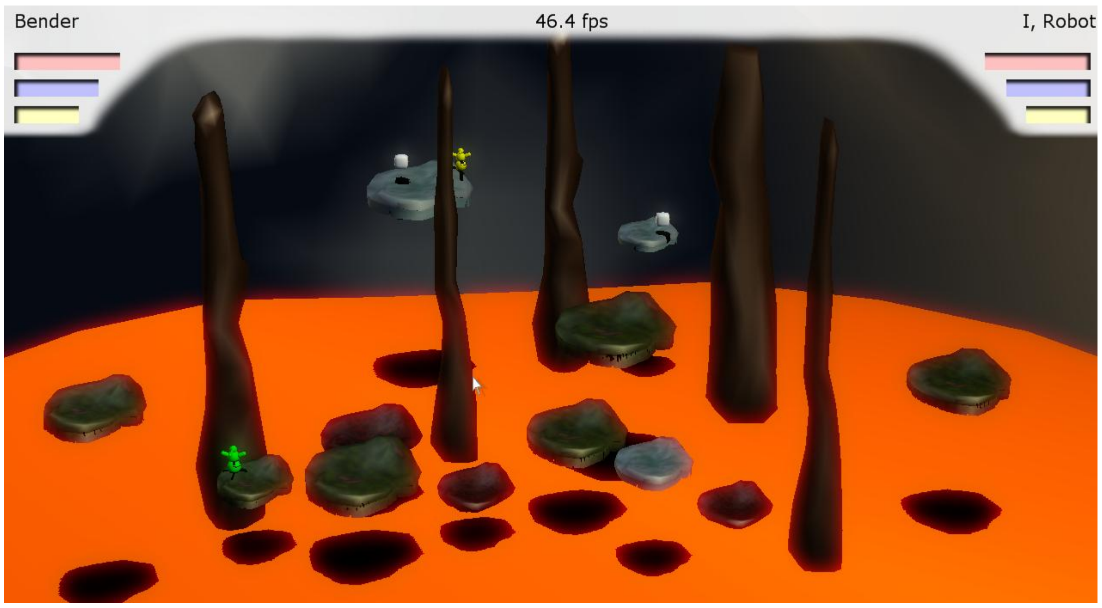
Some problems still remain, such as:

- The collision response for standing on top of an island has some flaws; it can happen that a player oscillates on top of an island or gets set on top although he collided with the island's border.

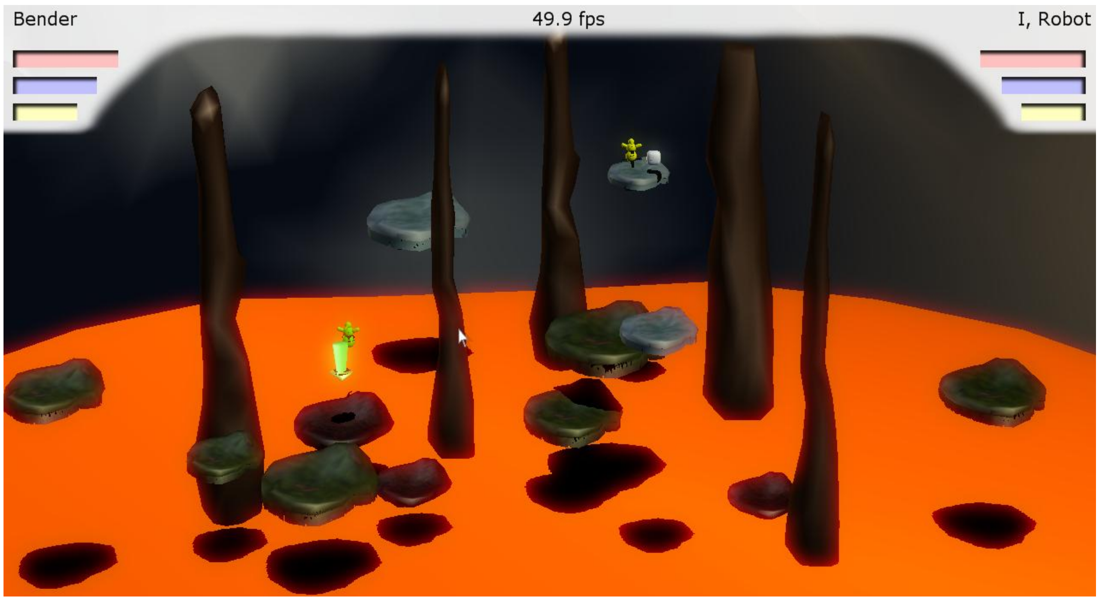
- Islands don't collide with the cave at the back, nor are they stopped from leaving the screen to the left, right or bottom.
- On island attraction, some collision response is not correct: Islands can sometimes go through pillars.

Collision response was particularly problematic, as it can heavily depend on the frame rate: if the frame rate drops and the time step increases, objects can fall through or collide again after the application of collision response – and the same (maybe inappropriate) response gets applied again. Therefore, collision response has to be fine-tuned and adapted to each object interaction combination which will take up quite some time. This frame rate dependence may also mean that we will have to multi-thread our engine, so draw and update code can be run on separate cores und a low update time step can be guaranteed.

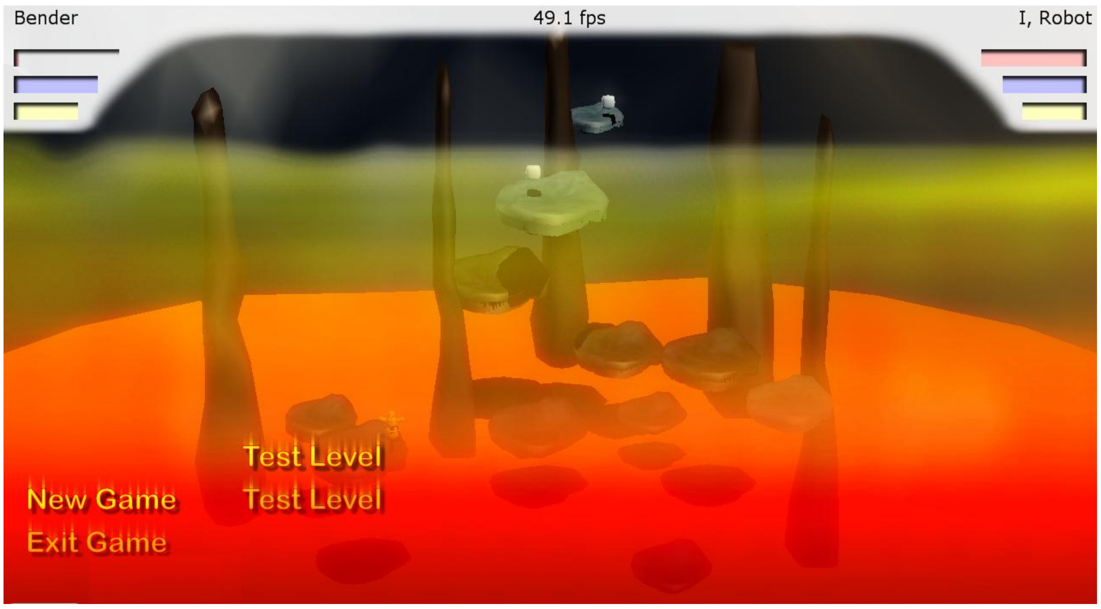
SCREENSHOTS



The current game screen including the HUD.



The green player jumping towards the selected island.



The Menu overlay.

PRODUCTION EXAMPLE - COLLISION DETECTION

OVERVIEW

To implement the game code in Project Magma, some sort of collision detection between a set of entities (namely the player, power-ups, islands and pillars) was needed. As with all the other parts of the software, the target was to keep the collision detection pluggable and easy to configure. As with all features, this allows for reconfiguring the collision detection at runtime. This has the advantage that we can test different collision volumes for different entities.

In accordance to all the other parts of the software, a new property, a collision entity, and a collision manager was introduced. Collision entities represent a “collidable” entity within space bounded by a collision volume. They are stored inside the collision manager which also tests for collisions between the entities. The binding between the simulation on one side and the collision entities and the collision manager on the other side happens inside the collision property which is attached to an actual simulation entity that should collide with other entities.

BROAD PHASE

Broad phase collision detection is currently not optimized. The collision manager uses the naïve approach testing each collision entity against each other entity.

COLLISION VOLUMES

Collision detection supports three different types of volumes:

- Bounding spheres
- Bounding cylinders aligned to the unit y-axis
- Triangle trees. These are trees of axis aligned bounding boxes containing triangles inside the leaf nodes. Each leaf contains up to five triangles.

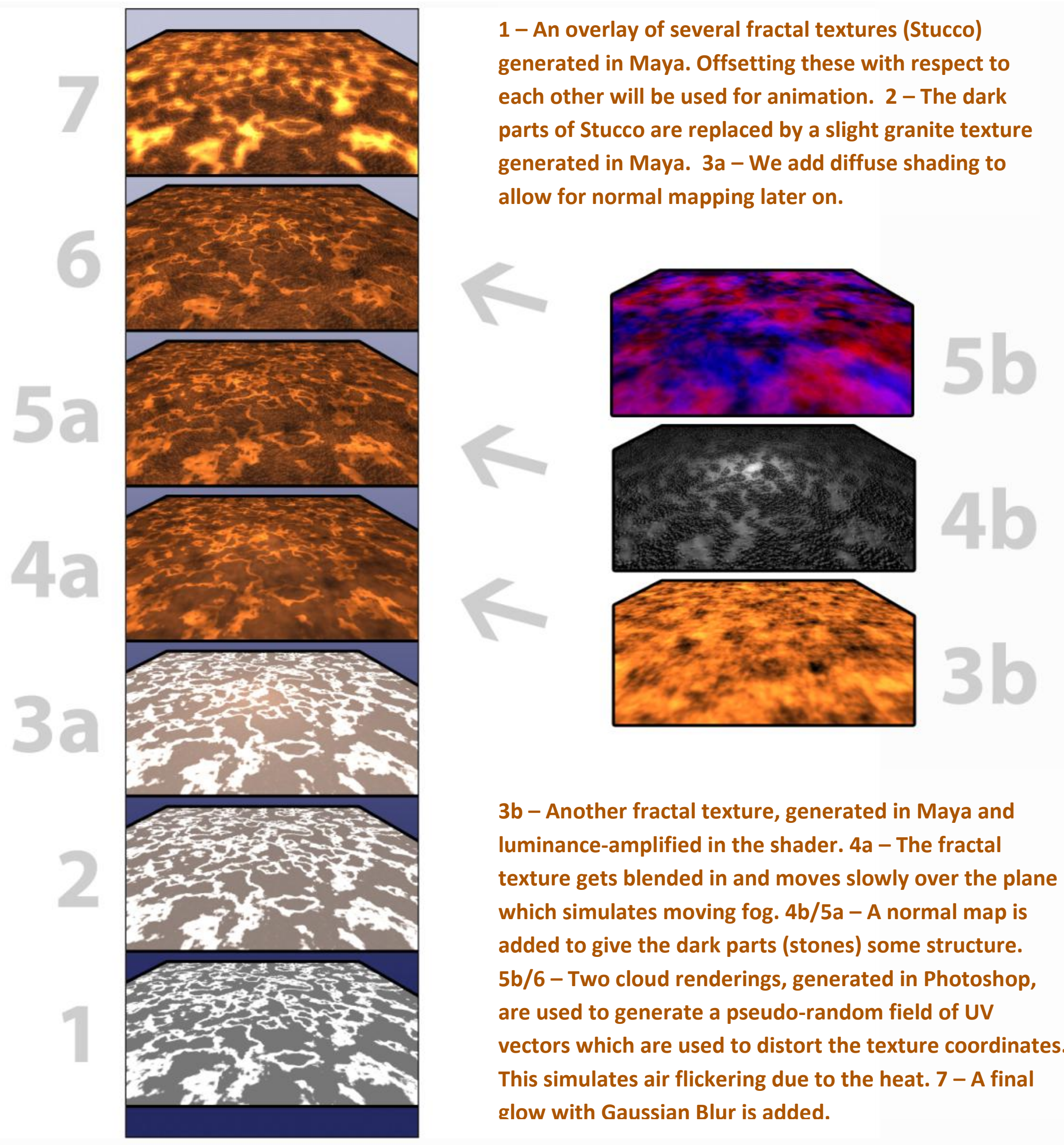
The content pipeline creates all three collision volumes for each triangle mesh. The level designer then chooses which bounding volume is assigned to a given entity.

PRODUCTION EXAMPLE –CREATING LAVA SURFACES

FIRST APPROACH: LAVA PLANES

We would like to show an example of a graphical element which we consider to be crucial for a credible ambience of our game. This serves both as a documentation for our own reference and for a work report for the lab.

We started our research in lava rendering by searching the web for tutorials describing how to create lava effects in offline rendering systems like Maya. We found http://en.9jcg.com/comm_pages/blog_content-art-94.htm to be the one with the nicest results and implemented it first in Maya and then as a GPU effect.

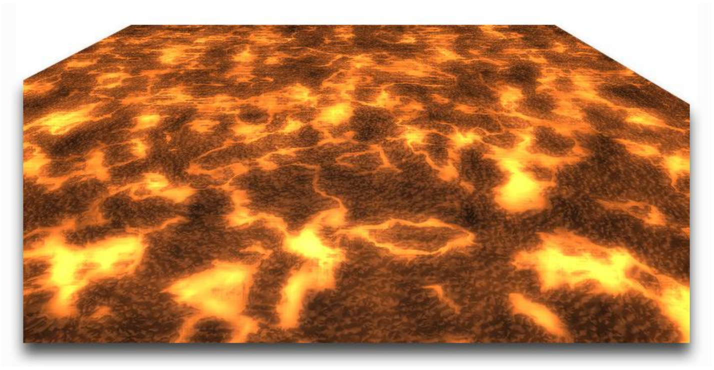


1 – An overlay of several fractal textures (Stucco) generated in Maya. Offsetting these with respect to each other will be used for animation. 2 – The dark parts of Stucco are replaced by a slight granite texture generated in Maya. 3a – We add diffuse shading to allow for normal mapping later on.

3b – Another fractal texture, generated in Maya and luminance-amplified in the shader. 4a – The fractal texture gets blended in and moves slowly over the plane which simulates moving fog. 4b/5a – A normal map is added to give the dark parts (stones) some structure. 5b/6 – Two cloud renderings, generated in Photoshop, are used to generate a pseudo-random field of UV vectors which are used to distort the texture coordinates. This simulates air flickering due to the heat. 7 – A final glow with Gaussian Blur is added.

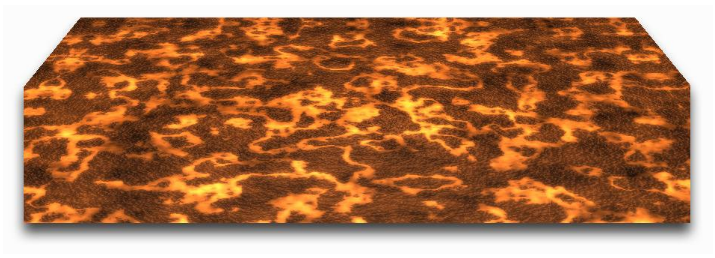
We had to omit the displacement part for now, but we got everything else to work with some tweaking. We added the heat flickering effect as described above by slightly distorting the texture coordinates.

GOING BEYOND PLANES: PARALLAX OCCLUSION MAPPING

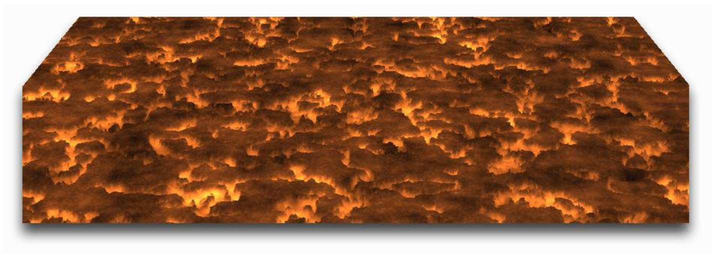


The effect of the shader described above looks already quite pretty when seen from a perspective projection like the one in the picture to the left.

However, we had to find out that the effect owes much of its dramaticism to the wide-angle perspective we've used during the development of the shader. As discussed in an earlier chapter, though, our gameplay requires an almost orthographic view onto the scene in order to maintain maximal clarity for the players navigating in the scene.



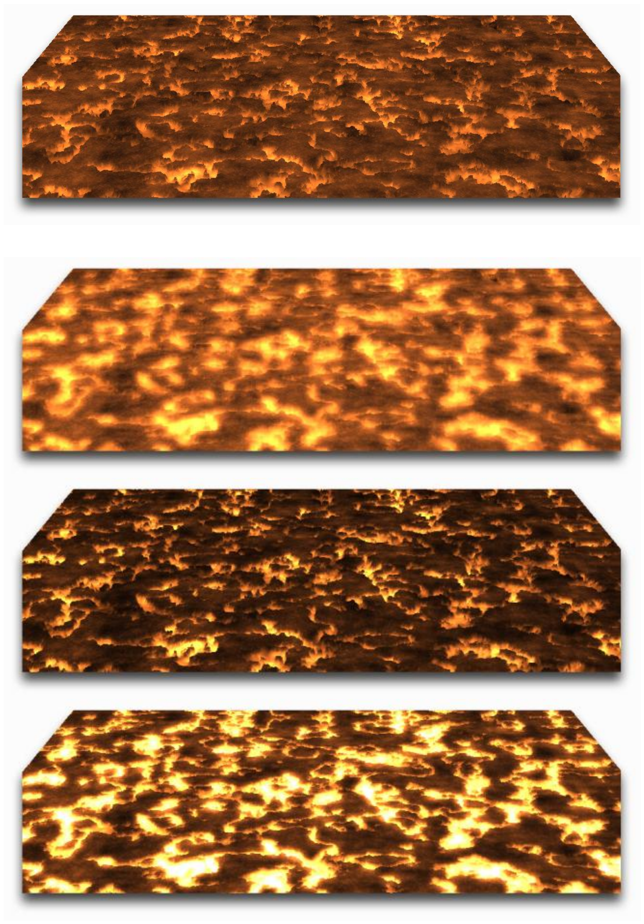
After using the camera parameters from the game itself, much of the effect is lost (see right). First, the pattern appears to be much more monotonous than before, and suddenly we miss the notion of depth. Since the angle between the camera and the ground plane is relatively flat in our setting, we thought that it would be nice to have some actual geometric structure in the lava instead of just plain normal mapping. To find out if this would help, we took an implementation of Parallax Occlusion Mapping and included it into our shader.



As we show on the left, we regained a large part of the depth of the scene we've lost previously due to the perspective change.

At this point, we started to get more creative by altering parameters of the individual layers. We inverted, compressed or luminance-scaled the height map, introduced new color mappings and changed the strength of PO mapping. Soon, it became apparent that small changes in individual parameters led to under- or oversaturation quite fast, and the need for some simple global tone mapping arose. As we already had a post-processing stage, this was easy to implement and it turned out that a 3rd order Lagrange polynomial with interactively modifiable parameters already does the trick. On the next two pages, we show examples of results we achieved with different parameter sets.

An increasing issue of PO mapping became the performance. We are currently working on emulating the same effect with several planes, alpha maps and alpha testing.



First – the original shader, just with Parallax Occlusion Mapping enabled.

Second – a very big glow radius and low-contrast settings in the HDR post-processing stage.

Third – low glow radius but relatively high contrast settings in the post-processing stage.

Fourth – higher glow radius, intentional oversaturation to emphasize the perception of a very bright light source in the lava.

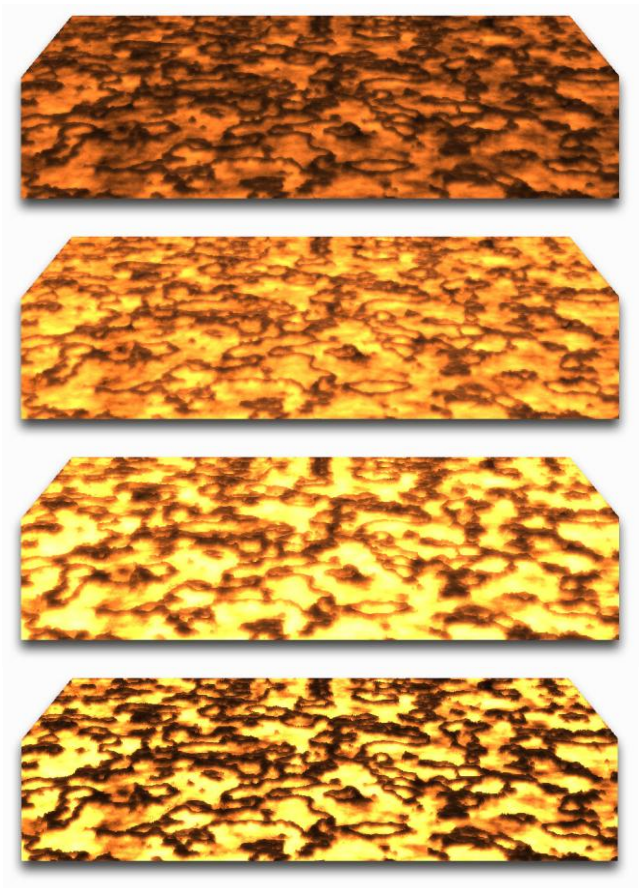
In this set, we inverted the depth effect of PO mapping by negatively scaling the occurring gradient term. The Stucco map which combines the textures (see earlier) is still unchanged, though.

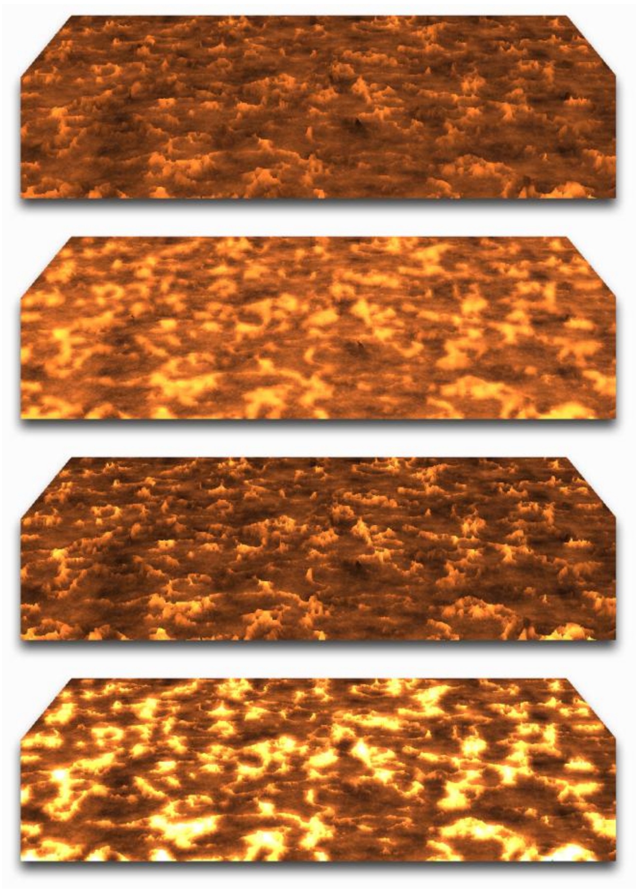
First – low glow radius and strength, linear tone mapping.

Second – all illuminations are scaled up to create an uniformly hot surface.

Third – exaggerated contrast.

Fourth – even more exaggerated contrast. The black ridges can be interpreted as floating ashes.





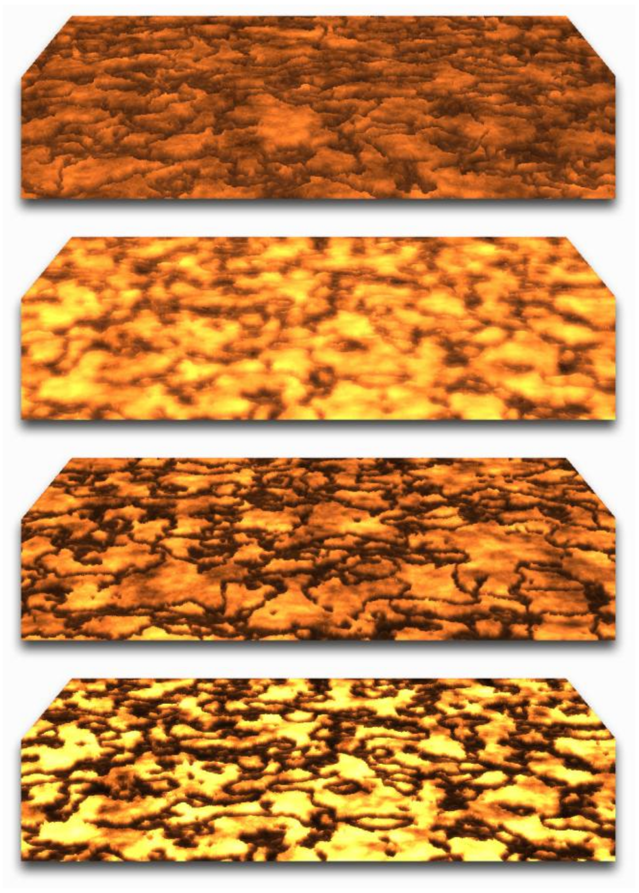
In this set, we inverted the Stucco texture which serves as both a height map and a blending operator between texture layers. Afterwards, we let the Gradient unchanged, so the entire effect is just inverted.

First – low glow radius and strength, linear tone mapping.

Second – a very big glow radius and low-contrast settings in the HDR post-processing stage.

Third – enhanced contrast. The bright structures can be interpreted as little flames which move along the surface.

Fourth – extreme contrast. The flame effect is exaggerated now to indicate that the fire is really bright.



In this set, we inverted both the Stucco texture and its gradient afterwards. This leads to big, bright, burning chunks on the surface.

First – low glow radius and strength, linear tone mapping.

Second – a very big glow radius and low-contrast settings in the HDR post-processing stage.

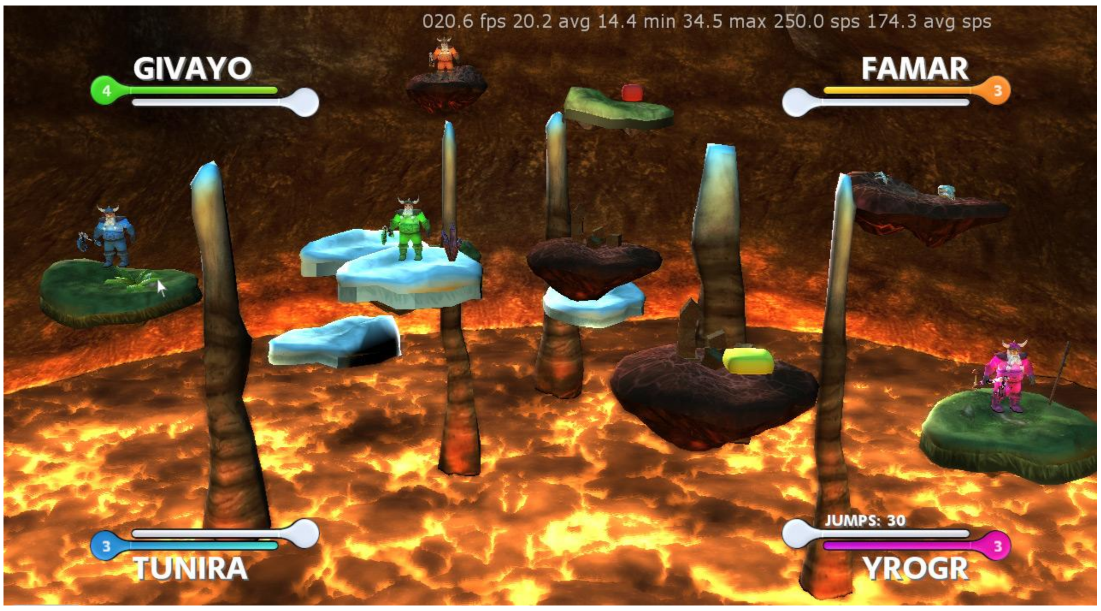
Third – enhanced contrast.

Fourth – extreme contrast.

PART 4 – ALPHA RELEASE

THE PRODUCT

The current release features all items from the desirable target. Graphics-wise those are: Textured pillar and island models, textured cave, animated lava and a generic particle system used for the ice spike, the flamethrower and explosions. Furthermore there is a newly designed HUD and a menu screen. On the game play side we have moving islands, island attraction, island repulsion, ice spikes, the flamethrower and direct combat in the form of hits with pushback. HDR from the high target is also already implemented.



```
020.6 fps 20.2 avg 14.4 min 34.5 max 250.0 sps 174.3 avg sps
```

CHANGES

Statistics (ReqG06) and high score (ReqUI02) have been moved into the high target. The default means of moving among the island has been changed from island jump (ReqP06) to island attraction (ReqP04). The jet pack can only be used when falling as a mean of saving one selves and doesn’t use any more fuel, as this has been removed as a resource. Island jumps have been restricted to certain distances. Island walking (ReqP05) has been replaced by island jumps after attraction. Island jumps over long distances and island repulsions are now only available through power ups. As a result of some testing, we streamlined the controls and put all means to move between islands (jump, attraction and jet pack) on one button – this will be evaluated further in the play testing phase. Furthermore, to improve performance we split rendering and simulation into two different threads.

ACHIEVEMENTS

Many features have been polished since the last milestone and are now visually pleasing and more usable. Those include:

- The lava effect (ReqL03) has been merged into the game, optimized and polished.

- Pillar and island models have been improved and textured. There are three island styles (burnt, icy and green) with different decoration.
- Power ups and selection arrows bounce in a sinus wave, so they can be spotted more easily
- The HUD has been completely redesigned and line with the streamlining of game play (only two bars: health and energy, indication of jumps and island repulsions).
- We created a particle system (see production examples) which has been used for the ice spike, and will soon be implemented in the form of explosion and burning effects.
- The ice spike's aiming has been improved, it is now able to avoid islands and pillars to a certain degree to better hit its target.
- Islands which get attracted push away other islands in their path and quickly arrive at their destination, though deceleration slowly towards it.
- The general movement of islands has been improved and hovering back to their original path around a pillar has been implemented.
- The implementation of a multithreaded architecture (one thread for rendering, multiple for simulation and collision detection) resulted in a large performance boost (see production examples).

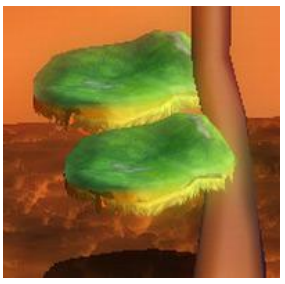
PROBLEMS

Most of the bugs should be fixed until the alpha presentation of Tuesday and the play testing of this week. We track all existing bugs using our own Mediawiki. Our biggest problems right now are keeping the performance around 30fps and eliminating the jerkiness which can result from the decoupling of rendering and simulation.

PRODUCTION EXAMPLES

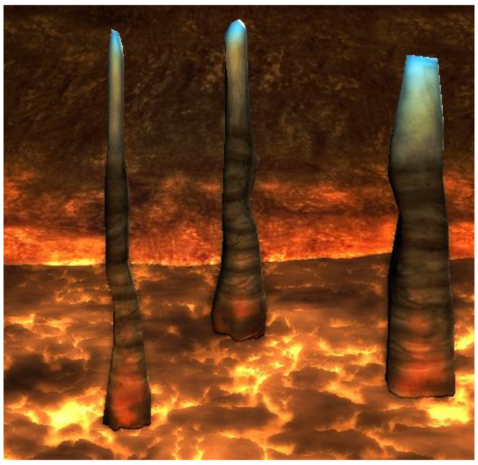
ENVIRONMENT

The environment now features different elements in their final version which previously were only available as dummies:

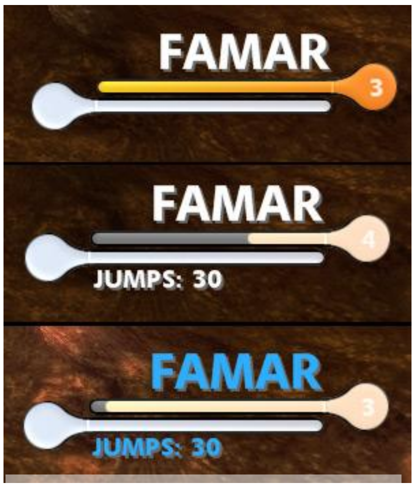

2 islands next to a pillar.

First, we have different island models now which correspond to different altitudes inside the cave: There are grassy islands on a middle level, icy islands on the upper and burnt islands on the lower level. Using pixel shaders, we added some windy grass parts on the side of the grass islands. Also, we have new models for pillars which feature snow on the top to indicate that they are on a higher altitude. As for the lava, we decided to go for a variation of the third picture in the interim report chapter. The cave can be seen in the background as well.

All elements except the lava are shaded with a fully-functional Phong shader with individual extensions, lit by three directional light sources. The first light source is a warm orange from below to simulate elements lit by the lava. This one has a very fast decay as can be seen on the image below. The second light is a cold blue one from above, indicating daylight. By tuning these lights accordingly, we've been contributing to the contrast between cold and warm tones which we wanted to achieve right from the start. The third light source, finally, is a moving spotlight coming from behind. This emphasizes the feeling that the actors are actually fighting in an arena and increases the contrast in the border regions. It will be a new high target to add a moving spot light model to the cave wall to justify this particular light source.


Three pillars in the lava inside the cave.

HUD



The new HUD. Top: Full Health and Energy. Middle: Damage is being sustained at the moment. Bottom: Player is frozen.

We created a new version of the HUD which has a focus on simplicity and better visual integration into the whole scene. Also, we added some blinking effects whenever damage is sustained in order to increase the feeling of being hurt (analogously to red tinted screens in shooting games). When the player is frozen, his name blinks in blue tones. The number of lives is displayed as a number inside the health bar. Below the energy bar, the current power-up details (if any) are displayed.

The HUD is mirrored according to its position on the screen – this can be seen in the full-screen picture above. In terms of implementation, the bars consist of different monochromatic components which are colored and combined in a pixel shader.

ANIMATIONS

The animated dwarf character standing on an island.

We are using the XNA Animation Component Library (ACL) from http://www.codeplex.com/animationcomponents to animate the player characters. We had to change some parts of the library since our models now need to be processed by both our own processor as well as the ACL processor. As for models, we are currently using the standard dwarf model that is supplied with the library but we hope to get an own model into our game within the next weeks. In terms of coloring the players, we have an alpha map on the dwarf's texture which indicates which parts of the model may be colorized how to what extent.

MULTITHREADING

OVERVIEW

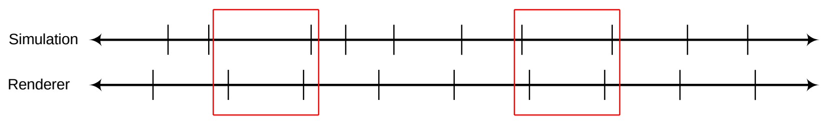
Running Project Magma on only one of the three cores of the Xbox resulted in performance problems during the alpha phase. The obvious optimization was to divide the game into a rendering and a simulation thread since both used about the same amount of CPU time.

One suggested approach was not to care about synchronizing the two threads, but to just use the simulation data as-is inside the renderer. But this approach could lead to inconsistent frames and possibly some other more serious problems. Another possibility is to keep the data the renderer needs in two places. On one hand the simulation still owns the master data; on the other hand the renderer owns a copy of the data which is periodically updated. Using this concept synchronization can be achieved with a minimal amount of overhead.

TECHNICAL DETAILS

The technical realization of the mentioned approach is quite trivial. On the simulation side a set of renderer-stubs are installed. The simulation always updates the data that needs to be passed to the renderer on these stubs. These stubs record changes using change-objects in one queue per simulation frame. After the simulation frame is done some intermediate code passes the queue in a synchronized manner from the simulation to the renderer. Whenever the renderer wants starts to render a new frame it checks whether it has received new update-queues. If so, it applies the changes provided by the queues to its copies of the simulation-data. This results in the renderer being updated in a consistent manner with only one short point of synchronization, namely the passing of the update queue. In addition the creation and application of the update queues is usually not a huge performance hit since there are not that many changes due to temporal and local coherence. The memory overhead is also quite low because the renderer does not need that much data to be copied. Usually it only needs copies of position, rotation and scale.

The drawback of this approach is shown in the illustration on the



right side. It visualizes the timeline of simulation and renderer frames. On each frame-change of the simulation (denoted with a vertical marker) some updates are passed to the renderer. If the simulation is running on an unstable, varying frame rate the situation might occur that the renderer has to render two consecutive frames using the same data. This can lead to a jerky frame rate which can result in the game appearing to run at a much lower frame rate. If, for instance, the renderer runs usually at about 30 frames per second the resulting sequence of pictures may look like the generated by a renderer running at half the speed (since some frames are really the same). We think that the solution to this problem lies in interpolating the values delivered by the simulation. Using interpolation we can avoid having to render the exact same frame twice, which should lead to a smooth animation of all the objects within the game.

PARTICLES

OVERVIEW

The simulation and rendering of particles is a non-trivial problem. Especially the simulation of many thousands of particles on a computer's or console's CPU is not feasible because they are just not designed for such tasks. Thus some research was used to implement the particle system for Project Magma. The main sources of information are:

- "Building a Million-Particle System" by Lutz Latta, published on Gamasutra in 2004: http://www.gamasutra.com/view/feature/2122/building_a_millionparticle_system.php [1]
- "UberFlow: A GPU-Based Particle Engine" by Peter Kipfer, Mark Segal, Rüdiger Westermann, published in 2004: http://ati.amd.com/developer/Eurographics/Kipfer04_UberFlow_eghw.pdf [2]
- XNA Sample: http://creators.xna.com/en-US/sample/particle3d [3]

There is also another interesting read that is, unfortunately, of no use, since it is using the native Xbox 360 SDK and not XNA:

- "Particle System Simulation and Rendering on the Xbox 360 GPU" by Sebastian Sylvan, published in 2007: http://www.ce.chalmers.se/~uffe/xjobb/ParticleSystemSimulationAndRenderingOnTheXbox360GPU.pdf [4]

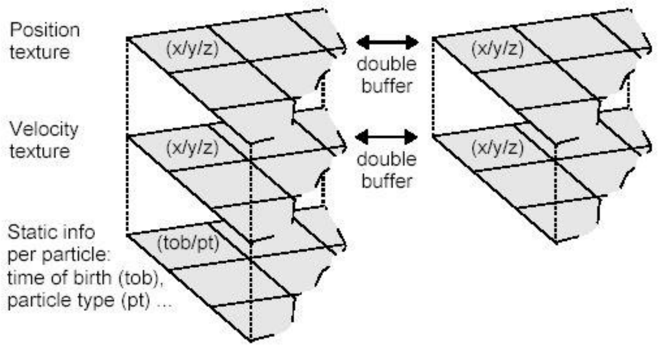
In general the readings discuss particle systems that are simulated on the GPU. But there are also two different ideas on how to approach the problem.

The first one uses so called stateless particles which are used by [3]. In this approach the programmer chooses a set of closed form functions that compute the parameters of a particle (such as position, size, etc.) depending only on a time parameter. There are several drawbacks: the particle cannot react to changing external forces and particles must always be rendered using an ever changing vertex buffer which puts a lot of strain on the bus transferring data from the CPU's local memory to the GPU's local memory.

The second approach which is taken by [1] and [2] are so called stateful particles. In this approach the state of a particle is stored inside a set of textures on the GPU. The particle simulation is then run on the GPU using a pixel shader. Using this design has the advantage that the data resides at all time on the GPU which prevents expensive transfer operations. On the other side there is the drawback that the GPU always simulates a number of particles depending on the texture size. Computational cost is therefore not determined by the actual number of particles simulated but by the maximum number of particles the system allows.

Project Magma implements stateful particles.

TECHNICAL DETAILS



When using a stateful approach to calculate a particle on the GPU the state of a particle is stored inside some resource residing on the GPU. On modern DirectX 10 compliant hardware there is the option to store particle data inside vertex buffers, process them using vertex shaders and to use the stream out feature to write to new vertex buffers. Unfortunately the Xbox does not support this feature. Therefore the state of particles is stored inside a set of textures: One position texture, one velocity texture, and a set of textures storing static particle data like its time of birth, its type, some random numbers associated to it or other data. The data is then processed by a pixel shader which outputs new values for position and velocity. Since a pixel shader cannot write into the same texture it is reading from the system needs to double buffer the position and the velocity texture. The illustration on the right is copied from the Gamasutra article and shows this setup. There is also another illustration showing the position texture of a particle system.

Creating new particles is quite easy. The systems can either track particle lifetime on the GPU, or, like it is implemented in Project Magma, use the texture as a ring buffer. New particle values are then simply rendered as single points onto their position in the texture.

Rendering is implemented using point sprites and one static, huge vertex buffer rendering each particle of the texture. Particle position and life are read inside the vertex shader using the vertex textures feature of shader model three. If the particle is not alive anymore it is offset to some off-screen location. Otherwise the shader renders it to its current position.

Running the particle system on the Xbox GPU and an additional set of modern high end GPU's has shown that the system is easily able to render many thousands of particles without noticeable impact on the performance of the game. We also experienced that currently the most expensive operation seems to be the upload of new particles to the GPU since this involves the modification of a vertex buffer.