MOONGATE:
MODULAR REAL-TIME STRATEGY ENGINE FOR XBOX 360 AND PC

ABSTRACT

This paper introduces MoonGate - a real-time strategy engine based on replaceable components, thus serving as an easily customizable educational environment for studying a wide range of problems from several research areas. The implemented engine supports alongside the Windows platform also Microsoft's Xbox 360 gaming console, making it the first open source starter kit and real-time strategy engine for Xbox 360. MoonGate's main goal is to attract students, academics and indie game developers to learn by creating highly interactive and visually attractive games, by providing easily understandable and highly customizable educational environment, which incorporates best features of modern commercial games, visualization environments and game middleware.

KEYWORDS

XNA; MoonGate; RTS; Xbox 360; .NET

1. INTRODUCTION

Out of many game genres that are available nowadays, one of the most important is the genre of real-time strategy games, since they are useful from an entertainment as well as serious games perspective [1]. Researchers such as [2], [3], [4] or [5] suggest, that real-time strategy games also offer a large variety of fundamental AI research problems.

Real-time strategy is the genre of computer games that encompasses tactical games that happen in real-time. "Real-time" means that there is a continuous flow of time in the game world, so that immediate decision making and responding quickly to arising situations is important. These games can be viewed as simplified military simulations played by two or more players where each player can be in control of potentially hundreds of units with specific properties and abilities.

One of the current problems is that commercial game developers and researchers do not focus at exactly the same elements. Up until now, game companies have spent more time on improving the game's graphics more than any other part of it and commercial RTS games are closed software, which prevents researchers, students and hobbyists from connecting their own modules to them. A shortage of artificial intelligence competitions based on real-time strategies also deprives artificial intelligence researchers and enthusiasts with an opportunity to compare their algorithms [6]. What is more, available free RTS engines are usually too complex to serve as a practical educational and demonstrational tool in courses (for example Spring [10] engine v.0.8.1 has 340641 lines of code in 1425 files).

In order to address these problems, MoonGate [7] – open source, real-time strategy game engine for Xbox 360 and Windows platforms was designed and implemented. MoonGate's main purpose is to attract academics, students and hobbyists to learn by creating games and give them an opportunity to easily study various problems by providing easily understandable and customizable educational environment accompanied by a repository of components varying from terrain, particle systems, bone animations to shaders, that are easily readable and reusable without the need to study nonrelated support parts of code like it is common in other engines.

MoonGate Engine was designed and implemented with the following in mind:

- Simple extensibility through usage of reusable components.
- Content pipeline that allows easy creation and import of content.

- Tweaking without the need of source code recompilation.
- Exploiting benefits of target platforms for learning purposes.

In order to achieve the mentioned properties, the XNA Framework and the Xbox 360 game console were chosen as the most suitable to create a base upon which MoonGate Engine was implemented. One of the reasons behind the selection of XNA Framework is the fact that since its release in 2006 XNA has seen a surge of momentum with more than 1 million downloads of the tool and more than one thousand academic universities globally [8] are using XNA Framework in their classrooms. This way, MoonGate can stay really close to its target audience – students, teachers, and indie game developers and keep constantly evolving.

2. EXISTING REAL TIME STRATEGY ENGINES

Currently there are only few open source real-time strategy engines freely available to general public that were developed to a phase when they are actually usable as a visualization tool or a test-bed for algorithms. Vast majority of produced engines are commercial, which means only very limited usability by students and researchers due to severely limited options of their modification. Some of the mostly used open source real-time strategy engines are the following.

2.1 ORTS – Open Real Time Strategy

The ORTS project [9] was started with a goal to create a free software system that lets people and machines play fair RTS games. It is a programming environment for studying real-time AI problems such as pathfinding, dealing with imperfect information, scheduling, and planning in the domain of real-time strategy games. The communication protocol is public and all source code and artwork is freely available. Users can connect whatever client software they like. This is made possible by a server/client architecture in which only the currently visible parts of the game state are sent to the players. This openness leads to new and interesting possibilities ranging from on-line tournaments of autonomous AI players to gauge their playing strength to hybrid systems in which human players use sophisticated GUIs which allow them to delegate tasks to AI helper modules of increasing performance. ORTS is not a single RTS game, it is an RTS game engine. Users define the game they want to play in form of scripts which describe all unit types, structures, and their interactions. These scripts are loaded by the ORTS server and executed. The second part of the ORTS system is client software which connects to the server and generates actions for objects in the game. The server sends player views to the clients and receives actions for all the player objects, which are then executed. This loop is executed multiple times a second. If the 3D graphics client is connected, the world is rendered using OpenGL and the user can issue commands using the mouse and keyboard.

2.2 Spring Engine

Spring [10] is a project aiming to create a new and versatile open source (GPLv2) real-time strategy engine. Spring is a multi-platform project written in C++, using OpenGL, OpenAL, SDL, boost, 7zip and Lua scripting language. At this moment Spring fully supports Windows and Linux platforms, Mac OSX version is currently not available. Spring is well known for massive battles limited only by the power of the host computer – up to 30000 units and up to 250 players can fight on a single map. Full featured lobby clients allow to easily play multiplayer games. These clients have built-in support for all standard features like automatic game and map downloading, chat and friends lists. Spring's architecture allows usage of third party AIs that can work very competently in many cases with multiple Spring engine based games. Very extensive Lua interface allows users to create custom (graphical) user interfaces. Through third party widgets, users are able to improve not only the GUI, but also gameplay. Spring with built-in physics engine supports realistic projectiles trajectories, deformable terrain, forest fires and dynamic water.

2.3 Glest

Glest [11] is a free 3D real-time strategy game built on a custom engine. It is a multi-platform project written in C++ with portability in mind, so it can be compiled easily on Windows, Linux, FreeBSD and Mac OSX. Glest uses the cross platform OpenGL API to render 3D graphics. For unit models and animations, Glest uses

its own 3D format; an export plugin for 3D Studio Max, and tools for Blender are available. Every unit, building, upgrade, faction, resource and all their properties and commands are defined in XML files.

3. MAIN GOAL

Although the MoonGate Engine was originally designed as a first starter kit for real-time strategy games for Microsoft's Xbox 360 gaming console that would allow fast creation of these games in an easy and convenient way, soon positive feedback from its users showed that it can also be a valuable tool not only for indie game developers, but also for students.

There are already companies exploiting the console's hardware in order to create edutainment software, like for example Educomp Group, education solutions provider and the largest education company in India that reaches out to over 25,000 schools, which chose Xbox 360 as a platform to promote its interactive learning programme [12], but these companies focus mainly on children attending elementary schools and create only simple educational games, rather than focusing on students attending university courses and people with game development as a hobby. On the other side MoonGate's purpose is also not to directly compete with projects like ORTS that focus solely and deeply on a single selected problem, which for example in ORTS's case is studying real-time AI problems. Of course, because MoonGate is a RTS engine, it is able to serve as a valuable tool for areas within AI research, for example:

Resource management. Resource management is a vital part of every strategy. Players must immediately create supply chain in order to start producing defense and attack forces and structures, climb up the technology tree and purchase upgrades for units.
Decision making under uncertainty. At the beginning of game players are not aware of the enemies' locations of buildings, units or places that are being used to harvest resources from. Each unit has certain radius in which it is able to "see" other units and it is up to the player to use units and their combinations in order to obtain intelligence as quickly and accurately as possible.
Spatial and temporal reasoning. Static and dynamic terrain analysis as well as understanding temporal relations of actions is of utmost importance in RTS games – and yet, current game AIs largely ignore these issues and fall victim to simple common-sense reasoning [13].
Collaboration. In real-time strategy games communication and coordination of actions among groups of units and players is a must.
Opponent modeling and learning. AI opponents in most contemporary real-time strategy games have great handicap when compared to human players – they are not learning from experience.

But what is important, MoonGate and RTS games in general are very useful also as a test-bed and visualization environment in many other areas like rendering of a large terrain, particle systems, bone systems and many others. MoonGate aspires to act as a bridge between commercial games, visualization environments and game middleware by providing open source, easily customizable environment for studying wide range of problems from several research areas.

The problem that often plagues (mainly freely available) game engines and starter kits is difficult extension. These engines and starter kits are not designed with extensibility in mind from the beginning. When users would like to extend them in some way it is often almost impossible to do so without making (rather large) changes in overall project structure, mainly due to changes not only in components, but also due to changes in connections among these affected components. Afterwards thorough regression testing is usually needed to verify correctness of changed couplings and parts of the code. These engines and starter kits are thus hardly usable – easy extensibility is one of the key features that are expected.

Some engines even use content that is very hard to understand and create. For example quite often can we see binary 3D models with built-in parameters for engine's model and texture processors that were set in 3D content creation application, shaders that are referenced directly from models or skeletal animations exported in an undocumented way. In this case it is difficult to create own game content, which again lowers the usability of an engine or a starter kit as a whole.

It is not an easy task to avoid these common pitfalls and create an educational environment that is not overwhelmingly complex and easily customizable. There are examples of successful projects in nearly every

game genre, like the already mentioned Spring from real-time strategy genre, that is often chosen for visualization of AI algorithms, or genre of role-playing games, where many solid educational videogames have been developed to run on one of the iterations of Neverwinter Nights [14] using the Aurora Neverwinter Toolset (Aurora is part of Neverwinter Night's installation). Many of these have been designed by teachers for their classrooms, and released to the general public.

If we look at these projects regardless of what genre they belong to, we can clearly see that these engines are completely modifiable, making it fairly easy to manipulate for desired educational outcomes, and although they present a full 3D virtual interactive environment, complete with anthropomorphically correct characters, their runtime requirements are relatively light. These features are basic principles which MoonGate follows as closely as possible.

4. SYSTEM OVERVIEW

MoonGate was designed from the beginning as a lightweight environment that tries to be as generic and flexible as possible. It provides large amount of functionality right out of the box, but allows quick and simple modification of each and every part. Clients - PCs and/or Xbox 360s are using a peer-to-peer network topology to exchange data during network sessions. One of the clients is always the session host. This computer is responsible for execution of the Game Script – script that defines game that will be played along with precise terrain definition and initial placement of objects on terrain. Each client must register Core Game Components – most basic components that are providing basic functionality, like for example a component responsible for rendering of terrain, an input management component or an object creation component. Additional Game Components are optional components that are not necessary for playing game, like the in-game console or a component showing the number of frames that are rendered every second. Clients can be also configured to run one or more AI modules.

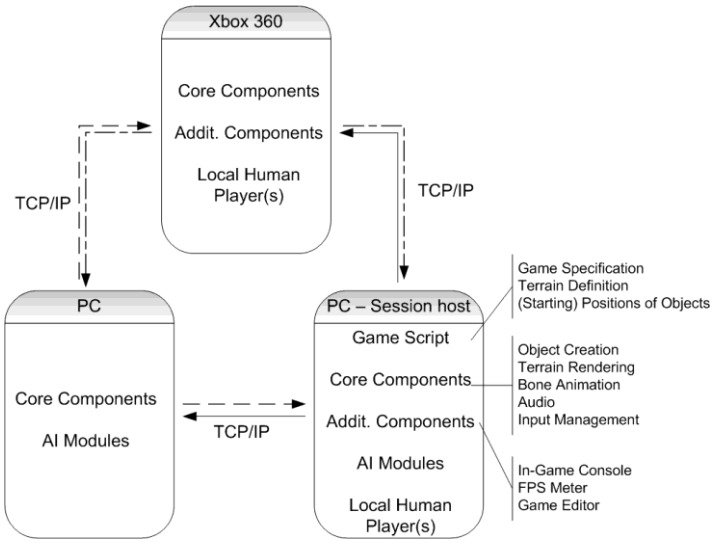

Figure 1. Example setup of a network game with three differently configured clients

The lowest layer of the engine provides a mechanism for Game Components registration and initialization and processing of game content in the form of importers and format processors. The implemented content pipeline supports currently the most frequently used tools and 3D models, textures, fonts and audio formats. On top of this layer are *GameServices* and *GameComponents*, which are responsible for the actual functionality.

The idea behind the *GameComponents* is to provide a framework for keeping reusable code in a nicely encapsulated form. The dependencies between classes can also be managed and de-coupled one from another, so that they can be removed, altered or replaced in isolation. They can be even dropped into other completely new projects quickly and easily. Components that need to access each other do so only through well-defined interfaces that could be provided by a different component in another game, or not at all.

GameServices are a mechanism for maintaining a loose coupling between objects that need to interact with each other. Services work through a mediator—in this case, *GameServices*. Service providers register with *GameServices*, and service consumers request services from *GameServices*. This arrangement allows an object that requires a service to request the service without knowing the name of the service provider.

For example, to register an object that provides a service represented by the interface *IMyService*, the following code would be used:

Services.AddService(typeof(IMyService), myobject);

The creation of a flexible internal structure allows simple change of any engine's part without the need of modification of other components. This approach greatly reduces the amount of possible errors and allows creation of specialized components that can be used without change in other projects in a plug-and-play style. Some of the most important components that provide functionality right out of the box are the following.

4.1 Input Management

The input management component provides a single point of access to user control input. On Xbox 360 keyboard and Xbox 360 controller are fully supported, on Windows platform it is also possible to use the mouse. Besides providing input, the input manager provides also the functionality of an in-game console. It is possible to define commands, execute them and display chosen values in real time in order to change MoonGate's internal variables and state. The console provides also a history of commands and an option to automatically complete commands. It is a useful tool not only during debugging, because it enables monitoring of system's internal status.

4.2 Terrain

The terrain component is one of the MoonGate's more complex components. When considering what approach should be used to render terrain, quadtree-based terrain[15] was chosen mainly due to its simple and easily understandable implementation and sufficient performance. The implemented terrain supports bump mapping and texture blending.

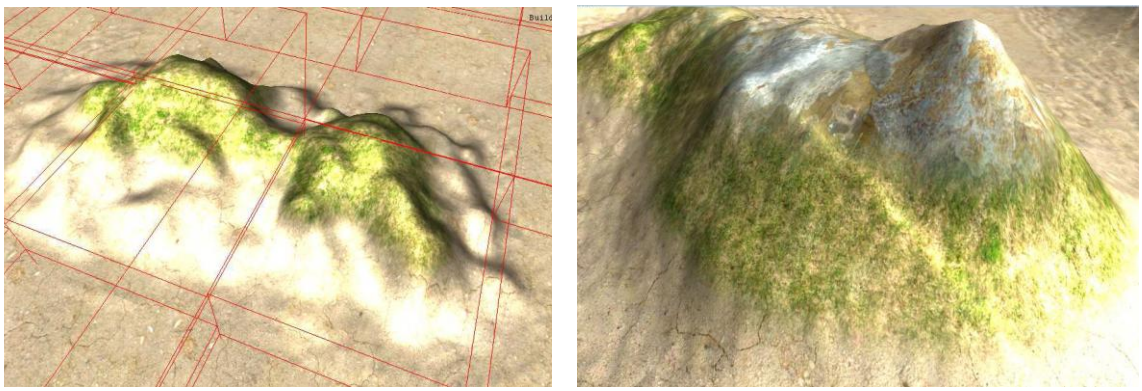

Figure 2. Terrain created by terrain component with visible quadtree structure and an example of terrain created by terrain component

Due to well defined interfaces that allow communication with other components, the default terrain component can be easily replaced with more sophisticated approaches that are able to handle rendering of a large and complex terrain with improved performance, like for example Geo-Mipmapping[16], without the need to change any other component or interface.

4.3 Particle Systems Framework

Particle component is a customizable lightweight 3D particle framework which uses point sprites. The particles are animated entirely on the graphics card using a custom vertex shader, so a large number of particles can be drawn with minimal CPU overhead.

Like the rest of the system, the particle component uses XML definitions to define properties of objects – in this case particle systems. This approach allows creation and tweaking the particle systems without the need to change the main game executable. There are several examples of particle systems in MoonGate that are available right out-of-the-box, for example fire, smoke, explosions or trails.

4.4 Objects creation

The heavy usage of flexible text-based formats like XML that are easily readable by humans and also computers ensures that not only various preferences, but also environment definition as a whole can be modified and tweaked without the need of project recompilation. One very important feature is also definition of all static and dynamic objects like vegetation and units directly in XML files along with their representation and properties. MoonGate goes beyond simple storing of independent values in XML files that can be commonly seen in most projects. A simple and intuitive hierarchy of definitions was designed and implemented in order to be used by MoonGate, to ensure fast learning and quick configuration.

```
<ModelInfo>
  <ID>Jeep</ID>
  <Path>models/units/jeep</Path>
  <Bones>
    <Bone>bone_turret</Bone>
  </Bones>
  <RenderMethod>ReplacementColor</ RenderMethod >
</ModelInfo>

< Blueprint >
  <ID>LightAttackJeep</ID>
  <Behavior>StandardUnit</Behavior>
  <Model>Jeep</Model>
  <Category>Ground</Category>
  <Health>600</Health>
  <Armor>100</Armor>
  <TurnSpeed>0.3</ TurnSpeed >
  <MoveSpeed>0.9</ MoveSpeed >
  <LOS>25</LOS>
</Blueprint>
```

```
<AnimationInfo>
  <Key>Jeep</Key>
  <Controllers>
    <Controller>
      <Bone>bone_turret</Bone>
      <ClassName>TurretControler</ClassName>
      <Attacks>GroundUnits</Attacks>
      <FireDist>80</FireDist>
      <ReloadTime>0.12</ReloadTime>
      <TurnSpeed>0.3</ TurnSpeed >
      <Bullet>
        <Type>SmallBullet</Type>
        <Sound>MachineGun</Sound>
        <MoveSpeed>130</MoveSpeed>
        <Damage>5</Damage>
        <Radius>3</Radius>
      </Bullet>
    </Controller>
  </Controllers>
</AnimationInfo>
```

Figure 3. Example of ModelInfo, Blueprint and AnimationInfo

To define an object we need to provide two XML definitions – *ModelInfo* and *Blueprint*. *ModelInfo* provides information about the 3D model used to visualize a given object (for example .X file), object's bones that should be available for manipulation and a preferred rendering method. *Blueprint* describes an internal representation of the object and serves as a template for the the engine's object factory. *Blueprint* also provides information about object's behavior which is implemented as a library and thus is easily reusable. This way the user is able to describe a new type of object whether static or dynamic in just a few lines really quickly and immediately use it in the environment.

While the previous two definitions covered creation of units, they did not provide a way to manipulate with parts of defined objects. In the genre of real-time strategies, units are often composed of several parts where each part acts autonomously to a certain level. A (simplified) example of this behavior can be a ship which consists of the main part – hull, several anti-ship cannons and several anti-aircraft cannons. These cannons are parts of the ship, but contain certain logic and animations which are characteristic for them. *AnimationInfo* describes individual parts of a model, their properties, animations and logic that controls them on lowest level.

4.5 Level Editor

The level editor that comes with MoonGate is not a standalone application like most editors that are available for real-time strategy games. MoonGate uses a custom built-in editor that is available directly from the game environment. Although this approach is more difficult to implement, is has a great advantage over the previously mentioned type – users are able to directly see the changes that they have made. There is no need to recompile the code or restart the application and the editor is available at any time.

MoonGate's editor works in three modes. The first is "terrain painting" mode, where users "paint" different textures on the terrain. Painting is implemented as a change of weights of textures in the terrain's vertices. Every change is automatically saved, so the next time after the user starts the application, the most recent values are loaded. The second mode is "static objects manipulation" mode. This mode allows manipulation with objects - users can add, remove, move, rotate and scale objects on terrain and immediately

after the editor is closed all changes are reflected into dynamic units' behavior, for example newly added objects that act as obstacles are avoided when units are moving.

The third mode is "unit placement" mode in which users are able to add, remove and move dynamic objects – units, which represent complex unit with certain behavior controlled by players. It is possible to create new units and assign them to various players or teams.

5. PERFORMANCE

The use of XNA allows to target besides PC platform also Microsoft's Xbox 360 gaming console. Compared to other edutainment platforms focused on learning multiprocessing game development, graphics and media, like for example Hydra Game Console [17], which is based on Parallax Multiprocessing Propeller Chip with 32-bit RISC CPUs, Xbox 360 is by far superior in performance and also ease of use due to relying on C# language instead of using custom C-like and BASIC-like languages, making it a very interesting platform for students, academics and indie game developers.

To understand the sources of performance bottlenecks that occur mostly on the Xbox 360 platform, one must realize that the XNA Framework on Xbox 360 uses the compact version of Common Language Runtime (Compact CLR) to run compiled intermediate language code. The Compact CLR is optimized for devices like PDAs and cell phones, where small size is more important than high performance. As such, the implementation of the Compact CLR on the Xbox 360 does not optimize floating-point code. Another problem is that the garbage collector on the Xbox 360 is not generational. As a consequence, when garbage collection occurs, all objects on the heap will be scanned to determine if they are alive or not. Finally, the just-in-time compiler does not optimize code as well, so small routines are not inlined.

To overcome these difficulties, MoonGate uses various mechanisms like object pools, manual inlining of critical parts of the engine, along with combinations of design patterns to avoid excessive garbage creation, keeping heap small and simple to speed up the garbage collection, which, according to feedback from the XNA community, is currently one of the biggest performance bottlenecks. Due to usage of both full and compact versions of CLR in XNA, MoonGate's users are able to indentify differences in performance on Xbox 360 and Windows platforms, learn through usage of code optimizations techniques and exploit multiprocessor environments on both platforms.

At the moment MoonGate runs at well over 60 FPS on most PC configurations and at more than 100 FPS on Xbox 360 with medium-sized map and tens of objects, which is comparable to other free RTS engines.

6. CONCLUSION

In this paper, MoonGate – an open source, real-time strategy game engine for Xbox 360 and Windows platforms was presented as a tool of choice not only for indie game developers, but also for students and hobbyists. MoonGate's main goal is to attract them to learn by creating highly interactive and visually attractive games and give them an opportunity to easily study various problems by providing easily understandable and highly customizable educational environment, which incorporates best features of modern commercial games, visualization environments and game middleware. What is important, MoonGate is the first open source starter kit and real-time strategy engine for Xbox 360.

MoonGate promotes simple extensibility through usage of reusable components, custom content pipeline extensions that allows easy creation and import of game content and tweaking without the need of source code recompilation. Its flexibility allows beside creation of a game in one of the most popular game genres also exploitation of Xbox 360's hardware for variety of tasks, ranging from shader development, rendering of terrain through particle systems to visualization of AI algorithms, which are very tightly bound to this game genre.

At the moment MoonGate is used by individuals and small teams that are using it as a base for custom strategy games and as a platform for experimenting with algorithms from various research areas.

In the near future, network component that is still in the alpha version will be replaced with more robust version that will be able to handle synchronization among connected users with better results. Moreover,

current basic material system will be enhanced. Since the XNA Framework does not provide standard graphics user interface controls out of the box, component that allows usage of these controls will be added to MoonGate.

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