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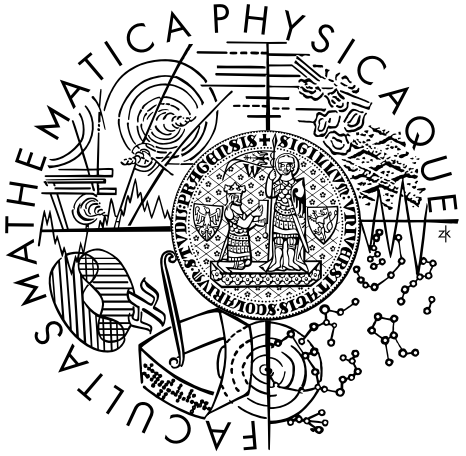

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The Dungeon Throne: A 3D Dungeon Management Game

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Study programme: Computer Science
Study branch: TODO: IPSS?

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Title: The Dungeon Throne: A 3D Dungeon Management Game

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Abstract: Abstract. TODO:

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Dedication. TODO:

Contents

Introduction

1. The Game

An example citation: Anděl [2007] TEST

1.1 Dungeon Managment Genre

1.2 Modifiability in Games

1.3 Similar Games

1.3.1 Dungeon Keeper

TODO: Design influence.

1.3.2 Garry's Mod

TODO: Modifiability influence. (Mainly game mechanics.)

1.3.3 Minecraft

TODO: Modifiability influence. (Mainly items.)

1.3.4 Dungeon Siege

TODO: ECS influence.

1.4 Thesis Goals

1.5 Thesis Structure ??

2. Problem Analysis

2.1 Game Design

- go over which features of the dungeon management genre will be used and why
- possibly talk about how they could be done? or leave this to implementation?

2.2 Engine Design

- maybe mention that the goal to make an engine and that's why UE or Unity weren't used
- say that since the game is to be modifiable and extensible, run time entity creation is a must (both for modding and testing)
- might be good mention the choice before explaining why the different options were/were not chosen so that the reader knows

2.2.1 Inheritance based (wording?)

- explain what is meant by the title (classic OOP design)
- explain that since inheritance has to be done by compile time and cannot be changed during run time, this would prohibit dynamic entity creation
- for the same reason, specifying entities in config files would generally be impossible (except with something like Roslyn)
- this kind of engine would also have to be planned a lot (to avoid inheritance hierarchy hell)
- ?same reason (inheritance hierarchy) would either prohibit or discourage some attribute combinations (like a walking wall) during future modifications?

2.2.2 Component based (wording?)

- define the Component design pattern (with references to the gamedesgin-patterns.smth book)
- mention that this is very similar to the component based implementation both Unity and UE4 use
- mention its relationship with both ECS and the inheritance based design

2.2.3 Entity Component System

- define the ECS design pattern
- mention how well it supports run time entity creation and modification
- mention ease of development this model creates
- mention ease of entity access (through ID)
- talk about the difference between Component and ECS patterns
- ?mention cache friendliness? (pro: well, it exists, con: not used that much in this game)

2.3 Programming Language

- talk about the need of fast language that can be used to create 3D games with the ability to be scripted using an embedded language (or itself)
- talk about the benefit of runtime code execution (testing)
- talk about the necessity of scripting without compilation

2.3.1 C++

- industry standard
- powerful and fast
- modifiability can be added through embedded languages
- lots of materials

2.3.2 Lua

- slower than C++, faster than other scripting languages
- can be scripted by itself
- there are no 3D rendering libraries
- high portability

2.3.3 Java

- Minecraft proved that it allows highly modifiable game development
- it also shown that the performance can be a big problem
- high portability

2.3.4 C# ???

- ?should this even be included? main reason for not selecting C# was that I didn't know it well when I started
- also back then runtime code compilation was unavailable

2.4 Scripting Language

- should be fast, easily embedded into C++ and also easily used by modders

2.4.1 Custom

- challenge, experience, can be created to suit the project
- slow development, big task
- probably slow and buggy

2.4.2 Lua

- industry standard
- maybe talk about some of the different games using it
- ease of embedding into C++
- no need to create anything, just connect it to C++

Bindings

- talk about most bindings being either dead, obsolete or very archaic
- those that are up to date are mostly focused on OOP in Lua, which isn't needed in this project
- creating new binding just for this project is easy, fast and the resulting binding will only contain the features that are needed

2.5 Libraries

- just mention something about reinventing the wheel and the areas for which 3rd party libraries were used

2.5.1 3D Rendering

- almost any game will have to use some library for this as going without would take years
- ??I only though about these in the beggining, should I add others just for comparison??
- mention that portability of the rendering library is much more important than for example the GUI library, since it's integrated deep into the engine while the GUI is not

OpenGL

- talk about what it is
- would allow later Linux port
- too low level, would slow the development process

DirectX

- talk about what it is
- similar problem to OpenGL (too low level)
- would prohibit eventual port to Linux

Ogre3D

- talk about what it is
- can wrap both OpenGL and DirectX
- higher level, lots of stuff already implemented
- describe basic usage of the library (entities, meshes, scene graph, ...)

2.5.2 Graphical User Interface

- main requirement is Ogre compatibility
- theoretically does not have to be portable as it can easily be changed (as it's not integrated into the engine)
- other requirements: graphical editor, ease of use, high level, all the widgets needed (buttons, scrollbars, editboxes, labels, ...)

Ogre Overlay

- talk about what it is
- too simple, would require for the widgets to be created during the game development process which would take a lot of time

CEGUI

- talk about what it is
- used to be bundled with Ogre
- easy to use, clean interface, good design
- ??? genrally advised by the Ogre community
- ??? used for Torchlight which proved what can be done with it
- graphical editor and existing skins
- ??I only though about these in the beggining, should I add others just for comparison??

2.6 Algorithms

- dunno about this section, not many known or big algorithms used in the game

2.6.1 Pathfinding

- talk about the problem of pathfinding
- talk about node graph vs vertex graph (or hows it called)???
- after mentioning node graph, give reason for grid form and 8 neighbours (bcuz of the view)
- also talk about the inclusion of portals in pathfinding and problems that have risen with it

Breadth-first Search

- just mention what it is and why it's not good (uniform cost of graph edges)

Dijkstra

- talk about what it is and why it's not the best alternative
- explain that it might be worth using when performance is not critical and we absolutely need the best path

A*

- talk about what it is (possibly also define heuristic as it should be seen for the first time now)
- mention that it's probably the most used one in games (provide examples?)
- ??mention how it goes well with e.g. portals??

- maybe go into detail about the default heuristic (PORTAL_HEURISTIC) which allows portal pathfinding (include previous iterations, portal component, problem with portal chains and possible fix)

Solution ??

- maybe this should be in the A* part as it's the only one actually implemented?
- describe the generic pathfinding system implemented in the game, switchable algorithms, heuristics and path types (define path type), algorithm and path type interface ...

2.6.2 Level Generation ??

- talk about how complex level generation isn't really needed due to the nature of the game (you dig your own hallways so only need gold distribution)
- mention that similar generic system to the pathfinding one is used
- ??probably go through the algorithm in pseudocode?? or explain it only?? if so, probably go through the part with the gold only and just mention the rest??

2.7 Serialization

- talk a bit about game state serialization in general
- mention that since the game should be extensible, manual save game editing without the need to write big editors would be nice for testing and possibly the creation of simple mod maps (and the save editor - if ever created - would be easy to make)

2.7.1 Binary

- mention that it's the most used (maybe give examples like UE4 save system etc.)
- it's also the most compact as it just meshes data together in binary
- lots of libraries (like boost)
- editing would require complex editor and does not allow code execution in the save file so additional save file functionality (like changing the wave system table, executing custom commands) would need to be made in C++ in a generic way, which would be bad for mods

2.7.2 XML

- mention losts of xml libraries
- talk about how it allows easy data change, which in a data driven game like this one means quite a lot
- but explain that it's bad because it disallows code execution

2.7.3 Lua

- since the game needs an extensive modding api with all sorts of setters/getters, all that's needed is to write serialization of components into a sequence of the API calls
- easy to implement, load is basically executing a script
- easy to modify using a text editor
- !!allows code execution to create special levels
- say that it's limitation is level size, e.g. 256x256 save file can be big (200MB) and very slow to load (10-20sec), but on the allowed level sizes (10-64) the load is almost instant and the resulting files small (16x16 is around 650KB)

3. Implementation / Dev Docs?

- give some basic overview of the project
- say how to tell my functions and Ogre/CEGUI/Lua functions apart
- maybe mention why the camelCase notation of Ogre/CEGUI was not used
- mention what the compiled binary needs to run (?list dlls?)
- say how to change the paths to resources and scripts directories

3.1 Engine (?Layout)

- describe Component - System - Helper - LuaInterface - ... relationship
- possibly create a picture
- describe the "workflow" of the game? or leave it to other sections?

3.2 Game

- !ask PJ: do I have to describe functions even if they have documenting comments?
- describe how the game is initialized
- explain OIS and Ogre callbacks (+ parent classes)
- brief description of its members vs just mentioning them vs ignoring them as they will be explained later?
- level creation (new_level && generate_empty_level)
- throne monitoring? (keeping throne ID so there is only one target of the enemies)
- possibly add a subsections describing Ogre and CEGUI initialisation

3.2.1 State Design Pattern

- describe the pattern
- describe the states of the game
- explain why the pattern is NOT used

3.3 Components

- go through components one by one with UML-like pictures describing theis members and purpose
- explain why strings are moved?
- explain why components need default values for every parameter of their constructor?
- go through some more complex concepts of the components (align states, maybe forward reference blueprints, etc.)

3.4 Systems

- define systems
- mention common base class and the reason for inheritance (list of systems...)
- describe the component-system relationship (none, system-component, system-components, systems-component, ...)

3.4.1 CombatSystem

- describe the update logic
- describe entity querying
- describe effect application
- talk about the fabulousness of the query & effect design!
- talk about the run away mechanism?
- talk about runtime projectile creation?
- talk about line of sight and LoS wrt BB?

3.4.2 EntitySystem

- describe the update logic
- describe cleanup (and its delay and why it's necessary)
- id system (back then vs now)
- entity creation process
- component containers
- describe component manipulation (add, load, set, delete, delete now, ...)
- mention entity registration for the entity creator window

- describe function array (reason, jmp table bonus, etc.)
- explain the macros!
- describe why constructors are delayed (so that the lua function where it's create continues before constructor call)
- maybe talk more about component loading from lua? or leave that to the scripting part? or never mention it?

3.4.3 EventSystem

- describe the update logic
- describe event persistence/destruction
- describe how to make event one (successful) pass only
- targeted/area events and area event expansion
- delete component vs delete entity discussion
- describe handling (fixed C++ vs Lua)
- this should be first time we encounter update periods and time multipliers, explain!

3.4.4 GridSystem

- describe the update logic (+freed/unfreed and Grid relation)
- talk about grid graphics used for debugging?
- explain structure placement
- describe alignment checks

3.4.5 TaskSystem

- describe the update logic
- talk about busy state, processing tasks and checking if task is complete
- probably only forward reference the Lua part? or talk about it right here? !ask PJ!

3.4.6 WaveSystem

- describe states and maybe mention why the State design patter wasn't used (too simple)
- describe the update logic of the different states (-¿ countdown, spawning, chilling)
- talk about the spawning mechanism, blueprint vector, spawn nodes
- talk about wave entity monitoring and wave ending
- talk about the wave table
- talk about the wstart and wend callbacks
- talk about endless mode
- possibly explain how to write a wave? or add that to the scripting part?

3.4.7 Other

- here explain in alphabetical order the remaining systems
- say why these are not as important (that is, not important to be described) as the others

AISystem

- describe the update logic
- mention update forcing (in relation to the update period mentioned earlier)

GraphicsSystem

- say how it's supposed to maintain all manual graphics logic but atm only does explosions (since it's the only manual graphics object)
- describe the update logic

HealthSystem

- describe the update logic
- mention configurable regeneration period

InputSystem

- describe the update logic
- explain initial purpose and why it's not used atm

ManaSpellSystem

- describe the update logic (both mana regen and entity spell casting)
- possibly talk about the relationship between player spells and entity spells

MovementSystem

- describe the update logic
- talk aboud move and checked_move (and can_move_to) and why checked is not used but can be from lua (and was intended for 1st person mode)

ProductionSystem

- describe the update logic
- explain how products are spawned and placed

TimeSystem

- describe the update logic (mention the multiple comps updated)
- explain time event handling (and use)
- explain time event advancements

TriggerSystem

- describe the update logic
- explain how triggering works and why it works that way (factions)
- explain the general trap concept?

3.5 Helpers

- describe what helpers are and how are they used
- forward reference the not-singleton status of EntitySystem?
- explain why they were created (use in Lua and optionally in C++ for better code readability)
- explain why they are slower than direct component manipulation
- explain component-helper relationship
- mention the general structure of a helper
- maybe talk about why they are namespaces and not classes? (+ namespace -¿ allows static class without any change basically)

3.6 Script

- talk about how it works (it's basically a wrapper facade)
- mention lpp::Exception
- explain the Lua C API (only informative? add a new section with a tutorial? tell the reader to read the Lua Programming Language 3rd edition book?)
- maybe go through some of the more complex functions?

3.7 LuaInterface

- talk about why it's needed (Lua needs static)
- talk about why it's centralised in one class?

3.7.1 Initialising the API

- explain the C++ function binding process
- explain the Lua module hierarchy
- explain other aspects besides function binding

3.7.2 Extending the API

- explain the general body of the interface functions (stack, return etc.)
- (super) small tutorial on how to add new interface functions

3.8 GUI

- talk about the GUI hierarchy
- explain initialization
- explain CEGUI button binding? maybe in general CEGUI manipulation?
- explain save/load file listing
- mention the GUIWindow class, base class of the following GUI windows
- explain why it has escape_pressed handler and does not use CEGUI handlers for that (would be needed for all subwindows, too much a hassle - also would probably disregard the conditional closing)

3.8.1 Console

- talk about how awesome it is during debugging
- explain how execution and printing works (+ the history concept?)
- explain why it does not execute lines but multi lines after the execute button is pressed

3.8.2 EntityCreator

- mention that currently it is used for entity placement and the creation part is supposed to be a graphical way to make entities that is not currently in the game
- explain how it works
- explain how it's used for testing
- maybe mention that this is where the registered_entity from EntitySystem is used

3.8.3 EntityTracker

- explain how tracking works
- talk about why it's useful
- mention the upgrade, exp convert and delete functionality?

3.8.4 ResearchWindow

- explain initialisation, how it works
- explain dummy_unlock and its relationship with serialization

3.8.5 Other

- say that these are generally not that complex and quite straight forward

BuilderWindow

- talk about building registration (how it relates to unlocking)
- talk about the assembly line (also used in spell casting window) and why it's good (lack of images -¿ buttons need to be big and readable)
- don't forget to mention that this is just a graphical front end to EntityPlacer (with price management etc.) as is EntityCreator (though that one ignores price, and has all unlocked even enemies)

GameLog

- just mention that it is basically the ingame chat posting info for the player
- also maybe again mention history (same as console)?

MessageToPlayerWindow

- talk about button renaming and action assignment
- then mention how to use this as a whole

OptionsWindow

- talk about actions, key bindings and video settings (+ how they are done?)

SpellCastingWindow

- talk about spell registration (how it relates to unlocking)
- just mention the assembly line (already explained in BuilderWindow)
- talk about the relationship with the SpellCaster and how spell casting works on this side (simple invoking of the spell caster and marking the spell as active if needed)
- don't forget to mention that this is just a graphical front end to SpellCaster basically

TopBar

- just say something about its purpose (monitoring of resources)

3.9 SpellCaster

- discuss the spell casting concept in the game
- mention the spell types
- explain why it's so damn cool (ease of spell creation, run time spell creation)
- forward reference the Lua spell structure, which is explained later in Scripting

3.10 Utilities

- just say that these are classes that are not directly part of the game world but are used as background tools that support the game

3.10.1 Camera

- talk about how it allows free/nonfree mode, resetting and backups
- maybe talk more about the free nonfree mode and how to toggle them (both keybind and command)

3.10.2 Effects

- talk about how awesome they are and allowed the creation of extensible effect application framework in CombatSystem
- explain how to write one
- mention that they are used as template arguments and as such should conform the given interface (also explain that)
- maybe ilustrate their structure on one of them

3.10.3 EntityPlacer

- explain its purpose and how it works
- explain why only the graphics component data is used (so it's ignored by the game world and serializer, etc.)

3.10.4 LevelGenerator

- explain their purpose and how to write one
- mention the cycle count constructor parameter
- mention the default tables in config (and that it's easy to add new ones)

RandomLevelGenerator

- say that this is just naive algorithm for a pseudo random level generation using number of neighbours that are gold deposits to determine if a gold deposit should be spawned

3.10.5 RayCaster

- explain that I'm a noob that stole other programmer's idea for this from the Ogre wiki
- explain why it's needed (polygon precision ray casting -¿ half cubes, without it only bounding boxes are checked and free space is impenetrable)

3.10.6 SelectionBox

- explain its purpose and how it works
- talk about single/area selection and multi selection using shift

3.10.7 Conditions

- explain their purpose, how they are used in querying and effect application
- mention that it's a good way for extensibility as new can be easily implemented
- mention that they are often used as template parameters and thus need to conform an interface (but not by inheritance)
- talk about the interface
- maybe demonstrate on an example

3.11 Pathfinding

- recapitulate form analysis that a modifiable function was used that allows different algorithms, heuristics and path types
- mentions its parameters (destruction, add path are primary!)
- mention how destruction works
- mentions why path addition is optional (for checks)

3.11.1 Grid

- explain its purpose and implementation
- mention that it only provides a set of grid related operations on a set of IDs it's provided (and assumes those are grid)
- mention random node placement and entity distribution
- mention free node list for ease (and speed) of access
- explain graph creation and linking
- explain general usage

3.11.2 Algorithms

- explain how they should be implemented (what functions, as they are used as template parameters)
- mention that A* is the only currently implemented
- mention portal implementation
- mention difference in complexity (component lookups)
- mention any other differences from a general A*

3.11.3 Heuristics

- explain how they are used and why they are inheriting a base class while other functors are not (state needed for some -¿ run away heuristic)
- maybe demonstrate on an example as the code is small?

3.11.4 Path Types

- explain what these things are and when they are used to check if the algorithm should stop
- explain their effect on the A* algorithm

3.12 Serialization

- talk about how easy component serialization is and how to create template specializations for new components
- show an example?
- explain the whole saving process, ents to be destroyed, unlocks, player, grid etc.
- explain the loading process

3.13 Player

- just say that it is used as a resource bank, keeping track of gold, mana, units etc
- mention that it also holds the starting unlocks used for new games (saved there during the game initialisation)

3.14 Singleton Design Pattern

- explain what this stuff is, its pros & cons
- mention that the main reason for its use in this game is having one instance, not that much global access

3.14.1 Script

- mention how two Lua virtual machines cannot communicate and data are bound to C++ (via EntitySystem) so it's completely unnecessary to have more than one Scripting engine

3.14.2 GUI

- why would we want to have two GUIs?
- mention that here is the global access very good for testing?

3.14.3 Player

- why would we want two sets of player resources?
- serialization preserves them and shown is only the main set (also used is only the main one)

3.14.4 Grid

- explains how it only operates on a set of given IDs that are made during graph creation (+ mentions it would be easy to implement their switch) so there does not need to be more than one pathfinding grid
- also mention that due to the nature of the game levels, it would be nonsense to have two grids

3.14.5 EntitySystem

- explain how even though it's getting passed around a lot (mainly Helpers), there could be a reason to use more than one EntitySystem instance (like a backup for example) and thus the Singleton pattern might not be the best choice
- maybe compare it to the 4 previous classes

3.15 Scripting

- talk about the API, possibly mention some API reference text file that I should make as an attachement

3.15.1 Initialisation

- talk about the config.lua & init.lua duo
- explain different options in config
- explain how scripts packs are added to init
- talk abut the core.lua file of each script pack and what it should do (probably with an example)
- explain how to add a new script directory
- explain how to override some behaviour
- explain the new level callback and for what it can be used (+ the return value meaning)

3.15.2 Entity Representation

- explain the structure of a script representing an entity (with a small example)

3.15.3 Blueprints

- explain what is a blueprint, how to make one and how to use it
- explain why it's a table and not just a function and why the functions in different blueprint should have different names

3.15.4 Research

- explain how to add new unblocks and modify existing ones

3.15.5 Spells

- explain the structure of a spell table and how to make new spell
- mention again the spell types and the difference they make in the spell table function implementations
- mention that spells can be made during run time for testing purposes

3.15.6 Creating a Mod (? Modification)

- provide a simple tutorial on how to make a new mod
- possibly the tower defense one?

3.16 Extending the Game

- small sequence of tasks that are needed for a new feature addition (that is component, system etc.)
- idea: show how a TargetedComponent would be implemented, allowing handlers for targeting/untargeting and how this could be used to create a chess mod

4. User's Documentation

4.1 System Requirements

4.2 Installation

4.3 About the Game

4.3.1 ??? Goal of the Game / Goal

4.4 Controls and Options

4.5 Research

4.6 Spells

4.7 Buildings

4.8 Units

Conclusion

Bibliography

J. Anděl. *Základy matematické statistiky.* Druhé opravené vydání. Matfyzpress, Praha, 2007. ISBN 80-7378-001-1.

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