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ΤΜΗΜΑ ΗΛΕΚΤΡΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ & ΤΕΧΝΟΛΟΓΙΑΣ ΥΠΟΛΟΓΙΣΤΩΝ

Σχεδιασμός και Ανάπτυξη Ψηφιακού Παιχνιδιού Μάθησης

Design and Development of Digital Learning Game

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Πάτρα
Δεκέμβριος 2024

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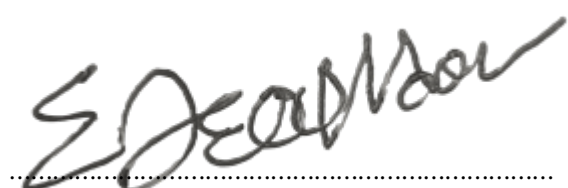
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Λέξεις-κλειδιά: Μάθηση βασισμένη στο παιχνίδι, Κβαντική Υπολογιστική, Κβαντική Μηχανική, Παιχνίδι για κινητά, Flutter

Abstract

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Keywords: Game-based Learning, Quantum Computing, Quantum Mechanics, Mobile Game, Flutter

Ευχαριστίες

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1 Introduction

1.1 Motivation

<https://www.theknowledgeacademy.com/blog/advantages-and-disadvantages-of-quantum-computing/>
<https://www.linkedin.com/pulse/pros-cons-quantum-computing-athik-nagappan-1nhef/>

Quantum computing utilizes the principles of quantum mechanics to process information and solve complex problems exponentially faster than classical computers. Quantum bits can exist in multiple states at the same time, offering great computational power, beyond the limits of classical computers.

The development and widespread use of quantum computing can help in fields such as pharmaceuticals, cryptography, artificial intelligence, materials science and more. Since quantum computing represents a new era for computer science, opening up new prospects for accelerating scientific discoveries, learning the basic principles of quantum computing is extremely important.

1.2 What is Game-Based Learning

<https://decodoku.medium.com/why-we-need-to-make-quantum-games-6f8c7bc4ace7> <https://elearningindustry.com/7-tips-game-based-learning> <https://www.gamedesigning.org/learn/game-based-learning/> <https://bedrocklearning.org/literacy-blogs/the-pros-and-cons-of-game-based-learning/>

Game-based learning is a very old practice; it did not start with the advance of modern technology. It can be defined as the technique of being educated by playing games. It integrates the characteristics and principles of games such as elements of competition, rewards and active user engagement, into learning activities. Games can be an interactive tool that can simplify challenging concepts and help learners understand complex ideas, engaging them into educational content.

1.3 Benefits of Game Based Learning

<https://bedrocklearning.org/literacy-blogs/the-pros-and-cons-of-game-based-learning/> <https://www.gamedesigning.org/learn/game-based-learning/>

First, game-based learning is more appealing to children, as it appears to be a game on the surface, but in the background it has the ability to stimulate children's curiosity and capture their imagination. It is a friendlier and more accessible mean of engaging young learners with a subject than traditional methods, as it is fun and motivating.

Game-based learning also has the ability to enhance critical thinking and problem-solving, as they involve human instinct to compete and desire to succeed. Because learners often compete with other players, they have to collaborate and share ideas. They must listen to and evaluate the opinions of other players and take into account the tactics of opposing teams.

Games often require users to react quicker to stimuli, make critical decisions in a short period of time and combine knowledge acquired during the game to solve complex problems. Due to their repetitive and interactive nature, they have the ability to improve retention and increase the brain's capacity to memorize things.

Also, as games are flexible, they can be adapted to different learning styles, levels and paces, meeting individual needs and can also give instant feedback about where gaps in knowledge are or provide specific tasks for the user to help cover these areas. In this way, they can further help learners to identify their strengths and weaknesses.

Comparing games to traditional textbooks, although the latter have been used for many years with success, their revision and renewal takes a long time and is difficult and costly. The cost of reprinting, redistributing and recycling or storing old textbooks must be taken into account. Even in the case of digital textbooks, there is a significant cost of disposal and renewal. By contrast, games are very versatile, their rules can be adapted easily, and their content can be changed quickly to keep pace with technological and scientific progress.

In summary, game-based learning offers a modern, engaging and flexible approach to education. It is a great way to improve learners' critical thinking and problem-solving skills, boost their creativity and keep them engaged and motivated. Also, unlike traditional textbooks, it can be quickly and cost-effectively updated, in order to reflect new information and technological progress.

1.4 Research Objectives

The aim of this thesis is to familiarize the learners with the basic principles of quantum computing, such as quantum bits and quantum gates. They should not be distracted or get tired due to the complexity of the game. The aim is to design a simple and accessible educational game, with few rules and clear objectives.

In order to play this educational game, one does not need to have a university background in mathematics or a strong background in quantum physics. The game can be played by anyone who is

interested in learning how quantum gates work and how they affect quantum bits.

In addition, it is desirable that the game could be played at any time and in any place, without the need of equipment or a computer. The aim is that the user can play even when he has limited time (e.g. travelling, waiting for public transportation, etc.), and for the game to be suitable for playing in a class, in the context of a lecture.

For these reasons, a classic digital game, for mobile devices, with simple mechanisms and low complexity should be chosen, whose rules and objectives should be adapted to the topic of quantum computing.

1.5 Thesis Structure

2 Literature Review

2.1 Computer Science Games for Higher Education

https://www.researchgate.net/publication/325046233_Games_for_Teaching_Computing_in_Higher_Education_-_A_Systematic_Review

2.2 Quantum Physics Games

2.2.1 Desktop and Web Games

:memo: **Name:** Name of the game :memo: **Created By:** Name of the creator (university or institution or student or individual) e.g. Student at University of Aalto :memo: **URL:** Where the game is hosted :memo: **Educational:** Was the game designed for educational purposes? True/False :memo: **Competition:** Was the game created for a competition? True/False :memo: **Course:** Was the game created in the scope of a course? True/False :memo: **Platform:** Desktop or Web

List Of Quantum Games

1) Finnish Game Jam

- Competition for game developers.
- Desktop games: User must download the source files and build the game.
- Browser games.
- Most of the games are available on itch.io:
- Games created by Finnish Game Jam are not designed for educational purposes.
- The target of this competition is to create games with limited time and resources but with unlimited creativity [[link](#)].

2) QPlayLearn

- Platform with web-based educational games.
- Uses interactive tools to make the learning process more effective and entertaining for different target groups [[link](#)].

3) [Quantum Games Course by Aalto University](#)

- Course offered by Aalto University
- Games are not designed for educational purposes.
- This course is designed to teach students how to design and develop games and also learn the basic concepts of quantum computing.

4) [Science At Home](#)

- Aarhus University
- Browser and desktop educational games
- Diverse team of scientists, designers and game developers that create scientific games, aiming at teaching by game-play [[link](#)]

5) github / gitlab

- Lots of desktop games. Most of them use Jupyter Notebooks.
- The majority of these games are not designed for educational purposes. They have been developed in the context of competitions or workshops.

6) [Decodoku](#)

- Has created a lot of quantum games. The games are hosted on itch.io.
- The games does not have an educational purpose.
- Most of them are designed to run on the [IBM Quantum Platform](#)
- Browser and desktop games

Conclusions: - Educational or not? - Quantum Computing or Particle Physics? - Designed by professionals, universities or just for fun? - Desktop or web? - Programming language - Technologies?
Consider adding table

2.2.2 Mobile Games

2.2.2.1 Google Play Store (for android devices)

- [Quantum](#)
 - Educational app
 - 13 chapters
 - 4 tests - 60 different questions
- [QuantumQ](#)
 - Puzzle game with theory

- Quantum gates and quantum circuits
- [Learn Quantum Physics](#)
 - Educational app
 - Designed for students and professionals
- [Quantum Computing](#)
 - Educational app
- [Quantum 3:](#)
 - Educational game designed by Michigan State University
 - Puzzle game
 - Particle physics

2.2.2.2 App Store (for iOS devices)

- [Quantum Mechanics](#)
 - Educational app
 - Particle physics
- [Qika Quantum Game](#): Qika is a quantum game which you need to apply quantum gates to qubits in the grid. You need to change the states of qubits by applying gates in order to reach the target measurement.
 - Puzzle game
 - Applying quantum gates to qubits in order to reach a target measurement !!! Basic concept of our game !!!
- [Quantum 3:](#)
 - Same as android game
 - Educational game designed by Michigan State University
 - Puzzle game
 - Particle physics
- [Quantum Kate AR](#):
 - Educational game
 - Casual -> Simulation -> Adventure game
 - Particle physics

2.3 Why a mobile game?

Conclusions: - Educational or not? - Quantum Computing or Particle Physics? - Designed by professional, Universities or just for fun? - Android or iOS? - Programming language - Technologies?
Consider adding table

2.3 Why a mobile game?

<https://www.ncfe.org.uk/all-articles/how-educational-games-are-changing-the-way-we-learn/>

https://www.researchgate.net/figure/Core-educational-value-of-mobile-games_fig5_360277617

<https://www.linkedin.com/pulse/top-7-reasons-using-mobile-apps-education-e-learning-industry-ved-raj>

2.4 Mobile Games Development Technologies

Short description of the technologies.

web based (js) OR android based (?) OR iOS based (consider also developing 3 separate apps for web/android/iOS?) cross-platform game: Use a cross-platform framework like flutter or react-native

2.5 Why Flutter?

Why we selected flutter? - cross-platform: Υπήρχαν πιο πολλές εφαρμογές android. Εμείς θέλουμε όλοι οι χρήστες να μπορούν να παίξουν, ανεξάρτητα από τη συσκευή που έχουν.
- Άλλα πλεονεκτήματα flutter π.χ. απόδοση/ταχύτητα σε σχέση με τις άλλες επιλογές??? - Επιπλέον της υποστήριξης από android και iOS, η εφαρμογή μπορεί εύκολα να διατεθεί και ως desktop ή web app. - Βιβλιοθήκες για κβαντικούς υπολογισμούς (συμβατές με το Dart version 3) * <https://pub.dev/packages/qartvm> * <https://pub.dev/packages/quantools> - Βιβλιοθήκες για πίνακες * https://api.flutter.dev/flutter/vector_math/vector_math-library.html * https://pub.dev/packages/advance_math (supports complex numbers and matrices)

3 Gamification and Game-Based Learning

<https://uwaterloo.ca/centre-for-teaching-excellence/catalogs/tip-sheets/gamification-and-game-based-learning>

Gamification is the integration of game elements, such as point systems, leaderboards, badges or other game-related elements, into conventional learning activities in order to increase student engagement and motivation. In other words, it integrates game elements into existing learning activities.

On the other hand, game-based learning is the design of learning activities so that the characteristics and principles of games are a key feature of these activities.

3.1 Game Elements

University of Waterloo [link to University of Waterloo](#) categorizes game elements into three main categories: Point Systems, Badges and Leaderboards.

3.1.1 Point Systems

Points or Experience Systems reward students for completing tasks, just like conventional grades. They can introduce some useful features in learning environments, such as:

Limitless Points

While conventional grading systems collect learning artifacts that accumulate to one hundred percent of a course grade, point systems can accumulate points without a fixed end, pushing learners to do even better.

Flexible Goals

The courses can be structured to allow learners collect as many points as they want or force them complete a certain number of assignments to reach a desired threshold.

Student Choice

Learners can collect points by completing assignments or tests or any other course-relevant activities. They are free to choose how to collect points.

Tracking

Points can be tracked via grade books and shared with the entire class.

3.1.2 Badges

Using badges can be a great way to reward learners for their work and keep them engaged and motivated. Badges can also be shared with the class to encourage competition.

3.1.3 Leaderboards

The use of leaderboards is a great way to motivate learners, by providing them with constant feedback of where they rank in comparison to other group members. There are two types of leaderboards, absolute and relative.

Absolute

https://scholar.google.com/scholar_lookup?hl=en&volume=63&publication_year=2013&pages=380-92&journal=Computers+%26+Education&author=A.+Dom%C3%ADnguez&author=J.+Saenz-De-Navarrete&author=L.+De-Marcos&author=L.+Fern%C3%A1ndez-Sanz&author=C.+Pag%C3%A9s&author=J.+Mart%C3%A9n-Herr%C3%A9iz&title=Gamifying+Learning+Experiences%3A+Practical+Implications+and+Outcomes
Dominguez et al. 2013

Absolute leaderboards rank all learners by some global measures, such as collected points. When this type of ranking is used, consideration must be given to the feeling of disappointment or discrimination that may be created against those in the bottom positions **Dominguez et al. 2013.**

Relative

Relative leaderboards rank and group learners according to relative criteria. A common example is a view in which learners see only those students who are directly above or below them, solving the disappointment and discrimination issues.

3.2 Gamification Strategies

There are three types of gamification strategies, Online Strategies, Classroom Strategies and Out-of-class Strategies [link to University of Waterloo](#)

3.2.1 Online Strategies

Discussion Boards

Learners can be prompted to participate in online discussions, before or immediately after class, by making them optional but awarding points for each post or reply to another post. They should be able to use the collected points as an extra help on an assignment or for improving their final grade.

Quizzes

Instead of presenting a set of seemingly unrelated questions, the usage of interactive and narrative quizzes is suggested. This helps learners see the implications of their answers and also helps them stay engaged.

3.2.2 Classroom Strategies

Jeopardy

<https://en.wikipedia.org/wiki/Jeopardy!>

Jeopardy-style [link to wikipedia](#) games can be used for chapter reviewing or midterm preparation and can provide enjoyment and enhance cooperation among learners in a familiar game structure.

Classroom Response Systems

Using classroom response systems can simplify the process of gathering responses from an entire class and can encourage participation by incorporating game elements such as point systems or leaderboards.

3.2.3 Out-of-class Gamification Strategies

Game-based learning environments

This strategy includes all games that are designed for educational purposes and do not require the presence of an instructor to be played.

Game-enhanced learning environments

These environments use commercially available games designed for entertainment purposes. Learners can play these games for fun and then discuss gaming experiences with other learners.

3.3 Pitfalls

<http://www.tandfonline.com/doi/abs/10.1080/87567555.2017.1295016> **Moore-Ruso et al. 2017** https://scholar.google.com/scholar_lookup?hl=en&volume=8&publication_year=2012&pages=30&journal=Games%2B+Learning%2B+Society&issue=1&author=S.+Nicholson&title=A+User-Centered+Theoretical+Framework+for+Meaningful+Gamification **Nicholson 2012**

There are some potential pitfalls that instructors may encounter when designing game-based learning activities **refer research as Moore-Ruso et al. 2017**. First, game elements may not be connected to learning objectives. Quite often the assignments are introduced without planning how they support the learning objectives. Also, sometimes the learning objectives are connected, but the context of the game is not. Thus, learners cannot retain knowledge or relate it to the subject. For game-based learning activities to be successful, learners must be able to retain and apply the knowledge they have been exposed to through the game. Furthermore, when students are focused on passing high stakes examinations, participating in a gamified environment can be seen as an unnecessary obstacle **refer to Berkling and Thomas**. Learners who are used to learning and being assessed by conventional teaching methods and are focused on achieving high grades may feel deprived in a gamified environment. They will fill uncertainty, discomfort and may find it difficult to adapt to new rules. Another common pitfall is to capture the imagination of students and inspire them. In order to avoid this, opportunities for play, exploration and collaboration for new goals must be introduced **refer to Nicholson 2012**.

4 Mobile Game Categories, Genres and Subgenres

<https://docs.gamerefinery.com/en/collections/112330-game-categories-genres-subgenres> <https://docs.gamerefinery.com/en/collections/112330-game-categories-genres-subgenres>
what-are-categories-genres-and-subgenres

Gamerefinery [2278730] has developed a flexible three-layer classification that allows mobile games to be easily grouped under distinctive genres. Each game is classified into a subgenre, according to its features and mechanics. This subgenre belongs to one genre, which in turn belongs to one category. This three-layered approach acts as a helpful taxonomy for market and game research, as it provides game developers a singular unified approach to categorizing games.



Εικόνα 4.1. Game Categories, Genres and Subgenres according to GameRefinery

There are 4 categories, Casino games, Sports, Mid-core and Casual games. Each category has genres, which will be described in detail below. At the genre level, the differences between the games begin to become apparent. At the third level, the subgenre level, the mechanisms of the games become distinct.

4.1 Category #1: Casino

The casino category contains only one genre, the casino genre.

4.1.1 Genre #1.1: Casino

This genre contains traditional casino and gambling games. It has five subgenres.

Bingo

Games about playing bingo with others are included in this subgenre.

Cards

Includes casino card games, such as poker or blackjack.

Slots

This subgenre includes casino games with slot machines.

Casual Casino

Includes games that combine gambling elements with casual gameplay. For example, a game may have a casual casino-style gameplay (e.g. using slot machines) along with elements such as town building.

Other

Casino games that cannot be part of the categories above.

4.2 Category #2: Casual Games

This category contains six genres.

4.2.1 Genre #2.1: Hyper Casual

These games have very simple controls and are easy to learn. They are designed for short playing sessions and are very straightforward. They are divided into six subgenres.

Puzzle

Games where you have to solve some kind of puzzles.

Tap

These games require timing and precise and fast reactions. The gameplay focuses on tapping or holding one or more fingers on the device' s screen at the right time.

Steer

Includes games that require timing and reaction and the gameplay focuses on steering an object either by tilting the device or with some fingers.

Swipe / Drag

The gameplay focuses on swiping fingers or dragging and releasing objects.

IO

The main idea behind these games is for the player to grow by destroying other players or bots smaller than him and ultimately become the king of the whole gameplay area.

Other

Includes hyper casual games that don' t belong to any of the subgenres described above.

4.2.2 Genre #2.2: AR / Location Based

These games utilize augmented reality elements and location technology. This category does not have subgenres.

4.2.3 Genre #2.3: Arcade

These games have straightforward controls and mechanics for short and casual playing sessions.

Platformer

Casual platformer jumper games, where the player has to get through stages by jumping, running or gliding, while avoiding obstacles and/or enemies.

Shoot Them Up / Beat Them Up

Includes arcade style shooting and fighting games, with simple controls and lots of action, with no real emphasis on precise aiming or tactics.

Tower Defense

These games use tower defense mechanics. Main goal of the players is to prevent the enemies from reaching a certain point or target on the screen. Usually the enemies come in waves of increasing difficulty.

Board Games

Includes classic board game titles, either direct conversions of traditional board games to mobile versions, or games that utilize board games mechanics.

Other

Arcade games that do not fit in any other subgenre.

4.2.4 Genre #2.4: Lifestyle

These are games that revolve around lifestyle themes, such as decorating, fashion or customizing the look and style of models.

Customization

This subgenre includes games that focus on customizing or designing things, such as wardrobes or rooms.

Interactive Story

These games have very light mechanics and emphasize on interactive storytelling. Players' decisions affect the progress of the story.

Music / Band

Includes games where music and rhythm are affecting theme and mechanics. There are many customization options regarding style and look.

4.2.5 Genre #2.5: Simulation

These are casual games focusing on constructing and developing farms, cities, worlds or entities, while completing several tasks and side quests to progress in the game.

Adventures

In these games, players are focusing on completing tasks and collecting various items in order to process. The mechanics are often pretty lightweight, as they are limited to tapping or dragging objects. Emphasis is placed on the story and collecting aspects.

Breeding

Includes games that revolve around breeding creatures with each other, in order to get new, better creatures (e.g. breed two dragons to get a stronger dragon)

Tycoon / Crafting

The mechanics of these games revolve around construction and resource management.

Sandbox

The players of these games are free to roam the world of the game. They can craft things that will help them survive or grow. Emphasis is placed on user-generated content.

Time Management

Includes games where the players have to complete various tasks quickly, accurately and in the right order.

Idler

‘Idler mechanics’ means that the game plays itself even if the application is closed. When the application is open, players can see progress happening all the time - even if they are not doing anything themselves (e.g. crops growing, money or energy keeps generating etc.).

4.2.6 Genre #2.6: Puzzle

These games are focusing on puzzle solving or trivia and often use traditional board game mechanics.

Match-Three Puzzle

In these games players have to match pieces together to clear them from the board.

Bubble Shooter

They are Match-Three puzzles where you shoot board pieces -instead of swapping them- to make matches and clear the board.

Merge Games

Includes games where the players have to combine similar objects to create new objects of a higher tier. Merging is used to clear boards or upgrade items.

Action Puzzle

This subgenre includes games that require speed, aiming or directing an object in order to solve puzzles.

Word Games

These are games where the players have to solve word puzzles, like constructing or guessing words from given letters.

Trivia

Includes games that test players' general knowledge by asking questions. They often consist of levels of increasing difficulty.

Coloring Games

These games use tap-to-color or swipe-to-color mechanics, allowing players to experience a digital version of a coloring book.

Hidden Objects

Games that revolve around finding and tapping hidden objects in static scenes to progress in the game.

Solitaire

Includes solitaire games, as well as Mahjong Solitaire.

Other

Games focused on puzzle solving that do not belong to any of the subgenres described above.

4.3 Category #3: Mid-Core

Mid-Core category contains four genres.

4.3.1 Genre #3.1: Shooter

These games are focused on shooting targets from either a first or third person perspective. They often offer a Player-Versus-Player (PVP) gameplay.

Battle Royale

This subgenre includes both first-person and third-person shooter games with Battle Royale mechanics, such as shrinking areas, corpse scavenging and last team/player standing victory.

Classic FPS/TPS

Includes first-person shooter games that emphasize on PVP and team gameplay.

Sniper

These are shooters that use a single-player sniper theme, emphasizing a less direct approach to combat, often encouraging players to use stealth and keep their distance from the battlefield.

Tactical Shooter

Games where players control tanks, robots or other vessels from a third-person point of view. They emphasize on PVP and team gameplay.

4.3.2 Genre #3.2: Card Games

This genre has only one subgenre.

Card Battler

In these games, players have or create a deck of cards and battle other players. They emphasize on PVP and card collecting aspects.

4.3.3 Genre #3.3: Role Playing Games (RPG)

These are games where you control and develop some characters and defeat enemies to progress in the game.

Action

These games incorporate elements of **adventure** games. Players have direct control over characters' movement and use of skills.

Fighting

This subgenre includes games where players control an on-screen character and engages real-time one-on-one close combat. The fights take place in a closed arena setting.

Massive Multiplayer Online RPG (MMORPG)

These games are capable of supporting large numbers of players simultaneously, in the same open world.

Turn-Based

In these games you form and develop a team of characters to fight enemies in a turn-based setting.

Puzzle

This subgenre includes games that are a mix of **Match-Three** and RPG mechanics. These games mix character development with solving Match-Three puzzles.

Idle

These games play themselves, like **casual idler games**, while the app is closed. Once the player returns to the game, the characters have developed, collected loot and progressed through the game.

Sovereign

Includes games where player gets the role of a ruler and manages a country, an empire or a kingdom, fictional or real.

Survival

These are games where the players have to survive in the wilderness, often fighting monster or other players, while developing their character' s skills and equipment or building stronger communities around them.

Tower Defense

This subgenre includes games that combine **casual tower defense** mechanics with RPG elements. They have characters that can be improved and item progression mechanics. They often have a deep storyline.

4.3.4 Genre #3.4: Strategy

The games of this genre focus on resource management, building construction or army development. At the same time, players can make alliances or fight against other player and clans.

4X Strategy

This subgenre includes games that focus on ‘Exploring - Expanding - Exploiting and Exterminating’ . Players have to focus on things like technology research, resource and troops management, open world exploration, base construction and fighting rivals.

Build and Battle

These are games where the players develop their bases, manage resources and create armies to battle both AI and human opponents. Battle mechanics emphasize on tactical thinking, which includes the proper deployment and direction of troops or spell casting.

Asymmetric Survival

Includes synchronous PVP games that use an asymmetric setup in team composition (e.g. 1 versus 4). Usually one side has the role of hunter and the other players/sides are hunted.

Tactical Battler

Includes games where players battle against non-playable characters (NPCs) or other players in a closed arena setup. These games also involve collecting and developing various aspects.

Multiplayer Battle Arena

These games focus on destroying the opposing team, together with your own team, in a closed arena setting.

4.4 Category #4: Sports and Driving

This category contains two distinct genres, sports and driving.

4.4.1 Genre #4.1: Sports

Games in this genre are all about sports or sport-themed action.

Arcade Sports

These games are based on a real-life sport, but with a very casual feel, for example with unrealistic physics or not using the exact rules of the sport in question.

Realistic Sports

This subgenre includes games that have realistic physics and graphics and an accurate rule-set of the sport in question.

4.4.2 Genre #4.2: Driving

Games in this genre are all about racing with cars, motorcycles or other vehicles or have a racing-theme action.

Arcade Driving

Includes racing games with an arcade setup with unrealistic physics.

Realistic Driving

These racing games have realistic physics.

5 Quantum Computing

6 Bibliography

