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Chapter 4. Gamification and Simulation

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Abstract. *Gamification and simulation methods are two of the most important components of serious games. In order to create an effective training tool, it is imperative to understanding these methods and their relationship to each other. If designed correctly, gamification techniques can build upon simulations to provide an effective training medium, which enhances learning, engagement and motivation in users. This chapter discusses their uses, strengths and weaknesses, whilst identifying how to most effectively utilise them in developing serious games.*
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1 Introduction

There are two core elements to any serious game: gamification and simulation. This chapter will discuss why these two parts play such an important role in serious games. It will also aim to help readers understand how both gamification and simulation can be used to enhance a serious game without undermining the learning objectives that are a fundamental part of their purpose. As both gamification and simulation can be overused, and in doing so overshadow the main objectives of a serious game, it is also important to consider the impact that one has on the other. With correct game design, the gamification techniques that will be discussed can build upon the simulation to provide the user with more incentive and drive to learn.

2 Gamification

Gamification uses elements commonly found in games to enhance other applications, with the central idea that the motivational potential of games can be transferred to non-game environments (Groening & Binnewies, 2019). The concept has a myriad of definitions, but most can be simplified to "the use of game design elements in non-game contexts", a definition provided by Groh (2012) to allow a broad application of the concept. Gamification is used in a variety of applications from encouraging people to work through their to-do lists (Habitica, 2019) to learning languages (Duolingo, 2019).

Considerable research has been conducted into how gamification can be used to enhance education. Dicheva et al. (2015) systematically reviewed papers that looked at introducing different types of gamification to this context. They concluded that gamification has the potential to improve education, provided that it is designed and used in the correct way. Although there are no hard and fast rules as to this 'correct' implementation of gamification, there are specific guidelines that can be put forward in order to help achieve concise and appropriate integration. For instance, Deterding et al. (2011) split gamification into five different levels:

1. ***Interface design –*** integrating badges, levels, leader boards or similar goal-oriented systems
2. ***Game mechanics –*** implementing systems that are common to games
3. ***Design principles –*** solving issues through game design approaches
4. ***Conceptual models –*** using particular game models while creating an application
5. ***Game design methods –*** applying specific practices and processes common to game design

These five levels will form the basis for the first part of the chapter on gamification, which will specifically consider how they can be introduced into serious games. Not every serious game requires all five aspects, and it may not suit the game for all of them to be introduced either. Instead, it is best to consider the subsequent sections as a guide on how to help provide interactivity and motivation. As seen in Figure 1**Error! Reference source not found.**, serious games can be independent from gamification entirely. It is thus important to judge whether gamification enhances or hinders the aims of the serious game to be developed.

Figure 1: The differentiation of gamification (Deterding, Khaled, Nacke, & Dixon, 2011)

2.1 Interface Design

The introduction of goal-oriented systems into games appeared with the earliest arcades in the form of a leader board and three initials to indicate the player. This simple form of interface design had players vying for the top spot long before home console systems were commonplace. A publisher for the Atari 2600 games console, Activision, took the concept of leader board scores a step further. Until about 1983 they sent players patches for reaching certain score requirements (Hilliard, 2013) (see Figure 2). These patches were the motivation for players to take part in the goal-oriented system that Activision had developed.

Figure 2: Some of the badges that Activision sent to players (Hilliard, 2013)

The release of Microsoft's Xbox 360 console system in 2005 (Dybwad, 2005) digitalised this form of achievements and thus sparked the extension of this aspect of gamification into the new environment. It also prompted Sony to introduce a version of this feature to their console, the PlayStation 3, three years after the original release (McMahon, 2017).

Today, games are primarily focused around achievement systems; though racing games and other competitive styles also use leader boards as a way of showcasing high scores. Gamification in today's applications and serious games also use a strong mix of leader boards and achievement systems.

2.2 Achievement Systems

Microsoft and Sony may have popularised digital achievements, but it is one of the main gamification elements across a myriad of non-gaming applications today. A wide range of studies aimed to determine the effectiveness of an achievement system in gamification. Groening and Binnewies (2019) concluded that a low number of difficult achievements can be used as a gamification system to improve performance. Although very similar, they concluded that achievements outperform conventional goal-setting systems, which is relevant for serious games with their learning objective.

Intrinsic motivation (i.e. motivation driven from within a person and not based on the surrounding world such as monetary rewards) is considered to be a highly productive force that encourages individual's behaviours (Deci & Ryan, 2000). Xi and Hamari (2019) investigated whether achievement systems can satisfy those intrinsic needs. They discovered that achievement-related features were the most positively associated with satisfying those intrinsic needs over social-related and immersion-related features.

Achievement based systems can thus be useful in encourage specific behaviours, provided the achievements are suitable within the context of the game. Not every serious game will benefit from having an achievement system in place, but it may be appropriate – and indeed productive – for serious games that are intended for shorter play sessions. Still, intrinsic motivation alone may not be enough to get players to seriously interact with the game. It may need the combination with an extrinsic reward to achieve intensive engagement.

4.3 Leader board Systems

Leader boards are frequently seen in games with a competitive nature and can be used in the same manner for serious games. They provide an extrinsic motivation to do better through competition: Whenever there is a way to score points, either from achieving in-game targets or meeting some other form of criteria, leader boards can be used as a way to distinguish players from each other and encourage self-improvement.

Since leader boards are so prominent, it is highly unlikely that anyone will require an explanation as to what leader boards are. Users intuitively understand the concept when presented with a list of names and corresponding scores. Leader boards do, however, present an issue with respect to data protection as they put people's names on prominent display. As such it is common practice to allow users to decide on an alias. This allows the player to decide what information they wish to share with other users of the system, while still encouraging the competition that leader boards are well known for.

4.4 Game Mechanics

One of the fundamental principles of gamification is the use of game mechanics in non-game systems. One of the principle game mechanics is the core game loop. A core game loop is a set of actions that a player has to repeat in order to progress through the game. The details vary from game to game, but every game has some form of core loop at its heart, usually following a structure close to the following: *acquire resources → train → battle* (co. Figure 3).

Figure 3: The core game loop of the popular mobile games "Clash of Clans" (left; Lara, 2017) and "Pokémon Go" (right; Das Gupta, 2016)

With serious games, a similar core loop can be achieved. Although, instead of the cycle being about resources, training and battles, a serious game cycle is more akin to the e-learning cycle of *learn → practice → test*. This cycle can be displayed to the user in a more gamified manner. A good example is *Duolingo* (Duolingo, 2019), which is an app for learning languages. This serious game introduced the concept of experience points, levels and virtual rewards to provide a richer core loop to its users.

4.5 Design Principles

One of the common game design principles is to start with a core game mechanic. This allows for the game to be focused around the primary element and helps to ensure that the final product feels like a complete package. The same holds true for serious games. Focusing on one core learning goal will provide a better experience for users than a game that tries to do too much.

Another game design principle is to ensure that the game's initial entry point is low, but still takes time to master. This 'easy to learn, difficult to master' principle is one that was adapted by Blizzard Entertainment, the creators of *Hearthstone* and *World of Warcraft,* with great effect (Cifaldi, 2010). A reason for this design choice was the multiplayer element, which can also transfer to serious games that wish to encourage collaborative (or competitive) elements. Having a multiplayer element introduces the complication of not being able to assume a player's skill level. Not every user will perform the same actions; unlike within a single-player game that can be quite linear and often possesses blocking points that require a player to gain a specific skill before moving onwards.

Still, when the objective of the game is to teach, it is important not to let the multiplayer aspects overpower what a player is trying to learn. Thus, keeping the idea of one core game mechanic (e.g. learning) at the heart of the game design can help ensure that the message remains consistent and strong throughout. Keeping the entry point low (i.e. allowing players to learn how to use the game quickly, while ensuring it takes time to master the game) can have the added benefit of ensuring that players will return rather than play it just once.

4.6 Conceptual Models

The phrase *conceptual model* is one that often prompts some confusion and bewilderment. It links in with the previous section about game mechanics, in particular the core loops. The conceptual model provides a visual way to showcase what the core loop, and other activities, will allow users to do and can also prompt a discussion on how best to gamify the application or serious game .

Figure 4 shows a conceptual model for a role playing game that highlights all the different interactions that can be performed. Melero and Hernández-Leo (2014) created a very similar conceptual model to identify the different ways that puzzles interact, showing that this idea can be performed for a variety of different game types.

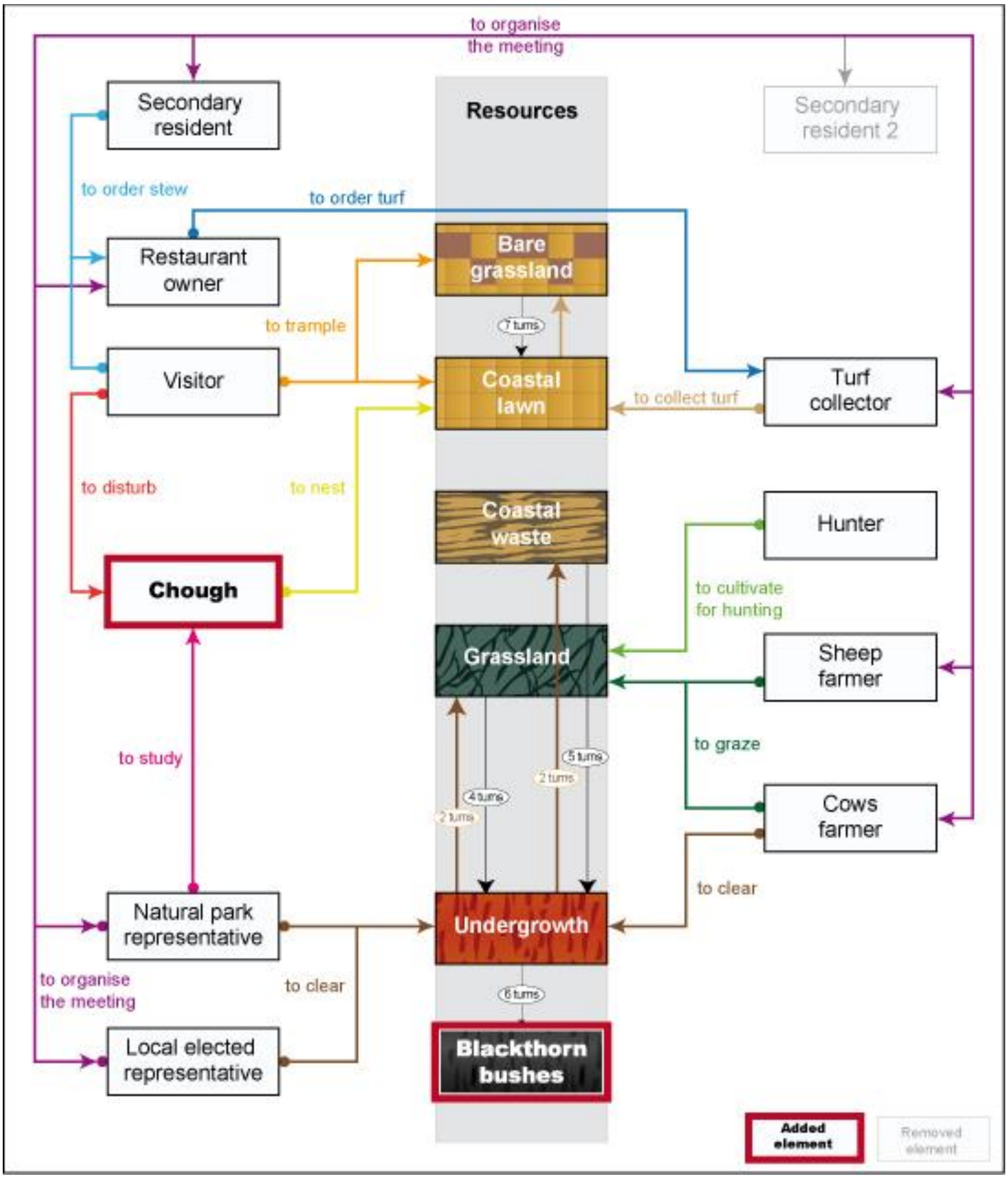

Figure 4: A conceptual model for a role playing game (Gourmelon, Rouan, Lefevre, & Rognant, 2011)

In serious games, the same form of conceptual model can be used to help ensure that the product is on the planned track before development begins. It is not expected that the models produced during this phase will be the final models (cp. section 4.7), as it is important to ensure that the development can change and adapt. However, these models provide real value in ensuring the interactions that are desired are feasible and that the gamification does not push the serious game past its learning objectives.

Relationships are just one example that can be shown through conceptual models. Depending on the style of the game, other elements may become important. In language learning apps, for instance, the focus is around the vocabulary and the grammar. In this instance, a conceptual model showcasing when different levels of vocabulary are introduced may be useful. Another useful conceptual model may be at what point grammar can be presented to the user without overwhelming them with too many new words.

4.7 Game Design Methods

The most well-known methodology used in both game development and software development is the agile methodology (Shama & Shivamanth, 2015). This is the principle of not designing everything outright and instead taking an iterative approach. This system is not unique to games but is used frequently throughout the software development world. The agile methodology allows for the software developers and game designers to ensure that they are meeting their client's brief, while allowing them to respond to any changes and new requirements that may emerge along the process.

This is not to say that the game should not have some forethought of design. Indeed, the majority of the game should be discussed and planned well before any development starts. Instead, the methodology encourages the client and developer to meet at regular intervals for updates on the progress. If any changes are required, the developers can begin to plan for how to implement those changes, whether this is because an idea has not worked as planned or because the basic requirements have changed in the lifecycle of the product.

The same principles apply in serious games, no matter whether the game is on a 2D platform or a virtual reality platform. Maintaining a close relationship between developers and clients is always valuable, as is having regular update meetings on the status of the game. The flexibility that the agile development methodology provides cannot be overstated.

4.8 Gamification Implementation

After looking at the different areas of gamification, the question remains how to best implement it. The short answer is, every adaption of gamification will need to be unique to the product being made. The best recommendation is to work in close collaboration between developers and end-users of the product to ensure that the gamification elements are right for the end-goal.

In the context of serious games, it is important to make sure that the learning goals are placed at the forefront of the development. Gamification should be primarily used to enhance and enrich the user's experience. If this is not the case than the serious game runs the risk of being closer to a recreational game or that its learning objectives are hidden entirely. Both will undermine the purpose and effectiveness of the serious game.

3 Simulation

Simulation is a core concept of serious games, which encompasses the ability to automatically process a set of variables over time based on external stimuli. Often these simulations replicate real-world processes to help identify patterns and/or anomalies in behaviour.

Historically simulations have been used to provide insights and feedback for new ideas or concepts and are commonly employed to prove mathematical theories or engineering principles. As an example, fluid dynamics is the process of calculating the flow of liquids and gases, which is applied extensively in aerospace engineering. Often fluid algorithms require extensive and continuous simulations to achieve a goal, whether it is validating engineering designs (Baysal & Eleshaky, 1992) or conducting fuel combustion simulations (Gosman & Loannides, 1983). In addition, simulations have been used within the manufacturing industry, the automobile industry, military and healthcare (Banks, 1998).

Modern systems within the 21st century have expanded this portfolio to increasingly complex challenges including educational clinical simulations (Cioffi, 2001) or applications in the law enforcement area such as crowd behaviour (Wijermans, Jorna, Jager, van Vliet, & Adang, 2013) or interviews and interrogations (Luciew, Mulkern, & Punako, 2011; see also Introduction). These newer forms of simulation show a movement from traditional mathematical simulations for engineering and design purposes to higher level conceptual simulations with a focus on enhancing education and understanding. This shift towards more general concepts for simulation has enabled serious games to utilise these new simulation applications to help reinforce current knowledge and learning. Many of these simulations follow one or a combination of mainstream simulation models; for instance, stochastic or deterministic simulation.

3.1 Deterministic Simulations

Deterministic simulation models are fully realised by the initial conditions and values of the system. If the simulation is re-run with the same conditions and parameters, the simulation will behave in the same way every time. Such predictable behaviour can be preferable depending on the requirements of the simulation (Hunecker, 2009).

Deterministic simulations are often used when all the variables required to influence a simulation are known and fully understood. This type of simulations can be found in applications for military training or wargaming, as these systems are expected to behave in a specific way in response to external stimuli (Chapman, Mills, Kardos, Stothard, & Williams, 2002). In serious games, many required behaviours are only comprised of known variables. For instance, the basic laws of physics are well documented and understood, and the makeup of a physics simulation within a virtual world often comprises known, quantifiable factors including weight, gravity, force and resistance. Also, serious games often simplify real-world behaviours into approximated representations, which can be simulated efficiently turning something, which could be represented by a stochastic model, into a simpler deterministic algorithm. This enables multiple simulations to be run concurrently without affecting the performance of the entire application.

Figure 5 gives an example of how a deterministic simulation model could work when simulating a dice roll within a serious game. If a user throws a pair of dice with the same force, in the same direction and from the same point in space, the result should be the same every time – in this case a roll of 6. Whilst the representation of forces, which could influence a dice roll are dramatically simplified compared to a real-world simulation, this approximated method would enable a computer to calculate these variables with minimal effort and a high degree of accuracy.

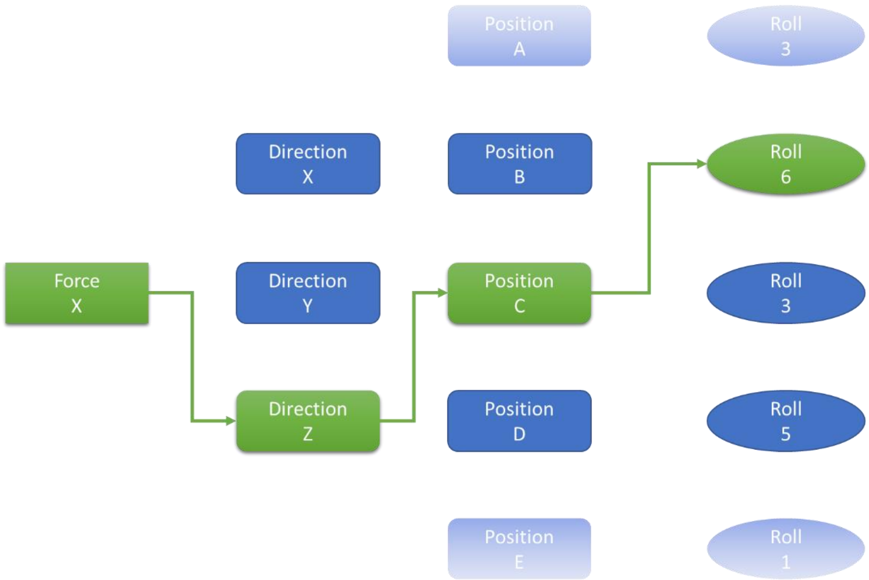

Figure 5: Deterministic dice example

3.2 Stochastic Simulations

Stochastic simulations are random in nature, combining known conditions with random variables to model a behaviour. These simulations can be run continuously to build a distribution graph of outcomes including probabilities and predictions. This capability makes stochastic simulations a perfect method for approximating an outcome, which cannot be determined in advance (Rubinstein & Kroese, 2016). For this reason, stochastic simulations have been used extensively within the financial industry to model market trends and potential investments.

Alongside models for artificial behaviour throughout the business sector, stochastic simulations are particularly suited for simulating the behaviour of natural phenomena across all aspects of science and technology. The ability to model variables with an unknown magnitude can help provide insights into complex behaviours and has been used extensively when simulating chemical systems (Gibson & Bruck, 2000), particle physics (Ceperley & Alder, 1980) and ballistic simulations (Tahenti, Coghe, Nasri, & Pirlot, 2017).

Building on our example earlier in Figure 5, a stochastic representation of this simulated dice throw would include some inherent variance or randomised behaviour, which would influence the result of the roll. Whilst this is more representative of the real-world behaviour of a dice throw, it can be counterproductive if a serious game required a certain level of control for a developer.

3.3 Simulations within Serious Games

Serious games often comprise of multiple simulations running concurrently, building a network of algorithms that are both influenced by and interact with each other. This dynamic structure of information can make designing and understanding the underpinning forces of serious games a significant challenge. However, understanding the responsibility of each simulation and its influence on the surrounding environment helps developers compartmentalise each function into its own discrete package.

Many serious games contain some form of physics simulation, which could be modelling the physical movement of a character or interactions with environmental objects. Artificial intelligence simulations are also commonly included in serious games, controlling virtual avatars in order to replicate real-world behaviour. When these systems exist simultaneously within a virtual environment, they continuously interact with each other. The AI could be moving agents, opening doors, picking up objects and updating its behaviour based on the state and location of these interactable items. This continuous interconnectivity between simulations is inherent within a virtual environment. Simplifying these systems into discrete packages helps expose the variables that can be influenced, ensuring the simulation behaves as expected.

As an example, a core concept of any physics simulation is gravity, which influences almost every aspect of a virtual world from how fast objects fall to how high a user can jump. Gravity is often measured in meters per second m/s^2, with Earth's gravity being roughly $9.8m/s^2$. Simulating any virtual environment on earth should use these values to influence physics behaviours, as almost all users have an intimate understanding of the effects of gravity. However, if a scenario is taking place on the moon, simply changing the value of gravity to $1.62m/s^2$ would have a drastic effect on gameplay. Users who could previously kick a ball only 5 meters would now be able to kick it 30 meters or more, increasing the impact of certain forces by a factor of 6 (see Figure 6).

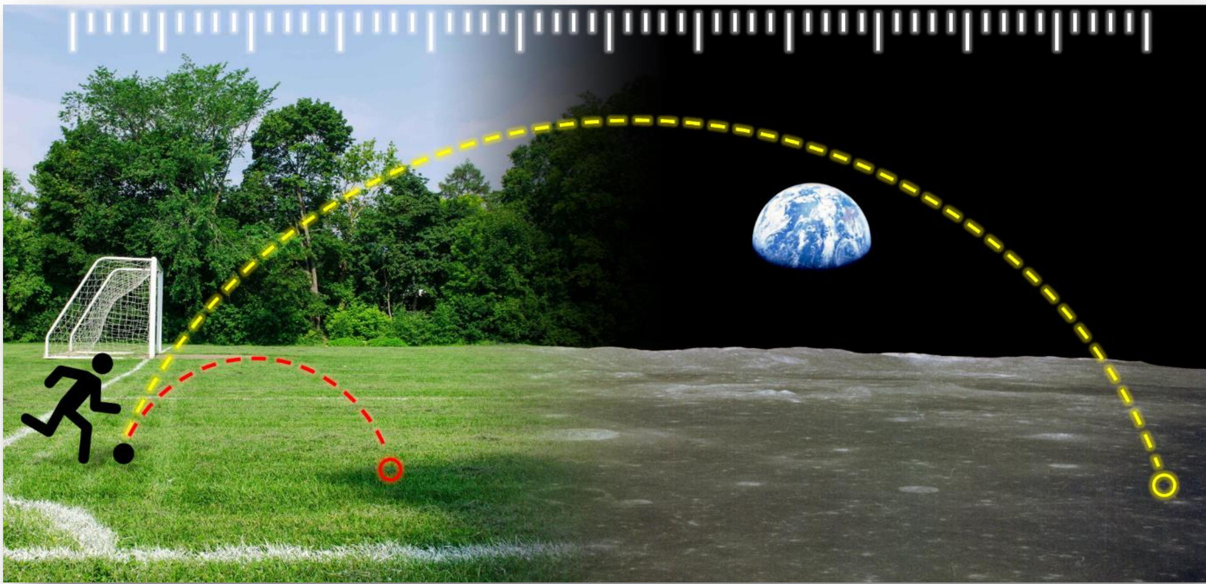

Figure 6: Simulating Gravity

Whilst Figure 6 gives a basic example of how changing a variable in a physics simulation can affect the wider environment, it only showcases a very basic deterministic model of simulation. Additional factors, which could influence the behaviour of a ball including air resistance and its weight, size, shape and material, and simulating these in an earth like or moon environment would show significant differences. A stochastic simulation model could better represent the impact of these additional features and expected behaviours, as no two kicks would ever be the same.

Physics simulations within serious games are almost always stochastic in nature, as this better represents the real world. However, this can be counterproductive as serious games need some form of predictability to meet educational requirements (Hunecker, 2009). Therefore, the educational requirements of a serious game have a significant impact upon the simulation methods utilised when realizing a virtual world.

When considering what form of simulated behaviour is required for a serious game, an understanding of the relative complexity of a system helps to define whether a capability is within the scope of a serious game. Some behaviour is standard and included in game development engines. However, others are more bespoke and can take months or even years to develop. As an example, physics, lighting, rendering and pathfinding are standard simulations which come pre-packaged. However, artificial intelligence and advanced physics behaviours require additional development and specialised expertise. This can result in a significant increase to the costs and development time of a serious game and should be evaluated to justify, which simulated features to include within a game.

Deciding what simulations are appropriate to meet the needs of a serious game is one of the fundamental challenges faced by developers and practitioners. Due to the complexity of some simulations and the availability of pre-existing implementations of others, there can be large discrepancies between the resource costs of two similar simulations. This can lead to misunderstandings between developers and practitioners and can result in unexpected delays and additional costs. These risks involved in utilising complex simulations mean it is extremely important to follow a clear and open development methodology, such as the one discussed in Chapter 7.

4 Conclusion

Gamification and simulation are two core components of any serious game. Without gamification methods, a serious game loses the unique capability to improve learning and motivation through intrinsic reinforcement, whereas simulations provide the underpinning behaviour required in order to realise a virtual world. Combined these components can build upon their strengths, interweaving the risk/reward models of gamification with the stochastic nature of simulations. This results in a platform, which remains engaging whilst educating users effectively and efficiently.

When designing and building a serious game, these are two of the most important factors in how effective it will be at training users. If the gamification methods and simulations are developed in line with the learning requirements of end users, they synergise to create an effective training platform (see Chapters 6 and 7). However, they must be reinforced by evidence about their effectiveness for a specific learning objective to ensure they help instead of hinder the learning process.

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