Using Gamification for Solving Resource Allocation and Serving in Employee Attendance Tracking System

Nina Zuccon, Matej Jurić, Marin Vuković, Renato Šoić
University of Zagreb
Faculty of Electrical Engineering and Computing
Unska 3, 10000 Zagreb, Croatia
{nina.zuccon, matej.juric, marin.vukovic, renato.soic}@fer.hr

***Abstract**. Serious games are becoming more and more popular means for solving real world problems. This paper proposes using gamification for solving resource allocation and serving problems in a real-world scenario. Two tower defense games are presented that are using employee attendance records for deducting the best strategies which could be employed in real system resource allocation and serving. Gameplay data of the players with the highest scores is analysed to derive the optimal strategies. The presented evaluation shows that both games results' can be used for optimising the real employee attendance system.*

Keywords. Gamification, serious games, resource allocation, serving

1 Introduction

Gamification and serious games are terms that are becoming more and more present nowadays. Gamification became a rather broad term over the years (Groh, 2012), but probably the most precise definition is "the use of game design elements in non-game contexts" (Deterding et al., 2011). While both terms often point to a situation where people or children learn better by playing such games, this paper focuses on an opposite idea. The idea of the paper is to encourage people - players - to use their abilities to solve real-world problems in an entertaining manner. After a sufficient number of players obtain good game scores, the gameplay data is analysed to derive the best strategies for finishing the game. The derived strategies can then be applied to real-world problems.

The problems we are trying to solve this way are resource allocation and serving in an employee attendance tracking system. Recently, we have developed and installed ultra-high frequency radio frequency identification (UHF RFID) portals on all entrances to Faculty of Electrical Engineering and Computing in Zagreb. All employees were given RFID tags with unique identifiers used for tracking. In total, there are seven portals that monitor employees' tags, corresponding to six entrances to the Faculty. The difference in number of portals and entrances is due to the fact that the main entrance to the Faculty consists of two doors, each covered by a single portal.

Immediately after the system was installed, we noticed variations in resource utilization on different entrances, since employees tend to use some entrances more frequently depending on the time of the day. Furthermore, once the RFID tags are read, the software service needs to filter the collected readings and decide whether they should be written in the database. This software service also showed significant load variations depending on the entrance and, as expected, on the time of the day. In this sense, RFID readers, antennas, filtering service, database, as well as the network elements used for transmitting the read identifiers, are referred to as resources in the system.

Without any optimization, all the elements are constantly active and waiting for a person with a RFID tag to walk through the portal to perform reading, filtering and storing process. The goal of the presented efforts was to use the readings of the system and try to create games that would allow us to solve issues regarding UHF readers and software service load. In this way, we could have a better insight into what resources should truly be active at all times, and which resources could be in suspended state for periods of time.

Therefore, we developed two games based on tower defense genre. The first game is related to resource allocation where players need to allocate limited resources in real time, mimicking our problem of covering all entrances to the Faculty depending on the employees going in or out of the building. The second game is trying to give us a better insight into software service load and the strategy for serving all the UHF readers in terms of filtering and storing the readings. Additionally, improving both resource allocation and serving could allow us to introduce more advanced, possibly personalized services which could be offered to employees.

The rest of the paper is organised as follows. Next section discusses related work and shows several examples of similar serious games. Third section presents the developed tower defense games and underlying logic regarding mapping real time onto game time. Finally, section four discusses results and the final section gives conclusion and possible guidelines for further work.

2 Related Work

Today, the idea of using real data in a virtual world is becoming more and more widespread. One of the best ways to motivate a person is turning a task into competition. That is exactly what scientific computer games make possible. By having fun, the players are also motivated to solve a complex problem.

Luis von Ahn was the first to come up with the idea of games with a purpose (Von Ahn, 2006) which would use people to help computers with problems they can't solve by themselves. He believes that the human intellect is an important resource in advancing computer processing. GWAP is described as a division of labour between humans and computers and it is used in many computer games nowadays.

The game ESP (Schofield, 2006), in which the user connects pictures with its keywords, could connect all Google's pictures with their keywords in just a few months with the assumption a large number of people play it. This feature could be used for upgrading image search algorithms and filtering of inappropriate content (Wightman, 2010). Another example of a similar game is PeekaBoom (von Ahn et al., 2006) which helps computers locate objects in images using meta-data collected while users play the game.

Some interesting examples of serious games are used in area of medical research. A game of such kind is EteRNA in which users try to design RNA using nucleotides. The wide spectre of users' solutions is then being analysed with the purpose of upgrading computer models of RNA (Bohannon, 2014). Phylo works in a similar way, giving its users the possibility of decoding genetic diseases (Kawrykow et al., 2012). One of the most known games with a purpose is Wikidata Game, a game which asks questions about various people, pictures, etc., and users provide answers. This way, it edits data in Wikidata, a structured repository of information that is the base of Wikipedia.

Sea Hero Quest should also be mentioned in this context. This is a game that collects valuable information related to symptoms of dementia using humans' spatial navigation (Aškić et al., 2016). Using classic research methods, it would usually take five hours to collect the required amount of data, while the game can provide it in only 2 minutes. Advanced solutions require complex decision-making support on real and continuously changing data, so this is still a developing research area.

Other than computer games used in scientific research, the most popular ones are those whose aim is purely to entertain the users. Games which simulate real places are gaining popularity rapidly. They use Google Maps API that provides users with a rich experience. In just one day, users can virtually visit countless different places. Google Maps API is used in tower defense games with real maps, games for parking practice, popular cities recognition and many other examples (Buczkowski, 2015).

Games with a purpose have a wide range of use, from network security, computer vision, content filtering and Internet search, to learning new languages, medical research, art and genetics. An interesting perspective to serious games was introduced by employing a collaborative approach, where the game provides valuable insight into collaborative problem-solving, but also provides a way of evaluating the quality of the selected team (Wendel et al., 2012).

The presented research in the field shows that gamification can indeed be used for solving real-world problems, such as the problem presented in this paper. Furthermore, insight into existing serious games showed us that it is necessary to plan the game based on the profile of the future players. Since our main target are younger people with experience in arcade-type games, it was decided to implement two arcade type games that would challenge the players' speed and the ability to make good decisions fast.

3 Implemented Games

For the purpose of solving resource allocation and serving problems, two games were developed: FERpocalypse and FERDefense. Both games have the same goal: defend the building from monsters, and the player who survives the longest is the overall winner. Currently, only the total time survived is the score for both games, and the list of top 10 players is presented within each game to encourage competitiveness.

FERpocalypse is used for solving the serving problem, where the player needs to shoot at enemies coming from each entrance to the building, shooting being done from a central location. FERDefense is used for resource allocation, where players have limited resources in terms of two slow-shooting and one fast-shooting turrets that need to be placed on entrances dynamically with regard to incoming enemies.

3.1 Serving game - FERpocalypse

FERpocalypse is a computer game based on real-world data – records of people entering the Faculty of Electrical Engineering and Computing in Zagreb. The user can pick a date from a given data set to simulate events in the game.

Based on the employee tracking records at the Faculty on the chosen day, the game generates monsters so their appearances in the game match the real data. The time of one level (corresponding to one day of real-world data) is scaled to four minutes. The scaling was done on experimental basis, in order to achieve playability of the game. For example, periods without tag readings (e.g., night, weekends) were removed, while intervals with many readings were scaled in a way that they do not overrun the player, but still make it difficult to defend the "tower" if serving is done poorly. An example of the game screen is shown in Fig. 1.

Figure 1 - Example screen of FERpocalypse game

The monsters are spawned on six entrances, which correspond to the seven portals, as explained earlier. After entering the building, monsters start moving towards the central tower trying to destroy it. The user attacks those monsters from the central tower with the goal of protecting the Faculty. Attacking is done by clicking in the specific direction, thus launching a projectile from the tower. When the monster is hit by a projectile, it is neutralized, and it disappears.

The user has 15 lives, each one being lost if the monster reaches the central shooting tower. Number of lives was also determined experimentally; some larger spawns of monsters that correspond to real-world larger events on the Faculty would otherwise be impossible to defend with the given dataset.

By moving reality into a virtual game, the challenge of serving clients in complex systems is implemented in a fun game. In this sense, every cannon that shoots at monsters in the game is a real-world RFID portal that needs to successfully read all the incoming employees. While the user is making his moves, they are being written in a file. Every move is defined by the entrance number near which the monster was shot. By analysing the results from players who achieved the highest scores, we are able to establish a pattern that works best in most cases and use it in real-life serving of clients at the Faculty.

3.2 Resource allocation game - FERDefense

FERDefense, a type of tower defense games, is a game that aims to analyse entrances to the Faculty. The point of the game is to defend the faculty from the employees, which are represented as enemies. The player defends the building by placing three turrets on five different faculty entrances, that correspond to RFID portals. The goal of the game is to defend the building as long as possible, by carefully placing the turrets that shoot the incoming monsters, depending on the intensity of incoming monsters that changes over time and entrances. An example game screen is shown in Fig. 2.

Figure 2 - Example screen of FERDefense game

Even though the Faculty has seven entrances, it was decided to ignore two of them because a very small amount of people entered through them. This was not ignored in the previous game, as shown in Figure 1, due to different nature of the gameplay. If the two least used entrances remained in this game as well, we would need to offer the players more turrets which would, in turn, result to much easier covering of all the entrances. The data used in the game had over 96.000 readings of which over 65.000 were recorded on the main entrance. Furthermore, over 16.000 readings were recorded on the second most popular entrance, while around 8000 tag readings were related to the last two entrances. That means that approximately 1000 readings were recorded on the two entrances which were ignored, which is 1.07% of total readings data.

During development and initial evaluation, it was decided that gameplay is most appealing when there are three turrets available, making the game difficult, but not impossible to finish. Of those three turrets, two are regular and the third one is a fast turret. The difference between regular and fast turrets is that the fast turret fires twice as fast as the regular turret. To compensate the fire speed, fast turret has slightly smaller range of 14 units, while the regular turret on the other hand has a range of 21.5 units. The reason two regular and a fast turret were chosen was because other combinations were tested, and the game was either too monotone or it was impossible to finish the game.

The player has 5 lives which are lost each time an enemy manages to reach the walls of the faculty. The number of available lives was also determined experimentally, to make the game difficult, but not impossible to pass.

The current game used for evaluation has 5 levels in total, each level corresponding to a single week. Each level has 5 waves of enemies which represent 5 work days of the week. The reason the weekends are not included is because the number of employees drastically declines over the weekend, the same as for FERpocalypse game.

4 Evaluation and Results

Both games were evaluated during development in order to achieve best playability, mainly related to time scaling and number of lives needed in order to pass the game. After development, both games were given to a set of different students that tried to finish all levels within each game. The results of their gameplay and some conclusions are presented for each game in the following text.

The dataset used for evaluation consisted of RFID readings during five weeks, from the end of December 31st 2018 to February 1st 2019. The reason this period was chosen is because the readings differed the most during it.

On average, there were between 2000 and 4000 daily readings during workdays, while the highest number of readings went slightly over 6000. In comparison, readings over the weekend ranged mostly from 200 to 400.

4.1 Serving game results

In the serving game the player's strategy is tracked with his every move being written into a file. When a player starts the level, the information about which day is being simulated is written into that file. As he continues playing the game and as he shoots a monster, the game tracks which gate was the eliminated monster from and in which second of the game it was shot. When the game is over, that is properly written into the file so one cycle of playing can be easily extracted from the others.

To test the game, three players were asked to play on the same level in order to compare their moves. What was interesting to notice is that even at the very beginning, specifically on the 8th move, their results started to differ. Moreover, as the level continued at a more dynamic pace, more and more differences could be seen between the players' strategies. The first fifteen moves from each of the three players with the highlighted differences are shown in Fig. 3.

During each level the player would mostly orient its shooting towards the main entrance, as expected. The reason for that is that most people would always go through the mentioned entrance, while the remaining five were similarly frequented, but always less than the main one. As a result, while playing, the player mostly shoots monsters from the main entrance, while for the remaining ones he has to think more carefully about his strategy. The reason for that is that two of the entrances are positioned closer to the central tower from which the user defends the building, meanwhile the other three are positioned further away. The motivation for that was the attempt to make the game map resembling to the real map. The different distances between the entrances and the central tower turned out to be an advantage, given that the closer entrances always had less monsters coming into the game, and the further entrances had more monsters, resulting with the player having to consider whether he was first going to attack the monsters closer to him or the ones further but with a higher amount of arrivals.

Started game at level 2019-02-12	Started game at level 2019-02-12	Started game at level 2019-02-12
Killed monster from gate 3 at 5.58	Killed monster from gate 3 at 7.86	Killed monster from gate 3 at 8.24
Killed monster from gate 6 at 7.24	Killed monster from gate 6 at 11.78	Killed monster from gate 6 at 10.24
Killed monster from gate 3 at 9.059	Killed monster from gate 3 at 12.4	Killed monster from gate 3 at 14.04
Killed monster from gate 6 at 10.56	Killed monster from gate 6 at 14.24	Killed monster from gate 6 at 15.82
Killed monster from gate 5 at 30.38	Killed monster from gate 5 at 31.12	Killed monster from gate 5 at 30.82
Killed monster from gate 4 at 30.66	Killed monster from gate 4 at 31.28	Killed monster from gate 4 at 31.16
Killed monster from gate 1 at 32.56	Killed monster from gate 1 at 34	Killed monster from gate 1 at 32.72
Killed monster from gate 5 at 34.02	Killed monster from gate 4 at 36.06	Killed monster from gate 4 at 36.82
Killed monster from gate 4 at 34.44	Killed monster from gate 5 at 37.36	Killed monster from gate 5 at 38.26
Killed monster from gate 1 at 36.5	Killed monster from gate 1 at 38.66	Killed monster from gate 1 at 39.7
Killed monster from gate 5 at 37.78	Killed monster from gate 5 at 40.5	Killed monster from gate 5 at 42.98
Killed monster from gate 4 at 37.9	Killed monster from gate 4 at 41.1	Killed monster from gate 4 at 43.42
Killed monster from gate 1 at 39.94	Killed monster from gate 1 at 42.82	Killed monster from gate 2 at 44.62
Killed monster from gate 4 at 41.94	Killed monster from gate 2 at 44.3	Killed monster from gate 1 at 45.36
Killed monster from gate 5 at 43.1	Killed monster from gate 4 at 46.1	Killed monster from gate 5 at 49.22

Figure 3 – Snippet from the output file with results from three players

To define an optimal strategy, the idea is to compare results from the best players, meaning the ones which eliminated all the monsters on a level or the ones who had the highest elimination rate on the selected level. By extracting the most common moves we could define a strategy that eliminates all the monsters in every, or at least most cases. By studying the given results, we could conclude that the user should pay the most attention to the main entrance, followed by the one above it and then occasionally alter the shooting direction between the remaining four entrances.

4.2 Resource allocation game results

In line with expectations, the main Faculty entrance has to be defended at all times, while the two other turrets have to be distributed among the remaining three entrances. Given that all entrances except the main one have relatively similar numbers of recorded employees the turrets will have to be relocated among those entrances most often.

The strategy that proved to be the most successful was placing a fast turret on the main entrance (represented by two portals on the right, in Fig. 2) and two regular turrets on other entrances as needed. Since the main entrance always has the biggest number of enemies, the attack there lasts longer than others. Because of that, after other entrances are defended, it is necessary to put an extra turret on the main entrance, so the enemies don't overrun the fast turret.

This leads us to the conclusion that, for the given dataset, the optimal strategy is to place the resource with the highest capabilities on the main entrance at all times. Other resources do not have to be so powerful but need to be constantly balanced between other available entrances according to incoming employees.

In real world this has been partially solved by the use of motion sensors, where each portal has a sensor that indicates whether a person is near the portal. The antennas in the portals are powered only when a person is nearby, so processing resources are directed towards the active portals only. So far it has proven that 2 processing resources at a time are enough for covering all the readings of low-intensity entrances.

5 Conclusion and Future Work

The paper presents an approach for solving real-world resource allocation and serving problems by using gamification, resulting in two serious games for each problem. The presented games use records of employee attendance to try and derive the optimal strategies for covering all entrances to the Faculty.

The most valuable fact extracted from initial result evaluations is that the main entrance needs to be supported with additional resources in peak periods, i.e. when most of the employees are arriving at work. As expected, serving is most challenging in the corresponding periods, as well.

After finishing the current research, some questions remained open and will be a subject of future work. For instance, time adjustments should be modified, so that enemy generation resembles actual employee arrivals, with respect to every unique employee (i.e., no grouping of employees). This would enable more precise analysis of both resource utilization and serving requirements. Regarding the game playability and usability, the plan is to perform additional evaluation with more players, in order to get their results but also get their feedback about what should be altered in both games in order to make them more interesting, dynamic and more appealing to wider player audiences.

For purposes of introducing additional services for the employees, the serving game could be extended with different types of monsters and projectiles (ammo) which could represent different employee categories. Furthermore, some additional towers could be introduced, representing the distributed approach to the implemented employee tracking system. In this case, a game could provide valuable insight regarding comparison of distributed vs. centralized system architecture.

When trying to generalize and move from the current domain of time attendance tracking, it is obvious that the used dataset is very specific since most of the users are entering the building on single entrance. However, other entrances become more interesting when we observe them as a separate system, because of more or less balanced load on these entrances depending on the time of the day. This can be used to derive more general model and to determine what would be the optimal resource and serving allocation in more balanced systems.

The ultimate goal of the proposed work is to try and derive more generalised models for resource allocation and client serving. In this sense, it will be necessary to try and experiment with different datasets. The work proposed in this paper can give us insight into optimal strategies for the observed case of time attendance. However, in order to solve other problems from different domains that are either well balanced over nodes (i.e. other entrances without the main entrance in our current case) or highly focused on single or a group of nodes (i.e. complete system with all entrances), we will try to run the games on various datasets from different domains. From the current state of the research, it is our opinion that the most difficult problems to solve will be the domains where there are occasional high loads on single or a group of nodes in limited periods of time. When looking at the real world, the first thing that comes to mind is traffic and different movement regularities in the morning and in the afternoon. So, in the future work our plan is to focus on such specific domains with the same approach and try to derive a general model for each domain or a set of similar domains.

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