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Gold Digger: a metaphor for searching behavior

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Abstract

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Chapter 1

Introduction

1.1 Overview

1.1.1 Problem statement

This project proposes to analyse user's searching behaviour in a context deprived of any cues that could allow them to exploit any previous experience in the task in order to achieve an optimal information foraging behaviour. User's performance will be recorded and evaluated to see if it matches data in experiments in which this context is present. Findings could help provide insight on people's choices when faced with a task that requires the same kind of skills that are required in information foraging with none of the context that they are presented with in experiments based on the same theories. Finally this project aims at making user's experience as enjoyable as possible for two reasons. Firstly it will avoid users feeling like they are performing work, removing them further from a standard information foraging task. Secondly, in order to enhance the number of users that play the game as well as the amount of games played.

1.1.2 The metaphore

Chapter 2

Survey

2.1 Background theories

2.1.1 Optimal Foraging Theory

One of the most interesting studies proposed by Sinevro which can help us bring out some interesting points on searching behaviours, is the one on crows foraging on clams. In this study, Sinevro tells us about the foraging behaviour of the common crow (Corvus caurinus) in the intertidal. This kind of crow, has developed a technique to open clams which requires it to take a short flight and drop clams on some rocks below it to crack them open. The cost (in energy) of searching for clams, and the one of handling them is almost the same, however, the cost (in time) of performing the same activities is 4 times more expensive with regards to searching. It is then difficult to understand why crows would reject a large amounts of the clams they find, especially given the fact that searching seems to take up so much time. The reason for this behaviour is to be found in the "average net profitability of the clams as a function of sizeâ(Sinevro 2006), which can be represented by the equation:

$$\frac{\textit{Energy}}{\textit{Time}} = \frac{\textit{Energy per clam as a function of size - (Search Cost + Handling Cost)}}{\textit{(Search Time + Handling Time)}}$$

It is very interesting to notice that predictions on the crow's behaviour in order to maximise energy gain per unit of time according to this formula, closely match its observed behaviour.

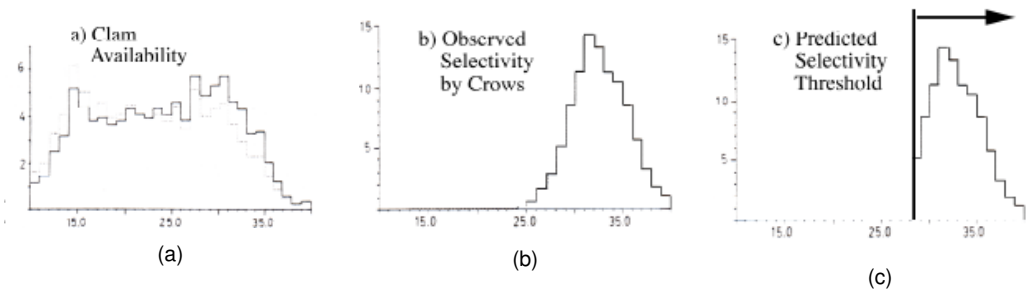


Figure 2.1: frequency of clams in class size (% on y axis) by clam length (x axis)

As we can see from (b) and (c) in fig 2.1, predicted behaviour seems to closely match observed behaviour. This kind of model, however, considers the disposition of prey in the environment to be random but, sometimes, prey items seem to have a patchy distribution (Sinevro 2006). In this case, an animal will have to travel between patches before it can start exploiting a new one. This creates two variables according to which an animal has to "make its decision" in order to maximise its rate of gain. The first one is the time spent within a patch to feed, and the second one is the time spent travelling between patches in which, crucially, the animal doesn't gain any energy and instead consumes it. A formula that effectively models this choice is:

$$\textit{Rate of energy gain} = \frac{\textit{Energy}}{\textit{Time}} = \frac{\textit{Energy or Load Size}}{\textit{(Travel time to patch + Foraging time to patch}}$$

Also known as "**Charnov's Marginal Value Theorem**" which generates an energy gain function like the one on the left. Here, we can see how there are two main areas delimiting the Cartesian space, the first one (on the left side of the curve) is the potential time the animal has to spend in between patches, whereas the second one is the potential time spent feeding in a single patch. An optimal allocation of time in foraging for this rate of gain will be represented by the tangent to the curve as shown in the graphs on the right. The red line is the tangent and the point of intersection with the curve determines the in-patch time that would be optimal for an animal to spend feeding.

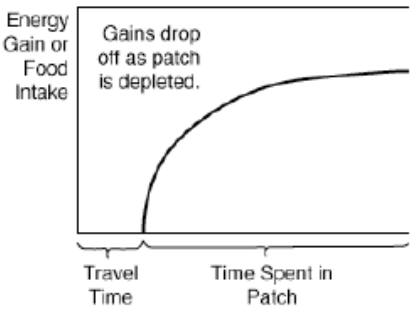


Figure 2.3: An energy gain function

The aim of this proposal is evaluate subjects' innate ability to reproduce similar behaviours while foraging for information rather than for food. To do this, the context of a gold digging strategy game has been chosen, in order to remove all proximal cues that might depend on the user's previous experience. In this environment, the user will have to perform the same kind of cost vs. benefit choices, however, he would not be able to adopt the strategies he consciously would. Following I discuss a paper by Pirolli & Card on Information Foraging which seems to support this intuition proposing experimental evidence and mathematical models. "

2.1.2 Information Foraging Theory

Pirolli & Card seem to start from the assumption that there are many similarities between the techniques adopted by animals foraging in the wild and the ones adopted by people in "Information Foraging". Because of the structure of today's society, in fact, it is not for food that we forage for. Food is usually readily available almost anywhere human settlements can be found, however, to purchase it, we need to engage in a "complex tributary of cultural tasks that engage our physical and social environments" (Pirolli & Card 1995) which demand us to develop numerous "information-based" strategies, in order to earn a living. Pirolli & Card begin by explaining that our adaptive success seems to be increasingly dependent on our mastery of techniques of information-gathering, sense-making, decision-making and problem-solving strategies. In turn,

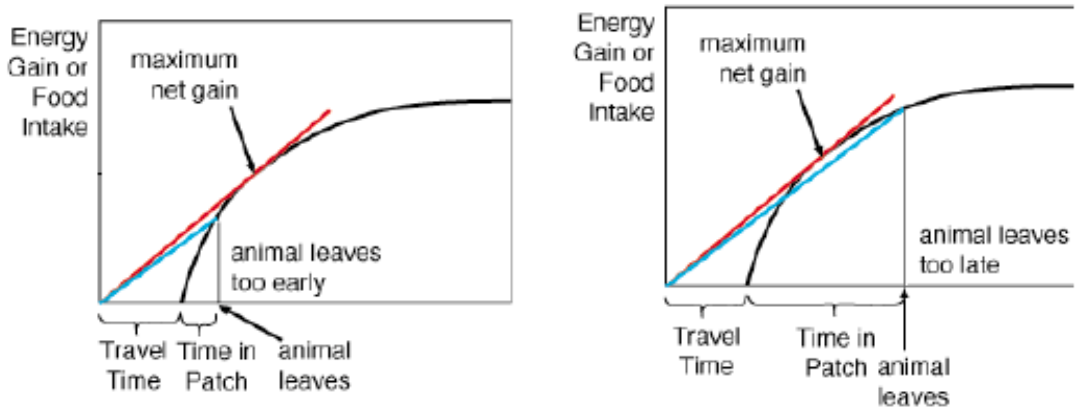


Figure 2.4: The optimal rate of gain

they claim, this leads us to implement strategies which are similar to the ones seen in foraging behaviours of animals in the wild. Here, we can observe patterns in food foraging behaviours which aim at maximising the energy intake while minimising the amount of energy spent while foraging.

In other words, our lives are increasingly dependent on the ways in which we organise and retrieve information in order to use it effectively to navigate and survive today's social (and sometimes physical) landscape. Pirolli & Card go on to claim that, the Information Foraging theory's main tenant is that: "when feasible, natural information systems evolve towards stable states that maximise gains of valuable information per unit cost. Cognitive systems engaged in information foraging will exhibit such adaptive tendencies" (Pirolli & Card 1995).

As a consequence, it is to be expected that people will modify their information foraging strategies as well as the structure of the environment itself, whenever possible, to "maximise the rate of gaining valuable information" (Pirolli & Card 1995). Better strategies will be the ones that will allow someone who adopts them to yield more information per unit cost. Furthermore, it is also expected that these strategies will evolve through time, in order to reach a seemingly stable state that maximises the potential gains.

The process of analysing the development of this kind of behaviour, is called "adaptation analysis". This kind of analysis is conducted here, as well as in biology, through the use of "optimisation models" to study the design features of organisms and artefacts. Optimisation models include three major components:

- *Decision assumption*, determine how much time is to be spend analysing a certain collection of information as well as which kind of content is worthwhile pursuing.
- *Currency assumptions*, determine how the choices made through decision assumptions are to be evaluated. In the context of Information Foraging, the relevant currency will be amount of relevant documents found, as opposed to the amount of energy gained in food foraging strategies.
- *Constraint assumptions*, determine what kind of limits will apply to the relationship between decision and currency assumptions. In Information Foraging, these include (but are not limited to) previous knowledge, available technology and task structure.

These models allow us to construct a framework for the evaluation in Information Foraging, however, it is not to be expected that any single individual will fully be conscious and even

evolve towards, an optimal awareness and implementation of these models. These models simply outline the possibility of "an advantageous adaptation if not blocked by other forces.

The main decision an organism has to make in its foraging endeavours (being it for food or for information) is determined by a problem of "Enrichment vs. Exploitationâ of a certain "patch of relevant documents (or food). The careful weighing of one against the other, will, in turn, determine its searching behaviour, comprehensive of "in-patchâ and "between-patch behaviours. When we decide to "enrichâ a certain patch of information, we engage in certain "enrichment strategiesâ which are meant to maximise the amount of relevant information per unit of cost that we are able to get from a patch. However, the adoption of these strategies themselves has a cost which should be considered when making the decision to move to a different patch and select a new set of documents. There are two main "in-patchâ enrichment strategies.

The first one is based on producing information packages that yield better results. This involves strategies like developing or acquiring better search tools, as well as spending time mastering them. The second one is based on filtering the incoming information into relevant topics or according to other decisional criteria devised by the foragers and that they came to realise as useful to their foraging needs.

Another way foragers can increase their gain in yielded by their foraging behaviours is by using "between-patchâ enrichment strategies. These are also of two kinds. The first one is constituted by what Pirolli & Card call "scent-detection strategiesâ. These strategies are based on the identification of proximal cues in the environment in order to make a choice on whether it would be fruitful to explore a certain "patchâ or move to another one based on detection of proximal cues. In the context studied by Pirolli & Card, this translates into identifying the relevance of a certain document, or group of documents by, for instance, its title and payoff, perceived clarity of writing or length.

A second kind of in-patch enrichment strategy is based on reducing the cost of getting from one information patch to another. While this is usually impossible for animals in the wild, because it involves modifying the environment, it is instead a very efficient way for information foragers to improve the rate of gain per unit cost. In the example proposed by Pirolli & Card this is shown in the re-organisation of the workspace of an employee whose job is to write a Business Intelligence Newsletter. The subject of their experiment, in fact, organised the different areas of his office, in order to minimise the time spent searching for relevant document by disposing the material he knew he would need more frequently, the nearest to his working station.

For the purpose of this proposal it is also important to consider the conventional models of foraging on which Information Foraging Theory is based. As it can be expected, to provide an efficient model of foraging, we will have to take into account equations which model both in-patch and within-patch behaviours. Given what previously stated, Pirolli & Card start by characterising the rate of gain of valuable information per unit cost R as the ratio of the total net amount of valuable information gained G divided by the total amount of time spent between patches T_B and exploiting within patches T_W a

$$R = \frac{G}{T_B + T_W} \tag{2.1}$$

Notably, this equation assumes that (1) "the total amount of information gained can be represented as a linear function of between-patch foraging time:

$$G = \lambda T_B g \tag{2.2}$$

And that (2) âĂIJthe total amount of within-patch time can be represented as:

$$T_W = \lambda T_B t_W \tag{2.3}$$

This, in turn, gives Holling's Disc Equation:

$$\begin{aligned} R &= \frac{\lambda T_B g}{T_B + \lambda T_B t_W} \\ &= \frac{\lambda g}{1 + \lambda t_w} \end{aligned} \tag{2.4}$$

This formulation, however, "addresses the problem of allocation of time between in-patch vs. between patch under certain strong assumptions". Because of this, Pirolli & Card have to devise their own interpretation which takes in to account that "(a) there might be different kinds of patches and (b) the total gains from a patch depend on the within-patch foraging time which is under the control of the forager. For this reason they have to include a value *i* representing the type of patches encountered at a rate of λ i and a value $t_w i$ representing the *policy* adopted by a forager on how much time to spend within each patch. The total gain can then be represented as the sum of all the values of *i* between 1 and P.

$$\begin{aligned} G &= \sum_{i=1} \lambda_i T_B g_i(t_{wi}) \\ &= T_B \sum_{i=1} \lambda_i g_i(t_{wi}) \end{aligned} \tag{2.5}$$

In the same way, the total amount of time spent within patches could be represented as:

$$\begin{aligned} T_W &= \sum_{i=1} \lambda_i T_B t_{wi} \\ &= T_B \sum_{i=1} \lambda_i (t_{wi}) \end{aligned} \tag{2.6}$$

Combining these two equations according to (eq. 2.1) gives us:

$$\begin{aligned} R &= \frac{T_B \sum_{i=1} \lambda_i g_i(t_{wi})}{T_B + T_B \sum_{i=1} \lambda_i t_{wi}} \\ &= \frac{\sum_{i=1} \lambda_i g_i(t_{wi})}{1 + \sum_{i=1} \lambda_i t_{wi}} \end{aligned} \tag{2.7}$$

This last equation is what Pirolli & Card call the "patch model for information foraging" which takes into account patches that yield different kinds of gain functions as well as different strategies to exploit them.

Figures (a), (b) and (c) are the graphical representation of the functions presented in the previous section according to Charnov's Marginal Value Theorem, they model the problem of allocation of time between in-patch vs. between-patch strategies. Here, between-patch search times t_B , t_{B1} and t_{B2} generate different tangents to the $g(t_w)$ gain function which, in turn, determines the optimal rate of gain R. The outside of the curve on the x axis represents between-patch

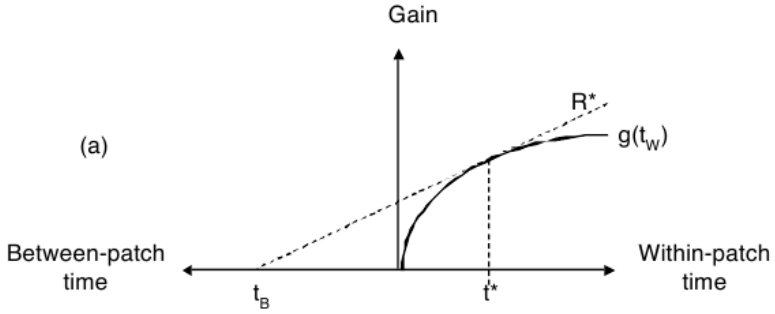


Figure 2.6: (a) - The Graph illustrates Charnov's Marginal Value Theorem where t* denotes the optimal amount of time spent within-patch given the intersection between the gain function $g(t_w)$and the tangent passing from t_B (the time spent between patches)

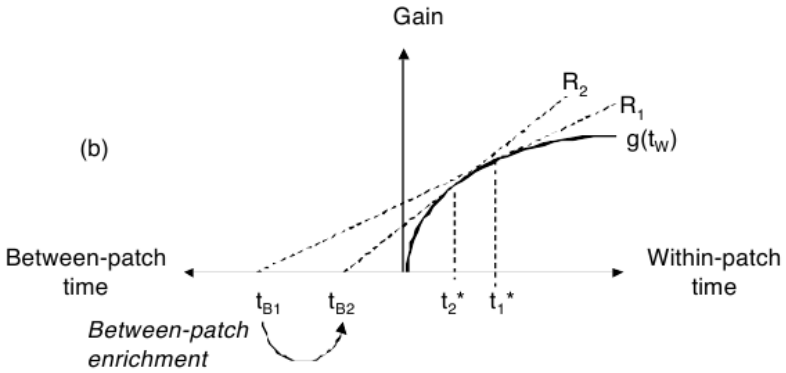


Figure 2.7: (b) - Shows the changes generated by the adoption of between-patch enrichment strategies. The tangent to the gain function $g(t_w)$ passing from t_{B2} determines that the optimal amount of time to spend in a given patch is now t_{2*} . The forager is now able to afford to spend less time in each patch.

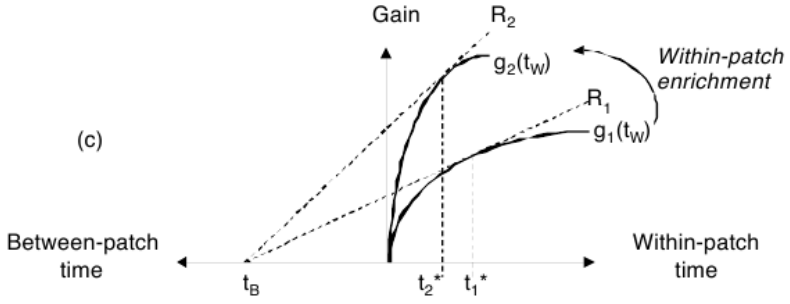


Figure 2.8: (c) - Shows the changes generated by the adoption of within-patch enrichment strategies. The new gain function $g_2(t_w)$ has a higher rate gain which allows foragers that spend the same amount of time between patches t_B will be able to reap more results in a shorter time.

time while, the inside of it, represent within-patch time. To determine the optimal rate of gain $R*$ one draws the tangent line to the gain function $g(t_w)$ and passing through t_B . The point of tangency will determine the "optimal allocation of within-patch foraging time $t*$".

This means that, the more time is spent between-patch, the less a forager will find it beneficial to spend time exploiting a given patch, always depending on the gain function g(tw). In Figure 2, in

fact, we see the effects of a between-patch enrichment like the one described previously (office re-disposition) which sets the optimal rate of gain in such a way that it will be more beneficial for the forager to spend more time within-patch to exploit it. Finally, in Figure 3 we can see the effect of within-patch enrichment (for instance, making information packages that yield better results). As we can see, within-patch enrichment, changes the gain function g(tw) determining higher gains per unit of time spent within-patch.

The objective of the experiment outlined in this proposal, is to be able to evaluate the strategies adopted by subjects in order to reach an optimal rate of gain and to analyse how they are able to choose between within/between-patch enrichment strategies to better their rate of gain per unit cost.

2.2 Previous studies

2.2.1 Searching behaviour

2.2.2 Gamification

Chapter 3

Design

The design of Gold Digger went through different iterations through the course of its development (see 4.2 Heuristic Evaluation), however some design choices were made in order to keep the user experience consistent throughout the website and enhance clarity and ease of use.

Separation between "game pages" and "site pages"

Because Gold Digger is both a website and a game, it seemed appropriate to somehow separate the "game environment" from the more "site-like" features and pages, while still maintaining a certain degree of coherence between them. "Game pages" are the ones immediately relevant to the game in itself, the ones that the user will most likely enter while playing Gold Digger. These are: **the Game/Mine page, the General Shop page, the Home Page** and **the World Map Page**. The other pages are said to be "site pages" and they include pages like the About page and the Leaderboards, which a user is not very likely to access while in the middle of a play through. Furthermore "game pages" all require the user to be logged in to be accessed while the "site pages" do not.
Notwithstanding this distinction, the user experience is not disjointed thanks to prominent recurring elements such as the nav bar on the top of the page and the landscape headline showing the name of each page.

3.1 Site Map

Navigation through the website is aided by a navbar located at the top of every page (with the exception of the 'game over' and 'end of the day' pages).

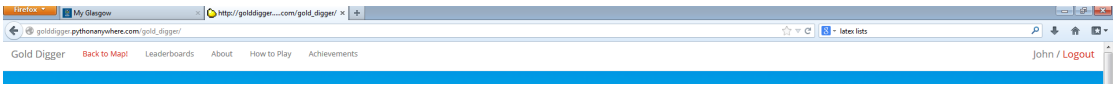


Figure 3.1: Gold Digger nav bar

From the navbar the user will be able to reach the following pages:

- The main page (by clicking on 'Gold Digger')
- The World Map page (if signed in)

- The Leadeboards
- The About page
- The 'How to Play' / Tutorial page
- The 'Achievements' page
- The User Profile page (if signed in)

finally, the user will also be able to logout at any moment by using the 'Logout' button on the top right. However, if the user is currently in one of the mines, clicking on one of these links will result on a warning message being displayed that will alert users that the gold gathered during the day will be lost if they leave the mine before exhausting the time at their disposal and reaching the end of the day.

3.1.1 Home, Registreation and Login

Figure 3.2: Home Page

On the landing page (homepage) users will be presented with a short **five-point explanation** of the game to quickly explain the mechancs of the game so that users could start playing as soon as poosible. To so this, they will have to login through the form on the left or register by clicking on the 'Register' button.

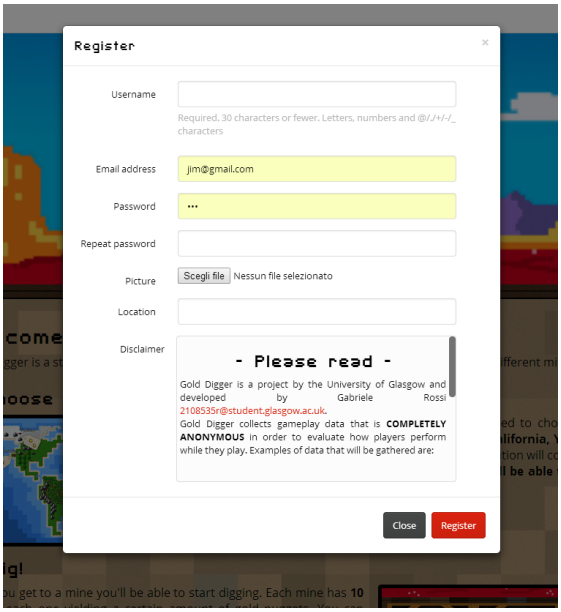


Figure 3.3: Registration modal

Clicking on the **'Register'** button will trigger a modal asking users to create a new username and password, as well as optionally entering their location and user picture. Finally, the modal displays a disclaimer in order to both make sure that the users are aware of the limitations of accessing the website and its purpose. Users who wish to have more information about Gold Digger are redirected to the 'About' page or offered a link to directly write an email to the developer.
Finally if a user enters wrong details or forgets to fill in a required field, (both for registration and login) an appropriate error message is clearly displayed for the user to see and try again. At present there is no limit to the number of attempts a user can make at logging in or registering.

3.1.2 World Map

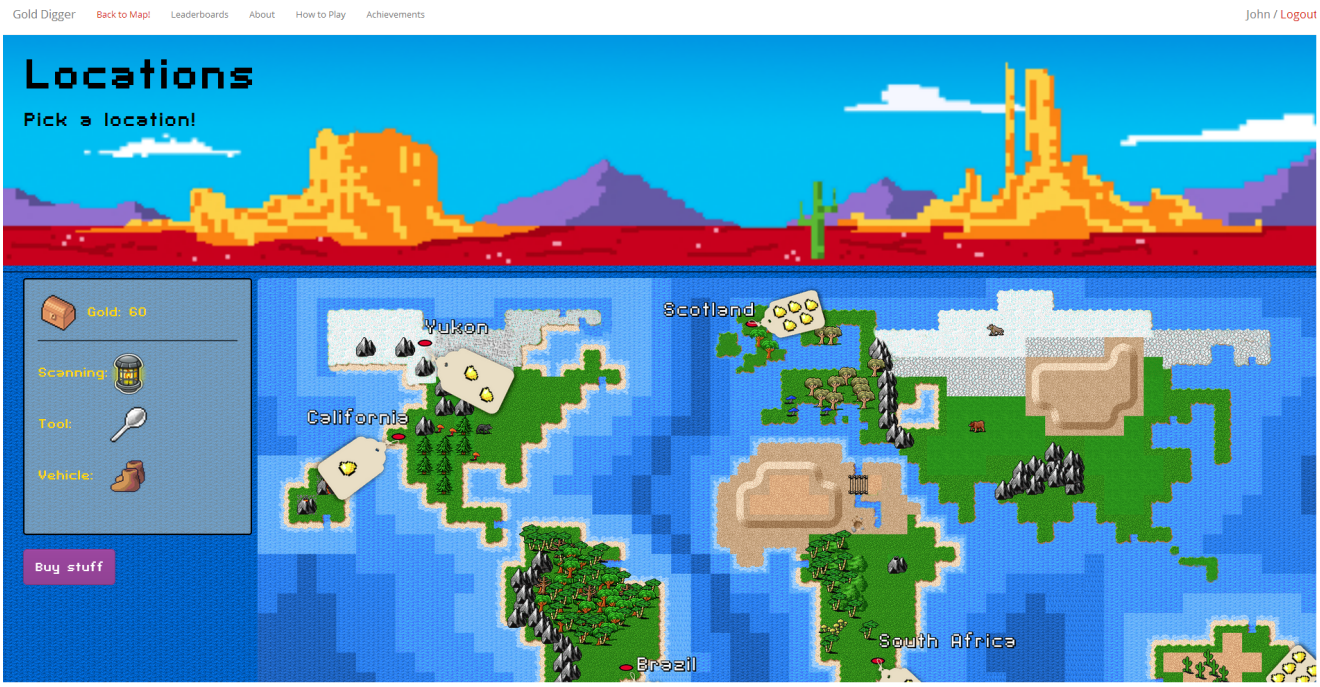
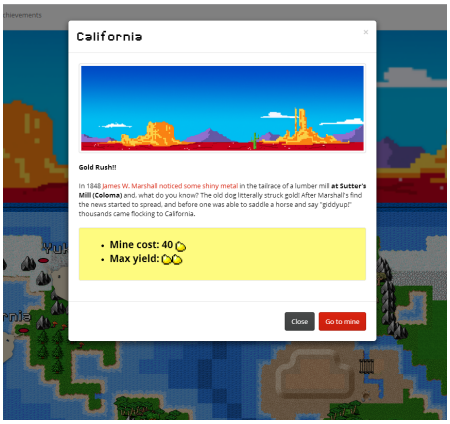


Figure 3.4: World Map

Once users have registerd or have been logged in, they are automatically redirected to the world map so that they can start playing immediately. On the left of the page, users can see the euqipment and the amount of gold they have at the moment. The side item panel appears on the left column of the page, once the user has logged in. The panel shows the items that users have equipped, together with the total amount of gold in their possession. By hovering

over each one of the items a tooltip will appear, showing the essential stats of each item. The presence of the side item panel has the function of both confirming the users that they are logged in and reminding them that their game session has started contributing to the uniformity of the user experience.



On the right hand side of the page users can access any of six locations: **California, Yukon, Brazil, South Africa, Scotland** and **Victoria**. Clicking on any of the locations will trigger a modal that displaying the scenery of the particular mine, some information about the gold digging history in that region (with links to Wikipedia articles), the cost of the mine and the amount of gold the user can expect to find. Starting from California and ending with Victoria, each mine is more expensive than the previous one but it also have a potentially higher gold yield. It is up to the player to enter the right mine at the right time.

Figure 3.5: California modal

3.1.3 Game Screen

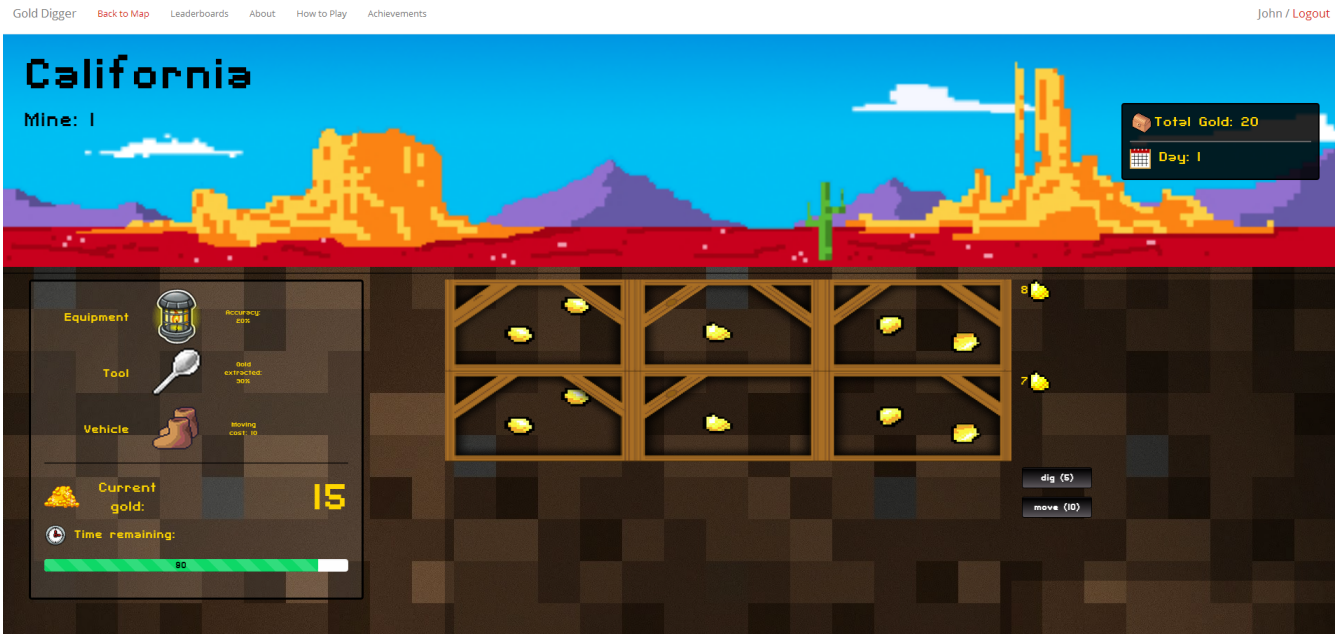


Figure 3.6: Mine

Once the users enter a mine, the appropriate amount of gold is removed from the total and they can start digging. Each mine presents a similar structure, except for the landscape and the amount of gold that can be found in each layer. On the top of the page we can see the landscape picture and the name of the location, as well as the number of mines that the user has dug into during the present day. As previously noted, on the left, we can find the equipment panel, in the middle we have the mine shaft and on the right have the **'Dig'** and **'Move'** as well as the yield of each layer that has been already dug. The left side panel contains here some more information than it does in the other pages where it appears:

- **Current gold**: the amount of gold gathered during the present day.

- **Time remaining**: the amount of time (in units of time) remaining before the end of the day.

Furthermore, because the left side panel's position is fixed, it will follow users as they get deeper and deeper in the mine, allowing them to always keep an eye on the game state without having to go back to the top of the page to check how many units of time they have left before the end of the day. Because the 'Current gold' is summed to the 'Total Gold' only at the end of the day, the total amount of gold, together with the number of days users have been digging without encountering a game over, is displayed in a small box on the top right of the page. The options available to the user and an example of gameplay are detailed in section 3.2.

3.1.4 General Store

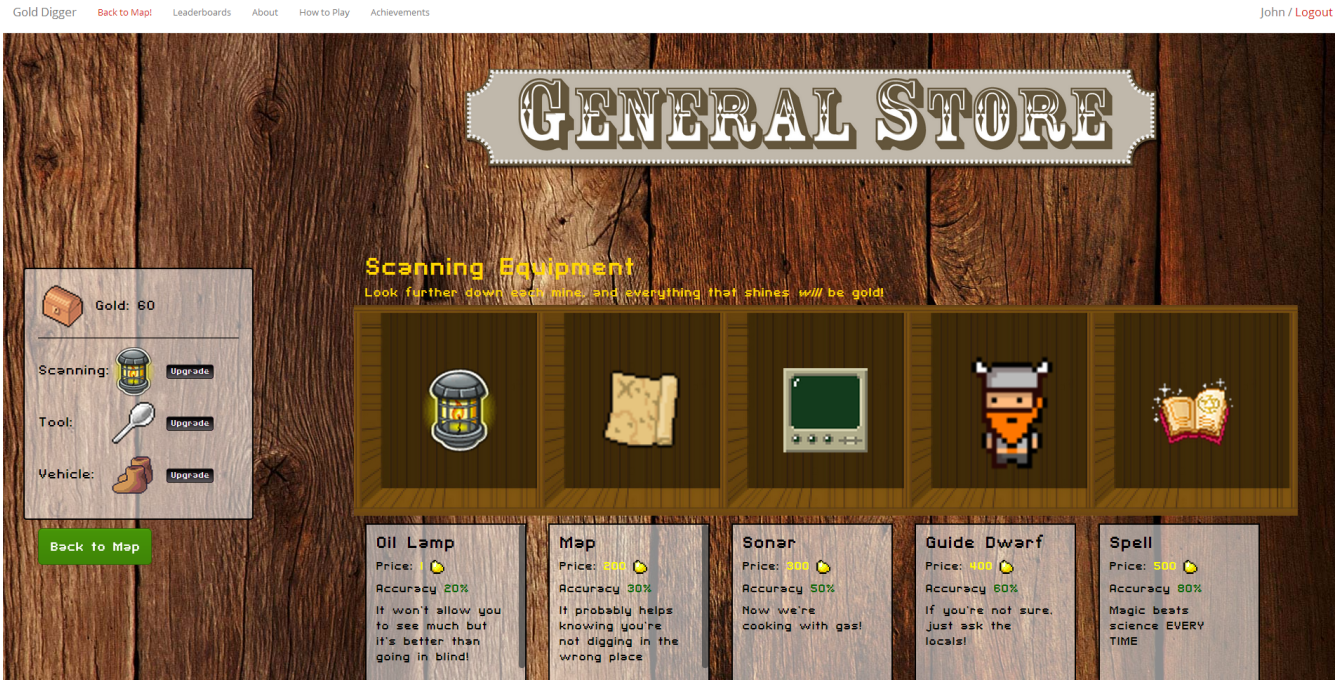


Figure 3.7: General Store

At the end of each day (by clicking on **'shop'**), or from the world map screen (by clicking on **'Buy stuff'**), users can access the **General Store** (see fig. 3.7). From here they are able to browse and purchase new items to help them in their digging. There are three groups of objects that the user can choose from **Scanning Equipment, Digging Equipment** and **Vehicles**. Each of these groups contains five different items with different cost and stats. Users are able to see the image associated with each item as well as its cost, stats and a short description in the small tex box underneath. If users decide to upgrade one of their item groups (Scanning, Digging or Vehicle) they can do so by clicking on the **'Upgrade'** button. At this point they will be presented with a small modal that reviews the item's stats, together with its picture, asking the user to confirm the purchase. If the users don't have enough gold to make the purchase, or if the purchase would cause them to not have enough money to enter the cheapest mine, an appropriate alert message is displayed, explaining why the purchase is not possible.

The choice to allow users to *upgrade* rather that *buy* items has been made because each of the items is better than the previous one in every respect and thus there is no reason why a user would chose to equip an item that they previously purchased, since this would not bring

any advantage at all. For instance, with digging tools, their cost, dig cost (the amount the user has to pay in time units to dig once) and extraction power (the percentage of gold that the user will be able to extract given a certain yield), are all increased from the least, to the most expensive. However, it would be easy to add items that have different combinations of these parameters and add, for example, a digging tool that, at a higher cost per dig also returns a higher percentage of gold. Finally, upon purchase, the new item is immediately added to the left side panel and the appropriate amount of money removed from the user's total through an AJAX call.

3.1.5 Leaderboards

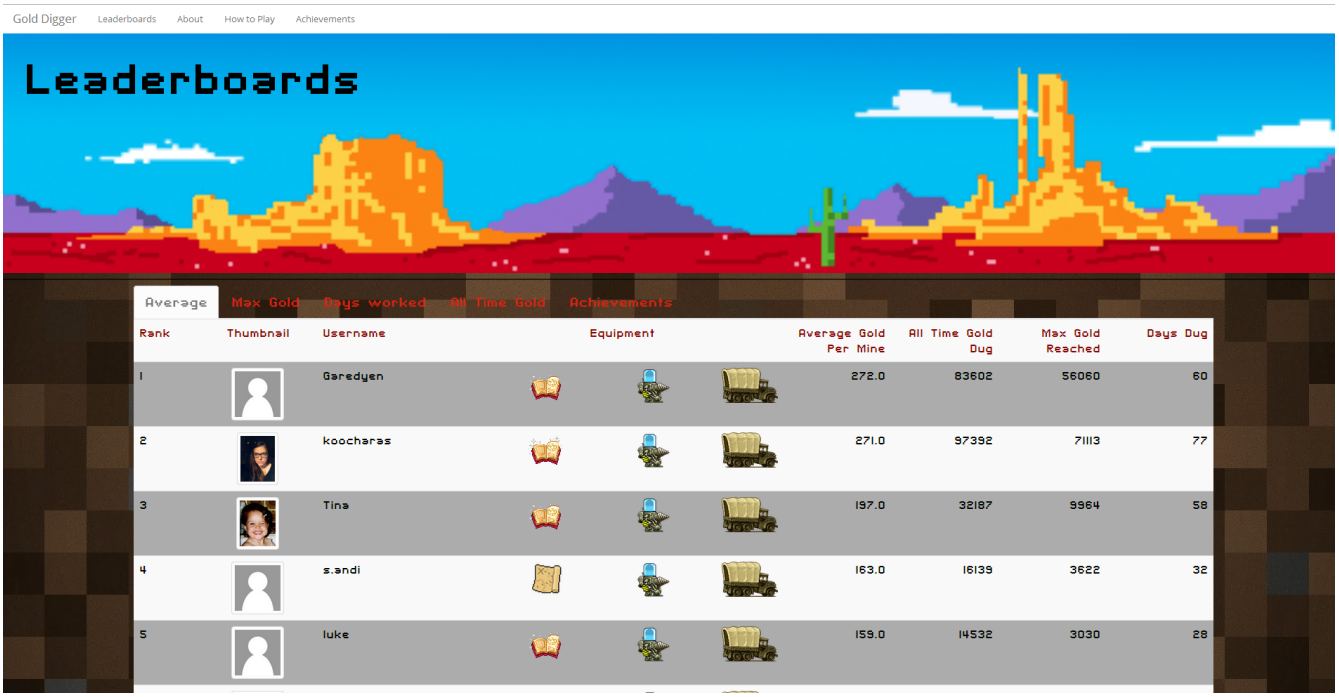


Figure 3.8: Leaderboards

On the **Leaderboards** (see fig. 3.8) page, users are able to check their performance and compare it to the other players'. There are four parameters by which users can be ranked, plus an achievements board that has no specific ranking criteria:

- **Average**: the total amount of gold ever dug by the player divided by the total amount of mines that were dug into.
- **Max Gold**: the maximum amount of Gold ever dug (the maximum amount of gold ever reached)
- **Days Worked**: the total amount of days of digging completed by the player (not zeroed on game over)
- **All Time Gold**: the cumulative total amount of gold dug by the player (not zeroed on game over)
- **Achievements**: shows the achievements gained by each player in no particular order (achievements are not ranked)

Each row of the the tables (excluding the 'Achievement' table) diplays the following parameters: Rank, Thumbnail, Username, Equipment (showing the image for each of the three item groups), Average Gold per Mine, All Time Gold Dug, Max Gold Reached, Days Dug.

3.1.6 Tutorial

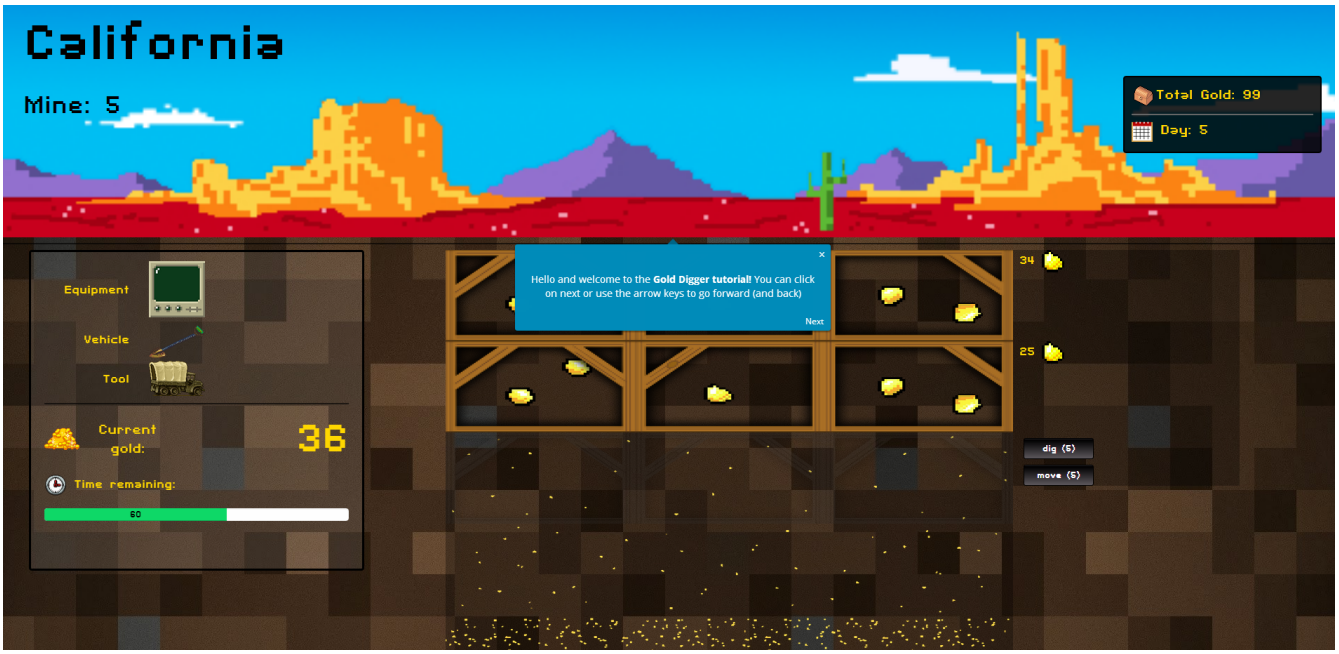


Figure 3.9: Tutorial

Because it is important for users to have a clear idea of the way the game works, all effort has been made to employ a visual approach that would be quick and easy to understand. To this end, upon entering, the **'How to Play'** page, a tour of the main game features is automatically launched. The javascript library **Trip.js** (see 4.4.6) highlights and points at the different parts of the game screen in order to get a quick visual explanation of the main game mechanics. Each of the labels has 'Next', and 'Previous' link, in order to let users go back to a previous point or skip explanations they already viewed.

3.1.7 Achievements

The **'Achievements'** page dispays all the achievemts badges together with their name, the condition that triggers them and their image. This page is needed in order for the users to be able to check which achievements they can aim for while playing. Two additional achievements (fig. 3.11) are not displayed here and are given only under special conditions:

- **Awesomeness**: given to the people who tested the "beta" version of the site.
- **Banana**: given to people who managed to find the game's Easter Egg

Achievements ans special achievements have been incorporated in order to both add an extra game feature to Gold Digger which wouldn't change the game mechanics too much an to give players an incentive to keep playing, especially since there is no particular "winning condition", fulfilled which a player has completed the game.

3.1.8 About Page

In this page, users are able to find the developer and supervisor's contact details as well as reading about the reasons behind the creation of Gold Digger and acknowledgements of the authors of some of the material used in the site.

3.2 Walkthrough

(1) Jill, the user, has just logged in (or registered) and has been redirected to the World Map. Her starting Equipment and Gold are as follows:

- **Gold**: 100
- **Scanning Tool**: Oil Lamp (accuracy: 20%, visibility: 2)
- **Digging Tool**: Spoon (dig cost: 5, gold extracted 30%)
- **Vehicle**: Boots (move cost: 10)

On the map, Jill clicks on California and a modal appears, from which she can see see that, although the mine doesn't yield much gold, it is relatively cheap to access it (she only needs to pay 40 gold nuggets to enter it).

(2) After clicking on 'Go to Mine', 40 gold nuggets are removed from Jill's total amount of gold and she is presented with a mine where no layer has been dug. On the top left hand side Jill can see the name of the location she is in and the number of the mine (now 1) whereas on the right hand side she can check her total amount of gold (now 60) and the number of days she

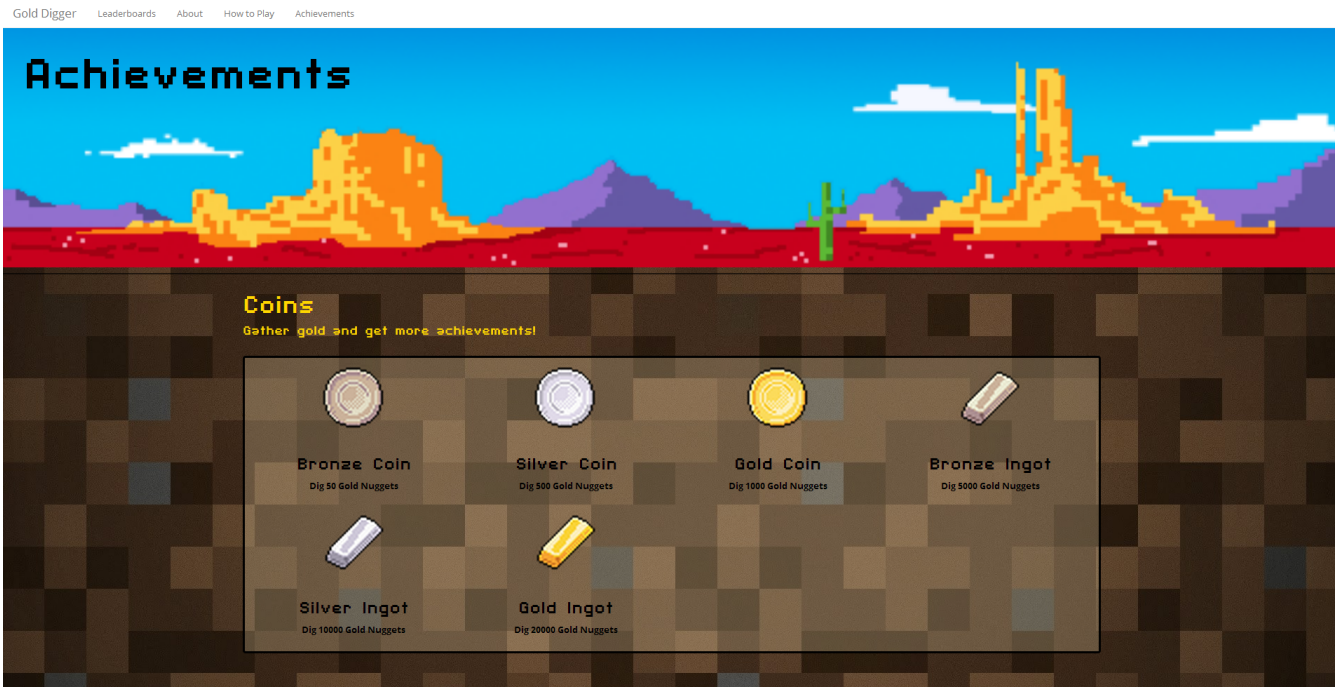
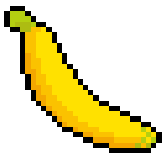


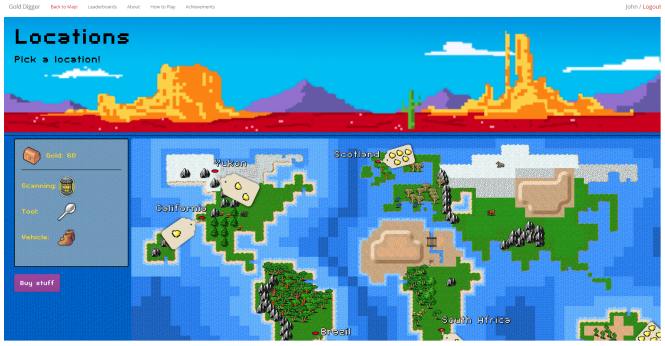
Figure 3.10: Achievements display

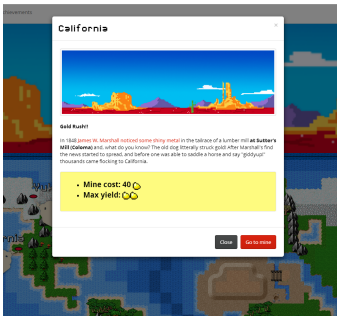
(a) You helped testing!



(b) You found the Easter Egg!

Figure 3.11: Special Achievements





has been digging. Thanks to her Oil Lamp she can see specks of gold in the first two layers but, because the lamp only has a 20% accuracy, it is possible that the amount of flecks that can be seen is deceiving.

- **Current gold**: 0
- **Time remainingl**: 100
- **Mine**: 1
- **Day**: 1

(3) Jill decides to dig through the first couple of layers layer of the mine by clicking on the 'Move' button on the right hand side of the mine shaft. She gains 17 gold nuggets and consumes 10 units of time (since each digging operation costs 5 units of time)

- **Current gold**: 17
- **Time remainingl**: 90
- **Mine**: 1
- **Day**: 1

(4) At this point Jill is not sure she might get much more gold from this mine and she doesn't want to spend precious time digging through layers of the mine that she has no information about. For this reason she clicks on 'Move' to get to a new mine (in the same location). To do this she must spend 10 units of time

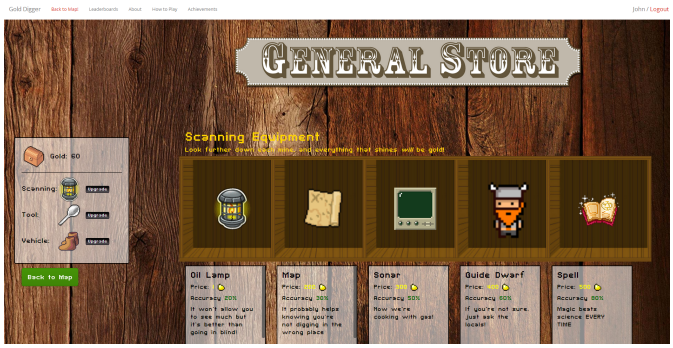
- **Current gold**: 17
- **Time remainingl**: 80

- **Mine**: 2
- **Day**: 1

(5) Jill continues to dig through some more mines and after a while she runs out of units of time. At this point, she is presented with the 'End of the Day' screen that sums up her progress during the day as follows:

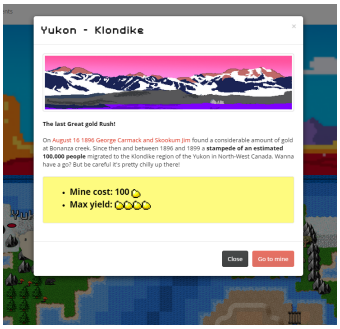
- **Today's gold**: 94
- **Total gold**: 94
- **Mines dug**: 6

Jill also receives the 'Bronze Coin' achievement for having dug more than 50 gold nuggets. From here Jill decides to go to the shop and see if she can purchase some new items



(6) Once in the shop Jill tries to purchase better scanning equipment, so she clicks on the 'Upgrade' button next to the Oil Lamp. Unfortunately she doesn't have enough gold to make this purchase yet, so a message alerts her that she would need to do some more mining if she wants to be able to purchase the item.

(7) To gather more gold, Jill goes back to the California mines and, as soon as she has 100 gold nuggets, she takes a gamble and spends them on accessing the Yukon mine. However, she doesn't perform very well and, at the end of the day she owns less than 40 gold nuggets. Because she doesn't have enough money to enter any of the mine, Jill loses her first game. However, clicking on 'Back to Map' will restore her to the initial conditions, if she bought any items they wold be lost.



3.3 System Architechture

Gold Digger is based on a 3-tier architecture. Each user is able to create a player account (client) containing all of the details entered upon registration, together with a set of game variables, set to their starting values. The client side renders HTML5 and CSS3 elements and graphics while updates to the game states are done mostly through AJAX, in order to avoid reloading the page. The game logic is coded in the middleware using the python-based Django framework (see 4.3.2). All of the user profiles as well as the other game objects and achievements are stored in the database while the corresponding graphics, as well as the rest of the game graphics are stored in the project's static and media folders. Finally, the middleware continuously updates a log file in order to monitor user behaviour and gather data to be parsed and analysed at a later stage.

3.4 ER Model

The above diagram describes the entity-relationship model for Gold Digger. There are 5 entities in Gold Digger:

- **User Profiles**: this entity contains several of the users' game stats, like the amount of gold at their disposal and the average amount of gold dug per mine as well as a reference

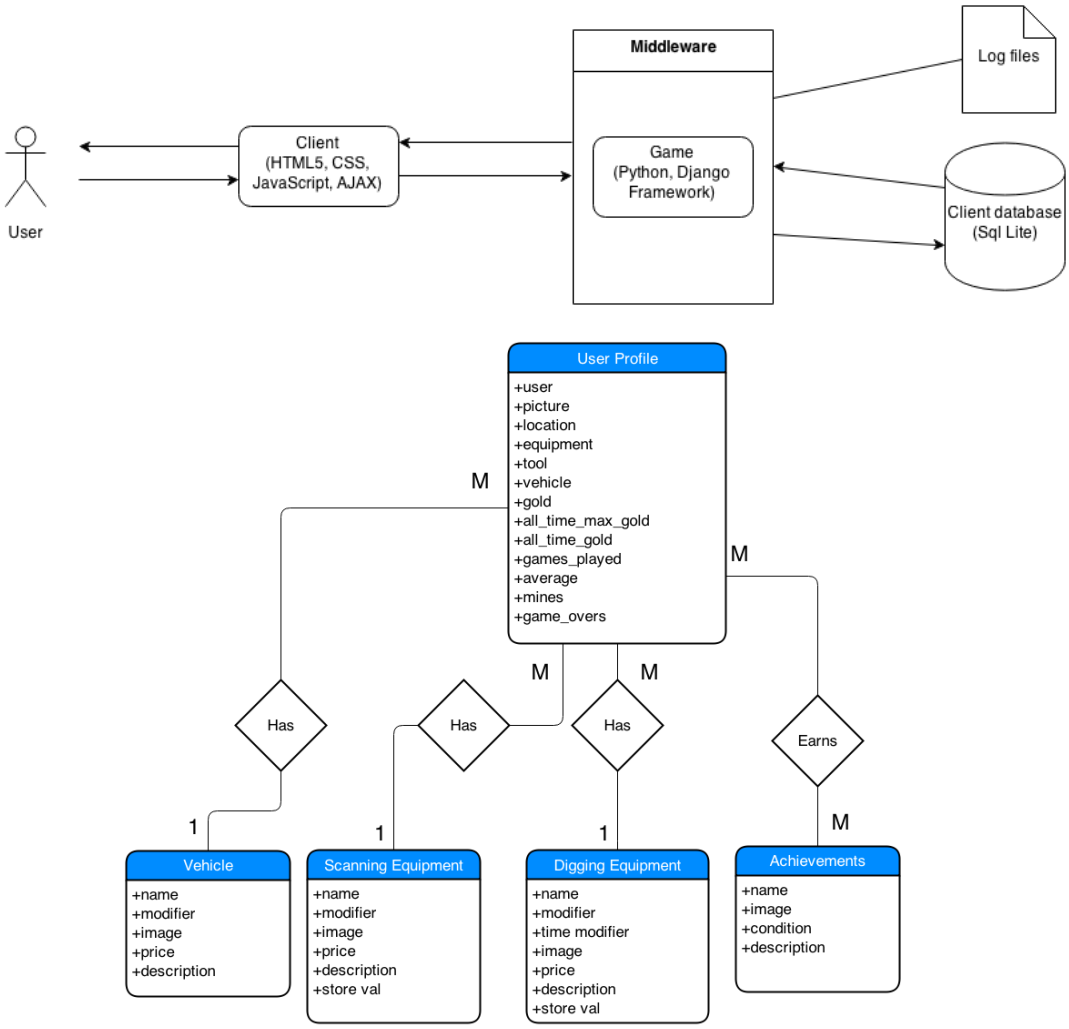


Figure 3.16: The Gold Digger ER diagram

to the Django object 'user' containing all the information regarding the user's password, username and email. This is necessary in order to take advantage of Django's very efficient user management system and keep the website as safe as possible

- **Digging Equipment**: this entity contains each of the tools' name, image, price and description. However, the most important attributes of this entity are the *modifier* and the *time modifier*. The*modifier* attribute is used by the game mechanics to calculate how much gold a user is able to extract from a given layer of the mine. It is a *float* number between 0.2 and 0.8 that will be multiplied by each of the amounts of gold in each layer. This way if the user is using, for instance, a shovel, she will be able to extract only 30% of the gold that is actually present in that layer (see **??**). The *time modifier* attribute, on the other hand stores the digging cost per digging operation of each of the tools and it is an integer that goes from 5 to 1 in decreasing order from the worst tool to the best.
- **Scanning Equipment**: this entity is quite similar to Digging Equipment but it does not include the *time modifier* attribute. The *modifier* attribute of this entity is responsible for calculating the cue array, that is in turn responsible for determining the amount of gold flecks that will be shown in each of the mine's layers (see **??**). Furthermore, because this attribute holds only float values from 0.2 to 0.8, a simple multiplication by 10 is used to determine the number of layers in which those specs are actually visible .

- **Vehicles**: this entity, like Scanning Equipment, only posses the *modifier* attribute. This is an integer in range 10 to 6 and it holds the value of time units to be subtracted from the day's time, for each digging operation.
- **Achievements**: the Achievement entity simply stores the name, image, condition and description of each of the achievements.

Relations

There are **four relations** between the above entities. Each player can only store only one relation to a particular Scanning Equipment, Digging Equipment and Vehicle object thus, these are all one-to-one relationships. However, because each user can earn many achievements, the relationship between the User Profile and the Achievement entity needs a separate database table to keep track of the user-achievement value couples. In this table, **User Achievements**, each row comprises two columns, each of which is a foreign key. The first one is the relation to a User Profile Object, and the second one is the relation to an Achievement object.

3.5 Graphics

One of the main elements of the design of Gold Digger was its graphic design. The general idea was to reproduce the look and feel of a retro 8-bit game as much as possible, without compromising the clarity and ease of use needed by a website. For this reason, 8-bit-style graphics were employed in most of the elements of the 'game pages' while Twitter Bootstrap was used in order to provide a simple minimalistic "framework" for the graphics to be displayed in.

Fonts

There are two fonts that have been used throughout Gold Digger. The first one is **Open Sans** (see 4.3.5). This font is part of the Twitter Bootstrap theme that provides the graphic framework for the site. It is used in areas with lots of text and in the navbar, where clarity the most important issue. However, throughout the site, most of the headings, scores, descriptions and game messages employ the font **SF Pixelate** (by ShyFonts) which has a pixelated look reminiscent of retro 8-bit games. All of the text in the 'game pages' is typed using this font.

Landscapes and World Map

There are six different landscapes in Gold Digger, each one associated with one of the locations that the user can travel to and dig into. Three of them (California, Scotland and Yukon) were created with a pixel-art specific (Pixen) program using a number of pictures for inspiration, while the remaining three have been produced by applying filters, modifying and coloring similar pre-existing pictures in Photoshop CS, to achieve the 'pixelated look'.

The World Map was created by importing a set of freeware game tiles into a freeware level design tool called 'Tiled' (see appendix **??**). This tool allow users to load a particular set of tiles and arrange them on a grid of their choosing. The tileset used for the World Map was originally created for the expansion and creation of new maps for the game "Tales of Middle Earth" but it lent itself very well to the task of creating a word map. After the first version of the map was completed, the location names and price tags were added with Photoshop CS 6 where other minor adjustments were also made.

Items and Achievements

Most of the items and achievements icons were made by Alis, a pixel artist who made them available for public usage (see **??**). However a minor percentage of the items were created by modifying sprites of the popular game METAL SLUG by SNK/Playmore. These sprites are all properties of their respective owners and no copyright is claimed upon them.

Chapter 4

Impementation

4.1 Development Methods

4.2 Heuristic Evaluation

4.3 Technologies

4.3.1 Python

Python is one of the most popular programming languages with great features such as a clear syntax and an extensive amount of documentation, libraries and native methods. The choice of using Python as a main programming language was very much tied to the web development framework chosen (Django). Nevertheless, Python has many advantages of its own, that became very important to the development of Gold Digger. The code snippet below, belongs to one of the yield generators (six in total), that are responsible for assigning a certain amount of gold to each layer of a mine. Two things are needed from the yield generators. The first one is that they generate yield according to a function whose parameters can be modified in order to balance the gameplay or extract different data from the users. The second one is that they generate yields with a certain randomness so that the user is not faced with the same mine over and over.

```
1     def scoti_quadratic_function(x, a, k):
2
3         b = random.randint(-10, 5)
4
5         y = (a*(pow((x - k), 2)) + 90)+b
6
7         if y < 0:
8            y = 0
9
10        rounded = int(round(y))
11        return rounded
```

Using Python, it is very easy to fulfill both of these requirements. The latter one is taken care of on line 3, where a simple call of the *random.randint()* method allows us to assign random integer in range -10 <= b <= 5 and thus modify the displacement of the curve. The former

requirement is fulfilled on line 5 where the quadratic yield function is defined with very simple syntax and the employment of the *pow()* method.

4.3.2 Django

Django is a very powerful, well documented, easy to use, extensive web development framework based on python. In Gold Digger, it provides the base on which all of the other technologies employed are built upon. The choice of Django, as a web development framework has been made for all the reasons listed above, but some were important in particular. Firstly, Django uses a Model View Template architecture. Each url request is handled by the Model middleware in Django and redirected to a specific View associated with it. The view, in turn, handles the request and provides the data to be passed to a the Template that further processes it and diplays it (see below for Django template code).

Another of Django's main features is the handling of SQLite databases through simple python commands. Because each user is associated with a User Profile object, frequent update of the database was needed in order to update all the game values and stats. The code snippet below, for example, is responsible for assigning an achievement to a player. This requires the method to be passed a reference of the user as well as reference to the achievement she gained and then, the user hasn't earn the achievement already, create a new row in the User Achievement database table (see 3.4. Django allows us to do this very easily, by simply checking if the user-achievement pair already exist in the database (on line 4) and, if not, go ahead and create it. As we can see, this only takes a few lines of very simple code. In the code snippet, the method returns a object (*myResponse*) containing all the information regarding the achievement in order to be sent back as a response to an AJAX call (see 4.3.7) an be subsequently displayed to the user.

```
1
2       myResponse = {}
3       if not UserAchievements.objects.filter(user=user, achievement=achievement).exists():
4           achieve = UserAchievements()
5           achieve.user = user
6           achieve.achievement = achievement
7           achieve.save()
8           print "Achievement UNLOCKED"
9
10          myResponse['achievement_name'] = achievement.name
11          myResponse['achievement_condition'] = achievement.condition
12          myResponse['achievement_image'] = achievement.image.url
13          myResponse['achievement_desc'] = achievement.description
14
15          return myResponse
16      else:
17          myResponse['unlocked'] = True
18          return myResponse
```

In this second code snippet we can also see how easy Django makes the querying and ordering of database objects. Here all the User Profile objects are pulled from the database and ordered according to different game stats to be displayed in the leaderboards page with the *.order_by* method.

```
1   def leaderboards(request):
2       context = RequestContext(request)
3       users_avg = UserProfile.objects.order_by('-average')
4       users_gold = UserProfile.objects.order_by('-all_time_max_gold')
5       users_games = UserProfile.objects.order_by('-games_played')
6       users_all_time_gold = UserProfile.objects.order_by('-all_time_gold')
7       users_achievements = UserProfile.objects.all()
8       achiev = UserAchievements.objects.all()
```

Another fundamental Django feature are **Django tags**. Django tags are enclosed in **{% ... %}** tags and allow the display of content in HTML documents. In the snippet below, for example, the HTML template is passed an array of 'block' objects which represent the layers of the mine. This array is iterated through using the **{% for block in blocks %}**. If the user's visibility (determined by her scanning equipment) and if the layer hasn't already been dug, the appropriate cues are displayed, using a second type of Django tags, enclosed between double curly braces.

```
1  {% if blocks %}
2  <div class="col-xs-5 mine">
3  {% for block in blocks %}
4  {% if visibility > block.pos %}
5  {% if block.dug == False %}
6  <div class="row flecks_{{ block.cue }} animated" id="goldlayer_{{ block.pos }}">
7  <div class="scaffold_1_shaded" id="scaffoldlayer_{{ block.pos }}">
8  <div class="points" id="points_{{ block.pos }}"></div>
9  <div class="comment" id="comment_{{ block.pos }}"></div>
10 </div>
11 </div>
12 {% else %}
```

These double curly braces allow, for example, for the appropriate gold flecks cues to be displayed. We can see this on line 6 where *class=row_flecks_{{ block.cue }}* will display a different row of flecks according to the value of *{{ block.cue }}*

Finally, because some variables associated with the user are stored in the Gold Digger database as discussed above, however, some other variable will need to change very often during the game but still need to be associated with each particular user.These are variables such as the user's current gold, the array of layers of each mine, and the number mines the user has been in. For them, *sessions* need to be implemented. Thankfully Django also offers session support:

```
1      request.session['has_mine'] = False
2      request.session['mine_type'] = ''
3      request.session['time_remaining'] = 100
4      request.session['gold'] = 0
```

The code snippet above is employed in the view that handles the choice of a location in the world map. Here the session values *hasmine* and *mine_type* are set to 'False' and 'null' so that a new mine can be created by the game view, the time remaining is set to 100 (beginning of the day) and the current gold is set to 0, since the player hasn't started digging in this particular location yet. Using Django, these variables are associated with the particular user session and can be used by all the other view without being singularly passed.

4.3.3 HTML5

HTML5 is the most common markup language for presenting content on the web. All of the elements of each page (visible and not) are defined by HTML5 tags, creating a structure in which content can then be easily styled thanks to CSS3 stylesheets and manipulated using both Django tags (see 4.3.2) AJAX calls (see 4.3.7). An example of both HTML5 styling and the usage of Django tags can be found in the Django section of this paper.

4.3.4 CSS3

As mentioned in the previous section, styling is applied to HTML5 elements via reference to CSS3 stylesheets. In CSS3 sheets we can define the parameters for the styling of each class, id or element that is present in one of the templates that display a link to a particular stylesheet. In the example below, we can see how styling is applied to the element with id 'home':

```
#home{
    background-position: 25%;
    background-image: url(/static/Wild%20West%20Background.png);
    background-repeat: no-repeat;
    background-size: cover;
    padding-bottom: 20%;
    padding-top: 5%;
    margin-bottom: 0;
}
```

here, a background picture for the homepage heading is defined and set in place using the *padding* parameters.Padding is one of the parameters for positioning and styling elements of that are associated with the HTML box model.

Animate.css

In addition to offering the possibility to style HTML5 elements, CSS3 also offers the possibility to apply animations to them. The Animate.css library (by Daniel T. Eden) in particular, makes this as easy as adding the 'animated' class to any element we wish to apply an animation to, together with an attribute defining the kind of animation. These animations are used mainly in the mines, to make each layer of scaffolding in the mine appear by descending from the top, as well as nicely presenting the new mine when it's first created. Since Gold Digger is fundamentally a video game, and since one of video games' fundamental features are their animations, it seemed non trivial to add some animated element to match user's expectations on this matter. Animate.css allows us to do this easily and cleanly.

4.3.5 Twitter Bootstrap CSS

Twitter Bootstrap uses a both CSS3 and Javascript to offer the possibility to apply sleek and minimalistic themes to webpages that implement a link to them. The theme used for Gold Digger, is '**Simplex**' (by Thomas Park for Bootswatch) and it has been very useful for the organization and styling of the many elements of each page. Firstly, Bootstrap offers a very easy to use grid system, that allows us to easily divide any section of the page in columns and sub-columns. This can be seen throughout the website where the left side column hosts the side item panel, the middle column the main content (for example the layers of a mine) and the right column holds any additional information or just provides spacing. Secondly, Bootstrap comes equipped with Javascript plugins for the display of modals and tooltips. The former ones, for example, are used both in the world map to display the details of a location and on the main page, to host the registration form. Finally, Bootstrap allows to display continuity of colour and graphics throughout the website, since to equal elements always corresponds equal graphics.

4.3.6 Javascript and JQuery

JQuery is a very useful Javascript library that allows to apply special animations and features to elements of a webpage. By writing functions that are activated upon key press, click or hover, we can make webpages even more interesting and interactive than by simply using CSS3 and Bootstrap. There are two main applications of JQuery and Javascript that contributed to the look and functionality of Gold digger.

Trip.js

Trip.js is a very useful library to implement guided tours of an web app or website. It allows developers to design explanatory labels for each of the elements of a web page, with the option

of highlighting them if necessary. Trip.js also incorporates Animate.css to allow the labels to be displayed with nice, tidy animations.

```
var trip2 = new Trip([
    {
        sel: $("#California_landscape"),
        content: 'Hello and welcome to the <b>Gold Digger tutorial!</b>'
        position: "s"
    },
 ...
$(document).ready(function () {
    trip2.start();
});
```

Here we can see one of the labels being defined and attahced to the #California_landscape element, with a particular message and position. Finally, upon page load, the *.start()* method is called on the Trip object (containing the array of labels) and the tour begins.

jquery-animate-numbers.js

This very simple JQuery plugin allows to animate numbers so that all the numbers in a given interval are displayed in a 'rolling' fashion.

HTML

1234

JS

$("#num").animateNumbers(4321);

In Gold Digger, this plugin is used in any page in which the amount of gold is incremented or decremented (like in a mine or in the shop). Animating numbers, like adding animations with Animate.css also contributes to the 'game feel' necessary for Gold Digger.

4.3.7 AJAX

AJAX stands for Asynchronous Javascript and it is an ensemble of technolgies that, together, allow a web page to exchange data with the server without having to reload the page itself. This is achieved through an extra layer of interaction between the server and the client that is known as AJAX Engine. In Gold Digger, AJAX is essential, especially in the 'game pages' in order for the user not to have a disjointed gaming experience in which, at every dig, the page is reloaded and has to be re-compiled every time. AJAX is also used in the general shop page, and in the assignment of achievements. Thanks to AJAX we are able to keep the game experience close to what the user would expect while playing any other stand alone game, since video games normally exist in a continuum and do not have to deal with the limitation of separating content in pages.

```
        $.ajax({
            type: "POST",
            url: "/gold_digger/ajaxview/",
            data: {block: pos, dig: gold, csrfmiddlewaretoken: csrf},
            statusCode:{
            200: function(response){
```

In the code snipped above, we can see part of the AJAX POST responsible for the update of the page after the user has decided to dig. Thanks to AJAX we can send, the position of the

block that's been dug, its yield and the security crsf middleware token (required by Django) to **ajaxview** in the views.py file so that it can be processed and return an appropriate response. Then, content is updated on the page using JQuery and Javascrip. In this case the update consists in showing the appropriate amount of gold nuggets, updating the current gold, decreasing the units of time and regulate the scrolling position.

4.3.8 Code Flow

In order to better explain how all the previously listed technologies work together, in this section we provide a description of the functioning of one of the core aspects of Gold Digger as a game: digging in a mine.

1. By selecting a location from the world map, the user sets the session variable 'location' to the name of the location selected and the '**has_mine**' parameter to an empty string.. Then the request is redirected to the **game2** view in order to initiate the game.
2. The **game2** view first checks if the '**has_mine**' variable contains an empty string (meaning that this is the first mine of the day) and then uses the 'location' value to determine which yield generator to select to generate the appropriate yield. There are six different yield generators and each one will generate an array of ten values, representing the amount of gold in each layer of the mine.
3. **yieldgen.py** is the module responsible for the generation of yields. Here all the different yield generators inherit the **make_yields** method from the yield generator class and define their own. This way we we are able to add as many yield generators as needed, by simply adding a new method implementing **make_yields** .
4. As described in Python section (see 4.3.1), each yield generator defines its own static function that will generate an array of yields according to a specific function that also introduces some randomness. Once the yield generator has been created, it is passed back to the **game2** view, where it is passed as a parameter to the **Mine** class, together with the accuracy value determined by the tool modifier, which will help generate the array of cues to be displayed later.
5. The Mine class creates a Mine object with all the parameters pertaining to the mine, together with an array of 'blocks', representing the values pertaining to each layer of the mine. Each Block object has: a position (an integer from 0 to 10), a gold yield (the value of the array of yields gnerated by **yieldgen.py** at the relevant position), a cue (generated by **cuegen.py**, and a boolean that is True or False, depending on wether the block has been dug or not.
6. The yield array is now generated calling **make_yields()** and each value passed to **cuegen.py** where the associated cue is generated. The cue is chosen at random in a range that is smaller and smaller the better the tool gets (see appendix A) and a new array of cues is generated. Each of the values is an integer from 0 to 5, representing the different patterns of gold flecks
7. Now that the mine has been generated, its array of blocks is passed as a parameter in the Django dictionary to the **game2.html** template in order to be displayed. As we've seen in 4.3.2 Django allows us to dynamically display content in templates thanks to the use of Django tags. Here, for instance, the array of blocks, is iterated through and each cue is displayed thanks to CSS3. In other words, the custom stylesheet applied to the page, contains a class for each cue number (*flecks_1*, *flecks_2*, ...) and a Django tag in place of the defining number determines which of them is displayed (this is also the way gold nuggets are displayed after the user clicks the 'dig' button.

8. When the 'dig' button is clicked (or the Enter key is pressed), an AJAX POST is sent to the **ajaxview** view, where all of the server side operations are take care of (like updating the 'current gold' session variable) and a JSON dictionary containing the relevant information (for instance, how much gold the user has been able to extract) is sent back to the AJAX file (see 4.3.7)

9. Finally, the appropriate content on the page is updated. A new layer of scaffolding is displayed with an animation (see 4.3.4), together with the gold nuggets and a small message to the user (like "GOOD" or "PAY DAY"). Finally, the scrollbar is adjusted so that the relevant part of the page is displayed. The page is not reloaded and the user can continue digging.

4.4 Testing

4.4.1 Unit Testing

4.4.2 Live Testing

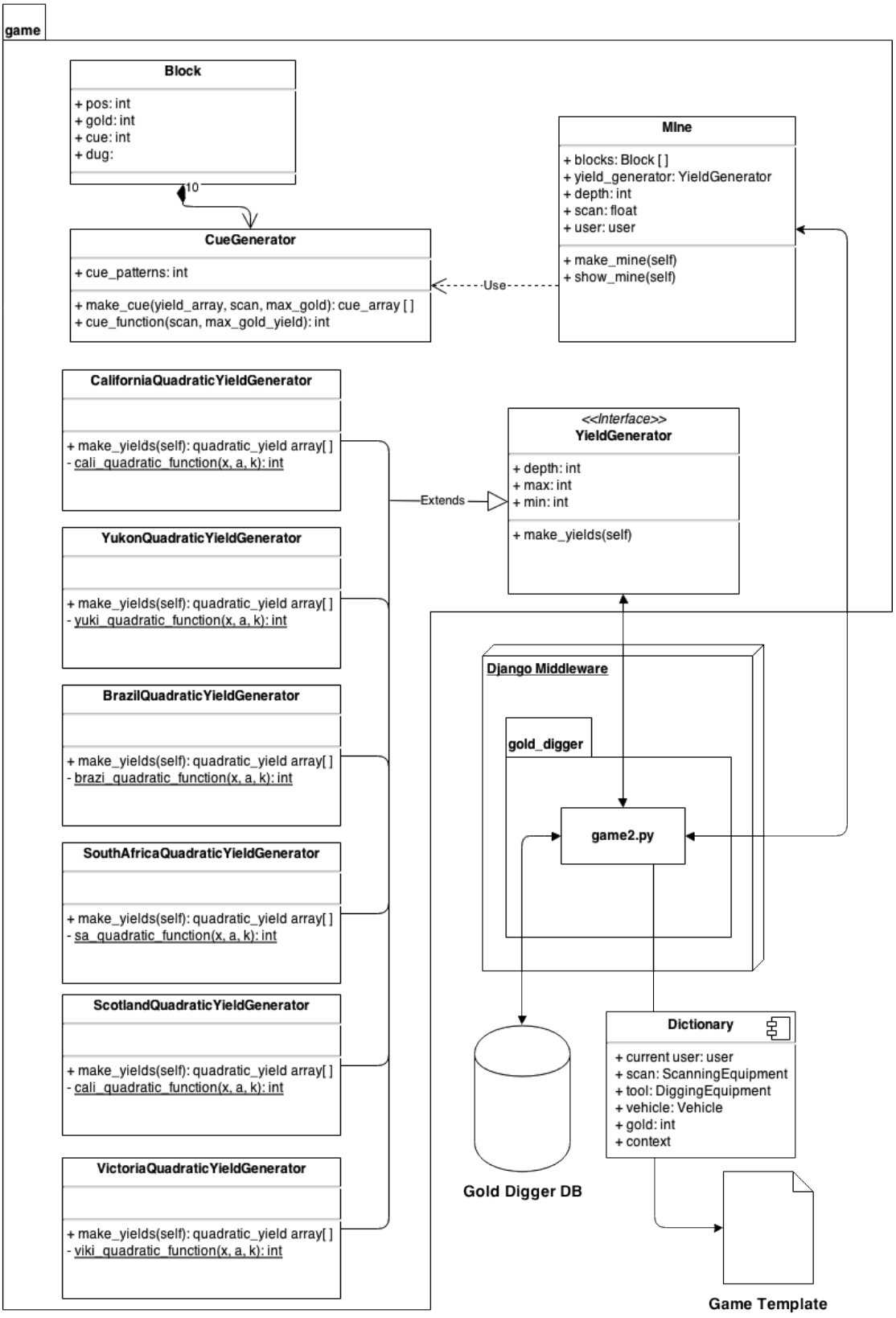


Figure 4.1: The class diagram illustrates the way the game object is prepared and sent to the template for display

Chapter 5

Results and Data

5.1 Data Logged

5.2 Data Analysis

5.3 Results

5.4 Reflection

Appendix A

First appendix

A.1 Section of first appendix

Appendix B

Second appendix

Bibliography