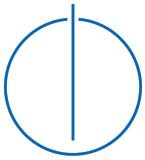
DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Masterpraktikum
Design Document

AR Escape the Room

Benjamin Braun
Maximilian Ludl
Nikolas Schneider



Contents

1 Escape Rooms

Escape Rooms are physical adventure games in which a team of players is locked inside a room. To escape this room, they need to solve a variety of puzzles and riddles using hints and clues found all around them; in most cases all riddles lead to one final code or key to open the door to their freedom. In addition to that, the players need to escape within a given time limit. Similar to a video game, most of the Escape Rooms are introduced with a story or flavour text to justify why the players are locked in the room as well as decoration in the room corresponding to the story. (See Figure 1.1)

Due to the popularity of Escape Rooms several alterations of the game are being published, some of which using VR as a game element or minimizing the game to a board game. Some of those will be listed in the following sections.

Figure 1.1: Example for an escape room in which the players need to steal a painting [1]

[1] https://escapegame-muenchen.de/die-kunst-des-klauens/

1.1 Escape the Room The Game

"Escape Room The Game" is a board game with the escape the room schema. (See Figure 1.2)

The main feature of the board game is that it is not limited to a specific room or location. It is also extendible by several expansion packs, one of which is an expansion featuring two VR-Rooms. (See Figure 1.3)

Figure 1.2: Escape Room The Game board game[2]

[2] https://www.spinmaster.com/product_detail.php?pid=p20781

Figure 1.3: Escape Room the Game VR Add On[3]

1.2 Cosmos VR Room

In this version of the Escape Room the players are "locked" in an completely virtual room and need to escape using a Leap Motion controller to interact with the virtual environment. The room itself is displayed by using an Occulus Rift. (See Figure 1.4)

One problem of a fully virtual escape room is that it trades in certain game features for the sake of illusion and special effects. On one hand, in contrary to the board game, the players level of immersion is higher and more intense in an fully virtual environment opposed to just sitting at a table. On the other hand a lack of physical interaction removes some of the Escape Rooms features, like the smell of the paper and the feel of it. In addition to that motion sickness may occur while playing, since the players are not moving physically in the room.

[3] https://escape-maniac.com/2017/11/28/test-escape-room-das-spiel-virtual-reality/

Figure 1.4: Cosmos VR Room: Reality (left); In-Game (right)[4]

1.3 Summary and Motivation

Escape Rooms are fun tests of wits and problem solving skills, which are seeing a steady rise in popularity since 2004. Besides using actual physical rooms, there are also increasing options for tabletop games and Virtual Reality set-ups.

We try to go beyond this and explore more possibilities using Augmented Reality to make a handy, more variable and portable Escape the Room game. It will be playable everywhere with just a smartphone and some printable assets.

[4] https://www.youtube.com/watch?v=5EDucfg9g8Q

2 Game Idea

The main idea of our game is to take the best of both, the Escape the Room board game and the VR set-up. In other words, our Escape the Room game should be immersive and also provide small illusions as well as special effects to improve the overall game experience. In addition to that, the game should be mobile and the users should be able to play it anywhere they want.

To realise this we decided on an AR set-up since it enables us to create more complicated puzzles without the need of complicated equipment. In addition to that, the only props needed are markers to be tracked. Due to the fact that we used a well-known device (mobile phone) for the AR application, it was expected that the users will not have any trouble navigating through the application.

In terms of gameplay the users should be able to play a physical adventure game extended by a mobile device along with an installed AR application. Also, they should be able to get hints and clues as well as being able to solve a series of puzzles within the application.

To increase the team building effect of our Escape Room game we decided on building the puzzles for an two team set up, each in a separate room, where the users should communicate with each other to solve the puzzles together.

The game was implemented using the Unity 3D Engine extended by the Vuforia AR Package.

3 Game Design

The design process of this game followed a relatively strict path. Every element of the application depends on the structure and flow of the game, which in turn fully depend on the puzzles and riddles contained in this Escape Room.

The first step was therefore to collect ideas for puzzles, then select the ones we want to use, flesh them out and bring them in a reasonable order, while establishing global dependencies and connecting every puzzle. Only then we could continue to design markers for them and finally implement them. The needed functionalities of the application were derived from the riddles as well.

3.1 Selection of Puzzles and Riddles

For our first brainstorming to find riddles we didn't restrict ourselves in any way, the possibilities of implementation or fun and difficulty were all topics for later.

To get inspiration we played an Escape Room board game in our group, and also watched videos of real Escape Rooms to get a feel of the usual riddles used in these scenarios. Of course most of these weren't really applicable for our game, since they heavily depend on physical props; but still quite a few general concepts and ideas made it into our collection and some even into the final game.

Our collection therefore consisted of riddles and puzzles from all sorts of different fields and mechanics, ranging from mathematical problems, poetic riddles, well-known logical challenges, cryptography, knowledge based quizzes, searching tasks, to small games and several physical interaction puzzles.

Since we already had such a diverse pool of ideas, we could design our game in the same fashion and select a handful of very different puzzles without getting repetitive, despite the natural restrictions of the environment of this game.

Just to name the types of riddles in the final game:

- Complete a sequence of numbers
- Find the sought-after word from context
- Encrypted texts

- Riddle in form of a poem
- Texts in a different language (Runes)
- Variation of Einstein's riddle
- Logical statements
- Find the correct sequence of items
- Find clues in a non-obvious environment (requirement to look in all corners)
- Derive information from two overlapping matrices
- Follow logical exclusion statements
- Switches-Puzzle
- Connect-all-elements-Puzzle
- Lay out the correct marker-parts

3.2 Integration into Game Flow

Just having a list of riddles doesn't make a game yet. One of the most important parts of the design process was to bring all elements into a thought-out order and connect them by creating dependencies.

The main idea of the game flow was to have the players unlock different stages, marked by coloured filters, which effectively cut off all puzzles and clues that aren't needed for quite a while. While this might seem too easy at first, it became clear very quickly that the difficulty level is still held more than high enough by the riddles themselves; not knowing what goes together or where to continue is ultimately the wrong kind of difficulty and just restricts fun. On top of that, since we only had four filters and therefore effectively five stages (counting the initial state of no filter unlocked), the amount of riddles and clues inside of one stage was still enough to provide some general clutter.

Now, in regards to creating dependencies, the four filter stages create the need for four "main puzzles", whose solutions would each unlock one filter, creating four symbolic bottlenecks in the flow of the game. At these points most of the solutions and clues run together, while they can be more "spread out" and multi-layered on the way to get there. This relatively simple concept provided a strong structure for the game

flow, which just needed to be filled. See Figure 3.1 for the flow chart used to structure the puzzles, containing colour codes to distinguish between the two rooms.

As our four main puzzles we chose: the riddle poem, Einstein's riddle, our "Portal" which required the player to find numbers among the stars, and a combination of the very similar interaction puzzles "Bulbs" and "Pipes". All of these have a distinct solution (sometimes numbers, sometimes words) which works perfectly as a password to unlock a filter.

All other riddles were tailored towards unlocking these main puzzles, helping solving them, or giving more clues for following elements. This could also be in more layers, for example: A solution of a puzzle can unlock a clue which helps understand a riddle which in turn unlocks the main puzzle.

Every Escape Room has a time limit to keep pressure on the players to solve the riddles fast, and our game is no different. While putting together the concept of our game, we had in mind to provide about enough content for roughly 20 minutes. The amount of riddles in the completed concept of the game flow had us expanding this time to 30 minutes, but without testing of the full game from people not involved in the development, we couldn't be sure what time frame is adequate.

The players are constantly reminded of their time ticking down by a timer in the app, visible at all times at the bottom of the screen. If this timer runs out, through either taking too long or some of the few time penalties from wrong inputs in the game, the game is over. Players are presented with a message of their failure and the option to either restart, or continue, now with negative time, to see how much longer the escape would have taken. This feature is mostly in the game to counter the frustration of having to start all over, and to give everyone the opportunity to see all puzzles of the game.

Figure 3.1: Flow chart of the first version of the game

3.3 Riddles with Unlocking Mechanics

Due to the nature of the game structure, most elements had to be unlocked first, before being usable or solvable. This was realized with a few different methods, although each of them had a slightly different purpose. All of these three mechanics made up the main parts of the UI.

3.3.1 Filter

As mentioned before, Filters were mostly used to guide the users from one stage of the game to another and lock later content away from the user. If a player was looking at a puzzle which he could or should not access at the moment, the marker was covered with coloured virtual hatching or in general a semi-transparent noise overlay. When the corresponding filter was unlocked and activated via the right code or keyword, the overlay disappears and the user can proceed to solve this puzzle. (See Figure 3.2)

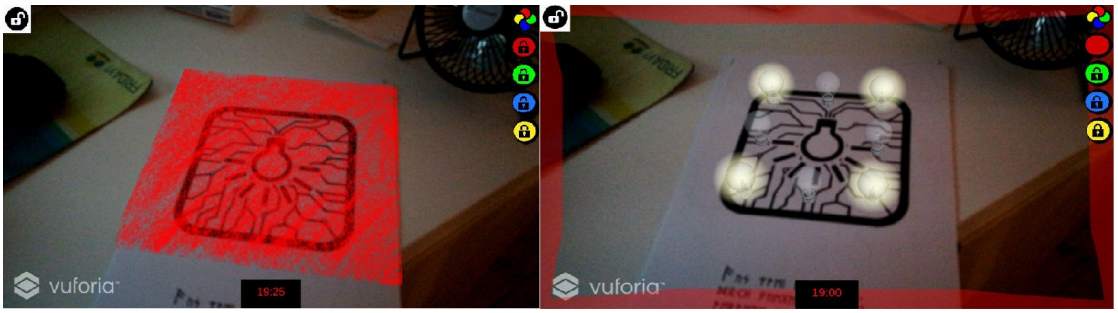


Figure 3.2: Marker with noise overlay (left); Marker unlocked (right)

3.3.2 Decoder

The decoder function of the application was mostly used to unlock new content within the puzzles. In the first version of the decoder the player was able to activate one of the five decryption algorithms and put in a key. This key was depending on the decryption algorithm chosen and could be either numerical or alphabetical. The decryption algorithms the player was able to chose from were:

- Beaufort Cypher
- Caesar Cypher
- Gronsfeld Cypher
- Reverse Caesar Cypher
- Vigenère Cypher
- Rune Translator

Figure 3.3: Decoder UI

Not all of the cyphers were actually used in riddles, but we put in a selection of most common or easily understandable cyphers to create more distractions and make it actually challenging to find the correct one for the given riddle.

The last option, the Rune Translator, wasn't a cypher in that sense and will be further explained in the next section.

The decryption algorithms were not implemented, the game was instead checking if the correct cypher along with the correct key was activated; showing the translated AR picture if the input was correct, or responding with an error message otherwise.

While the filters were primarily used to narrow the amount of content available at one time, the decoder's main task was to broaden the amount of puzzle pieces needed to solve a specific riddle.

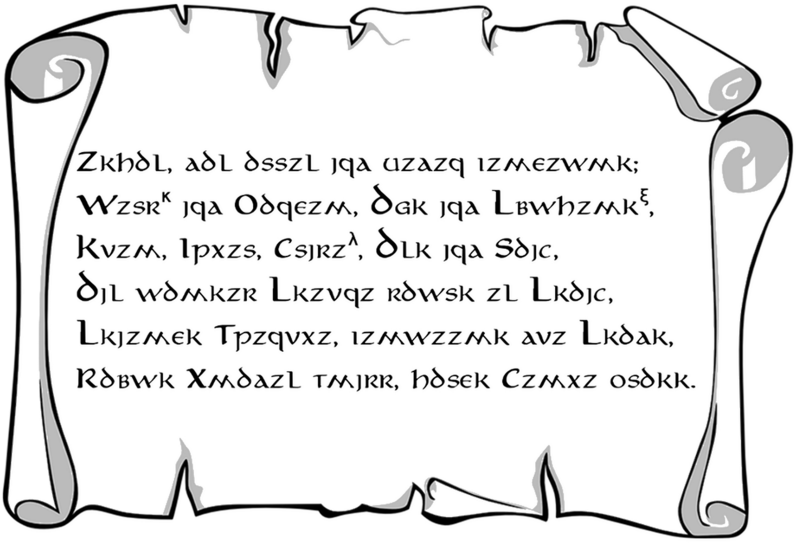


Figure 3.4: Encrypted poem

As an example, our riddle poem, which is from J.R.R. Tolkien's "The Hobbit", might be more or less quite easily solved (especially if a player recognizes the source and remembers the solution) if we would just print it on a marker as it is, which would already unlock the first filter. Instead we printed an encrypted version on the marker, making it unreadable. (See Figure 3.4)

Normal Escape Rooms would maybe have the players decode the text by hand at this point, but our big advantage is Augmented Reality. Instead of the tedious and not difficult, but time-intensive task to translate it, we have the application do it for the players and can let them focus on the actual riddle. But in order to get the translation out of the decoder we need two more pieces of information, the cypher and the key, opening an opportunity to introduce two more riddles needing to be solved beforehand. Thus the "web" of riddles is growing wider inside of a game stage through the use of this decoder function.

3.3.3 Runes

The Rune Translator was a sub-function of the decoder, but its primary function was again quite different. Runes were used in the markers as a way to hide information in the real world (while giving a more mysterious look to the printed markers), and engage the use of AR more. Since we had a few clues on the markers that just consist of plain text, being able to read them straight from the paper would be too boring, and it poses the problem of not being able to hide clues that are only important far later in the game, leading to confusion.

As a result, most of the textual clues are only printed in runes, and also filter-locked if necessary. However it should not be too hard to read these clues, so the unlocking of the Rune Translator was made quite simple.

At the first activation of this function, the player gets presented six rune stones and has to choose the correct one that will help him read runes (It is a rune that can have the meaning of "inspiration", thus justifying this mechanic in the lore). (See Figure 3.5)

Which one that is can be found on one of the marker posters in form of a little hint, so the only remaining difficulty is to match up the hint to one of the rune stones on the device. In case of the division in two rooms, only one team has the hint, so the success of this unlock also depends on the describing skills of the player.

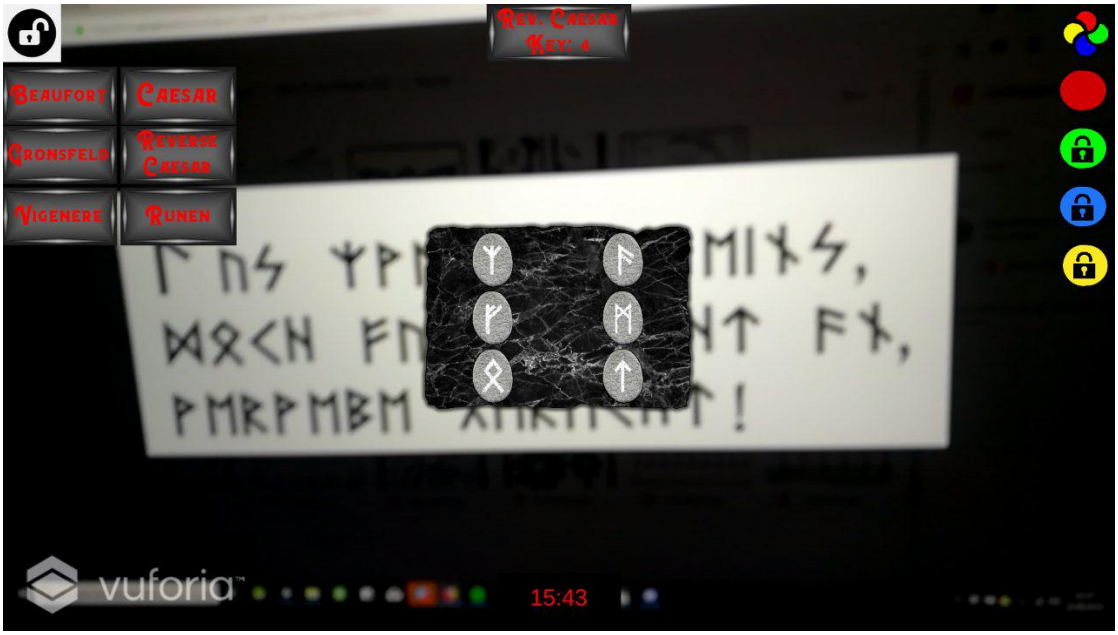


Figure 3.5: Rune selection for unlocking the rune translator

Once the translator is unlocked, it stays that way and the players are able to see the translation of any rune texts, as long as the Rune Translator is chosen in the decoder.

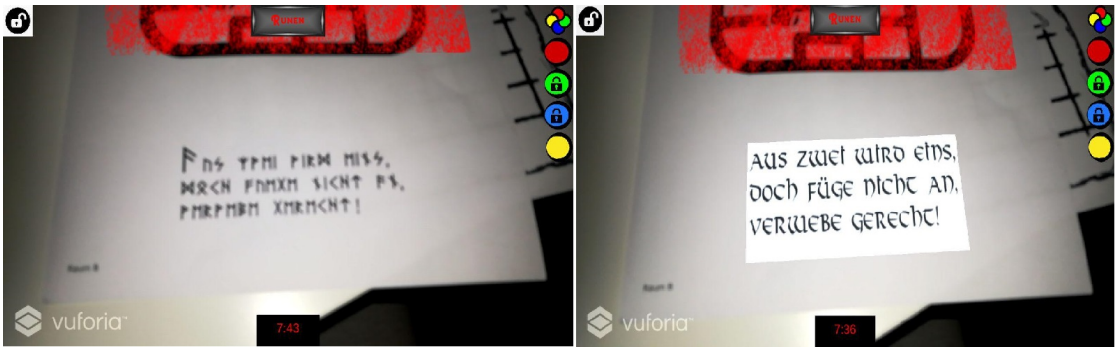


Figure 3.6: Runes without translation (left). Runes with activated translator (right)

Similar to the decryption algorithms, the application doesn't actually translate the runes, it just shows the corresponding text in the Latin alphabet. The runes on the paper are showing the actual clue though, and could even be read without the translator, given the corresponding knowledge.

3.4 Puzzles with 3D Elements

Similar to the VR versions, AR Games can use 3D graphics to enhance the game. There are different options: Enhancing puzzles with graphics to improve the user experience, or create puzzles that could hardly be done without a 3D device. Using devices like smartphones or tablets, the user can interact with these games by simply touching the screen. A raycast is then shot into the virtual world and intersects with the objects, enabling some things to happen.

3.4.1 Enhancement of User Experience

An example would be a puzzle, in which the players have to "sacrifice" three objects in the correct sequence to advance. This puzzle could easily be designed without any graphics, since the user just has to find out the right order of some things, but this would arguably be very dull. Instead, all things to sacrifice are rendered as 3D objects in front of a bowl with fire in it. The user has to touch the objects and an animation plays, showing them being thrown into the bowl. If the user selects them in the right sequence, he sees a visual input and knows he is done. This implementation promised a much better experience than having the same puzzle on paper.

3.4.2 Mini Games

Not possible in the real world, or at least quite hard to conceptualise without any gear, are games in which the objects change their status. Two examples of this were implemented. The first one, "Pipes", is a scene having several pipes in which the user has to rotate them until all pipes are connected. The other, "Bulbs", has several light-bulbs that change their on/off status when the user touches them. There are 8 light-bulbs. When the user touches one, it and its two neighbours switch their light. The goal is to have them all on. This puzzle is not particularly hard, but serves as a nice diversion from the more theoretical puzzles.

3.4.3 Searching Games

Also very difficult to realize in real world games, a window is created through which the user can see into space. There are some numbers among the stars; some are seen at once, but others are hidden. In order to find them, the user has to look at it from different angles, i.e. look from other positions with the device towards the marker. This is not a challenging puzzle, but it needs the user to think outside the box and look at the problem from (literal) different angles.

3.5 Marker Design

The general goal of the marker design was to make it unapparent that they are markers. Therefore no QR-Code-looking graphics were used, everything had to be a picture or text with some form of meaning. For puzzles with 3D content, the marker resembled what will be seen in AR, to give a hint of what to expect, and to make all markers memorable.

The players should have to try and scan every element on the posters to see if it hides AR content, because even the few clues which are just on the paper aren't any different from the actual markers in design.

3.5.1 Posters

Since the vision of this game is to play it by just getting the app and printing out the markers, we tried to keep all markers together on a number of DIN A4 papers, rather than having loads of differently sized single markers.

This resulted in the design of a few posters with different styles:

- Some contain a number of smaller markers for riddles and clues, together with print-only clues. This type of poster needs the players to come back to them again

and again to use all the different riddle parts on it, posing a small difficulty in not mentally marking this poster as done right away after the first riddle is solved on it. (See Figure 3.7)

- Most of the other posters contain just one of the bigger markers and maybe some relevant clues on the side. For this style it was important to have the whole puzzle and most of its clues together on one piece of paper, in order to avoid confusion. Examples of this would be the marker for our "Portal", in order to properly look into space the marker has to be quite big and is the only one on the poster, just a little hint written in runes is beneath it. (See Figure 3.8)

  Another example are the markers for the two mini games, "Bulbs" and "Pipes", which share a poster together with another important rune clue. The solutions to these two puzzles have to be combined, so it is important that all three elements are together here. (See Figure 3.9)

- One poster has a slightly different marker on it, because this one has a different AR picture for each of the four filters. Players have to come back to it and scan it again with every new filter they unlock to get a new puzzle piece to the final marker. (See Figure 3.11)

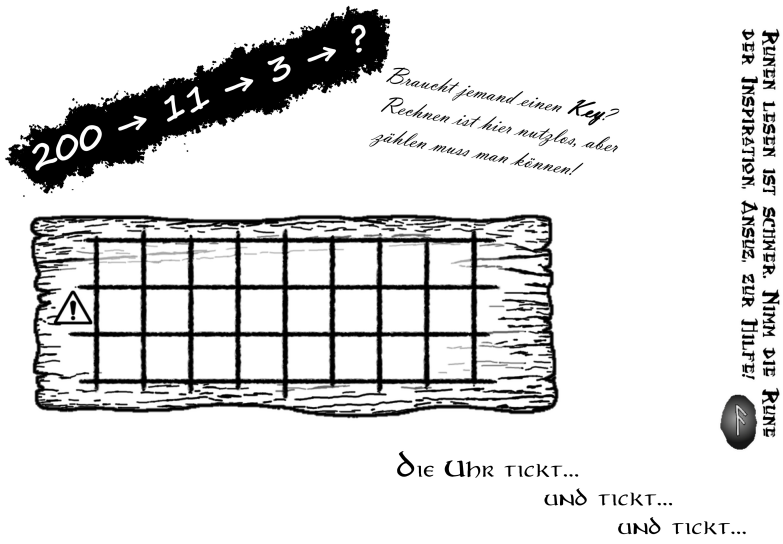


Figure 3.7: A poster with many smaller hints and riddles

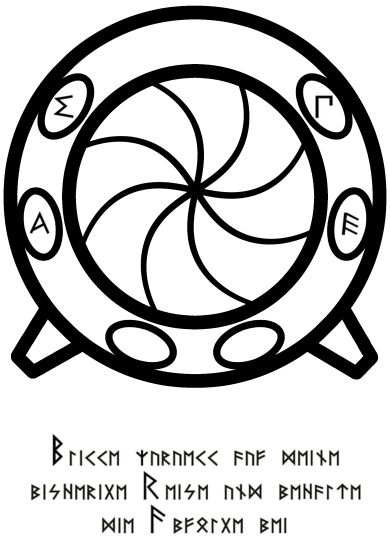


Figure 3.8: Poster for the "Portal"-puzzle

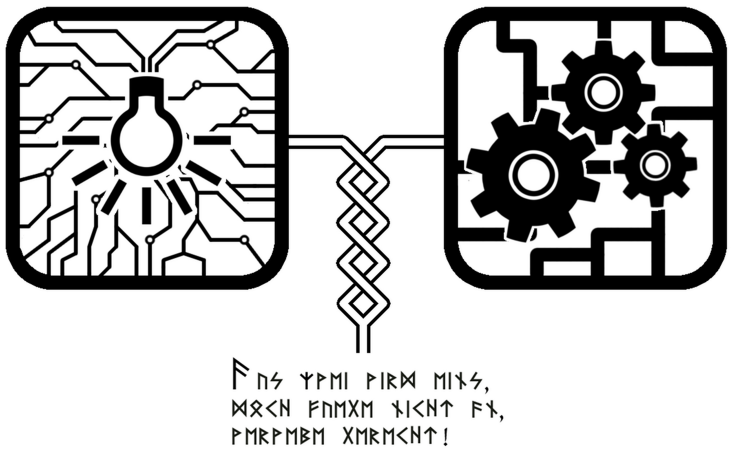


Figure 3.9: Poster for both mini games "Bulbs" and "Pipes"

3.5.2 Division into Two Rooms

Our initial vision of this game had two teams in different rooms in mind, that need to cooperate to escape together. In order to balance these two rooms, we tried to keep the

amount of puzzles and posters in each room about equal, as well as having a rough mirroring in types of posters and riddles.

Each room had one poster with many smaller markers on it, containing one of the most important split-up riddle, the tables (or matrices) that match up. One has letters and numbers in its grid, not making any sense, and the counterpart has markings in some of its cells. If the players read only the marked cells in the first table, they will get the solution. This poses a classic communication task. (See Figure 3.10)

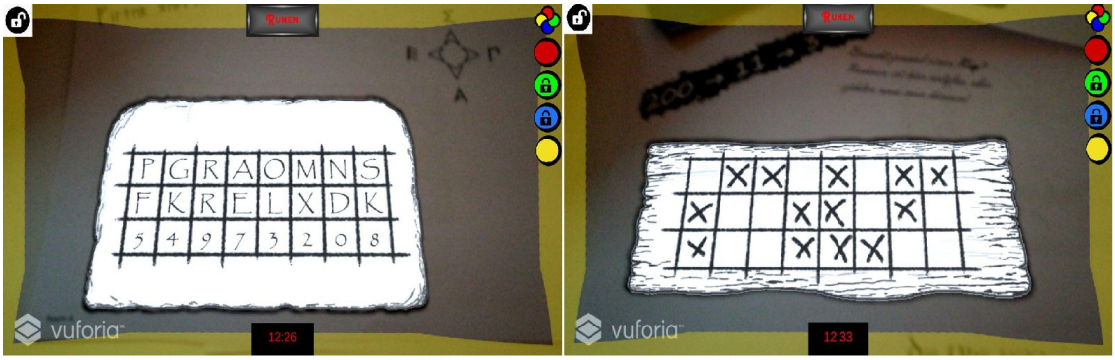


Figure 3.10: Table in room A (left); Table in room B (right)

While the tables riddle has been designed with two rooms in mind, other puzzles were simply split up in a similar manner, to keep both rooms balanced and engage more need for teamwork. One example where this could be done easily was Einstein's riddle. It offers six hints to solve it with logical conclusions, so we gave each room three of the hints. This does raise the level of difficulty as a side effect, since both teams can only get half of the hints in spoken form, missing the visualisation aspect, which often plays an important part in solving logic problems.

Besides the obvious split-up puzzles, as much dependencies as possible were created between the two rooms. Clues to a riddle are usually on the other side; if cypher and key are needed, they will be in separate rooms and so on. The four main puzzles, used to unlock the filters, were also placed equally in both rooms, so only one team can get the code for the next filter (although the second team has to help solve the riddle for them in almost all cases, so it's always a team effort), which then has to be communicated to the other team, so both can continue.

Towards the end, we wanted both teams to escape together, so the players from the so-called secondary room had to unlock something in order to get into the primary room. For this we had envisioned to use our "Portal" again. By following specific instructions from the other side, the team would be able to "commutate" the previous window into space to a path into the other room (Since people aren't able to crawl

through paper, despite the magic of AR, the portal would just instruct them to go into the other room once solved).

To create a justified need for both teams being in the same room (besides there only being a door into freedom in the primary room), the poster with the two markers for our mini games "Bulbs" and "Pipes" (See Figure 3.9) wasn't split up, suggesting having to solve both puzzles side by side, one for each team, and then combining both solutions into the code for the final filter. From there on only the wrap-up has to be solved and then both teams are free, to not keep all players in this small space for too long. The details on the mechanics of this final escape are described in the next segment.

3.6 Final Escape with Real World Elements

To finally get out of the room, we wanted to have something special instead of just another code or password, and it should feel like every part of this journey contributed something to this final effort. That's why there is the before mentioned marker, which can be visited again with different results for each new filter. In the two-rooms-setup, this was also split up into two markers which would each correspond to two of the four filters, so both rooms had to contribute half of the parts needed for the escape, but for simplicity this can be viewed as just one; in later versions of the game it became just one. (See Figure 3.11)

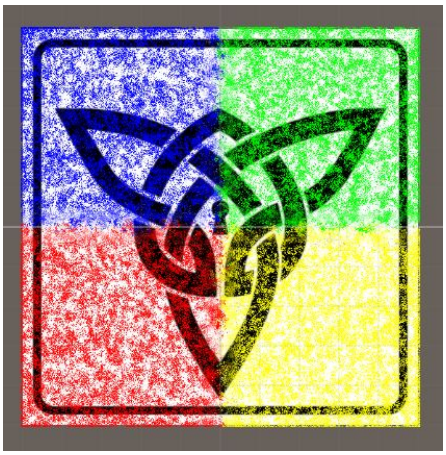


Figure 3.11: Marker with different contents for each filter

For this part of the game we have the only real life interactions with things other than the posters: Eight small marker pieces would be scattered across the rooms, from

which four make up the two-by-two marker that opens the final door. To find out which of these eight are the correct ones and in which position these puzzle pieces have to go in order to create the only scan-able marker, this special multi-use marker has to be scanned with every filter separately, each giving the position of one of the pieces. (See Figure 3.12)

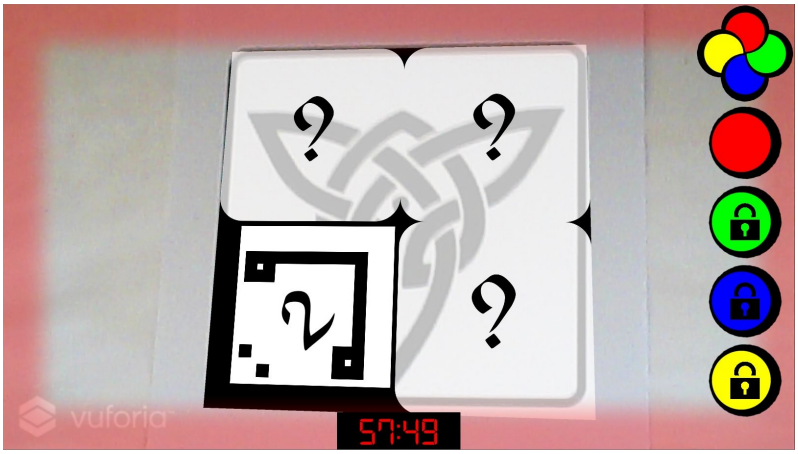


Figure 3.12: Active red filter gives one of four positions for the final marker pieces

The players would scan this multi-use marker with the first unlocked filter and hopefully recognize that it's pointing to one of these pieces in the room, so little by little the key to escape the room is put together over the course of the game.

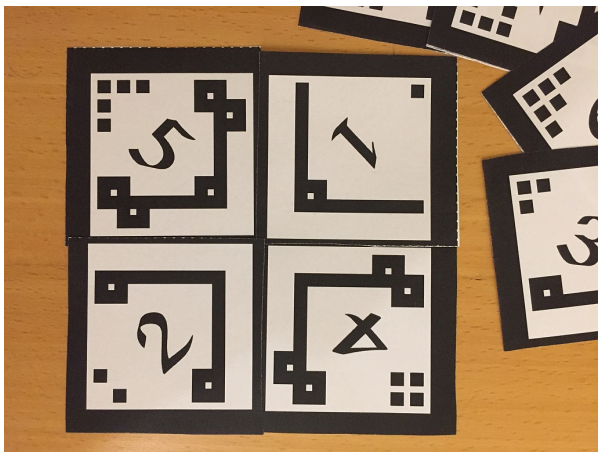


Figure 3.13: Marker pieces laid together

4 Testing and Overhaul

4.1 Demo Day

During Demo Day 2018, this project was tested by several groups with varying numbers of players. Two simple rooms were designed and build out of pin boards, in which up to two people were located. Both groups had to communicate in order to advance the game.

4.1.1 Demo Version

Since it became clear in the later stages of development that our game would be quite long, far too long for an event with hopefully lots of people wanting to check it out, we had to develop an abridged version.

While cutting out some of the longer puzzles, we had to make sure the flow of the game is still working as intended, resulting in a few swaps of puzzle positions and connections.

In detail, we left out two of the most difficult and time intensive logic puzzles, Einstein's riddle and the second part to the portal, which lets the players move to the other room. Instead we gave both rooms the marker for the final door, now locked with the code gathered from the planets inside the portal. In turn we also had to cut the part with collecting marker pieces.

In order to keep the more visual and interactive puzzles in the game, we put "Bulbs" and "Pipes" in front of the portal, since everything after wouldn't be in the game anymore. This of course led to only needing two filters. The first one is unlocked as usual with the riddle poem, demonstrating the use of the decoder function. This filter then unlocks the interaction puzzles, whose combined codes are used for the second and final filter, unlocking the offering platform and the portal. See Figure 4.1 for a visual representation of this abridged game structure.

While this demo version seems very short from just the description, the estimated 20 minutes given by the application's timer were many times still too short to solve all puzzles and escape the room.

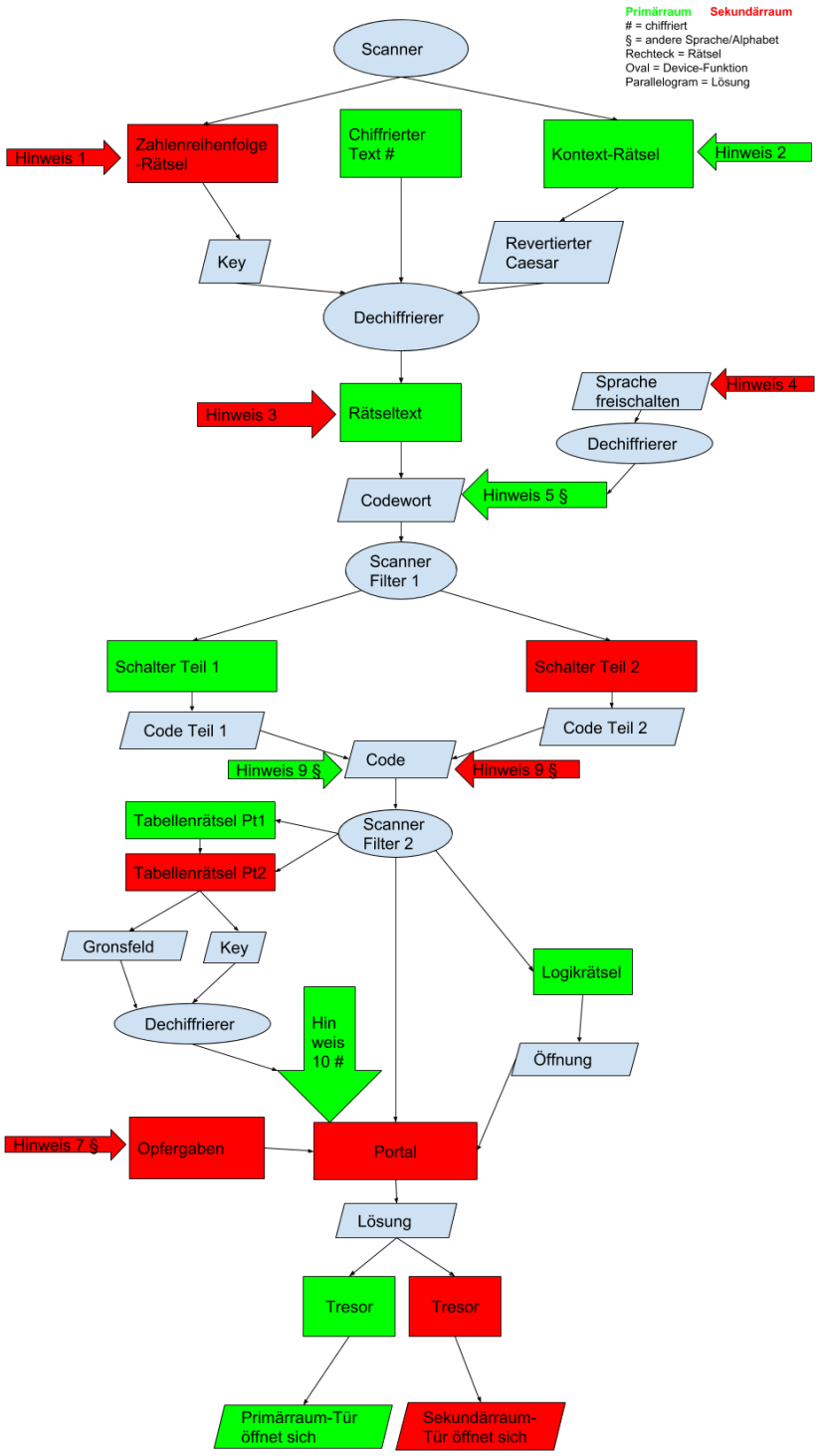


Figure 4.1: Flow Chart of the Demo Version

4.1.2 Feedback

The feedback was mainly positive, the players mostly enjoyed the game. However, there were some issues:

- Communication between the groups did not work well. Due to the nature of Demo Day, it was very loud and noisy, therefore people had problems hearing the other group.
- Without proper introduction to the game features, people had trouble understanding how to play the game. This could be solved by adding a proper tutorial to the game.
- If one group solved the puzzles in their room faster than the other, they had to wait for the other group until they could continue. Sometimes it also was not clear that in order to advance, they would need information from the other group.
- Some puzzles and riddles felt unintuitive. The players did not always understand what was demanded.

4.2 Version II

After Demo Day, we took all collected information, feedback, observations and issues, and redesigned the whole game accordingly, in both conceptual and implementation aspects. At this point only the shorter demo version was fully done, so it was a fitting time to have these changes take effect.

4.2.1 Conceptual Changes

The most apparent and drastic modification to the overall game design would be the decision to get rid of the split into two rooms. While this was an interesting and ambitious idea, we felt it brought up more problems than actually providing additional value and fun.

Some of the arguments that convinced us to make this decision were:

- Communication was very difficult at Demo Day. While it usually won't be as loud when the game is played, people playing this game might not always find two rooms where they can still talk to each other as easily as in the setup with just a pin board between them.
- Communication was also very ineffective from a human standpoint, meaning that very rarely players knew what information the other team would need. They

either tried to describe the markers in useless details, or, more often, didn't tell the others about found solutions at all or just forgot about talking with each other. While some aspects of this were envisioned exactly like that, posing as the natural difficulty in working together, it rarely worked out in the end and just brought up unnecessary confusion.

- In a similar fashion, players didn't recognize when they needed information from the other team to advance, or the other way around, not recognizing when they found something the other room needs. This problem could maybe be worked around by having the game tell the users when they need something from the other side or should share solutions, but that approach kind of defeats the original purpose; hand-holding isn't good design in an Escape Room.
- Asymmetry of solving speeds leads to waiting time. As we explicitly saw in our tests at Demo Day, it would happen almost after every riddle that one team solved something faster than the other, which then had to wait for information from the other room. Naturally this wasn't expected most of the time, so instead of waiting, the players confused themselves by trying to find the next clue, the next solvable riddle, but it just wasn't there. This interrupted the game flow heavily, and this happened almost after every riddle, alternating for both rooms.
- Finally, with the separation into two rooms we also halve our content for each player. The Escape Room game is at long as it would be in one room, but each player only gets to see a part of the riddles and puzzles. One might think this raises the replay value, but since both teams have to know all the solutions, that doesn't work.

While the communication issues could maybe be solved by designing and implementing some methods to prevent said problems, especially the last two arguments made it clear that the game would benefit greatly by fusing the two rooms into just one.

Additionally, at Demo Day we observed players having much more fun in helping each other, once we allowed the teams to go into the other room, if they had to wait on the other team at the moment. Essentially, all players went from one room to the other as a group, solving each riddle together and switching to the other side if needed, and had much more fun in that, despite the amount of walking involved.

Therefore the decision was made, the rooms were put back together, and the game structure had to be adapted accordingly in regards to all split up riddles. Luckily this wasn't too much of a task, since most riddles depending on solutions from the other team now simply depend on solutions from other posters within this room.

For example the riddle of the two tables, while it doesn't need exact describing anymore, they are still on different posters and matching the two contents together takes the same amount of effort.

Other riddles needed a slight redesign though, for example the two posters with each three hints of Einstein's riddle became just one with all six hints; same for the special markers that give different marker-piece positions with every new filter, instead of two markers with two filters each we now only have one, responding to all four filters.

For a complete overview of the games structure after all changes, see Figure 4.2. The colours of the elements now correspond to the different game stages, marked by their filter colour.

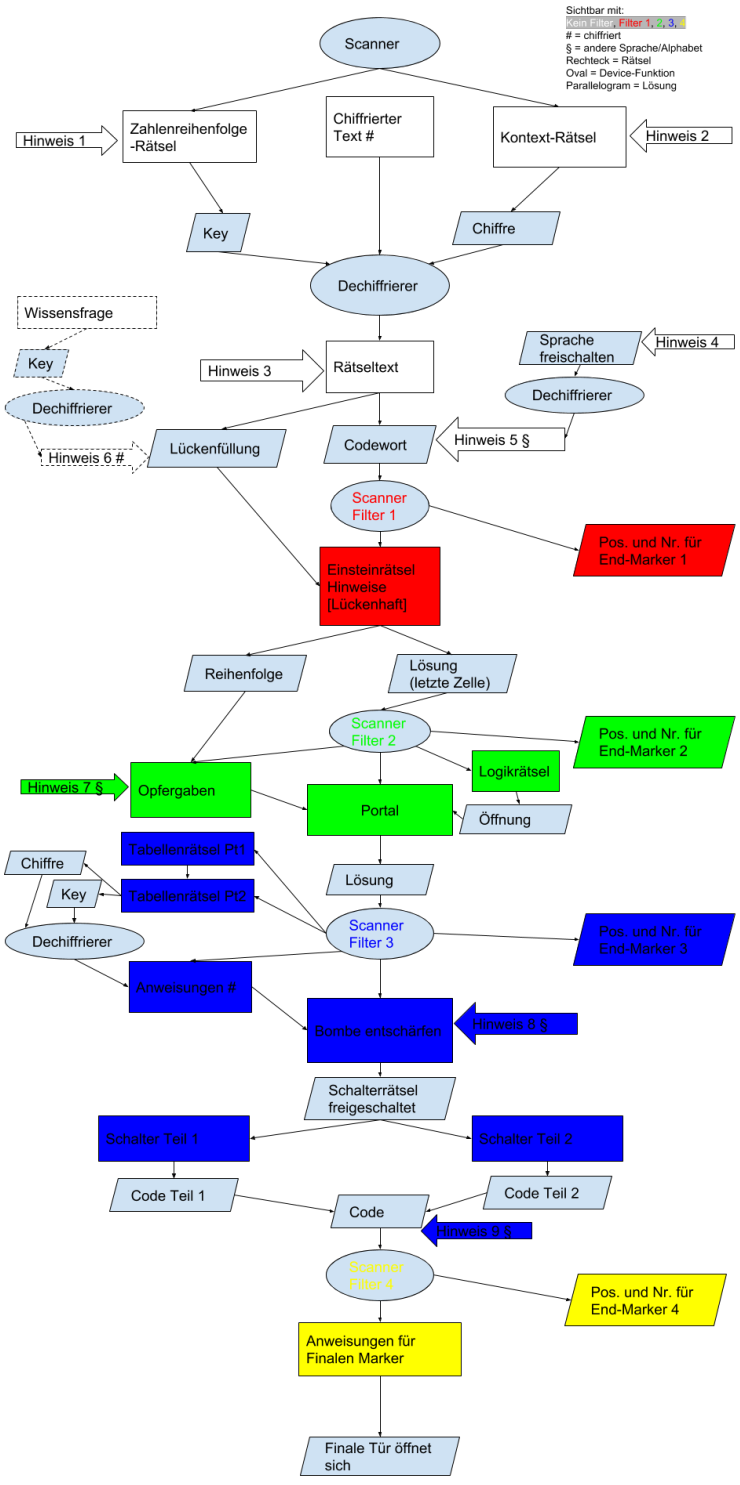


Figure 4.2: Flow Chart of Version II (final) of the game's structure

4.2.2 Implementation Changes

Puzzle Re-skin

One puzzle was impacted more heavily than the others: The "commutation" of the portal to get into the other room. It obviously wasn't needed anymore to get into the other room, but we didn't want to just delete this riddle from the game, especially since three other markers would become obsolete as well because of its dependencies.

Therefore a new place had to be found, resulting in a total redesign while the core mechanics stay the same. Instead of having to push the correct buttons on the portal to transform it into a path to the other room, the players now have to defuse a secret bomb inside of their device, that gets activated once the players scan any of the two markers for our mini games "Bulbs" and "Pipes" (since this was the point in the process of the game where the commutation of the portal had to occur). The mini games can only be solved once the bomb is defused. How this is achievable is still the same process as with the portal, somewhere in the room is an encrypted text (the tables-riddle gives cypher and key) that, once translated, provides instructions in form of some logical exclusion statements, to defuse the bomb by cutting cables on it. To provide a sense of danger, a wrong cutting try results in an explosion and a heavy penalty on the player's time limit. Once correctly defused, the mini games become available and the normal game can continue.

This is the only rather severe change we had to make to our riddles in terms of implementation, but the feedback and observations from Demo Day also resulted in some change to the application itself and the User Interface.

User Interface

Concerning the functions of our application and its UI, we observed most players having problems with knowing when to use which element, most problems occurred with the decoder. Although from a logical standpoint it should be quite apparent to use a function called "Decoder" when encountering an encrypted text, but the players seemed to forget about this element of the app regularly.

This issue can very well be solved with an extensive tutorial, but with our general overhaul a different approach was used. The UI now only consists of the button for the filters (with a more detailed description of it in the start screen), and nothing else. All other functions only come up when needed.

When scanning an encrypted text, the decoder pops up with a message similar to "Encrypted text identified! Choose the correct cypher and enter the correct key to decode the text." It shows the five Cyphers to choose from, each asking for a key once chosen. The cypher and key then get saved and stay active until reset by the user. If

any encrypted text gets scanned while a cypher is active, the game will check if it's the correct one and either display the decrypted text or pop up an error message saying that cypher or key may be wrong, and in turn open the decoder UI again.

With this method, the Rune Translator is of course no longer part of the decoder, but rather its own function of the UI, working very similar to the decoder. When a marker with runes gets detected, the interface for selecting a rune stone pops up automatically. Same as in previous versions, choosing a wrong rune stone results in a time penalty, while the correct one will activate rune translation forever, now translating any runes immediately.

Further changes include the locked filters now displaying a hint as to where the code can be found, to make it easier to match any found solutions from riddles to the place where they are needed, since this was very confusing in previous versions of the game.

The final version of the game now has a time limit of 60 minutes. While being about three times as much as planned and estimated at first, this time is still quite tight, depending on the abilities of the players of course. Coincidentally, most real life Escape Rooms also have a time limit of one hour, giving us a good insight into the amount of content of real Escape Rooms.

5 Conclusion and Future Work

5.1 Conclusion

The project was overall very successful. Our main goals were achieved:

- Markers can be easily printed, and with one hand-held device, the game can be played everywhere.
- The setup of this Escape Room is as easy as it gets, especially since it only consists of one room now.
- The addition of 3D graphics and mini games enhanced the gaming experience.
- The tracking and gameplay is fluent. No stuttering or lag.
- Our game has content for about one hour, with a high difficulty level and a large variety of riddles and puzzles.

5.2 Future Work

While the game is already promising, there is still much room to expand.

5.2.1 Split Into Two Teams

Sadly we had to scrap this idea for our project because it did not enhance the gameplay the way we expected, but we think there are several ways to get it working. The two main problems, communication and delay, have to be solved. For communication to work, there some way to contact the other team with the hand-held devices could be added. Some oral solution would be preferred, like a two-way radio.

The delay, that automatically happens when one team is faster than the other, leads to waiting and thus boredom. It is very hard, if not even impossible, to design puzzles such that both teams never have to wait.

Therefore, it would be better to add some things to do while the team is waiting. For example, some mini games or additional riddles that might give useful hints for later puzzles could be added.

5.2.2 Head-Mounted Display

The biggest disadvantage of using devices like tablets or smartphones: One has to hold them. Especially always having to point their cameras to markers can be tedious. Using HMDs could solve this problem, but they have their own challenges.

Due to the nature of the room in which the players often run from one marker to the other, only wireless HMDs would be suited. Also, every player now needs a HMD, since you can't share the view with a HMD like you can with a tablet. This would result into a very expensive setup.

Mini games that required touching inputs must be redone such that they can be played with HMDs. New ways of pointing to objects or even just clicking on the UI must be found.

5.2.3 3D Targets

The game mainly tracked 2D Targets, i.e. printed pictures. Vuforia allows complex 3D models to be tracked and augmented.

We already tried our hands at tracking 3D-printed statues as additional hints in the game, but hit a few problems. For example, due to unknown limitations only one database for a 3D object can be active at one time. Using more than one model will be more challenging.

5.2.4 Marker-less Tracking

Google's ARCore enables marker-less tracking methods and can be combined with Vuforia to create a game that uses both ways of tracking. The challenge is to find ways to utilize this tracking for Escape the Room games.

5.2.5 Expansion of the Core Game

We implemented one complete Escape Room game, but of course there is always room for more.

One option would be to put more riddles and puzzles into this Escape Room, which isn't even that hard to do, since we were working with game stages; adding more stages just takes some minor adjustments to the game structure, but can easily expand this room with double the amount of content or even more.

While that approach just adds to the length of the game, there is also the option to take the core structure and application of this project, and simply fill it with new riddles and puzzles. There is a lot of potential for expansion packs or new "modules". The application would need to be adjusted and made into a more flexible tool, so that a

variety of different Escape Rooms can be played with the same app, by simply loading up the module and printing the corresponding marker pack.