ESCAPE Y2K - An Integrated Escape Room

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***Abstract*—"ESCAPE Y2K" is an interactive escape room experience that relies on computer engineering as its main control source. The escape room is built to be an autonomous, immersive, sci-fi, horror experience. A variety of sensors will be used to accomplish this including a sonar range finder, noise sensor, pressure and heat sensors, nfc/rfid, and movement sensors. Other technology to be implemented includes image/audio processing, bluetooth, and digital/analog circuit design. A stretch goal for this project is to make this room modular and portable, allowing it to be set up in any place and with any size of room.**

One of the major themes of the escape room is time travel. The experience will run on a clock that ticks between 1:00 PM and 12:00 (midnight) where certain events are dependent on the time. This can include cabinets opening during a specific time interval or locks having different passcode combinations depending on the hour hand. Players in the room are able to rewind or forward the time however they wish based on the minimum and maximum the time can go. Past 8:00, the game will transition to a nighttime mode where fake windows in the room will shine a light to simulate a creature looking inside. If a player is caught in this light, the room enters a danger state and the team will incur a penalty to the amount of time they have to escape. This penalty will also occur if the clock reaches 12:00. The game will conclude either when the players all exit the room safely, or the game clock expires.

The maximum amount of time players will have to escape will be 30 minutes, however, this may lessen if the player clock reaches midnight or if any of the players are seen by the monster. Each puzzle will take between 3 and 5 minutes to solve, allowing for a maximum of 7 or 8 (maybe) puzzles. Another stretch goal is to create a pool of puzzles from which the room can draw, giving each group that comes into the room a unique escape experience. These puzzles will be hard, but will still be easy enough to actually allow players to enjoy the experience and not be frustrated by the difficulty level of the puzzles.

***Index Terms*—Analog, Embedded Systems, Escape Room, Horror, Interactive, Networking, Science Fiction**

I. Introduction

Escape rooms are a fun and engaging way to promote critical thinking and puzzle solving for children and adults alike. In most established escape rooms, there is a level of behind the scenes interaction with a room operator, triggering events and unlocking clues as the players progress. This usually works quite well and allows for some additional variability if the operator is given some creative freedom with how they run the escape room. However, it also has an inherited limitation with requiring an operator for the room to function. For our capstone senior project, we will create an autonomous escape room experience with multiple puzzles and random clue selection to operate with some level of variance without the requirement of an external human operator.

In general, innovation in the escape room industry is minimal; if you've been to one or two you've seen how pretty much any of them are going to work. The level of difficulty from room to room may vary, and some of the puzzles could be interesting, but there haven't been any groundbreaking changes made to the scene since its inception. Our goal is to create a system and design philosophy that will allow for a more streamlined and easily modifiable design process for making more complex and dynamic escape rooms. We will accomplish this with custom analog and digital systems, as well as a variable program to be executed on a central microcontroller to drive the escape room's interactive elements.

The theming of Escape Y2K is an time-traveling analog horror experience. The story and aesthetics of the room will be inspired by the public panic spurred from the unknown consequences to possibly occur as digital system clocks update their year count to '00', and the ambiguity between it's interpretation as '2000' (Y2K) or '1900'. The room will incorporate 'time-traveling' elements to play into this ambiguity and assume that a total system failure would happen in all digital systems when the game clock strikes 12:00 AM on the turn of the century.

II. Our Vision

Our vision for this project is to take a unique spin on the formula that is most commonly used in escape rooms. Instead of using a large amount of analog puzzles and a "host" that is in charge of controlling which parts of the room are locked and unlocked when players complete certain actions, the room will adapt and progress on its own as players advance through the various puzzles.

What is an escape room?

If you arent very familiar with escape rooms, the basic idea is to provide people with an interactive and exciting puzzle experience. Players start by being "locked" in a room (you're never actually locked in, for safety reasons) with a set of instructions that lead them through a series of puzzles. Some of these puzzles are more traditional, such as solving a cypher or figuring out a combination for a lock, while others make

the players think a little bit deeper. Many of these puzzles are on the simple size in an attempt to have a good balance of fun and difficulty. And, many of these rooms attempt to fit their puzzles within a certain theme, such as escaping from an Egyptian tomb or trying to escape from the zombie apcalypse [1].

History of Escape Rooms

There are a variety of escape rooms all throughout Utah and in other parts of the world as well. The phenomenon started between 1981 and 1984 with the introduction of TV game shows "The Adventure Game", "The Crystal Maze", "Fort Boyard", and "Knightmare" [1]. Other mediums, such as escape the room video games, were also gaining traction during these years and after, and in 2003 the first prototype escape room was showcased at GenCon Indy by an individual named Jeff Martin. 2007, however, was the first year when escape rooms really began to pick up speed with the creation of Real Escape Game by Takao Kato in Kyoto, Japan [2]. The first commercially available escape rooms began to show up in the United States around the years 2012-2014, and as of November 2019 there are over 50,000 escape rooms worldwide [1].

Our motive behind the project

Although not the first idea for our senior project, we feel that an escape room checks all of the boxes that we are hoping to fulfill with the project. Some of these requirements were that our project have some sort of meaning or functional purpose, that our project be fun or interactive, and that it be something that excited us as a group, not just as individuals. We originally thought of developing some sort of art piece based in computer science, which would have been given meaning and have had some form of interactability, but wouldn't have provided us with the level of fun we were hoping to achieve. We also thought of a variety of different games we could create, however, nothing seemed to really interest every member of the group. The escape room is something unique, interesting, interactive, and will hopefully provide those that are able to play with a fun and memorable experience!

How players will know what to do

Many escape rooms use a type of "Mission Video" to explain what is going to happen in the escape room [2]. For our escape room, we are going to use a tape player that gives the people in the room information about the story and why they are in the room in the first place. This tape player will also have other uses, which are explained in more detail in the section about all of the puzzles in the escape room.

III. What makes our escape room unique?

Because this escape room is being developed as a comuter engineering senior project, it will have a distinct emphasis on puzzles that involve imbedded computing, giving our room a deeper sense of connection between the separate parts. This means that we will be using technology as a central theme throughout the room to help convey the emotions that we are hoping the players will feel and also make the puzzles more interesting.

How horror plays a role

In life, horror is an incredibly good motivator. Imagine you are being hunted by some alien creature that is here to destroy the world and the only way to escape is so solve a collection of puzzles; you would gladly partipate! In our escape room, this exact situation is something that we will be utilizing to push players to solve the puzzles as fast as possible.

The Monster: All horror experiences begin with a mysterious and dangerous monster that is on the hunt. Our room will feature such a monster that will come out when spesific events are triggered or when the player clock reaches a certain time.

CRT TVs: Something that we wanted to incorporate into our escape room was a sense that you could still see the "outside world". Our original idea was to create some sort of false window box that we would mount on the wall or a TV with an image of "outside", but we decided to adjust that vision a little bit. Now the idea is more in line with the idea of analog horror, as we will be using CRT TVs to give players a glimpse into what is happening outside as Y2K approaches.

The main image that we will be showing on the tvs is a picture of the old Windows XP wallpaper (pictured below). This image will slowly shift to a more horrifying version of the wallpaper as the player clock advances, giving players a sense of the urgency that the world is going to end. Secondly, these tvs will be used as the windows through which the monster is able to interact with the players. We are hoping to find a way to fill the room with a red floodlight if the monster is looking into the room and a player is caught in its sight.

The tvs will be positioned in a way that prevents players from doing certain things while the monster is looking into the room (unless they're willing to take the penalty of being seen). Such actions include reversing/fast-forwarding time on the player clock, using the tape player,

Audio: We've got a subwoofer that were okay with pushing to its limits. This section is going to be about the peripherals we are using to interface with our audio devices and what we are going to do with the subwoofer to hopefully make the experience scarier.

Decoration

As previously mentioned, escape rooms are usually based around a theme that affects almost every part of the room. These things include the tools that the players are given, another list item, and especially how the room is designed. We have a few ideas for how we want our room to look, but the portability aspect of our room may make intricate decorations difficult. However, we want to make our escape room experience as multi-dimensional as possible.

IV. Initial Room Layout

While many aspects of our escape room are likely to be somewhat modular, and able to be re-arranged quickly, some

puzzles and in-game events will demand certain elements of the room to be set up in specific locations relative to each other. For example, the clock controls, game clock, and action clock should all be in close proximity to each other for ease of access. The CRT "windows" should form a cross centered on the audio cassette player to limit access to the player during certain events. Finally, certain props will be needing to be kept in repeatable locations or lock boxes for consistency in certain puzzles.

In the below diagrams, there are a few key elements to notice. The black boxes with white screens represent the CRT "windows" that will have sensors and lights to trigger during in-game events. The grey towers are filing cabinets, to play into the office aesthetic of the game. The light green slab on the desks in the corner is where we will have the chessboard, and the yellow head represents one of the busts that will be included in some puzzles. The center podium will hold the cassette player. Finally, the orange circle is the time clock, and the nearby green box represents the clock controls.

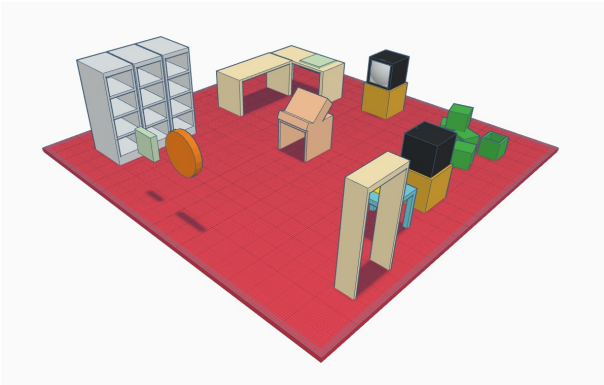

Fig. 1. Front isometric scale depiction of the initial escape room layout.

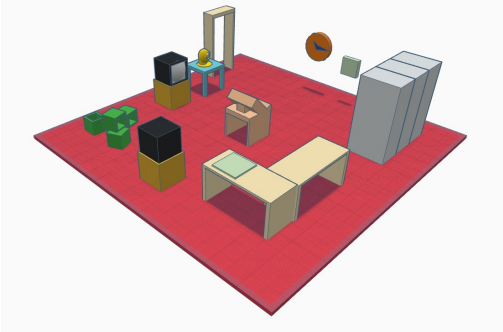

Fig. 2. Rear isometric scale depiction of the initial escape room layout.

V. Puzzles in our Escape Room

This section contains a list of all of the puzzles that our escape room will feature, as well as the solution to each of them. If you haven't already experienced the escape room, be warned that this section does contain spoilers and will prevent you from experiencing the joy of solving the puzzles on your own.

This section will be greatly expanded on as we decide what other puzzles we want to incorporate and how they will function. A stretch goal we have is to have a pool of around 10-15 puzzles that can be randomly selected, so that each time a player is in the room the experience will be different from the last. More may be added, depending on time contstraints and how many ideas we have, but this is the idea for now.

Furthermore, we want to develop puzzles that take between 3-5 minutes to solve. This will be a hard balance to achieve because we really want the puzzles to feel rewarding to solve, but also not frustrate the players to a point when they are no longer able to continue with the escape room. Various tests will be run on friends, family members, and anyone else who would like to help us tune the puzzles until they arrive at a happy medium.

A. *Chess Board Puzzle*

One of the main puzzles that our room will be centered on is a chess board in the center of the room. This puzzle will be one of the first things that players see, but also the last puzzle that they will solve. Throughout the room and after solving various puzzles, players will receive chess pieces that, when arranged in the correct format, will open the door that is keeping players in the room and stop the catastrophic end of the world due to Y2K.

We have two ideas for the chess board puzzle. Both ideas are based off the gold contact pins that are used to charge a pebble watch (and in other places in electronics as well). Basically, the idea is to have these golden pins in each (or at least a lot) of the spaces of the chess board, with a magnet underneath to help align the chess pieces when placed by the user. Only the pins that are used in the solution would be wired up, decreasing the amount of soldering that would be required to make the chess board and also leaving all of the other spaces as "dummy" spaces. The image below shows such a mechanism, one that would be used for charging a smartwatch.

For our first idea, we are thinking of imbedding resistors with different values into each of the chess pieces. Then, if the chess piece is placed on a space that is wired for the solution, the resistor value from that piece would be read and analyzed. If it is the correct value for that space, part of the puzzle would unlock. And, if every piece is placed in the correct location, the door to the room will open and the players will be able to escape!

The second idea is a bit less flushed out, however, the premise is the same. However, instead of using a resistor to denote which piece is in which location, we would hook up some sort of tiny microcontroller that has been programmed to, when powered on, just transmit its name over and over. This would allow a computer to read the value that is being transmitted and determine if the piece has been placed in the correct location.

Fig. 3. Depiction of the contact pins that we plan on using for chess piece identification.

B. Bust

A small bust of a statue's head will be attached on a disc and situated on a podium. This bust can be rotated physically, which will rotate the disc under it as well. On the podium is a small hole that may contain a key or chess piece. The disc will also have an indent on it. When the players rotate the bust, if the disc is rotated so that the indent is overlapping with the hole on the podium, the players are able to retrieve the key or chess piece. As a bonus, the direction the bust is facing will be either the lock the key unlocks or a clue as to where the chess piece goes.

C. Tape Player

An audio cassette player will be centered in the room, with one tape nearby to be played as players first enter the room. The general function of the tape player will be to both give the players story elements and instructions on puzzles as they play, as well as be used to play clues or hints to the active puzzle that the players are working on. Beyond these basic functions of the cassette player, we will run wires from our microcontroller and digital audio player into the built-in speaker of the cassette player to inject noises or music files while the cassette player is not actively in use, or no tape is even in the deck. This will add to the horror experience, and emulate rouge transmissions being received over the duration of the escape experience.

D. Encoded Audio/Radio Signal

There are many devices available to convert an audio signal, supplied via an AUX audio cable to a radio signal that can be transmitted via bluetooth or a similar radio protocol. One interesting application of this intended to be implemented in this project is to either have a personal voice recorder or audio cassette have a "key" encoded in the audio that will need to be transmitted to another device in the room to unlock a lock box or clue. For example, a voice recorder may be found which has a password spoken by a specific person's voice as a room access key. This recording will be played to the correct access point to complete the puzzle and unlock the next item.

E. Puzzle 5

F. All other puzzles...

Currently, we have this limited number of planned puzzles, but more puzzles are expected to be added as stretch goals. We plan on having this escape room experience last only between 20 to 30 minutes, but this is a flexable duration that may change if time permits us to add a system that selects only certain puzzles to be used in a given playthrough. This would allow for greater variability, and for users to play the escape room more than once and solve different puzzles each time. Once we have more base systems in place to make puzzles designing to be more streamlined, we can add both to the number and complexity of puzzles.

VI. Materials Needed

In order to have a functioning project that we can be proud of, we are going to need a lot of materials. A list of these materials have been included below

- Central microcontroller
- Visual sensors (on "windows" for sensing players)
- Analog or soft-image displays (to act as windows)
- Chess board
- Audio cassette player
- Writable audio cassette tapes
- MP3 digital audio controller
- Motors (To act as lock releases)
- Solenoids
- Wireless communicaion modules
- Storage containers
- Busts with detachable modules
- Turntable podium

Clock

The clock that we have planned to use will be controlled through a single motor that turns the dial used to set the clock (if you were planning on using it normally). We have already created a mechanism that will control the clock and also allow others to control the clock as well. Under no user input, the clock will function as normal, ticking forward at a constant rate of one hour per minute. There are also two buttons, a fast-forward and a reverse button, that give players control over the time that the clock is displaying. Once a button is pressed, the clock will spin quickly either forward or backwards, adjusting the events that are taking place in the room. An image of the clockhas been included below.

Our early prototype for this control is incredibly rough and does not use the microcontroller or the motor that we are hoping to use in the final project, and is mostly just a proof of concept. In the final project we are going to use a stepper motor that will allow us to have a much finer level of control over what time the clock is displaying, and will also help the central computer keep track of what time is being displayed. Furthermore, we are going to be 3D printing

Fig. 4. The big clock that we are using for the "Player Clock".

mounting brackets and other components that will help the motor stay in place, rather than the mess of broken popsicle sticks and duct tape that it currently is.

VII. Initial Mechanical Plans

Traditional escape rooms use physical switches and locks to prevent access to certain information or items until their related puzzles are completed or their key is found. Often, this takes the form of traditional physical locks, with either combinations or keys. For the players to find the combination, there is a puzzle with the correct combination embedded within it, or the combination is hidden in some other form of media. Physical keys can be simply hidden arround the room, or be teased to the players to hint at what puzzle must be completed to gain access to the physical key (like using magnets to move the key out of a hole). While we will incorporate these traditional lock methods in our escape room, we will also try to use more novel methods of controlling player access to resources via computer controlled elements.

A. Electromagnetic Locks

Because many of our puzzles will include some form of electronic elements, it will be easy to add a electromagnetic locking system that holds a door or drawer closed while the electromagnet is powered, and at the completion of a puzzle, the magnet is turned off to grant access to the contents within the container. While this can be a simple solution to controlling player access to key materials or information, it may not be clear for players to identify what container has just become unlocked. An auditory cue may be heard when the magnet deactivates, but if there are other sounds when this happens, it can be difficult to identify where in the room the magnet has turned off.

B. NFC/RFID

Another electrical access control system is near-field communication and radio frequency identification systems. These are often used for apartment and hotel access systems, and use either a keycard or fob with an internal inductive circuit to open doors. We could make use of a similar system to control access to certain areas of our escape room, but as this would require more specialized and expensive equipment, we will only use this if a later-designed puzzle would benefit greatly from its implementation.

C. Self-opening Motorized Latch Control

In order to take advantage of the more unique control elements available to us by using computer systems to control an autonomous escape room, we have devised a custom access control system that will hold a container securely closed when locked, and open entirely on its own when unlocked. It will include a system consisting of either stepper motors or servo motors, and a solenoid. If the container includes a hinge, it will only require one motor and solenoid, but if the lid will remove entirely, it will need at least two motors.

The motor(s) will have a metal arm attached to the motor shaft. This arm will rest between the door or lid of the container, and a metal plate attached to the inside of the door or lid when locked. This metal plate will only cover one half of the motor's movable range, and when the container is "unlocked", the motor will rotate its metal arm out from under this plate, allowing the door or lid to be freely moved. At this point, an active extruding solenoid will quickly activate and hit the door or lid of a container, to open it without the player needing to do so manually. This will remove any ambiguity about what container was just unlocked, so the players can quickly collect their earned materials and continue with the escape room experience.

VIII. Communication Protocols

As of now, we are trying to decide between two communication protocols that will be used to control majority of the connections in our room. These two protocols are Wi-Fi and Zigbee, and each of these have their unique benefits associated with them. A third communication protocol, bluetooth, is also something that we are thinging of incorporating, however, this will be more of a secondary communication protocol and will not be the driving force behind how our components will communicate with each other.

Wi-Fi

Wi-Fi will act as an incredibly reliable and secure option for our senior project. One of the benefits of Wi-Fi is that is it so widely supported. There are lots of libraries that would make communication and connection over Wi-Fi as simple as possible. Plus, the connection range is incredibly good over Wi-Fi, and the data rate is quite high (around 54 Mbps) [4]. There are two drawbacks to Wi-Fi, however, the first being that it uses a bit more energy than Zigbee to operate, which may become a problem depending on how many of our components

need to operate on a portable energy source. The second is that there are so many other devices that operate using Wi-Fi, and we may want the privacy that a connection through Zigbee would provide.

Zigbee

On the other hand, Zigbee would be an interesting option for a variety of reasons. The most beneficial reason to using Zigbee would be its topology. Zigbee uses a mesh network topology, which allows each of the network devices to connect with one another, rather than being dependent upon a central hub to manage the details of the escape room. This would decrease the number of "network-hops" a command would need to traverse, allowing components to tell locks when their puzzle has been solved. We may end up needing a central hub, so this benefit could nullified, but I digress. Furthermore, Zigbee is much less widely used than Wi-Fi providing us with a unique experience when trying to get all of our components to communicate with one another. It also consumes less energy and has a lower data transmission rate than Wi-Fi (maxing out at 250 Kbps), which could help our wireless components be more energy efficient [4]. These details are yet to be explored, however, and will need to be more properly considered when we have a more developed plan as to what our escape room is going to require.

IX. Risk and Mitigation Assessment

There are various risks that we have identitifed, however, more may present themselves as we progress through the project. One of the major risks is the possibility of the items and puzzles in the escape room potentially breaking which would make the room impossible to complete. A way to mitigate this risk is to have a manual override that can be activated if a puzzle is not working as intended. It would also be wise to have substitute puzzles that can swap in for puzzles that do not work.

There is a risk of evacuation in the case of any emergency that can occur while players are enjoying the escape room experience. Having cameras installed in the room will allow the game moderators to keep watch on the players for safety. On top of this, a way for players to communicate with the game moderators allow for anybody to exit whenever they like. A manual override on the lock for the door also means that the players are never truly locked inside.

Players in the escape room will most likely come across parts of the room that are not part of the experience and can potentially cause harm if not handled properly. This may include an outlet on a wall that is installed in the room beforehand or other electronic components that break easily. Having signals used for these objects, the risk can be mitigated by letting players know that they should not be touching or considering that as a part of a puzzle. This can be done with red tape, where players are instructed that anything with red tape on it is not part of the escape room and should not be touched.

X. Testing

Different puzzles and modules of the game will be tested before combining them all into what will become the escape room. Each module will have its own specifications on what it should do. For example, the chess board puzzle will have lots of different combinations tested just to make sure that only the correct one will trigger a signal, which later will be the signal that allows the players to leave the room. Modules will also be tested on durability to make sure it is sturdy and not prone to easily breaking. Players will be instructed to treat every object with care, so hopefully the modules will not be tested of their strength outside of the testing environment.

When each module is tested according to their specifications, and works with small testing programs, then they will be combined into the bigger room script of the game. From there, testing will be done for the room as a whole to make sure that players are able to complete it. It may also be necessary to bring in people unfamiliar with the game to try it out themselves, that way feedback can be given of whether certain puzzles need to be harder or easier. For the stretch goal, each possible combination of puzzles would have to be tested to make sure there are no dead end routes.

XI. Resources

We are going to need a lot of resources in order to complete this senior project. Our escape room is going to be marginally different from other escape rooms that we have encountered in the wild due to the autonomous nature of the project. However, one of the resources that we will be taking advantage of are other escape rooms, as we would like to do a few before next semester to use them as inspiration for the puzzles that we will include in our own escape room.

Furthermore, we are going to be doing a fair amount of research to find documents written by people who have attempted projects similar to ours. One of which is from a group of Germans who titled their paper "Teaching Embedded Systems by Constructing an Escape Room" [3]. Their escape room was constructed as a collection of individual projects completed by various groups of students, however, the escape room that they were able to create is a great source of inspiration and we will be on the hunt for other articles such as this.

XII. Demo

The demo planned for this proposal is the clock that will be integral to the puzzles in the escape room. Players must be expected to manipulate this clock to activate certain events in the game, along with the clock moving by itself throughout. Thus, a big analog clock will have controls tied to it that either moves it forward in time or back in time. The clock cannot go before 1:00 or past 12:00, and whatever time the clock is at should be able to be read by a computer.

Likely, the analog clock will most likely just be a display to an internal counter that counts on its own based on clock speed. By pressing either a "forward" or "reverse" button, the counter will increment or decrement and update the display

on the clock alongside transferring the value to a computer. This will make the time easily stored and tracked which will help towards scripting certain events in the escape room.

XIII. Conclusion

Conclusion

References

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