ESCAPE Y2K - An Integrated Escape Room

1st Kyle L. Sedgwick
College of Engineering
University of Utah
Salt Lake City, U.S

2nd Jake D. Bales
College of Engineering
University of Utah
Salt Lake City, U.S

3rd Nami Eskandarian
College of Engineering
University of Utah
Salt Lake City, U.S

***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 using digital/analog circuit design, image/audio processing, communication protocols, and embedded computing. Players will interact and solve puzzles under a time limit while avoiding fictional threats within the game in order to complete the experience and win. This is done with a time travel mechanic that allows players to forward or reverse an artificial clock that changes the time within the room and activates certain events that could both benefit and disadvantage them.**

***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 created 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 allows for a more streamlined and easily modifiable design process for making more complex and dynamic escape rooms. We accomplished 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. Background and 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.

One of the major themes of the escape room is time travel. The experience runs on a physical game 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 darker, nighttime mode where more horror elements will come into play that can affect the game's timer. The demonstration of Escape Y2K uses a eight minute initial play timer, which players have the ability to extend using codes found in the escape room. Unlike other traditional escape rooms, in Escape Y2K, solving time is not a given hard limit, but rather an asset which can be expanded or reduced by player actions. In a final, perminant installation of Escape Y2K, the starting time would be expanded to 20 minutes to allow for more exploration to occour before being dangerously short on time.

What is an Escape Room?

Escape rooms provide participants with an interactive and exciting puzzle experience. Players start by being "locked" in a room (for safety reasons, players are never really locked inside) 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 [**?**].

III. What Makes This Escape Room Unique?

Because this escape room is being developed as a computer engineering senior project, it will have a distinct emphasis on puzzles that involve embedded 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.

The Story

Our escape room will be inside the office of a computer engineer/scientist acutely aware of the existential threat of a time traveling beast capable of destroying the world as we know it when the turn of the century occours on new year's day 2000 (Y2K). At this time, the beast will gain access to our dimension through a software oversight with how dates are stored in computer systems of the time. The correction to this global flaw rests in the office the players find themselves in, and they must hurry to disseminate the correcting code before time runs out and the beast escapes.

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: Many 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 specific events are triggered or when the player clock reaches a certain time. If the monster is revealed to the players, this will activate an event which will speed up the game timer which shortens the time it takes to complete the room. The monster is an active threat that the players must watch out for to avoid losing precious time to solve every puzzle.

CRT TVs: An original idea for the escape room was to create some sort of false window box that mounts on the wall or a TV with an image of "outside world", but the vision had to be adjusted a little bit for flexibility. Now the idea is more in line with the idea of analog horror, as stationary CRT TVs give players a glimpse into what is happening as Y2K approaches.

The main image that the tvs show is an animated version of the old Windows XP wallpaper (pictured below). This image will slowly shift to a more unsettling, discolored version of the wallpaper as the player clock advances. If the clock reaches midnight, the monster event will occur which speeds up the game timer. At any time if the players choose to speed up or reverse time, the TVs will play an effect similar to fast forwarding or reversing a tape. Using a microcontroller, multiple video files will be stocked and played on the TV depending on the state of the game. The time position chosen for the video is also synced with the time on the clock.

Fig. 1. The image shown on the TVs. As time goes on in-game, the scenery gets a little more disturbing.

These TVs are also where the monster will appear to the players during the monster events. At certain moments during the nighttime segment, a light will occasionally shine out of the television screen across the room. This light acts as the "vision" of the monster, and if a player is caught in the light then the monster will appear for the players, speeding up the game timer. During this monster event, time will stop and the players cannot change the time until they exit the monster's field of vision. To detect players, a proposed idea is installing a camera onto the TVs and using image processing to find players that are brightened by the light. There is also the potential solution of requiring players wear a vest with a color that the monster detects. The microcontroller will communicate with the central computer running the game to know what to play and notify if a player is detected.

Fig. 2. TVs shine light that can reveal players to the monster.

Audio: Audio is one of the most important elements of both horror experiences and enviornmental storytelling. In this escape room, we will be making extensive use of hidden speakers, audio distortion, and mechanical sound production to create a deep auditory experience for the players. Many sound effects and voices can be stored on a micro SD card of a MP3 controller to be triggered during certain events, or make the cassette player "play itself" when no tape is inserted (by hijacking the speaker wires). Auditory cues will be implemented when unlocking different boxes using electromagnets, solenoids, or other mechanical devices to make a directly more

natural sound. We intend to keep the players engaged and "on edge" with unexplained noises being a frequent occourence.

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. Project Implementation

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 TVs should be pointed across the audio cassette player to limit access during certain events. Finally, props need 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 TVs that 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.

Safe-Cracking Puzzle

A. Potentiometer Tuning

Radio Number Station

B. Audio Control and Tapes

C. Props and Hints

D. Adding Time

E. TVs, State, and Detection

F. Time Control and the Clock

G. Circuit Design

H. Box Control

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.

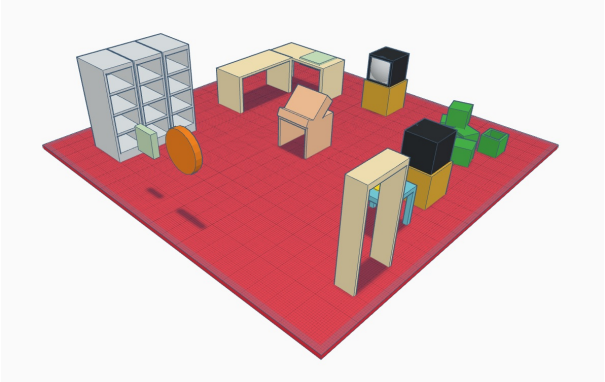

Fig. 3. Front isometric scale depiction of the initial escape room layout.

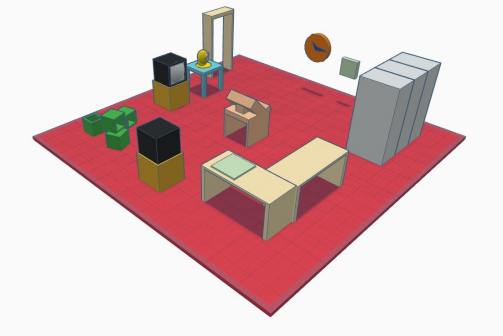

Fig. 4. Rear isometric scale depiction of the initial escape room layout.

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

We have three ideas for the chess board puzzle. Two of the three ideas are based off the gold contact pins that are used 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.

The third and final idea is to use magnetic switches underneath each of the places where we are wanting the players to put the pieces. Each piece would have a magnet inside, and when they are all placed on the correct squares the final door to the room would open. This solution is most assuredly easier since we are no longer able to identify which piece is in a given square. However, if we are unable to figure out a good way to implement the previous two solutions this is a definate option.

Fig. 5. Depiction of the contact pins that we plan on using for chess piece identification.

For our first idea, we are thinking of embedding 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, when a button is pressed then the door to the room will open and the players will be able to escape! This will likely be done by communicating to the central computer when the button is pressed whether the players have successfully completed the puzzle or not.

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.

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. Pressure Sensitive Chair

Another idea that we have for a puzzle is something that requires every member of the escape room to participate. Essentially, the idea is to have a number of chairs scattered throughout the room. Within each of these chairs we will embed a pressure sensor that can detect when one of the players in the room has sat down in that chair. Once every player in the room sits in the chairs that are scattered about, a lock of some sort will open and the players will be able to progress!

In order to properly implement this puzzle we are going to need a few things. First of all, we are hoping that the players will be able to move the chairs around the room freely, giving the illusion that they are just normal chairs. This is going to require a small microcontroller to be hidden within the base

of the chair that has Wi-Fi capabilities (most likely the ESP 32 board, due to its small size and on-board Wi-Fi) and at least one GPIO pin to detect the change in pressure when a player sits down on the chair. Furthermore, the board needs to have a relatively low power consumption so that the chair battery doesn't die during the length of time the players will be in the escape room.

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.

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, a motor spins the clock either forward or backwards, adjusting the events that are taking place in the room. An image of the clock has been included below.

Fig. 6. The big clock that we are using for the "Player Clock".

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 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.

On top of the game clock is the game timer which will be displayed next to the door. This timer shows the remaining amount of time left to complete the game and is visible at all times. When the monster is revealed to the player during certain nighttime segments, the timer will go down at a faster rate which will dissuade players from getting the monster's attention. Using an LED display, the time will be outputted based on the value retrieved from the central computer's internal timer.

VI. Evaluation

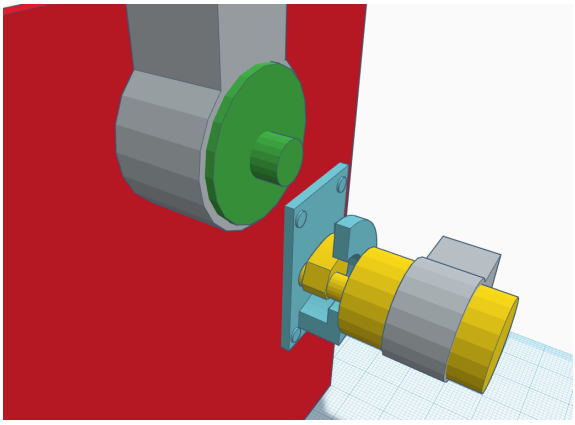

Fig. 7. When the motor arms are under the metal plate, the container remains locked

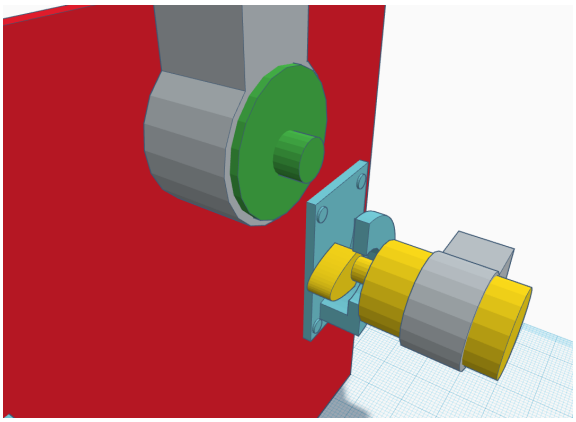

Fig. 8. When the arms are rotated out from the metal plate, the container is unlocked and can manually be opened.

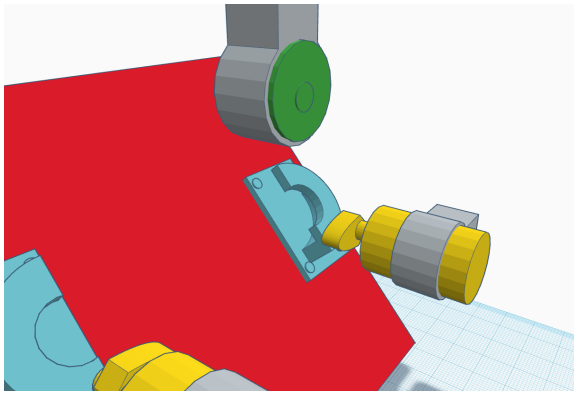

Fig. 9. The internal solenoid can be used for several effects. For example, when facing the container opening, it can pop the door open automatically. If it is facing a wall, it will create a knock sound, or if it does not contact with anything, it can make a clicking noise to signal the box is unlocked.

VII. 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) [**?**]. 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 [**?**]. 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.

VIII. Conclusions

In conclusion, we are confident that this project will help us grow and become more capable engineers in the future. We are going to learn more about how to deal with lots of interconnected micro-systems, how to create a compelling and immersive story, how to properly document and track our work, and how to work together as a team on a long-term development project. All of these things are incredibly valuable to prospective employers, and we are excited to leave college as prepared as possible to enter the workforce. Furthermore, this is a project that we are all incredibly excited about, which will help us produce something that we can be proud of by the end of next semester!

IX. Appendix A: Reference Material

A. Bill of Materials

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

- Programmable microcontrollers
- Analog clock
- Cameras
- Small CRT televisions
- Chess board and pieces
- Audio cassette player
- Writable audio cassette tapes
- MP3 digital audio controller
- Speakers
- Motors (To act as lock releases)
- Solenoids
- LED Display
- Adjustable RGB lights
- Wireless communication modules
- Storage containers
- Busts with detachable modules
- Turntable podium

X. Appendix B: Troubles of note during development

References

[1] "Escape room," Wikipedia, 10-Feb-2023. [Online]. Available: https://en.wikipedia.org/wiki/Escape_room. [Accessed: 24-Mar-2023].

[2] A. Ascalon, "Escape rooms: Everything you need to know (2022)," Escape Rooms — Everything You Need To Know (2022), 01-Dec-2022. [Online]. Available: https://theescapegame.com/blog/what-is-an-escape-room/. [Accessed: 24-Mar-2023].

[3] M. Pfeifer, B. Völker, S. Böttcher, S. Köhler, and P. M. Scholl, "Teaching embedded systems by constructing an escape room," Proceedings of the 52nd ACM Technical Symposium on Computer Science Education, 2021.

[4] B. Priya, “What are the differences between Zigbee and Wi-Fi,” Tutorials Point, 17-Mar-2022. [Online]. Available: https://www.tutorialspoint.com/what-are-the-differences-between-zigbee-and-wi-fi. [Accessed: 03-May-2023].