

ESCAPE Y2K - An Integrated Escape Room

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Abstract—Escape rooms engage player's critical-thinking skills by placing them inside a locked room that requires them to complete puzzles in order to escape. These rooms can be difficult to create and control due to the amount of variables present and the fact most of them require someone behind the scenes to control the room. “ESCAPE Y2K” is a science fiction analog horror escape room that differs from usual implementations by being completely autonomous. This room uses digital/analog circuit design, image/audio processing, communication protocols, and embedded computing for its puzzles and game flow. Players are able to “travel through time” to activate unique events that assist progression through the room which is controlled by a central server that runs a script that sends and receives signals to ESP modules throughout the room. This escape room was presented on the Computer Engineering Capstone Demo Day where students and faculty got to play with a chance to escape the end of the world!

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. Potential exists for an autonomous escape room where players follow a game script without the requirement of an external human operator. This project determines to create a system and design philosophy that allows for a more streamlined and easily modifiable process for making more complex and dynamic escape rooms. Custom analog and digital systems, as well as a control program executing on a central server drives the escape room’s interactive elements. A solution such as this can greatly heighten scopes and stakes of escape rooms in the future, providing uniquely exciting experiences for the players and eases the jobs of the room owners due to automation.

The escape room created for this demonstration is “ESCAPE Y2K”, a science fiction analog horror experience. Inspired by the public panic caused by the Y2K scare, spurred from unknown consequences as digital system clocks update their year count to ‘00’ and the ambiguity between it’s interpretation as ‘2000’ (Y2K) or ‘1900’, “ESCAPE Y2K” will be set before the start of the new millennia on January

31, 1999. Due to technological disturbance, scientists have discovered a creature that will destroy all of humanity, its presence and danger felt in televisions spread across the room. It is up to the team of players to discover how to send this creature back using puzzle solving and time travel. Using a remote to forward and reverse a clock that represents in-universe time, they can stop the year from turning to 2000 which causes total system failure and humanity to end. This inspires the tagline of the game: “Don’t let the clock strike midnight.”

II. BACKGROUND

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. Escape rooms may also have themes to them for world building such as an Egyptian tomb or trying to escape from the zombie apocalypse [1]. In order to successfully escape, it is expected that the team of players all work together to solve every puzzle before time runs out.

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. A similar idea was done by the 2021 Technical Symposium with “a course with the overarching goal of designing and constructing an automated escape room” [2]. Outside of that however, most of the effort will be drawn from a creative process for telling a story; providing presence to players by immersing them with puzzles using old technology. Old phones, cassette players, televisions, and other props from the Y2K era will be modified for horror and also allow for puzzle solving. All of this will be done with the explicit purpose of showing off the wireless communication between the server and the puzzles to keep track of player progression.

III. PROJECT IMPLEMENTATION

Most aspects of this escape room are modular and able to be re-arranged quickly, but some puzzles and in-game events will demand certain elements of the room to be set up in specific locations relative to each other. The CRT TVs should be pointed across the audio cassette player to limit access during certain events. They must also be in positions such that players can actually avoid detection. Finally, props need to be kept in repeatable locations or lock boxes for consistency in certain puzzles and ease in resetting.

A. Safe-Cracking Puzzle

One of the puzzles that implemented was a safe cracking puzzle. A hint for this puzzle was recorded on a cassette tape that would help the players know which numbers they needed to turn the safe to. Once the puzzle was reset by turning the dial to zero and holding the reset button until the lights flashed, if they turned left until they got to 33, right until they got to 72, and left again until they reached 11 then the puzzle would be solved! However, players were only able to solve this puzzle when the player clock (the giant physical clock) displayed a time between 2:15 and 4:30. If all of the above conditions were met, a puzzle box would open, showing them a plugboard combination. An image of the puzzle has been included below.



Fig. 1. This was the safe dial puzzle that was included in the escape room.

B. Potentiometer Tuning

The potentiometer puzzle does not provide a direct solution with clear feedback on how it ought to be solved. Instead, the four dials need to be placed in the correct orientation by trial and error. This puzzle uses the analog signal inputs to find the voltage between each pair of potentiometers for a total of three analog signals. Because this puzzle uses analog signals, the ESP module boards are unable to be used as they have no analog capabilities.



Fig. 2. The potentiometer puzzle. The left LED is always on, while the right only turns on upon completion.

The five LEDs on the box light up when the respective voltage across the pair of potentiometers is in the correct range (like variable voltage dividers). Because they need to either be determined as “correct” or “incorrect” without any variability between them, the LEDs are set up with digital signals to turn on or off when the correct voltage is reached. The first (furthest left) LED turns on when the device has power, and the last (furthest right) only turns on when the middle three are illuminated and the correct time frame is shown on the clock. The remaining LEDs are interdependent on one another, and do not hint at the correct position of any individual dial, only when all four are in a valid orientation together.

C. Radio Number Station

The “number station” puzzle utilizes the most abstract clue of the three main room puzzles. Unlike the other puzzle clues, there is no hint at to what box to use. The tape itself only contains five numbers to align with a box that has five number switches. The A side of the tape is played in reverse, so it is nearly impossible to understand what numbers are being stated, but a hint printed on a separate sheet of paper urges the player to listen to the message backward by flipping the tape over. While this is not how cassette tapes physically work, the B side of the tape is recorded separately with the audio playing forward. The static and information on the tape is inspired by “number stations” that were played on radio transmissions during the cold war.

Once the players listen to the recording in the correct orientation, they are able to simply use the number switches on the provided box to enter the stated combination. The switches output signals based on the binary values of each number, which are decoded by an Arduino Uno to determine when the puzzle is complete. Like the other three initial puzzles, it is

not fully determined complete until the correct combination is displayed and the correct time frame is reached in the game clock.

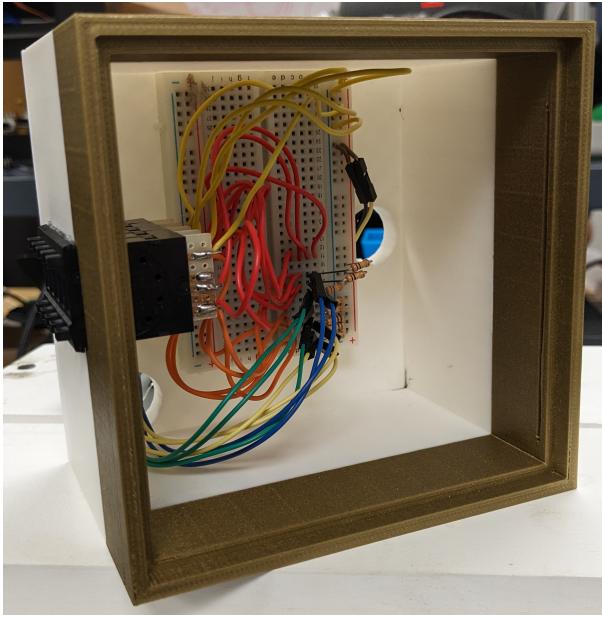


Fig. 3. The internals of the number station puzzle. The black box on the left is the number switch module.

D. Audio Control and Tapes

The interactive nature of an escape room leads to several factors being included just for the sake of immersion. The audio tapes found in the room provide vital hints, but two devices in the room contained additional circuitry just to play sound effects without the players controlling them. Accomplishing this task required a ESP module (which hijacked the power from the host device boards) and a SD card-reading MP3 player (controlled by UART between the ESP and itself). The main program would communicate to the ESP modules to play sound effects either randomly, or when particular events occur. For example, the “scream” sound effect could be played randomly to startle players in the room while the “monster footsteps” would play when the entity was about to trigger its seeking event. For the sake of a more entertaining demo, the control panel application could be used to manually play any of the pre-recorded sound effects on the tape player or telephone dock.

Recorded audio hints were more vital to the escape room’s completion, but did not need to be included in the room’s programming (with the exception of the final hint). The audio cassettes each contained a hint on the A-side of the tape for players to put into the tape player to listen to (which was independent of the remote-triggered sound effects). We did not need to modify the mechanical parts of the cassette player for this project, only the electrical parts.

The final hint did require wireless signals to play, as opposed to the recorded tapes. After completing the second puzzle, players are given a key that grants them access to



Fig. 4. MP3 controller and speaker inside of telephone dock.



Fig. 5. The central audio tape player, with modified internals.

a telephone handset. The charging contacts were shorted so when they are placed on the dock, the ESP module in the dock detects the phone was put down and signals the internal MP3 player to play the final hint (which is stored on it’s SD card). Unlike the other hints, this recording only plays once, demanding the players pay close attention before it turns off for good, adding an additional element of intensity to the room.

E. Adding Time

Originally, the idea was to give players a set amount of time to complete the room. Fifteen minutes seemed to be a reasonable amount time to give them because the puzzles were designed to take about 5 minutes each to solve and there were three puzzles. However, the nature of the room brought a wonderful idea to play with. Players not solving the puzzles might just be standing around for a large majority of their time in the escape room. In an effort to keep everyone bustling about, one puzzle was set aside for a special purpose. This puzzle has a keypad on the face, and when a correct combination was entered it would give players an extra minute to escape the room. An image of the keypad box has been included in Figure 7.

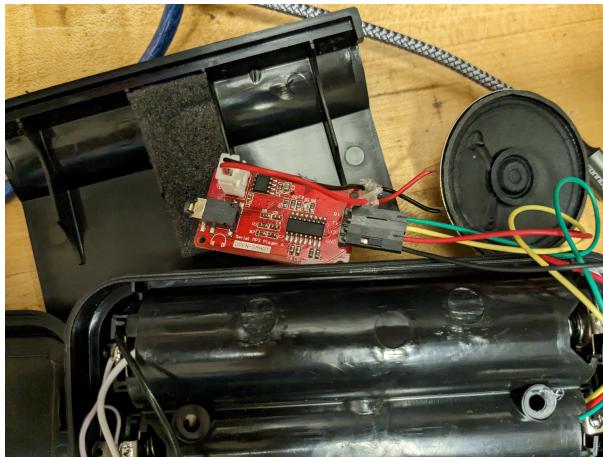


Fig. 6. MP3 controller and speaker inside of cassette player battery door.

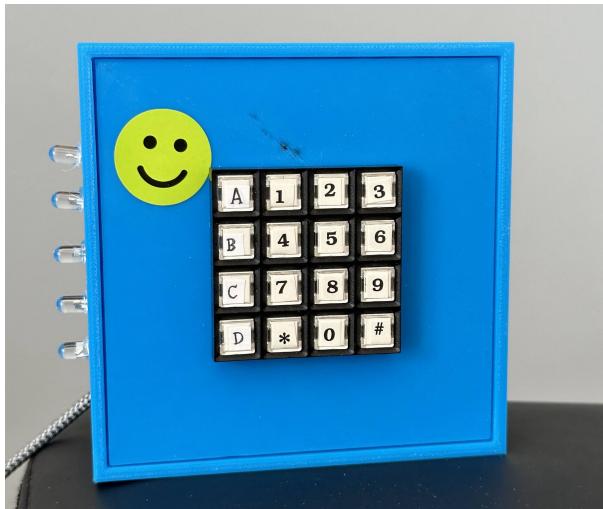


Fig. 7. Image of the keypad box puzzle that allowed players to increase the amount of time they were allotted to solve the room.

However, in order to make this a bit more complicated, the combinations were broken down into math problems that, when solved, would reveal one of the combinations. This would help to keep some players busy while others did their best to solve the room within the allotted time, and also cause the room to end quicker if players were unable to correctly calculate all ten math equations.

F. TVs, State, and Detection

In accordance with the time period the game is set in, a CRT TV and monitor were procured and used to capture the state of the game as players make their way through the escape room. A mini PC is connected to each TV and using python-vlc, a library that links VLC Media Player and Python, and receives signals from the server to play certain videos. Figure 8 provides screenshots of these different states which play on the TVs with audio playing through bluetooth speakers located on the edges of the room for surround sound. A game timer is

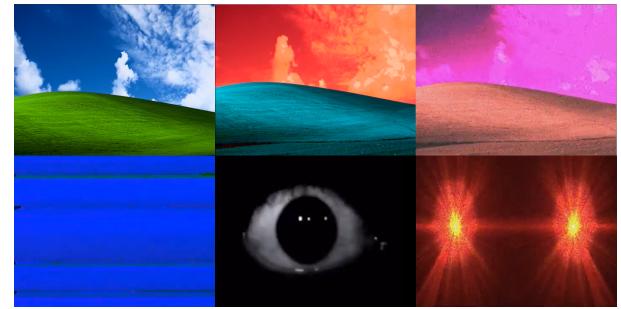


Fig. 8. Screenshots of different videos shown on the TVs. First image is the ‘Game’ state. Second image is the ‘Game’ state when it reaches nighttime. Third image is the ‘Midnight’ state. Fourth image is the ‘Time Travel’ state. Fifth image is the ‘Seek’ state. Sixth image is the ‘Monster’ state.

also shown on each TV to show exactly how much real-life time players have left to complete the room.

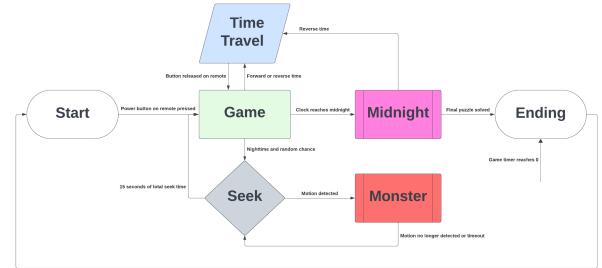


Fig. 9. A flowchart representing the different states of the game.

1) *Start*: This is the resting state of the game where nothing is happening and is simply waiting for players to start. All TVs will be dark during this state. When the players wish to play the game, they push the power button on the remote and point it at the TV to start the clock, game timer, and move to the ‘Game’ state.

2) *Game*: This is the general state of the game. An animated Windows XP Wallpaper with serene ambience will play with the time of the clock being reflected by the video. Every ten ticks of the clock, the mini PC will receive a signal to update the time of the video for any syncing issues. When the clock reaches 60 ticks, the color of the video will distort and the ambience will turn into a darker, more horrifying sound. This is to represent that the players are getting closer to midnight, and will also act as a signal that the monster is able to seek for the players.

3) *Midnight (Panic State)*: The ‘Midnight’ state is considered a panic state that will deplete the game timer at a quicker pace than usual. This state is reached when the clock has reached 12:00 and will only stop when the clock is reversed or the game ends. The Windows XP wallpaper has gone fully distorted with a bell tolling the new millennium and distorted screaming of the end of the world. It’s unadvised players let the game get to this state since they will incur time penalties, however this state is required to solve the final puzzle as a way to introduce tension as the room comes to a close.

4) *Time Travel*: When the players use the remote to either forward or reverse the clock, the screen will resemble fast forwarding or reversing an old VHS. When the game is at this state, the monster cannot show up.

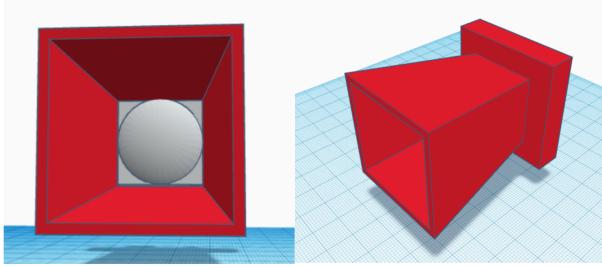


Fig. 10. CAD screenshots of the print used for the PIR motion detectors located on top of the TVs. The motion detector is inserted in the bottom facing into it, with its range limited by the cone shape of the print.

5) *Seek*: When the clock is considered to be at “nighttime” (which is represented by the usual game video being reddish) then the monster will search the room for the players on random chance. A PIR motion sensor was used to detect motion and located on top of each TV with a print as shown in Figure 13 to restrict its searching area to act as the TVs field of vision. To warn players of this state, the cassette player will play a sound of looming footsteps before the eye appears on the screen searching around the room. This will last for 15 seconds as the motion sensor now starts polling to see if motion is detected. When motion is detected, the state will change to the ‘Monster’ state until motion is no longer detected, in which it returns to this state to finish the 15 seconds it searches for. When the 15 seconds are up, it will return to the ‘Game’ state. The clock is paused during this state.

6) *Monster (Panic State)*: The ‘Monster’ state is considered a panic state that will deplete the game timer at a quicker pace than usual. This state is reached when motion is detected during the ‘Seek’ state and will revert to the ‘Seek’ state when motion is no longer detected. There is also a timeout of 5 seconds in case hardware issues arise to not crushingly punish the players. During this state, the monsters presence will be felt in the room as a scream and horrible noises are played to induce stress in the players. This is a horror experience, after all.

7) *Ending*: There are two endings to the escape room on a win and a loss. When the game timer reaches 0, a video will play “ejecting” a VHS before static fills the screen. When the players solve the final puzzle, everything will shut down and remain dark for a few seconds before a video will play showing old footage of old new years celebration for the year 2000. These videos cut to black at the end of them, signifying the end of the escape room. The players can then be either proud of their win or lament their loss depending on which ending they got.

G. Time Control and the Clock

In “ESCAPE Y2K”, there were two different times that the players needed to pay attention to. One of them was the timer that showed the remaining time the players had left to complete the room while the other was the clock represented the time in the game world. This section will focus on the latter: the clock that represented the time in the game world. Players were given control of this clock by pressing “fast forward”, “rewind”, or “play” on a remote that they were given, allowing them to return to different time periods within the room. The clock that was used was the same clock that was purchased during initial planning stages, however it was retrofitted with quite a few new components.

The above figure shows the back of the clock once all

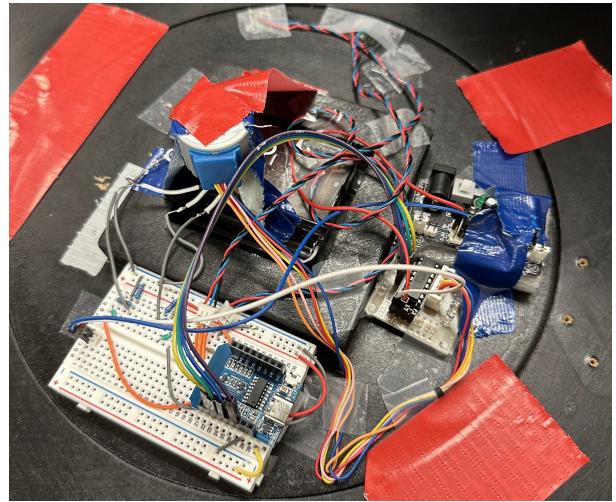


Fig. 11. The back of the clock with all of the components installed that allowed it to fulfill its desired function

of the components had been successfully installed. These components include the following...

- An ESP module to run the clock and connect to other components
- A stepper motor and its driver
- A rotary encoder to track how far the stepper had turned
- Two slot interrupters, so the clock knew when it reached both 1300 hours and 0000 hours

Installing all of these components allow for remotely turning the clock, resetting the clock, triggering events when the clock reached midnight, etc. Furthermore, the three puzzles in the room were all dependent upon the time that the clock was displaying. Three periods of time were set aside during which players could solve one of the puzzles. If the game clock went past the given time period, the puzzle pertaining to the previous period would deactivate and the next one would activate. And finally, as the clock got closer to midnight, the chance that the monster would appear increased from 0% to 1% to 2%, each percent value pertaining to one of the three-time blocks.

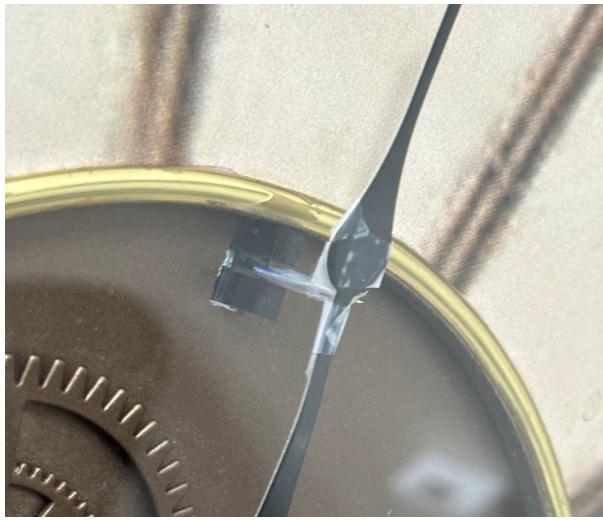


Fig. 12. On the clock there were two slot interruptors. This was one of them already interrupted.

H. Wireless Communication and Circuit Design

One of the central ideas behind what makes this escape room different from other escape rooms is that all of the puzzles can communicate wirelessly with a central server, indicating when they had been solved. Using this information, the server could then communicate wirelessly with the locked puzzle boxes, telling them to open without needing any external intervention. This paradigm was used extensively throughout the escape room, allowing special events to trigger themselves and allowing certain components to connect and function asynchronously (while the main timer and game clock are synchronous), giving the room a sense of interconnectedness. This wireless communication was achieved through the use of a dummy WiFi router and Arduinos with ESP modules attached to them, restricting their connection to the internet as a whole but allowing them to talk on an interconnected LAN network.

This network was further enhanced by the implementation of a server, which would propagate signals to any module that may need to be informed of an event and keep track of the current state of the room. An "admin control panel" was also developed, which allows any user that is "behind the scenes" to activate special events, lock or unlock boxes, and reset the current state of the room.

IV. EVALUATION

"ESCAPE Y2K" was completed, and fully functional as a computer-controlled escape room experience. For demo day itself, the control panel for the room was used to provide assistance and allow other guests to play sound effects remotely to interact with the room if they could not participate actively. While the technical aspects of "ESCAPE Y2K" were all implemented and functional for the demonstration, there were a few aspects that could be improved for later revisions of this (or other) computer controlled escape room.

A. Functionality

There were several physical aspects of "ESCAPE Y2K" that could have failed during the demonstration, from dislodged wires, misaligned clock hands for the slot-interrupt sensors, jammed autoboxes, or general hardware failure. Thankfully, due to careful consideration of transportation and attention during re-assembly, these were all successfully avoided. If additional funding were available, it would be possible to make printed circuit boards for all breadboard components, which are the biggest concern for re-assembly and reliability issues.

After the approximate hour and 45 minutes of re-assembly, the room was able to be fully tested for function and connectivity reliability before guests were let into the room. While being used, none of the above concerns caused any practical issues for guests, but unfortunately, no teams managed to finish the escape room due to time constraints (which will be addressed in the following subsections). While everything physically operated as it should, there were a few aspects that a second revision would address to make things run even smoother.

B. Mechanical Shortcomings

Many components of student-made projects can be extremely fragile due to limitations of time, funding, or uncontrollable factors like mistakes on the side of the end-user. Thankfully, the users did not cause any problems over the duration of the demonstration, and nothing had serious reliability issues. However, there are a few aspects that had potential to cause issues if factors were slightly different.

One such concern is the fragility of puzzle boxes and the clock. Because the clock relies on a relatively cheap stepper motor, custom 3D printed mounts, and finicky slot-interrupters, there are multiple aspects that hold potential of breaking. Should the clock module be revised, a full enclosure for the motor would be 3D printed that could house the separate encoder much closer. By covering the motor entirely, it would prevent accidental dislodging or mechanical movement not detected by the encoder. The slot interrupters could have a metal wing affixed below the clock hand, to be more stable and secure than the tape wing used for the first revision.

Concerns on the fragility of puzzles could simply be solved by making custom PCBs would remove reliability concerns of loose wiring. With additional funding, the containers could also be made from more rugged materials, rather than 3D printed (although 3D printing was fine for demonstration purposes).

C. Creative Adjustments

Guests of the room provided feedback from their experiences to improve a revised escape room. Much of this feedback was not necessarily on the technical side, but rather for the experiential aspects of the room, such as immersion and logical flow. For individuals inexperienced with escape rooms, having a system that does not require an operator can make it extremely difficult to try to understand where to start looking

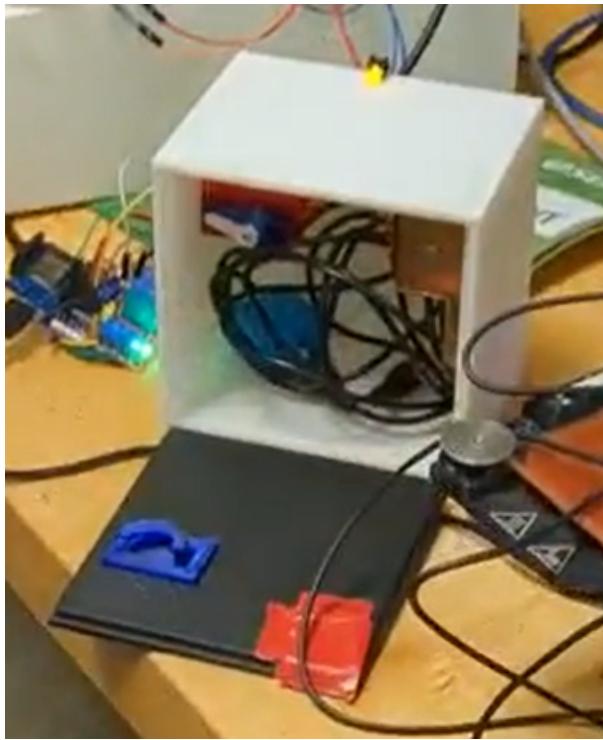


Fig. 13. 3D printed autobox with servo latch and solenoid opener.

in the room, so some changes can benefit less experienced players.

The biggest and most consistent piece of feedback received was on timing. Eight minutes is simply not enough time to get situated in the room and rationally look for clues. A basic attempt at improving this was the ability to add time back with the use of codes. However, with such a short initial time, this still was not particularly helpful. The unique ability to get working time back is central to “ESCAPE Y2K”, so the code system could be made more accessible to allow for more time extensions. The easiest (and realistically intended) solution is to give players more base time when the room starts. With the amount and complexity of puzzles, 20 minutes would be an ideal starting time for the room.

Another unique aspect of “ESCAPE Y2K” that could use play-tuning is the appearance of the entity through the television monitors. While its presence was restricted to about a one-percent chance of appearing every second while the clock was after 8:00 PM, these chances could stack on with additional time if the chance was completed while the entity was already seeking in the room. Simply preventing this from happening could let players be less intruded by the entity, while still keeping it as an important aspect of the room. As this is purely a creative change, its ideal implementation would still need to be flexible to further feedback as changes are continually made.

V. CONCLUSION

One of the greatest joys of creation is to allow others to experience your creation for the first time. This prototype for a completely autonomous escape room had one of the underappreciated pleasures of allowing the ability to simply watch players play the room. This gave us lots of time to take notes on what worked and what was difficult without worrying about control, but it also exhibited the spark of ideas and creative problem solving that makes escape rooms so captivating. Setting puzzles up to communicate with each other wirelessly presented opportunities for complex interactions with players alongside maintaining their progress. With further development, more and more escape rooms can utilize smart engineering for rooms that run by themselves (with supervision for safety in case of failure). This could also open up even more opportunities for increasingly complex game mechanics alongside standard puzzle solving which can release the floodgates for advanced experiences. Ideas include a random selection of puzzles each playthrough, passcodes that keep changing, hacking into computers, keys using RF reading, and many more. Like how “ESCAPE Y2K” ends with the new millennia, this concept could also usher in a new age in escape rooms that redefine what it takes to escape.

VI. APPENDIX A: REFERENCE MATERIAL

A. Bill of Materials

In addition to plenty of general components, such as resistors, LEDs, and jumper wires, here is a list of the more specialized components needed for “ESCAPE Y2K.”

- 4 Arduino Unos
- Analog clock
- 15 ESP2622 modules
- 2 Small CRT televisions
- 2 UART Micro-SD MP3 controllers
- Audio cassette player
- Writable audio cassette tapes
- Speakers
- 5 Servo Motors (To act as lock releases)
- 5 Solenoids
- Stickers to denote interactive components
- Digital video to analog AV converter
- Several USB-C cables and power adapters for ESP and Arduino boards
- 12V power supplies for autoboxes
- 9V power supply for clock
- 3 spools of PLA printing filament
- Relay modules (1 per autobox)
- Mini windows PC

VII. APPENDIX B: TROUBLES OF NOTE DURING DEVELOPMENT

Most aspects of the “ESCAPE Y2K” project went relatively smoothly. Bugs were encountered, as is to be expected, but nothing lead to any major issues for the demonstrated product. One of the few concerns that came up during the construction

of the room was components without proper documentation. For example, the number switch puzzle did not include a datasheet with the switch module, as it was just found in the lab's spare parts. The closest datasheet found online shows it being used with a common-power configuration, but the pull-down resistors in the circuit didn't fully pull down off pins, leading to logical errors. After some testing along the common-power side, it was switched to use common ground. After some re-wireing and re-programming the ESP modules, a common-ground configuration worked very reliably for the final room.

Issues involving timing for hot key presses were also an issue when it came to the TVs. When a signal comes into the server that requires the mini PC to activate two hot keys (in scenarios where the videos and timer are interacted with at the same time such as starting or resetting the game) there would have to be enough time in between the functions to avoid one of them not working correctly.

The final issue that gave a significant amount of concern leading up to demo day is the lack of a dedicated large-scale testing space. Due to the unique nature of an escape room demanding a certain layout of the room, and requiring a lot of physical interactions to be tested makes testing without a controlled space very difficult. In addition to the relative layout of puzzles being a vital aspect to test, the additional use of restricted motion sensors makes exact testing nearly impossible prior to setting up in the actual demo space. Any chance to have a controlled space to test should be taken advantage of for projects of this scale and nature.

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