A Novel 3D Printed Maze Lock System

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Abstract:
A lock has been essential in humanity's history; as always, personal effects need to be secured. The lock was simply a thick stick and a latch with a design coping with civilization's progress. Nowadays, there are various lock types such as mechanical, high-tech password-protected, electronic, fingerprint, far-infrared, gene, etc. In a lock, the key is the most crucial element, and the development of the key is the most diverse. It ranges from a simple metallic key to an electronic control key, body characteristics key, gene key, etc. In this paper, we describe a novel maze lock system based on a 3D printed maze, a freely moving metallic ball enclosed inside the maze, two metal sides, a hook, and a hook pusher. Each printed maze can be different since the maze is computer-generated with an algorithm ensuring a random design with a solvable maze. One of the commercial applications of this lock system is in novelty and gift shops. As the lock system can be easily printed, assembled, and installed on-site on items such as fancy boxes, turning them into magic boxes. To open the box, you must remember the maze and move the metallic ball to the correct position manipulating the box in the three dimensions. Besides remembering the maze, the metal ball's sound when it hits the metal sides gives another piece of information in guiding the metal ball. This lock system has been patented by the authors in the United States Patent and Trademark Office (USPTO) with the patent number US 11,311,793B1 dated April 26, 2022.

Keywords: 3D printing, Maze lock, Puzzle lock, Lock system.

1. Introduction

With the need to secure personal effects, many different types of locking arrangements have been devised throughout history. Archaeologists found the first known key/locking systems in the Palace of Khorsabad in Assyria (present-day Iraq) in the middle of the 19th century as seen in Figure N1. The use of locks and keys can be traced back to 4000 B.C. [1]. The key is the most important component of a lock, and its development has been the most varied. It ranges from a simple metallic key to an electronic control key, body characteristics key, gene key, etc.

For securing small items, a lockbox may be used which refers to a container or otherwise enclosed space with a built-in lock. Such lockboxes have been typically used as cash boxes, treasure boxes, tool boxes, and the like. Traditionally lock boxes employ a padlock and a physical key, which is part of a locking mechanism, which keeps the lid of the container closed and prevents its opening after personal items have been placed within the box and the padlock has been locked. However, this

presents the difficulty of securing the physical key and locating the physical key each time the lockbox needs to be locked or unlocked. More recently, locking mechanisms have become available such as electronic locks, high-tech password-protected locks, fingerprint locks, Bluetooth locks, far-infrared locks, gene locks, and the like, which may solve the problem of managing the physical key, but such locking mechanisms may be expensive to incorporate in the lockbox and require a power source.

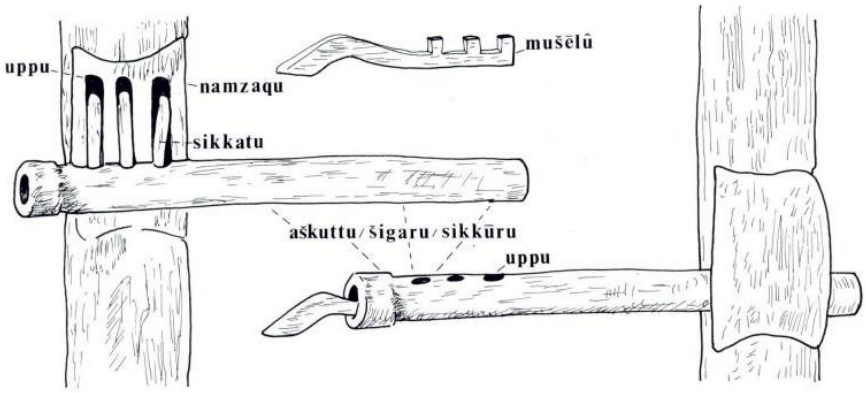

Figure 1: Key and lock system dating back to 4000 B.C [1]

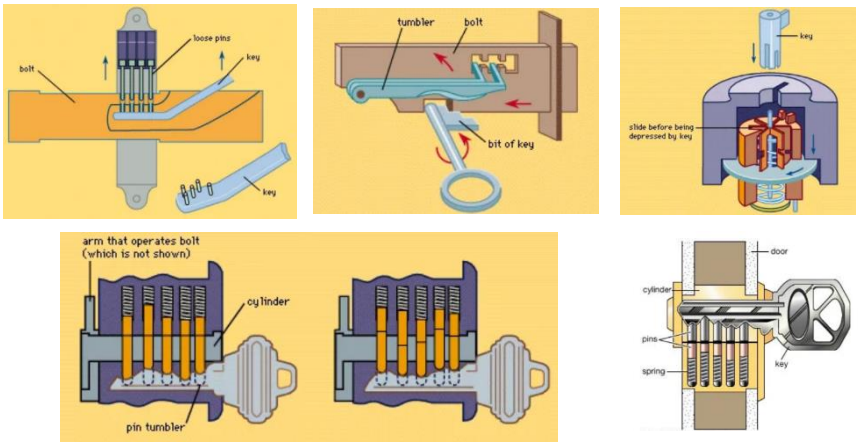

Figure 2: Some key and lock systems [2]

Additionally, it may be desired for the lockboxes to incorporate an element of intrigue, for example, making the process of opening the lockbox a game or a puzzle to be solved. Such types of lockboxes are known in the art and are referred to by different names such as puzzle boxes, magic boxes, trick boxes, secret boxes, and the like. Such lockboxes employ locking mechanisms that may be opened by solving a puzzle, with some requiring only a simple move and others a series of discoveries. However, the incorporated puzzle in the lockbox could be seen by a second person with access to the lockbox and thus could be solved with some intelligence and manipulation by that second person. Additionally, when the lockbox is utilized for storing personal items, the owner of the lockbox may

wish for the unlocking mechanism to be private, so that the lockbox cannot be physically accessed by any other person and with the solution to the lockbox known only to the owner.

Mazes are traced back to ancient Greek and explained in their mythology books; an example is the most famous maze ever built, associated with the Greek Myth of Theseus and The Minotaur. A maze can be a single-dimensional maze or a three-dimensional multi-level maze comprising a series of stacked maze elements.

In this paper, we describe the design of a mechanical lock based on a 3D printed maze, a freely moving metallic ball enclosed inside the maze, two metal sides, a hook, and a hook pusher. Each printed maze can be different since it is computer-generated with an algorithm that ensures each designed maze is randomly generated and solvable. The maze can be a multi-level with varying degrees of difficulty. The lock system has many applications, and an obvious application is using it in novelty and gift shops. As the lock system can be easily printed, assembled, and installed on-site on items such as fancy boxes chosen by the customer, transforming them into magic boxes. To open the box, you must remember the maze and move the metallic ball to the correct position manipulating the box in the three dimensions. Besides remembering the maze, when the metal ball hits the metal sides, it makes a sound that gives another piece of information to guide the metal ball to its rightful place.

The lock system design reported here is unique, and to the best of our knowledge, no apparatus exist similar to this design. This lock system has been patented by the authors in the United States Patent and Trademark Office (USPTO) with the patent number US 11,311,793B1 dated April 26, 2022 [1], and also prototypes were built.

2. Literature review

A puzzle, maze, or labyrinth lock is a look with a mechanical puzzle consisting of a lock with hidden or unusual mechanics. Sometimes they are called trick locks because there is a trick that needs to be found to unlock them. A key sometimes is required, and sometimes it is a part of the trick mechanism. However, there are trick locks with no keys. Solving these puzzles is by unlocking the lock. What makes each puzzle lock unique is the method or "trick" you need to be figured out to unlock it. Some of these locks have an internal mechanism with the secret moves needed to open them.

A patent search with the keywords for our design is conducted. To the best of our knowledge, no patent matches the proposed design. To explore and investigate the available patents, the keywords used are as follows. First, we used "Maze" AND "Lock." We found only one relevant patent [4]. It is an old patent with a date of 1851. The design has two portions communicating with one another only by a revolving bolt cab, which is the only means of locking and unlocking. However, the concept is different from our design. There is another patent [5], but it is irrelevant as it is related to a hanger for mounting an object on a surface such as a wall.

A puzzle lock is a lock incorporating some puzzle mechanism, especially a combination lock. There are many types like 2D puzzles, 3D puzzles, rotating puzzles, dynamic puzzles, etc. Using the keywords "Puzzle" AND "Lock", we found several patents, and some are in [6-20]. We also tried the keywords "Labyrinth" AND "Lock". We found several, but all were similar to puzzle locks. The

most relevant ones are in [21-25]. However, in all these patents, the concept and design are different from our design.

We found a door chain lock with a maze pattern attached to the door on searching the internet. The door will open only when the maze has been completed [26]. Also, a 3D printed sliding puzzle lock [27], and a 3D Printed Safe Box with Labyrinth Lock [27], [28-29]. However, all of them are different from our design.

3. Problem formulation

An innovative, secure lock system is needed. Simultaneously, it should help in training eye, ear, and hand coordination, enhancing problem-solving skills, expanding the brain while improving reasoning skills, and relieving stress, keeping the brain focused and the hands busy.

The lock should have a clear commercial application and can be easily manufactured, assembled, and installed on-site on items such as fancy boxes, making them magic boxes.

4. The proposed solution to the problem

Figure 3 shows the proposed solution of the 3D printed maze system when implemented in a box. As shown in the figure, the hook fastener is on the inside of the box top, while the lock hook can be seen at the bottom.

The solution is a mechanical lock based on a 3D printed maze, a freely moving metallic ball enclosed inside the maze, two metal sides, a hook, and a hook pusher. Each printed maze can be different as the maze is computer-generated with an algorithm ensuring a random design and a solvable maze.

Figure 3: The proposed solution

To open the box, one must remember the maze and move the metallic ball to the correct position by manipulating the box in the three dimensions. Besides remembering the maze, the metal ball's sound when it hits the metal sides gives another piece of information in guiding the metal ball. The procedure for opening a typical box is shown in Figure 4.

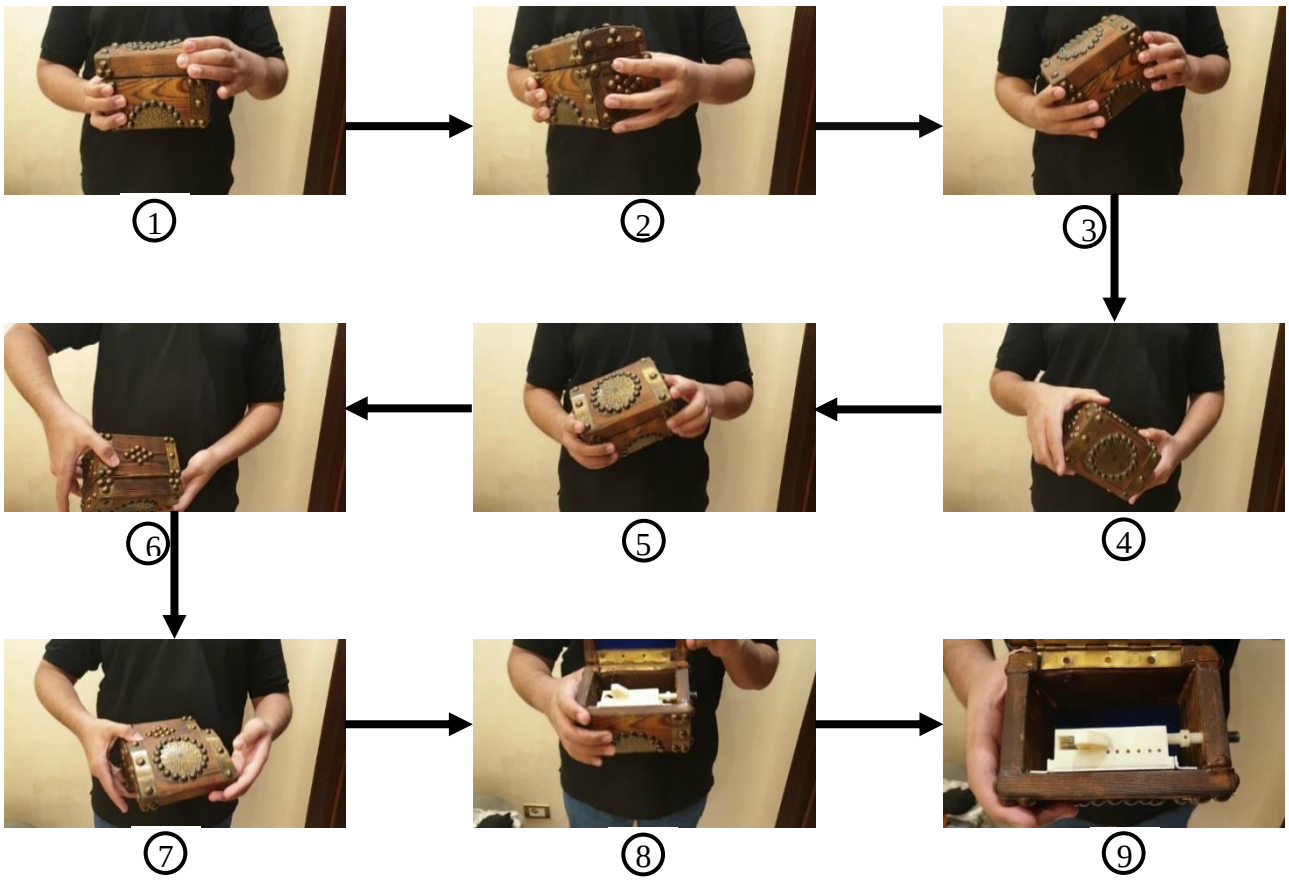

Figure 4: The procedure for opening a typical box

5. Design Methodology of the Proposed Design

Figure 5 shows a diagram of the design and the main parts, while Figure 6 shows the back after removing the metal back cover.

The main parts of the design are described as follows:

5.1 3D Printed maze with front and back metal covers:

The maze is multi-level, and the one shown in Figures 3 and 4 is an example of a two-layer maze. The maze will be printed on a 3D printer, and each printed maze is unique since it is computer-generated. The maze has front and back metal covers. These metal covers have an essential function in creating sounds used for guiding the metal ball in the right direction when the ball hits the sides.

5.2 Rod assembly:

The assembly consists of a rod with a rod stopper, a compression spring, and a pin. The rod is kept in position by the openings in the maze structure and also by a pin. The end side of the rod inside the maze is hollow to house the compression spring, as shown in Figure 7, and it has an opening to ease fixing the compression spring, which will be confined by the inside of the rod on one side and by the pin on the other side. The rod stopper will limit the rod's movement so that it cannot reach the hook pusher and move the hook to the open position. The compression spring function is to push back on the applied force used to open the lock and return to its original position when the force is released.

The pin is 2 mm in diameter and has the function of keeping the rod in place and as an endpoint fixation of the compression spring.

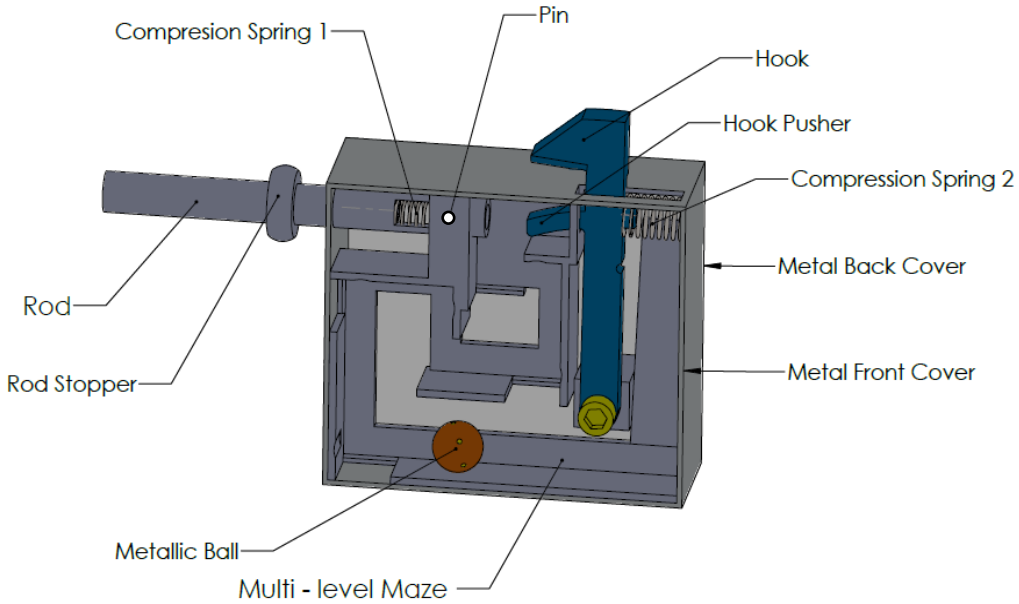

Figure 5: Main parts of the design

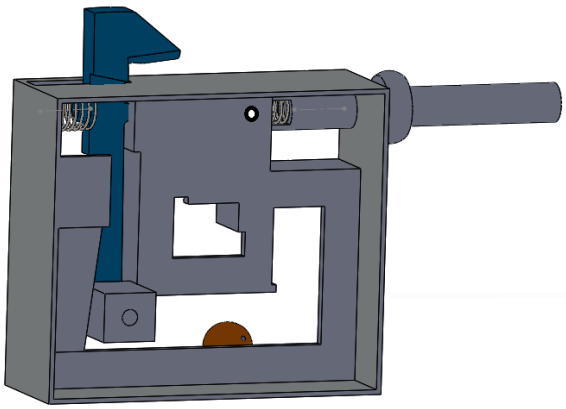

Figure 6: The device as seen from the back after removing the metal back and front covers

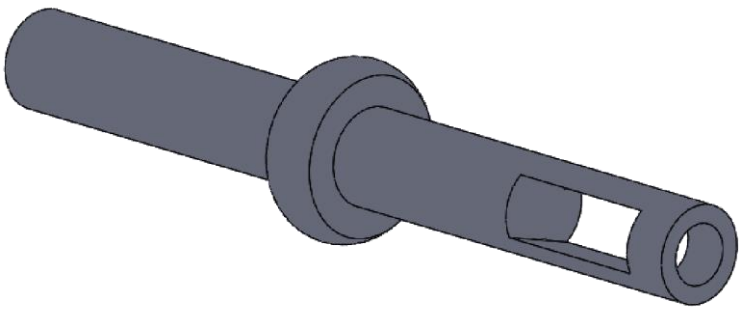

Figure 7: The rod

5.3 Metallic Ball

It is a 10 mm metallic ball. Its importance in the design is explained in Figures 8 and 9. In Figure 8, the ball is not in the correct position, thus pushing the rod to the end will not move the hook and the look remain closed. However, this situation is changed when the ball is in the correct position, as pushing the rod will move the hook and open the lock.

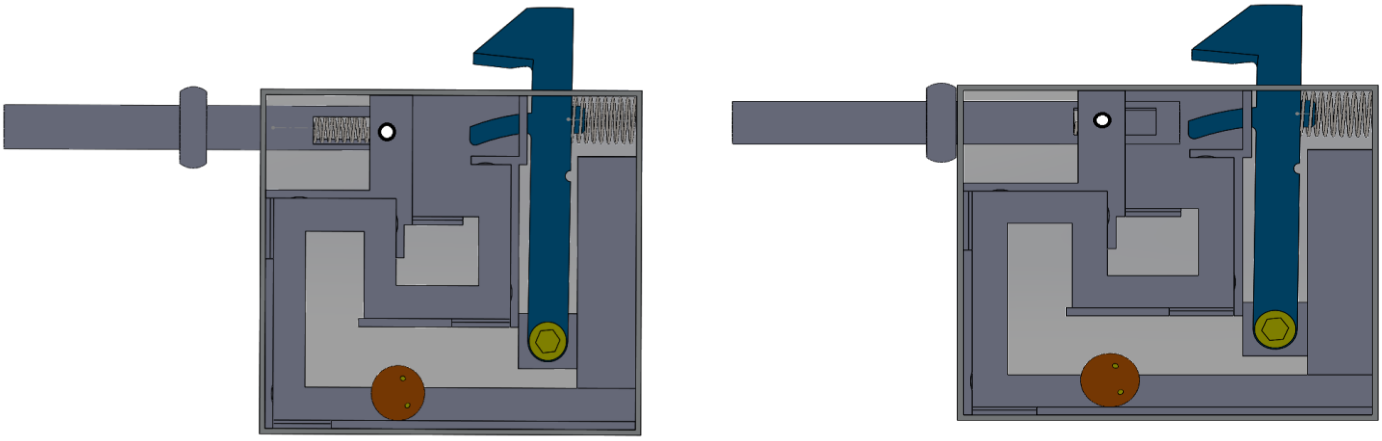

Figure 8: The ball is not in the correct position

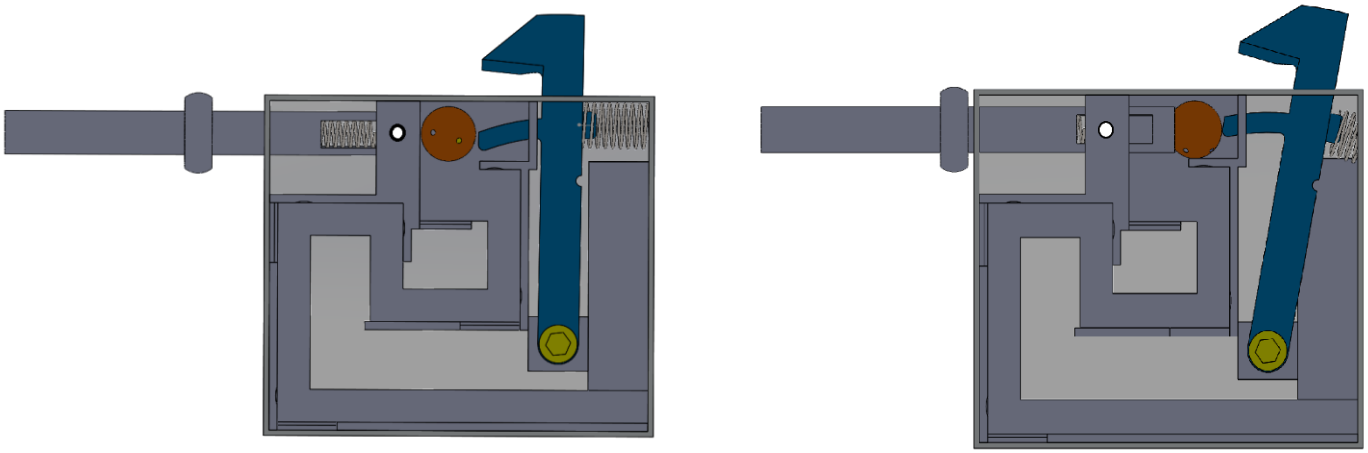

Figure 9: The ball is in the correct position

5.4 Automatic Maze Generation (AMG)

Automatic Maze Generation (AMG) is closely related to the Maze Router Problem (MRP) which is well-known in the design automation of electronic systems [30-37]. It is a grid-based routing method widely applied in solving gridded routing problems subject to various practical constraints. The main goal of the Maze Router Problem (MRP) is to find the shortest path between two nodes and if the connection exists, it is guaranteed to find the path.

The MRP is used with some modifications for Automatic Maze Generation (AMG). The details are not discussed in this paper.

6. Preliminary results

A two-layer typical device has been designed and built and integrated into a box, as can be seen in Figure 3. Testing the functionality is performed, as can be seen in Figure 5. The design worked as planned.

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