

Theory of Recursed

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In this article, various aspects of Recursed are described, including mechanics, gadgets, and theoretical analysis of it.

This article is aimed towards people trying to make a custom Recursed puzzle, or people who are interested in theoretical side of Recursed. If the reader of this article haven't see the ending of Recursed, then one is advised against continue reading this article, as this article contains many strategies of Recursed where discovering them is a big fun part of the game.

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1 Introduction

Recursed is a puzzle game released in 2016, developed by Portponky. The main objective of a Recursed puzzle is to reach to a destination using various game elements.

1.1 Game Elements

1.1.1 Room

A *room* is a rectangular area with tiles and various items in it. The size of a room is 20×15 , where there are 20 tiles horizontally and 15 tiles vertically.

There can be items (which will be described later) in a room, and there is no (logical) limit how many items can be in a room.

A player can't go outside of a room. The left, right, or top edge of a room is blocked by an invisible barrier, which prevents the player from escaping. However, any item can go past the invisible barrier (by throwing or using a fan). Items gone beyond the left or the right edge will be removed¹, but items went beyond the top edge will be there, which can be retrieved after removing the fan.

When the player reaches the bottom edge of the room, the player will bounce. However, this behavior is *not* used to solve any of the puzzles in the game, as it is impossible² to do.

1.1.2 Crystal and Diamond

A *crystal* is a fixed item in a room, marking a destination of a puzzle. If a player collects a crystal, the player will exit the puzzle and it will be marked as crystal-solved.

A *diamond* appears in a paradox room, which can be entered after a player invokes a paradox. When a diamond is collected, the player will exit the puzzle and it will be marked as diamond-solved.

After invoking a paradox, a crystal will be unable to be collected. When a player attempts to collect a crystal after invoking a paradox, the crystal will simply disappear when touched.³

1.1.3 Jumping

Jumping can be done by a player to make the character jump 3 blocks high.

¹There was a bug that items gone beyond the left or the right edges were not removed, but it will be fixed in a future update.

²Actually, it is possible to touch the bottom edge in the puzzle "Dump".

³This behavior was introduced by the developer to prevent players from getting crystal easily with fans obtained from a paradox room.

1.1.4 Block

A *block* is the simplest item.

1.1.5 Throwing

Throwing can be done by a player to throw items, such as blocks and keys.

1.1.6 Key and Door

A *key* is another item which can be used to open a door.

1.1.7 Chest

Chests are most distinguished item in Recursed.

1.1.8 Green Objects

1.1.9 Water and Acid

1.1.10 Paradox

A *paradox* can be happen with green chests. Details on how to invoke a paradox is explained in section 2.2.

1.1.11 Jar

1.1.12 Fan

1.1.13 Oobleck

1.1.14 Glitch

1.1.15 Other Items

Rings are present in Recursed. When a thrown ring hits a wall, it emits sound, which is used in the main Recursed puzzles to tell stories. Other than that, it has no function. While there is no use of rings as puzzle elements in the main Recursed puzzles, nevertheless rings can be used as puzzle elements.

Restart crows appear when a puzzle becomes unsolvable.

1.2 Tiles

1.2.1 Empty

1.2.2 Solid

1.2.3 Ledge

1.2.4 Water and Acid

1.2.5 Buoy

2 Game Mechanisms

Like many other puzzle games, Recursed has various patterns in its solutions of puzzles, and it has some uncommon situations where the game would handle

by doing expected or unexpected actions, where in advanced puzzles a player might have to use them to solve those.

2.1 Terms

Even though game elements are already described in the previous section, when discussing a solution to a puzzle, terms related to rooms can be very confusing. So there should be some clarification on those terms.

2.2 Ways of Invoking a Paradox

To invoke a paradox, a player must enter a green chest, find *the* green chest, remove it from the room it originally was in, then get out of the green chest. For example, assume that a puzzle consists of two of two rooms A and B, and there are chests in each room, a green chest β in A leading to B, and a chest α in B leading to A. From the room A, a player enters the room B by getting into β . In the room B, the player enters the room A again by getting into α . Then, the player gets out of α by holding β , then put β in the room B. Then, if the player tries to exit from the room B into the room A, then the player should will be in the position where β is in the room A. However, since β is not in the room A anymore, the game can't find the position where the player should be. Therefore, a paradox appears.

Removing a green chest (a player is currently in) from the room (it originally was in) is an absolute requirement for a paradox to happen. However, there are multiple ways to remove a green chest α from the room it originally was in.

1. By moving α to another room⁴, as shown in the example.
2. By throwing α to out of the room by dropping it under the bottom edge of the room, or throwing it outside of the room⁵.
3. By unlocking a door which wasn't unlocked in the instance of the room when the player entered α , then putting α on the door so that the door would obstruct it.
4. By making a different wet state of the room α is in, then place α in a different place of the room where a buoy would obstruct it.
5. By converting it into a normal chest by submerging α into acid.

3 Complexity of Recursed

There haven't much research on algorithms to solve a Recursed map, or how complex such an algorithm would be.

⁴A jar for the same room α is in does not work. A glitch room does work.

⁵This currently does not work because of the previously mentioned bug.

3.1 Definitions

First, let's introduce a proper decision problem based on the puzzle of Recursed.

Definition 3.1. The *Standard Recursed Decision Problem*, or the *Standard RDP* for short, is the problem of determining whether a puzzle P is solvable, where P is given as list of rooms $\{r_1, r_2, \dots, r_n\}$. Here, the size of a room r_i is fixed to be 20×15 , and the number of initial items in a room r_i is bounded by a fixed constant. (To prevent the constant from increasing arbitrarily, let's set the constant to 300, the number of tiles in a room.)

Therefore, the length of the input for the Standard RDP can be represented in $\tilde{\Theta}(n)$ in terms of the amount of rooms n , for any proper encoding (where additional $\log n$ terms might appear due to specify room #).

There are several interesting sub-problems of the Standard RDP.

Definition 3.2. The *Pure Recursed Decision Problem*, or the *Pure RDP*, is a subset of the Standard RDP where none of objects in a room is green.

In any instance of the Pure RDP, any chest is a pure function. So, for any item and any chest, going into the chest with the item will result in a set of finite, fixed actions.

Definition 3.3. The *Simple Recursed Decision Problem*, or the *Simple RDP*, is a subset of the Pure RDP where no fissures present in any of the rooms.

3.2 Simple RDP \in PSPACE

Conjecture 3.1. *There is a fixed polynomial function $p(n)$, such that in any instance P of the Simple RDP, if there's a solution to P , then there will be a solution to P such that the maximum number of items in a room in any step of the solution is bounded by $p(n)$, where n is the amount of rooms in P .*

Conjecture 3.2. *There is a fixed polynomial function $q(n)$, such that in any instance P of the Simple RDP, if there's a solution to P , then there will be a solution to P such that the maximum depth achieved in any step of the solution is bounded by $q(n)$, where n is the amount of rooms in P .*

Conjecture 3.3. *The Simple RDP is in PSPACE.*

3.3 Standard RDP \in NP-Hard

Theorem 3.1. *There is a reduction from 3-SAT to the Standard RDP.*

4 Recursed Solver

Currently, there is no available automatic Recursed solver. And this would be impossible to do if the Standard RDP turned out to be in Turing-complete. However, various heuristics might be used to check the solvability of a puzzle. For example, if there's no reference to a chest with a key, then it is certain that the puzzle can't be solved, and this was used to spawn crows in the game.