

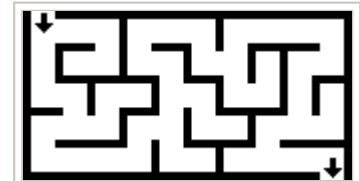
Maze

From Wikipedia, the free encyclopedia

A **maze** is a complex tour puzzle in the form of a complex branching passage through which the solver must find a route. This is different from a labyrinth, which (strictly speaking) has an unambiguous through-route and is not designed to be difficult to navigate (despite the common uses of the word to indicate various complex, confusing structures). The pathways and walls in a maze or labyrinth are fixed (pre-determined). Maze-type puzzles where the given walls and paths may change during the game are covered under the main puzzle category of tour puzzles.

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A small maze

Maze construction

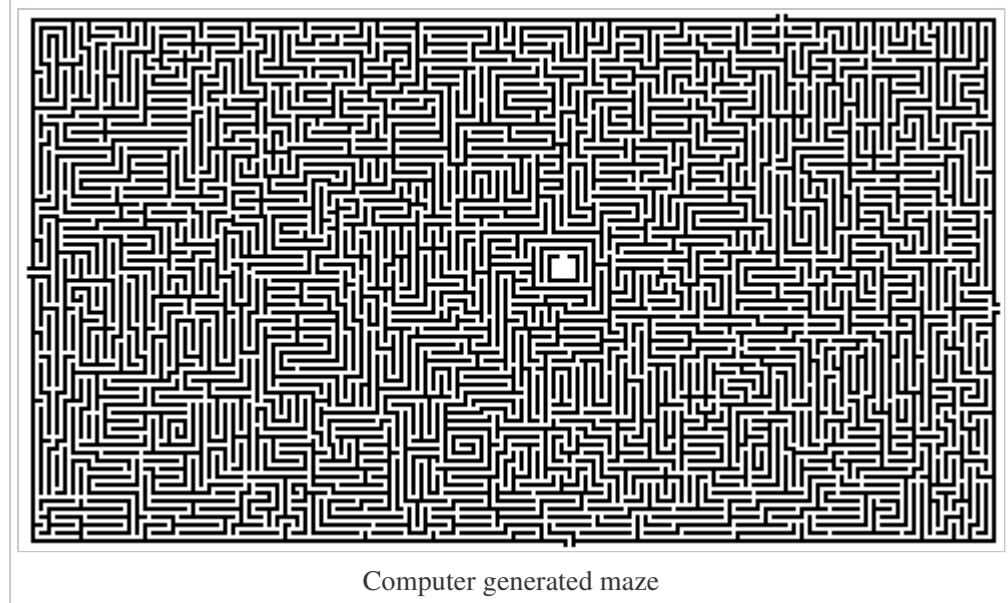
Mazes have been built with walls and rooms, with hedges, turf, or with paving stones of contrasting colors or designs, or in fields of crops such as corn or, indeed, maize. Maize mazes can be very large; they are usually only kept for one growing season, so they can be different every year, and are promoted as seasonal tourist attractions. One type of maze consists of a set of rooms linked by doors (so a passageway is just another room in this definition). Players enter at one spot, and exit at another, or the idea may be to reach a certain spot in the **maze**. Mazes can also be printed or drawn on paper to be followed by a pencil or fingertip. One of the short stories of Jorge Luis Borges featured a book, called *The Garden of Forking Paths*, that was a literary maze. Various maze generation algorithms exist for building mazes, either by hand or by computer.

Generating mazes

There are many different approaches to automate the generation of mazes.

Stack-based approach

This is one of the simplest ways to generate a maze using a computer. Consider the space for a maze being a large grid of cells (like a large chess board), each cell starting with four walls. Starting from a random cell, the computer then selects a random



neighbouring cell that has not yet been visited. The computer removes the 'wall' between the two cells and adds the new cell to a stack (this is analogous to drawing the line on the floor). The computer continues this process, with a cell that has no unvisited neighbours being considered a dead-end. When at a dead-end it backtracks through the path until it reaches a cell with an unvisited neighbour, continuing the path generation by visiting this new, unvisited cell (creating a new junction). This process continues until every cell has been visited, causing the computer to backtrack all the way back to the beginning cell. This approach guarantees that the maze space is completely visited.

As stated, the algorithm is very simple and does not produce overly-complex mazes. More specific refinements to the algorithm can help to generate mazes that are harder to solve.

Solving mazes

The mathematician Leonhard Euler was one of the first to analyse plane **mazes** mathematically, and in doing so made the first significant contributions to the branch of mathematics known as topology.

The following algorithms are designed to be used inside the maze by a traveler with no prior knowledge of the maze.

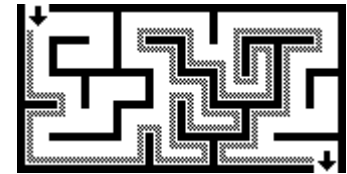
Random mouse algorithm

This is a trivial method that can be implemented by a very unintelligent robot or perhaps a mouse. It is simply to proceed in a straight line until an obstruction is reached, and then to make a random decision about the next direction to follow.

Wall follower

The wall follower, the best-known rule for traversing mazes, is also known as either the *left-hand rule* or the *right-hand rule*. If the maze is *simply connected*, that is, all its walls are connected together or to the maze's outer boundary, then by keeping one hand in contact with one wall of the maze the player is guaranteed not to get lost and will reach a different exit if there is one; otherwise,

he or she will return to the entrance. If the maze is not simply connected (i.e. if the start or endpoints are in the center of the structure or the pathways cross over and under each other), this method will not be guaranteed to help the goal to be reached.



Wall-following can be done in 3D or higher dimensional mazes if its higher dimensional passages can be projected onto the 2D plane in a deterministic manner. For example, if in a 3D maze "up" passages can be assumed to lead northwest, and "down" passages can be assumed to lead southeast, then standard wall following rules can then be applied.

Pledge algorithm

Disjoint mazes can still be solved with the wall follower method, if the entrance and exit to the maze are on the outer walls of the maze. If however, the solver starts inside the maze, it might be on a section disjoint from the exit, and wall followers will continually go around their ring. The Pledge algorithm (named after Jon Pledge of Exeter) can solve this problem (see "Turtle Geometry: the computer as a medium for exploring mathematics", Abelson & diSessa, 1980).



Robot in a wooden maze

The Pledge algorithm, designed to circumvent obstacles, requires an arbitrarily chosen direction to go toward. When an obstacle is met, one hand (say the right hand) is kept along the obstacle while the angles turned are counted. When the solver is facing the original direction again, and the angular sum of the turns made is 0, the solver leaves the obstacle and continues moving in its original direction.

Note that the use of "total turning" rather than just the "current direction" allows the algorithm to avoid traps shaped like an upper case "G". If one proceeds left into the trap, one gets turned around a full 360 degrees by the walls. A naive "current direction" algorithm gets into a limit cycle as it leaves the lower rightmost wall heading left and runs into the curved section on the left again. The Pledge algorithm does not leave the rightmost wall due to the total turning not being zero at that point. It follows the wall all the way around, finally leaving it heading left on the bottom outside.

This algorithm allows a person with a compass to find his way from any point inside to an outer exit of any finite and fair two-dimensional maze, regardless of the initial position of the solver. However, this algorithm will not work in doing the reverse, namely finding the way from an entrance on the outside of a maze to some end goal within it.

Tremaux's algorithm

Tremaux's algorithm is an efficient method to find the way out of a maze that requires drawing a line on the floor to mark a path, and is guaranteed to work for all mazes that have well-defined passages. On arriving at a junction, pick a direction and mark it and the direction you came from. When arriving at a marked junction pick an unmarked passage if possible. If it is not possible to pick an unmarked passage take a marked one, marking it again (you can pick the path you came from). Never pick a twice marked path, where you will never need to take any passage more than twice. If there is no exit, this method will take you back to the start. [1]

Tremaux's algorithm was referenced in The Simpsons episode Stop, or My Dog Will Shoot! when Lisa proposes this method for finding the exit of a tricky corn maze.

Mazes in science experiments

Mazes are often used in science experiments to study spatial navigation and learning. Such experiments typically use rats or mice. Examples are

- the Barnes maze
- the Morris water maze
- the radial arm maze.

Other types of mazes

Logic mazes

See Logic maze. These mazes use same rule as the other mazes other than "don't cross the lines" to restrict motion. Examples are

- Area-mazes or A-mazes, which the area of the tile stepped on must alternately increase and decrease with every step.
- Dice mazes, in which a die is rolled onto cells based on various rules.
- Number Mazes, in which a grid of numbers is navigated by traveling the number shown on the current square.
- Multi-State mazes, in which the rules for navigation change depending on how the maze has been navigated.

Mazes in higher dimensions

It is possible for a maze to have three or more dimensions. A maze with bridges is three dimensional, and some natural cave systems are three dimensional mazes. The computer game Descent utilized fully three dimensional mazes. Any maze can be topologically mapped onto a three-dimensional maze.

Picture maze

A maze that forms a picture when solved. See picture maze.

Dead end maze

A maze game where the route creates the dead ends.

Turf mazes and Mizmazes

A pattern like a long rope folded up, without any junctions or crossings.

Publications about mazes

Numerous mazes of different kinds have been drawn, painted, published in books and periodicals, used in advertising, in software, and sold as art. In the 1970s there occurred a publishing "maze craze" in which numerous books, and some magazines, were commercially available in nationwide outlets and devoted exclusively to mazes of a complexity that was able to challenge adults as well as children (for whom simple maze puzzles have long been provided both before, during, and since the 1970s "craze").

Some of the best-selling books in the 1970s and early 1980s included those produced by Vladimir Koziakin, Rick and Glory Brightfield, Dave Phillips, Larry Evans, and Greg Bright. Koziakin's



Inside the labyrinth of villa Pisani at Stra, near Venice

works were predominantly of the standard two-dimensional "trace a line between the walls" variety. The works of the Brightfields had a similar two-dimensional form but used a variety of graphics-oriented "path obscuring" techniques - although the routing was comparable to or simpler than Koziakin's mazes, the Brightfield's mazes did not allow the various pathway options to be discerned so easily by the roving eye as it glanced about. Greg Bright's works went beyond the standard published forms of the time by including "weave" mazes in which illustrated pathways can cross over and under each other. Bright's works also offered examples of extremely complex patterns of routing and optical illusions for the solver to work through. What Bright termed "mutually accessible centers" (*The Great Maze Book*, 1973) also called "braid" mazes, allowed a proliferation of paths flowing in spiral patterns from a central nexus and, rather than relying on "dead ends" to hinder progress, instead relied on an overabundance of pathway choices. Rather than have a single solution to the maze, Bright's routing often offered multiple equally valid

routes from start to finish, with no loss of complexity or diminishment of solver difficulties because the result was that it became difficult for a solver to definitively "rule out" a particular pathway as unproductive. Some of Bright's innovative mazes had no "dead ends" - although some clearly had looping sections (or "islands") that would cause careless explorers to keep looping back again and again to pathways they had already travelled. The books of Larry Evans focused on 3-D structures, often with realistic perspective and architectural themes, and Bernard Meyers (*Supermazes* No. 1) produced similar illustrations. Both Greg Bright (*The Hole Maze Book*) and Dave Phillips (*The World's Most Difficult Maze*) published maze books in which the sides of pages could be crossed over and in which holes could allow the pathways to cross from one page to another, and one side of a page to the other, thus enhancing the 3-D routing capacity of 2-D printed illustrations.

A recent book by Galen Wadzinski (*The Ultimate Maze Book*) offers formalized rules for more recent innovations that involve single-directional pathways, 3-D simulating illustrations, "key" and "ordered stop" mazes in which items must be collected or visited in particular orders to add to the difficulties of routing (such restrictions on pathway traveling and re-use are important in a printed book in which the limited amount of space on a printed page would otherwise place clear limits on the amount of choices and pathways that can be contained within a single maze). Although these innovations are not all entirely new with Wadzinski, the book marks a significant advancement in published maze puzzles, offering expansions on the traditional puzzles that seem to have been fully informed by various video game innovations and designs, and adds new levels of challenge and complexity in



Maze at St. Louis Botanical Gardens

both the design and the goals offered to the puzzle-solver in a printed format.

Further reading

- Adrian Fisher & Georg Gerster, *The Art of the Maze*, Weidenfeld & Nicolson (1990) ISBN 0-297-83027-9
- Jeff Saward, *Magical Paths*, Mitchell Beazley (2002) ISBN 1-84000-573-4
- W.H. Matthews, *Mazes and Labyrinths: Their History and Development* (1927). Includes Bibliography. Dover Publications (1970) ISBN 0-486-22614-X
- H. Abelson and A. diSessa, *Turtle Geometry: The Computer as a Medium for Exploring Mathematics* (The MIT Press 1980).

Mazes open to the public

Europe

- Altjeßnitz, Germany, Sachsen-Anhalt, near Dessau (hedge maze, c.1750) On Google Maps |
- Aschaffenburg (Park Schönbusch), Germany, Bavaria (hedge maze, c.1829)
- Berlin (Erholungspark Marzahn), Germany (hedge maze, opens June 2007)
- Blake House Craft Centre, Braintree, Essex, England (Open July-Sept)[2]
- Castlewellan, Northern Ireland, world's largest permanent hedge maze[3]
- Chatsworth House, England (hedge maze)
- The Crystal Palace, England. A hedge maze built into a copse
- Hampton Court Palace, England (hedge maze)
- Hoo Hill Maze, Shefford, Bedfordshire, England
- Kentwell Hall, Long Melford, Suffolk, England
- The Labyrinth in Moomin_World, Finland
- Labyrinthia, Silkeborg, Denmark.
- Leeds Castle, Maidstone, Kent, England. Designed by Adrian Fisher
- Longleat, England (hedge maze)
- The Murray Star Maze, Scone Palace, Perth, Scotland (hedge maze). Designed by Adrian Fisher
- Noah's Ark Zoo Farm, Bristol, England (longest hedge maze in the world, planted 2003) [4]
- Parc del Laberint d'Horta, Barcelona, Spain (hedge maze)
- Paulton's Park, Hampshire, England(hedge maze)
- Richings Park Amazing Maize Maze, Richings Park, near Heathrow, England (Open July-Sept) [5]
- Saffron Walden, Essex, England (hedge maze)
- Samsø, Denmark [6]
- Schönbrunn Palace, Austria (small entrance fee, tower at the center to overlook the hedge maze)
- Symonds Yat, Herefordshire, England
- Worden Park, Leyland, Lancashire, England



Public hedge maze in the "English Garden" at Schönbusch Park, Aschaffenburg, Germany

North America

- America's Largest Corn Maze Shakopee, Minnesota, USA Sever's Corn Maze
- Children's maze (made out of packs of hay), Ashland Berry Farm, Ashland, Virginia, USA.
- Davis' Mega Maze, Sterling, Massachusetts USA (3-D adventure corn maze). Designed by Adrian Fisher. [7]
- Dole Plantation, Wahiawa, Hawaii, home to the World's Largest Maze. [8]On Google Maps
- Labyrinthe du Hangar 16, Montreal, Canada. [9]
- Magnolia Plantation, Charleston, South Carolina, USA
- Maize Quest is the "Largest Collection of People-Sized Mazes in the World" with mazes made of Fence, Rope, Stone, Turf, Corn, Invisible Dog Fencing, Straw Bales, Tiles, Living Bamboo, and Earthen Mounds. New Park, Pennsylvania, USA Maize Quest Fun Park
- Maze Mania, Garden City, South Carolina USA (Interchangeable fence Maze appropriate for children and adults)
- The Maze on Centre Island, Toronto, Ontario, was a Centennial gift to the city by its Dutch-Canadian community in 1967. This topiary maze is open to public for free year-round
- Mohonk Mountain House hedge maze, New Paltz, New York

Africa

- Serendipity Maze, Mouille Point, Cape Town, South Africa. Hedge maze by the sea.
- Soekershof Walkabout Mazes and Botanical Gardens, Robertson, Western Cape, South Africa. 13870 m² net area. Links to mazes and labyrinths in South Africa.

See Also

Corn maze

External links

- Mazes: Construction and Solution with Java illustration
- Maze Algorithms: This site explains the different types of mazes and how to generate and solve them
- Times Online: Britain's best mazes
- W.H. Matthews, *Mazes and Labyrinths* (1922) online version of W.H. Matthew's classic book
- Labyrinthos Jeff Saward's website
- Briefing Room CNN's Barry Neild offers escape routes
- Labyrinth Society
- cornmazedir.com Directory of hundreds of mazes in the USA and Canada}
- Learn How to Draw Mazes
- 4D Maze Game John McIntosh's Java-based free maze game in 3D and 4D first-perspective

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