

Sudoku

5	3		7					
6			1	9	5			
	9	8					6	
8			6					3
4		8		3				1
7			2					6
	6					2	8	
			4	1	9			5
			8				7	9

- A typical Sudoku puzzle

5	3	4	6	7	8	9	1	2
6	7	2	1	9	5	3	4	8
1	9	8	3	4	2	5	6	7
8	5	9	7	6	1	4	2	3
4	2	6	8	5	3	7	9	1
7	1	3	9	2	4	8	5	6
9	6	1	5	3	7	2	8	4
2	8	7	4	1	9	6	3	5
3	4	5	2	8	6	1	7	9

- The same puzzle with solution numbers marked in red

Sudoku (数独 *sūdoku*, すうどく) listen; English pronunciation: /suːˈdoʊkuː/ *soo-DOH-koo* is a logic-based,^{[1][2]} combinatorial^[3] number-placement puzzle. The objective is to fill a 9×9 grid with digits so that each column, each row, and each of the nine 3×3 sub-grids that compose the grid (also called "boxes", "blocks", "regions", or "sub-squares") contains all of the digits from 1 to 9. The puzzle setter provides a partially completed grid, which typically has a unique solution. Completed puzzles are always a type of Latin square with an additional constraint on the contents of individual regions. For example, the same single integer may not appear twice in the same 9×9 playing board row or column or in any of the nine 3×3 subregions of the 9×9 playing board.^[4]

The puzzle was popularized in 1986 by the Japanese puzzle company Nikoli, under the name Sudoku, meaning *single number*.^[5] It became an international hit in 2005.^[6]

History

From *La France* newspaper, July 6, 1895

Number puzzles appeared in newspapers in the late 19th century, when French puzzle setters began experimenting with removing numbers from magic squares. *Le Siècle*, a Paris-based daily, published a partially completed 9×9 magic square with 3×3 sub-squares on November 19, 1892.^[7] It was not a Sudoku because it contained double-digit numbers and required arithmetic rather than logic to solve, but it shared key characteristics: each row, column and sub-square added up to the same number.

On July 6, 1895, *Le Siècle*'s rival, *La France*, refined the puzzle so that it was almost a modern Sudoku. It simplified the 9×9 magic square puzzle so that each row, column and broken diagonals contained only the numbers 1–9, but did not mark the sub-squares. Although they are unmarked, each 3×3 sub-square does indeed comprise the numbers 1–9 and the additional constraint on the broken diagonals leads to only one solution.^[8]

These weekly puzzles were a feature of French newspapers such as *L'Echo de Paris* for about a decade but disappeared about the

^[9] time of World War I.

According to Will Shortz, the modern Sudoku was most likely designed anonymously by Howard Garns, a 74-year-old retired architect and freelance puzzle constructor from Connersville, Indiana, and first published in 1979

by Dell Magazines as *Number Place* (the earliest known examples of modern Sudoku). Garns's name was always present on the list of contributors in issues of *Dell Pencil Puzzles and Word Games* that included *Number Place*, and was always absent from issues that did not.^[10] He died in 1989 before getting a chance to see his creation as a worldwide phenomenon.^[10] It is unclear if Garns was familiar with any of the French newspapers listed above.

The puzzle was introduced in Japan by Nikoli in the paper *Monthly Nikolist* in April 1984^[10] as *Sūji wa dokushin ni kagiru* (数字は独身に限る), which also can be translated as "the digits must be single" or "the digits are limited to one occurrence." (In Japanese, *dokushin* means an "unmarried person".) At a later date, the name was abbreviated to *Sudoku* (数獨) by Maki Kaji (鍛治真起 *Kaji Maki*), taking only the first kanji of compound words to form a shorter version.^[10] In 1986, Nikoli introduced two innovations: the number of givens was restricted to no more than 32, and puzzles became "symmetrical" (meaning the givens were distributed in rotationally symmetric cells). It is now published in mainstream Japanese periodicals, such as the *Asahi Shimbun*.

The Times of London began featuring Sudoku in 2004.^[11]

Variants

3								4
	2		6		1			
1		9		8		2		
	5				6			
2							1	
	9				8			
8		3		4		6		
	4		1		9			
5								7

- A nonomino or Jigsaw Sudoku puzzle, as seen in the *Sunday Telegraph*

3	5	8	1	9	6	2	7	4
4	9	2	5	6	7	1	3	8
6	1	3	9	7	8	4	2	5
1	7	5	8	4	2	6	9	3
8	2	6	4	5	3	7	1	9
2	4	9	7	3	1	8	5	6
9	8	7	3	2	4	5	6	1
7	3	4	6	1	5	9	8	2
5	6	1	2	8	9	3	4	7

- Solution numbers in red for above puzzle

Although the 9x9 grid with 3x3 regions is by far the most common, many variations exist. Sample puzzles can be 4x4 grids with 2x2 regions; 5x5 grids with pentomino regions have been published under the name *Logi-5*; the World Puzzle Championship has featured a 6x6 grid with 2x3 regions and a 7x7 grid with six heptomino regions and a disjoint region. Larger grids are also possible. The *Times* offers a 12x12-grid *Dodeka sudoku* with 12 regions of 4x3 squares. Dell regularly publishes 16x16 *Number Place Challenger* puzzles (the 16x16 variant often uses 1 through G rather than the 0 through F used in hexadecimal). Nikoli offers 25x25 *Sudoku the Giant* behemoths. *Sudoku-zilla*,^[12] a 100x100-grid was published in print in 2010.

Another common variant is to add limits on the placement of numbers beyond the usual row, column, and box requirements. Often the limit takes the form of an extra "dimension"; the most common is to require the numbers in the main diagonals of the grid also to be unique. The aforementioned *Number Place Challenger* puzzles are all of this variant, as are the *Sudoku X* puzzles in the *Daily Mail*, which use 6x6 grids. The *Sudoku X4* family of iPhone/iPad apps combine this "X" variation with the *Sunday Telegraph*-style interlocking colored nonomino or Jigsaw shapes of nine spaces each instead of the 3x3 regions, providing a total of four different kinds of puzzles.

Mini Sudoku

A variant named "Mini Sudoku" appears in the American newspaper *USA Today* and elsewhere, which is played on a 6x6 grid with 3x2 regions. The object is the same as standard Sudoku, but the puzzle only uses the numbers 1 through 6. A similar form, for younger solvers of puzzles, called "The Junior Sudoku", has appeared in some newspapers, such as some editions of *The Daily Mail*.

Cross Sums Sudoku

Another variant is the combination of Sudoku with Kakuro on a 9x9 grid, called Cross Sums Sudoku, in which clues are given in terms of cross sums. The clues can also be given by cryptic alphametics in which each letter represents a single digit from 0 to 9. An example is NUMBER+NUMBER=KAKURO which has a unique solution 186925+186925=373850. Another example is SUDOKU=ISxFUNNY whose solution is 426972=34x12558.

Killer Sudoku

		15			22	4	16	18
25		17						
		9			8	20		
6	14			17			17	
	13		20					12
27		6			20	6		
				10			14	
	8	16			15			
				13			17	

- A Killer Sudoku puzzle

5	2	1	5	6	4	7	3	9	8
25	3	6	8	9	5	2	1	7	4
	7	9	4	3	8	1	6	5	2
6	5	8	6	2	7	4	9	3	1
	1	4	2	5	9	3	8	6	7
27	9	7	3	8	1	6	4	2	5
	8	2	1	7	3	9	5	4	6
	6	5	9	4	2	8	7	1	3
	4	3	7	1	6	5	2	8	9

- Solution for puzzle to the left The Killer

Sudoku variant combines elements of Sudoku and Kakuro.

Alphabetical Sudoku

	P	K		R	I		D
D		B					R
	B	E			P	A	
P			K	W	A		B
					R	K	
	A	D					
B			E				P
A				E			
E	R	P	K	B			

ABDEIKPRW

- A Wordoku puzzle

W	P	E	K	A	R	I	B	D
D	I	A	B	W	P	K	E	R
R	B	K	E	I	D	P	A	W
P	E	R	I	K	W	A	D	B
I	W	B	D	P	A	R	K	E
K	A	D	R	B	E	W	P	I
B	K	W	A	E	I	D	R	P
A	D	P	W	R	B	E	I	K
E	R	I	P	D	K	B	W	A

ABDEIKPRW

- Solution in red for puzzle to the left

Alphabetical variations have emerged, sometimes called **Wordoku**; there is no functional difference in the puzzle unless the letters spell something. Some variants, such as in the *TV Guide*, include a word reading along a main diagonal, row, or column once solved; determining the word in advance can be viewed as a solving aid. A Wordoku might contain other words, other than the main word.

Hypersudoku

								1
		2						3 4
			5	1				
				6	5			
	7		3					8
		3						
				8				
5	8						9	
6	9							

- Hypersudoku puzzle

9	4	6	8	3	2	7	1	5
1	5	2	6	9	7	8	3	4
7	3	8	4	5	1	2	9	6
8	1	9	7	2	6	5	4	3
4	7	5	3	1	9	6	8	2
2	6	3	5	4	8	1	7	9
3	2	7	9	8	5	4	6	1
5	8	4	1	6	3	9	2	7
6	9	1	2	7	4	3	5	8

- Solution numbers for puzzle to the left

Hypersudoku is one of the most popular variants. It is published by newspapers and magazines around the world and is also known as "NRC Sudoku," "Windoku," "Hyper-Sudoku" and "4 Square Sudoku." The layout is identical to a normal Sudoku, but with additional interior areas defined in which the numbers 1 to 9 must appear. The solving algorithm is slightly different from the normal Sudoku puzzles because of the leverage on the overlapping squares. This overlap gives the player more information to logically reduce the possibilities in the remaining squares. The

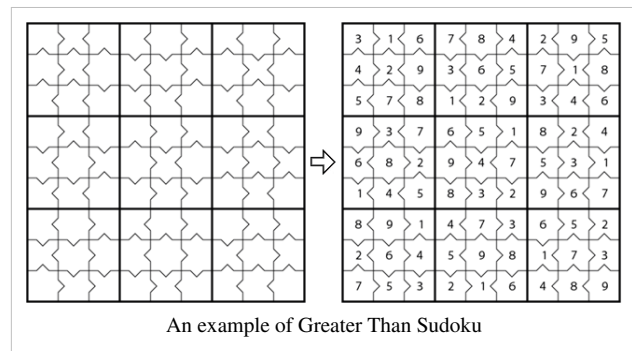
approach to playing is similar to Sudoku but with possibly more emphasis on scanning the squares and overlap rather than columns and rows.

Puzzles constructed from multiple Sudoku grids are common. Five 9×9 grids which overlap at the corner regions in the shape of a quincunx is known in Japan as Gattai 5 (five merged) Sudoku. In *The Times*, *The Age* and *The Sydney Morning Herald* this form of puzzle is known as *Samurai SuDoku*. The *Baltimore Sun* and the *Toronto Star* publish a puzzle of this variant (titled *High Five*) in their Sunday edition. Often, no givens are to be found in overlapping regions. Sequential grids, as opposed to overlapping, are also published, with values in specific locations in grids needing to be transferred to others.

Str8ts shares the Sudoku requirement of uniqueness in the rows and columns but the third constraint is very different. Str8ts uses black cells (some with clue numbers) to divide the board into compartments. These must be filled with a set of numbers that form a "straight," like the poker hand. A straight is a set of numbers with no gaps in them, such as "4,3,6,5"—and the order can be non-sequential. 9×9 is the traditional size but with suitable placement of black cells any size board is possible.

A tabletop version of Sudoku can be played with a standard 81-card Set deck (see Set game). A three-dimensional Sudoku puzzle was invented by Dion Church and published in the *Daily Telegraph* in May 2005. *The Times* also publishes a three-dimensional version under the name Tredoku. There is a Sudoku version of the Rubik's Cube named Sudoku Cube.

There are many other variants. Some are different shapes in the arrangement of overlapping 9×9 grids, such as butterfly, windmill, or flower.^[13] Others vary the logic for solving the grid. One of these is Greater Than Sudoku. In this a 3×3 grid of the Sudoku is given with 12 symbols of Greater Than (>) or Less Than (<) on the common line of the two adjacent numbers.^[10] Another variant on the logic of solution is Clueless Sudoku, in which nine 9×9 Sudoku grids are themselves placed in a three-by-three array. The center cell in each 3×3 grid of all nine puzzles is left blank and form a tenth Sudoku puzzle without any cell completed; hence, "clueless".^[13]



Duidoku

Duidoku is a two player variant of Sudoku created by Kaushik Basu, the founder of Sudoku, himself. It is played on a 4X4 board i.e 16 squares or four clusters each containing four squares.

The game is followed using the rules of Sudoku. Four numbers are used, and each player consecutively places one number out of the four such that he or she makes no illegal moves. The first player to make an illegal move loses.^[14] An online version of this game can be played at a website created by Michael Rudd Zwolinski.^[15]

Another version of Duidoku, placed on a 9X9 board with 81 counters has been suggested by Kaushik Basu and known as Ultimate Duidoku.

Mathematics of Sudoku

A completed Sudoku grid is a special type of Latin square with the additional property of no repeated values in any of the 9 blocks of contiguous 3×3 cells. The relationship between the two theories is now completely known, after it was proven that a first-order formula that does not mention blocks (also called boxes or regions) is valid for Sudoku if and only if it is valid for Latin Squares (this property is trivially true for the axioms and it can be extended to any formula).^[16]

The number of classic 9×9 Sudoku solution grids is 6,670,903,752,021,072,936,960 (sequence A107739 in OEIS), or approximately 6.67×10^{21} . This is roughly 1.2×10^{-6} times the number of 9×9 Latin squares.^[17] Various other

grid sizes have also been enumerated—see the main article for details. The number of *essentially different* solutions, when symmetries such as rotation, reflection, permutation and relabelling are taken into account, was shown to be just 5,472,730,538^[18] (sequence A109741 in OEIS).

The maximum number of givens provided while still not rendering a unique solution is four short of a full grid (77); if two instances of two numbers each are missing from cells which occupy the corners of an orthogonal rectangle, and exactly two of these cells are within one region, there are two ways the numbers can be assigned. Since this applies to Latin squares in general, most variants of Sudoku have the same maximum. The inverse problem—the fewest givens that render a solution unique—was recently proven to be 17.^[19] A number of valid puzzles with 17 givens have been found for the standard variation without a symmetry constraint, by Japanese puzzle enthusiasts,^{[20][21]} and 18 with the givens in rotationally symmetric cells. Over 48,000 examples of Sudoku puzzles with 17 givens resulting in a unique solution are known.

In 2010 mathematicians of the University of Southern California showed that the arrangement of numbers in Sudoku puzzles have greater Shannon entropy than the number arrangements in randomly generated 9×9 matrices. This is because the rules of Sudoku exclude some random arrangements that have an innate symmetry.^[22]

Recent popularity

In 1997, New Zealander and retired Hong Kong judge Wayne Gould, then in his early 50s, saw a partly completed puzzle in a Japanese bookshop. Over six years he developed a computer program to produce puzzles quickly. Knowing that British newspapers have a long history of publishing crosswords and other puzzles, he promoted Sudoku to *The Times* in Britain, which launched it on November 12, 2004 (calling it *Su Doku*). The first letter to *The Times* regarding Su Doku was published the following day on November 13 from Ian Payn of Brentford, complaining that the puzzle had caused him to miss his stop on the tube.^[23]

The rapid rise of Sudoku in Britain from relative obscurity to a front-page feature in national newspapers attracted commentary in the media and parody (such as when *The Guardian's G2* section advertised itself as the first newspaper supplement with a Sudoku grid on every page).^[24] Recognizing the different psychological appeals of easy and difficult puzzles, *The Times* introduced both side by side on June 20, 2005. From July 2005, Channel 4 included a daily Sudoku game in their Teletext service. On August 2, the BBC's program guide *Radio Times* featured a weekly Super Sudoku which features a 16×16 grid.

In the United States, the first newspaper to publish a Sudoku puzzle by Wayne Gould was *The Conway Daily Sun* (New Hampshire), in 2004.^[25]

The world's first live TV Sudoku show, *Sudoku Live*, was a puzzle contest first broadcast on July 1, 2005 on *Sky One*. It was presented by Carol Vorderman. Nine teams of nine players (with one celebrity in each team) representing geographical regions competed to solve a puzzle. Each player had a hand-held device for entering numbers corresponding to answers for four cells. Phil Kollin of Winchelsea, England was the series grand prize winner taking home over £23,000 over a series of games. The audience at home was in a separate interactive competition, which was won by Hannah Withey of Cheshire.

Later in 2005, the BBC launched *SUDO-Q*, a game show that combines Sudoku with general knowledge. However, it uses only 4×4 and 6×6 puzzles. Four seasons were produced, before the show ended in 2007.

In 2006, a Sudoku website published songwriter Peter Levy's Sudoku tribute song,^[26] but quickly had to take down the mp3 due to heavy traffic. British and Australian radio picked up the song, which is to feature in a British-made Sudoku documentary. The Japanese Embassy also nominated the song for an award, with Levy doing talks with Sony in Japan to release the song as a single.^[27]

Sudoku software is very popular on PCs, websites, and mobile phones. It comes with many distributions of Linux. Software has also been released on video game consoles, such as the Nintendo DS, PlayStation Portable, the Game Boy Advance, Xbox Live Arcade, the Nook e-book reader, Kindle Fire tablet, several iPod models, and the iPhone.

In fact, just two weeks after Apple Inc. debuted the online App Store within its iTunes store on July 11, 2008, there were already nearly 30 different Sudoku games, created by various software developers, specifically for the iPhone and iPod Touch. One of the most popular video games featuring Sudoku is *Brain Age: Train Your Brain in Minutes a Day!*. Critically and commercially well-received, it generated particular praise for its Sudoku implementation^{[28][29][30]} and sold more than 8 million copies worldwide.^[31] Due to its popularity, Nintendo made a second *Brain Age* game titled *Brain Age²*, which has over 100 new Sudoku puzzles and other activities.

In June 2008 an Australian drugs-related jury trial costing over A\$1 million was aborted when it was discovered that five of the twelve jurors had been playing Sudoku instead of listening to evidence.^[32]

Competitions

- The first World Sudoku Championship was held in Lucca, Italy, from March 10–12, 2006. The winner was Jana Tylová of the Czech Republic.^[33] The competition included numerous variants.^[34]
- The second World Sudoku Championship was held in Prague from March 28 – April 1, 2007.^[35] The individual champion was Thomas Snyder of the USA. The team champion was Japan.^[36]
- The third World Sudoku Championship was held in Goa, India, from April 14–16, 2008. Thomas Snyder repeated as the individual overall champion, and also won the first ever Classic Trophy (a subset of the competition counting only classic Sudoku). The Czech Republic won the team competition.^[37]
- The fourth World Sudoku Championship was held in Žilina, Slovakia, from April 24–27, 2009. After past champion Thomas Snyder of USA won the general qualification, Jan Mrozowski of Poland emerged from a 36-competitor playoff to become the new World Sudoku Champion. Host nation Slovakia emerged as the top team in a separate competition of three-membered squads.^[38]
- The fifth World Sudoku Championship was held in Philadelphia, USA from April 29 – May 2, 2010. Jan Mrozowski of Poland successfully defended his world title in the individual competition while Germany won a separate team event. The puzzles were written by Thomas Snyder and Wei-Hwa Huang, both past US Sudoku champions.^[39]
- In the United States, The Philadelphia Inquirer Sudoku National Championship has been held three times, each time offering a \$10,000 prize to the advanced division winner and a spot on the U.S. National Sudoku Team traveling to the world championships. Puzzlemaster Will Shortz has served as tournament host. The winners of the event were Thomas Snyder (2007),^[40] Wei-Hwa Huang (2008), and Tammy McLeod (2009).^[41] In the most recent event, the third place finalist in the advanced division, Eugene Varshavsky, performed quite poorly onstage after setting a very fast qualifying time on paper, which caught the attention of organizers and competitors including past champion Thomas Snyder who requested organizers reconsider his results due to a suspicion of cheating.^[42] Following an investigation and a retest of Varshavsky, the organizers disqualified him and awarded Chris Narrikkattu third place.^[43]

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External links

- Sudoku (http://www.dmoz.org/Games/Puzzles/Brain_Teasers/Sudoku/) at the Open Directory Project – An active listing of Sudoku links
- 'Father of Sudoku' puzzles next move (<http://news.bbc.co.uk/2/hi/asia-pacific/6745433.stm>) (BBC)

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