# **CS64: Computation for Puzzles and Games**



## **Autumn 2022** Lecture 4: Nikoli Puzzles, Part 2

## **Chess scandal update**

#### UNITED STATES DISTRICT COURT EASTERN DISTRICT OF MISSOURI: EASTERN DIVISION

HANS MOKE NIEMANN,	)		
Plaintiff,	)	CIVIL ACTION NO.	
v.	)	JURY TRIAL DEMANDED	s*** just
SVEN MAGNUS ØEN CARLSEN A/K/A	)		got real
AS D/B/A PLAY MAGNUS GROUP,	)		5
CHESS.COM, LLC, DANIEL RENSCH A/K/A "DANNY" RENSCH, AND	)		
HIKARU NAKAMURA,	)		

Defendants.

#### **COMPLAINT**

Plaintiff Hans Moke Niemann ("Niemann"), by and through his attorneys Oved & Oved

please do not sue CS64

## Last time

- Nikoli-style logic puzzles are "NP-complete"
  - it's easy to verify a solution (polynomial time)
  - hard to actually solve a puzzle (exponential time)
  - a way to solve any one of the puzzle types efficiently would also let us solve the others

Let's Begin nikoli Puzzles!



A lot of people enjoy solving puzzles every day to escape the pressures of the world. With Nikoli logic puzzles you need just paper, pencil, and an active mind, no expensive programs or training.....

## Most logic puzzles are NP-complete, not NP-hard

- NP-hard problems can't even have their solutions checked efficiently
- This would of course be undesirable for logic puzzles (solvers like to know when they have things right!)



## **nikoli**

#### We are the best in keeping the Nikoli style.

相変わらずで世界

Nikoli has been creating puzzles for 40 years and is surely a one-of-a-kind company in the world.

We have created the world's largest crossword puzzle that has been verified by the Guinness World Records <sup>®</sup>, and have coined the puzzle, "Sudoku", which is now enjoyed in more than 120 different countries. Human-crafted puzzles will always have a special place in this techdominated world we live in today. Japanese English Home Puzzles News nikoli book shop



## nikoli

Japanese English Home Puzzles News nikoli book shop



## nikoli

#### We are the best in keeping the Nikoli style.

相変わらずで世界

Nikoli has been creating puzzles for 40 years and is surely a one-of-a-kind company in the world.

We have created the world's largest creasword puzzle that has been prified by the Guinness World Records ", and have coined the puzzle, "Sudoku", which is now enjoyed in more than 120 different countries. Human-crafted puzzles will always have a special place in this techdominated world we live in today. Japanese English Home Puzzles News nikoli book shop



パズルを作り続けて40年間、世界で類のない会社です。 世界最大のクロスワードを作り、ギネス世界新記録®でも認定されました。 数独(SUDOKU)と名付けたパズルは世界120カ国以上で楽しまれています。 これからは、ヒューマン・クラフテッド・パズルの時代です。

> though the original Japanese doesn't make this claim – "the puzzle called / (re)named Sudoku"

## What does it mean to write the Nikoli style well?

Let's look at...

## Kakuro





Solution

Sample

Progressing

## What does it mean to write the Nikoli style well?



NB: also not originally a Nikoli puzzle ("Cross Sums")



Sample



Progressing



Solution

## What does it mean to write the Nikoli style well?

Also note: this is an actual math (arithmetic) puzzle!

## Kakuro





Solution

Sample

Progressing



Solution

### **Bold: in puzzle** Italics: about where I stop having the patterns memorized

Nikoli Kakuro often

J. IZ
4: <b>13</b>
5: 14, 23
6: 15, 24
7: 16, 25, 34
6: 123
7: <b>124</b>
8: <b>125</b> , 134
9: 126, 135, 234
10: 127, 136, 145, 235

2.49

10: **1234** 11: 1235 12: 1236, 1245 *13: 1237, 1246, 1345* 

15: 12345 16: **12346** 17: **12347**, 12356 *18: 12348, 12357, 12456*  16: **79**15: 69, 78
14: 59, 68
13: 49, **58**, 67
24: 789
23: 689
22: 589, 679
21: 489, 579, 678
20: 389, 479, 569, 578

17:89

30: **6789** 29: 5789 28: 4789, 5689 27: 3789, 4689, 5679

35: 56789 34: 46789 33: 36789, 45789 *32: 26789, 35789, 45689* 



Solution

### **Bold: in puzzle** Italics: about where I stop having the patterns memorized

3: <b>12</b>
4: <b>13</b>
5: 14, 23
6: 15, 24
7: 16, 25, 34
6: 123
7: <b>124</b>
8: <b>125</b> , 134
9: 126, 135, 234
10: 127, 136, 145, 235

10: **1234** 11: 1235 12: 1236, 1245 *13: 1237, 1246, 1345* 

15: 12345 16: **12346** 17: **12347**, 12356 *18: 12348, 12357, 12456*  16: **79**15: 69, 78
14: 59, 68
13: 49, **58**, 67
24: 789
23: 689
22: 589, 679
21: 489, 579, 678
20: 389, 479, 569, 578

### 30: **6789**

17:89

Although this is an easy puzzle, Nikoli Kakuro generally heavily use a small number of common patterns.

## Contrast with this Kakuro generator...



Where to begin?



23-in-3 is always 6, 8, 9

8 or 9 can't be part of 10-in-3 (too big)



23-in-3 is always 6, 8, 9

8 or 9 can't be part of 10-in-3 (too big)

#### 4 total left over in the 10-in-2

4-in-2 is always 1, 3 7-in-3 is always 1, 2, 4





We have a 2 and 4 left in the 7-in-3.

The 2 can't go in the 20-in-3 column, since there is no 18-in-2. So the 4 must be there.



We have a 2 and 4 left in the 7-in-3.

The 2 can't go in the 20-in-3 column, since there is no 18-in-2. So the 4 must be there.

And so on. This part was easy for me (an experienced Nikoli Kakuro solver) to fill in. But now what?



## Now it's a very different puzzle



Who has all the 27-in-5s memorized? *Not me* 

Can fill in candidates for 23-in-3 but it only helps so much

# Now it's a very different puzzle



Who has all the 27-in-5s memorized? *Not me* 

Can fill in candidates for 23-in-3 but it only helps so much

21-in-3 and 22-in-3 have a smaller number of options, but this isn't helping much



# A good idea

- Write every possibility for every row/column
- Look at each, one at a time
- See if any numbers are forced by the constraints of just the crossing clues, and if so, fill them in (and update the possibilities)
- Keep looping until the puzzle is done





# A good idea that may not work

- Write every possibility for every row/column
- Look at each, one at a time
- See if any numbers are enough! forced by the constraints of just the crossing clues, and if so, fill them in (and update the possibilities)
- Keep looping until the puzzle is done



## What about paint by numbers / nonograms

### Example [edit]

#### empty Nonogram

					2	2			
		0	9	9	2	2	4	4	0
	0								
	4								
	6								
2	2								
2	2								
	6								
	4								
	2								
	2								
	2								
	0								

					2	2			
		0	9	9	2	2	4	4	0
	0								
	4								
	6								
2	2								
2	2								
	6								
	4								
	2								
	2								
	2								
	0								

#### **Bummer**:

It isn't necessarily sufficient to just keep checking individual rows to see if any cells can be filled in.



## Don't get too excited, Mario, it's NP-complete!

### Complexity Theory Bowser wins again



## The dreaded "bifurcation"

- AKA "guess and check" when you're not sure which of two branches to take, try one and be prepared to backtrack
- Many solvers (including me) don't like having to do this. e.g., "I had to bifurcate twice on that tournament puzzle". Why not?
  - Harder for many humans to backtrack (chess, Go, etc. players are good at it, I'm not)
  - Feels less satisfying to have to "guess" instead of finding an intended path

## The dreaded "bifurcation"

- AKA "guess and check" when you're not sure which of two branches to take, try one and be prepared to backtrack
- Many solvers (including me) don't like having to do this. e.g., "I had to bifurcate twice on that tournament puzzle". Why not?
  - Harder for many humans to backtrack (chess, Go, etc. players are good at it, I'm not)
  - Feels less satisfying to have to "guess" instead of finding an intended path
- Counterpoint: But some solvers might like it! (And may find Nikoli's reliance on common patterns dull)

## But isn't guessing the solver's fault?

"A puzzle should be a battle of wits that the author expects to lose"
 Dan Katz

## But isn't guessing the solver's fault?

- "A puzzle should be a battle of wits that the author expects to lose"
   Dan Katz
- So what if it's true that the solver didn't *have* to guess?
  - When things go well, it's because the solver is awesome
  - When things don't go well, it's generally blamed on the puzzle
     and it's not fun

## But isn't guessing the solver's fault?

- "A puzzle should be a battle of wits that the author expects to lose"
   Dan Katz
- So what if it's true that the solver didn't *have* to guess?
  - When things go well, it's because the solver is awesome
  - When things don't go well, it's generally blamed on the puzzle
     and it's not fun
- Puzzle authors may need to do some ego management / stroking. Posing an intellectual challenge is inherently stressful and can back the insecure solvers among us into a corner ("oh no! I'm supposed to be smart, and yet I can't solve this!")

С	andidate	es can be	C Edited	High	lighted	Chaine	d / <mark> </mark> Sh	own	9		Take Step	
_											Check for solved cells	
	1 3	1	1		_		1 3	3	_		1: Hidden Singles	No
۹.		6	6	7	2	4	6	6	5	1	2: Naked Pairs/Triples	No
	89	8	8		_		89	8	-		3: Hidden Pairs/Triples	No
	3					3	2		2		4: Naked/Hidden Quads	
в	5	2	456	5.6	1	5	4 6	7	4 6	2	5: Pointing Pairs	
	89	2	8	9	- <b>L</b>	9	89		9	-	6: Box/Line Reduction	No
				-		-					Tough Strategies	2
	1 3	1	1		0	_ 3	1 3	3	2	_	✓7: <u>X-Wing</u>	'es
~	- 5	4 6	456	56	ð	5	4 6	4 6	2	3	✓8: <u>Simple Colouring</u>	
	/ 9	/	1	9		9	9				✓9: <u>Y-Wing</u>	
	1	1000	1	1							10: <u>Swordfish</u>	
D	-	9	4	-	3	6	2	5	4	4	✓11: <u>XYZ Wing</u>	
	78		78	8		U U	-	5	7		✓12: <u>BUG</u>	
						1	-	-			Diabolical Strategies	2
=	6	1	2	F	7	1	3	1 3	0	5	✓13: X-Cycles	
	0	4	<b>Z</b>	3	/	3	4	4	0	Ĩ	✓14: XY-Chain	
						5				-	✓15: <u>3D Medusa</u>	
		_									16: Jellyfish	
F		5	3	2	4		6	1	6	6	17: Unique Rectangles	
	78				-31	89	7 9		79		18: Fireworks	
		1	1			1			1		19: SK Loops	
G	4	6	56	2	Q	1	5.6	2	1 6	7	20: Extended Unique Rect.	
	-	78	78	5	9	8	78	~	7		✓21: Hidden Unique Rect's	
											22: WXYZ Wing	
4	1	2	1	1	~	2		0	1	8	23: Aligned Pair Exclusion	
1	5	3	- 5		6	2 I	45	9	4	Ŭ	Extreme Strategies	7
	/8		/8	8			/ 8		/		✓24: Exocet	-
		1	200				3	3	1 3		25: Grouped X-Cycles	
ונ	2	6	9	4	5	7	6	6	6	9	26: Empty Rectangles	
	-	8					8	8			201 Einned X-Wing	
				Ve	rsion 2.	09				-	28: Finned Swordfish	
		9	ee Stra	teav Ov	erview	docume	ntation	1			29: Altern, Inference Chains	
v	Wing				01-110-11	abcanto	marior				30: Sue-de-Cog	
î	Row->C	(01) 4 +	aken off	C3. ha	sed on	CE28					31: Digit Forcing Chains	
í	Row->C	ol) 4 t	aken off	C7, ba	sed on	CE28					32: Nishio Forcing Chains	
(	Row->C	ol) 4 t	aken off	E7, ba	sed on	CE28					33: Cell Forcing Chains	
											34: Unit Forcing Chains	
											35: Almost Locked Sets	
											36: Death Blossom	
											37: Pattern Overlay Method	
											38: Ouad Forcing Chains	
											"Tripl and Enror"	
											39: Bowman's Bingo	
											Bowman's Bingo	
											Strong Link	-
											Key: Mask Liek Group/AD	21

stuff below this line rarely shows up even in Sudoku championships