
A TALE OF TIC-TAC-TOE

THE DAY MY STUDENTS PLAYED

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Mathfest
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WILDCAT PROOFS WORKSHOP

This talk: Case study of a day in my Wildcat Proofs Workshop

Course description

- Supplemental (optional) course for UA proofs course
- 1 unit Pass/Fail
- No prerequisite or corequisite requirements
- Minimal stress: students graded for effort and participation

WILDCAT PROOFS WORKSHOP

Course objective:

- To share the performance of research-level mathematics with students who typically won't have access to this experience until graduate school. To both develop intuition for what a mathematician does and to develop appreciation for the creative side of mathematical discovery.

WILDCAT PROOFS WORKSHOP

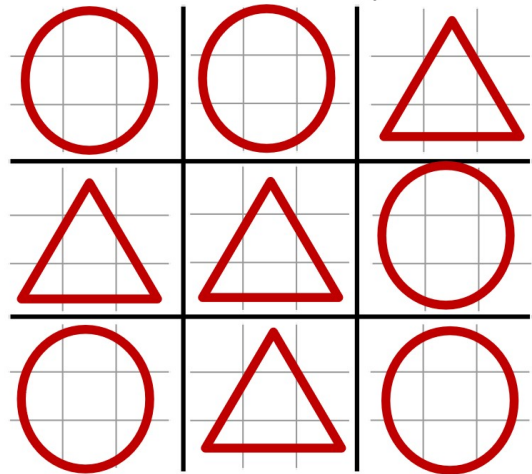
Challenges I faced

- Small group of students from different levels
- Students were hesitant to share incomplete ideas
- Students wanted to work on their own

ULTIMATE TIC-TAC-TOE

Class was split into two teams of 3 to play Ultimate Tic-Tac-Toe (Math with Bad Drawings by Ben Orlin)

- If a team plays their token on the (m,n) space of a small board, their opponent must play in the small board located in the (m,n) position
- If a team is sent to a small board which is won or full/tied, that team can play anywhere
- The game ends when the large board is won or tied



ULTIMATE TIC-TAC-TOE

Why introduce this game?

- Easy to learn, interesting mechanics
- Low-stakes group activity to encourage teamwork
- Interest builds (first few moves feel “random”)

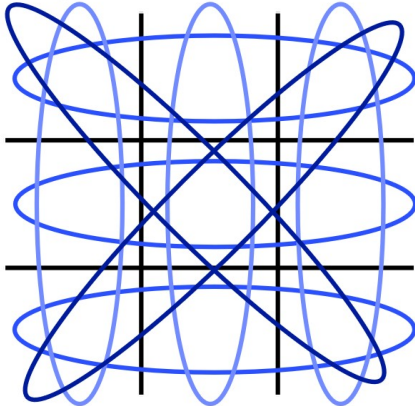
Student response

- “Can we finish the game?” Ans: “No, I have another activity planned”
- “...Can we spend next week’s class playing?” Ans: “...I’ll think about it”

TIC-TAC-TOE DAY!

Warm-up 1: A few more rounds of Ultimate Tic-Tac-Toe

Warm-up 2: Consider a normal TTT game. List all winning combinations.



- Initial responses:
 - The top/middle/bottom row
 - The left/center/right column
 - Upward/downward diagonal

Can we name the spaces to make the relationships between the combinations more clear?

TIC-TAC-TOE DAY!

Warm-up 1: A few more rounds of Ultimate Tic-Tac-Toe

Warm-up 2: Consider a normal TTT game. List all winning combinations.

(1,1)	(1,2)	(1,3)
(2,1)	(2,2)	(2,3)
(3,1)	(3,2)	(3,3)

- Matrix notation
 - (1,1)(1,2)(1,3)
 -
 -
 -
 -

TIC-TAC-TOE DAY!

Warm-up 1: A few more rounds of Ultimate Tic-Tac-Toe

Warm-up 2: Consider a normal TTT game. List all winning combinations.

(1,1)	(1,2)	(1,3)
(2,1)	(2,2)	(2,3)
(3,1)	(3,2)	(3,3)

■ Matrix notation

- (1,1)(1,2)(1,3)
- (2,1)(2,2)(2,3)
- (3,1)(3,2)(3,3)
- (1,1)(2,2)(3,3)
- ...

TIC-TAC-TOE DAY!

Warm-up 1: A few more rounds of Ultimate Tic-Tac-Toe

Warm-up 2: Consider a normal TTT game. List all winning combinations.

1	2	3
4	5	6
7	8	9

■ Numbering the squares

- 123
 -
 -
 -
 -
- 213 231 132 ...

TIC-TAC-TOE DAY!

Warm-up 1: A few more rounds of Ultimate Tic-Tac-Toe

Warm-up 2: Consider a normal TTT game. List all winning combinations.

1	2	3
4	5	6
7	8	9

■ Numbering the squares

- 123
- 456
- 789
- 147
- 258
- 369
- 159
- 357

TIC-TAC-TOE DAY!

Main question: What are the winning combinations if, instead of playing tic-tac-toe on a regular TTT game board, you played on one of the following game boards?

- **Cylinder**
Curve the TTT grid and glue the left side to the right side
- **Mobius strip**
Stretch the TTT grid, give the left side a half twist, then glue to right side
- **Torus**
Curve the cylindrical board and glue the upper ring to the lower ring

TIC-TAC-TOE DAY!

Main question: What are the winning combinations if, instead of playing tic-tac-toe on a regular TTT game board, you played on one of the following game boards?

- Cylinder
 - Mobius strip
 - Torus
- **Initial reactions**
 - Students quietly sat and thought about the problem individually
 - “Well obviously the normal solutions have to be solutions to the new version.”
- “Why is that obvious?”

TIC-TAC-TOE DAY!

Main question: What are the winning combinations if, instead of playing tic-tac-toe on a regular TTT game board, you played on one of the following game boards?

- Cylinder
 - Mobius strip
 - Torus
- **Initial reactions**
 - Students quietly sat and thought about the problem individually
 - “Well obviously the normal solutions have to be solutions to the new version.”
- “But do the alt. versions have MORE winning combos?”

TIC-TAC-TOE DAY!

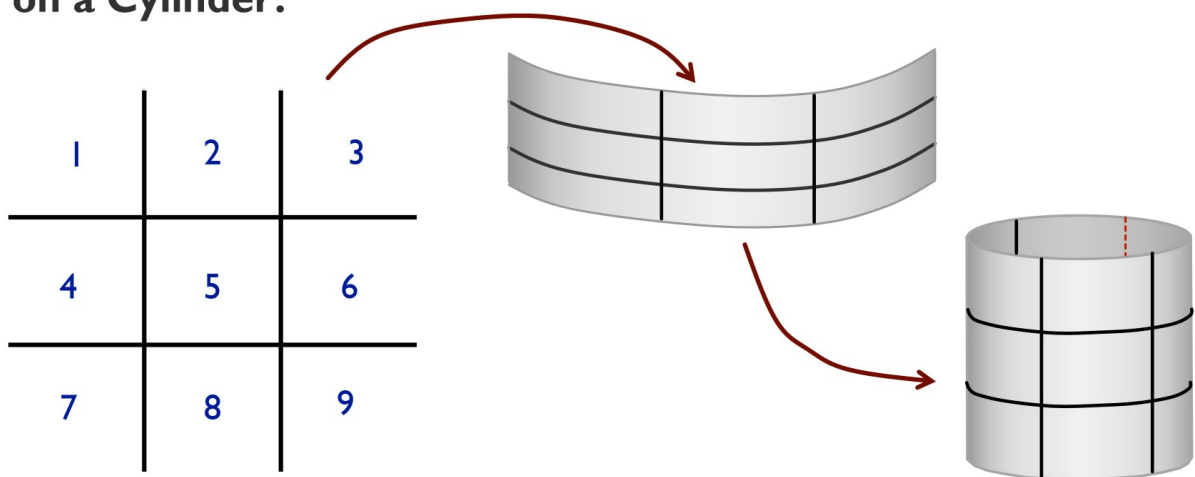
Main question: What are the winning combinations if, instead of playing tic-tac-toe on a regular TTT game board, you played on one of the following game boards?

- Cylinder
 - Mobius strip
 - Torus
- **Initial reactions**
 - Students quietly sat and thought about the problem individually
 - “Well obviously the normal solutions have to be solutions to the new version.”

“Try pairing up with someone and playing a few games...”

TIC-TAC-TOE DAY!

TTT on a Cylinder:



TIC-TAC-TOE DAY!

TTT on a Cylinder:

1	2	3
4	5	6
7	8	9

- 123 ■ 258 ■ 168
- 456 ■ 369
- 789 ■ 159
- 147 ■ 357

TIC-TAC-TOE DAY!

TTT on a Cylinder:

1	2	3
4	5	6
7	8	9

- 123 ■ 258 ■ 168
- 456 ■ 369 ■ 348
- 789 ■ 159
- 147 ■ 357

TIC-TAC-TOE DAY!

TTT on a Cylinder:

1	2	3
4	5	6
7	8	9

- 123 ■ 258 ■ 168
- 456 ■ 369 ■ 348
- 789 ■ 159 ■ 249
- 147 ■ 357

TIC-TAC-TOE DAY!

TTT on a Cylinder:

“Are you sure we have them all?”

1	2	3
4	5	6
7	8	9

- 123 ■ 258 ■ 168
- 456 ■ 369 ■ 348
- 789 ■ 159 ■ 249
- 147 ■ 357 ■ 267

TIC-TAC-TOE DAY!

TTT on a Cylinder:

1	2	3
4	5	6
7	8	9

“Are you sure we have them all?”

Discussion between students

- We won't have new vertical solutions because the up-and-down options haven't changed

TIC-TAC-TOE DAY!

TTT on a Cylinder:

1	2	3
4	5	6
7	8	9

“Are you sure we have them all?”

Discussion between students

- We won't have new horizontal solutions because the sideways options haven't changed

TIC-TAC-TOE DAY!

TTT on a Cylinder:

1	2	3
4	5	6
7	8	9

“Are you sure we have them all?”

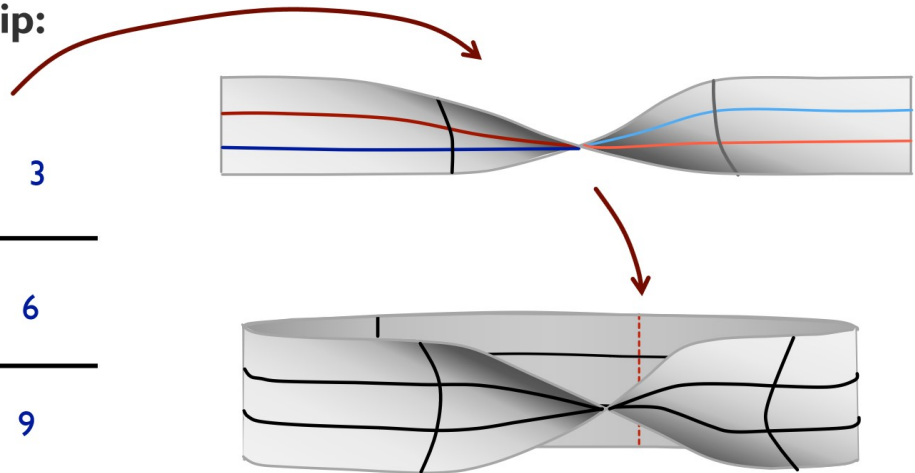
Discussion between students **YES**

- We CAN have new diagonal solutions
- 4, 5, and 6 will each be in two diagonals; remove repeats (159, 357)

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

1	2	3
4	5	6
7	8	9



TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

1	2	3
4	5	6
7	8	9

Students' hypothesis
 Since we're still gluing the left/right edges, this might be similar to playing on a cylinder

- 123
- 456
- 789
- 147
- 258
- 369
- 159
- 357

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

1	2	3
4	5	6
7	8	9

129
 ?!?!?

- 123
- 456
- 789
- 147
- 258
- 369
- 159
- 357
- 129
- ...

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

“Hint: Think about that the game board looks like to an ant walking on it”

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “horizontal” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “horizontal” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “horizontal” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “horizontal” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “horizontal” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “diagonals” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “diagonals” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “diagonals” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “diagonals” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

Extra “diagonals” win conditions

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

TIC-TAC-TOE DAY!

TTT on a Mobius Strip:

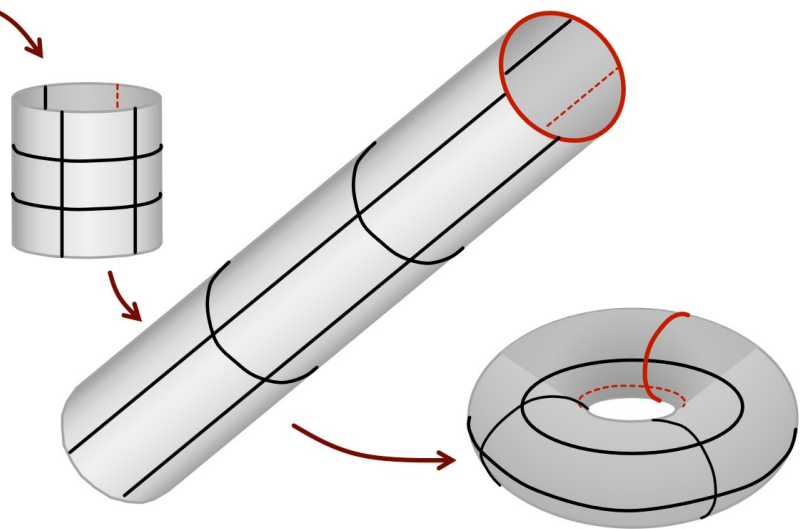
1	2	3
4	5	6
7	8	9

- 123
- 258
- 189
- 678
- 456
- 369
- 129
- 489
- 789
- 159
- 237
- 126
- 147
- 357
- 378
- 234

TIC-TAC-TOE DAY!

TTT on a Torus:

1	2	3
4	5	6
7	8	9



TIC-TAC-TOE DAY!

TTT on a Torus:

1	2	3
4	5	6
7	8	9

Students' hypothesis
 Since we're gluing the left/right edges AND the top/bottom edges, this should have more solutions than the cylindrical board

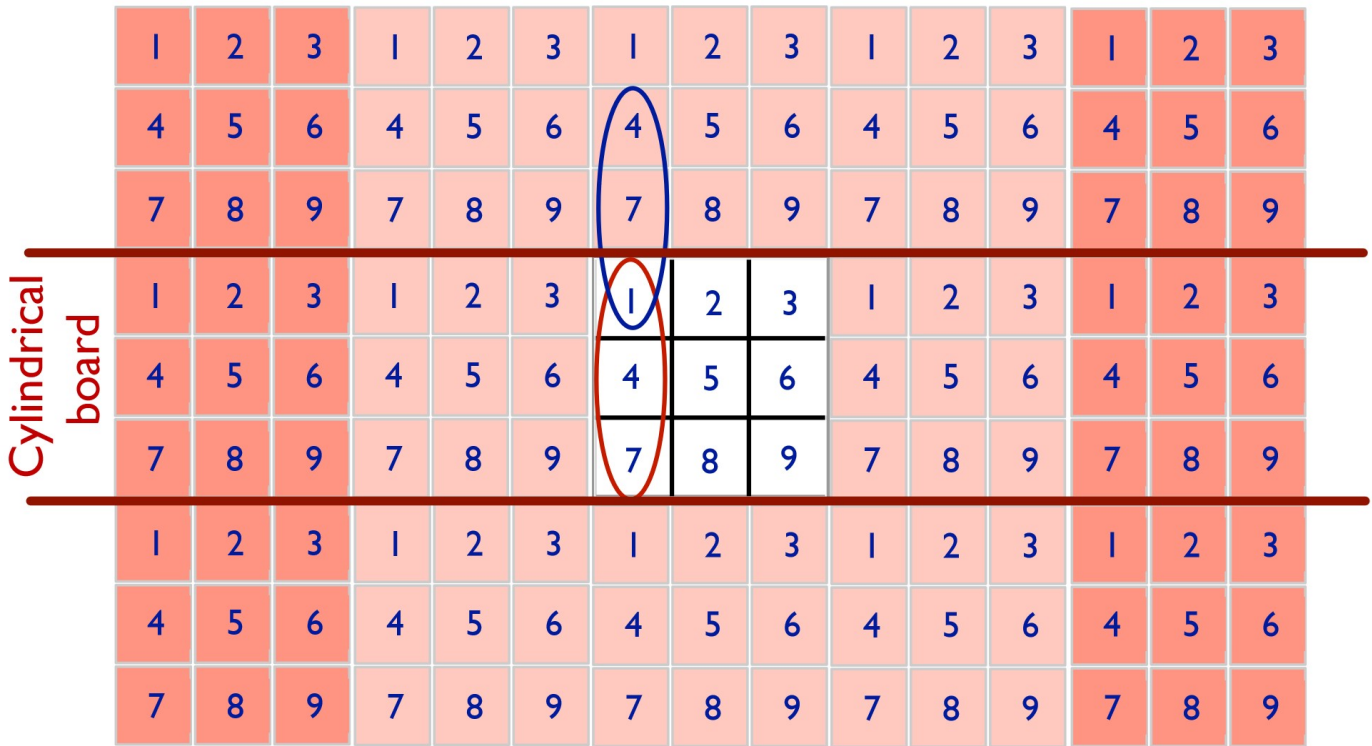
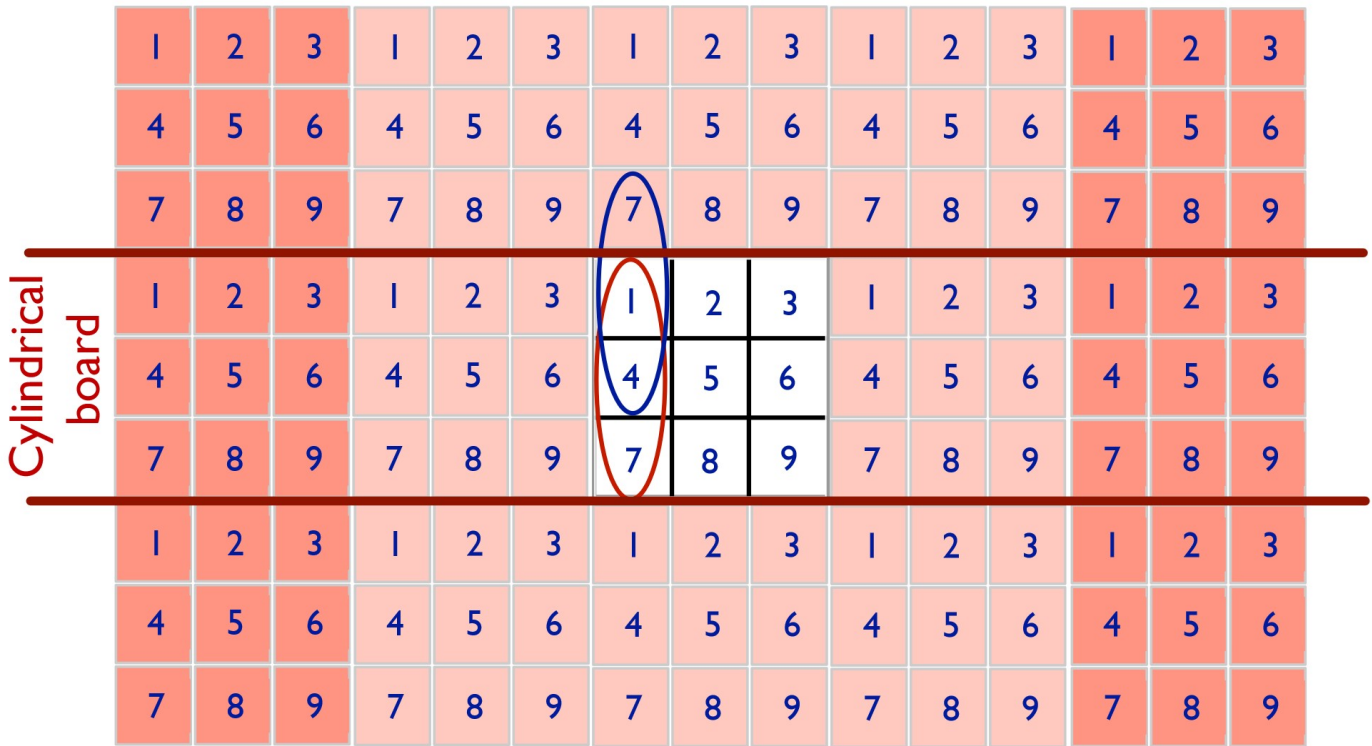
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|-------|-------|-------------|
| ■ 123 | ■ 258 | ■ 168 |
| ■ 456 | ■ 369 | ■ 348 |
| ■ 789 | ■ 159 | ■ 249 |
| ■ 147 | ■ 357 | ■ 267 + ... |

Trying to play on the torus is really annoying...

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

Cylindrical board

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



Cylindrical board

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

Cylindrical board

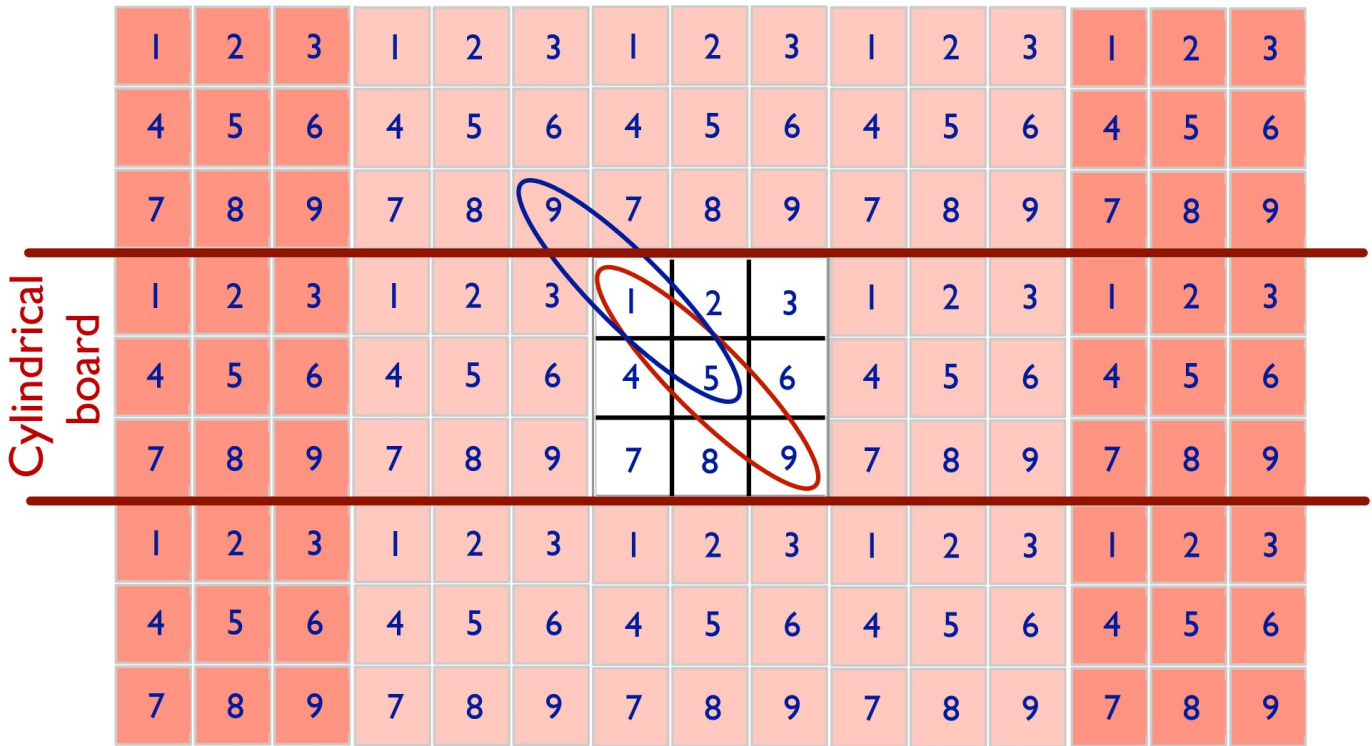
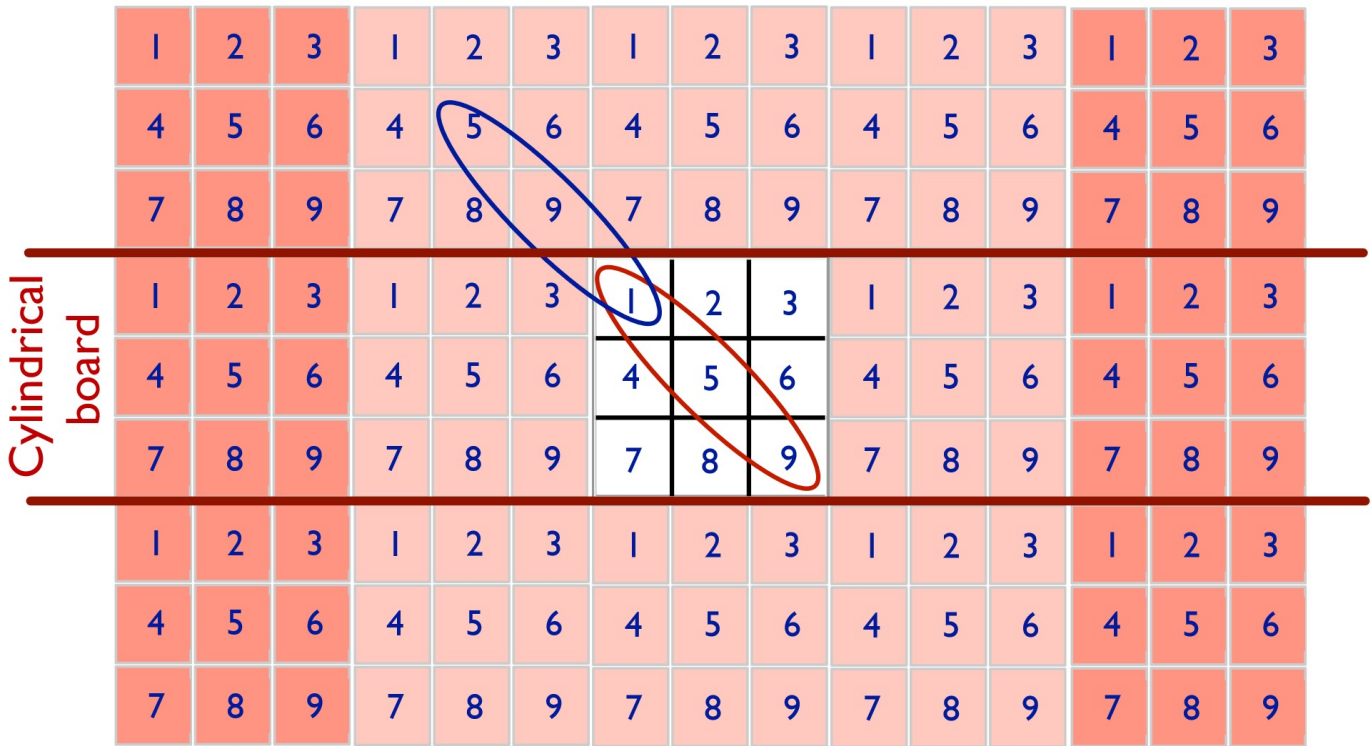
1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
7	8	9	7	8	9	7	8	9	7	8	9	7	8	9
1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
7	8	9	7	8	9	7	8	9	7	8	9	7	8	9
1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
7	8	9	7	8	9	7	8	9	7	8	9	7	8	9

Cylindrical board

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

Cylindrical board

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



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

1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
7	8	9	7	8	9	7	8	9	7	8	9	7	8	9
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1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
7	8	9	7	8	9	7	8	9	7	8	9	7	8	9
<hr/>														
1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
7	8	9	7	8	9	7	8	9	7	8	9	7	8	9

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

TIC-TAC-TOE DAY!

TTT on a Torus:

1	2	3
4	5	6
7	8	9

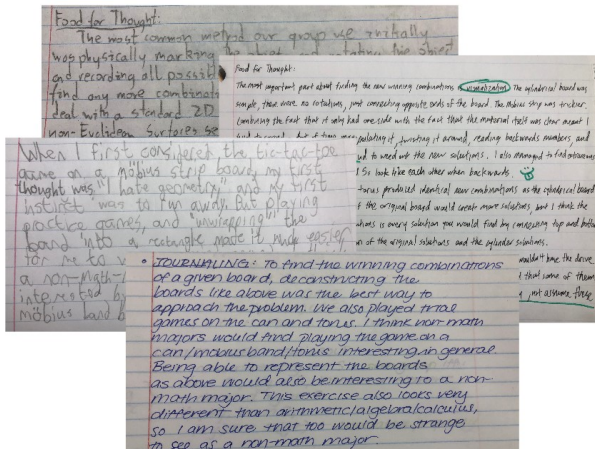
Students' hypothesis
 Since we're gluing the left/right edges AND the top/bottom edges, this should have more solutions than the cylindrical board

Students' conclusion

Every possible vertical or diagonal combination can always be found in the same "strip" made by the cylindrical board. So there are **NOT** any extra winning combos!

TIC-TAC-TOE DAY!

Student feedback



“This feels more like a puzzle game on an app”

“I did find it fascinating that the torus produced identical new combinations as the cylindrical board”

“unwrapping the band... made it easier”

“This... looks very different than arithmetic/algebra/calculus, so I am sure that would be strange to see as a non-math major”

(It is an app! <https://bit.ly/2NZnvcY/>)

WILDCAT PROOFS WORKSHOP

Students organically discussed and refined notation

Students explored new objects and saw the value in changing perspectives

Students saw that previous arguments could be extended and reused

Opened the door for game theory, topology, etc

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Course objective:

- To share the performance of research-level mathematics with students who typically won't have access to this experience until graduate school. To both develop intuition for what a mathematician does and to develop appreciation for the creative side of mathematical discovery.

Thank you for your time!

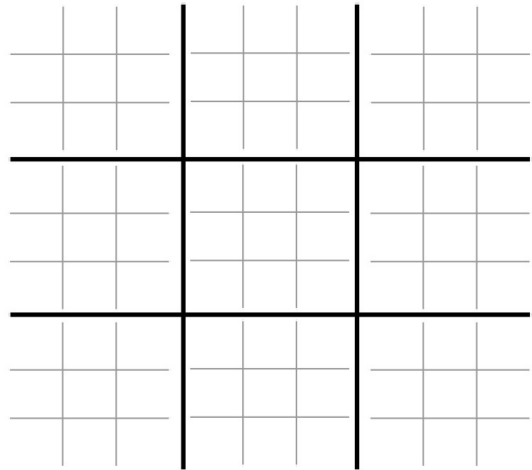
Dr. Nicole Fider

nfider@math.arizona.edu

ULTIMATE TIC-TAC-TOE

Class was split into two teams of 3 to play Ultimate Tic-Tac-Toe ([Math with Bad Drawings](#) by Ben Orlin)

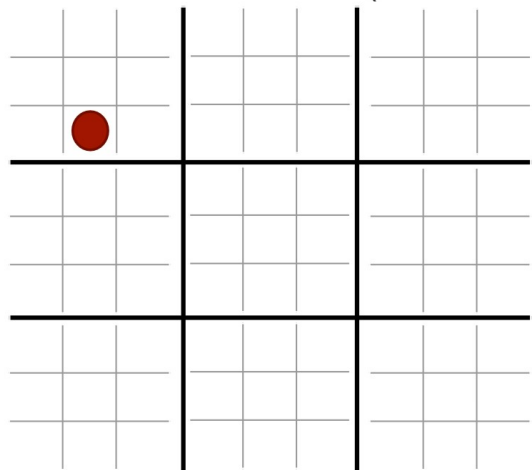
- If a team plays their token on the (m,n) space of a small board, their opponent must play in the small board located in the (m,n) position
-
-



ULTIMATE TIC-TAC-TOE

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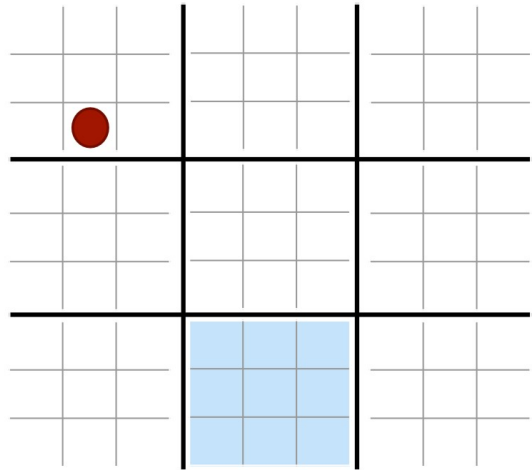
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-



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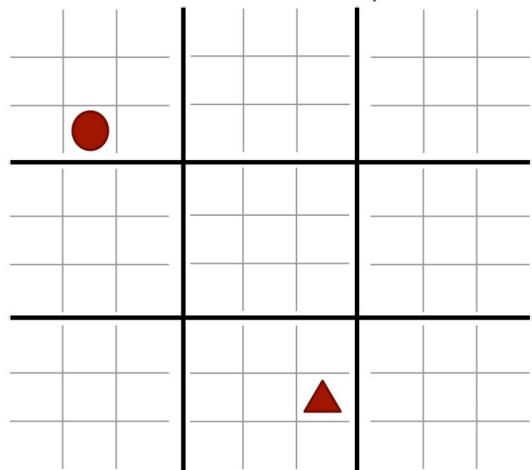
- If a team plays their token on the (m,n) space of a small board, their opponent must play in the small board located in the (m,n) position
-
-



ULTIMATE TIC-TAC-TOE

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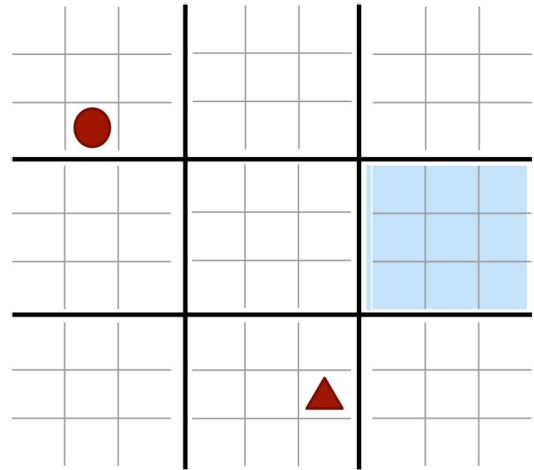
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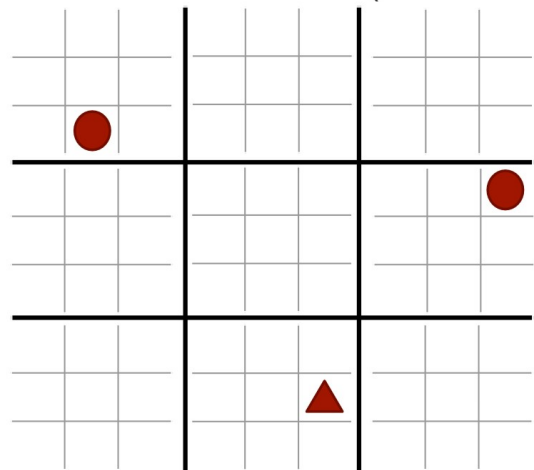
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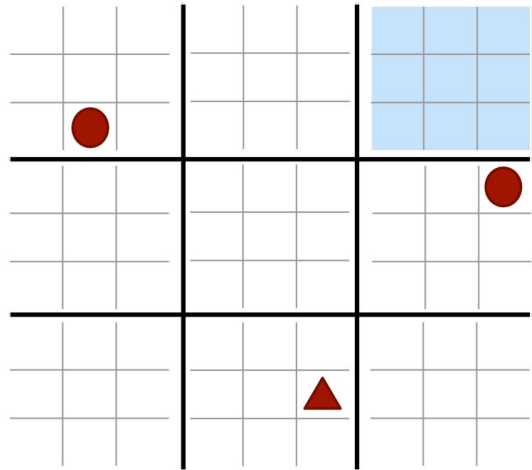
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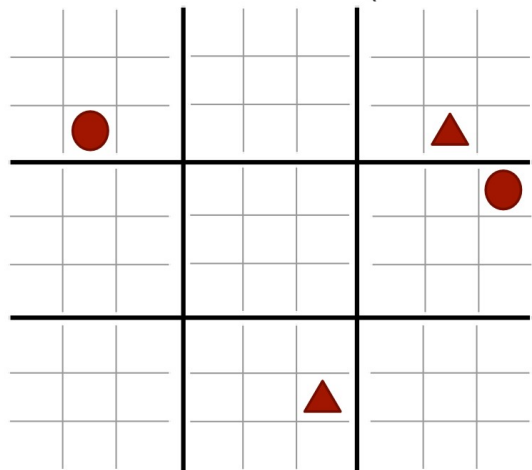
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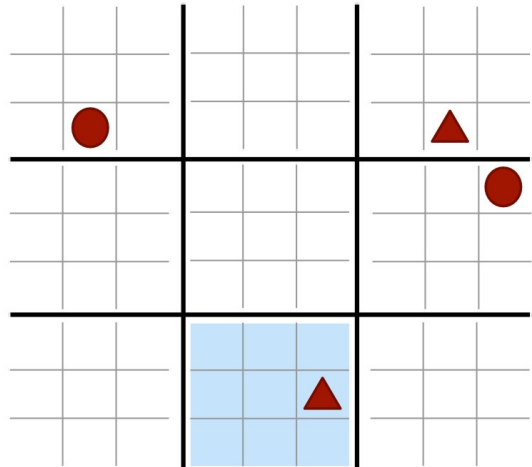
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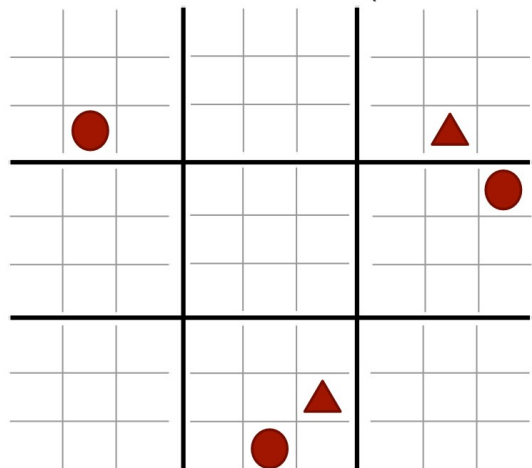
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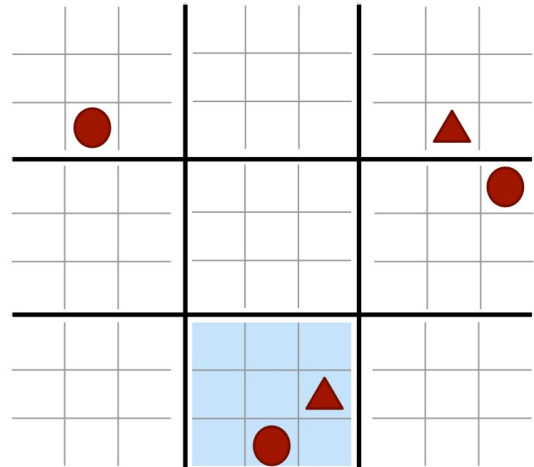
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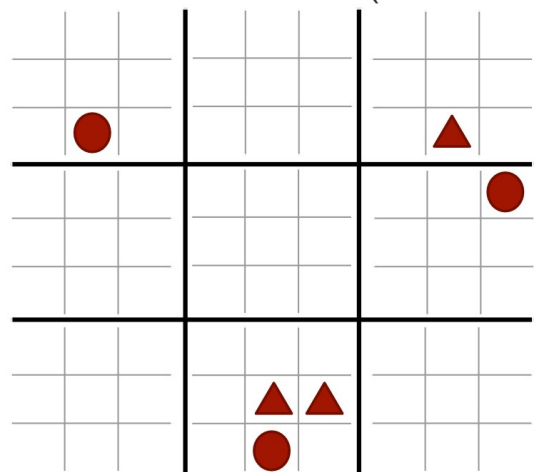
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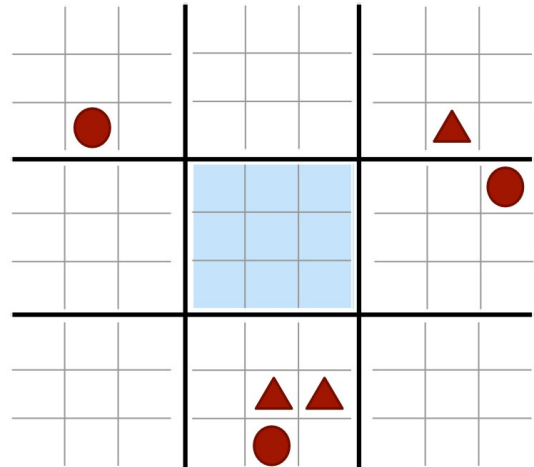
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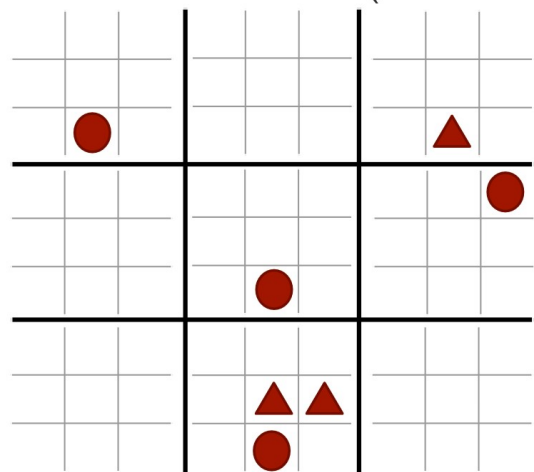
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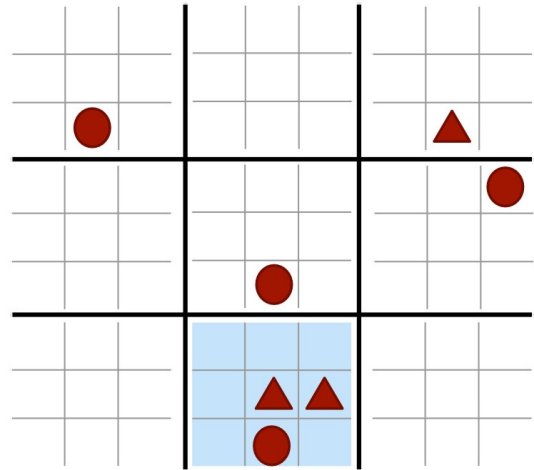
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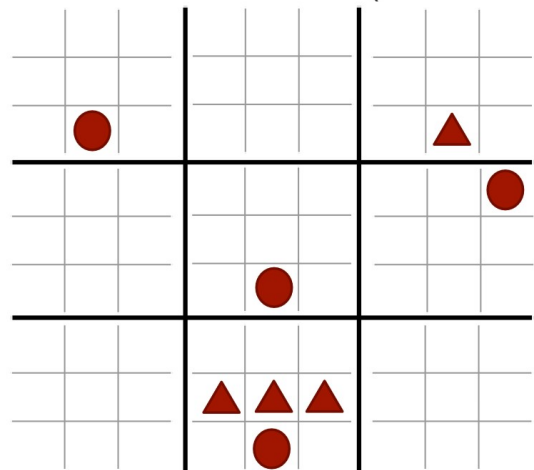
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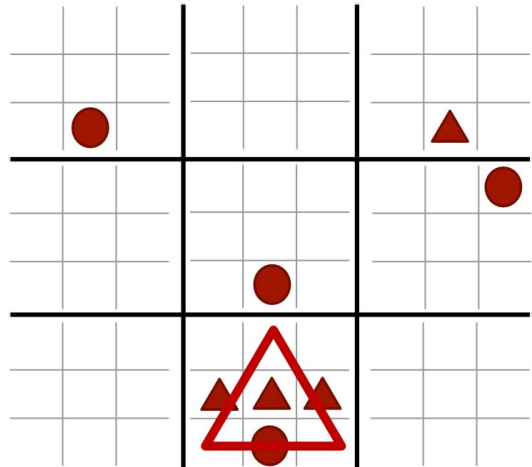
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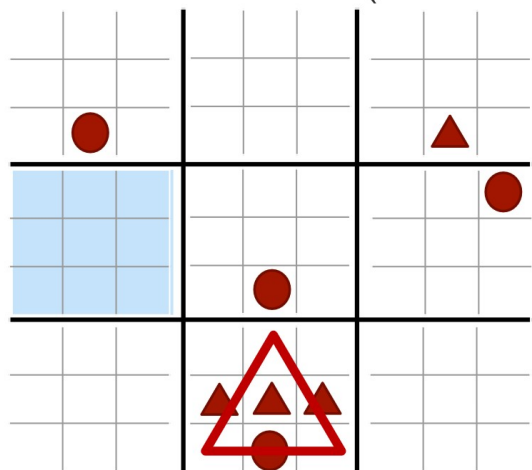
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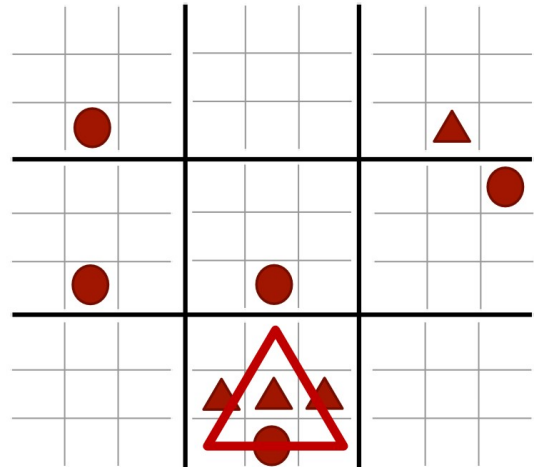
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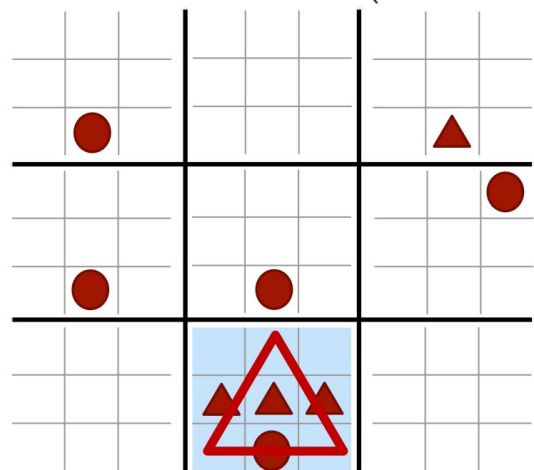
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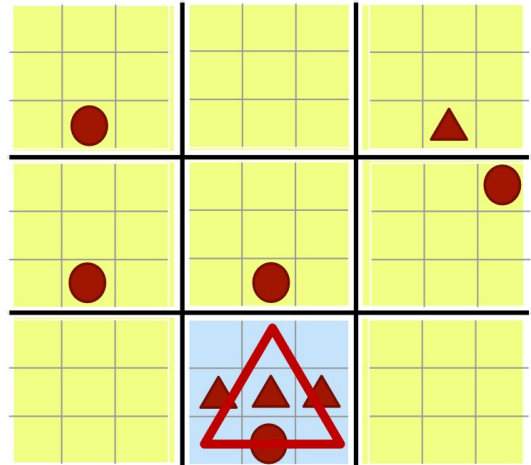
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- The game ends when the large board is won or tied

