Stand Up Indulgent Gathering

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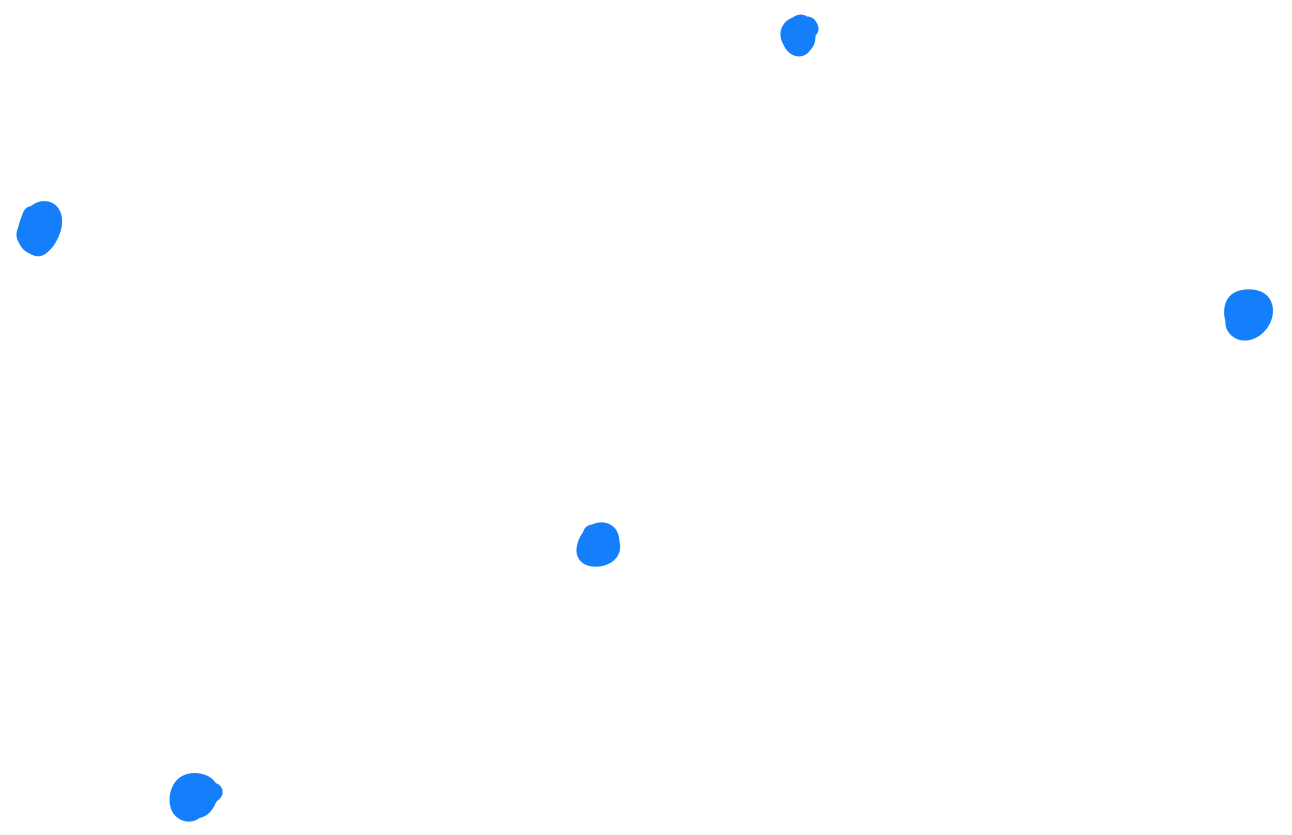
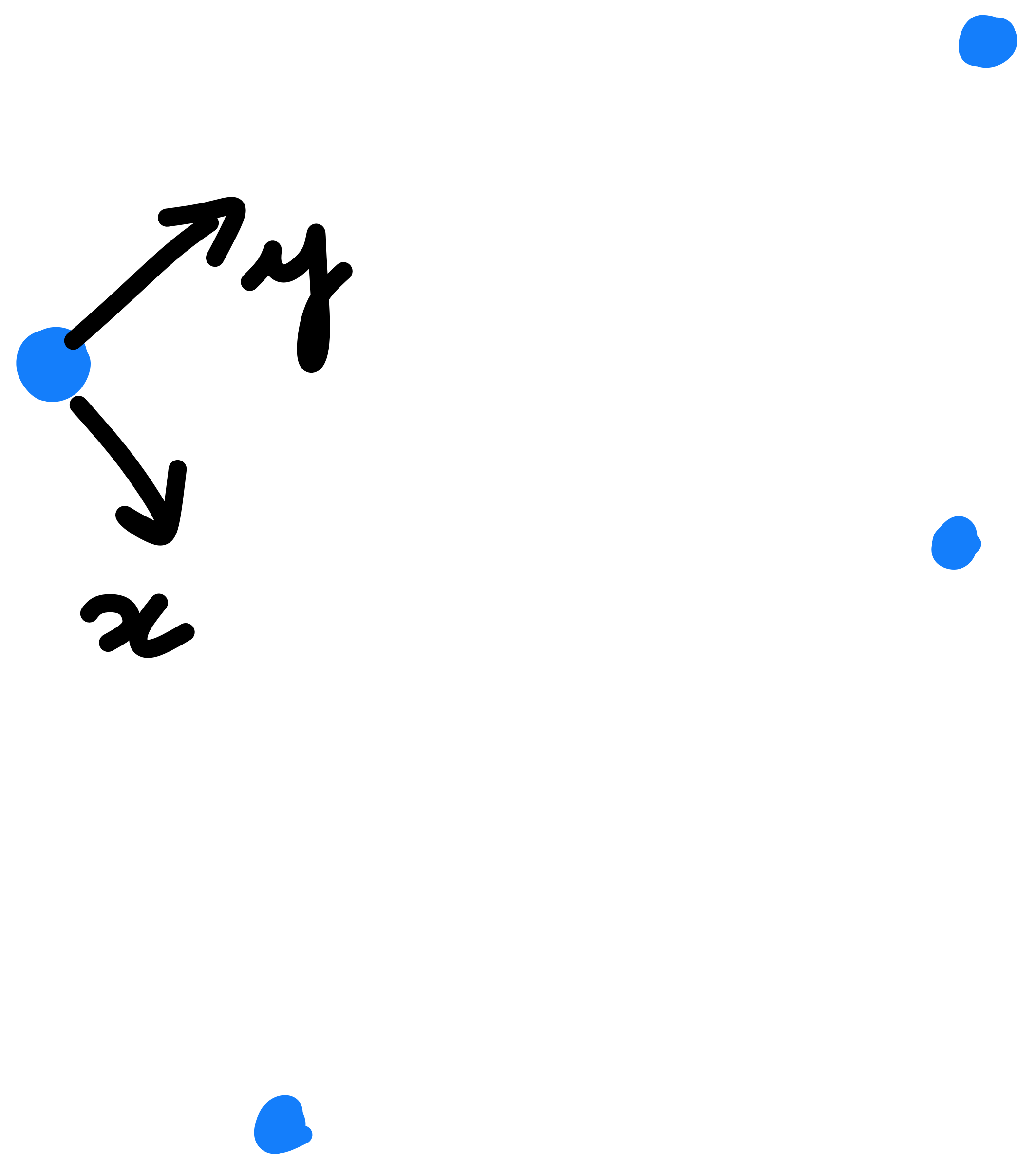
Mobile Autonomous Robots

- Anonymous
- Uniform
- Disoriented
- Silent
- Oblivious



Execution Cycle



- Look
- Compute
- Move

- Fully-Synchronous
- Semi-Synchronous

Execution Cycle

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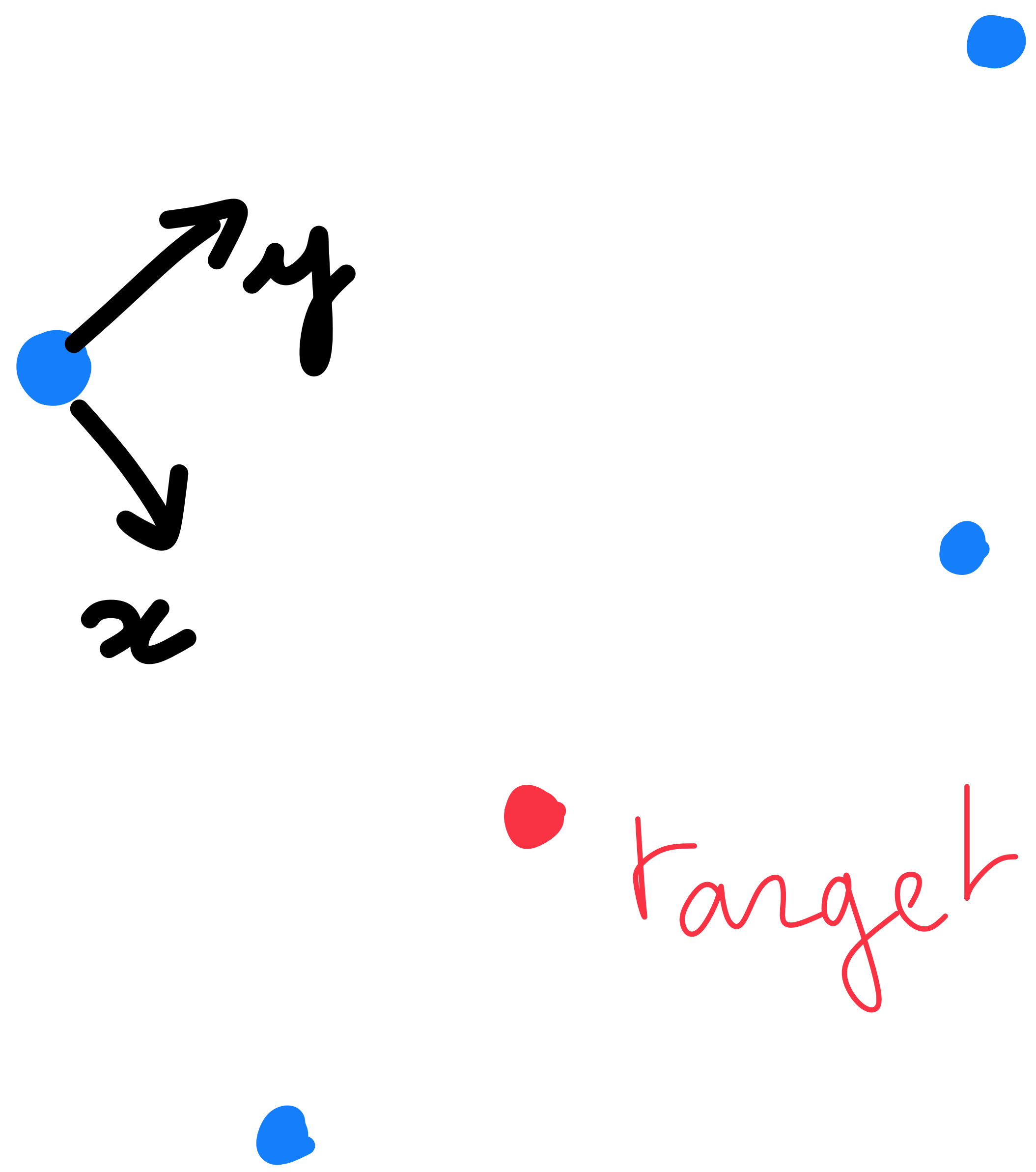
- Compute
- Move



- Fully-Synchronous
- Semi-Synchronous

Execution Cycle

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- Compute
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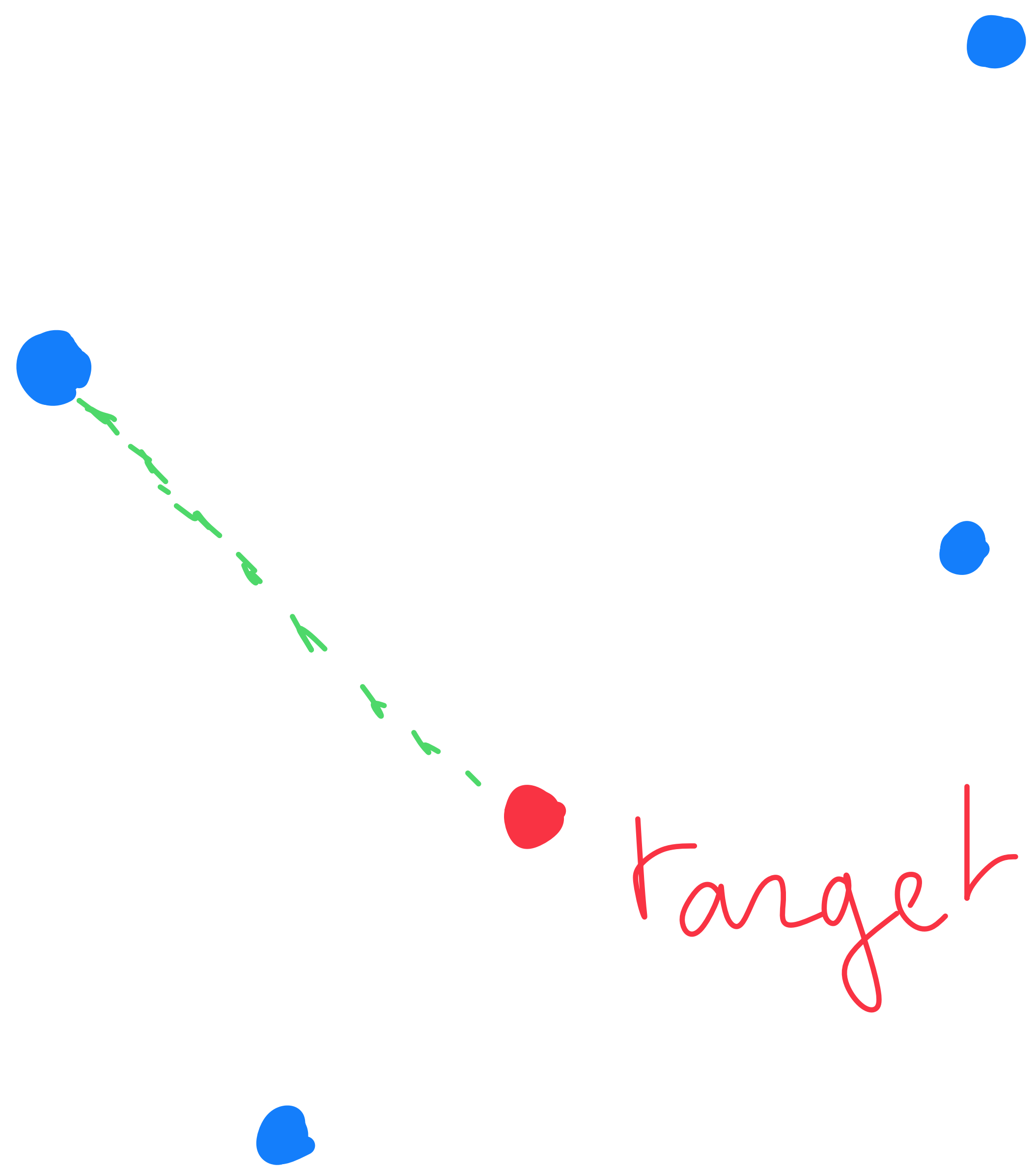

- Fully-Synchronous
- Semi-Synchronous

Execution Cycle

- Look
- Compute
- Move

- Fully-Synchronous
- Semi-Synchronous

	t = 1	t = 2	t = 3	...
Robot 1	LCM	LCM	LCM	...
Robot 2	LCM	LCM	LCM	
Robot 3	LCM	LCM	LCM	

Execution Cycle

- Look
- Compute
- Move

- Fully-Synchronous
- Semi-Synchronous

	t = 1	t = 2	t = 3	...
Robot 1	LCM		LCM	...
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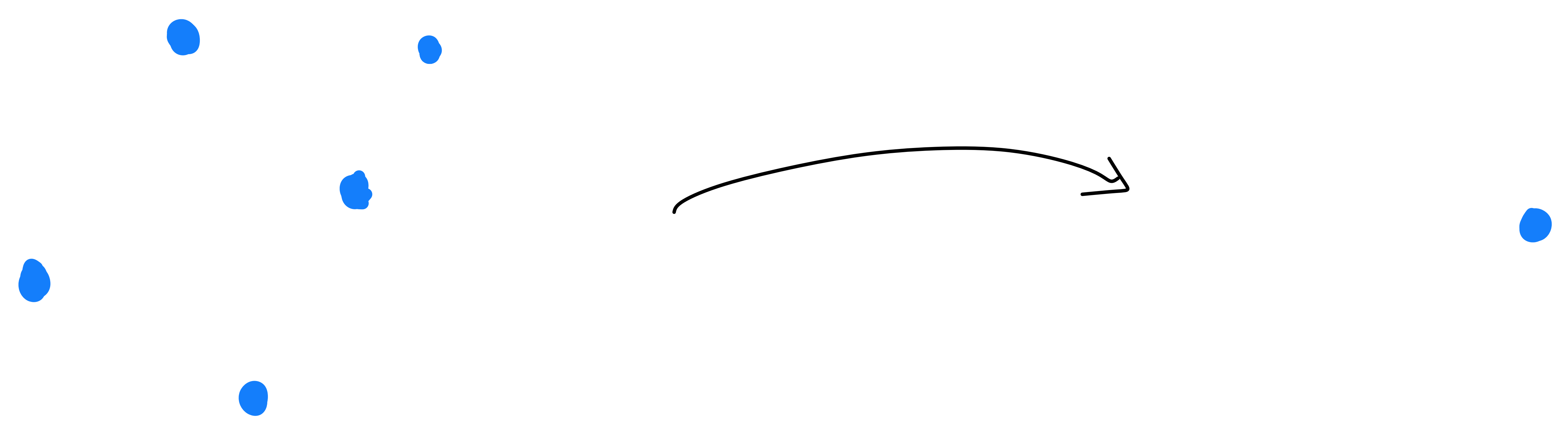
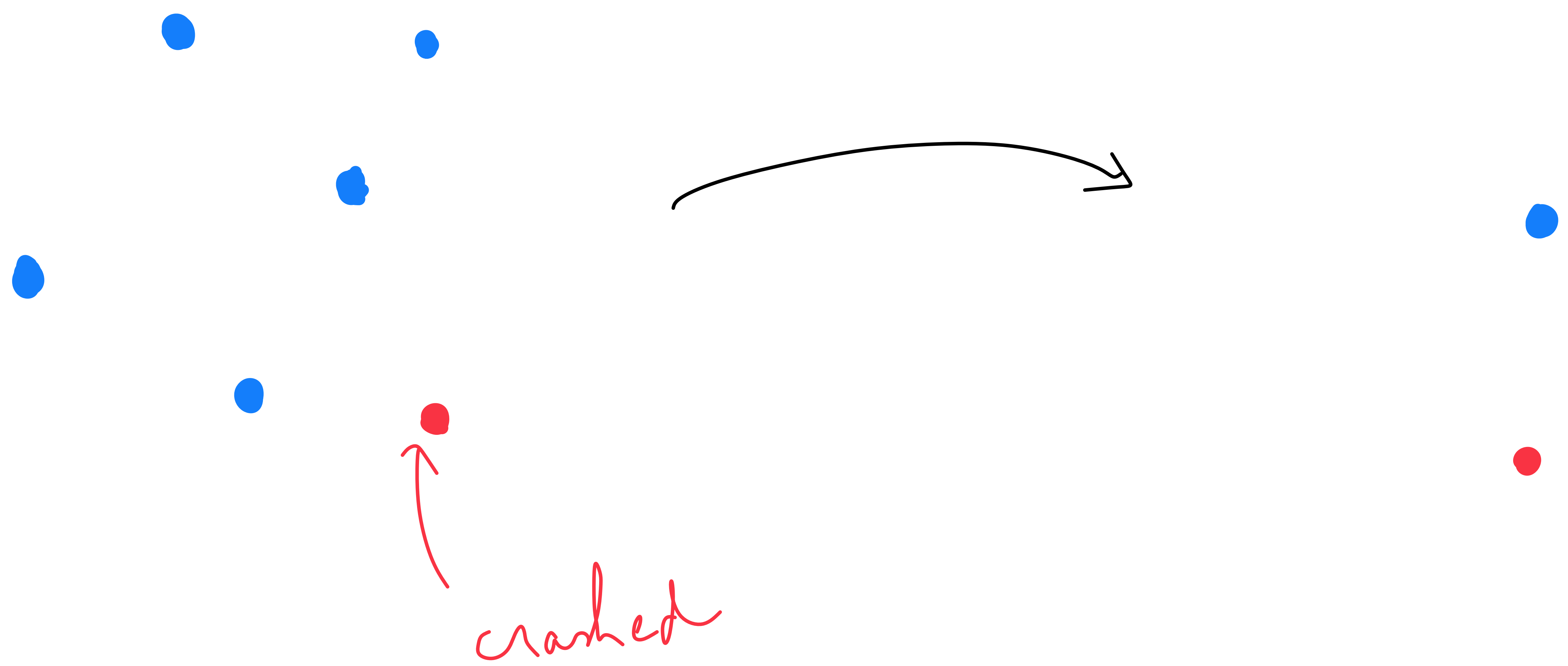
The Fundamental Problem of Gathering



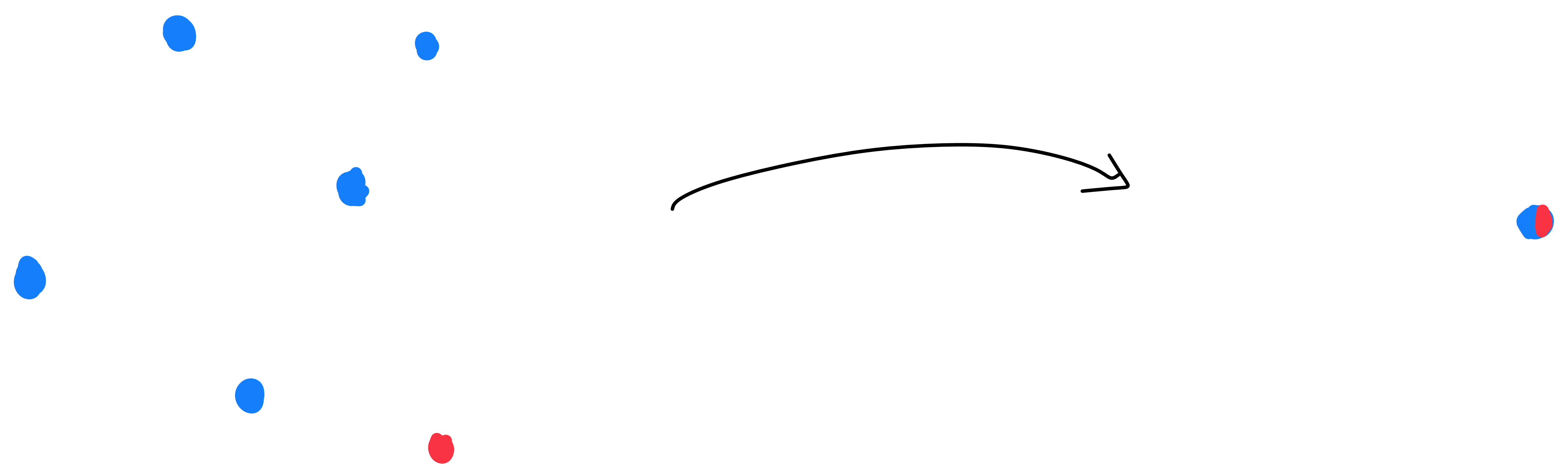
Fault-Tolerant Gathering

Weak Gathering



Stand Up Tolerant Gathering

Strong Gathering



Related Work

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Gathering:

Related Work

Gathering:

Solvable in FSYNC [SY1999]

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Solvable in SSYNC with common coordinate system. [SY1999]

Related Work

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- **Solvable** in FSYNC [SY1999]
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Related Work

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Solvable in SSYNC with up to n-1 crashes with multiplicity detection and non-bivalent initial configuration [Bramas&Tixeuil2015]

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Stand Up Indulgent Gathering (Strong Gathering):

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Stand Up Indulgent Gathering (Strong Gathering):

Unsolvable in SSYNC, even with common coordinate systems and lights with infinite # of colors [SSS2020]

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Solvable in FSYNC with two robots [SSS2020]

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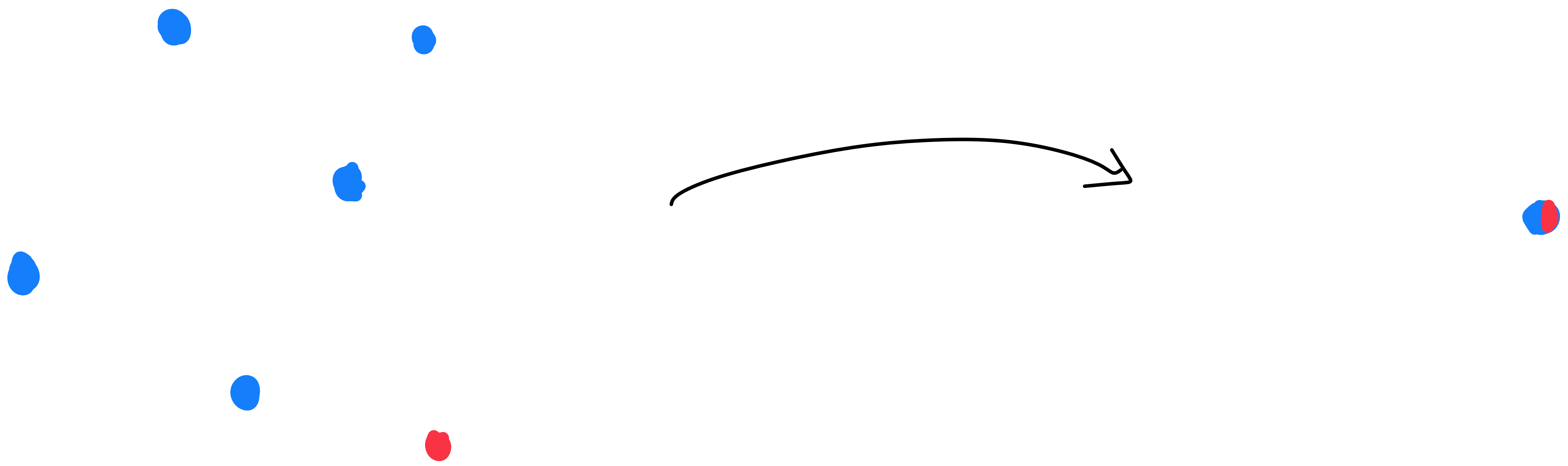
Stand Up Indulgent Gathering (Strong Gathering):

- **Unsolvable** in SSYNC, even with common coordinate systems and lights with infinite # of colors [SSS2020]
- **Solvable** in FSYNC with two robots [SSS2020]
- **Solvable** in FSYNC with n robots [ALGOSENSOR2021]

Stand Up Tolerant Gathering

Strong Gathering



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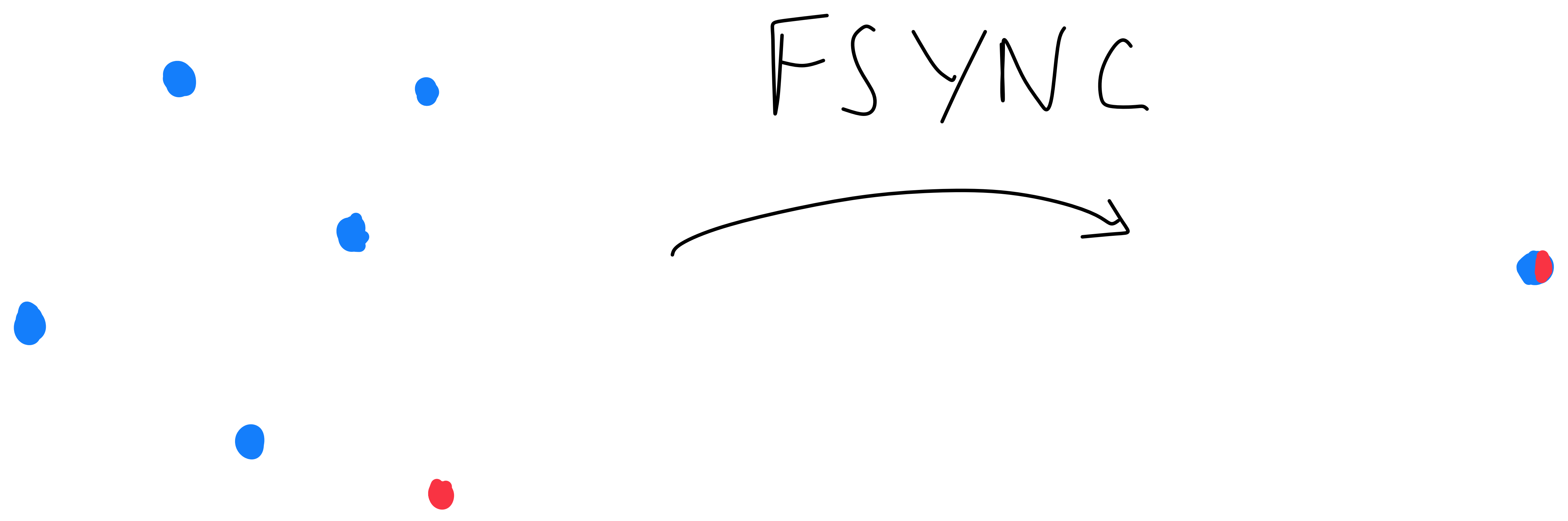

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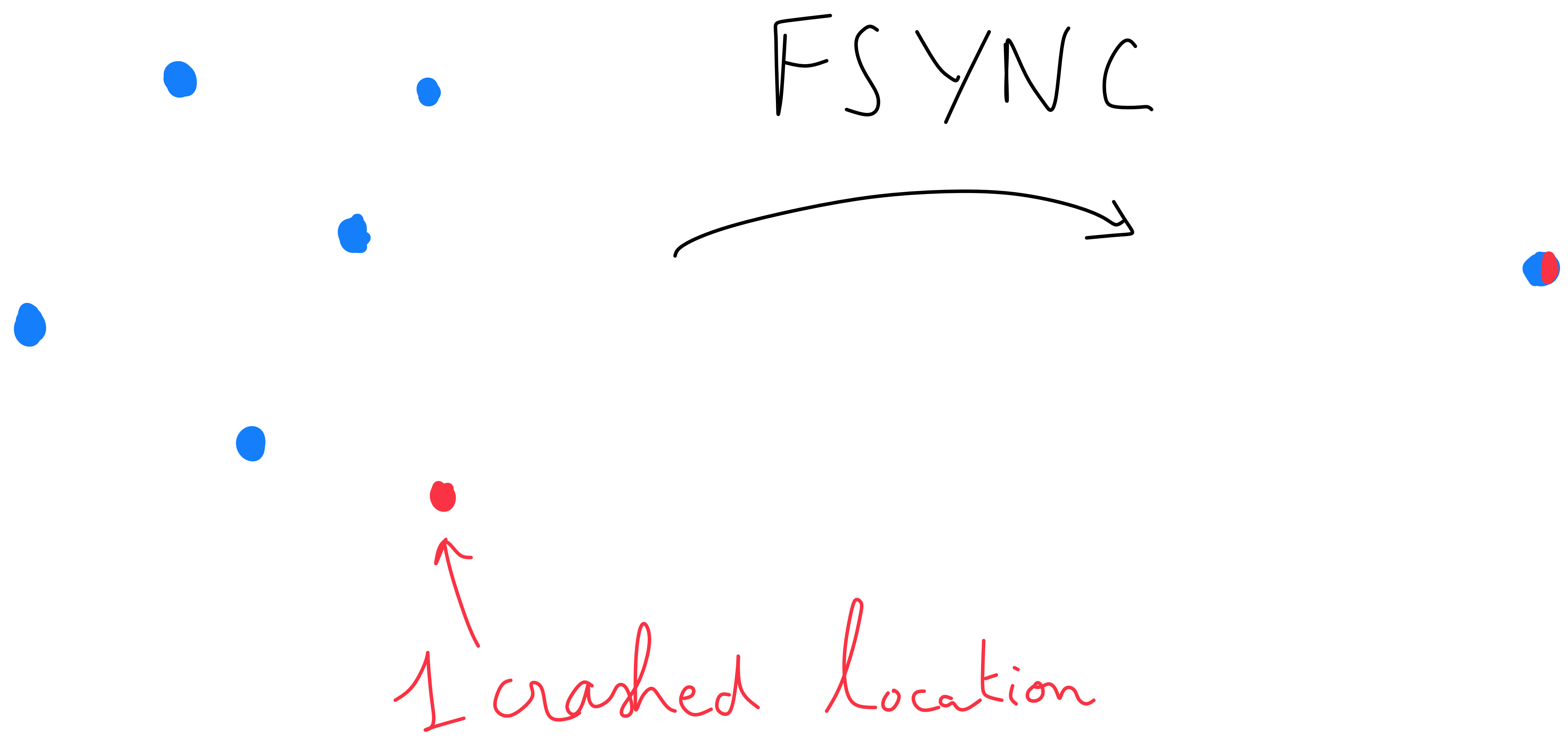

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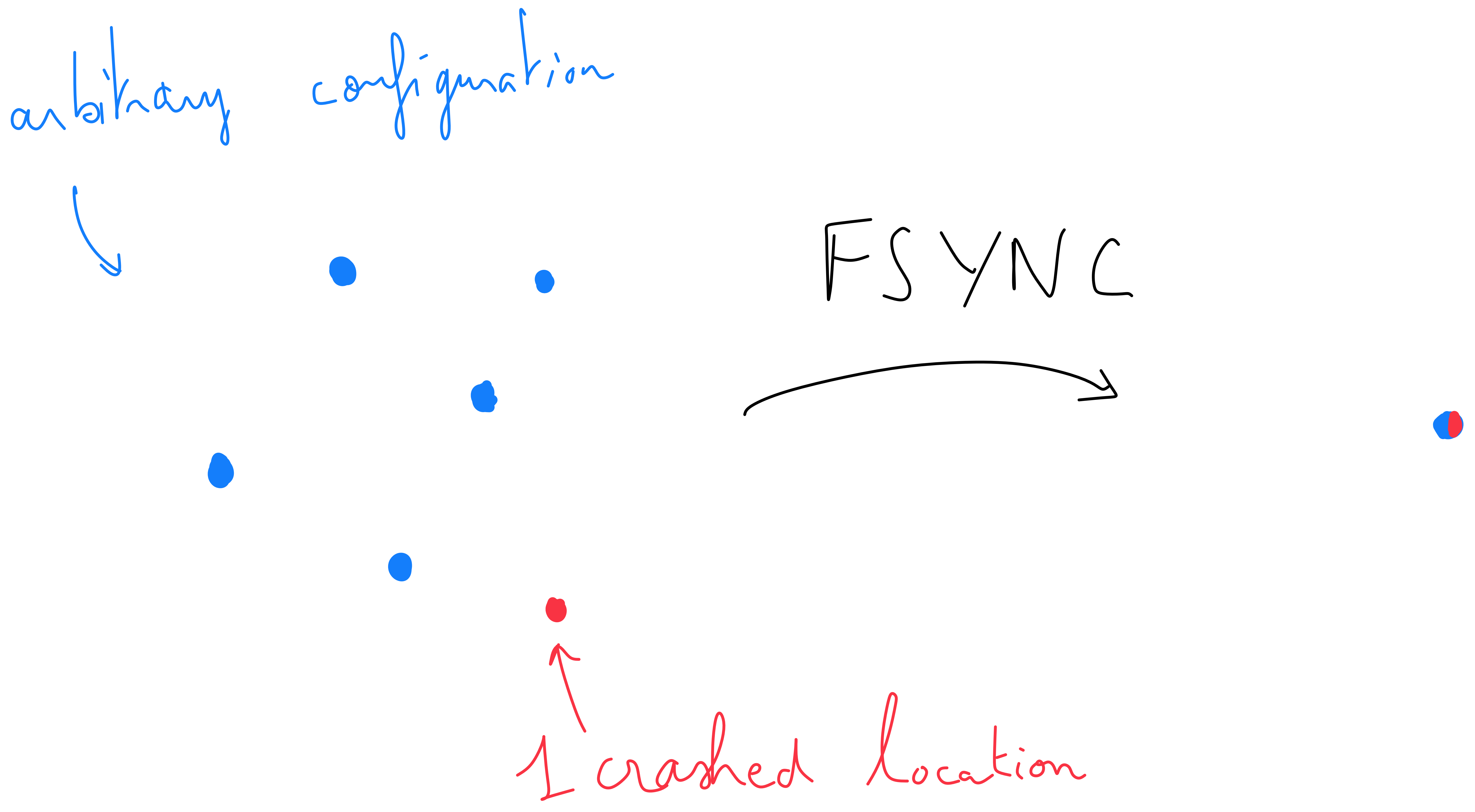

Stand Up Tolerant Gathering

Strong Gathering

arbitrary configuration

may contain multiplicity (but no detection)

1 crashed location

Impossibility Result

With 2 robots in SSYNC [SSS2020]

Impossibility result

[SSS2020]

Let A be an algorithm that solves the SUIR problem with lights
(infinite memory and communication capabilities)

Impossibility result

[SSS2020]

Let A be an algorithm that solves the SUIR problem with lights
(infinite memory and communication capabilities)

Lemma: *in an execution, if only one robot r is activated, then there is a round when r is dictated to move to the other robot.*

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[SSS2020]

Let A be an algorithm that solves the SUIR problem with lights
(infinite memory and communication capabilities)

Lemma: *in an execution, if only one robot r is activated, then there is a round when r is dictated to move to the other robot.*

Proof: Indeed, if the other robot is crashed, we know that in finite number of rounds r moves to the other robot.

Impossibility result

[SSS2020]

Theorem: *SUIR is not Solvable in SSYNC (even with lights and common coordinate system)*

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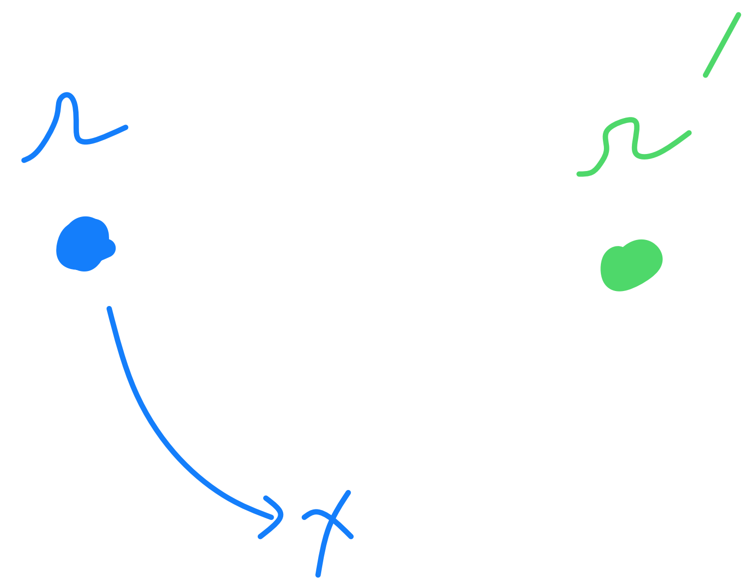

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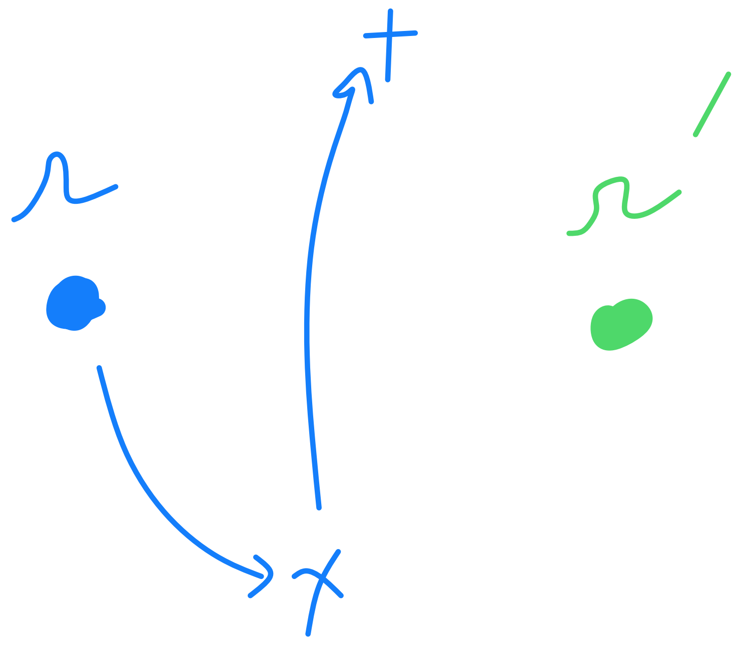

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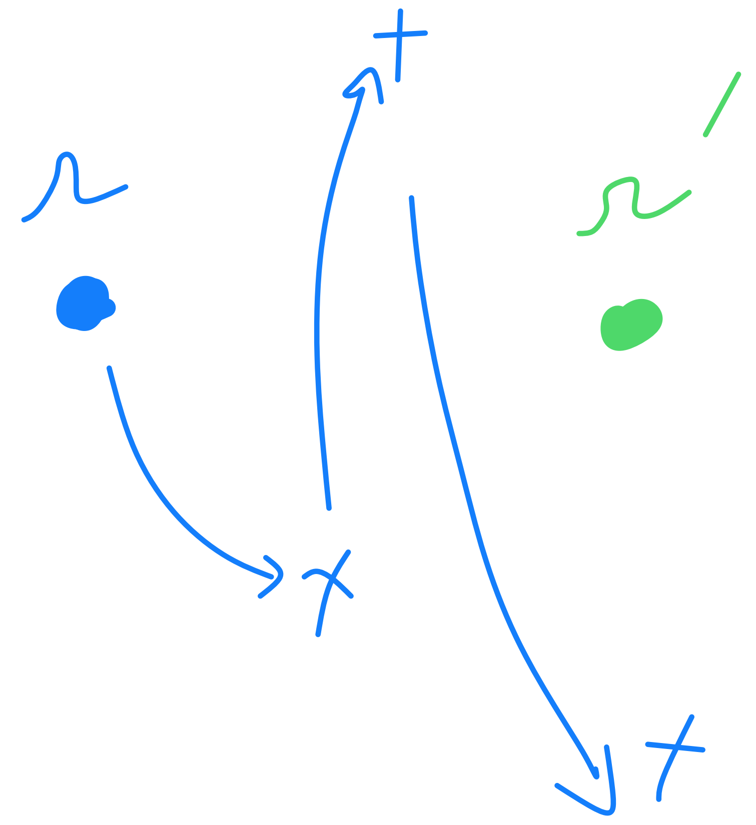

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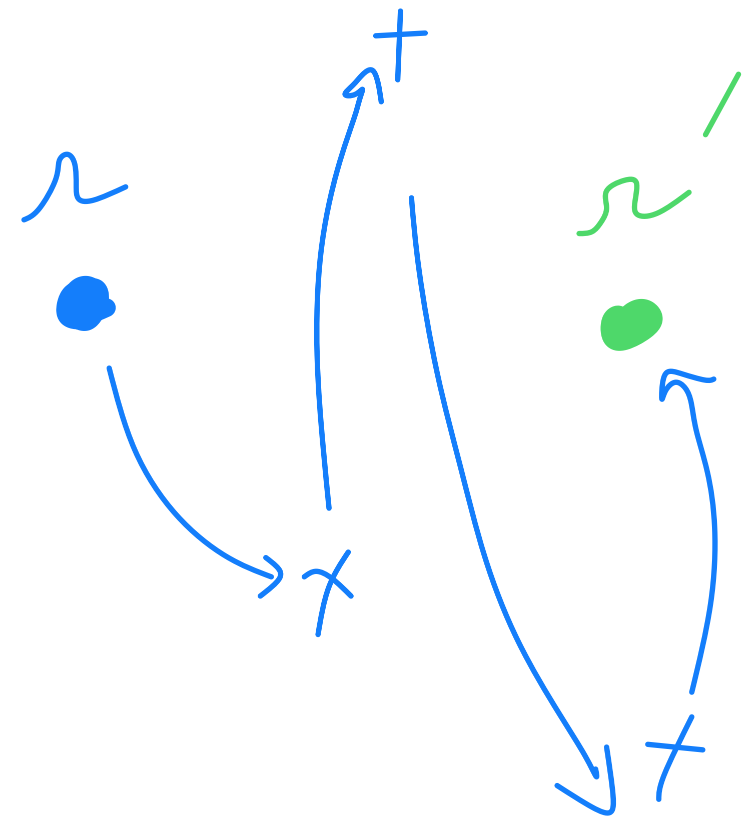

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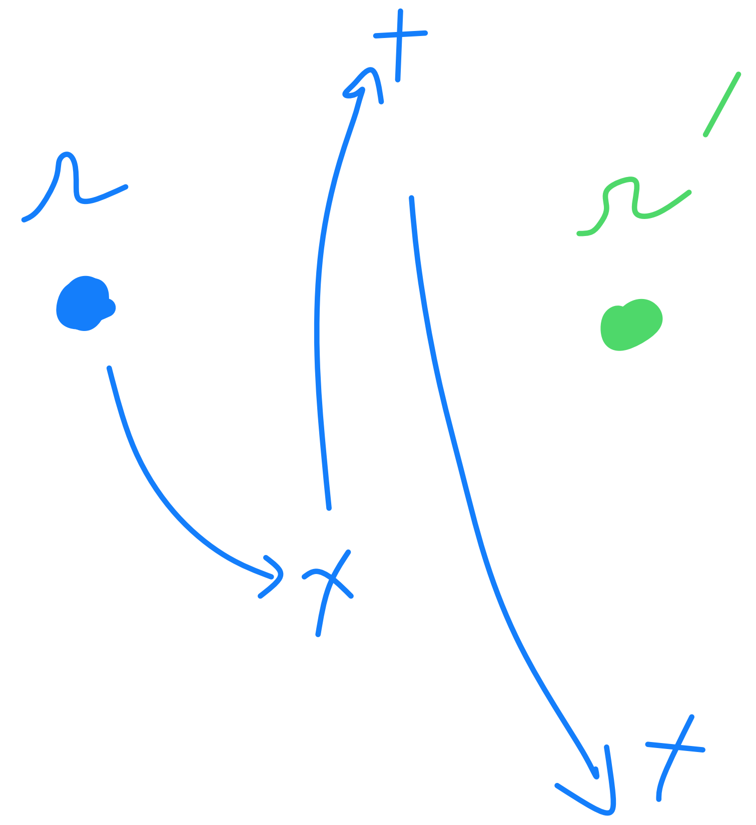

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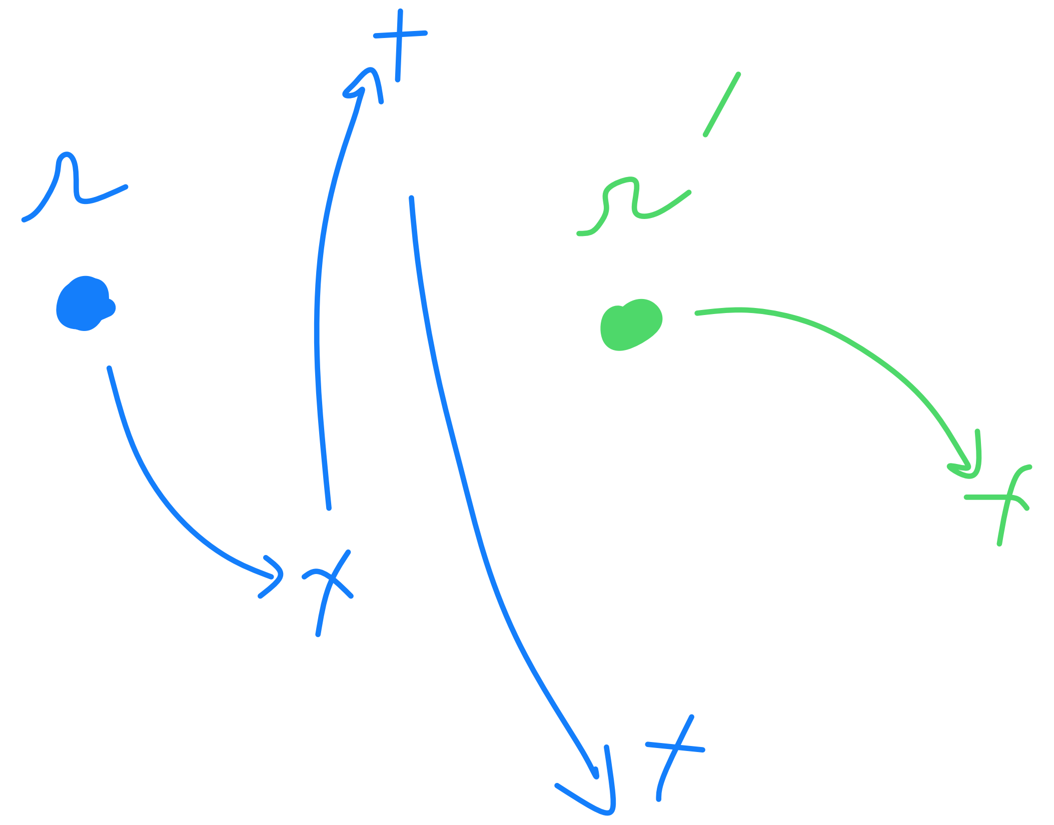

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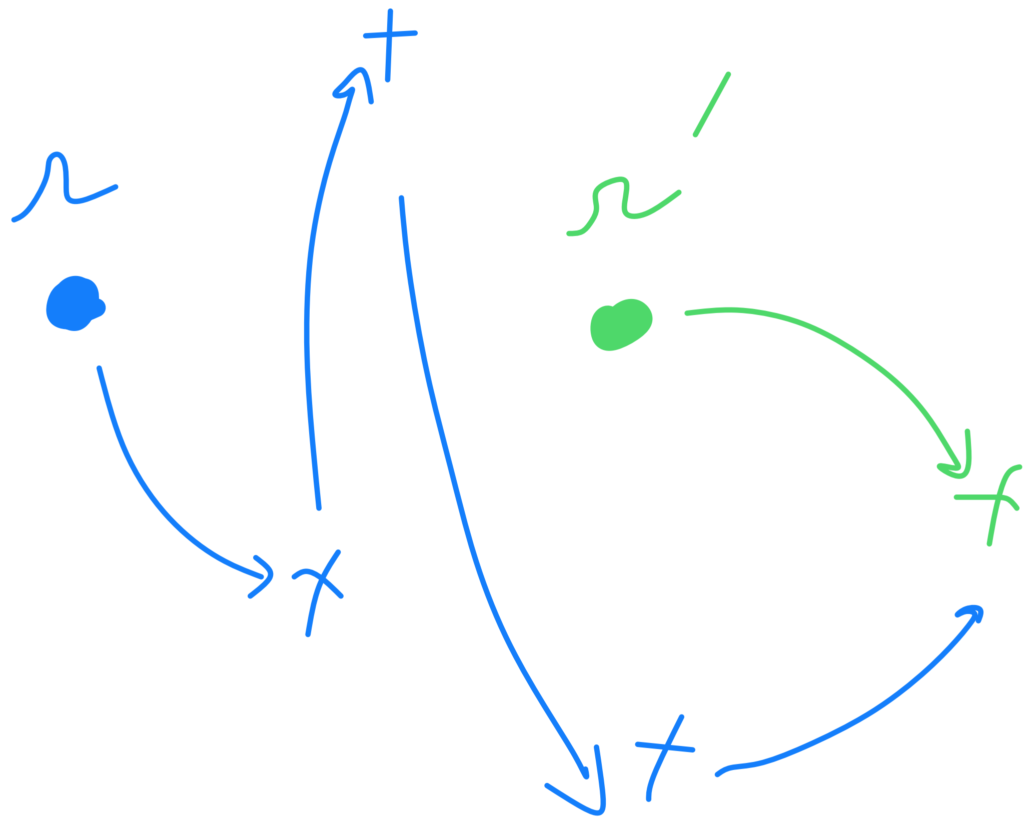

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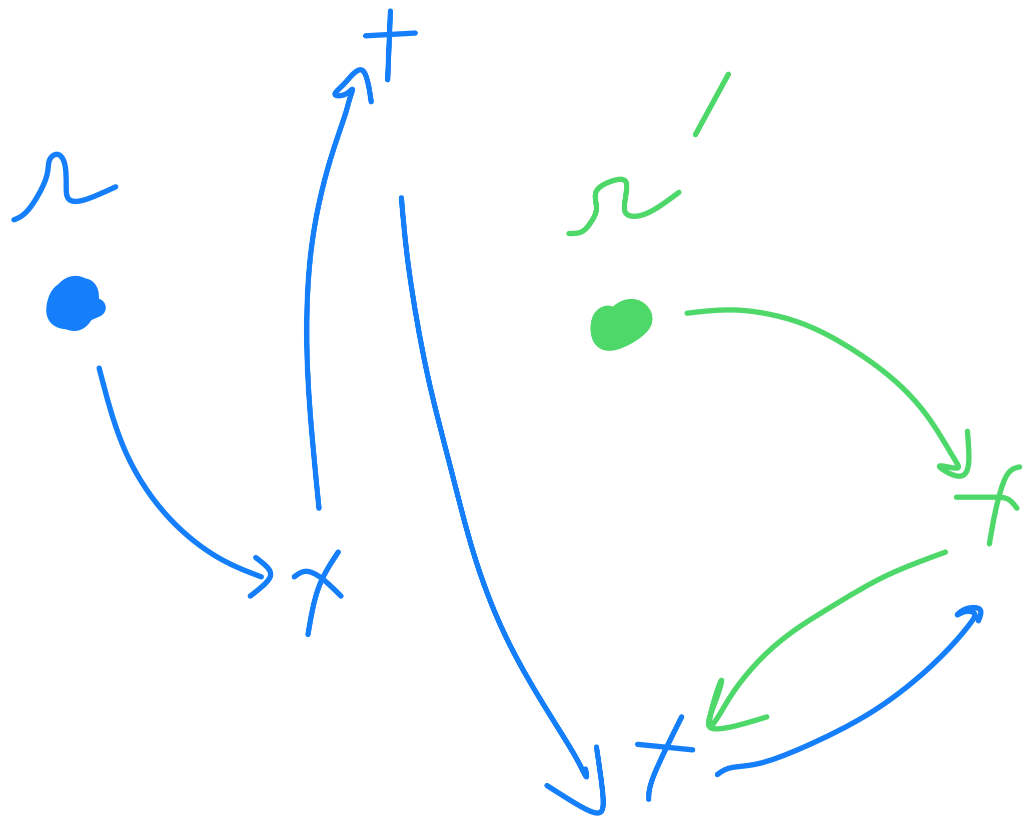

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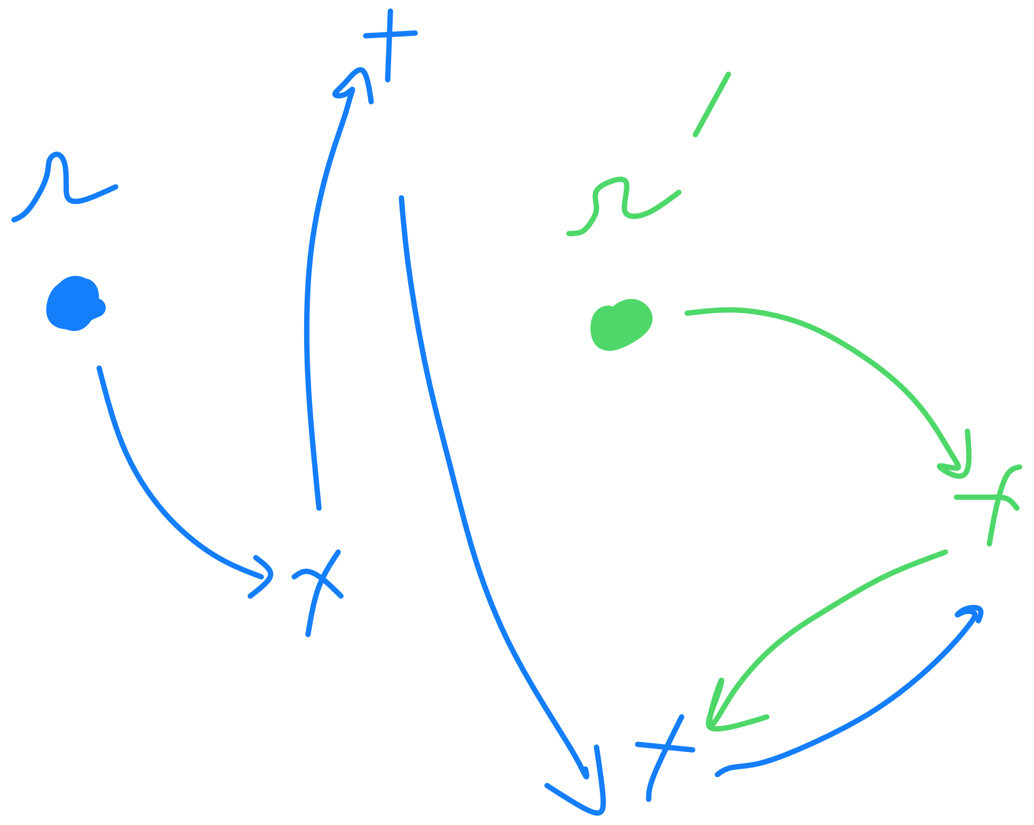

The scheduler is fair otherwise there exists an execution where only r (or r') is activated, without moving to the other robot, contradicting the previous Lemma.

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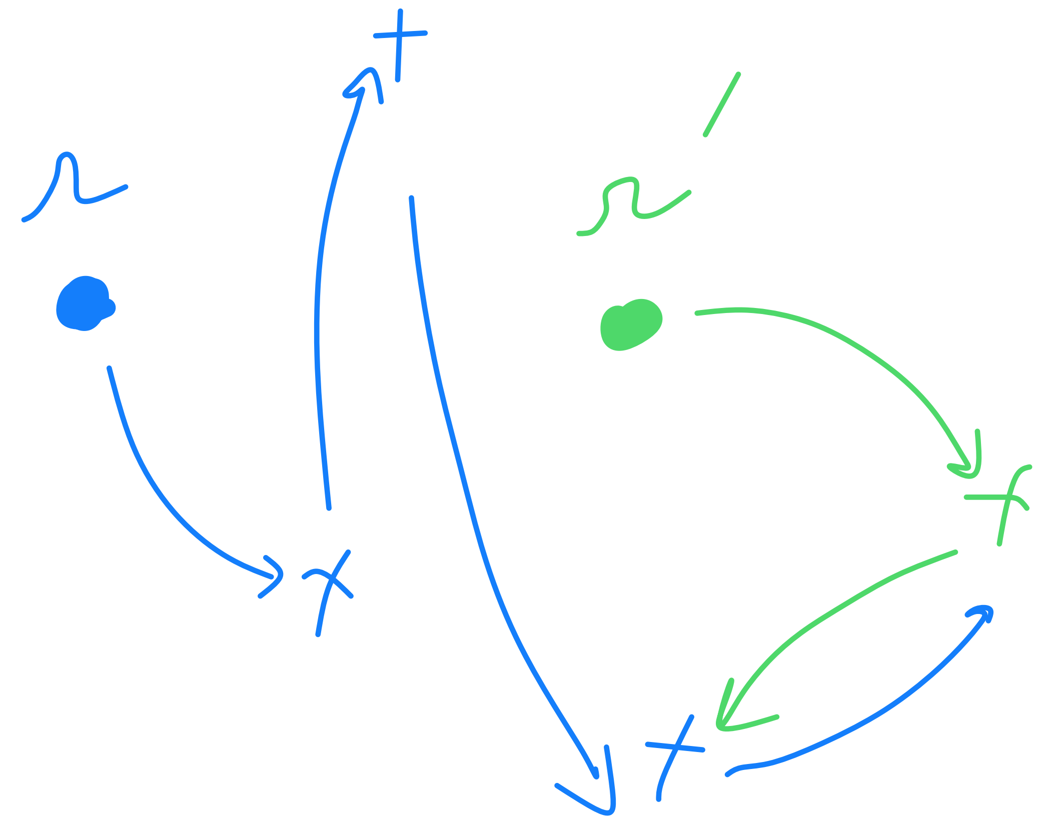

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After each round the robots are not gathered.

Solution with 2 robots

[SSS2020]

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Maybe it seems impossible at first because both robots see the same thing, hence do the same thing:

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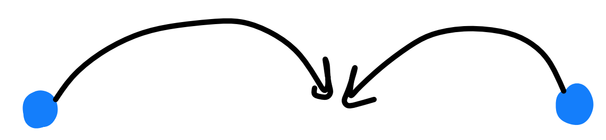

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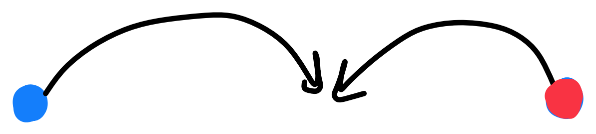

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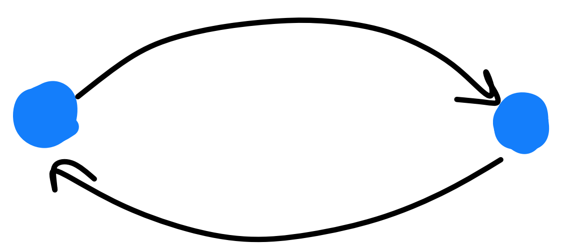

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But if r moves to the middle "alone", r’s view has changed!!

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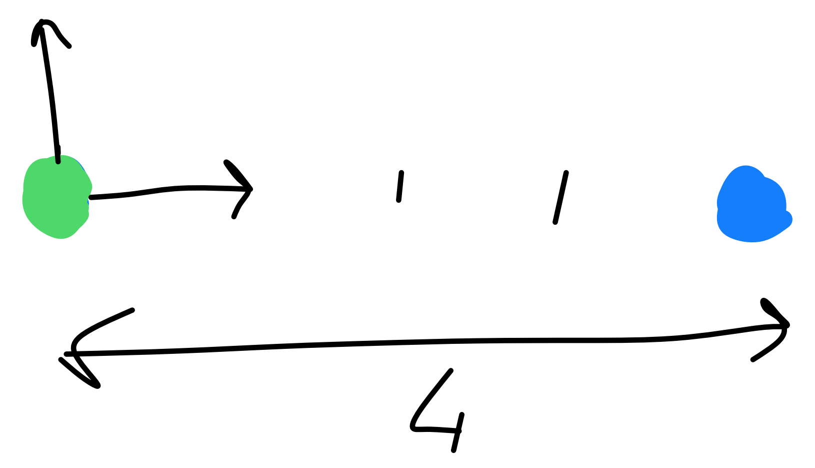

Solution with 2 robots

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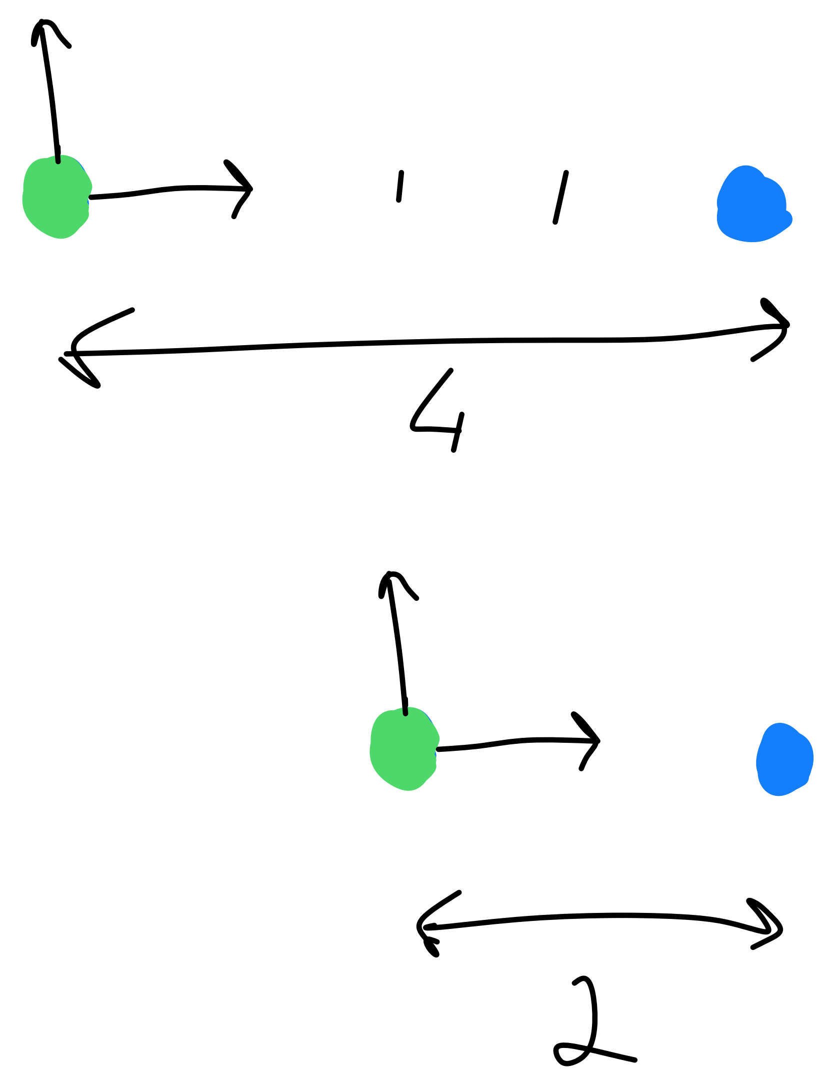
After



Solution with 2 robots

[SSS2020]

But if r moves to the middle "alone", r's view has changed!!

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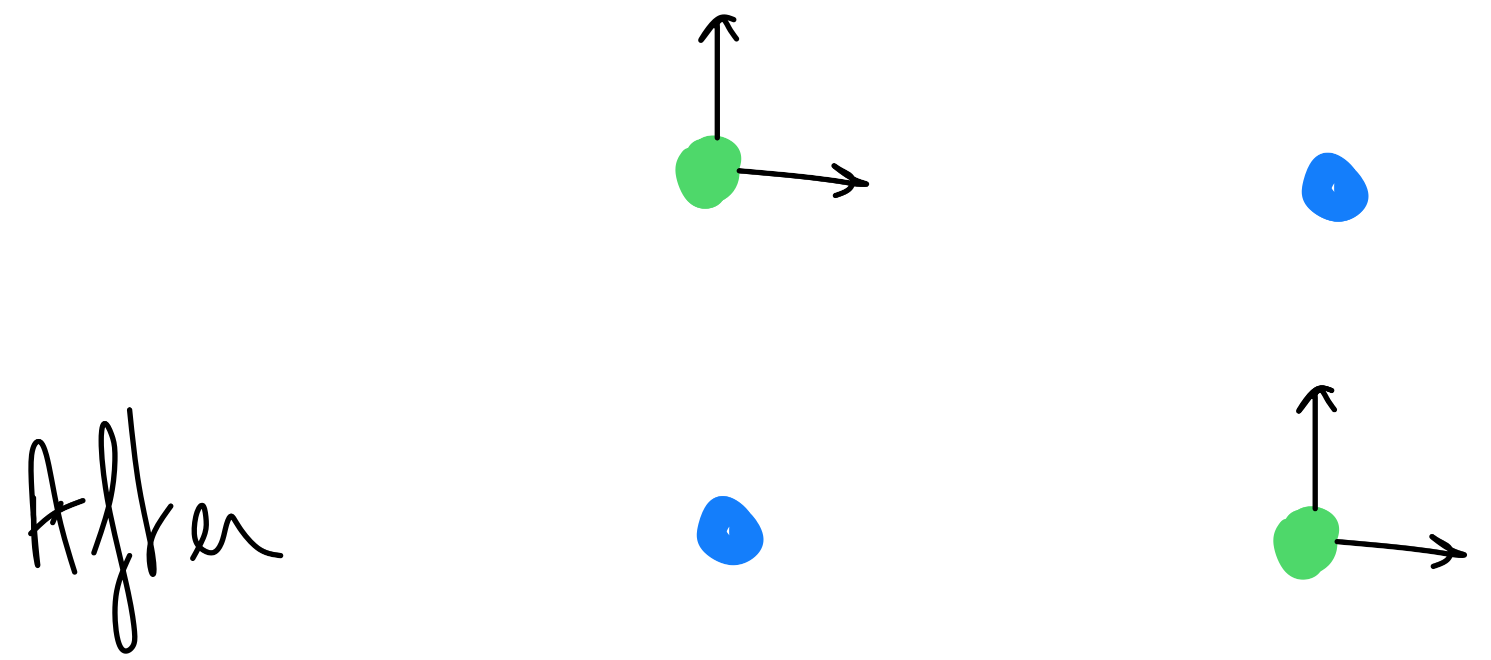

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And if robots swap their positions, their views have changed!!

So the key is to use the distance between the robots and the orientation of the axe, because those are fixed.

Solution with 2 robots

[SSS2020]

If d is the distance between the two robots (seen by robot r, executing the algorithm)

Solution with 2 robots

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Let $i \in \mathbb{Z}$ such that $d \in [2^{-i}, 2^{1-i})$

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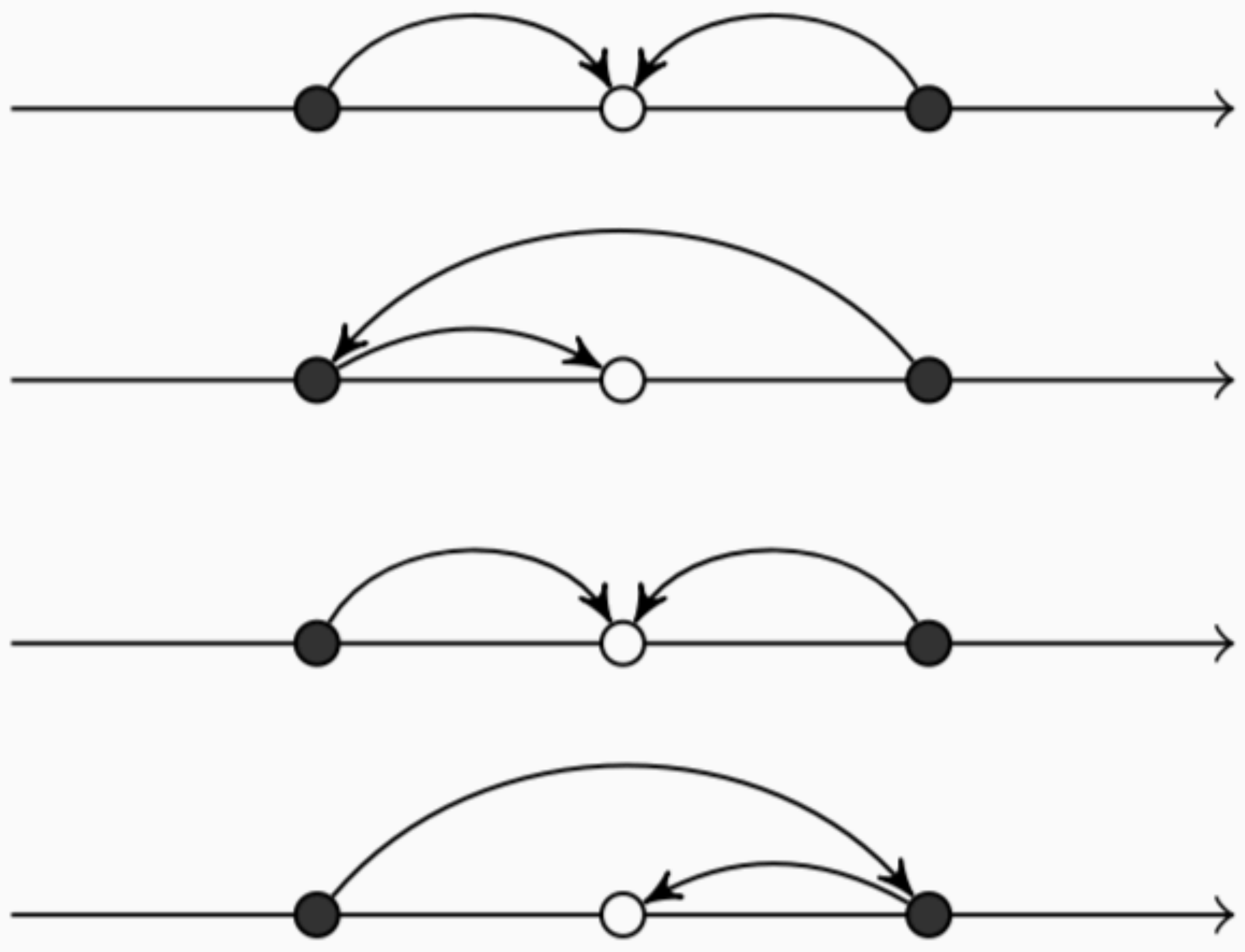

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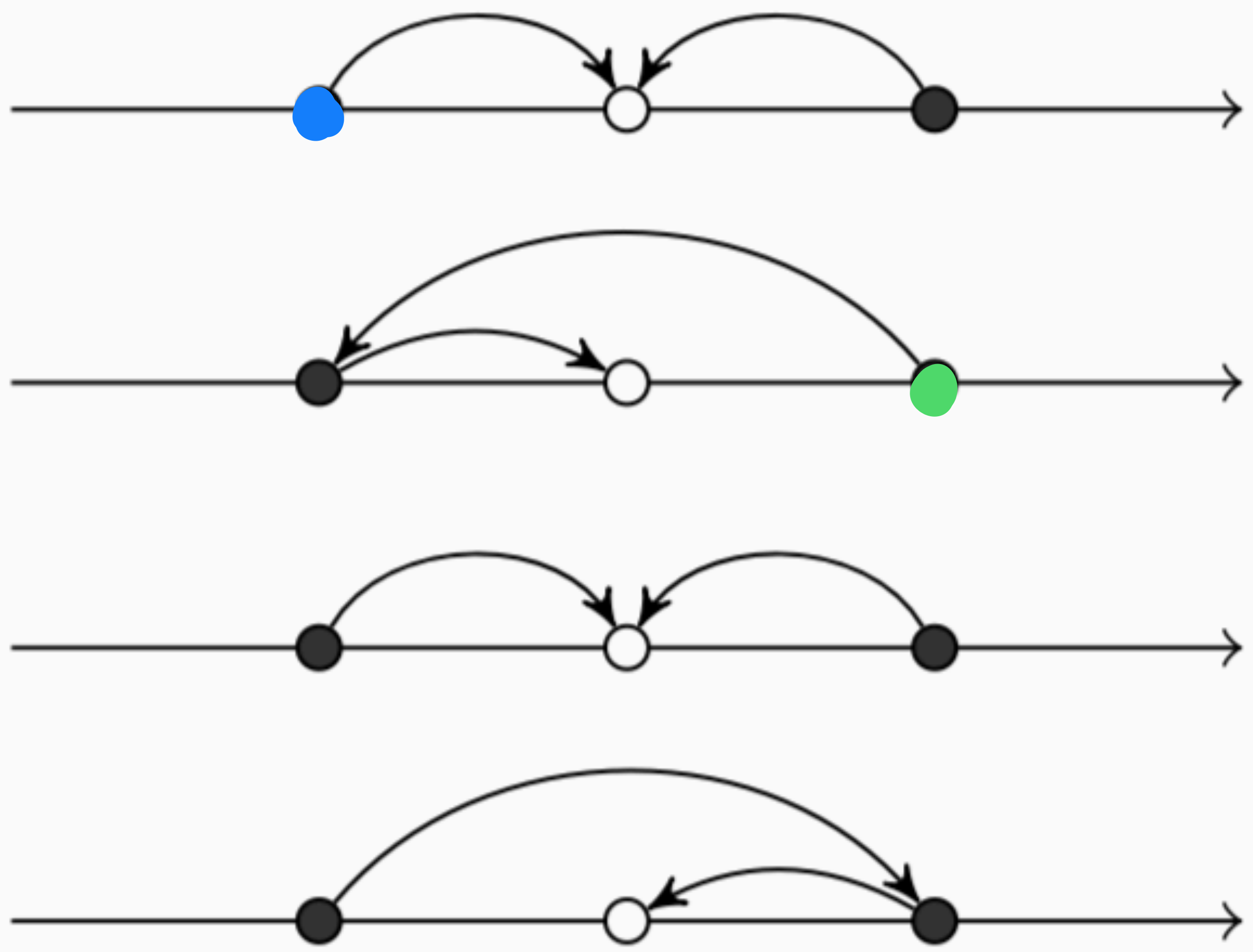

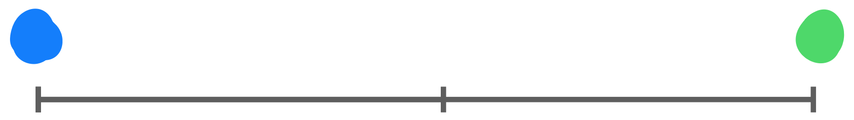

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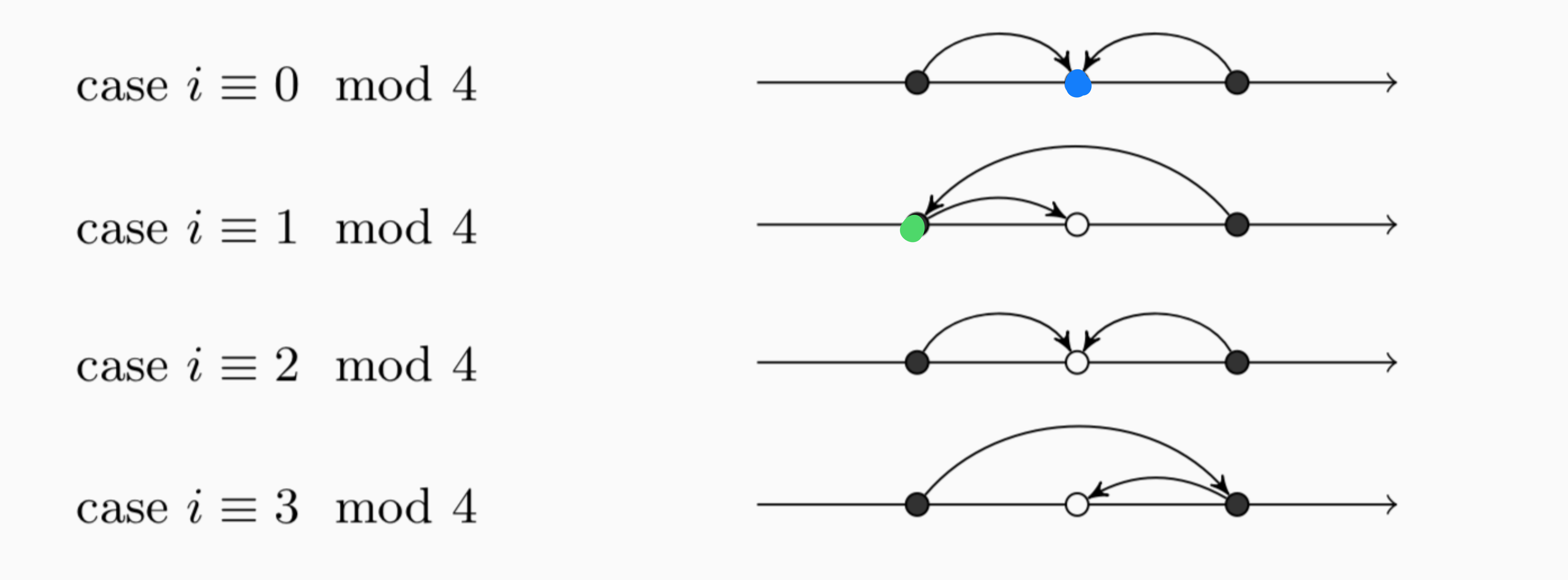
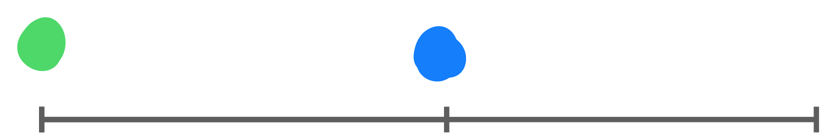




Solution with 2 robots

[SSS2020]

If d is the distance between the two robots (seen by robot r, executing the algorithm)

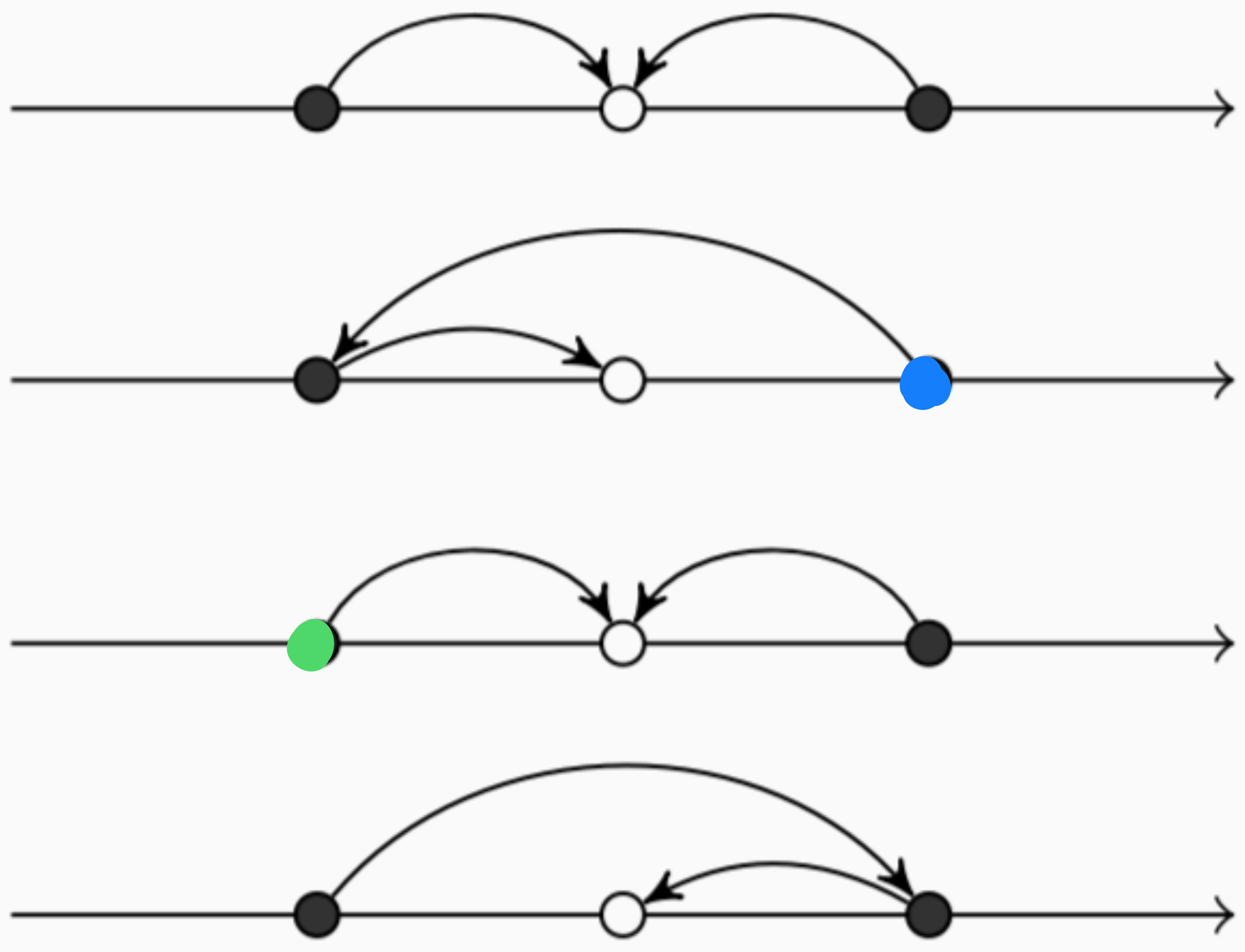
Let $i \in \mathbb{Z}$ such that $d \in [2^{-i}, 2^{1-i})$

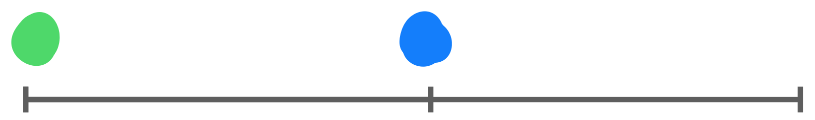
case $i \equiv 0 \mod 4$

case $i \equiv 1 \mod 4$

case $i \equiv 2 \mod 4$

case $i \equiv 3 \mod 4$





Solution with 2 robots

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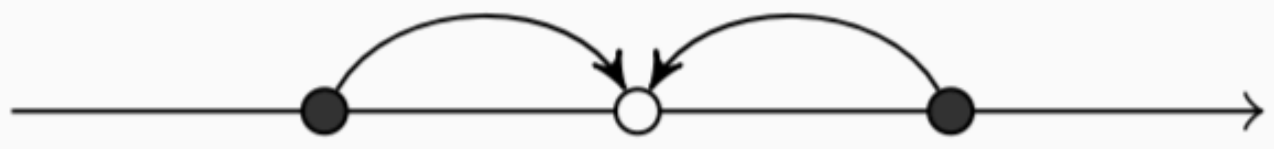
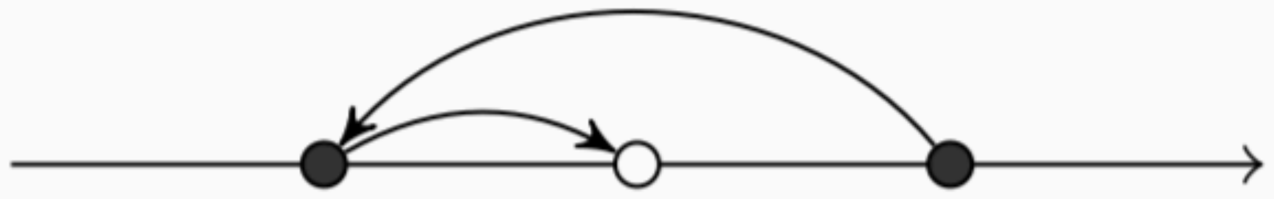
If d is the distance between the two robots (seen by robot r, executing the algorithm)

Let $i \in \mathbb{Z}$ such that $d \in [2^{-i}, 2^{1-i})$

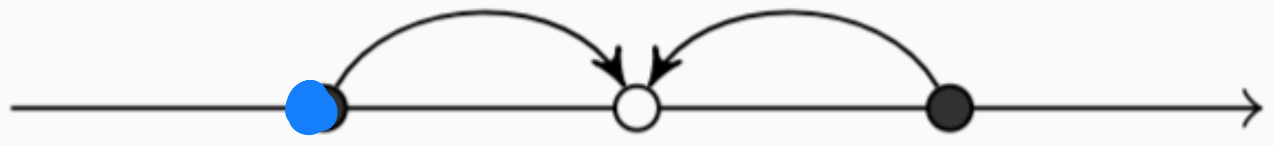
case $i \equiv 0 \mod 4$



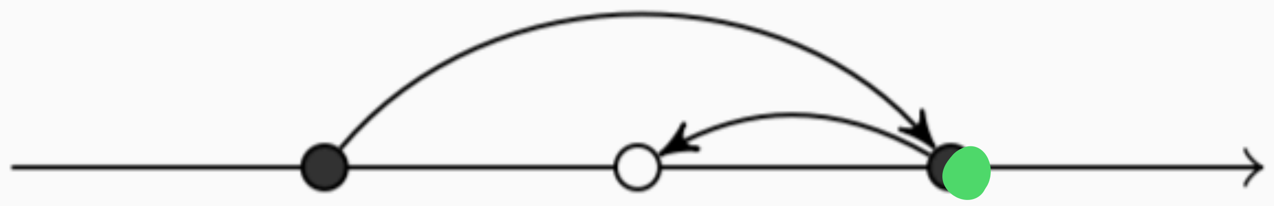
case $i \equiv 1 \mod 4$

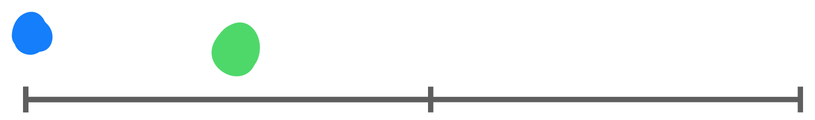


case $i \equiv 2 \mod 4$



case $i \equiv 3 \mod 4$





Solution with 2 robots

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Let $i \in \mathbb{Z}$ such that $d \in [2^{-i}, 2^{1-i})$

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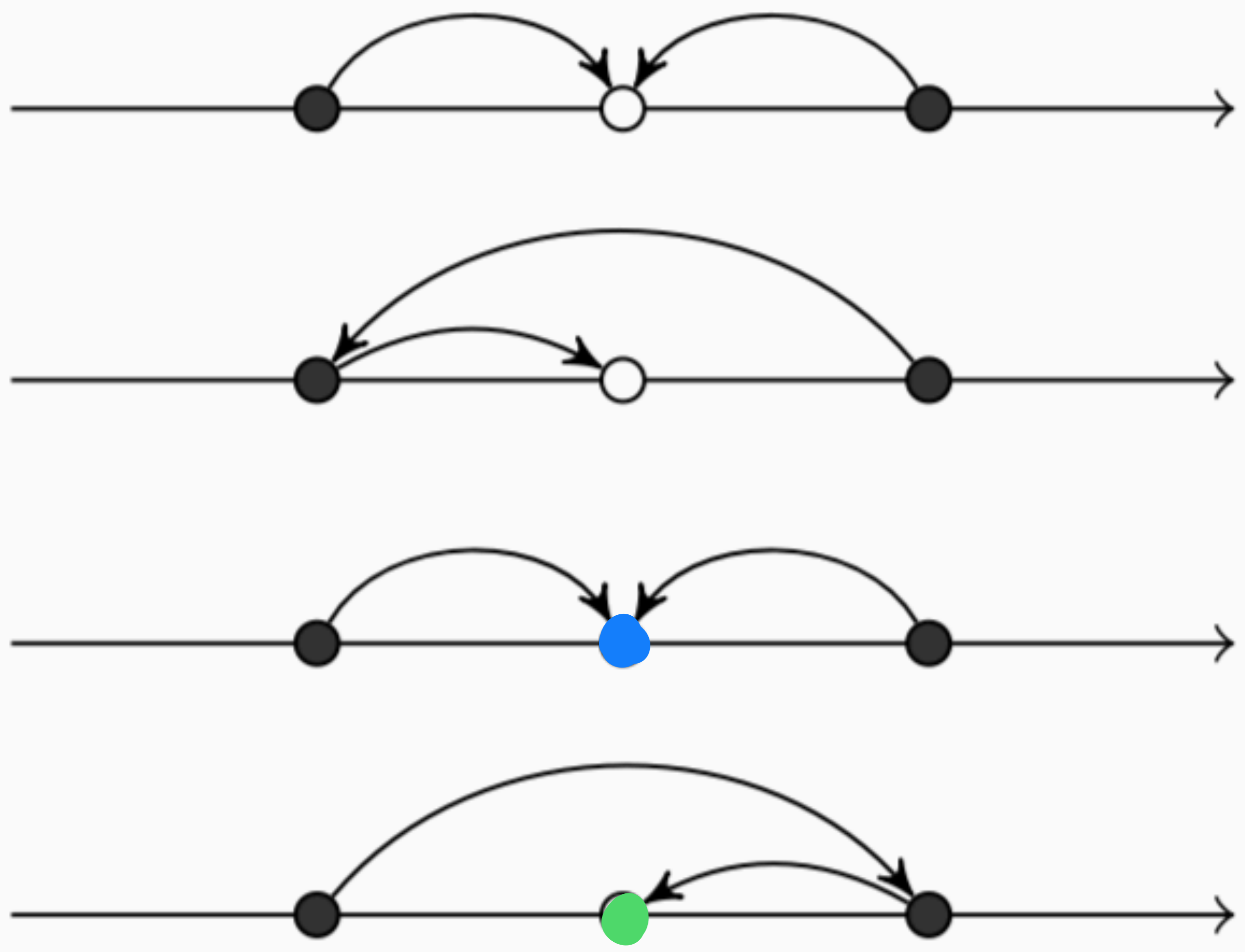

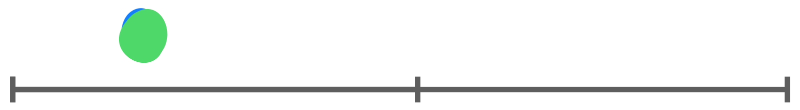

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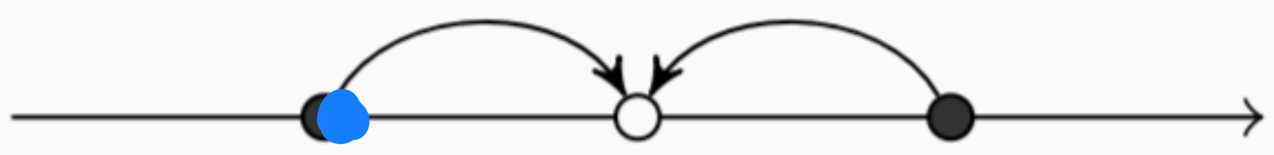
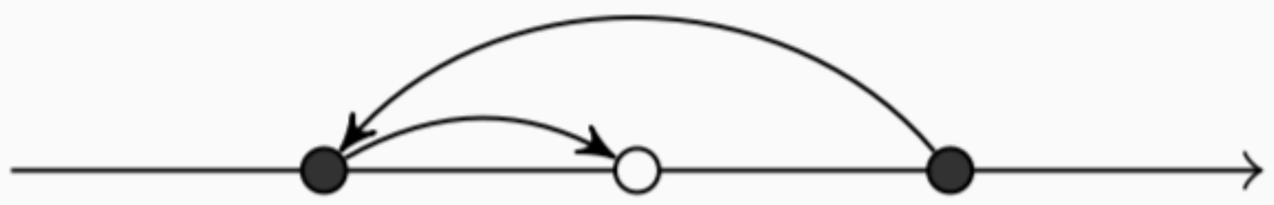
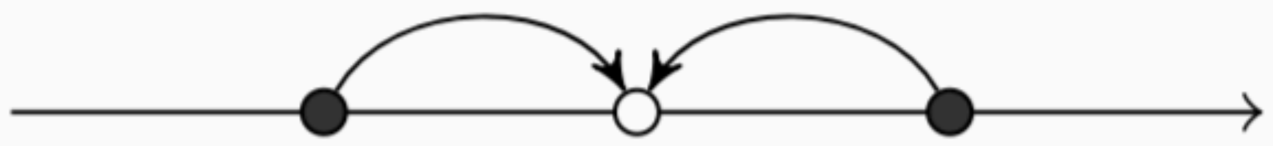


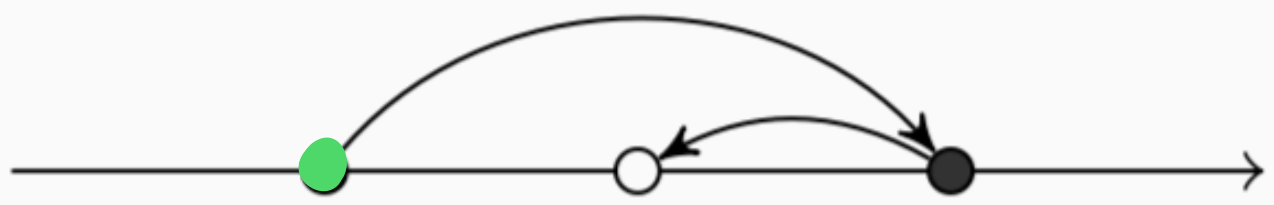
case $i \equiv 1 \mod 4$



case $i \equiv 2 \mod 4$



case $i \equiv 3 \mod 4$



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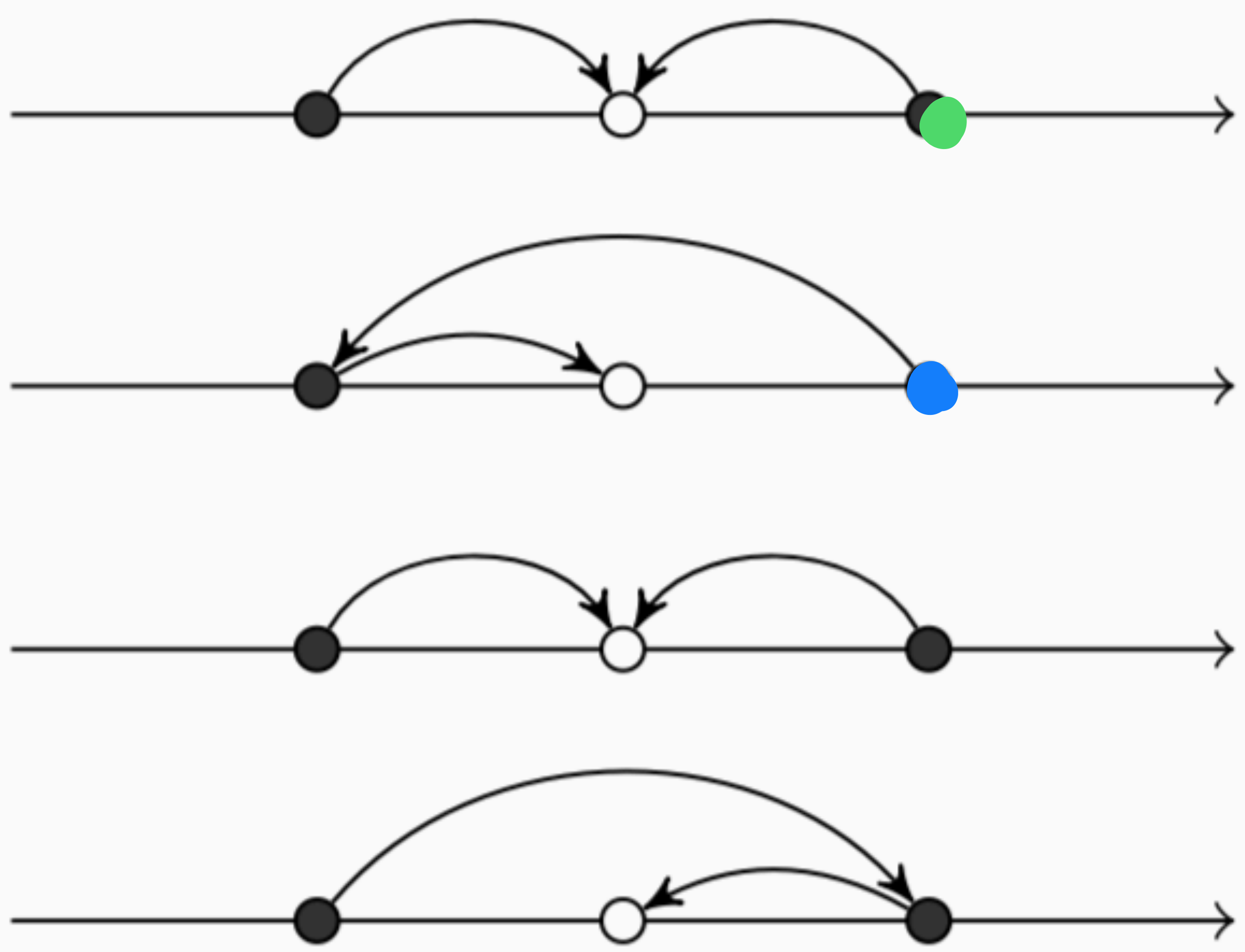

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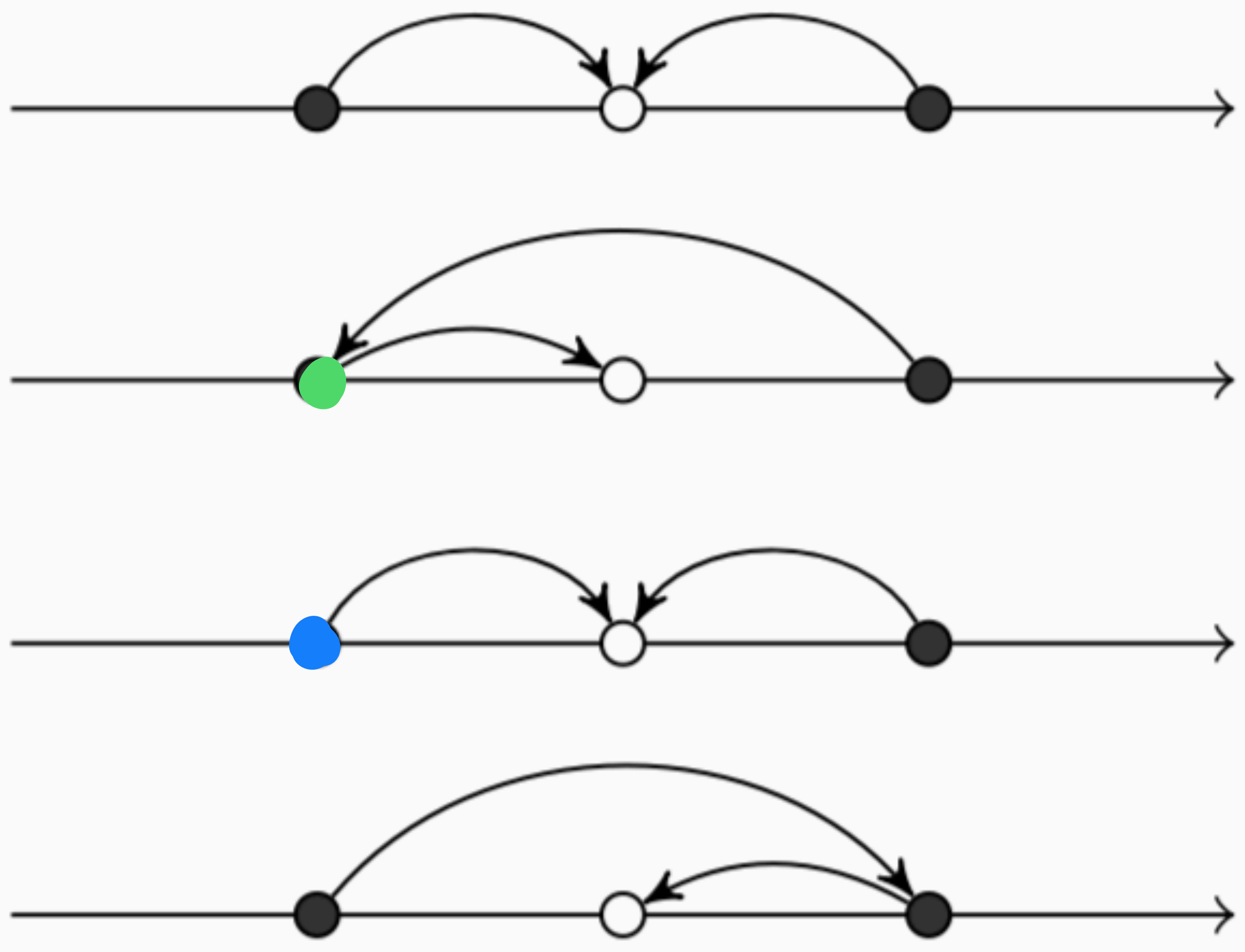

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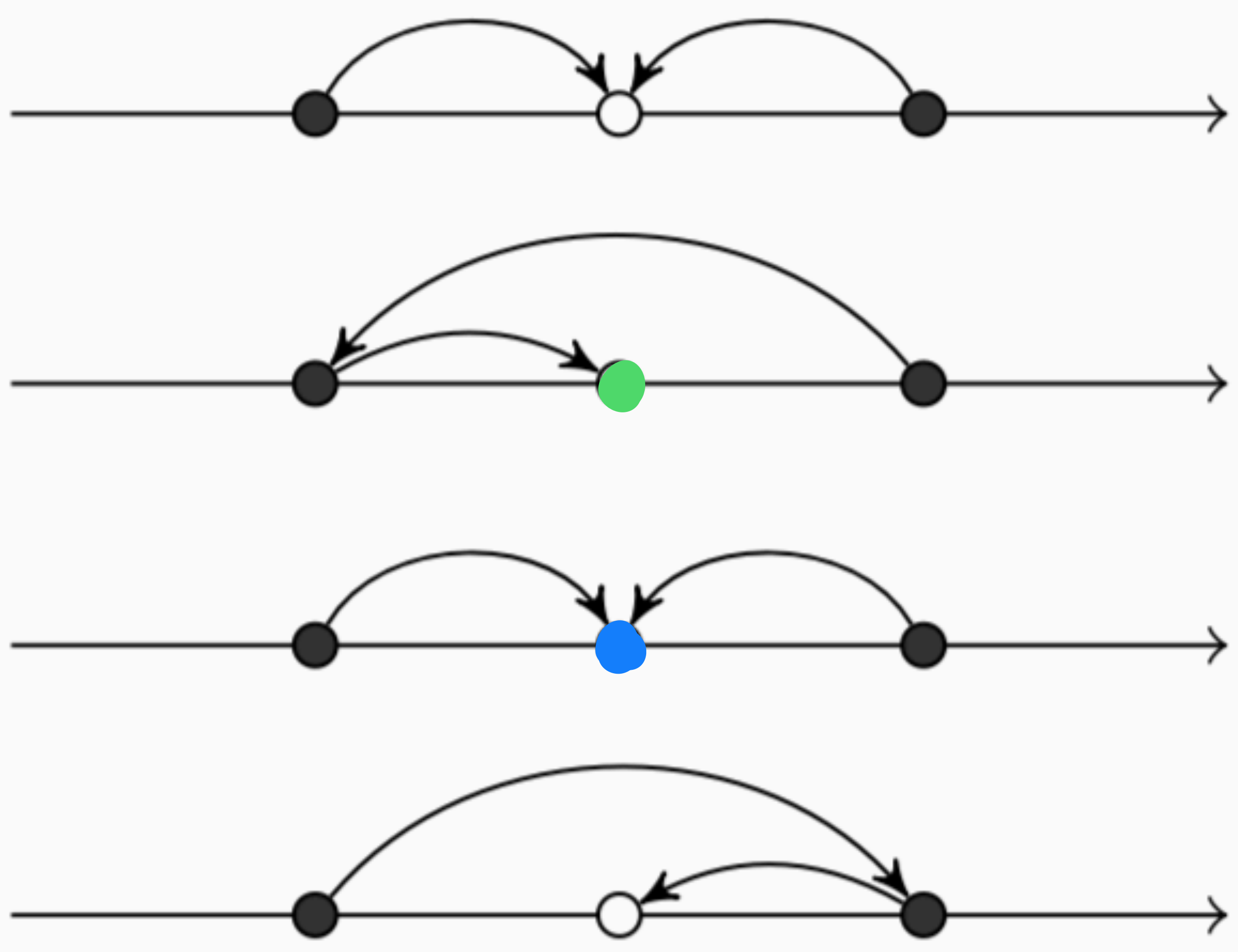

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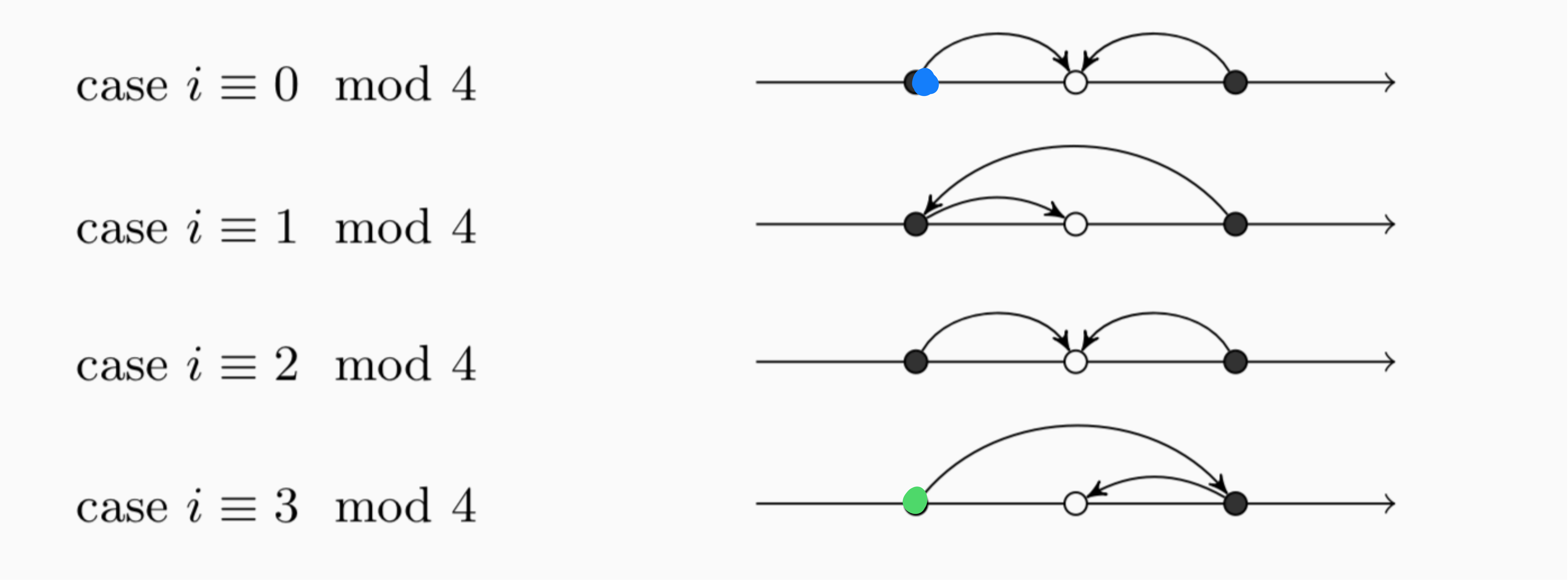

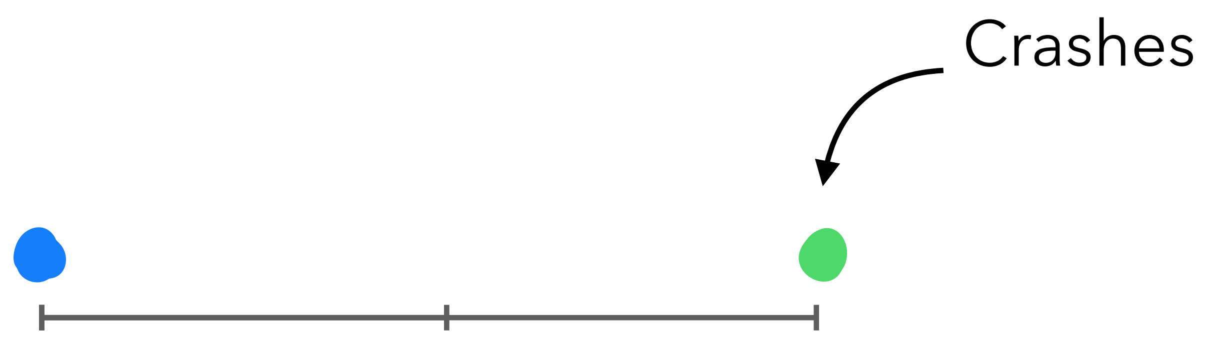

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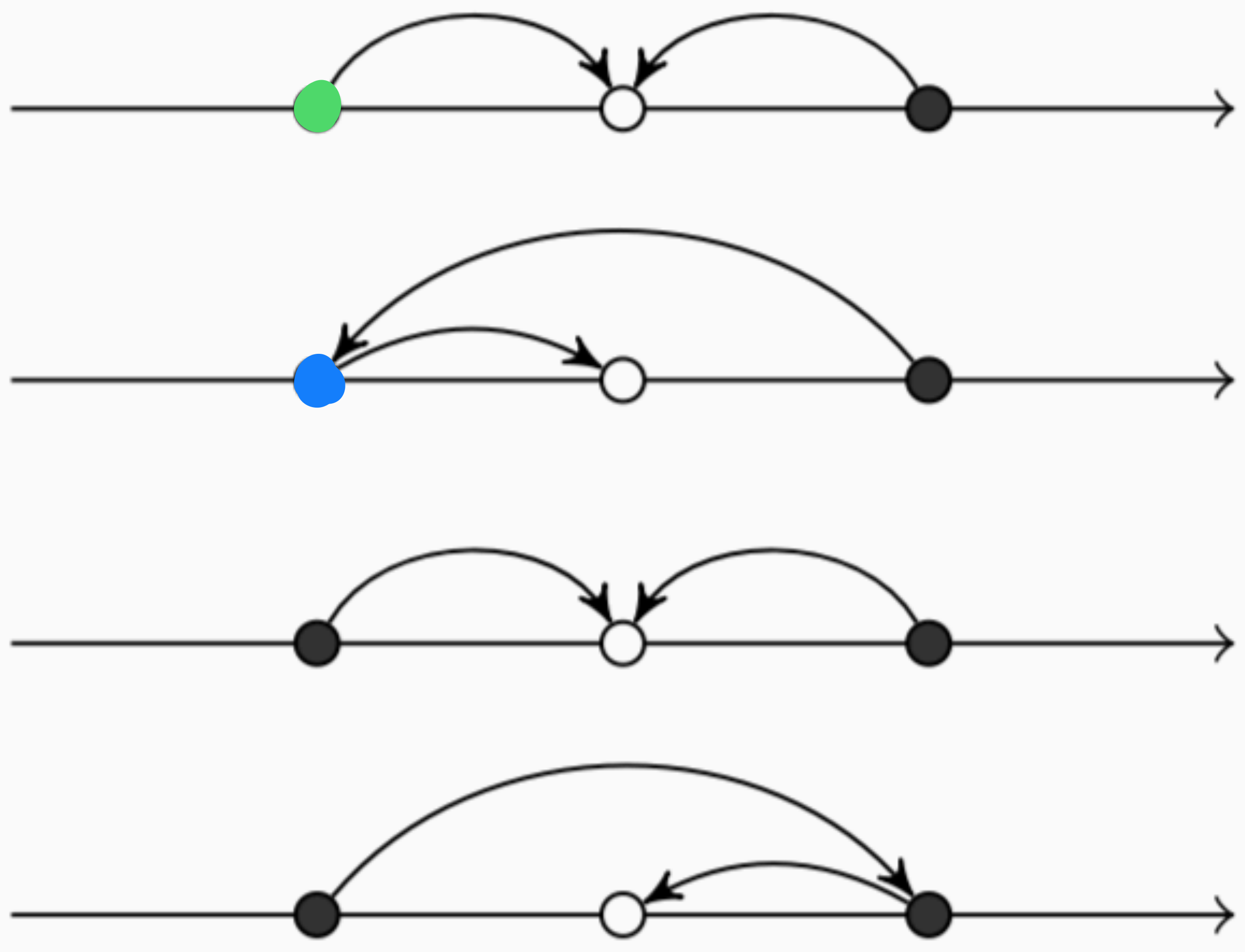

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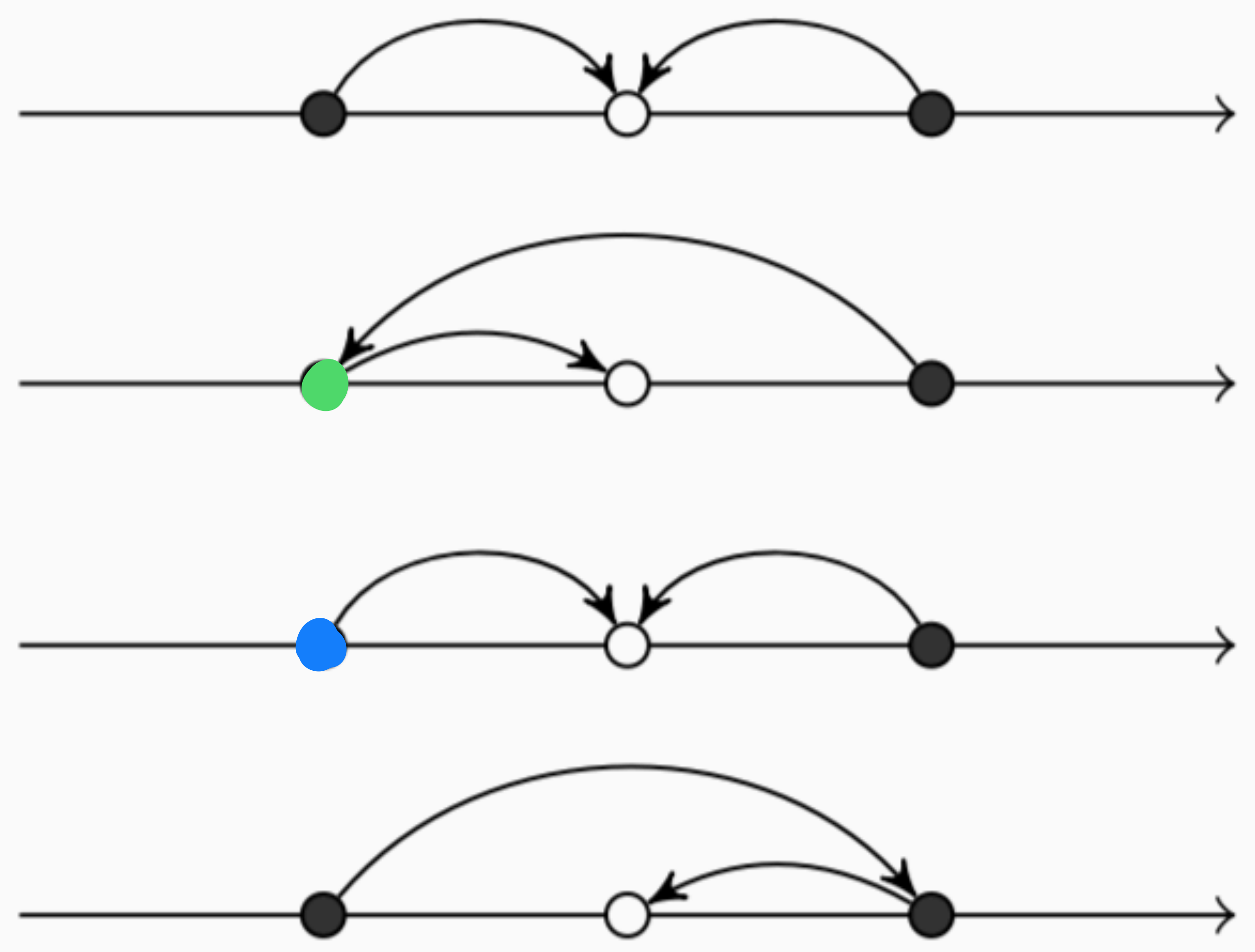

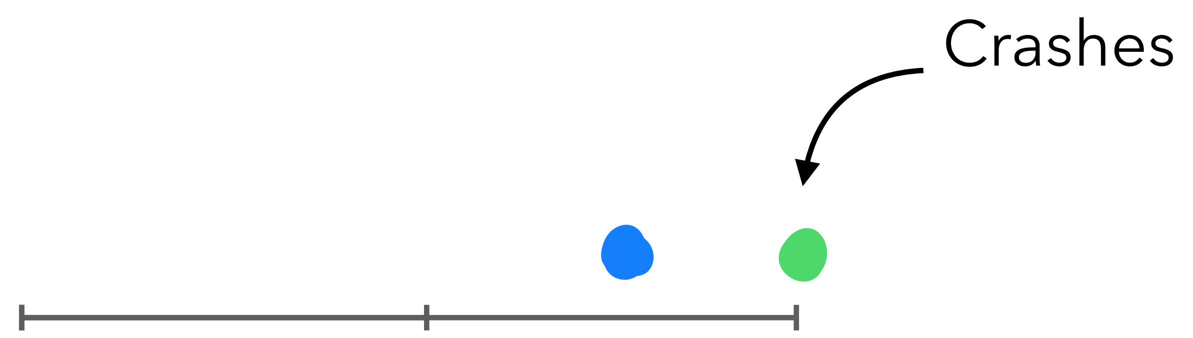

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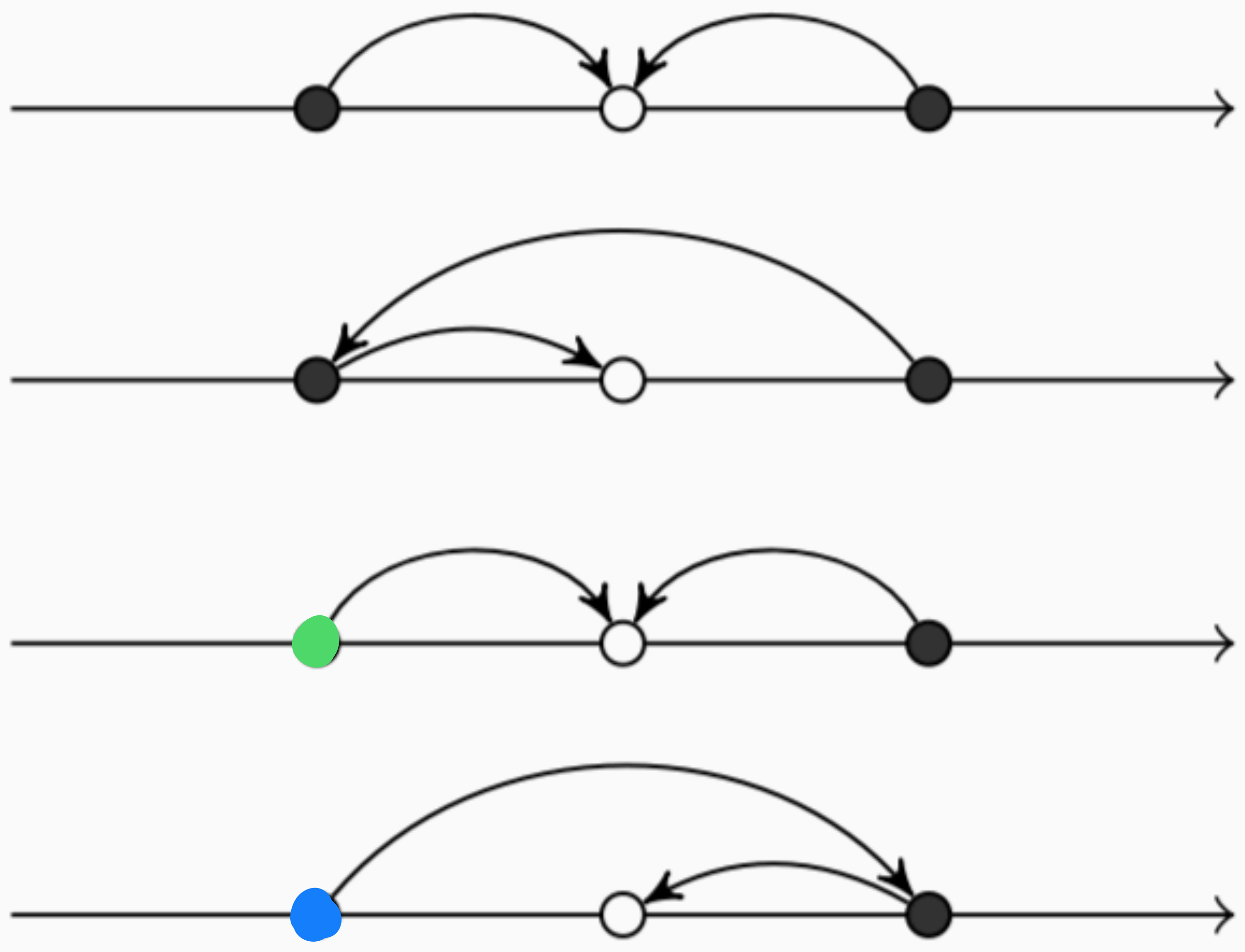

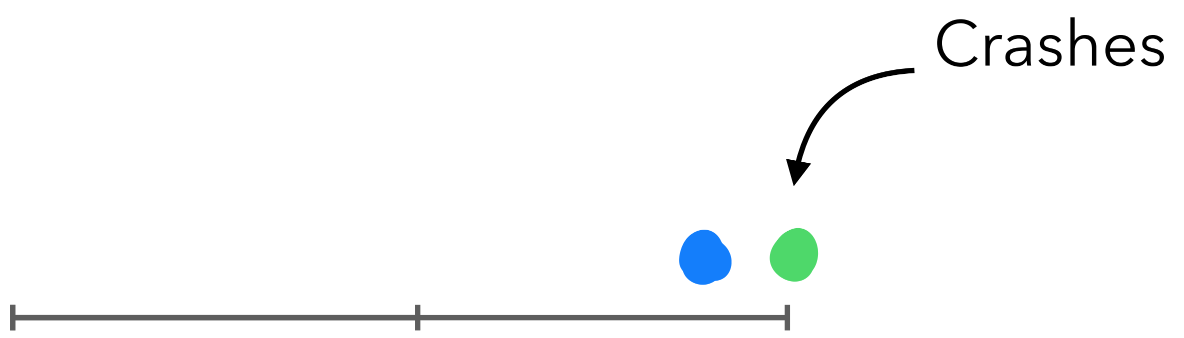

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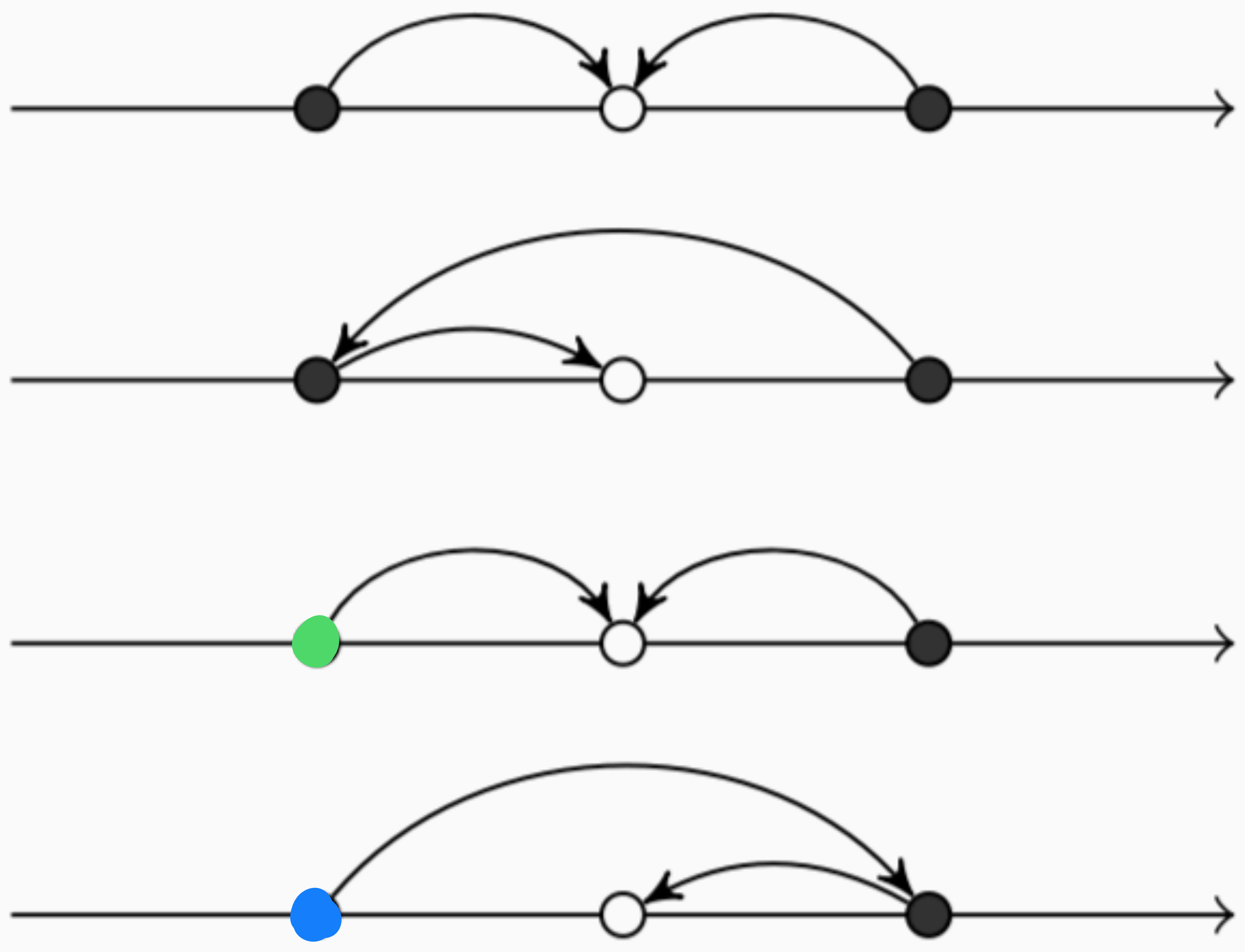
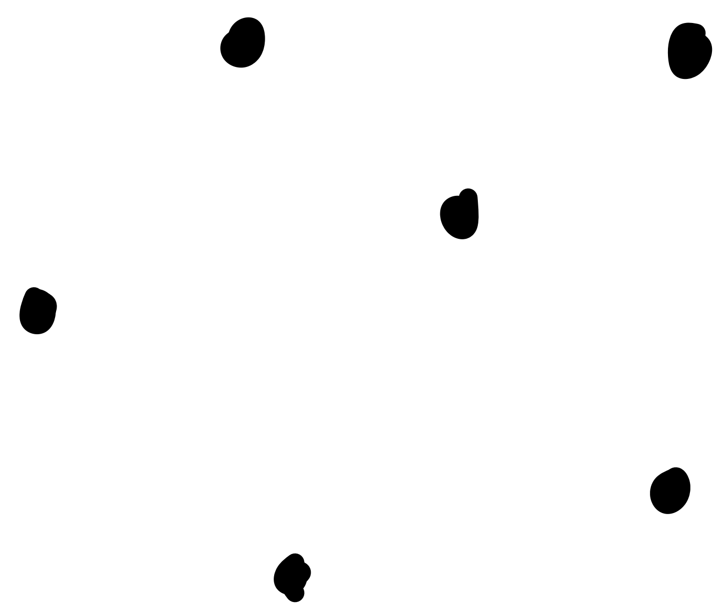


Solution with $n > 2$ robots

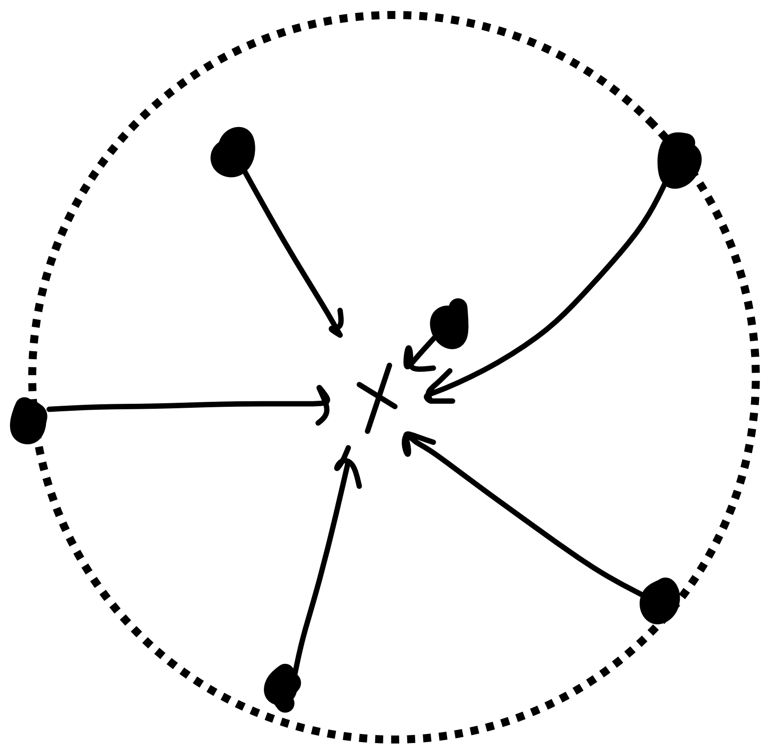
How to start

n > 2



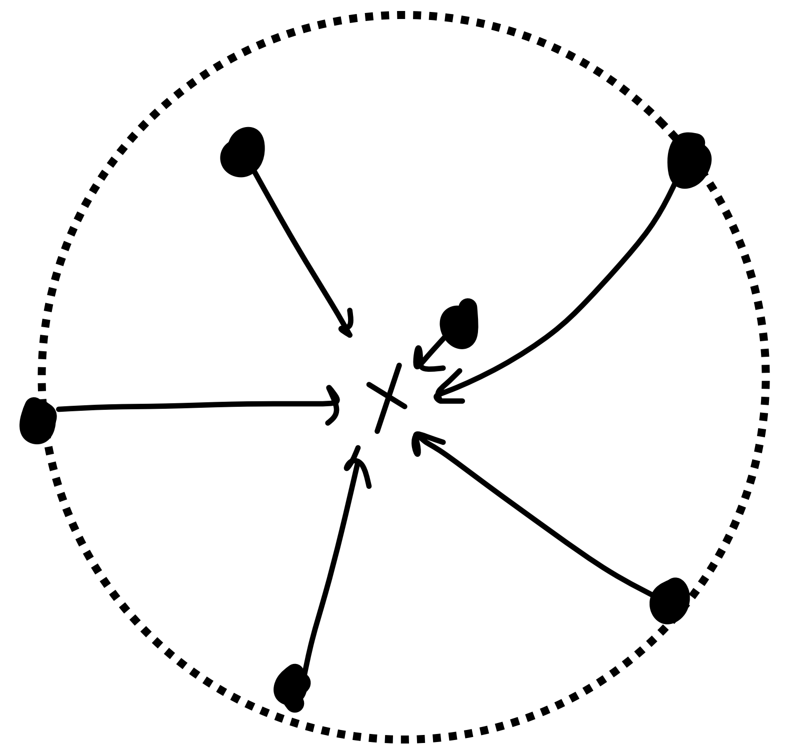
How to start

n > 2



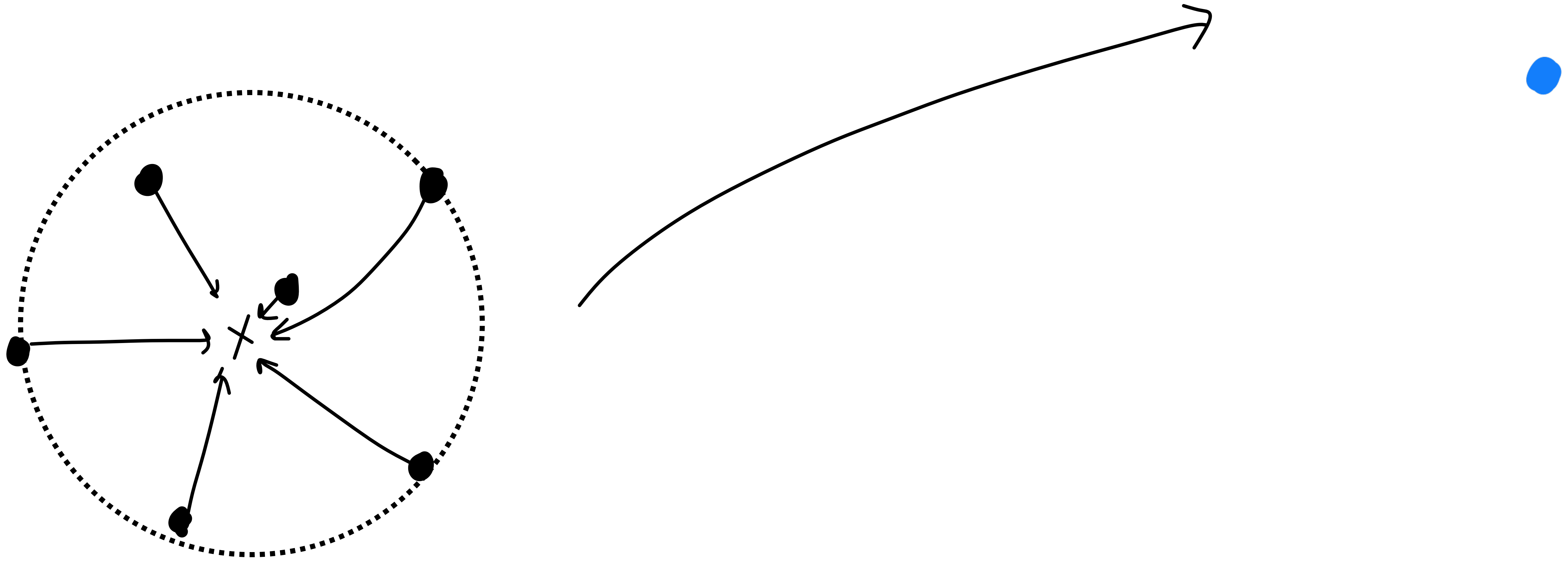
How to start

n > 2



How to start

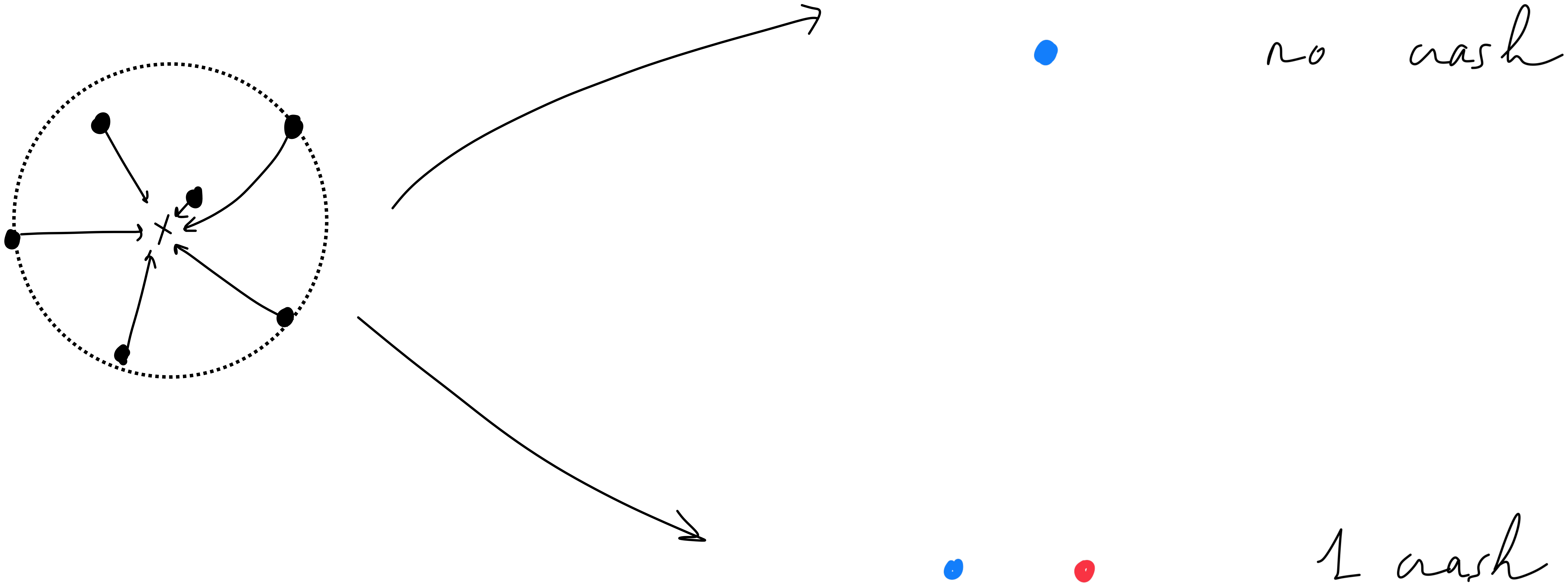
n > 2



no cash

How to start

n > 2



What we would like to do

- If all the robots are correct we want all of them to execute move to middle

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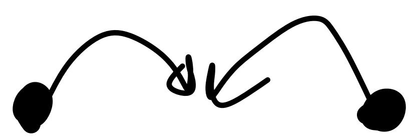
i = 1



What we would like to do

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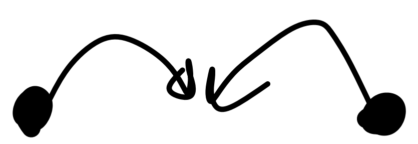
$i = 1$  ← works if all robots have the same level

What we would like to do

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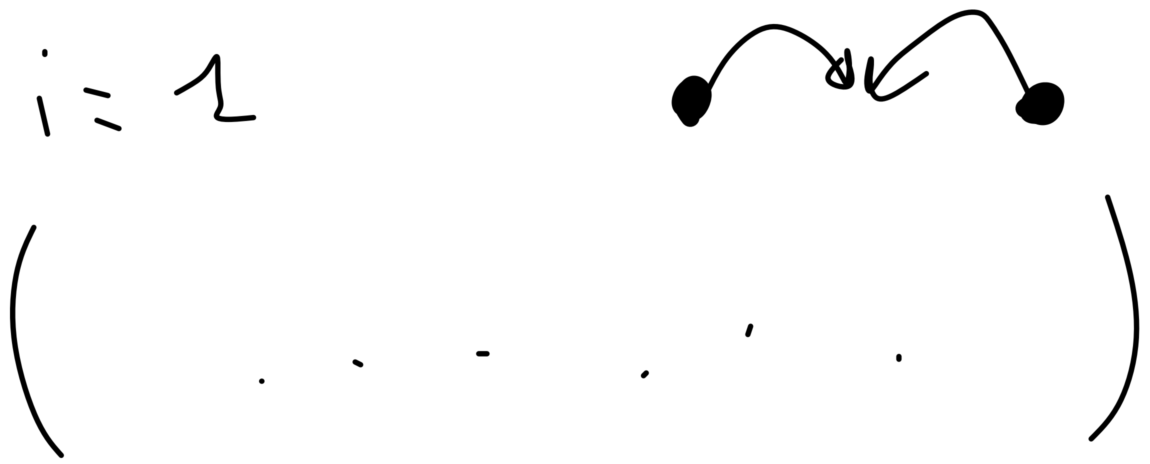
$i = 1$



← works if all robots have the same level

What we would like to do

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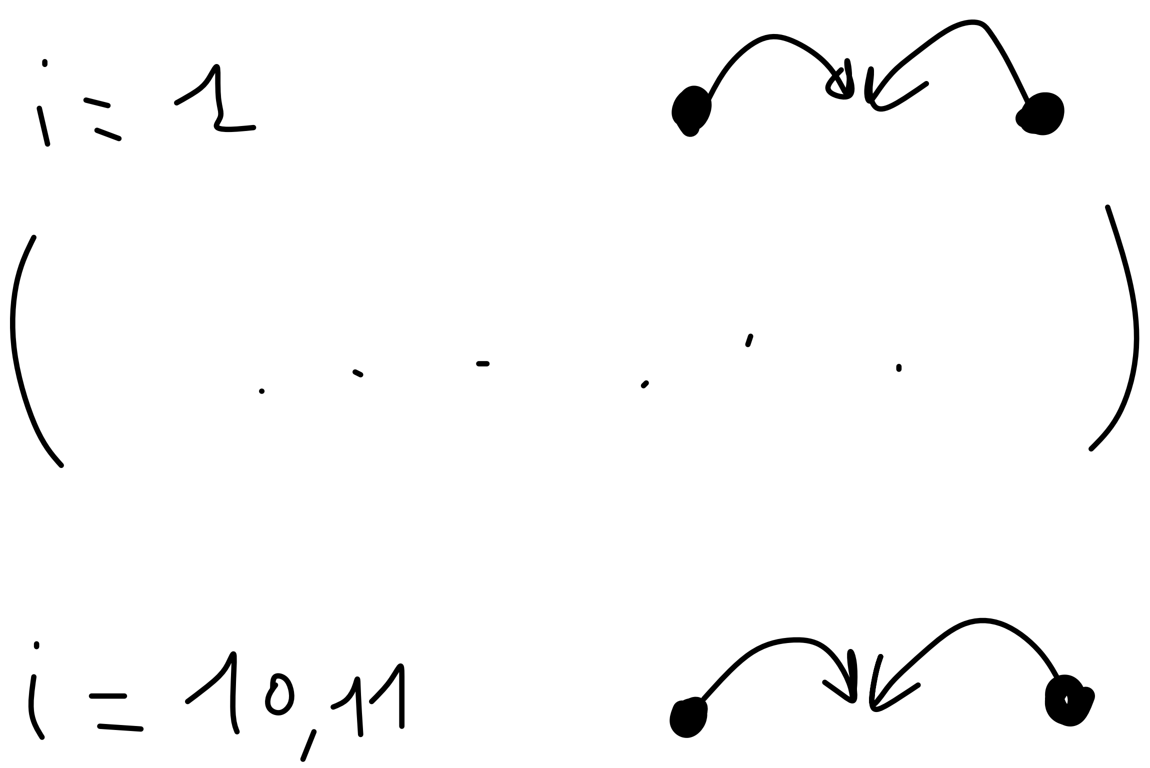
$i = 1$ ← works if all robots have the same level

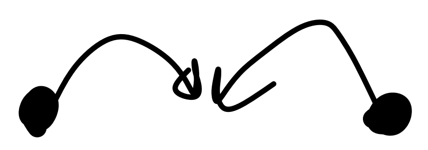


$i = 10, 11$

What we would like to do

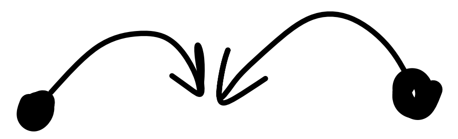
- If all the robots are correct we want all of them to execute move to middle

$i = 1$



← works if all robots have the same level

$i = 10, 11$

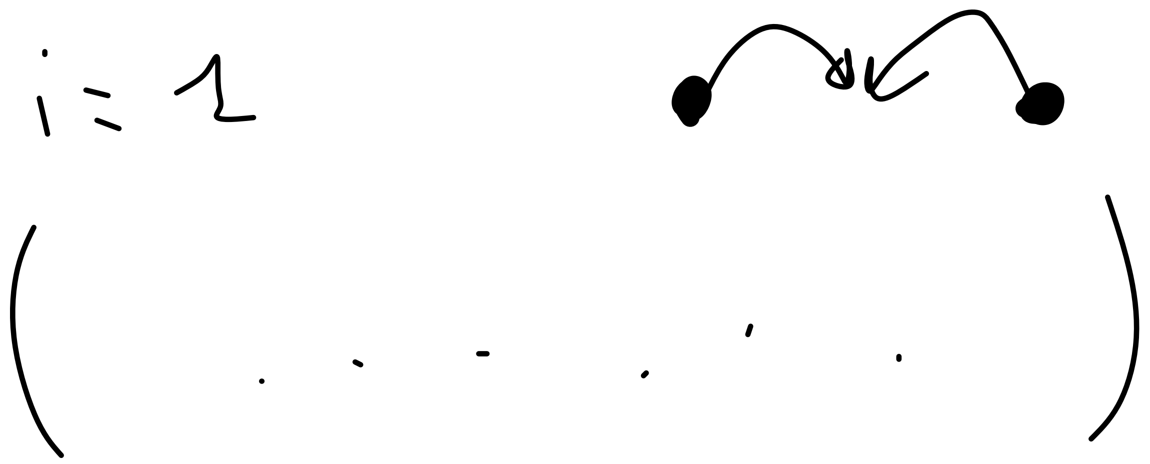


← works if Δlevel ≤ 2

What we would like to do

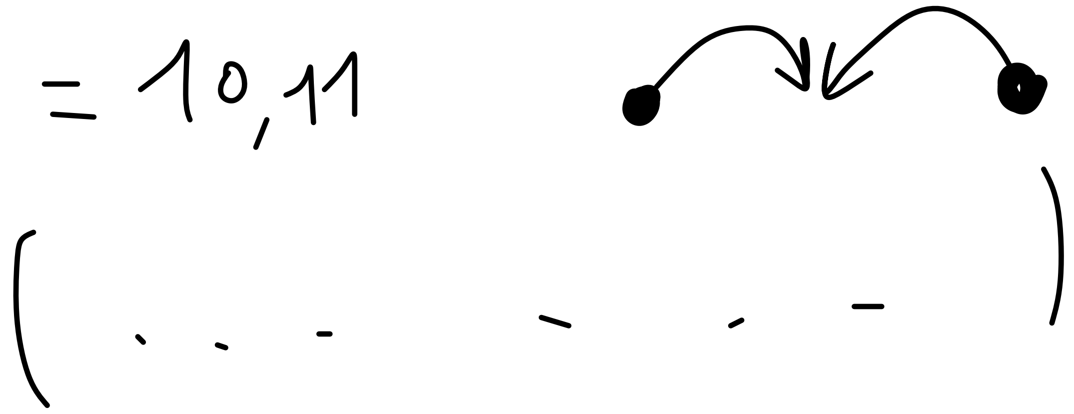
- If all the robots are correct we want all of them to execute move to middle

$i = 1$



← works if all robots have the same level

$i = 10, 11$



← works if $\Delta_{level} \leq 2$

What we would like to do

- If all the robots are correct we want all of them to execute move to middle

$i = 1$

← works if all robots have the same level

$i = 10, 11$

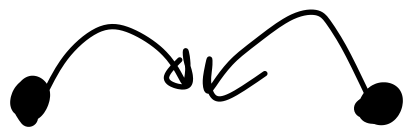
← works if Δ level ≤ 2

$i = 100, 101, 102$

What we would like to do

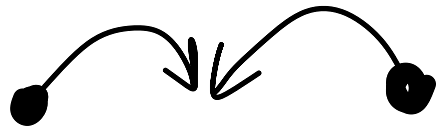
- If all the robots are correct we want all of them to execute move to middle

$i = 1$



← works if all robots have the same level

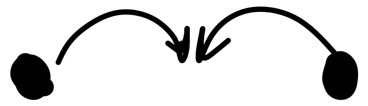
$i = 10, 11$



← works if $\Delta_{level} \leq 2$

$\Delta_{level} \leq 3$

$i = 100, 101, 102$



What we would like to do

- If all the robots are correct we want all of them to execute move to middle

$i = 1$ ← works if all robots have the same level

$i = 10, 11$ ← works if $\Delta_{level} \leq 2$

$\Delta_{level} \leq 3$

$i = 100, 101, 102$

$\vdots$

What we would like to do

- If all the robots are correct we want all of them to execute move to middle

$i = 1$ ← works if all robots have the same level

← make sure level increases

$i = 10, 11$ ← works if $\Delta_{level} \leq 2$

$\Delta_{level} \leq 3$

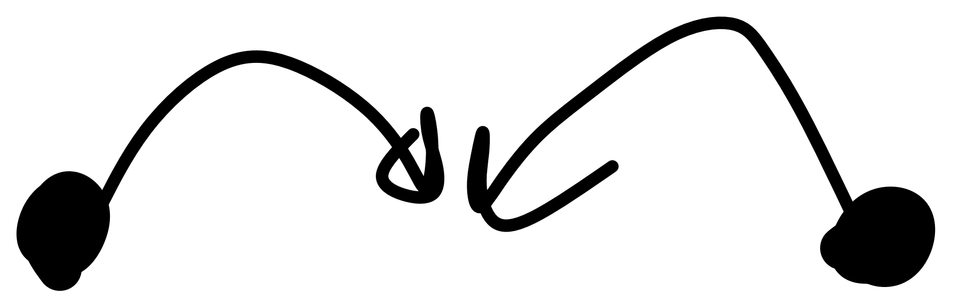
$i = 100, 101, 102$

⋮

What we would like to do

- If all the robots are correct we want all of them to execute move to middle

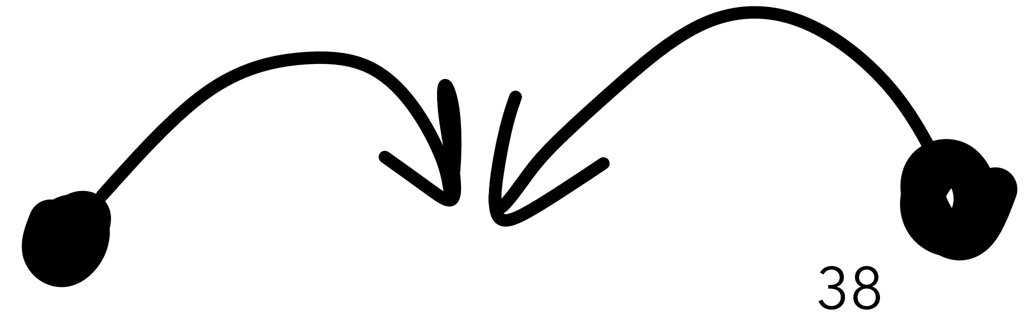
$i = 1$



← wor

← make sure

$i = 10, 11$



← wo

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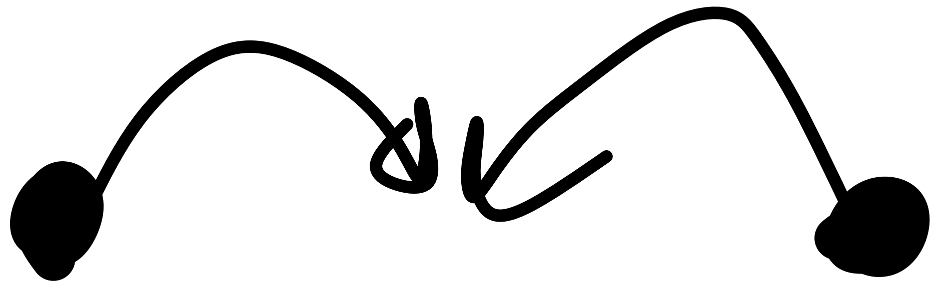
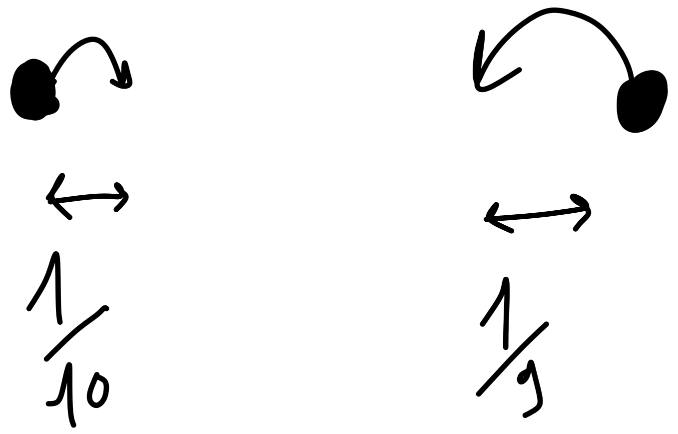


$i = 2$



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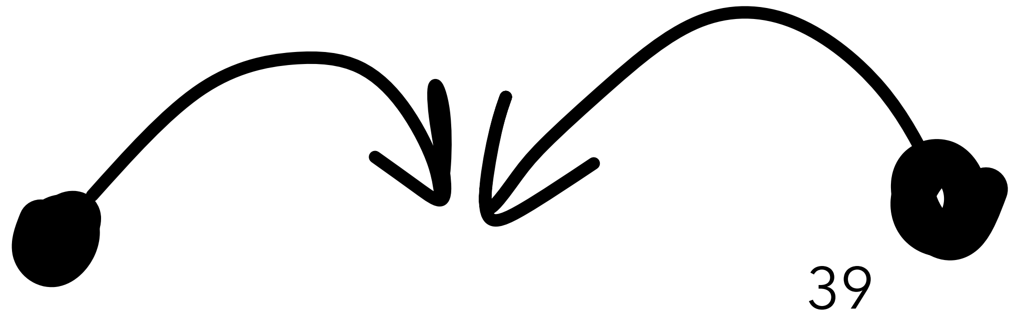

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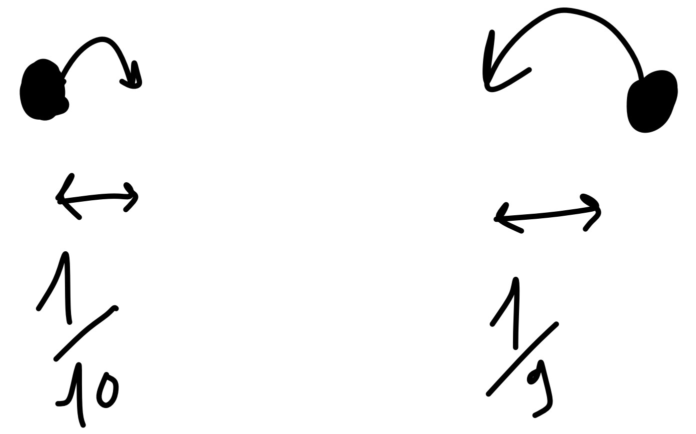

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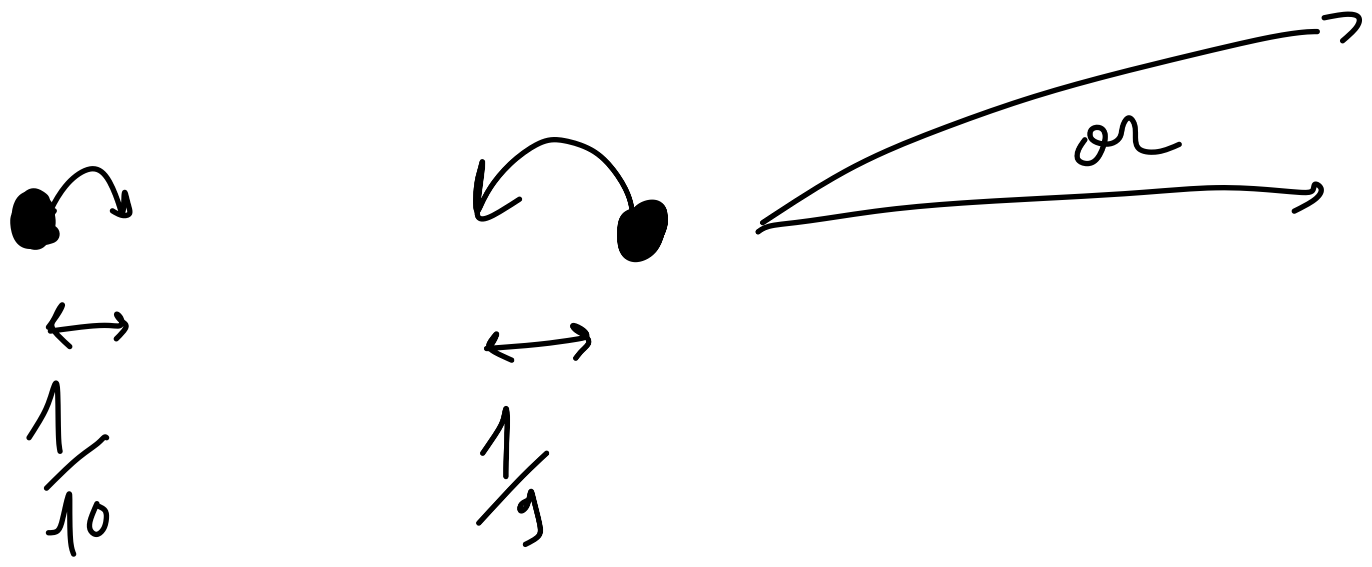

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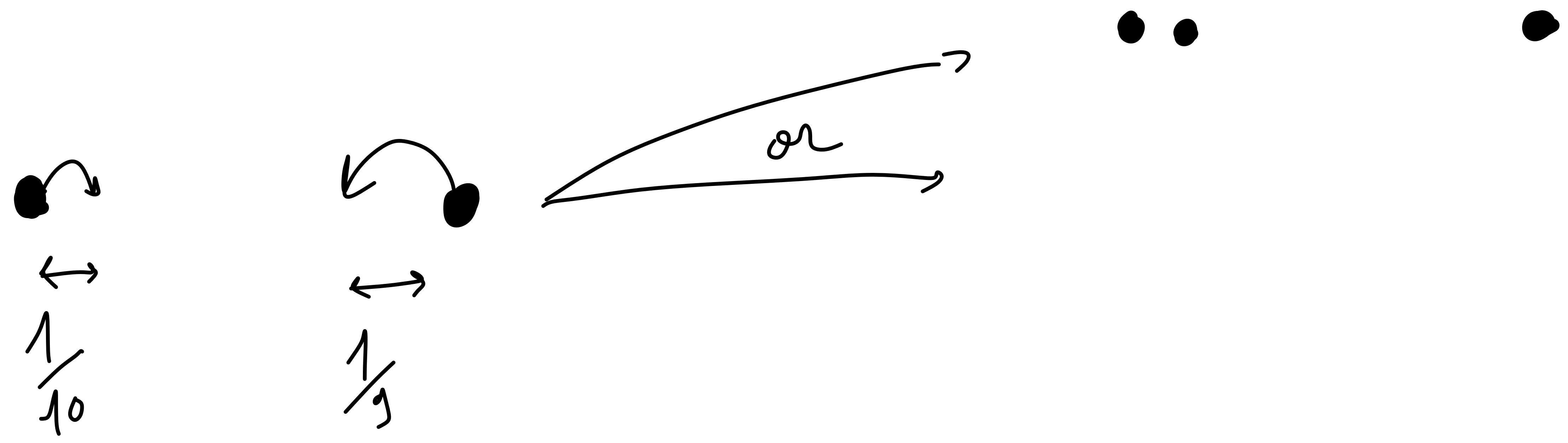

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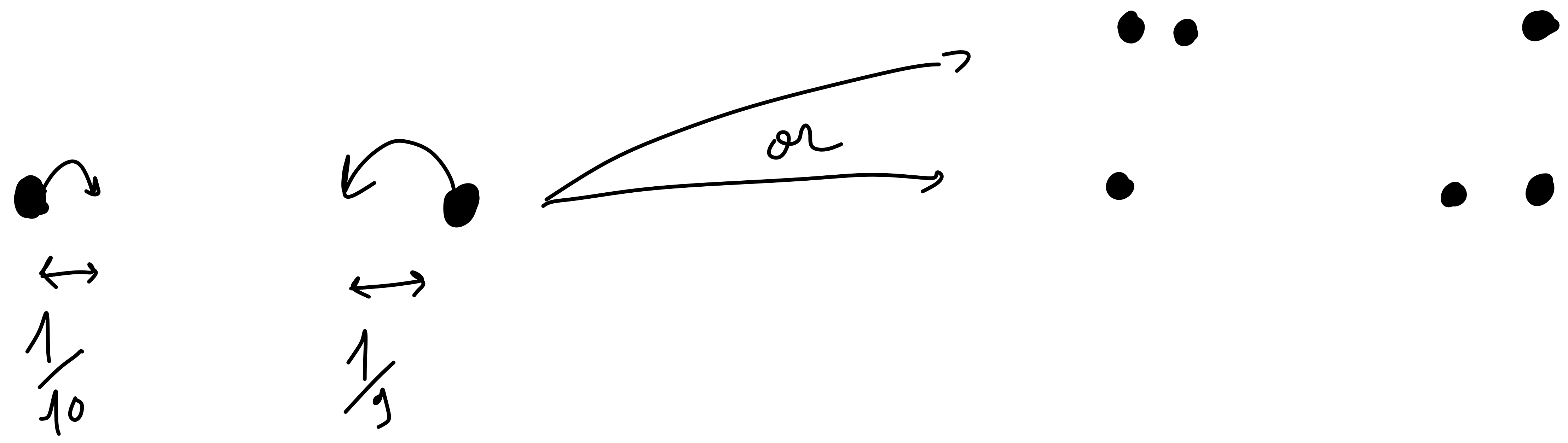

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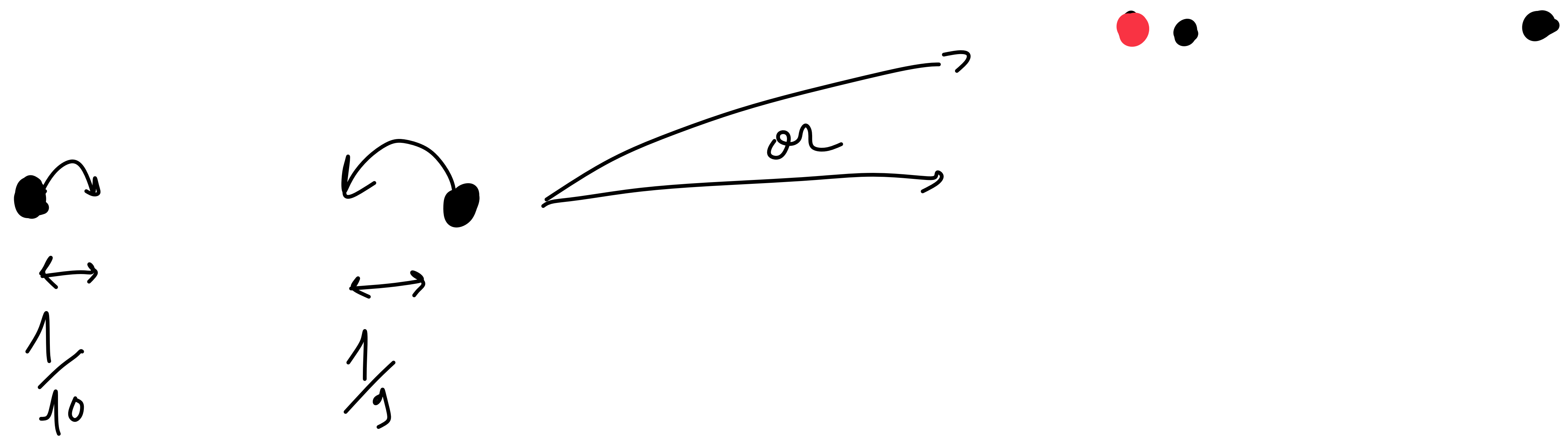

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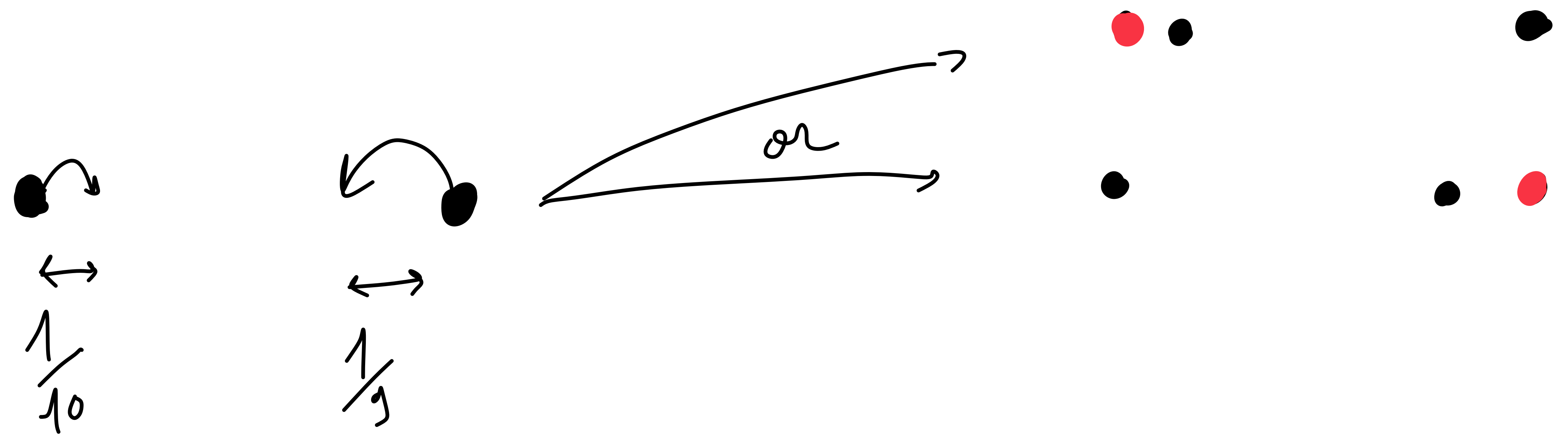

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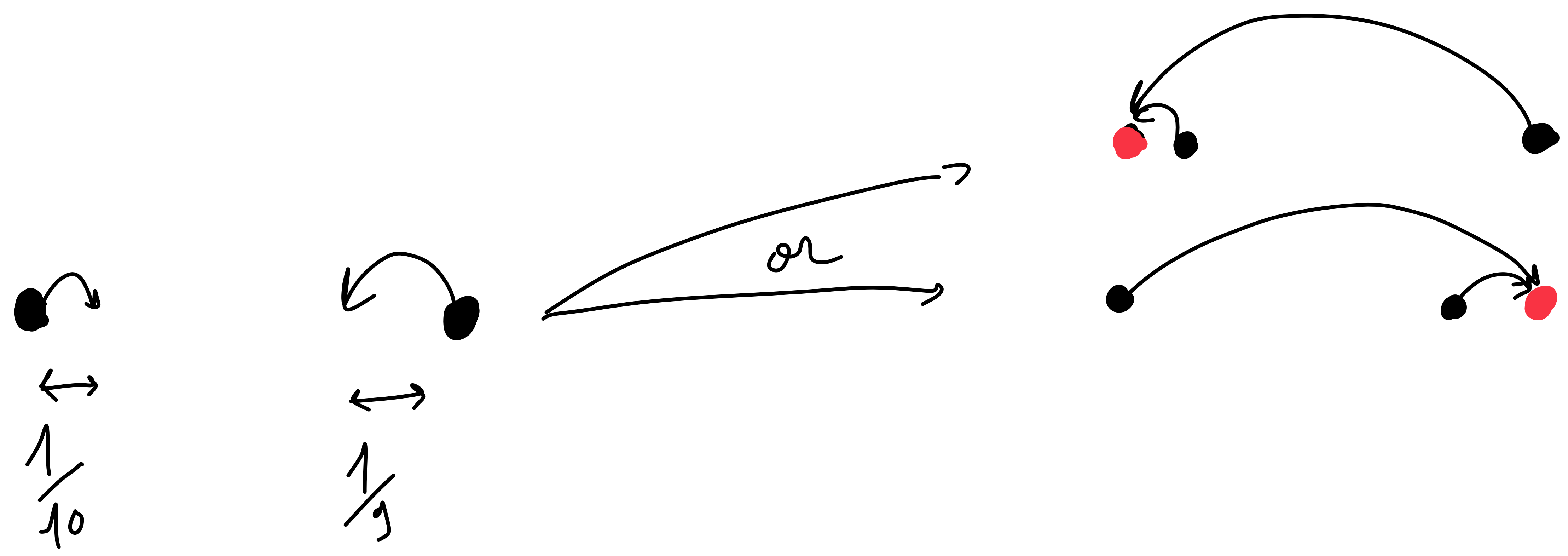

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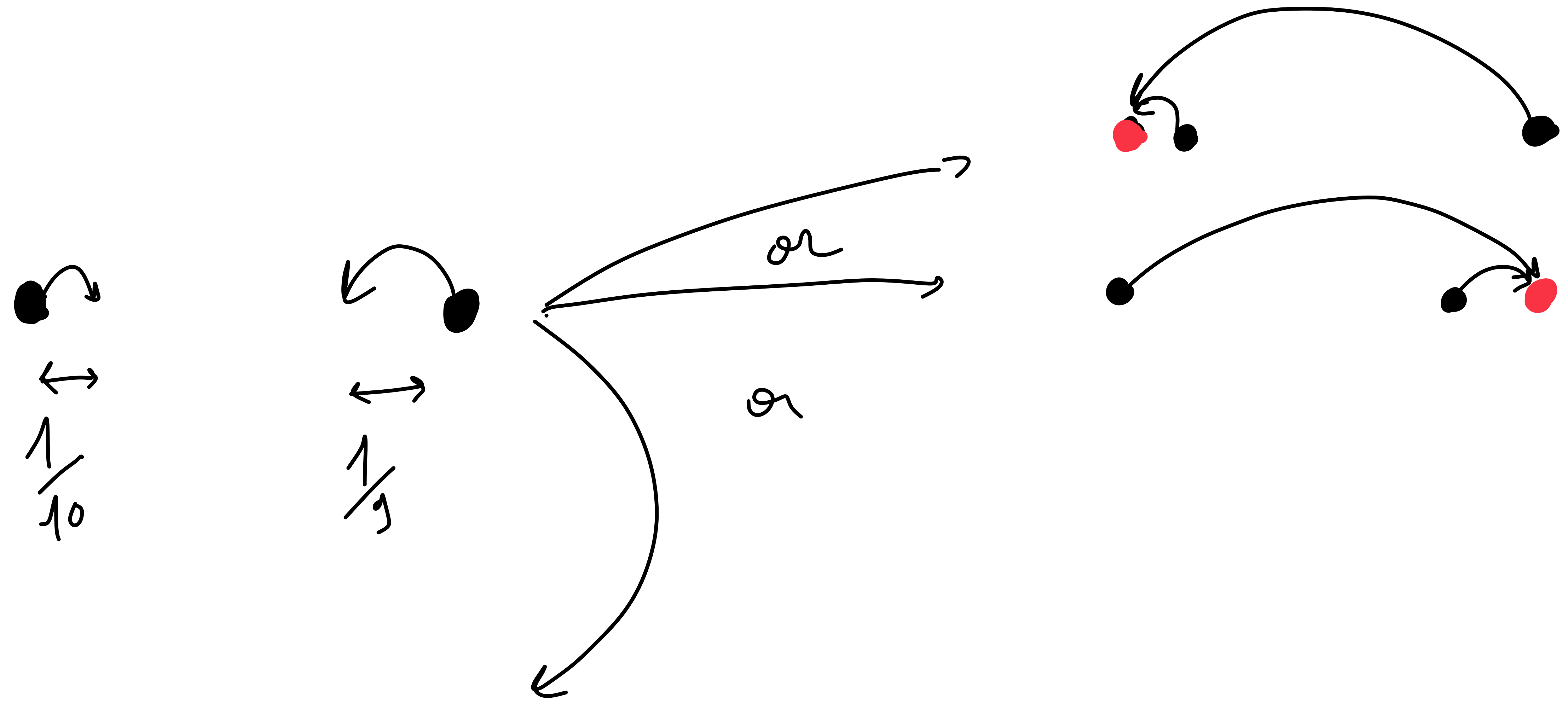

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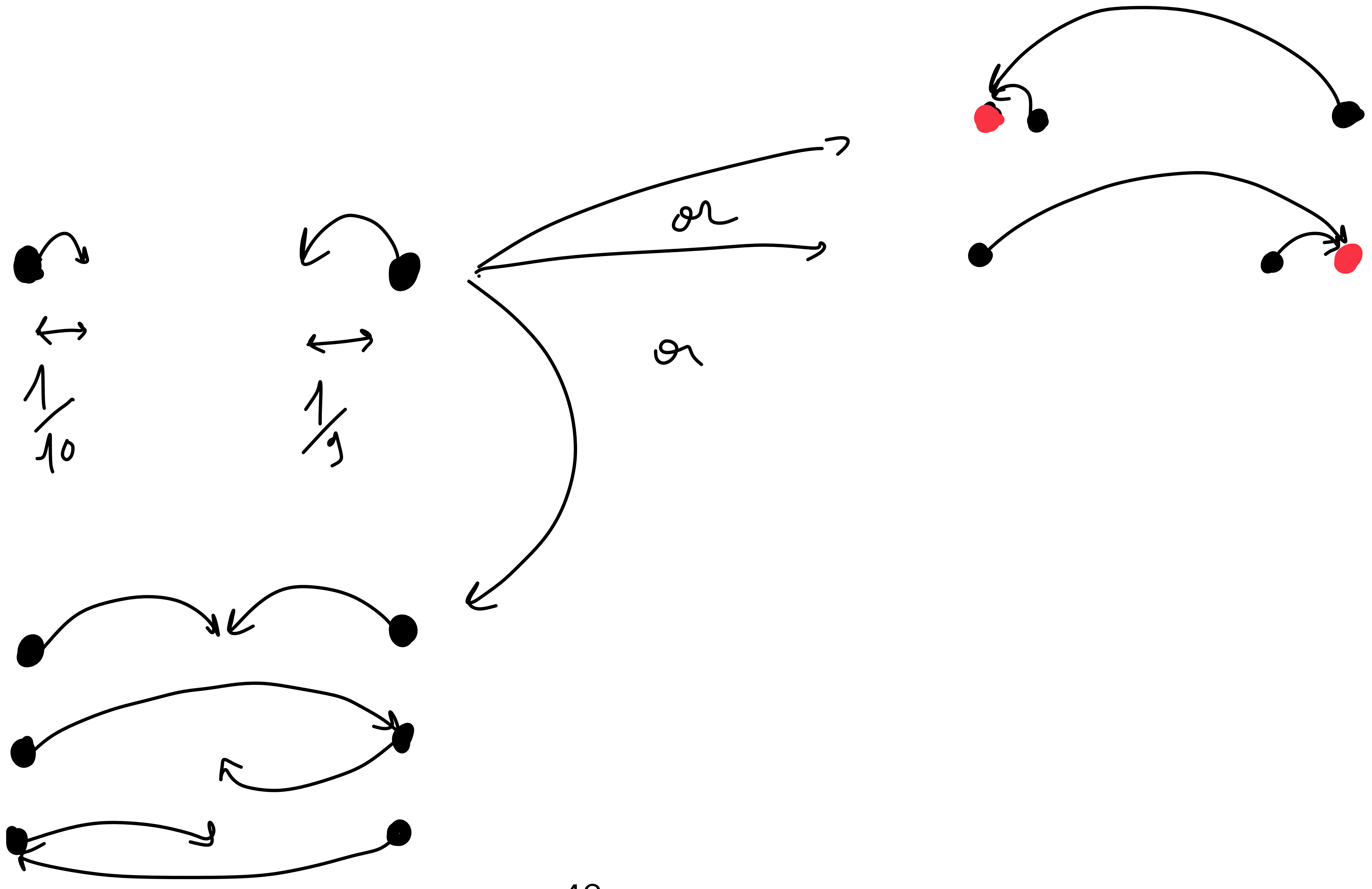


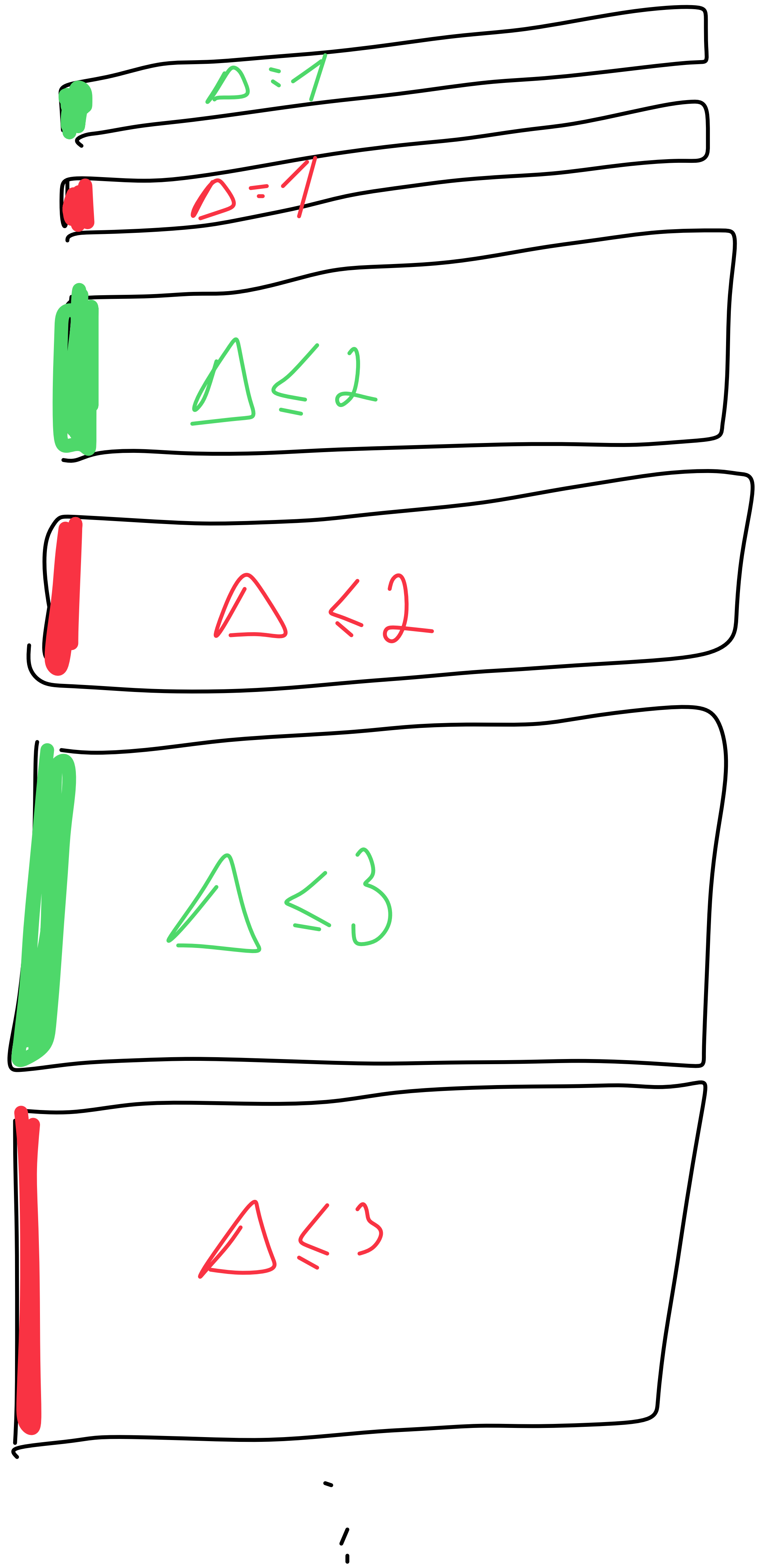
i = 3

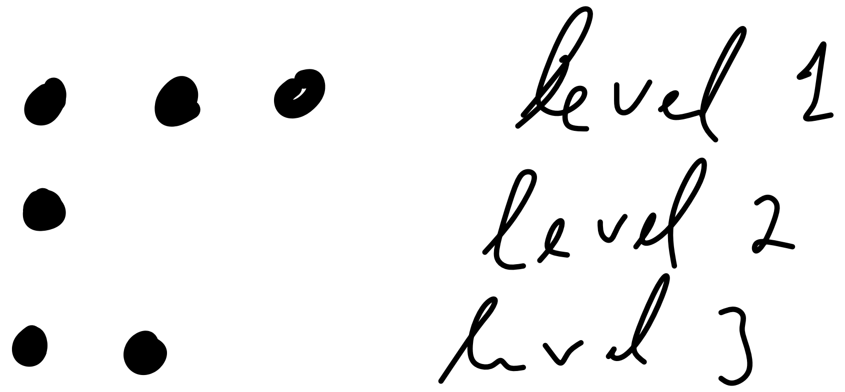
i = 4

i = 5

The Level-Slicing Technic

level i





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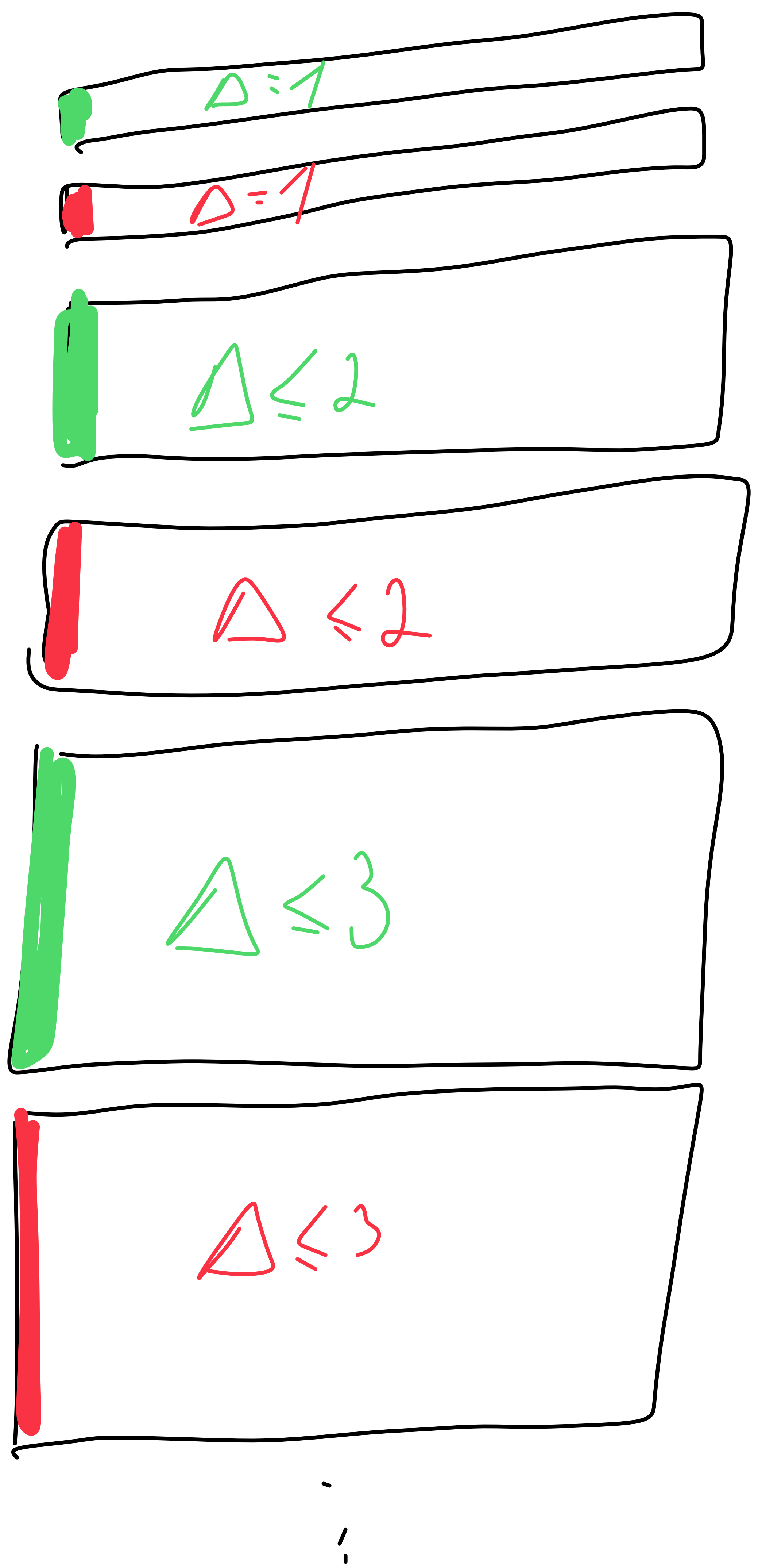

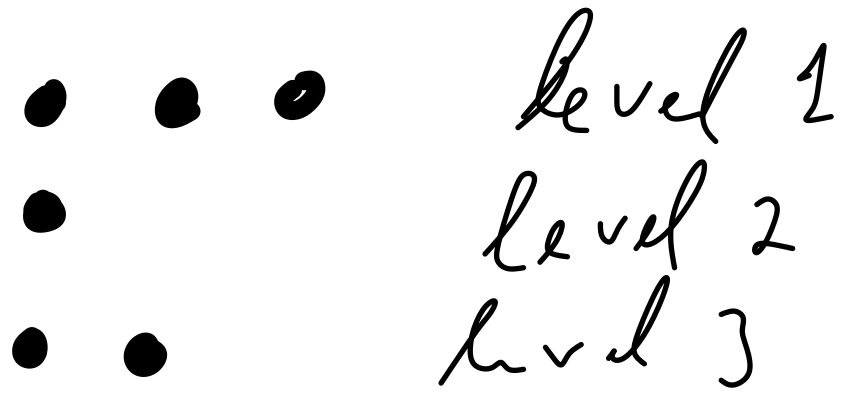

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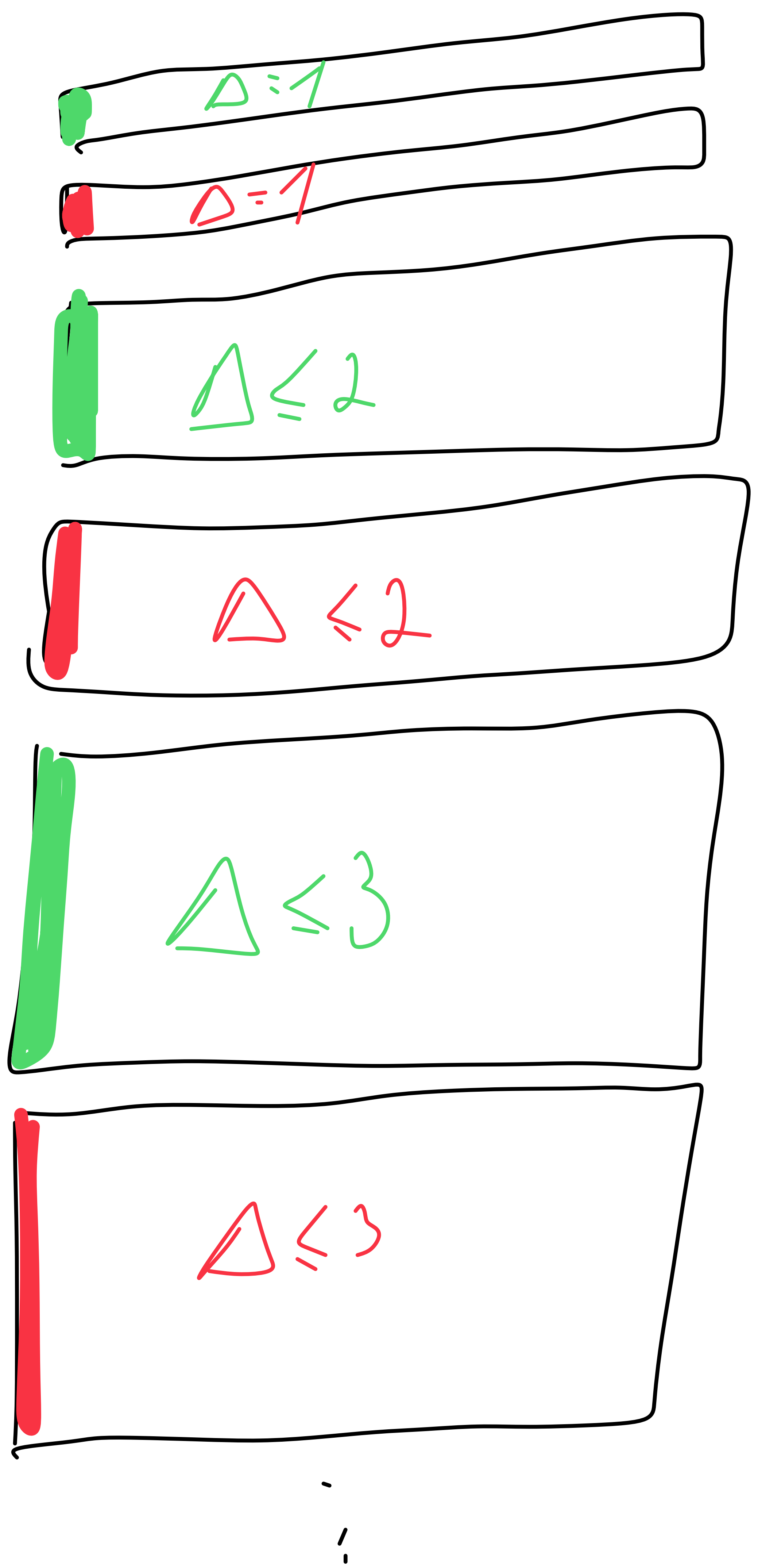

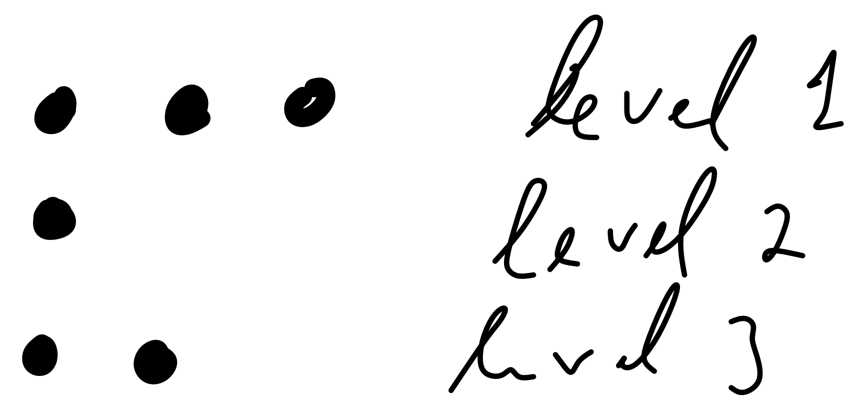

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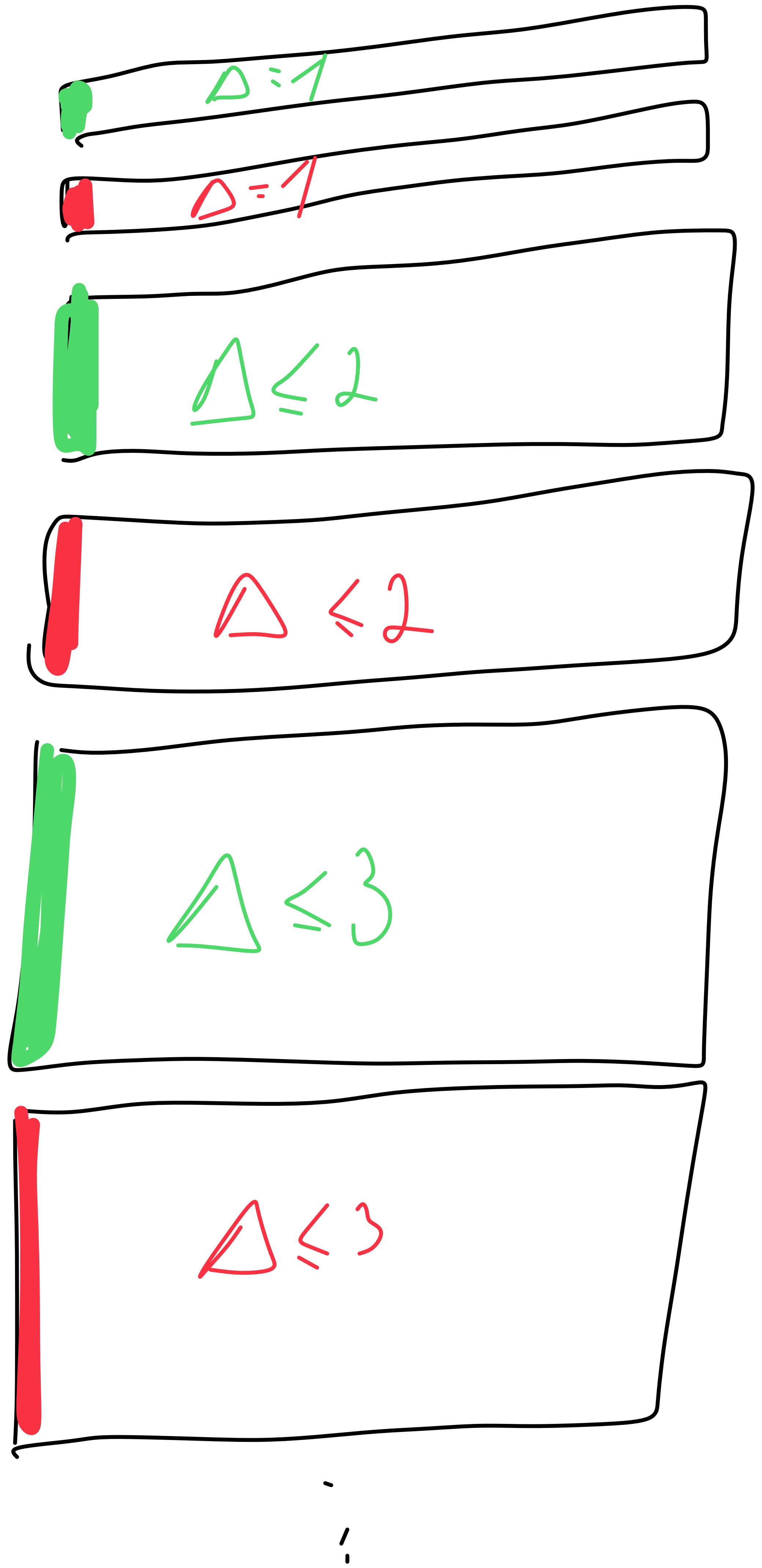

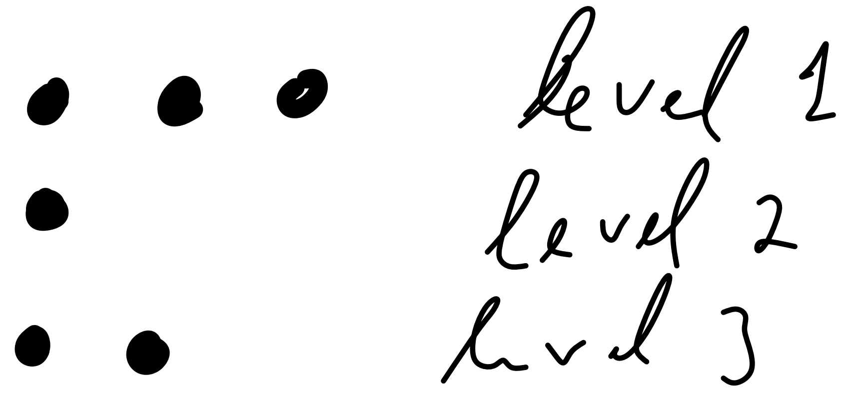

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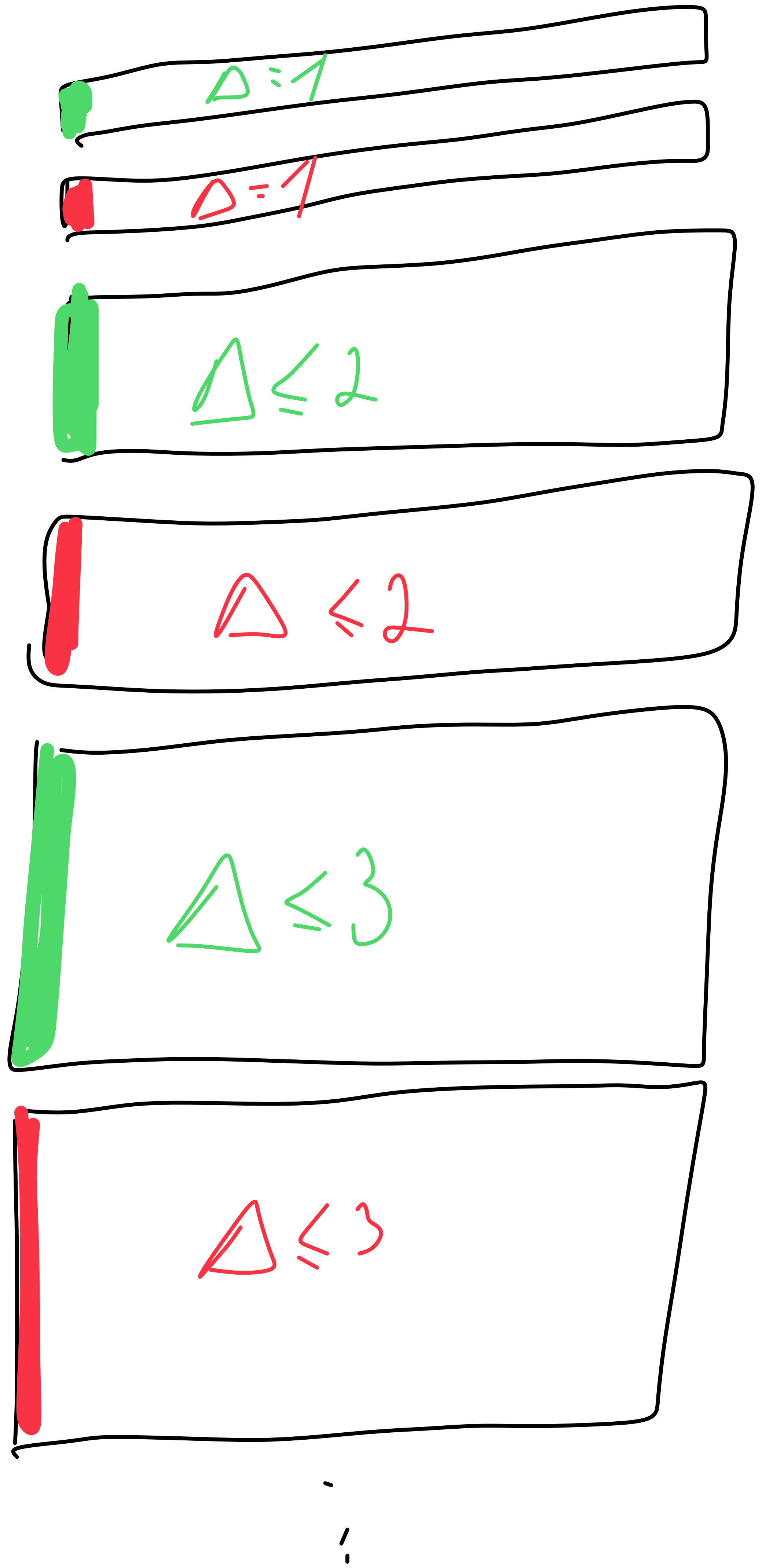

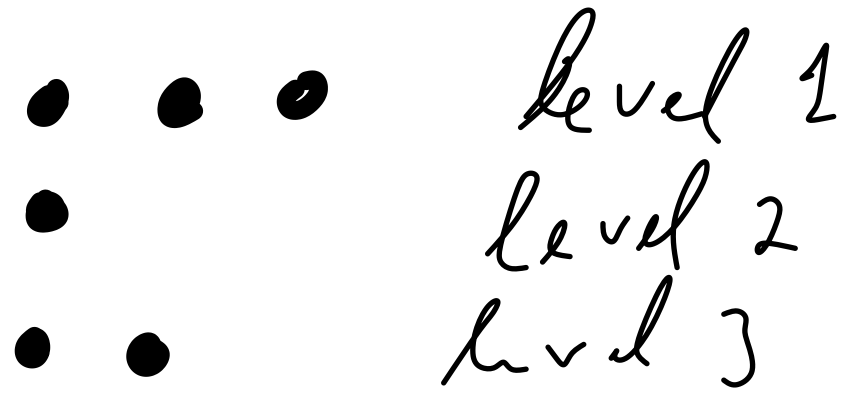

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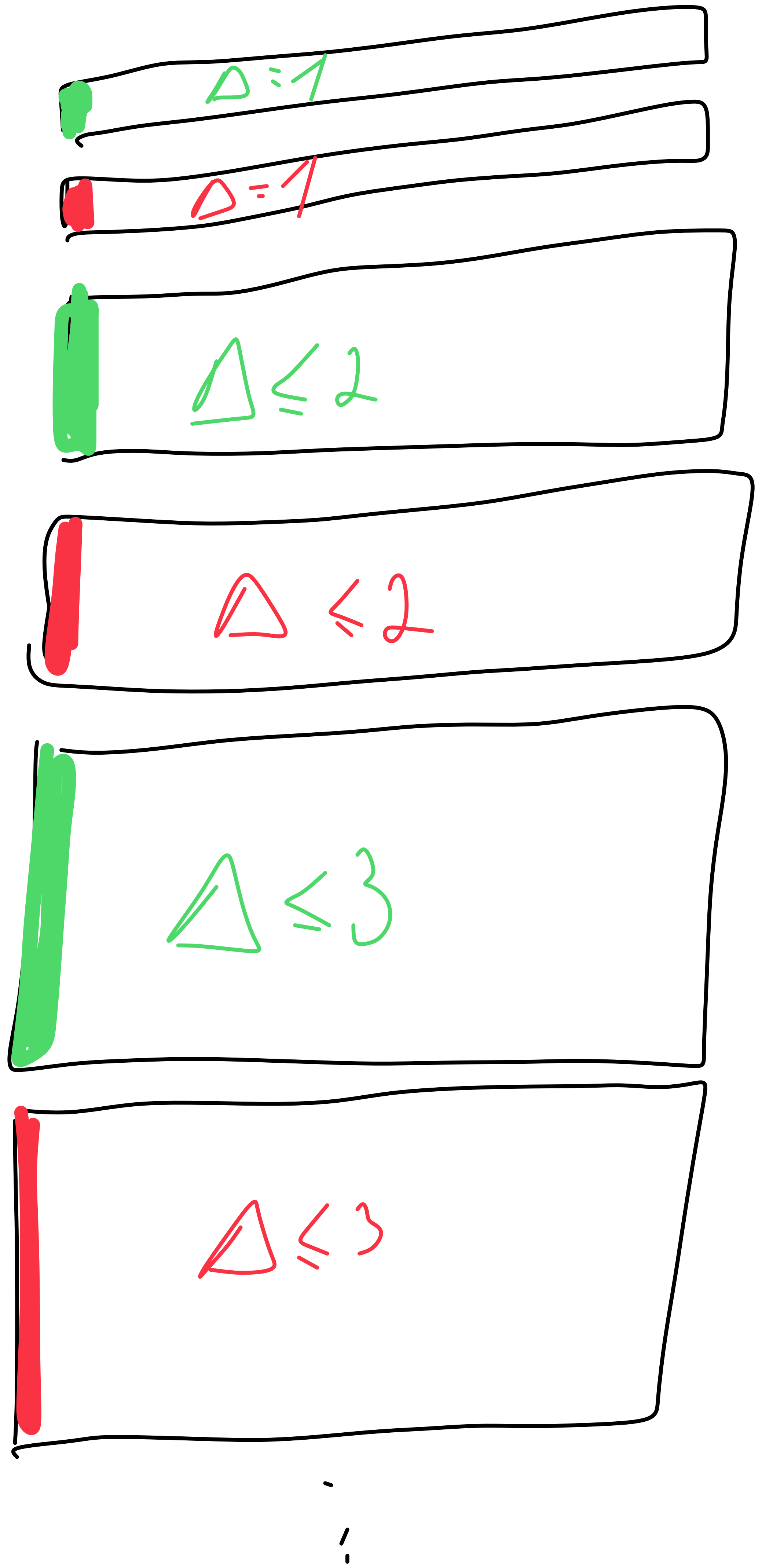

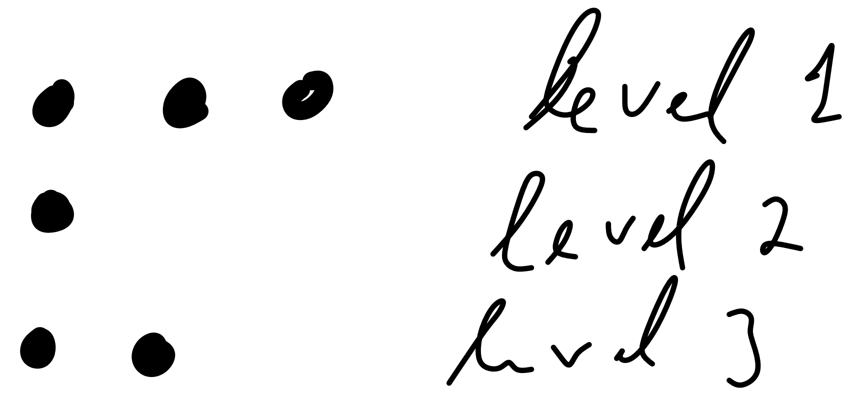

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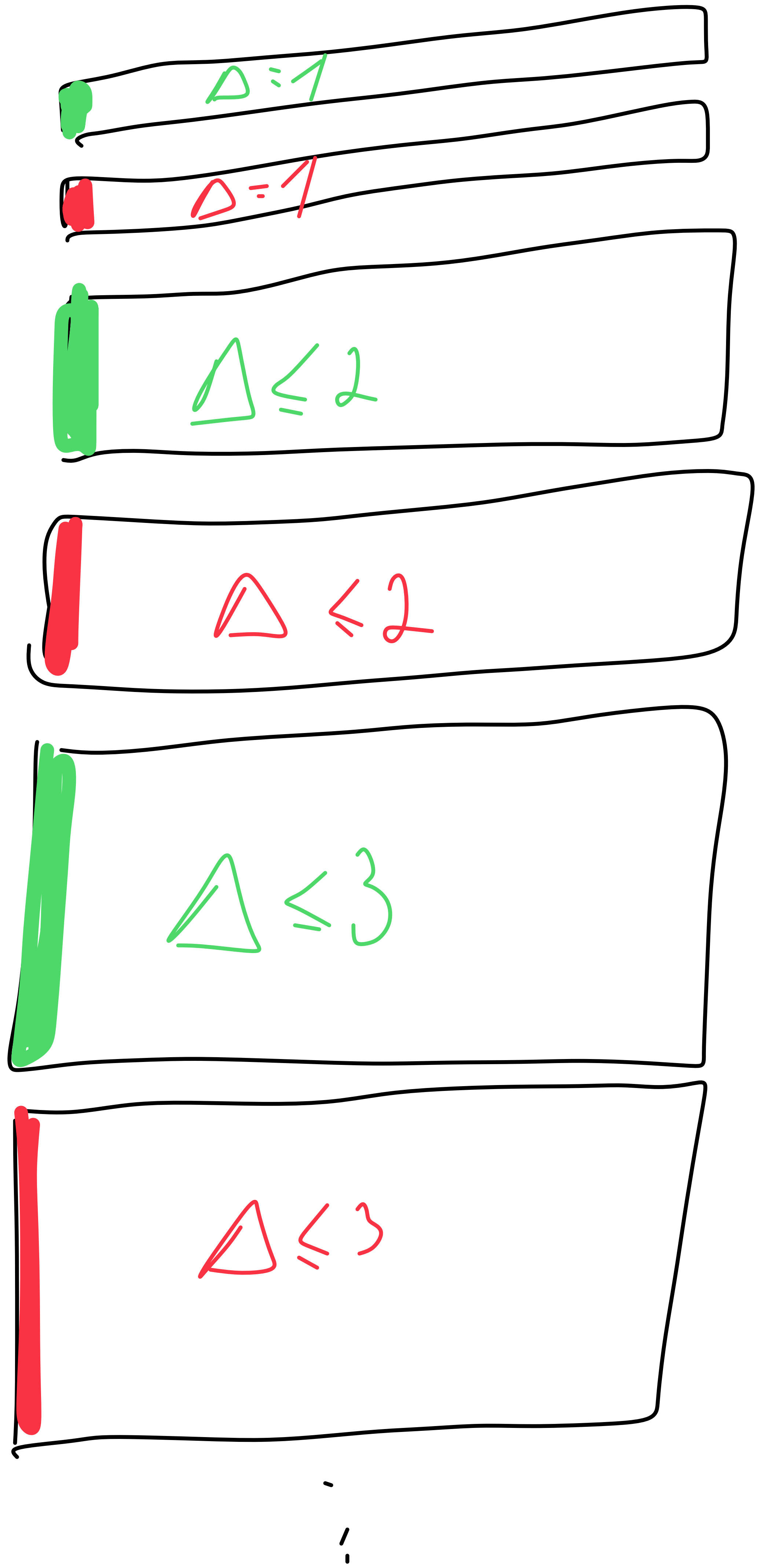

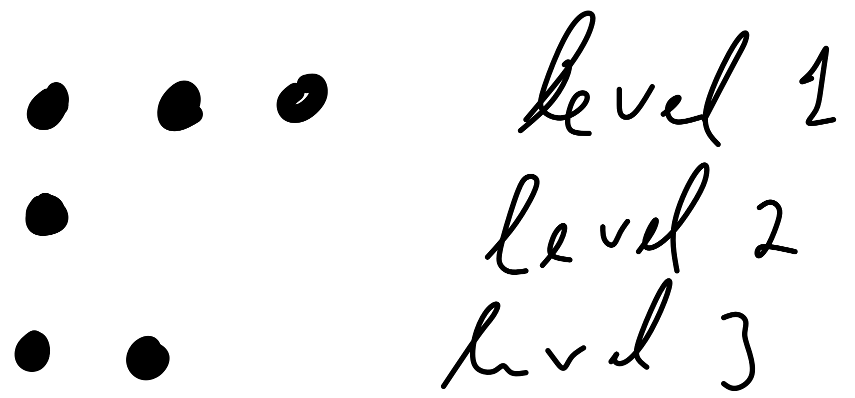

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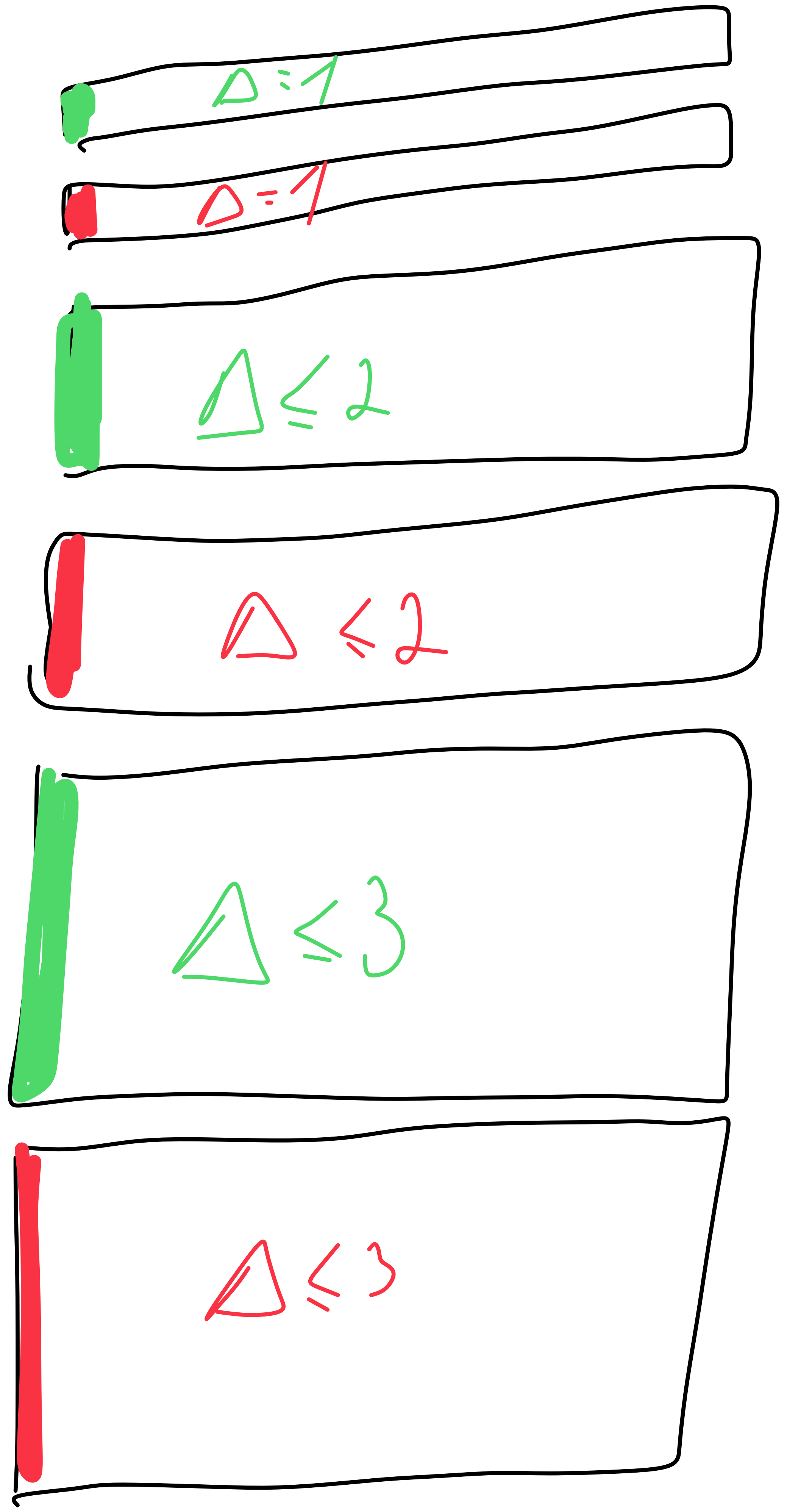

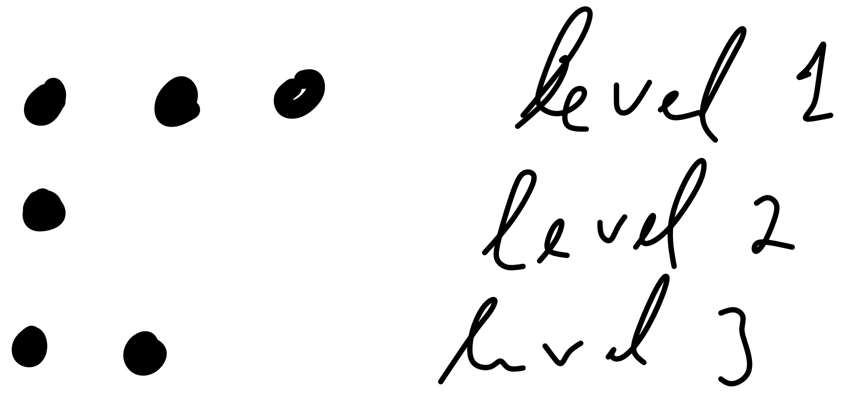

Conclusion

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Thank you!