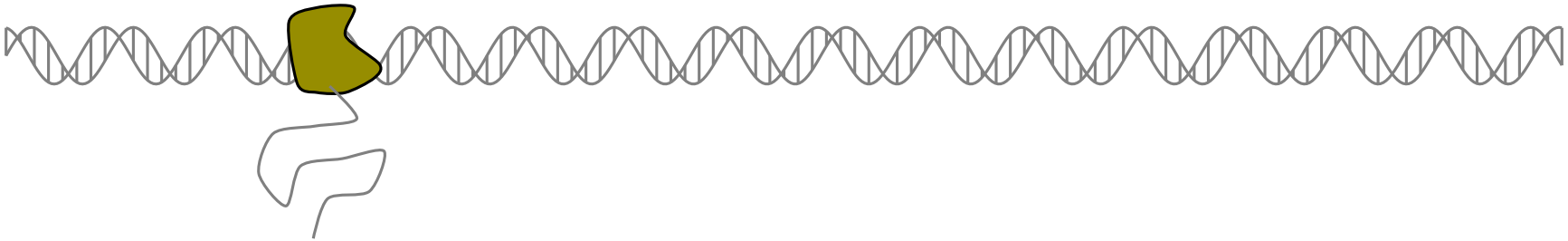
On Turedo Hierarchies and Intrinsic Universality

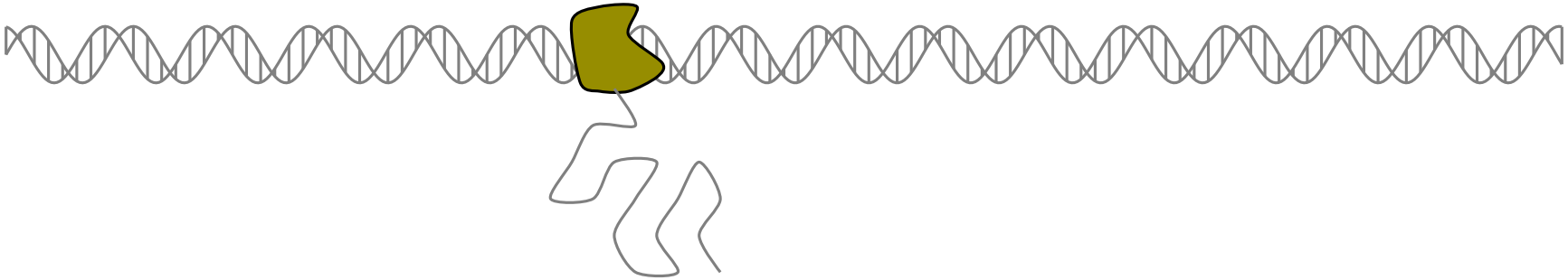
Samuel Nalin, Guillaume Theyssier

DNA28. August 8, 2022

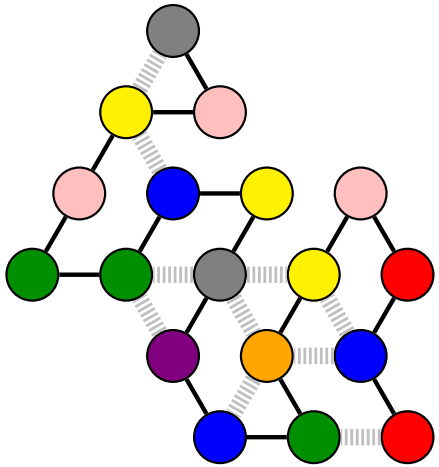
Turedos, motivation

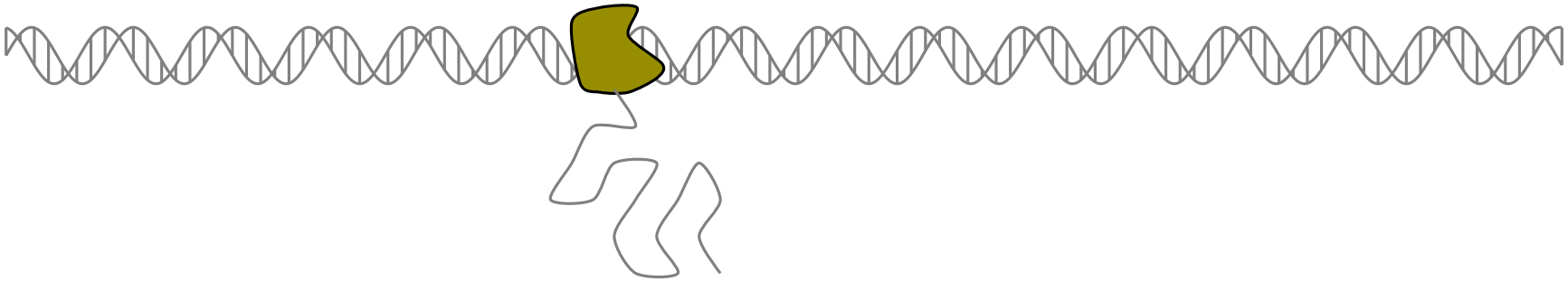


Turedos, motivation



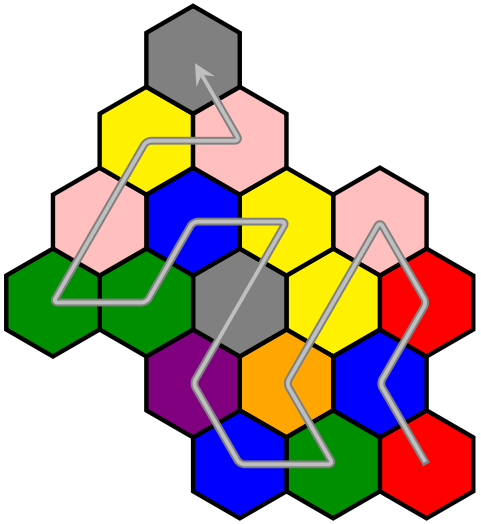
Turedos, motivation

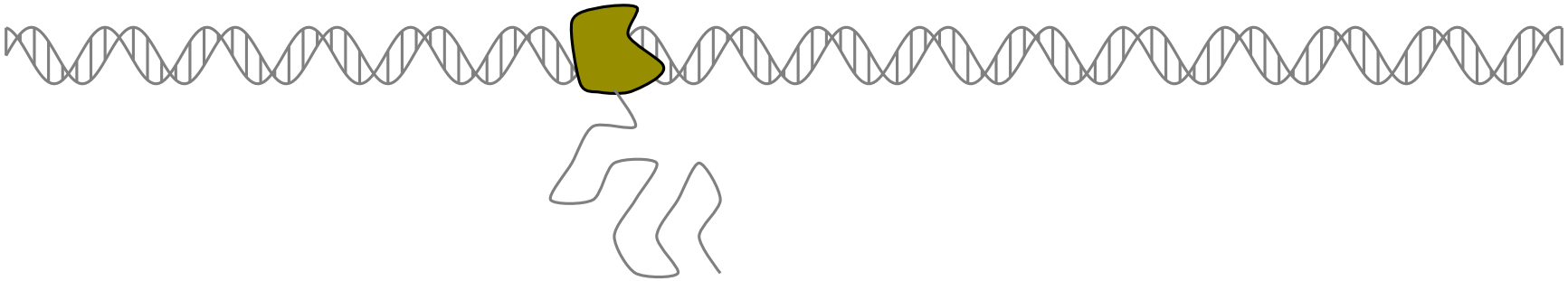




RNA folding $\subseteq$ Oritatami Systems

Turedos, motivation

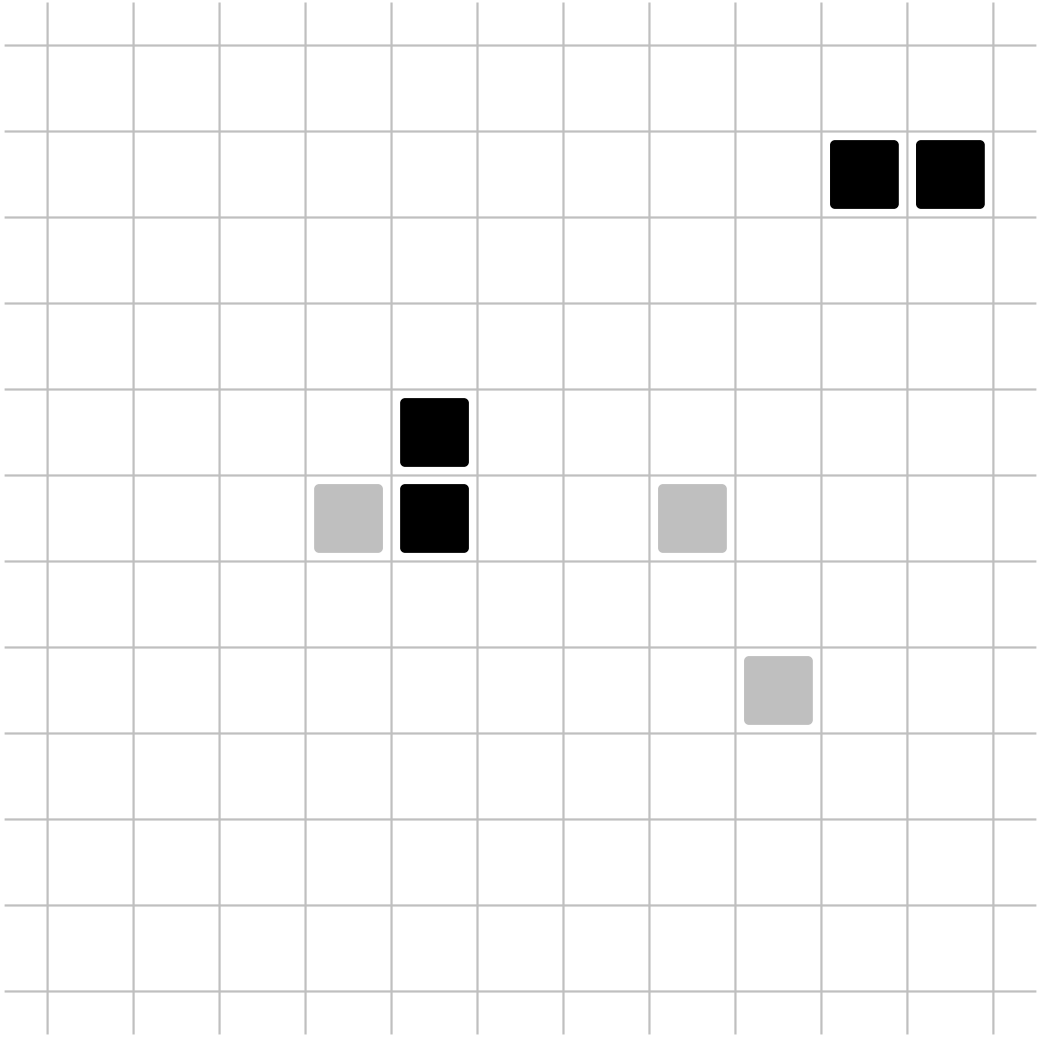




RNA folding $\subseteq$ Oritatami Systems $\subseteq$ Turedos

Turedos, definition - example

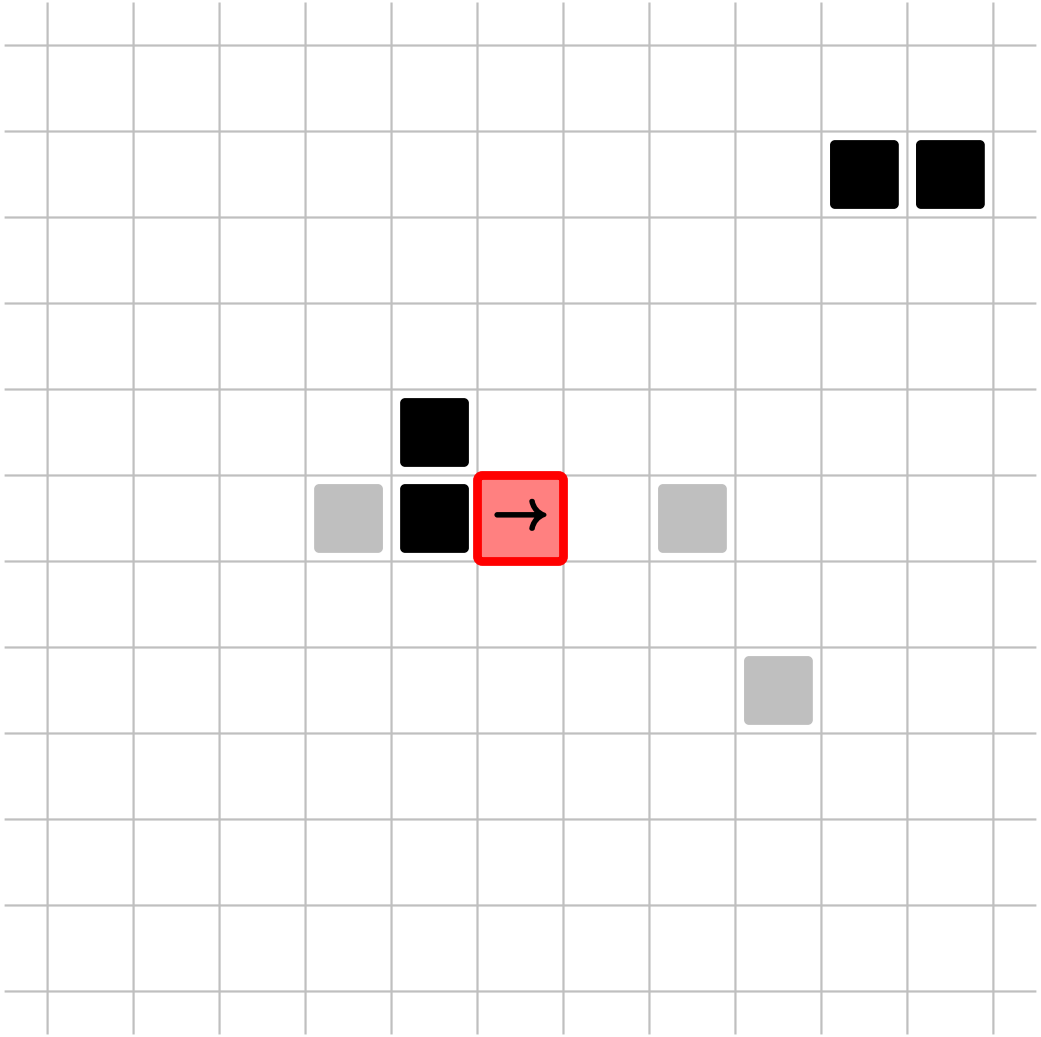
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\boxed{\rightarrow}, \boxed{\uparrow}, \boxed{\leftarrow}, \boxed{\downarrow}\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

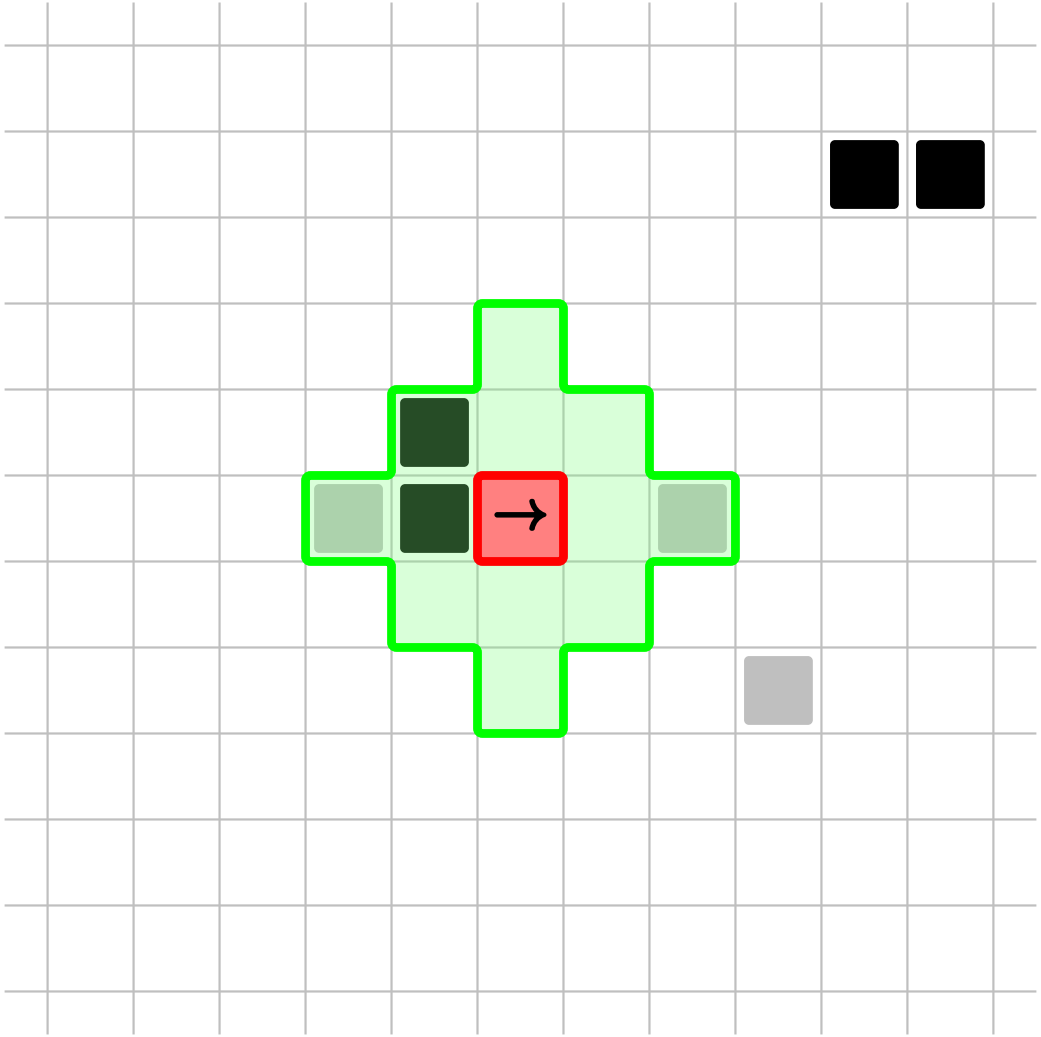
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\boxed{\rightarrow}, \boxed{\uparrow}, \boxed{\leftarrow}, \boxed{\downarrow}\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

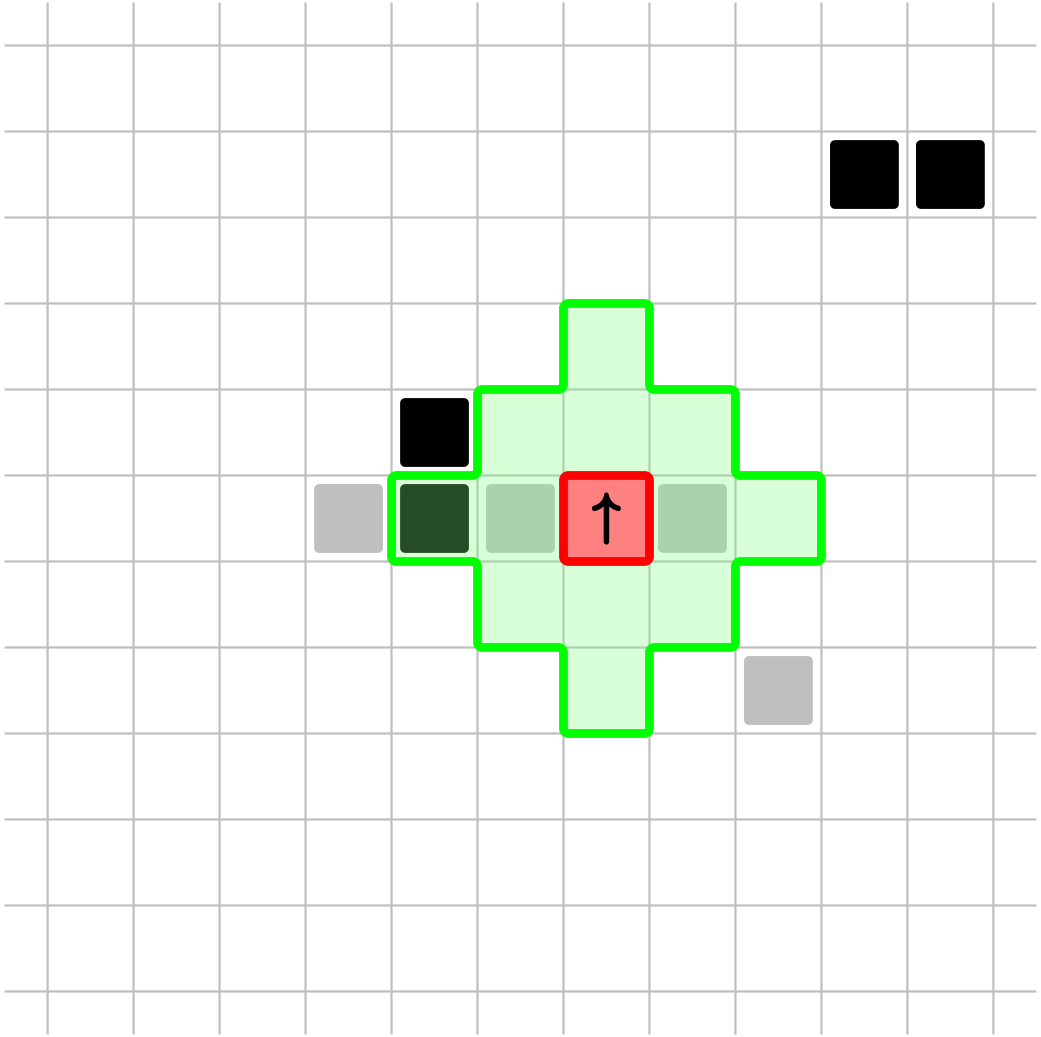
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\boxed{\rightarrow}, \boxed{\uparrow}, \boxed{\leftarrow}, \boxed{\downarrow}\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

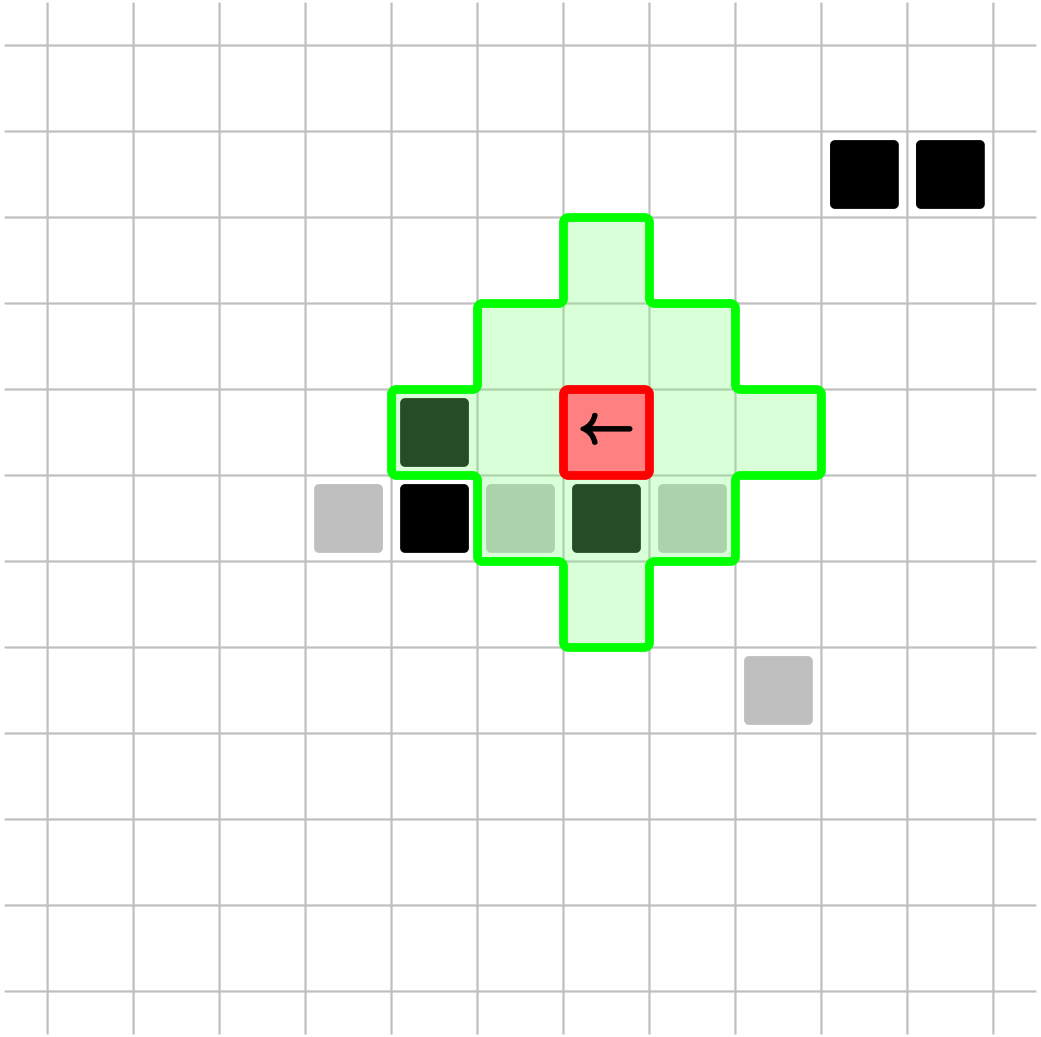
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

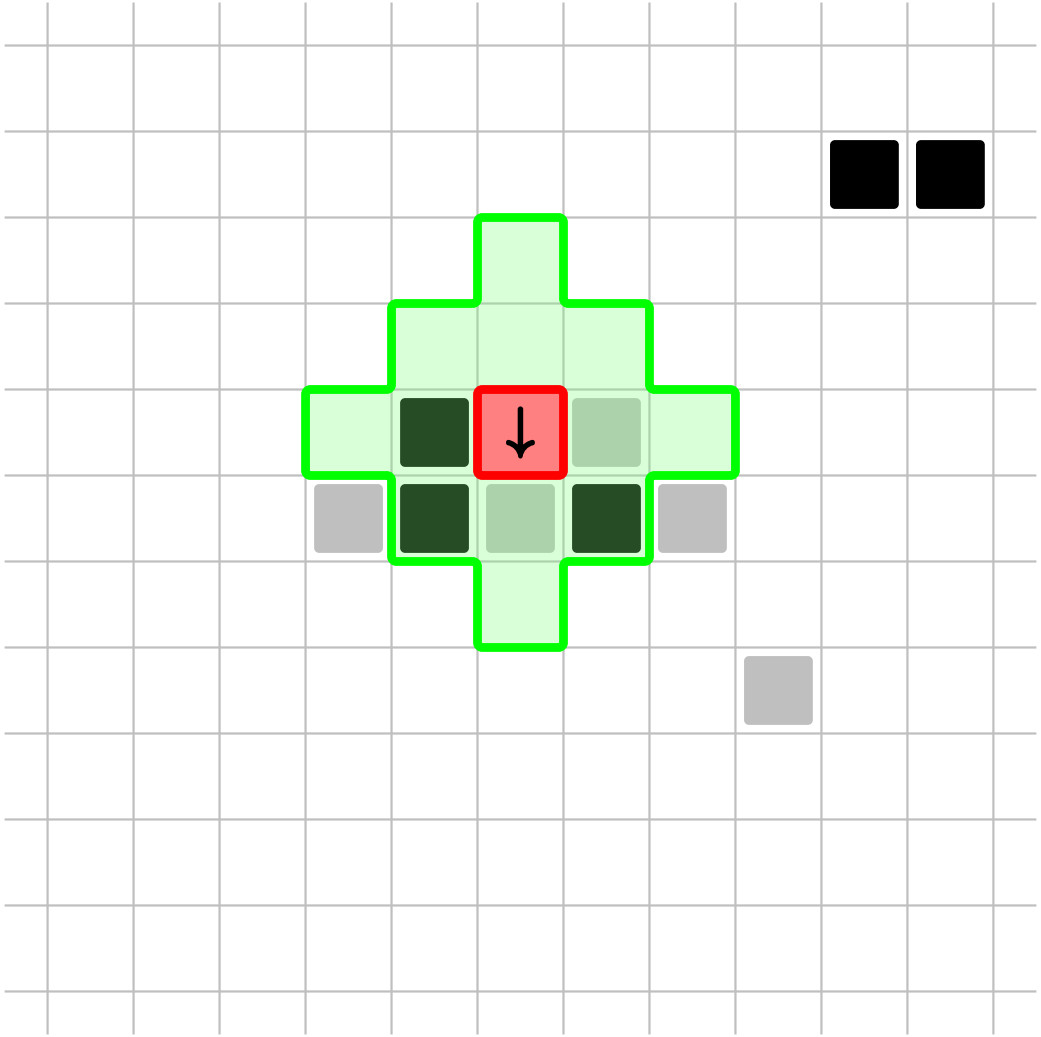
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

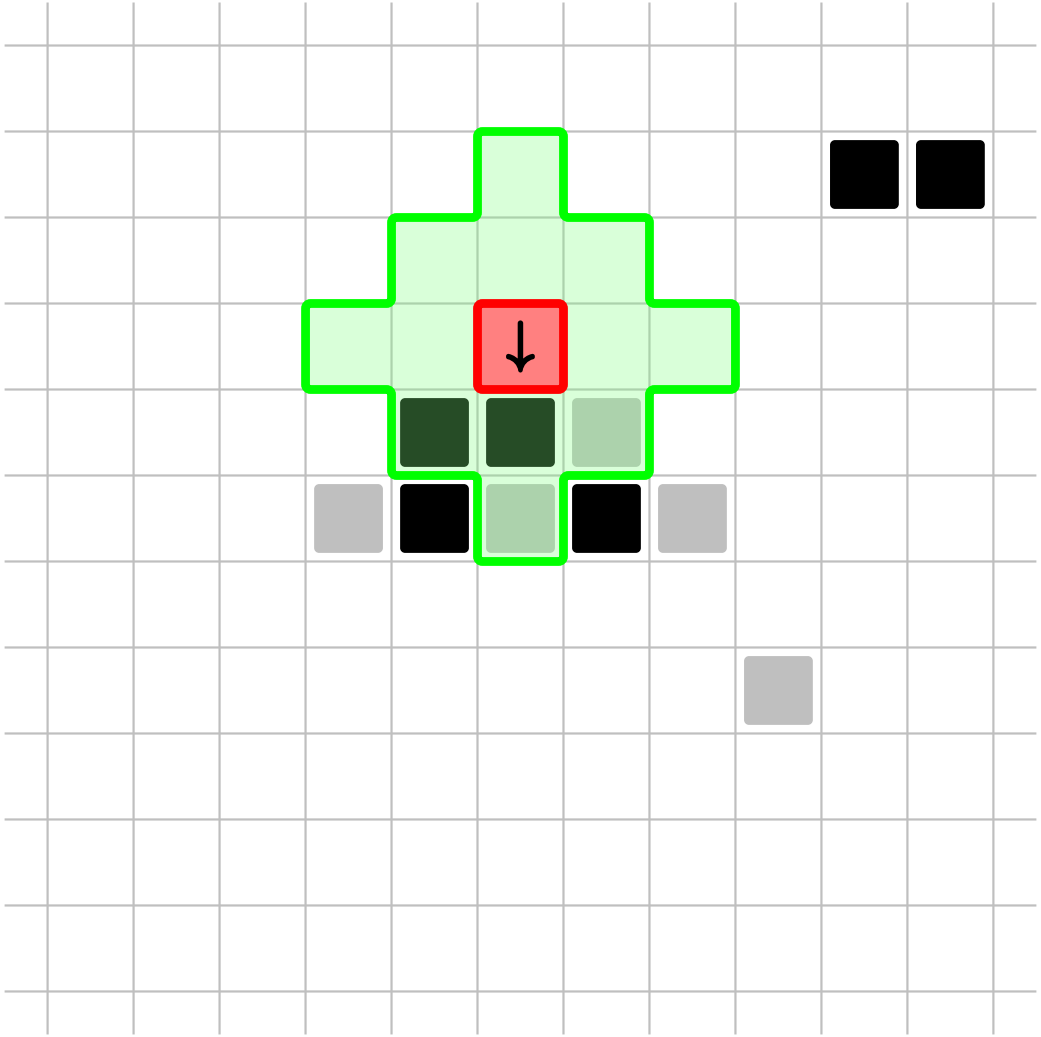
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

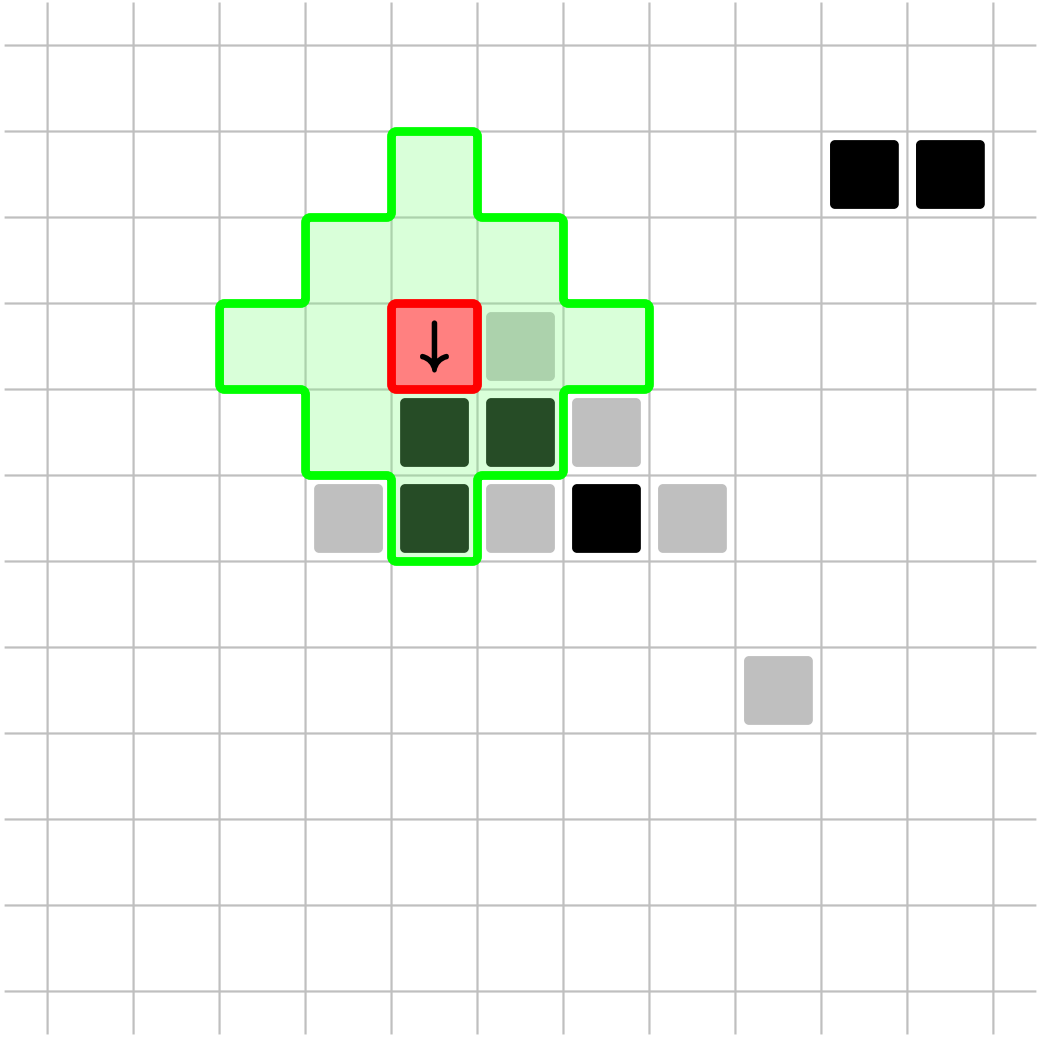
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

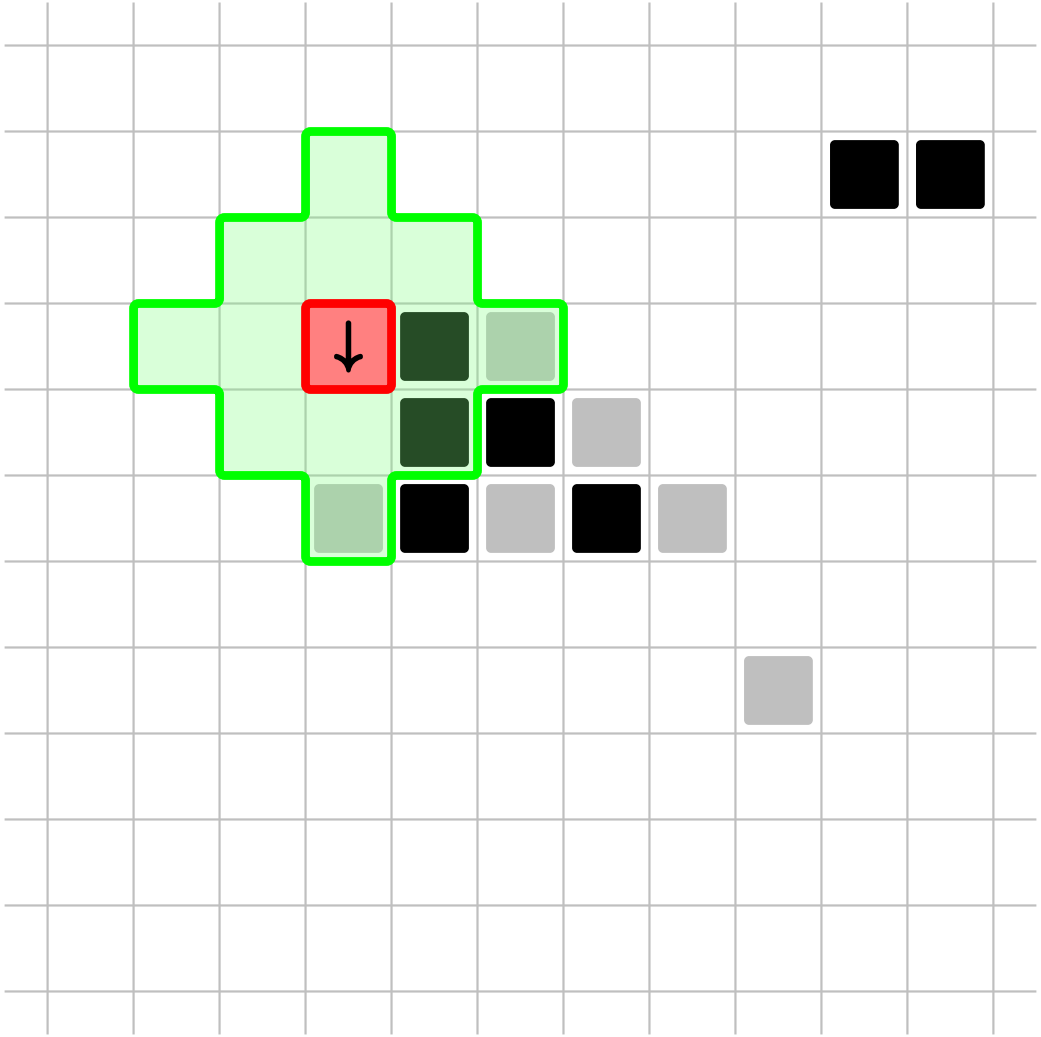
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

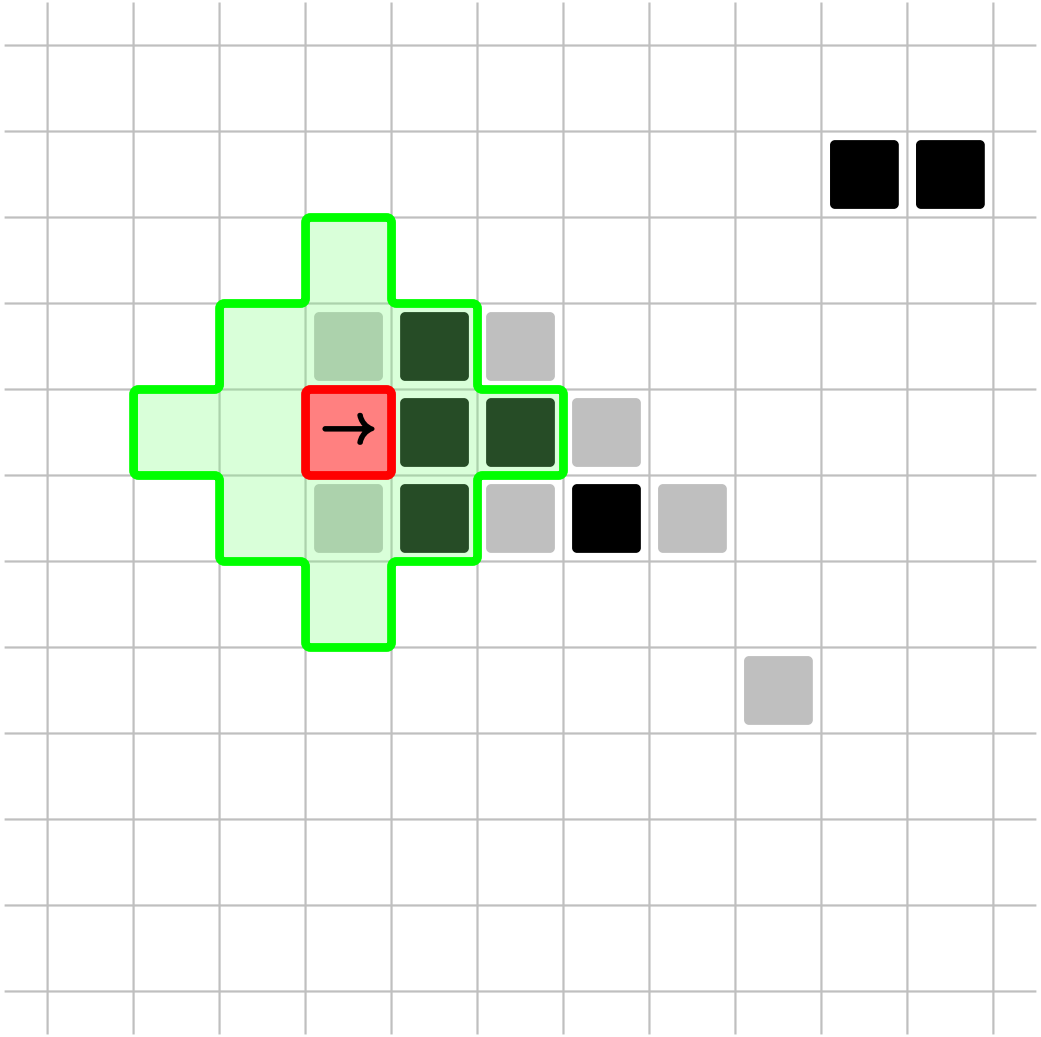
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

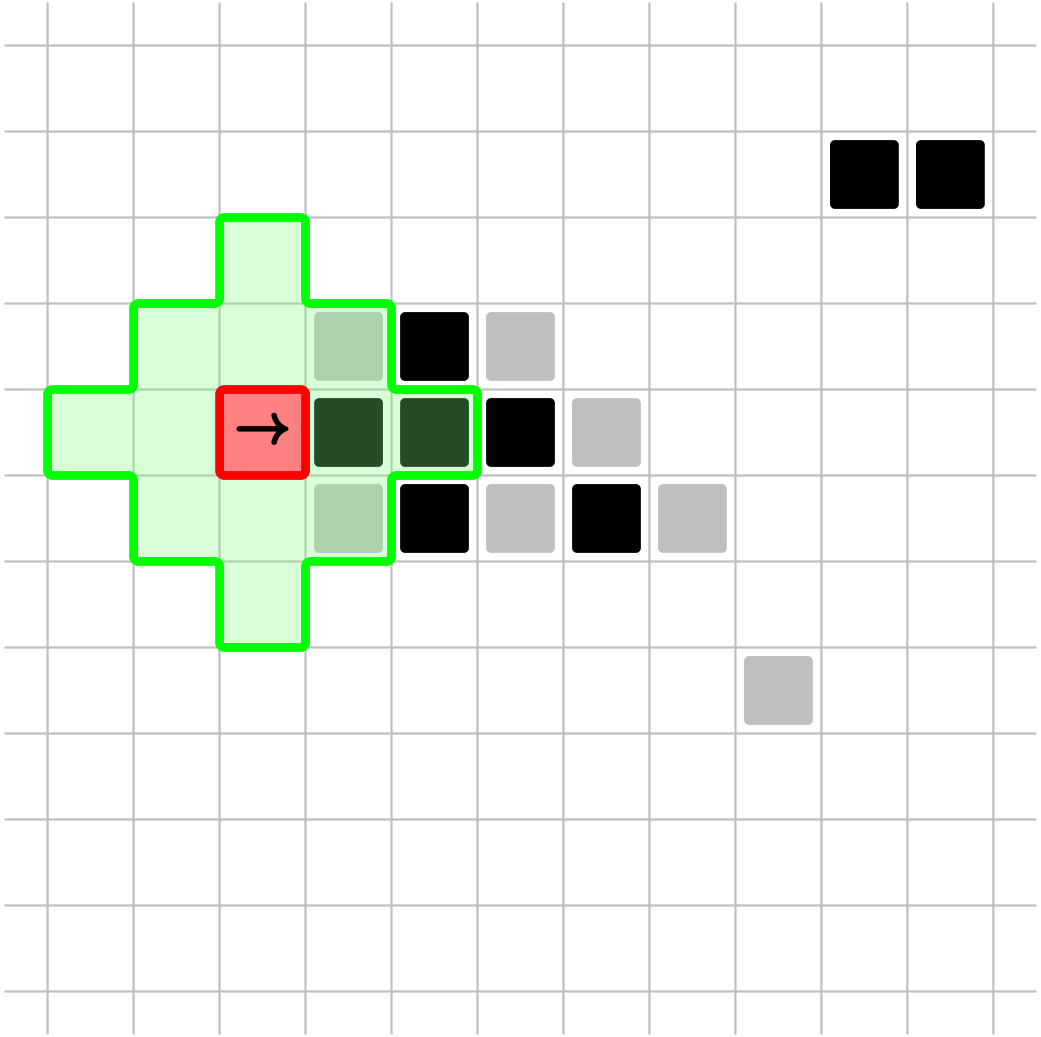
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

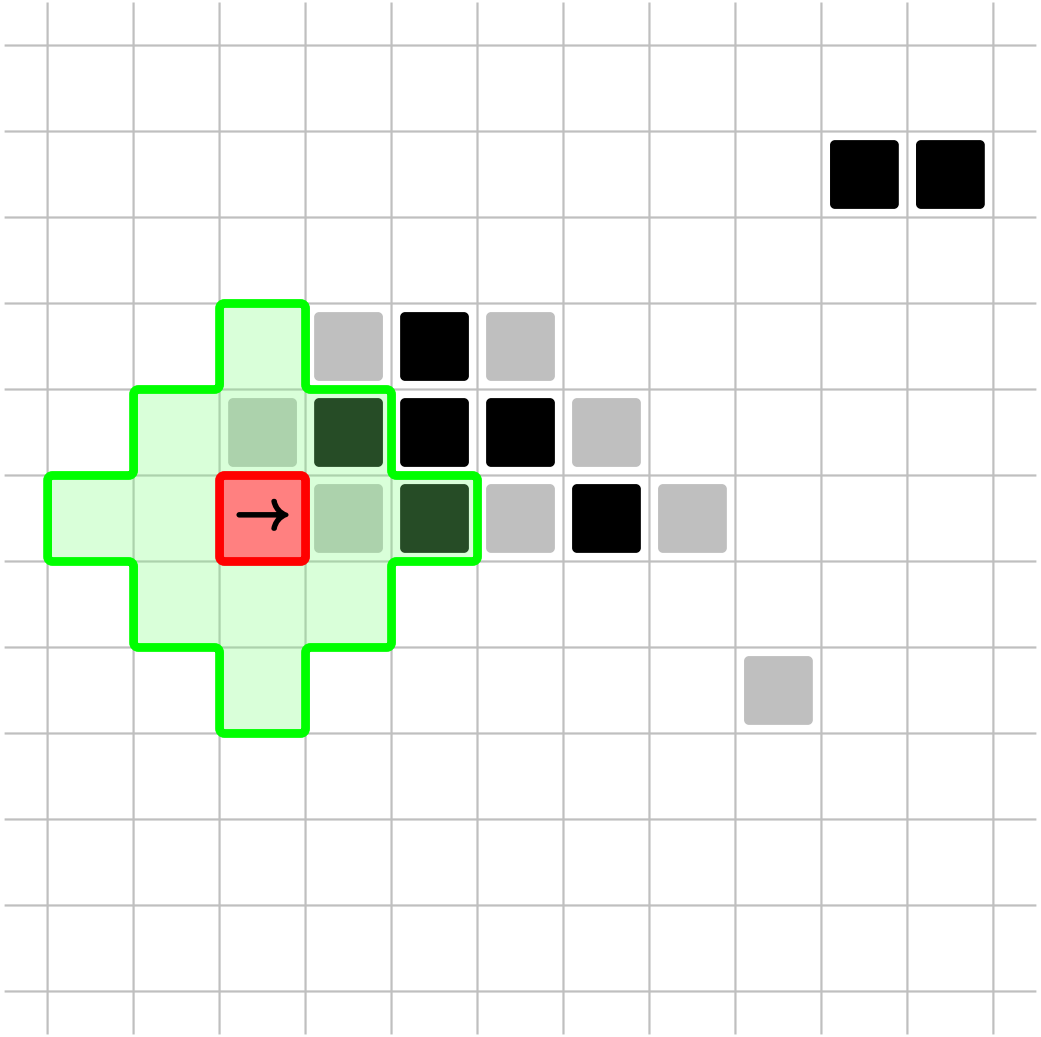
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

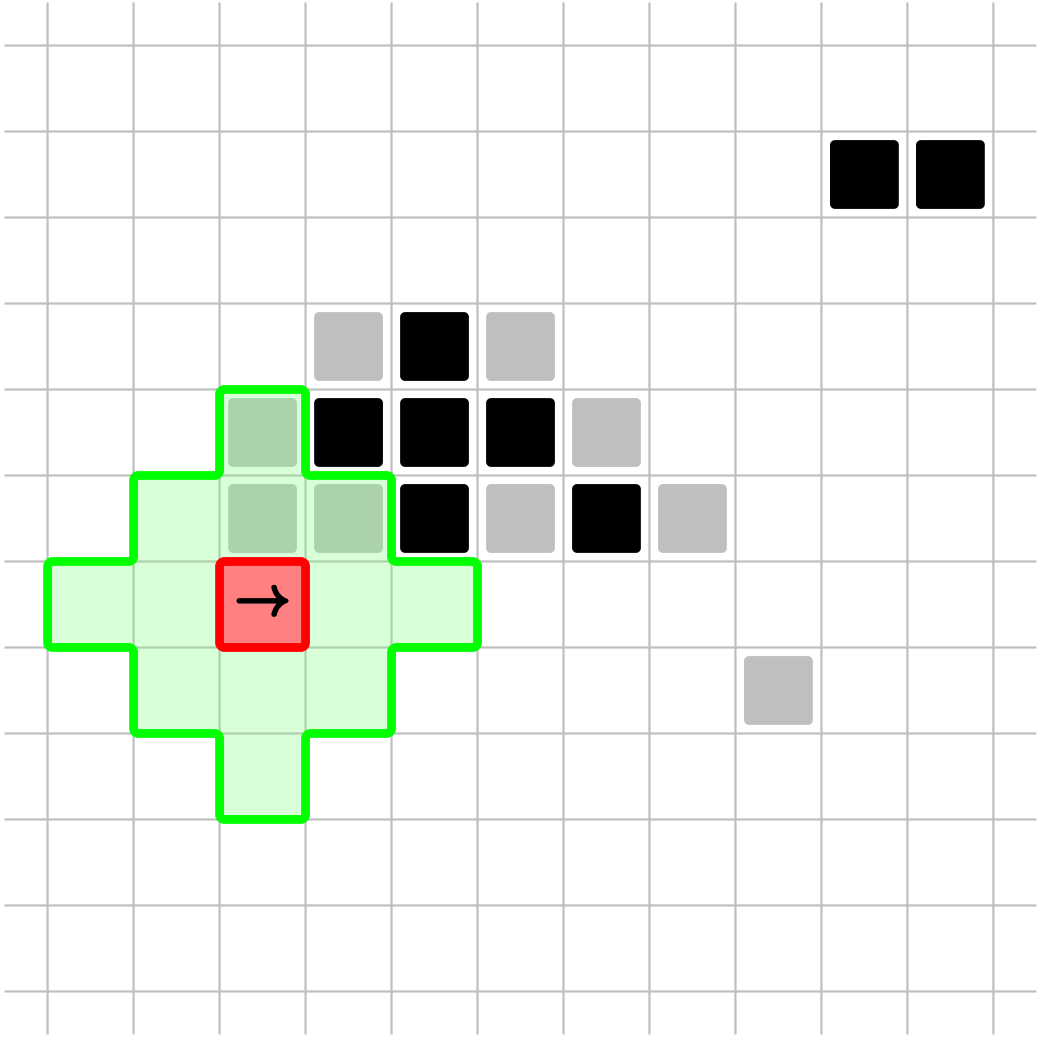
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\boxed{\rightarrow}, \boxed{\uparrow}, \boxed{\leftarrow}, \boxed{\downarrow}\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Turedos, definition - example

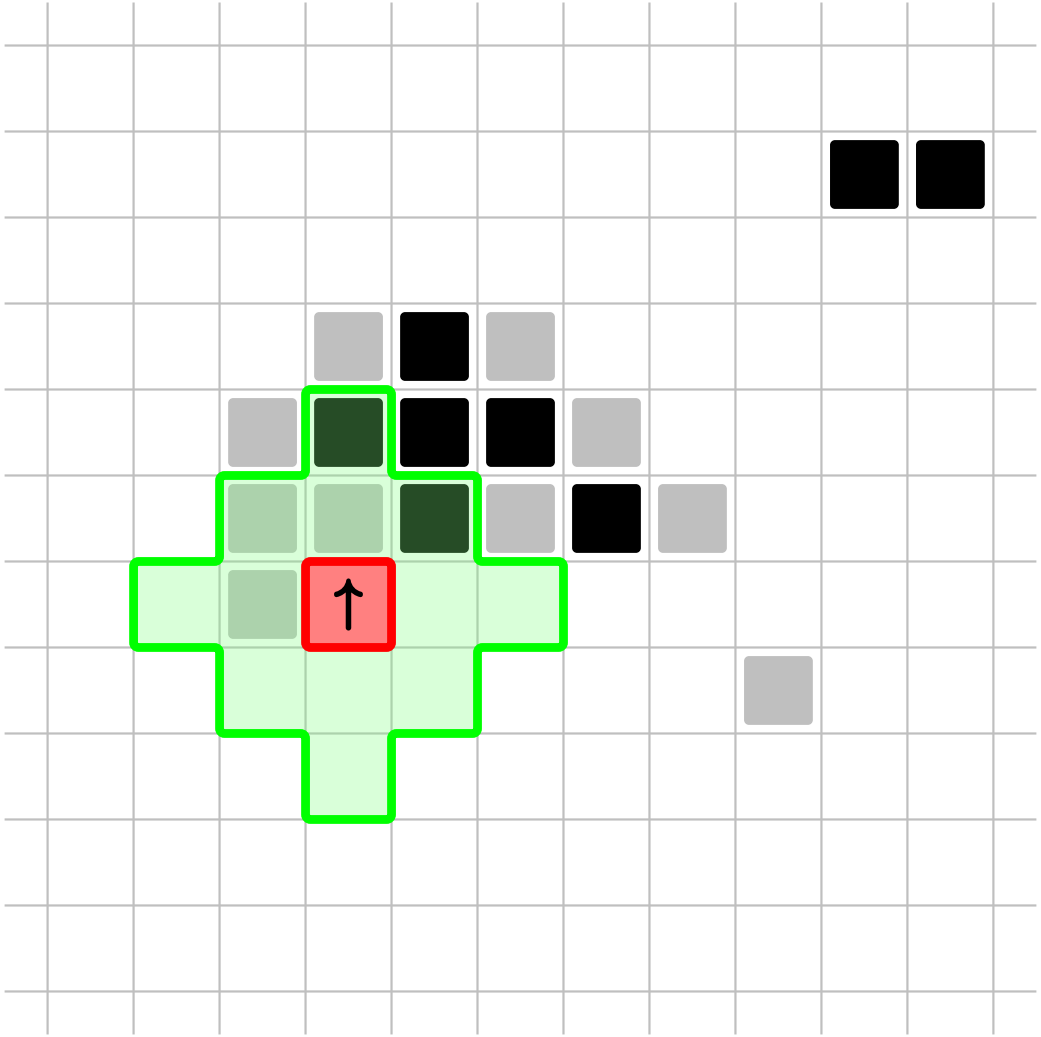
$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$



Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

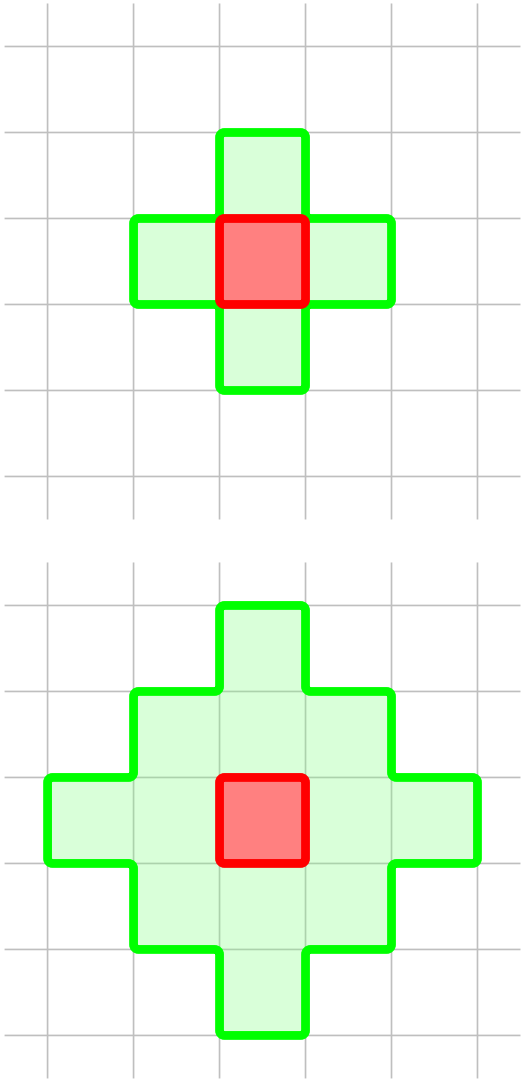
Turedos, definition - example

$A = \{\square, \blacksquare, \blacksquare\}$; $Q = \{\rightarrow, \uparrow, \leftarrow, \downarrow\}$; $\delta : Q \times A^{B_d(r)} \rightarrow Q \times A \backslash \{\square\} \times B_1(r)$

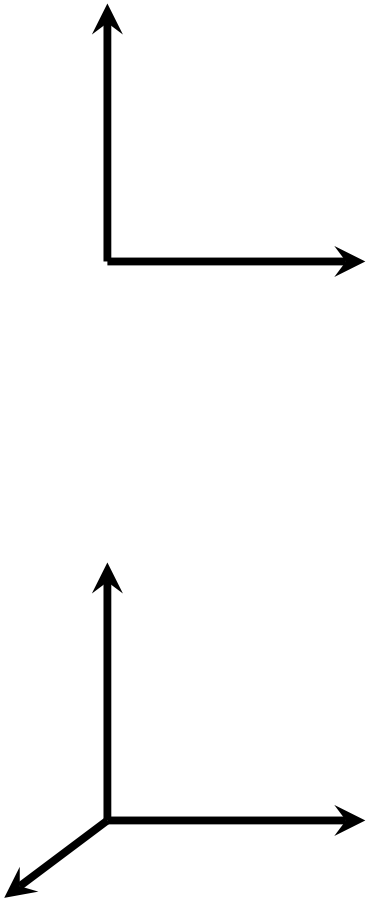


Writes Σ mod 2 of neighborhood. If possible follows head arrow and updates it $\circlearrowleft$ otherwise goes to next $\circlearrowright$ available position.

Influential parameters

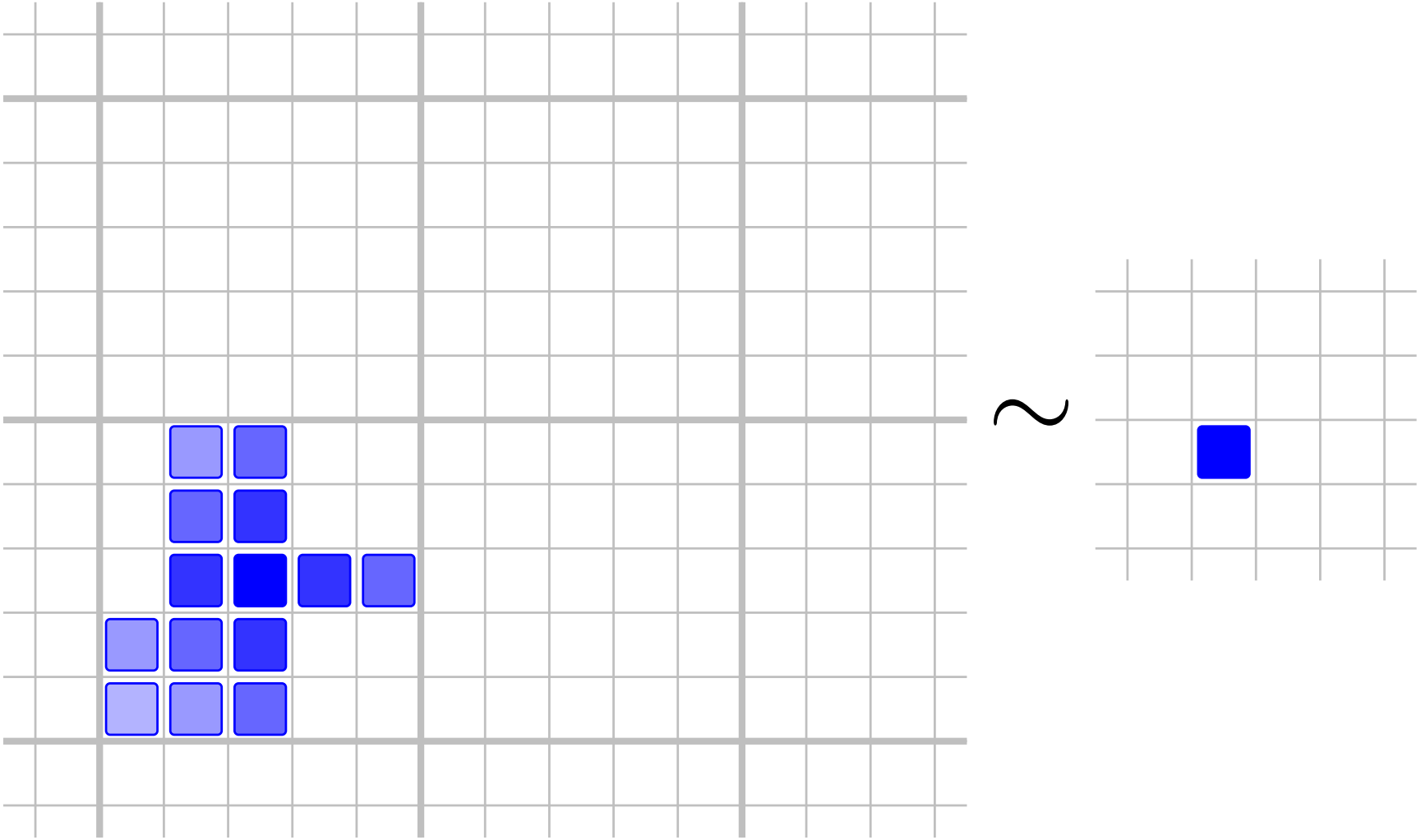


Radius



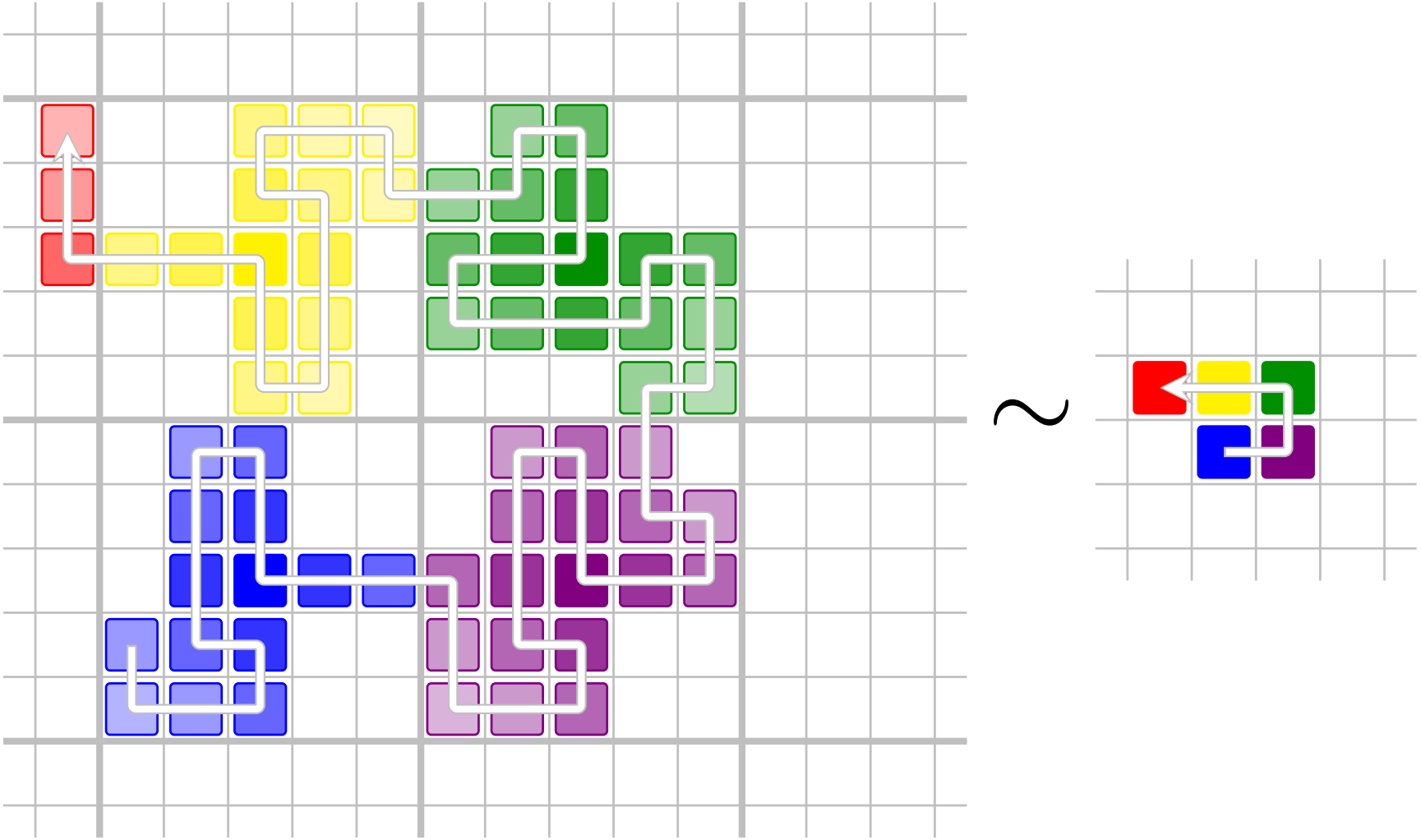
Space

Turedos, simulations



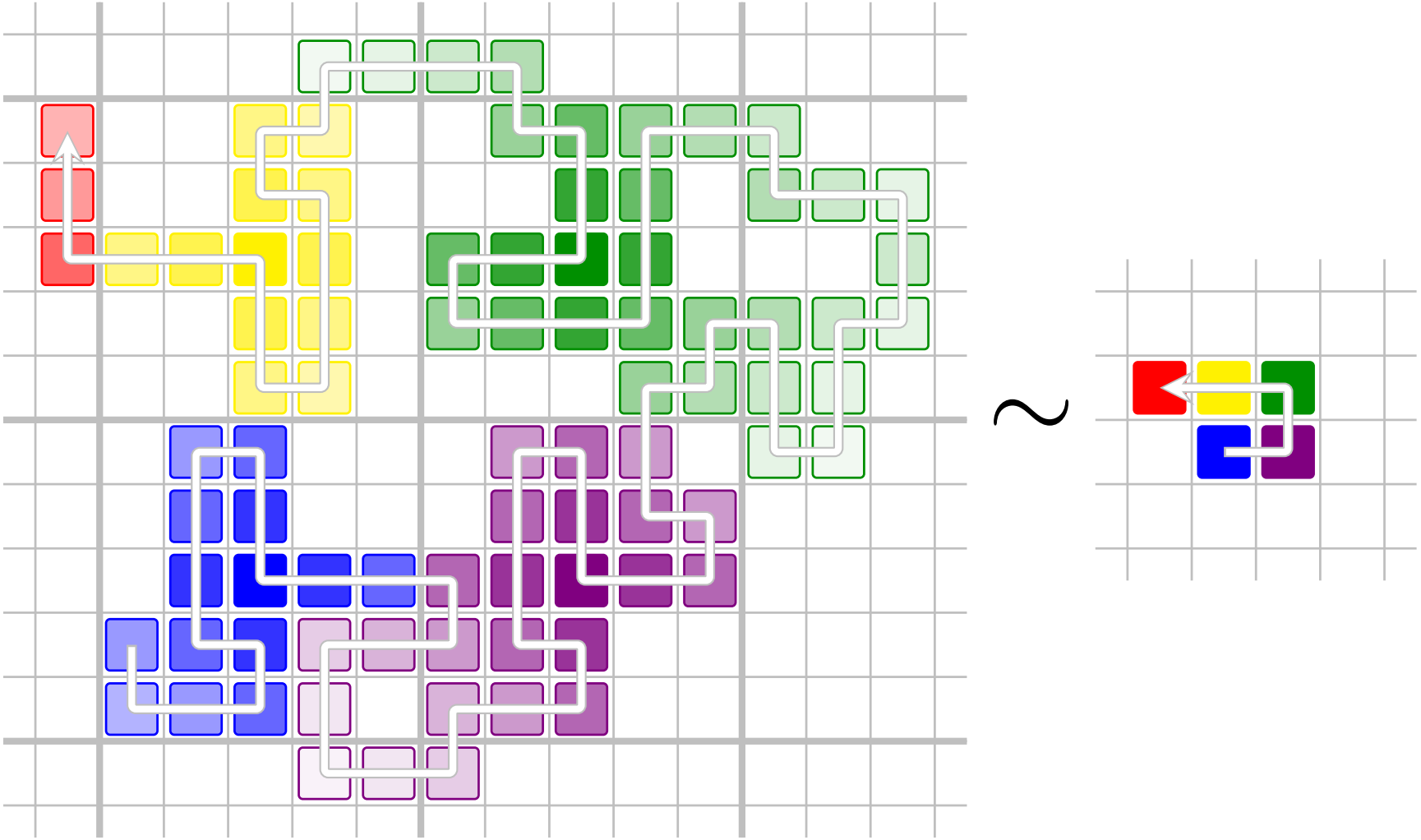
One block encodes one position.

Turedos, simulations



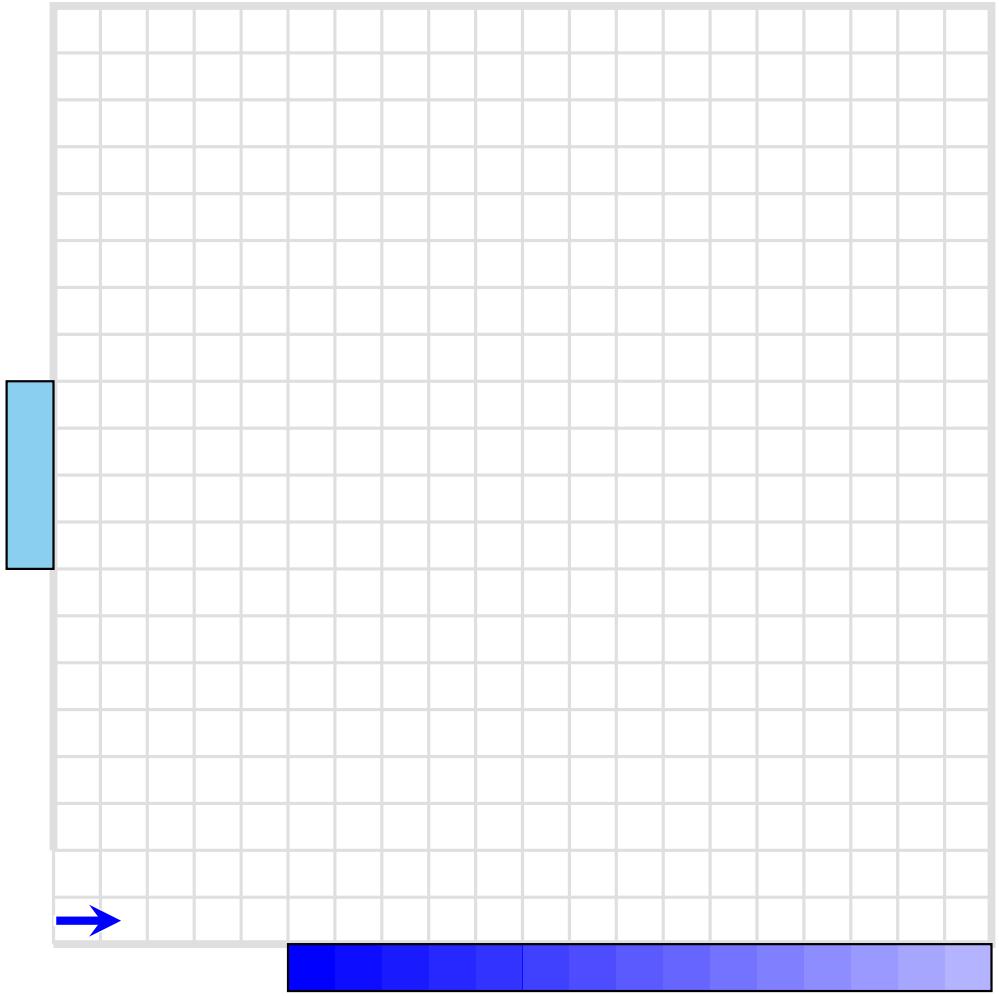
Regular Simulation: when simulating one position, the turedo stays in the corresponding block.

Turedos, simulations



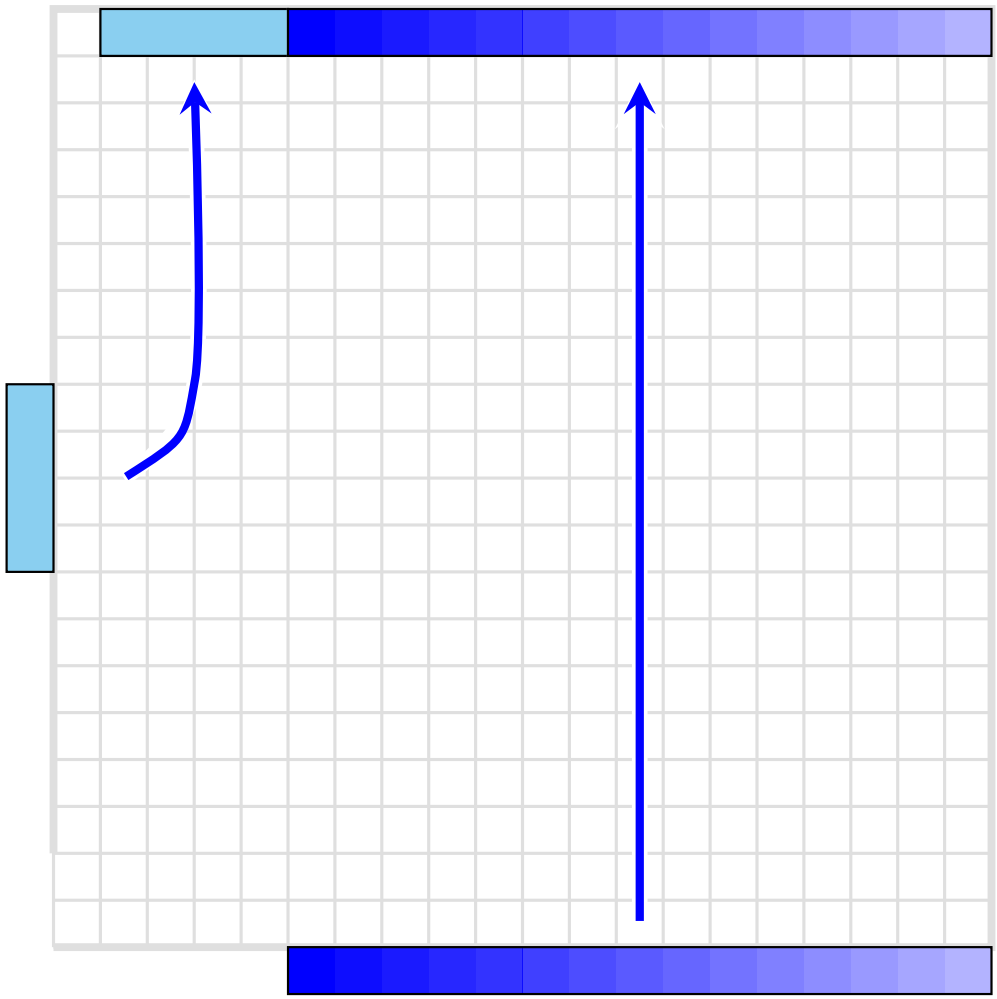
Liberal Simulation: the turedo can wonder out of the designated block.

A 2D radius 3 trick



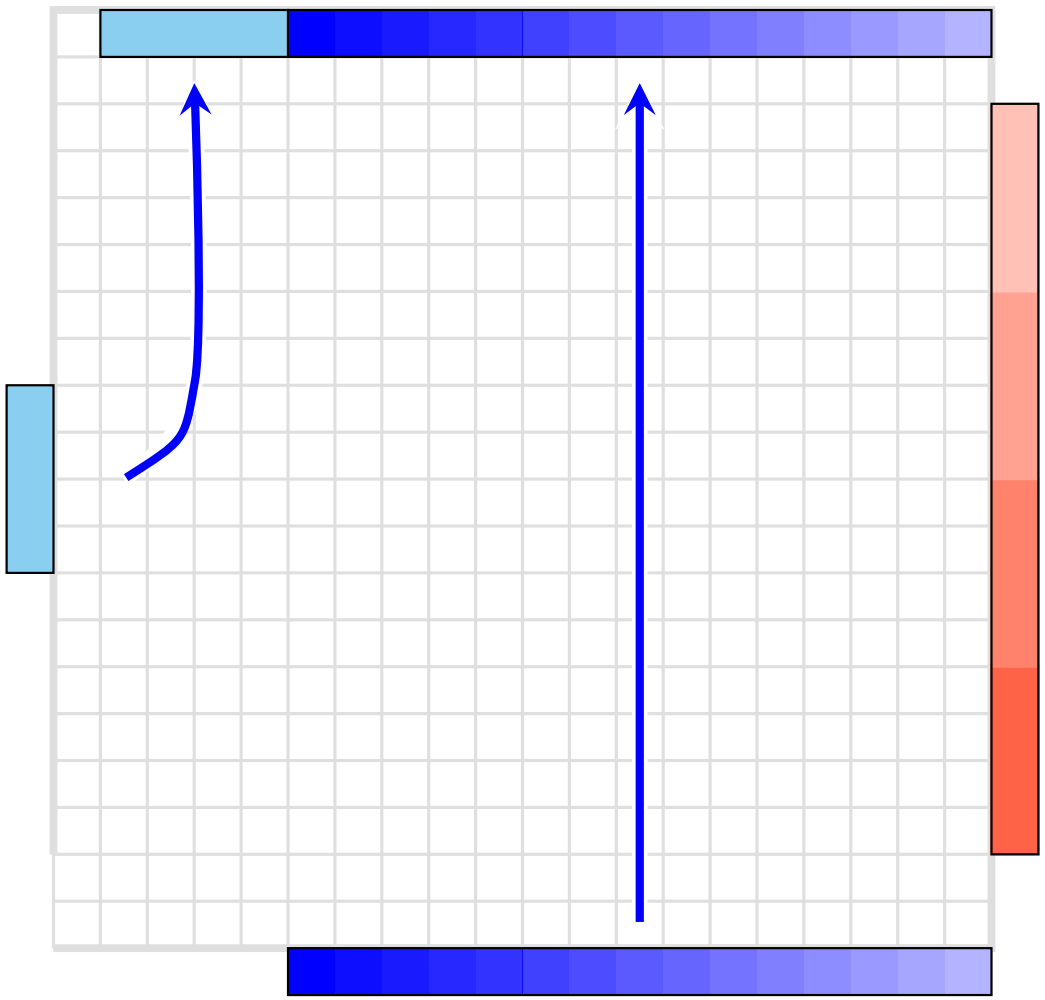
Bring first the blue information up and then the red information left.

A 2D radius 3 trick



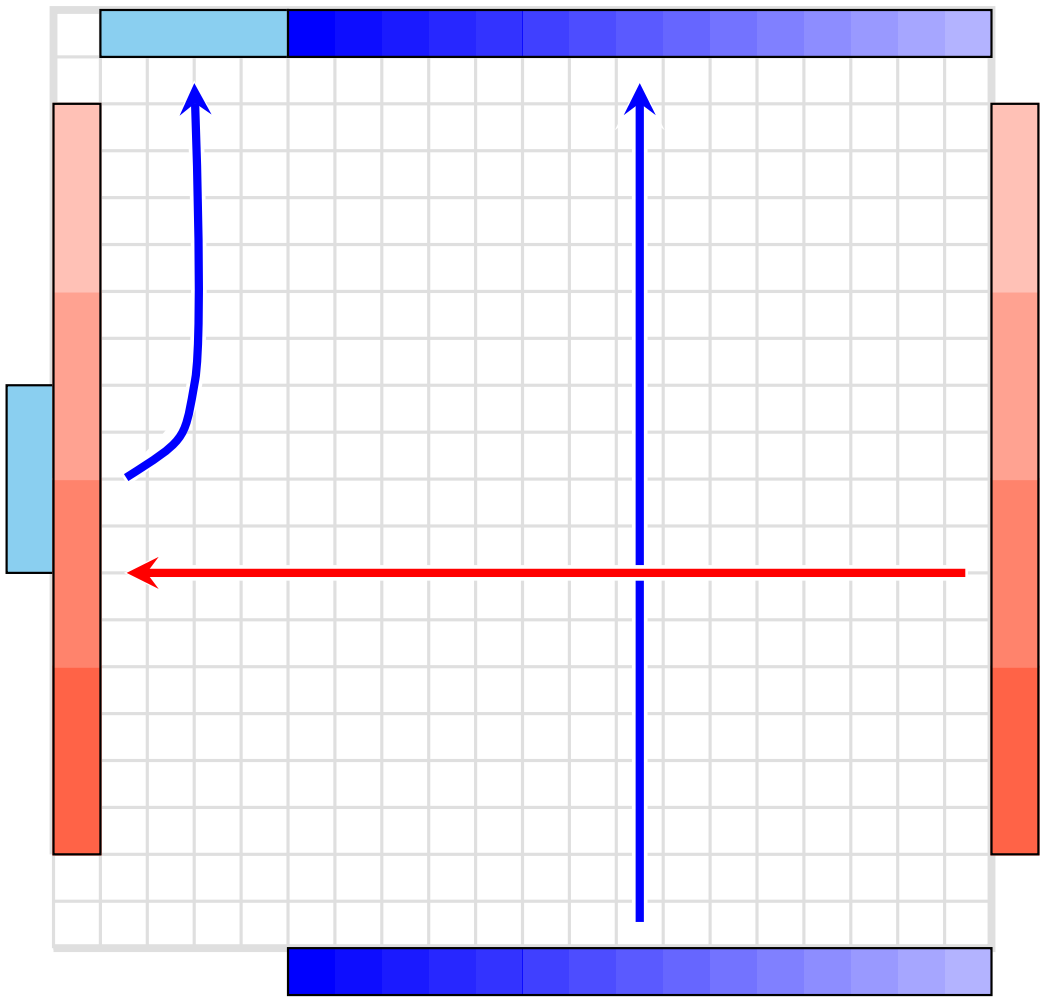
Bring first the blue information up and then the red information left.

A 2D radius 3 trick



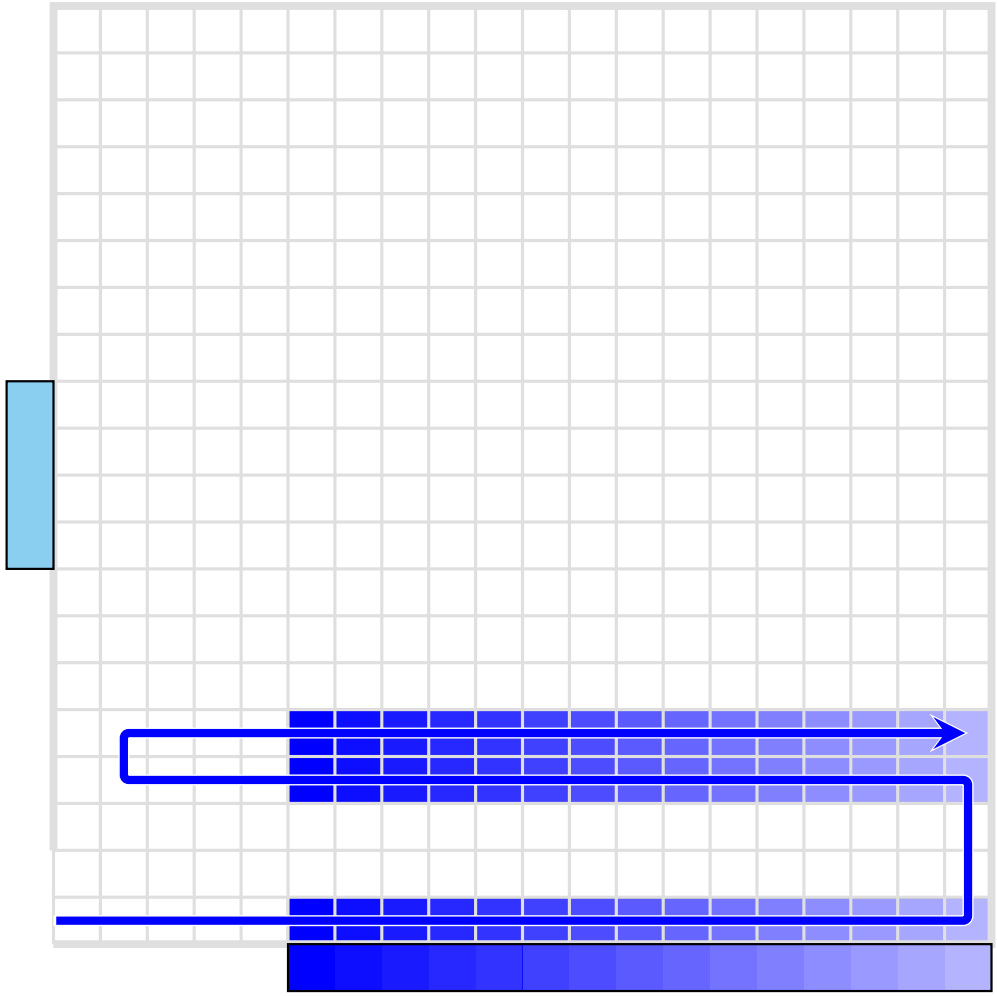
Bring first the blue information up and then the red information left.

A 2D radius 3 trick



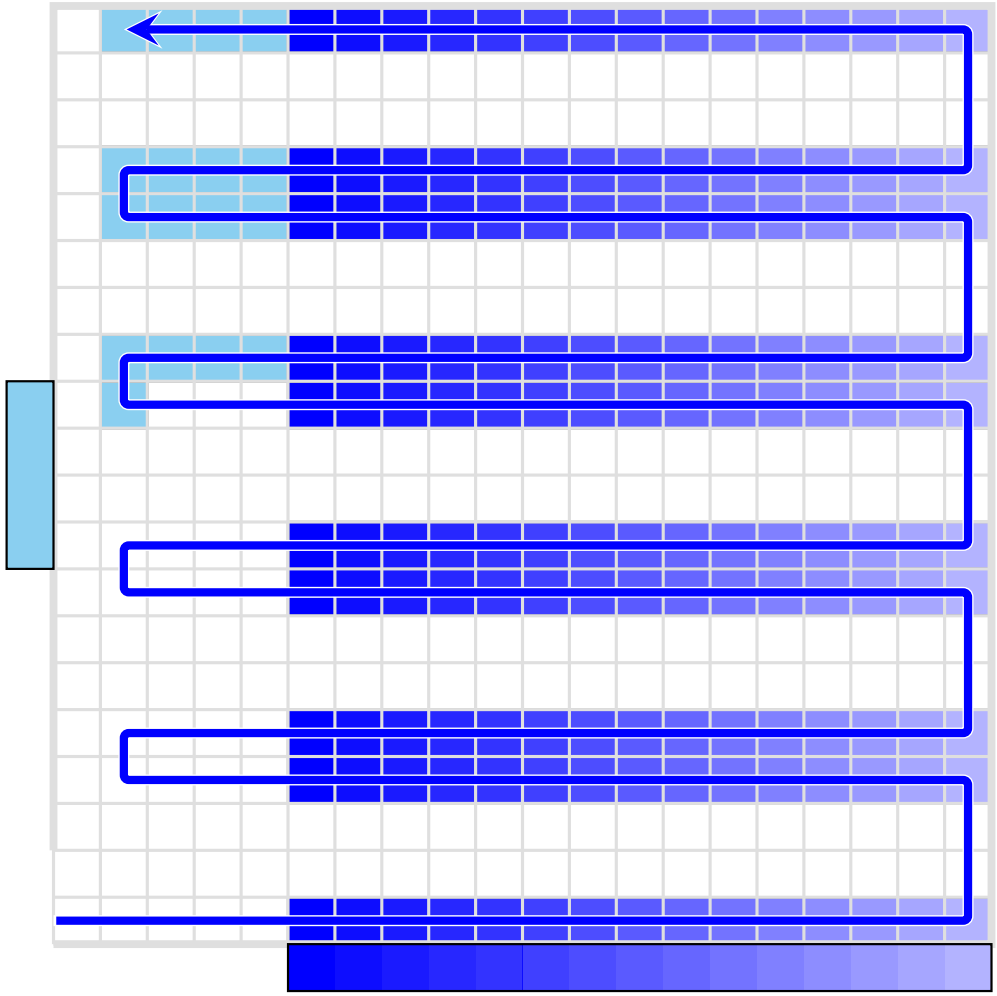
Bring first the blue information up and then the red information left.

A 2D radius 3 trick



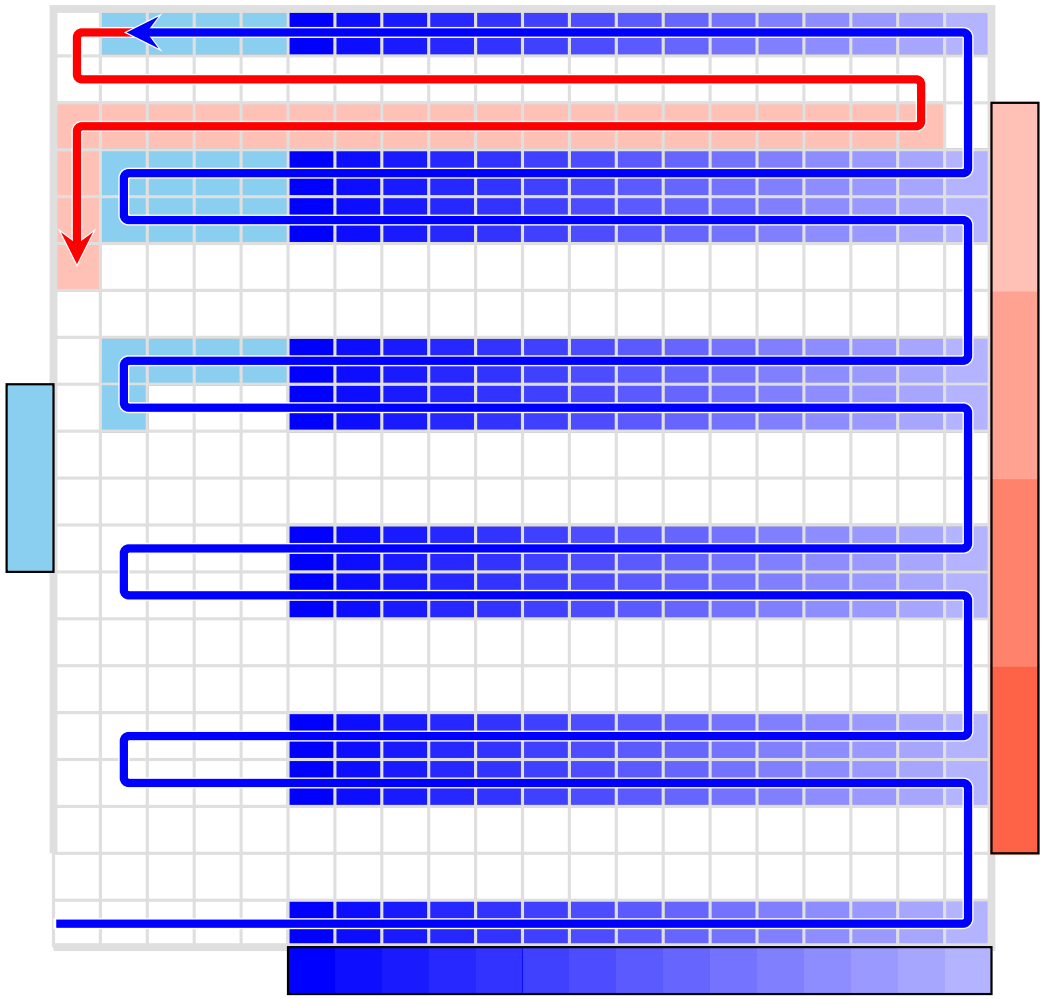
Bring first the blue information up and then the red information left.

A 2D radius 3 trick



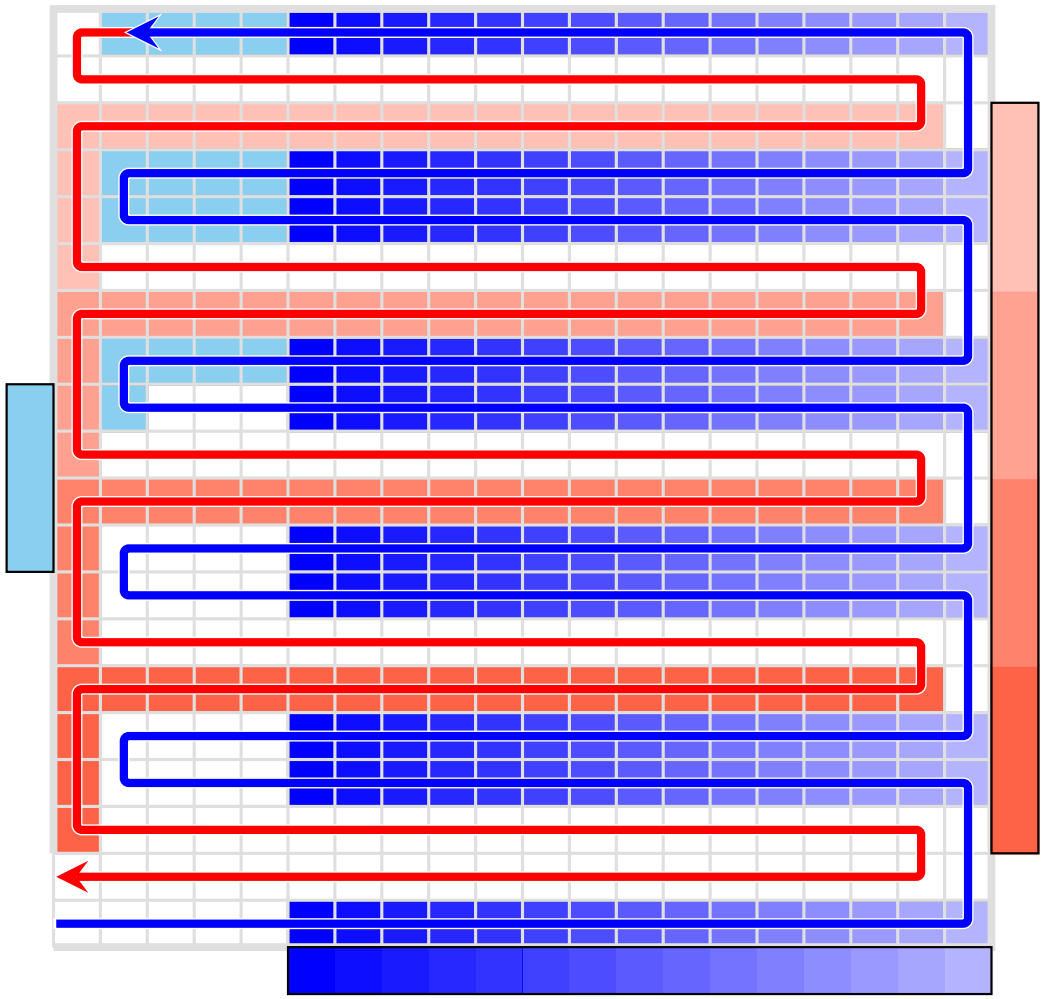
Bring first the blue information up and then the red information left.

A 2D radius 3 trick



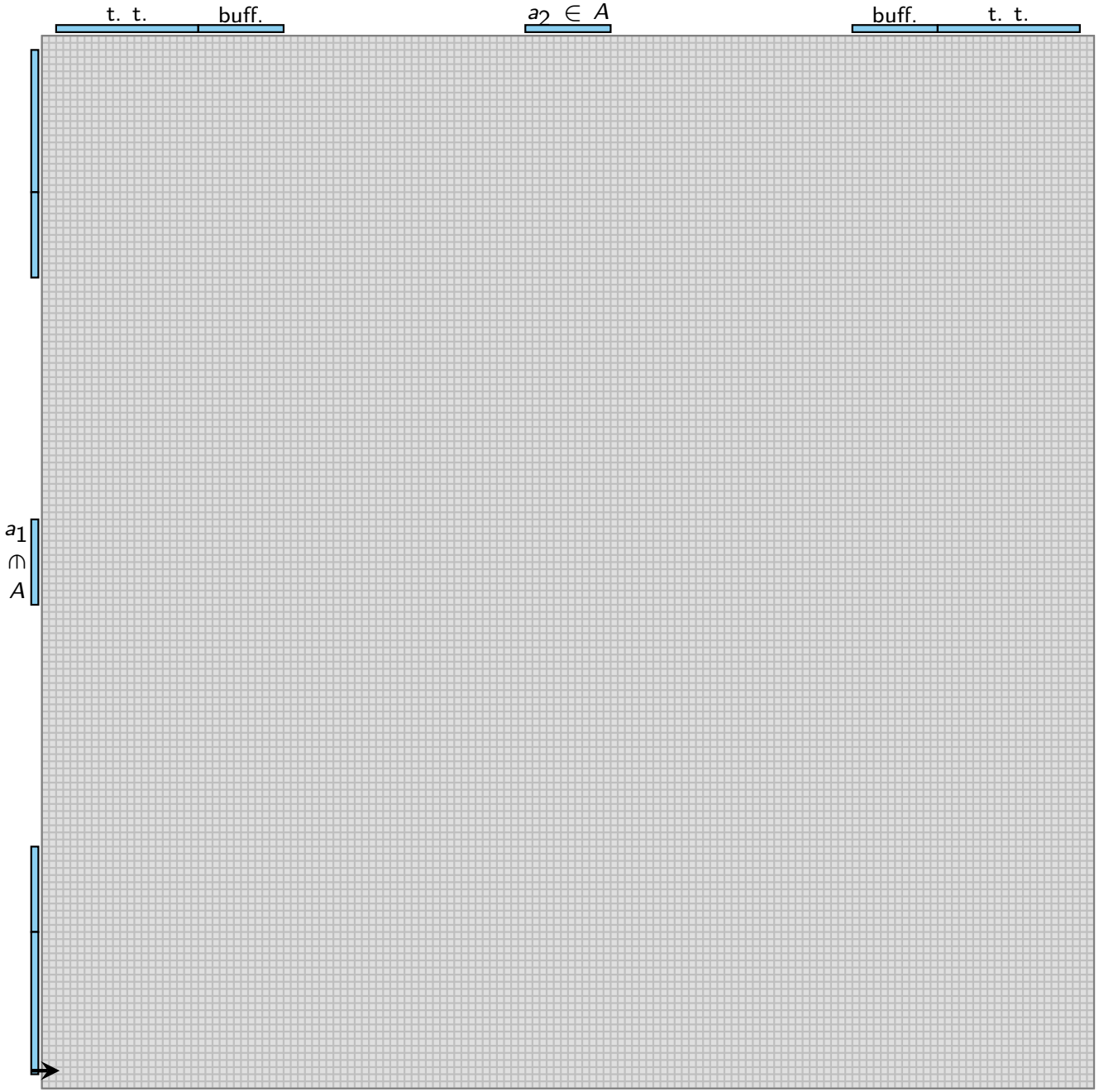
Bring first the blue information up and then the red information left.

A 2D radius 3 trick

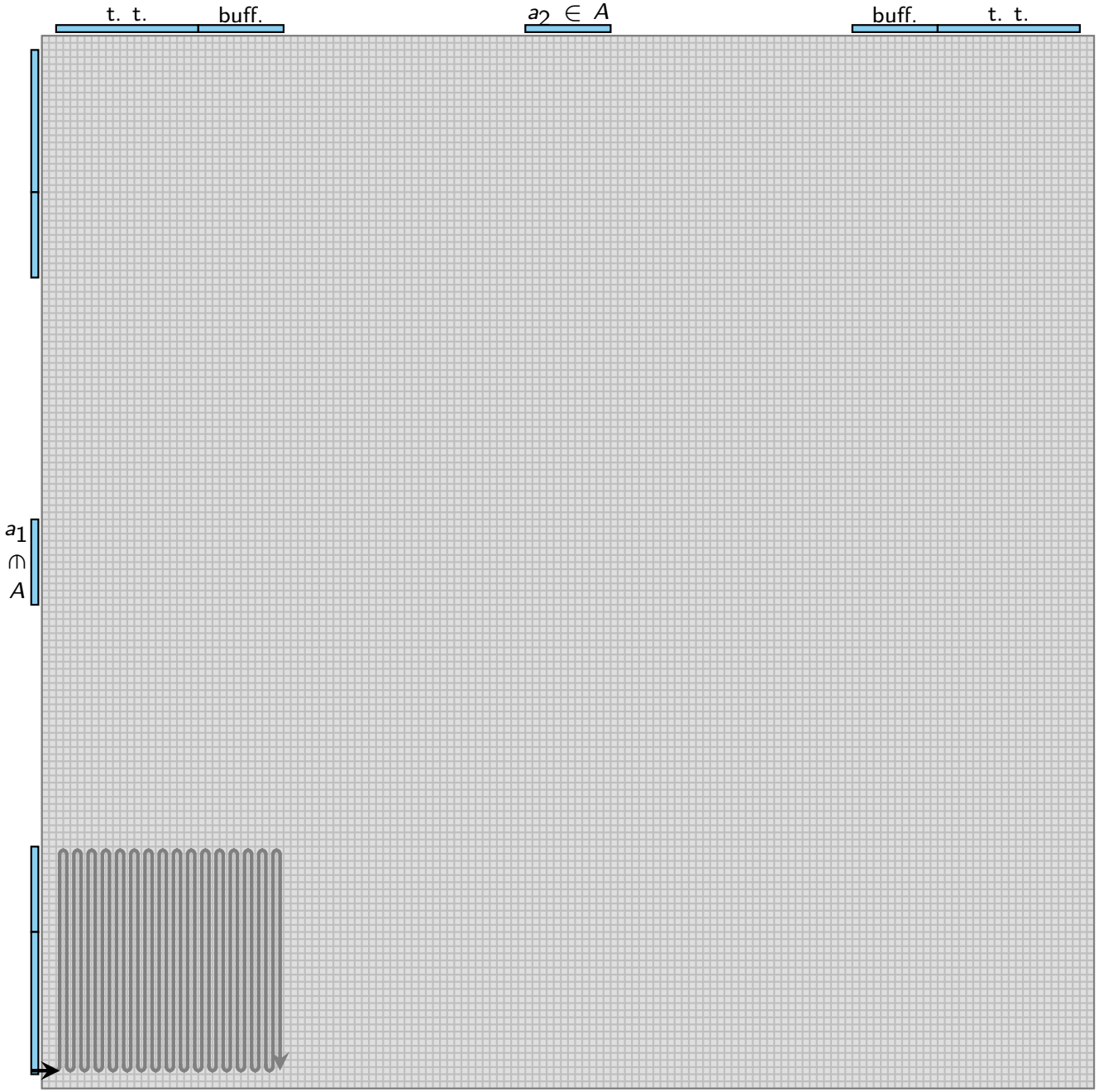


Bring first the blue information up and then the red information left.

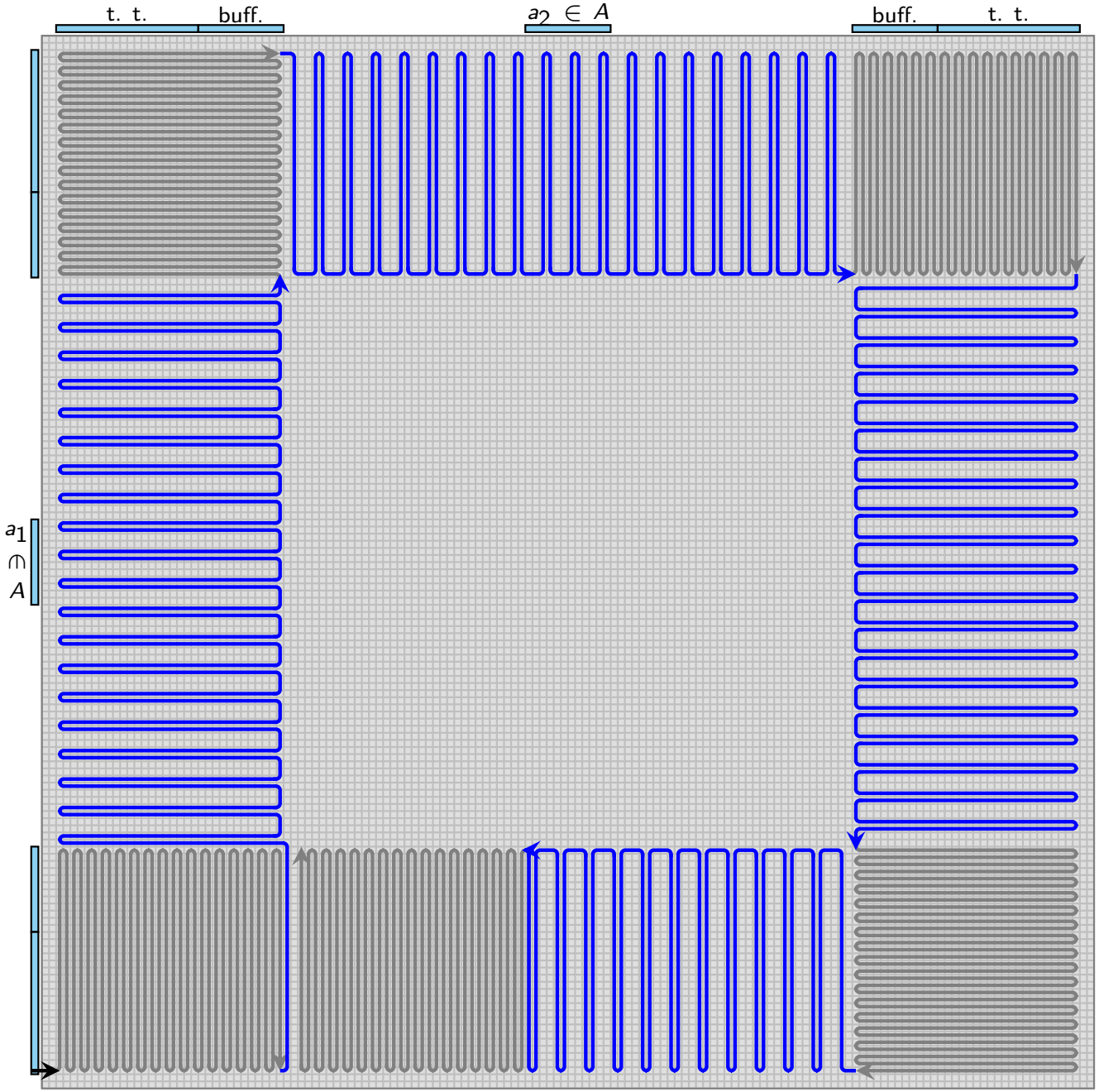
2D Universality: a radius 3 simulating any radius 1



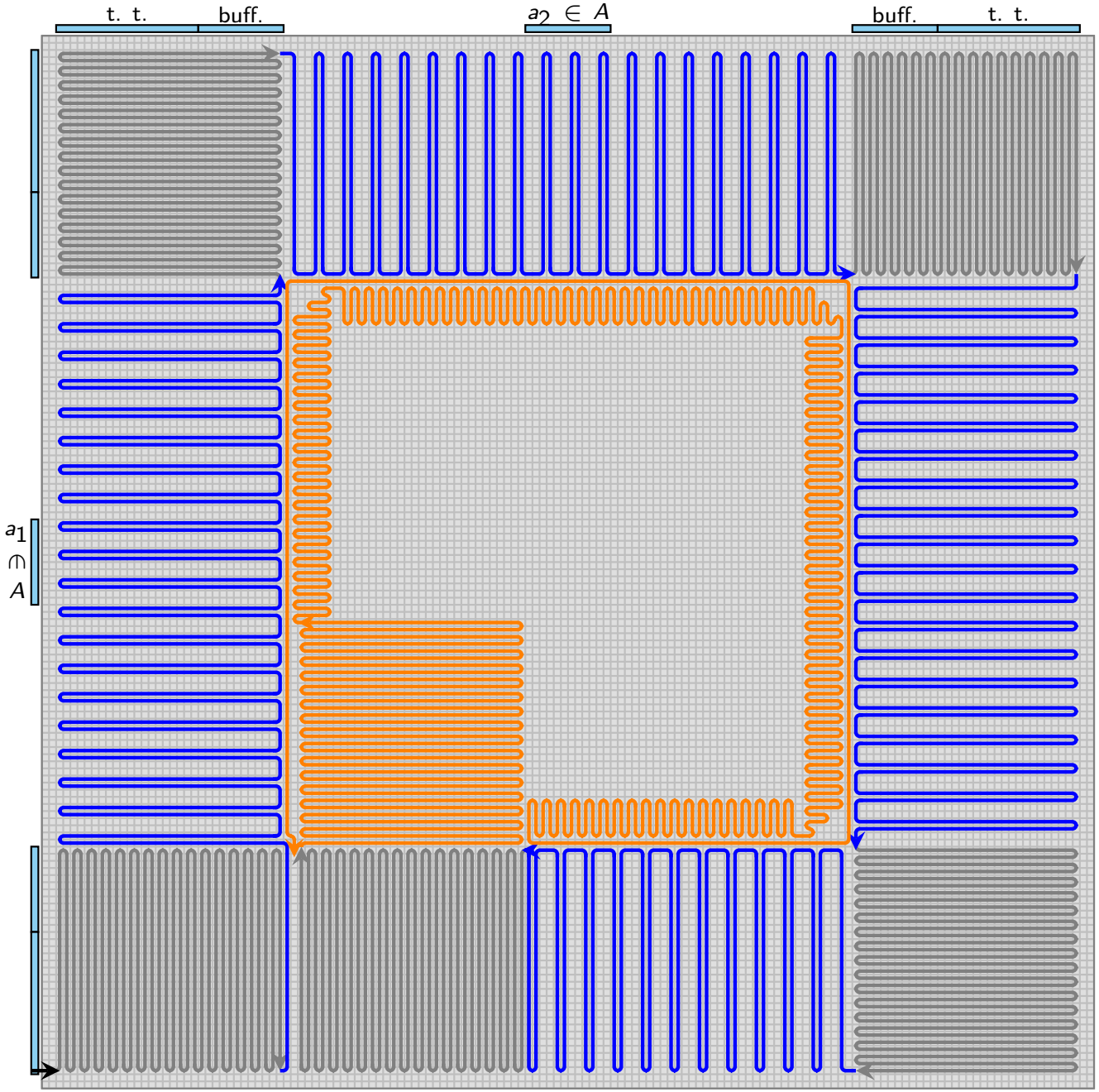
2D Universality: a radius 3 simulating any radius 1



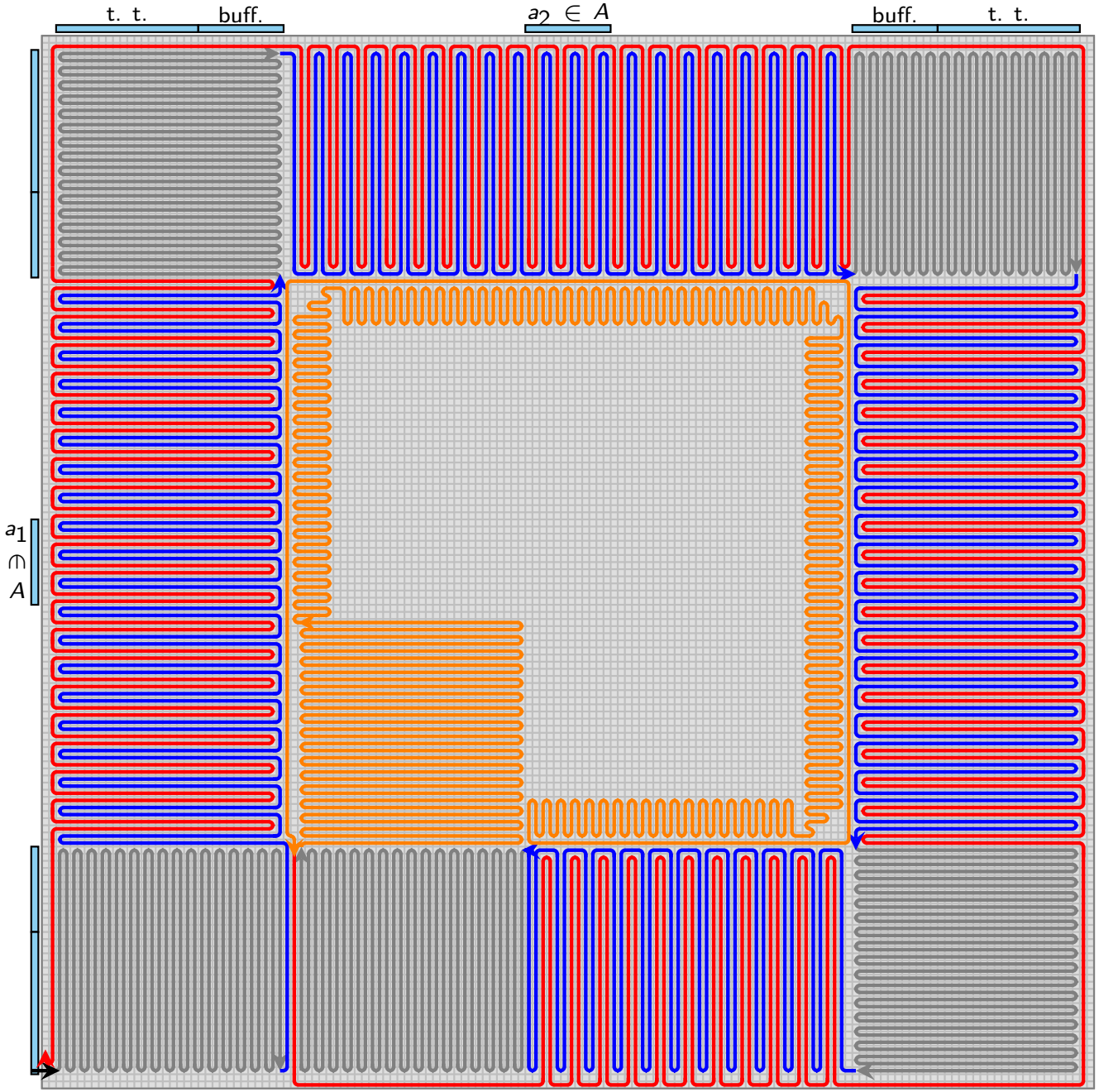
2D Universality: a radius 3 simulating any radius 1



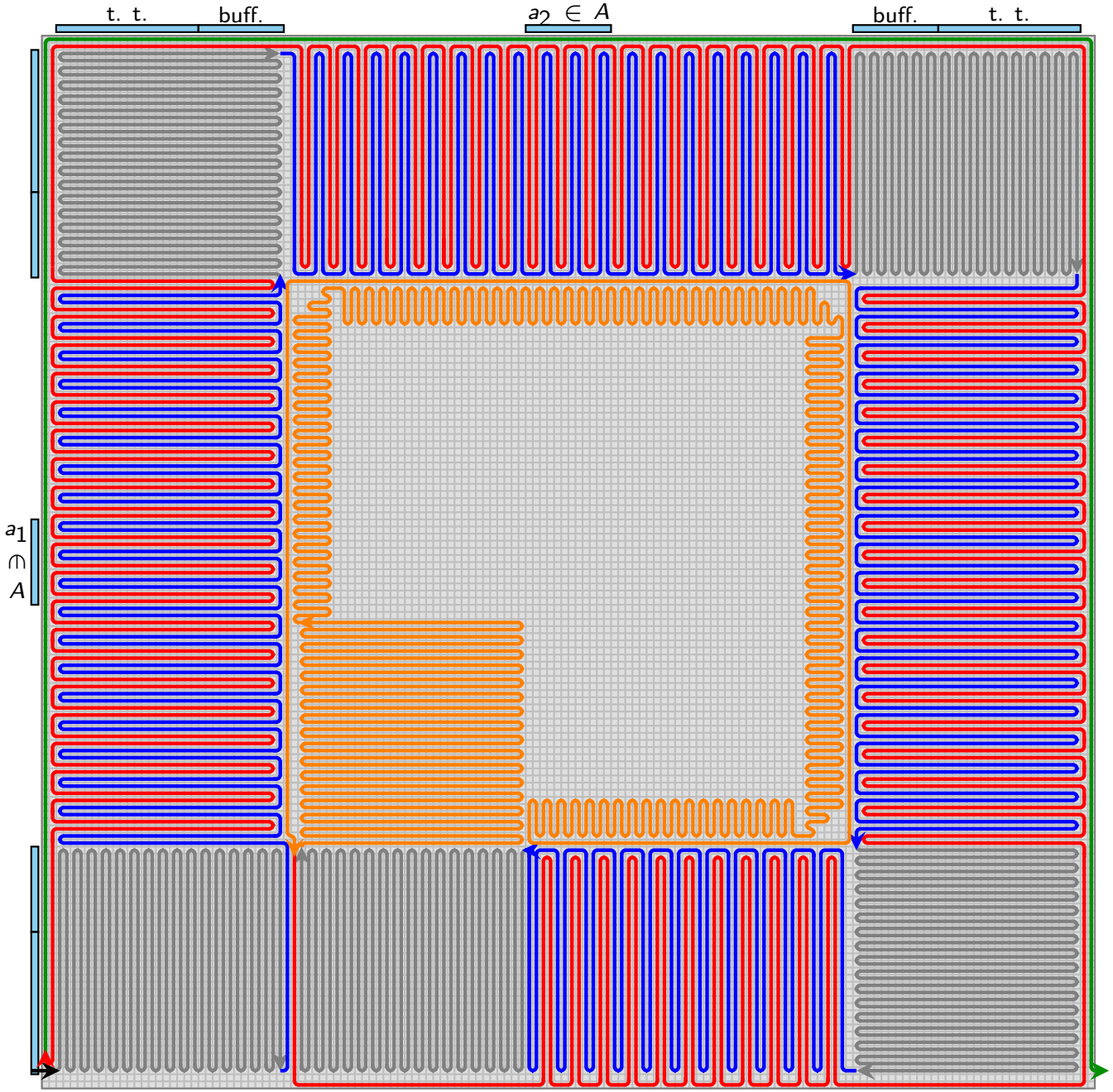
2D Universality: a radius 3 simulating any radius 1



2D Universality: a radius 3 simulating any radius 1



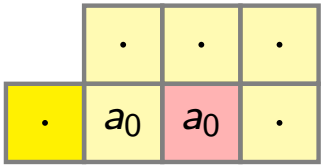
2D Universality: a radius 3 simulating any radius 1



2D rigorous simulation: a strict hierarchy

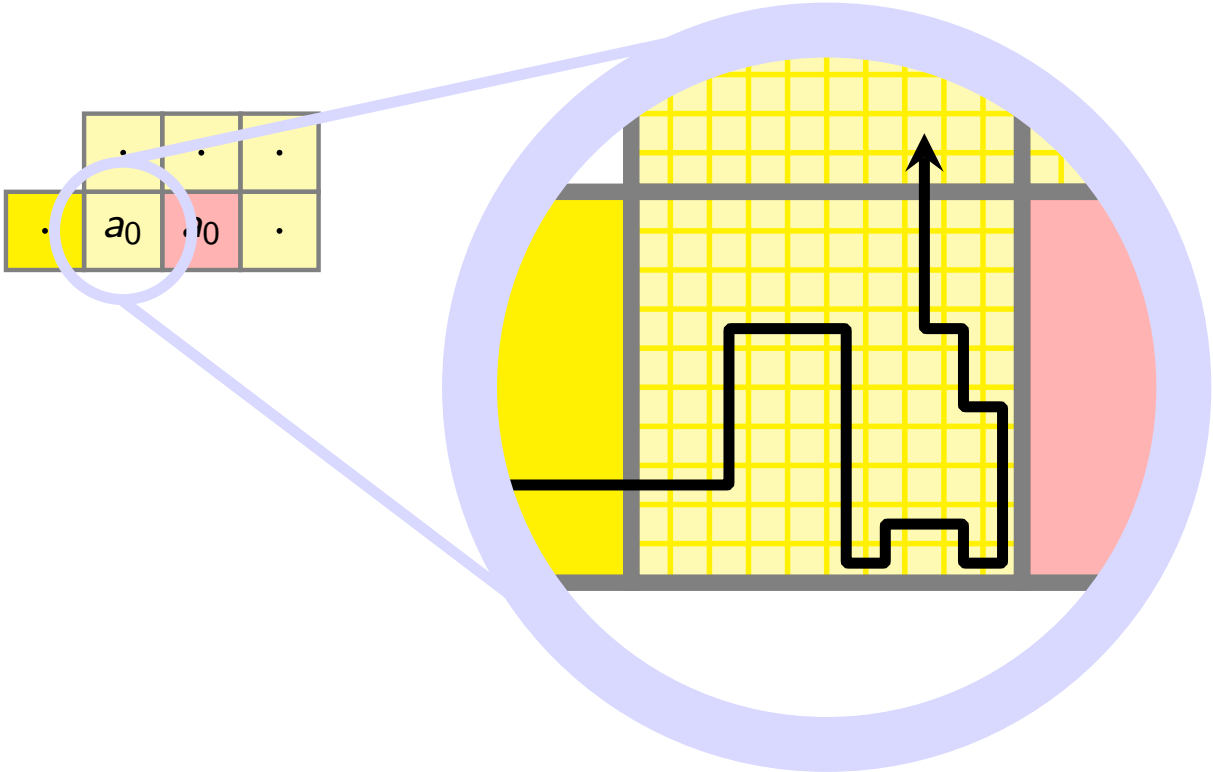
Given a radius 1 turedo, there exists a radius 1 turedo that it cannot simulate.

2D rigorous simulation: a strict hierarchy



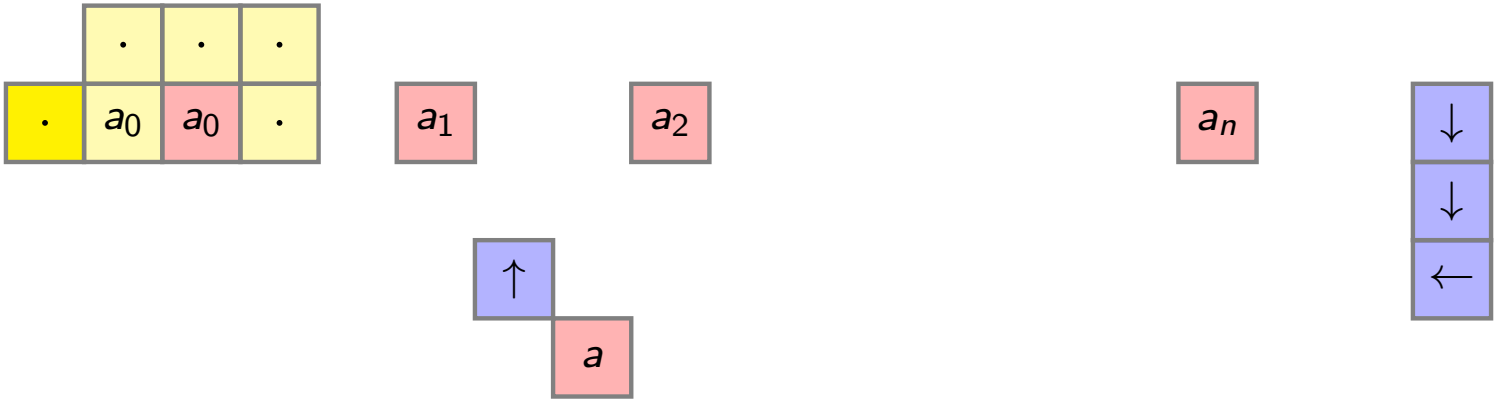
Given a radius 1 turedo, there exists a radius 1 turedo that it cannot simulate.

2D rigorous simulation: a strict hierarchy



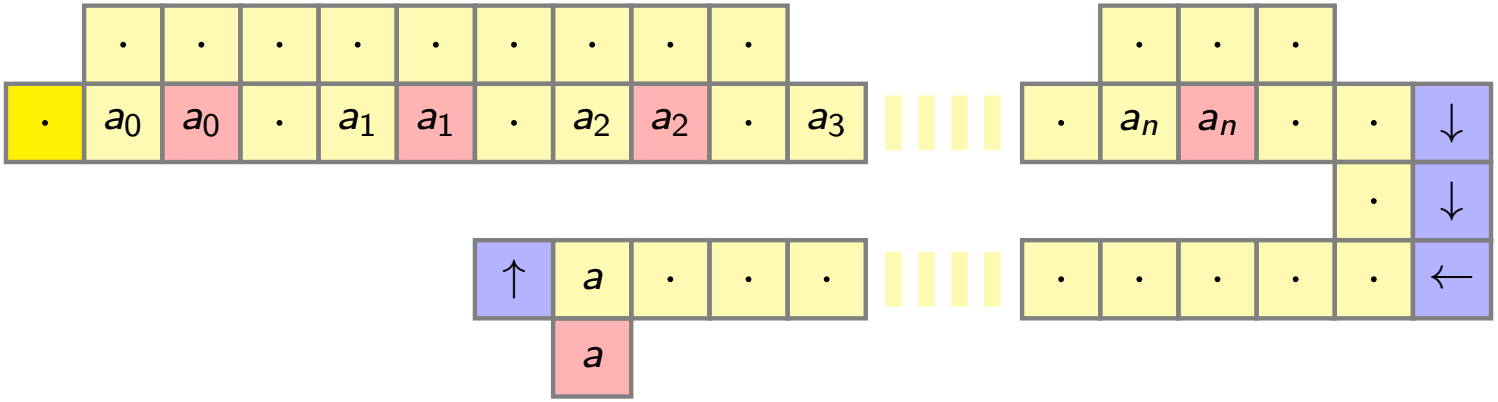
Given a radius 1 turedo, there exists a radius 1 turedo that it cannot simulate.

2D rigorous simulation: a strict hierarchy



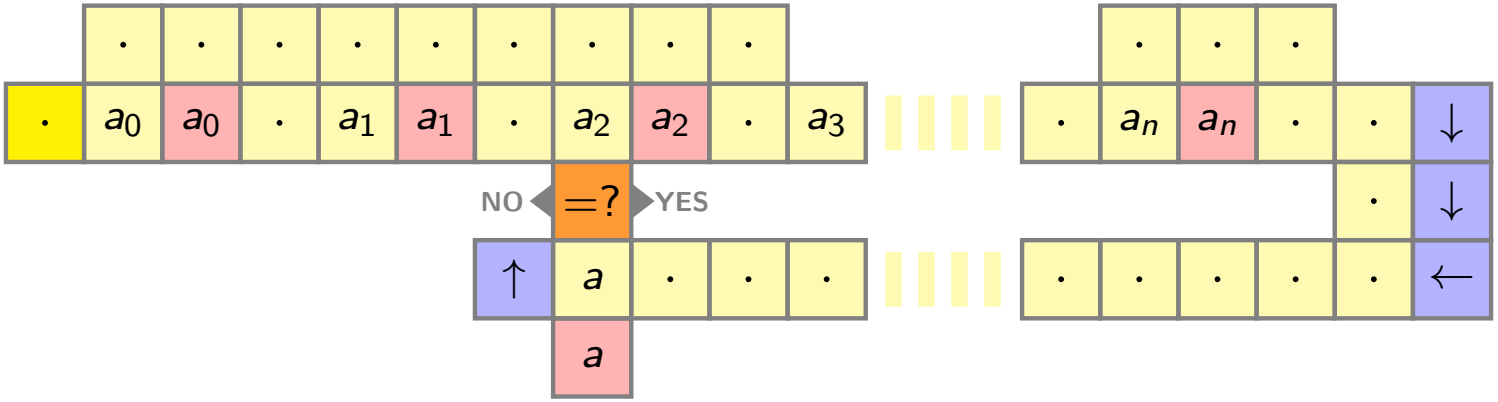
Given a radius 1 turedo, there exists a radius 1 turedo that it cannot simulate.

2D rigorous simulation: a strict hierarchy



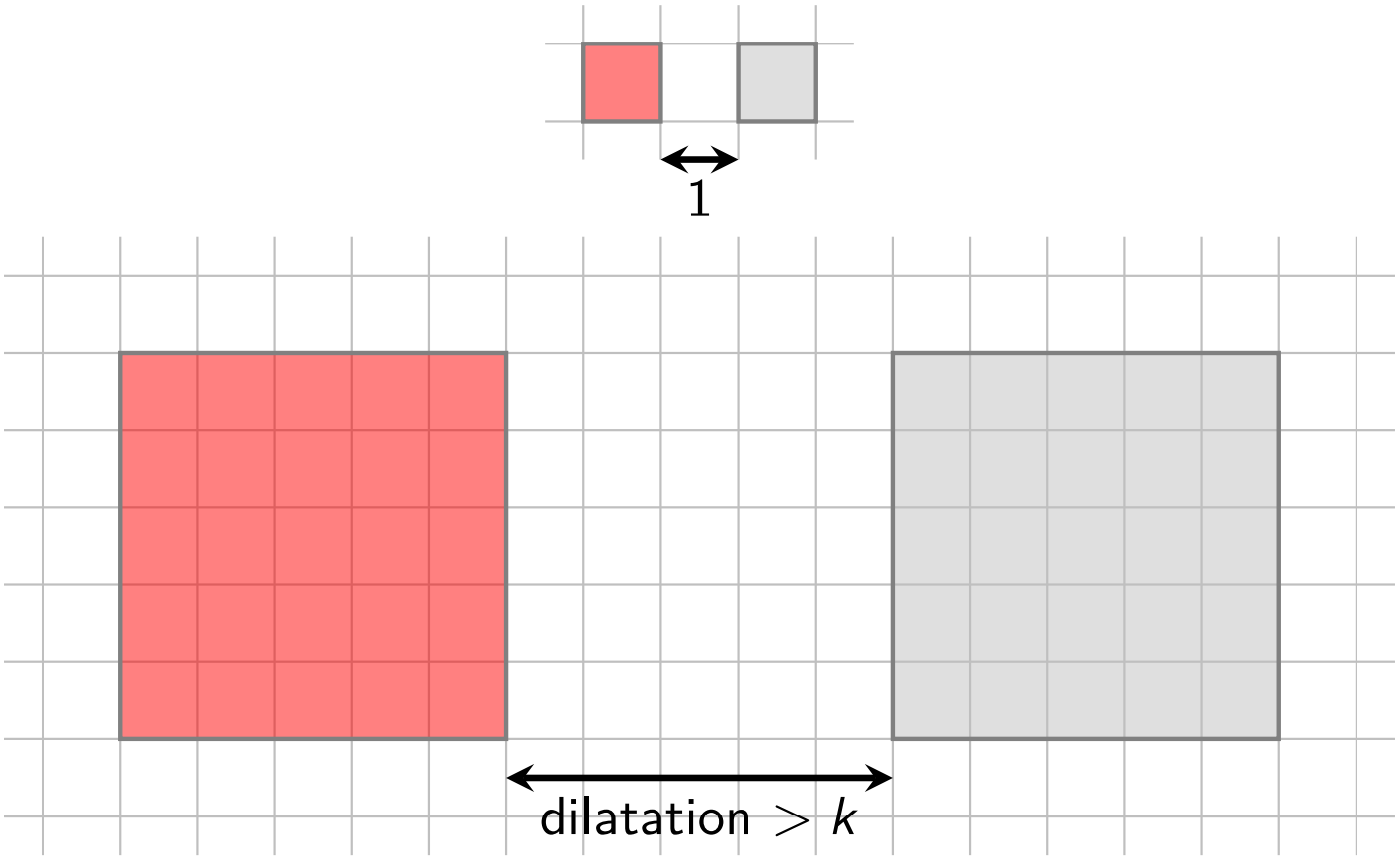
Given a radius 1 turedo, there exists a radius 1 turedo that it cannot simulate.

2D rigorous simulation: a strict hierarchy



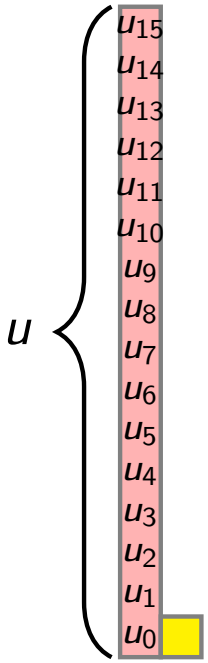
Given a radius 1 turedo, there exists a radius 1 turedo that it cannot simulate.

2D rigorous simulation: a strict hierarchy



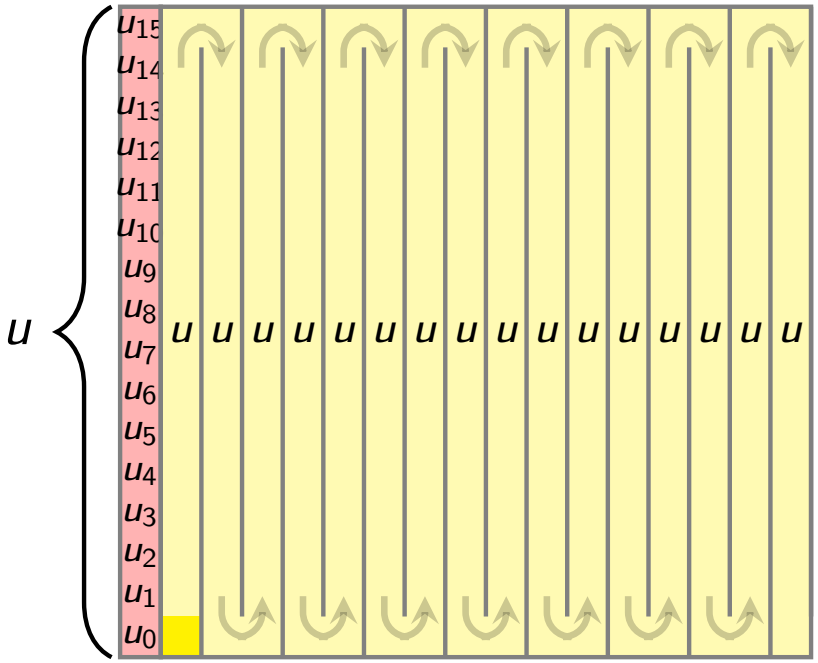
Given a radius k turedo, there is a radius 2 turedo that it cannot simulate.

2D liberal limitations



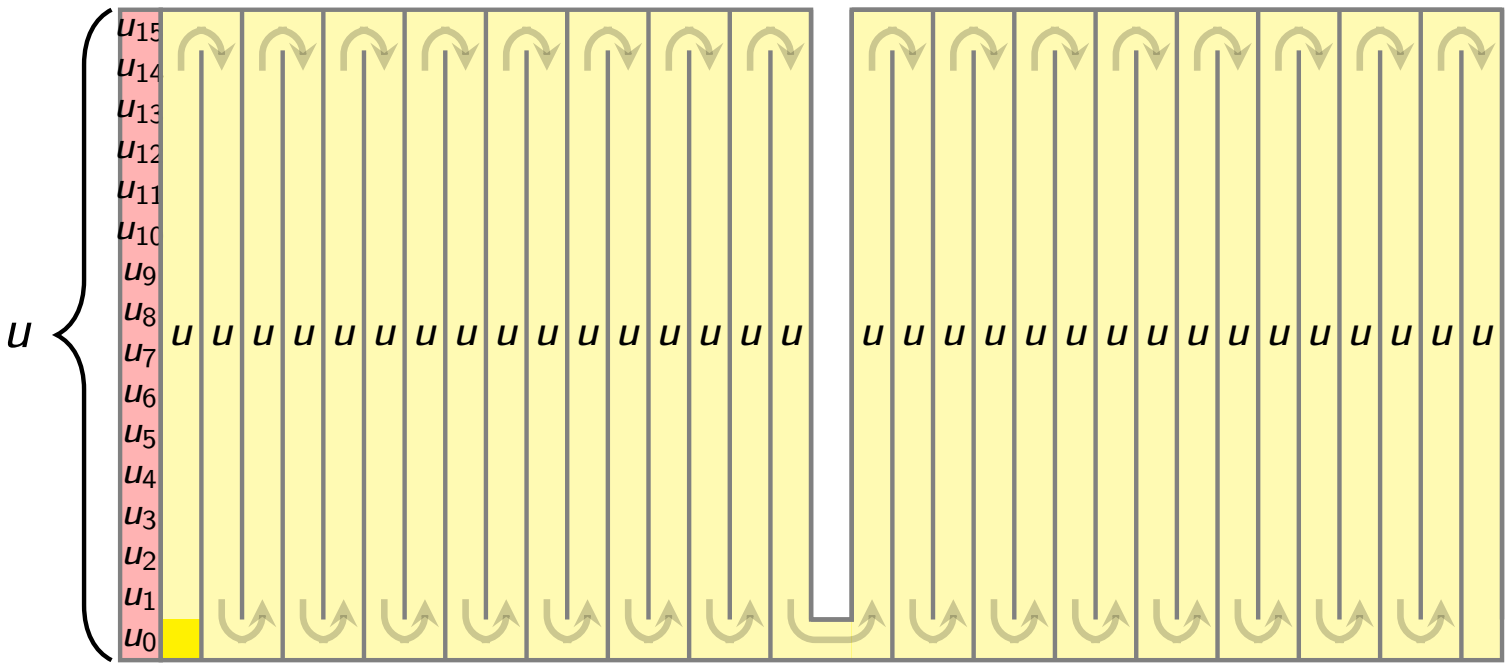
There is a radius 2 turedo that no radius 1 turedo can simulate, even liberally.

2D liberal limitations



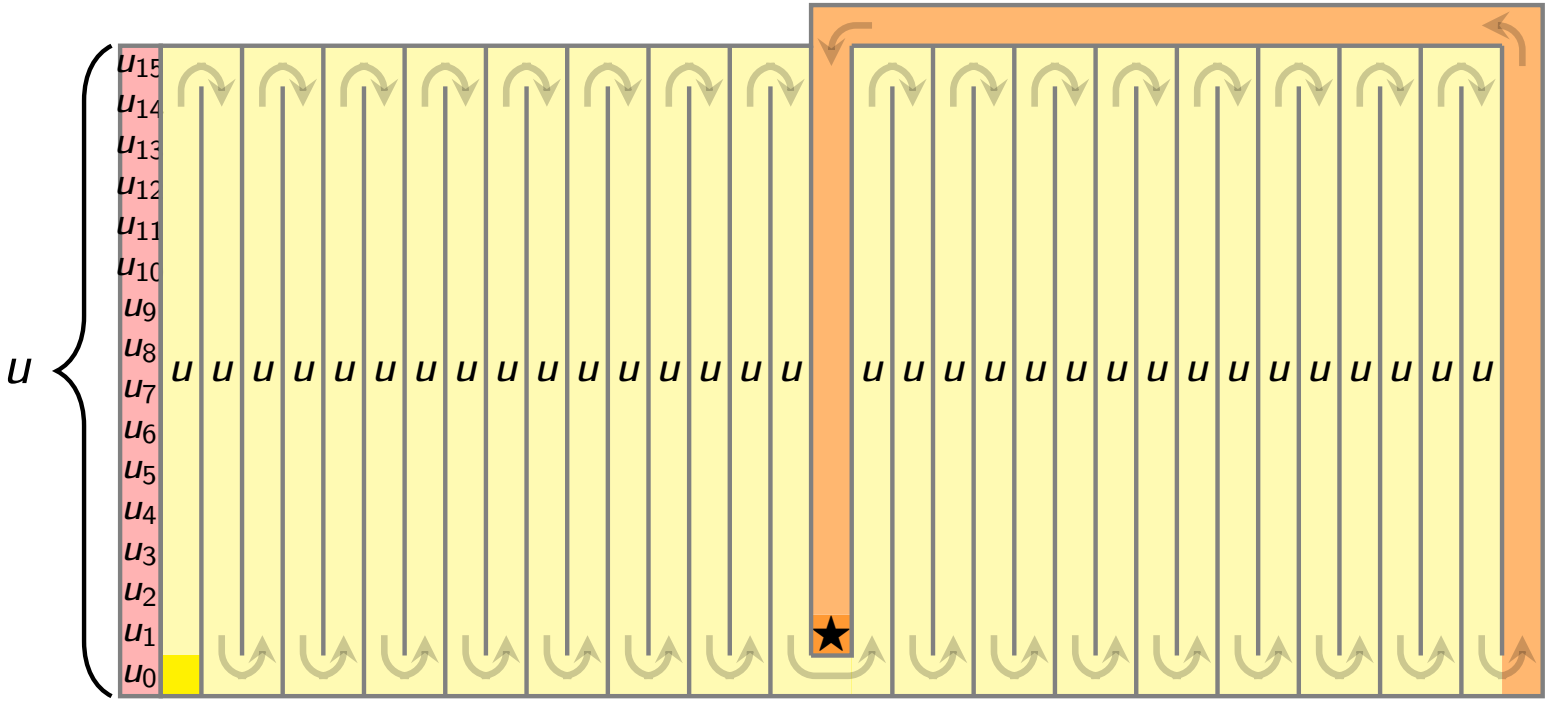
There is a radius 2 turedo that no radius 1 turedo can simulate, even liberally.

2D liberal limitations



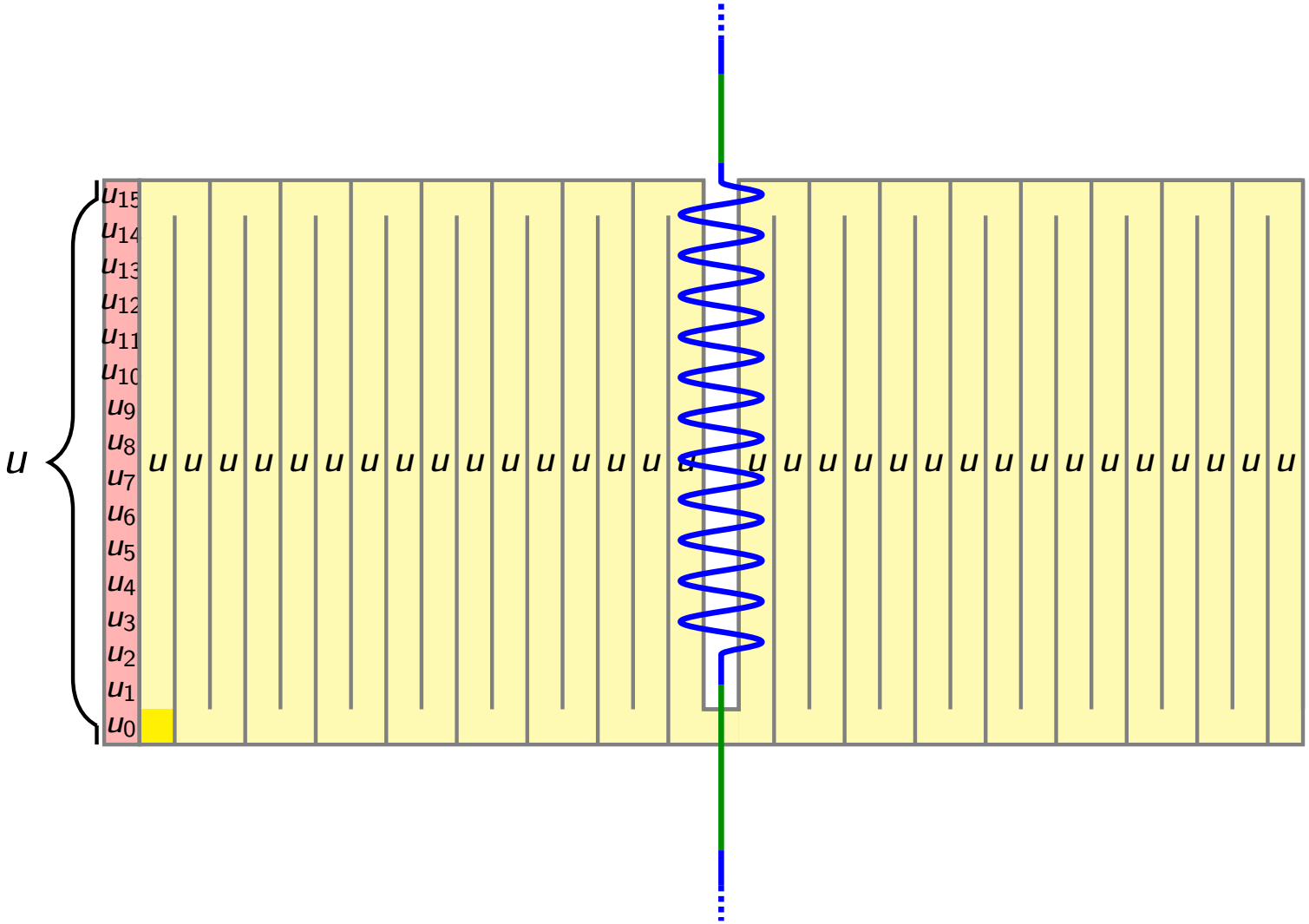
There is a radius 2 turedo that no radius 1 turedo can simulate, even liberally.

2D liberal limitations



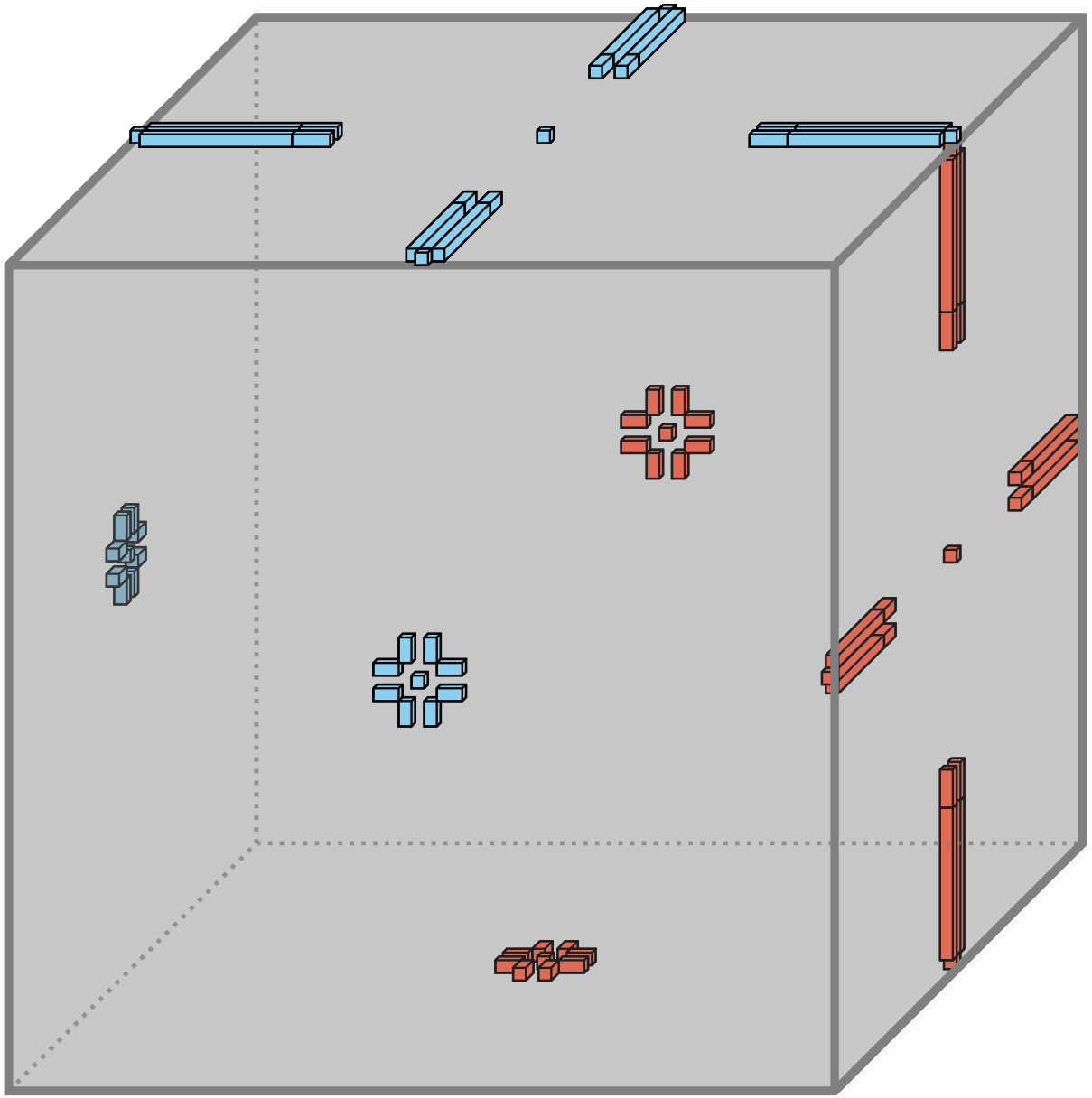
There is a radius 2 turedo that no radius 1 turedo can simulate, even liberally.

2D liberal limitations

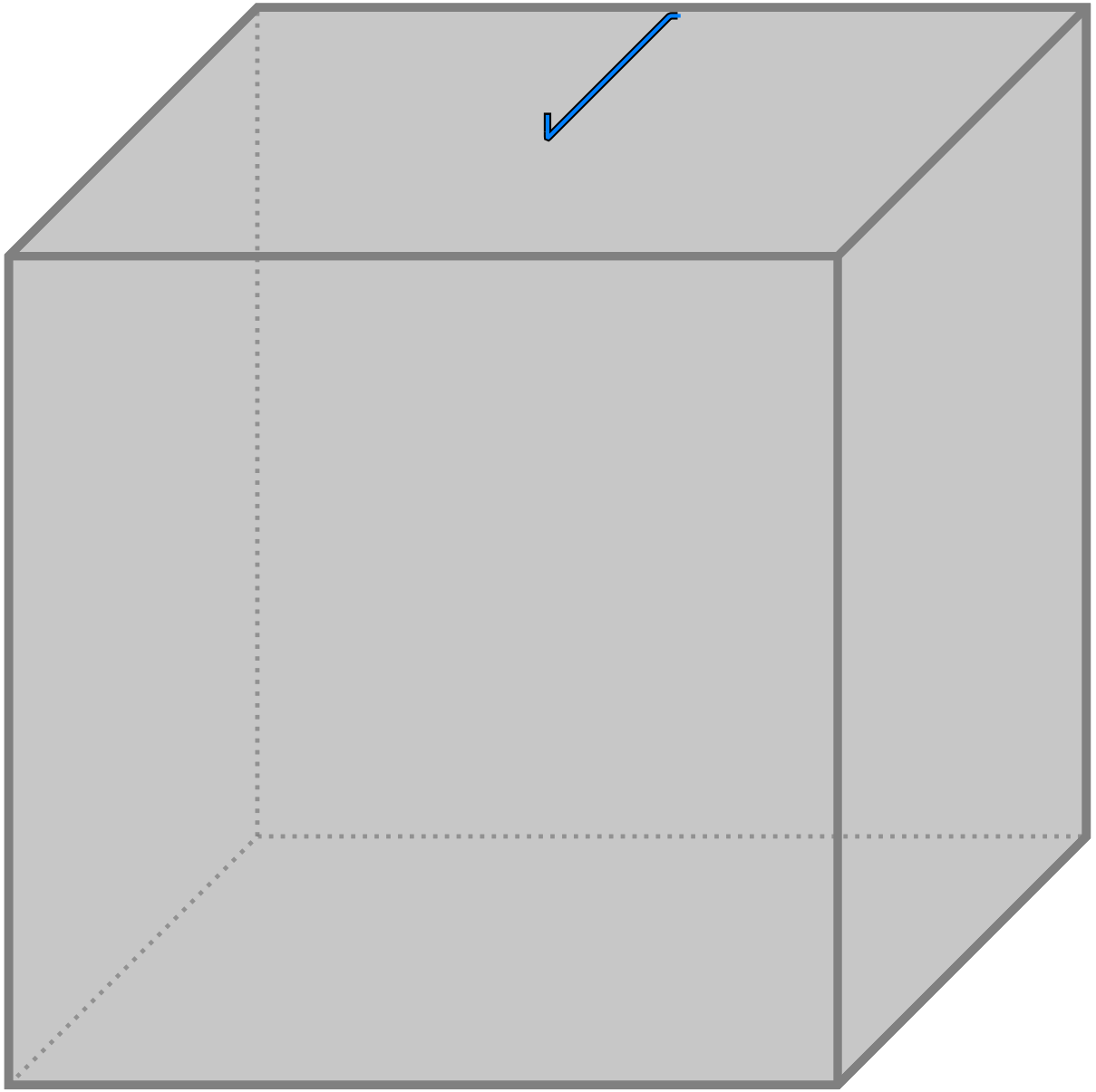


There is a radius 2 turedo that no radius 1 turedo can simulate, even liberally.

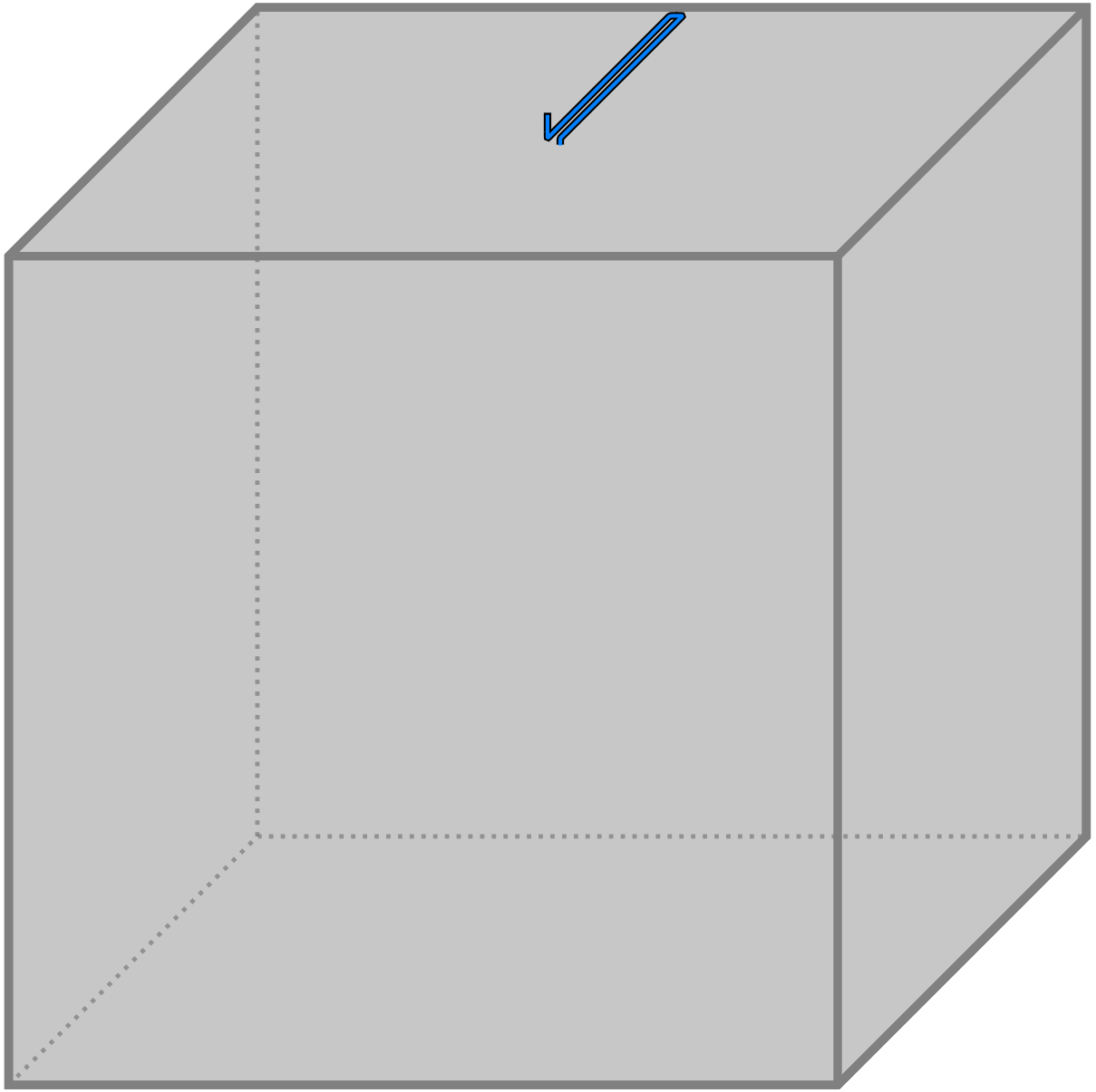
The 3D advantages: a radius 1 simulating any radius 1



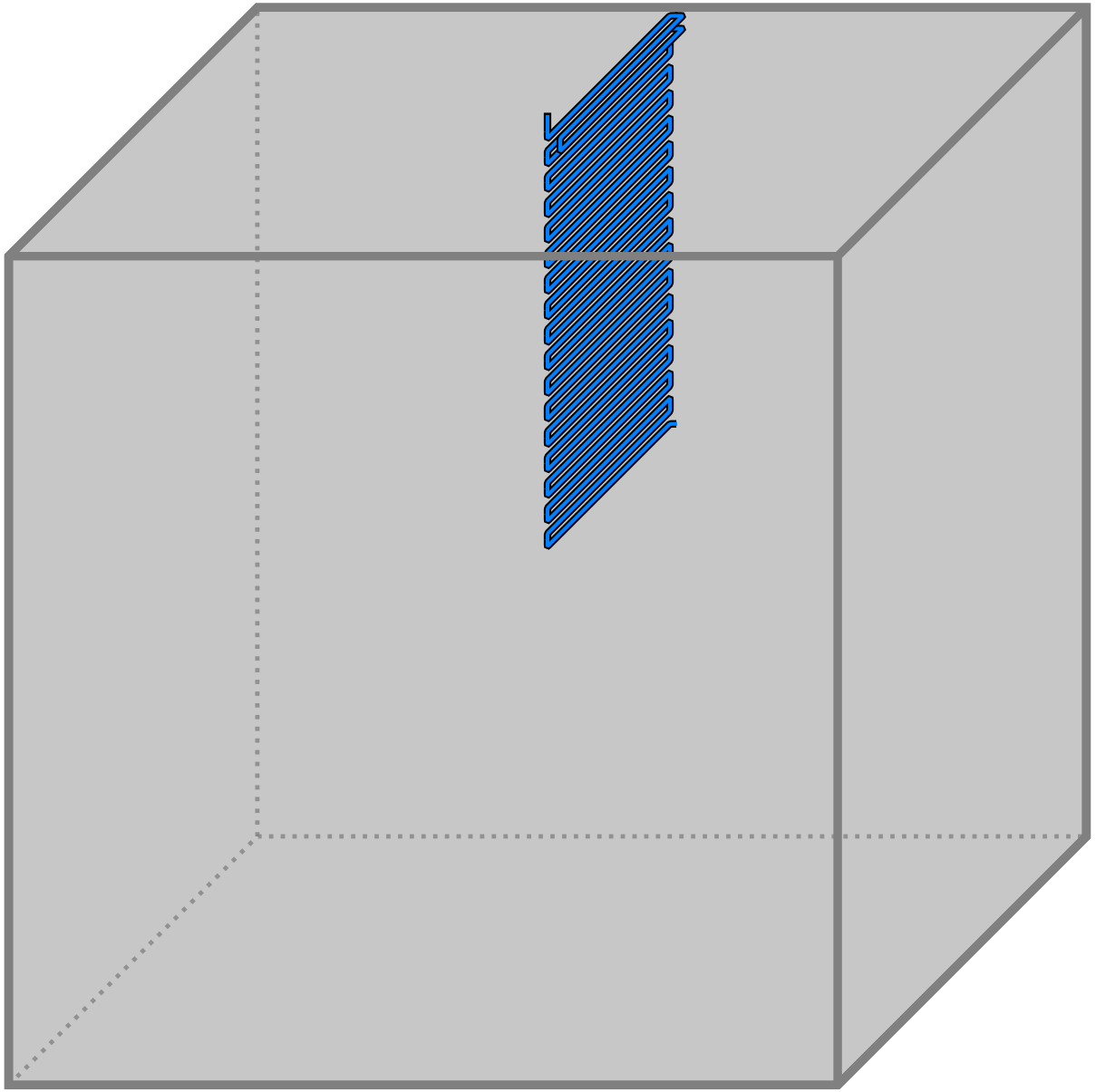
The 3D advantages: a radius 1 simulating any radius 1



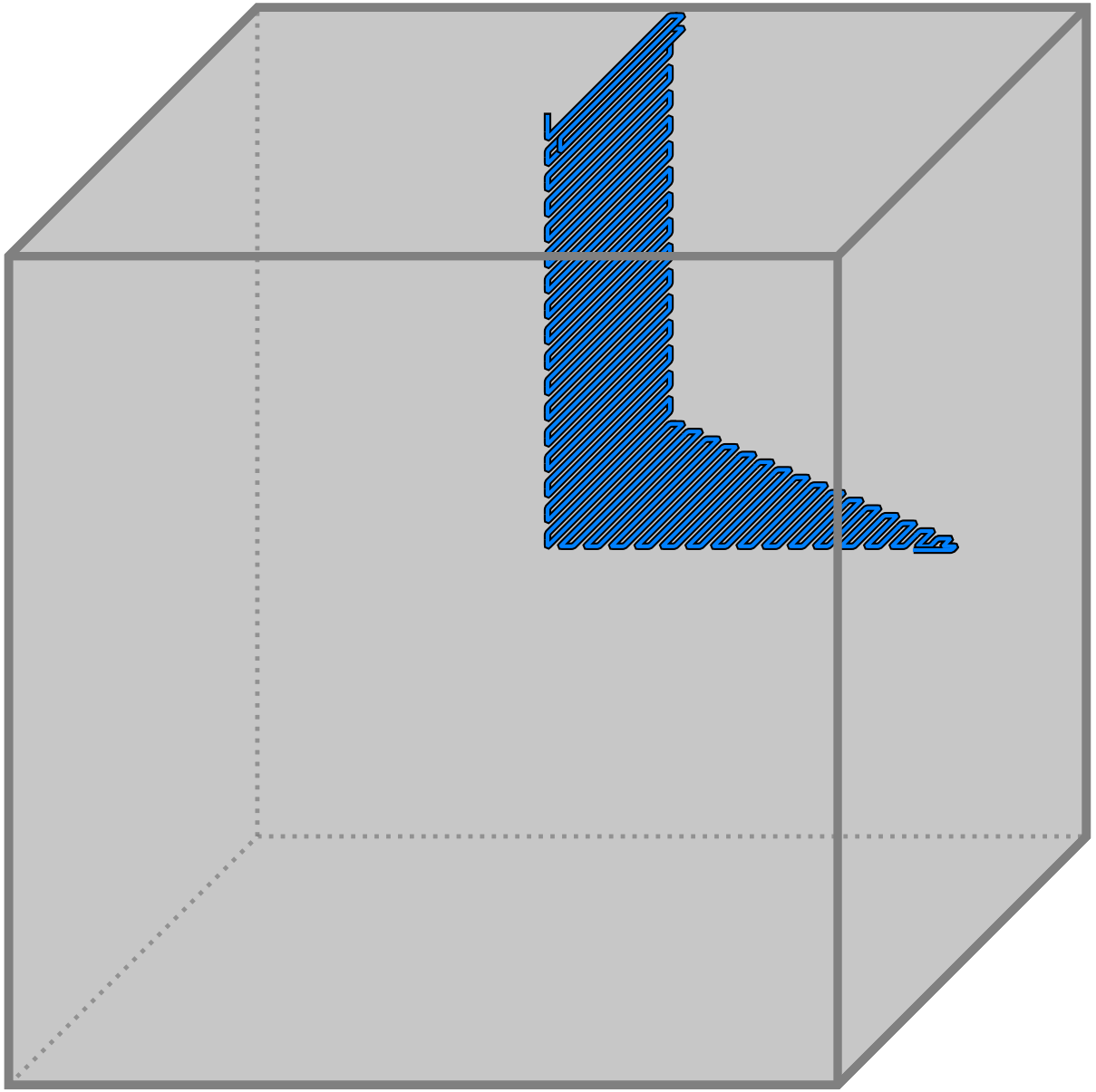
The 3D advantages: a radius 1 simulating any radius 1



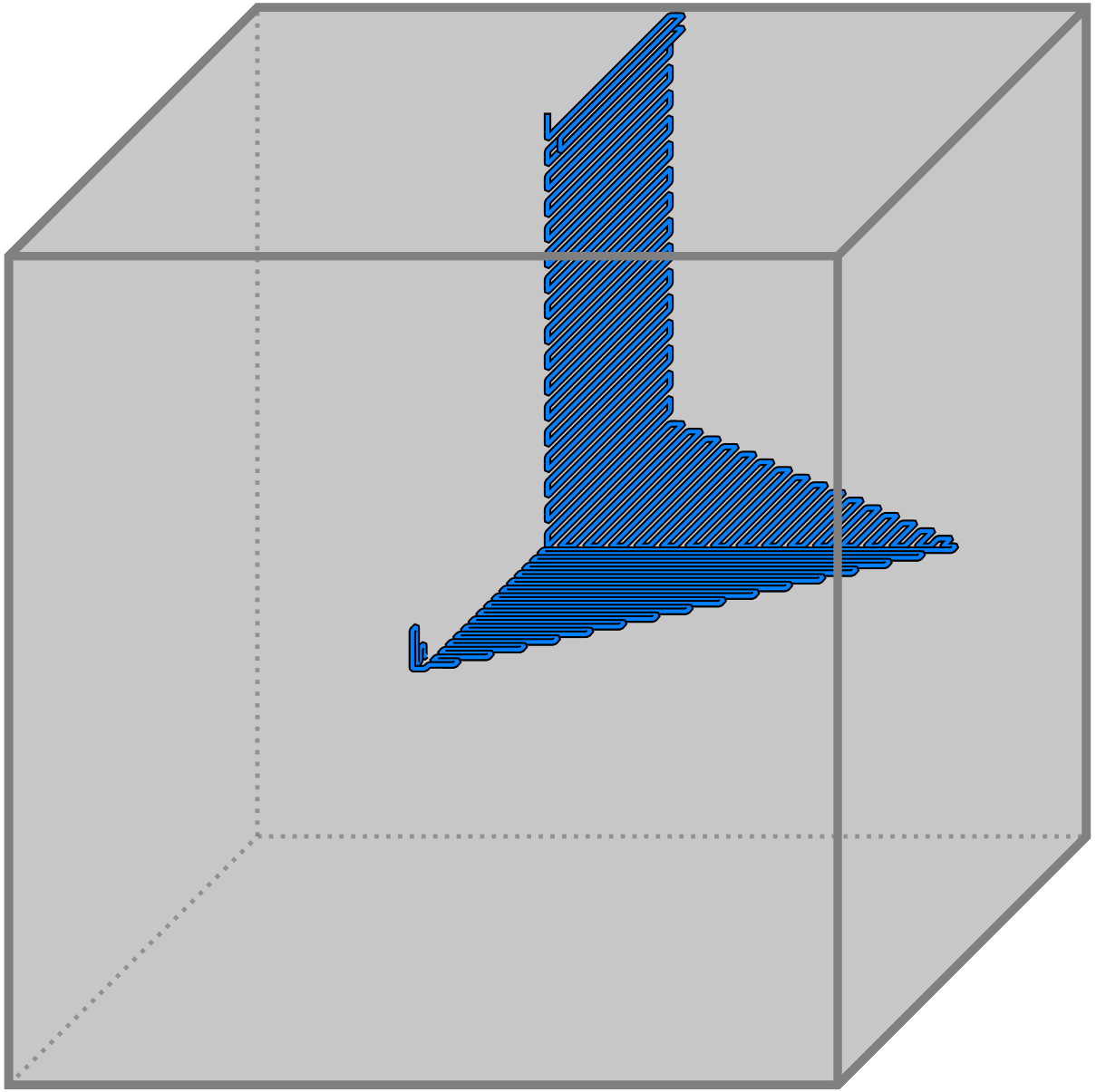
The 3D advantages: a radius 1 simulating any radius 1



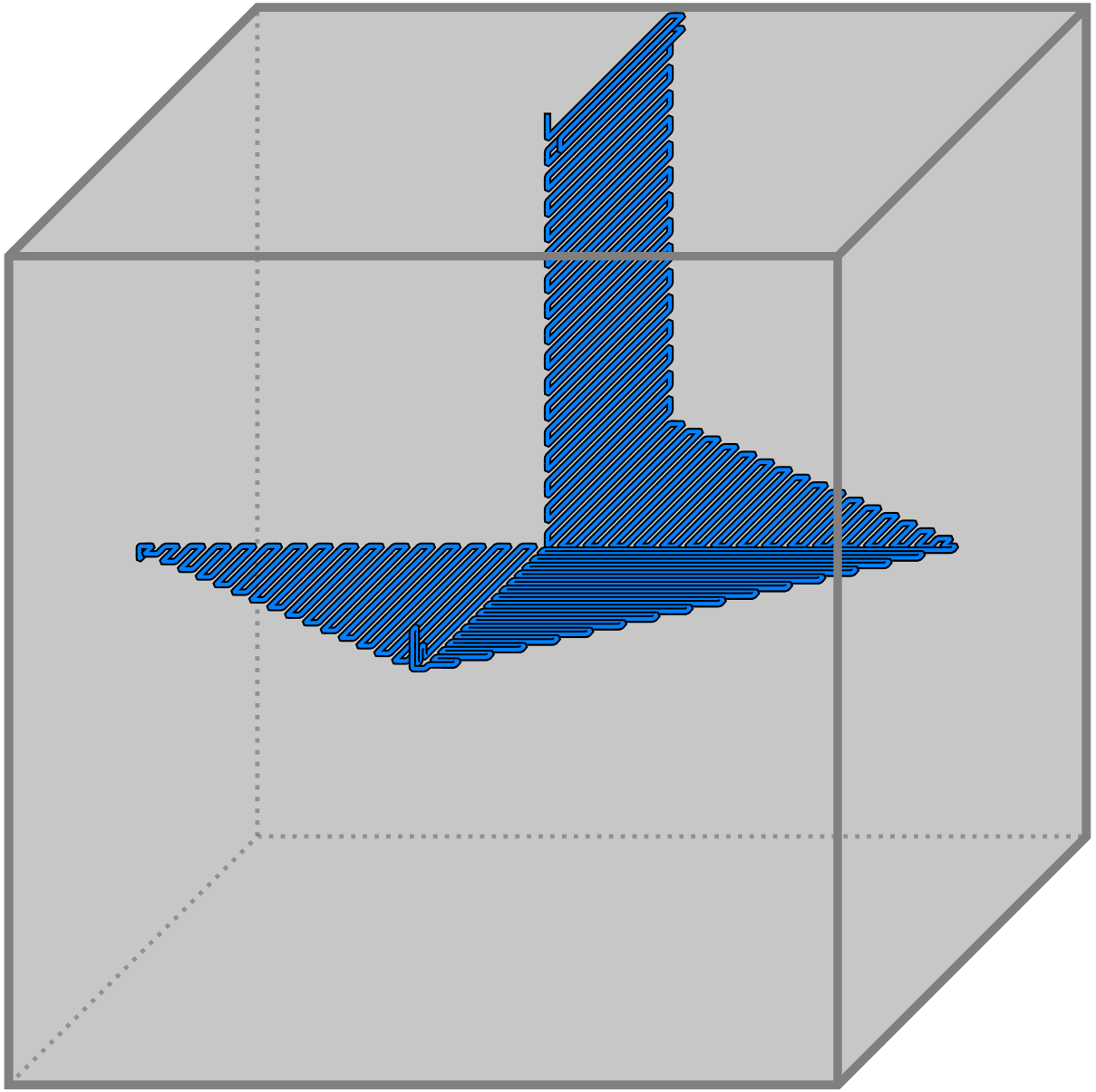
The 3D advantages: a radius 1 simulating any radius 1



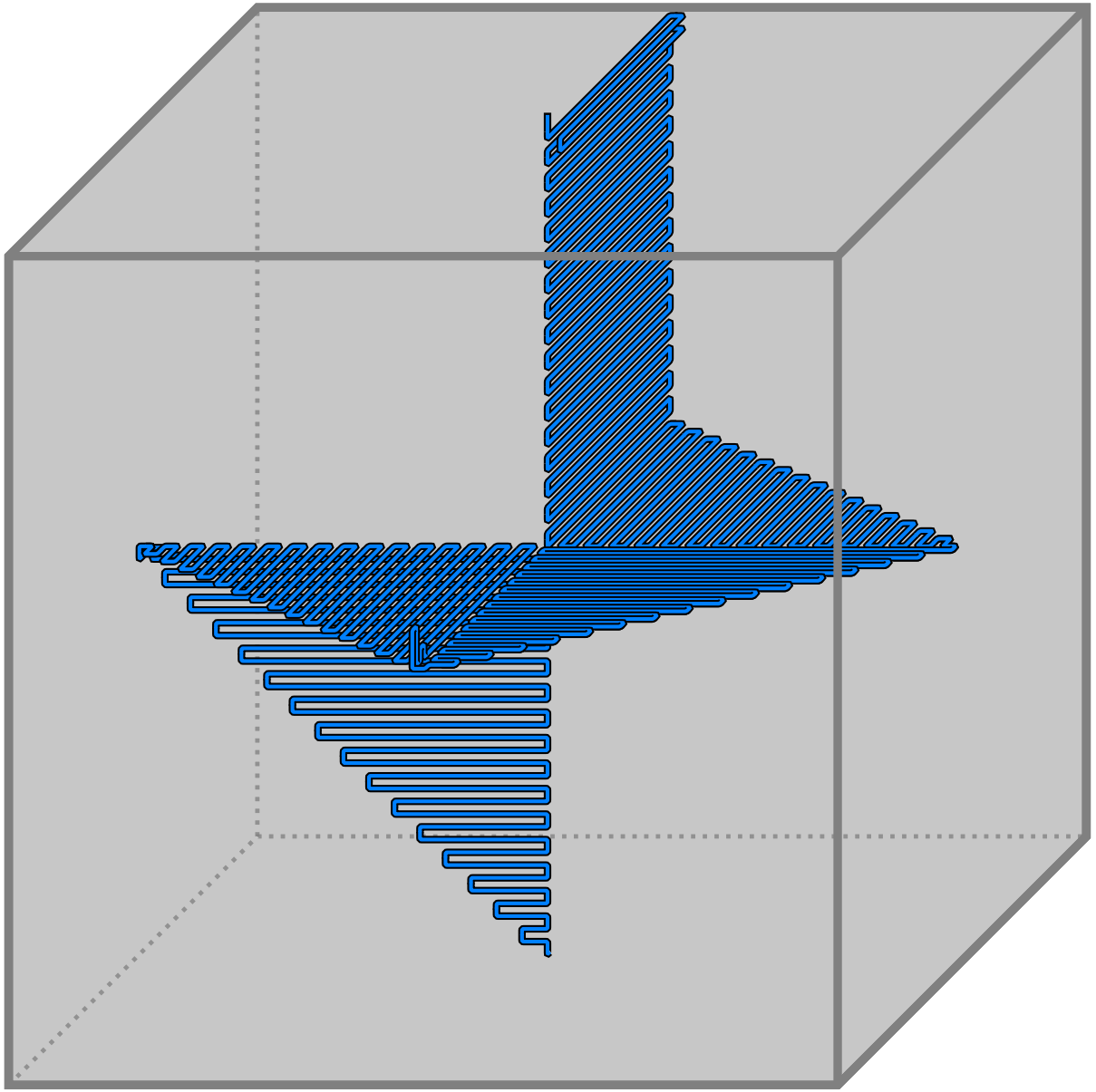
The 3D advantages: a radius 1 simulating any radius 1



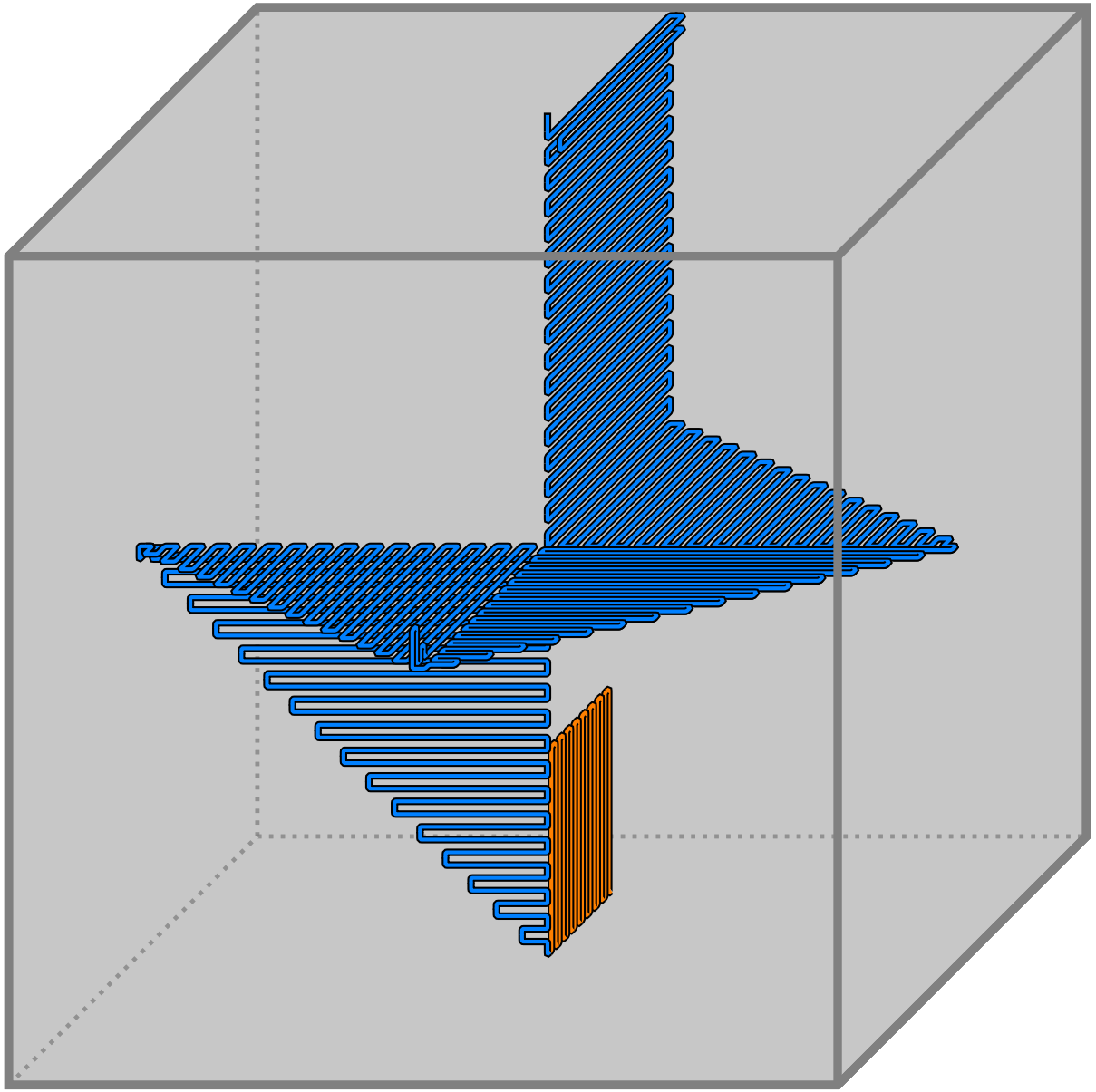
The 3D advantages: a radius 1 simulating any radius 1



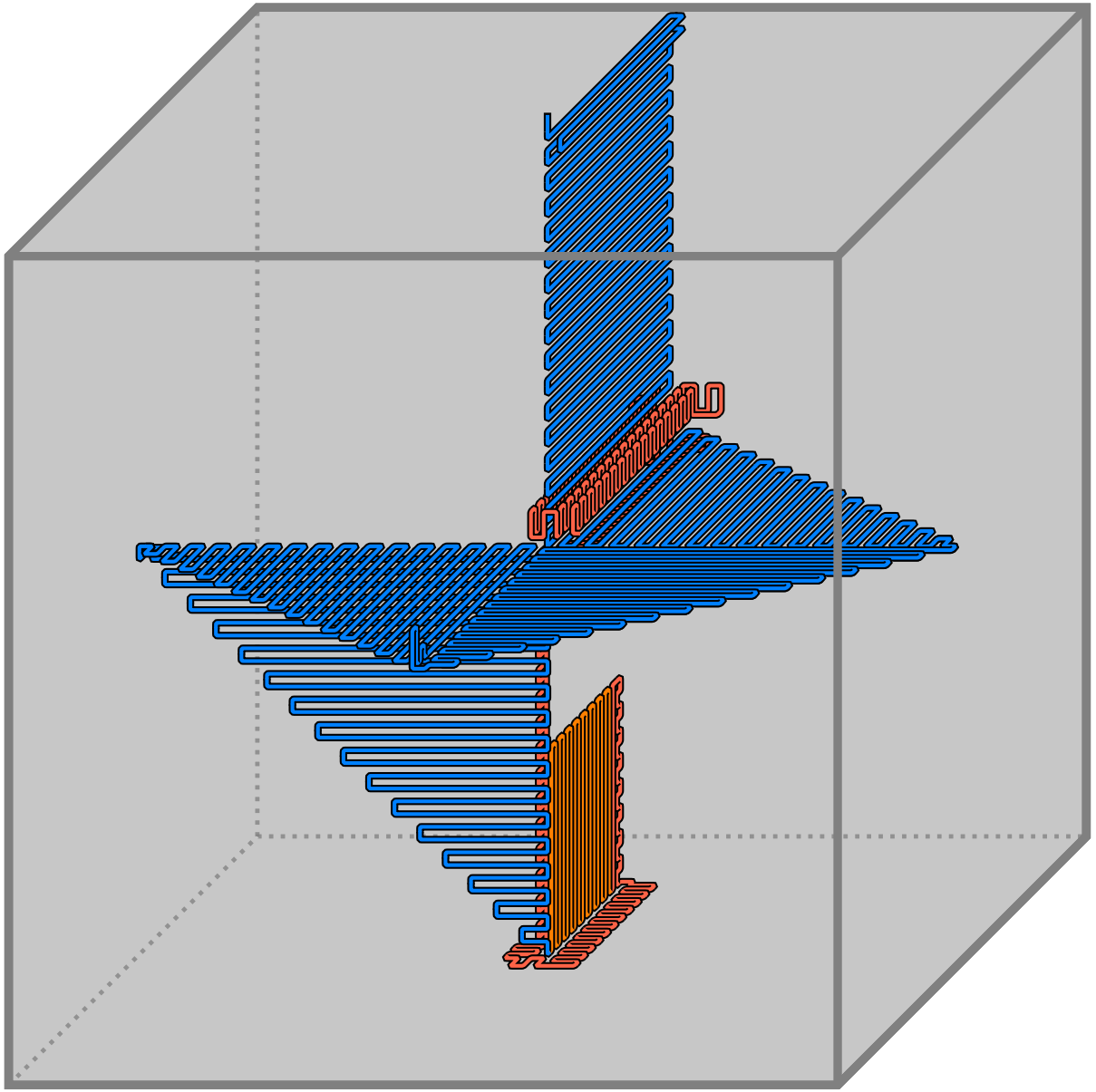
The 3D advantages: a radius 1 simulating any radius 1



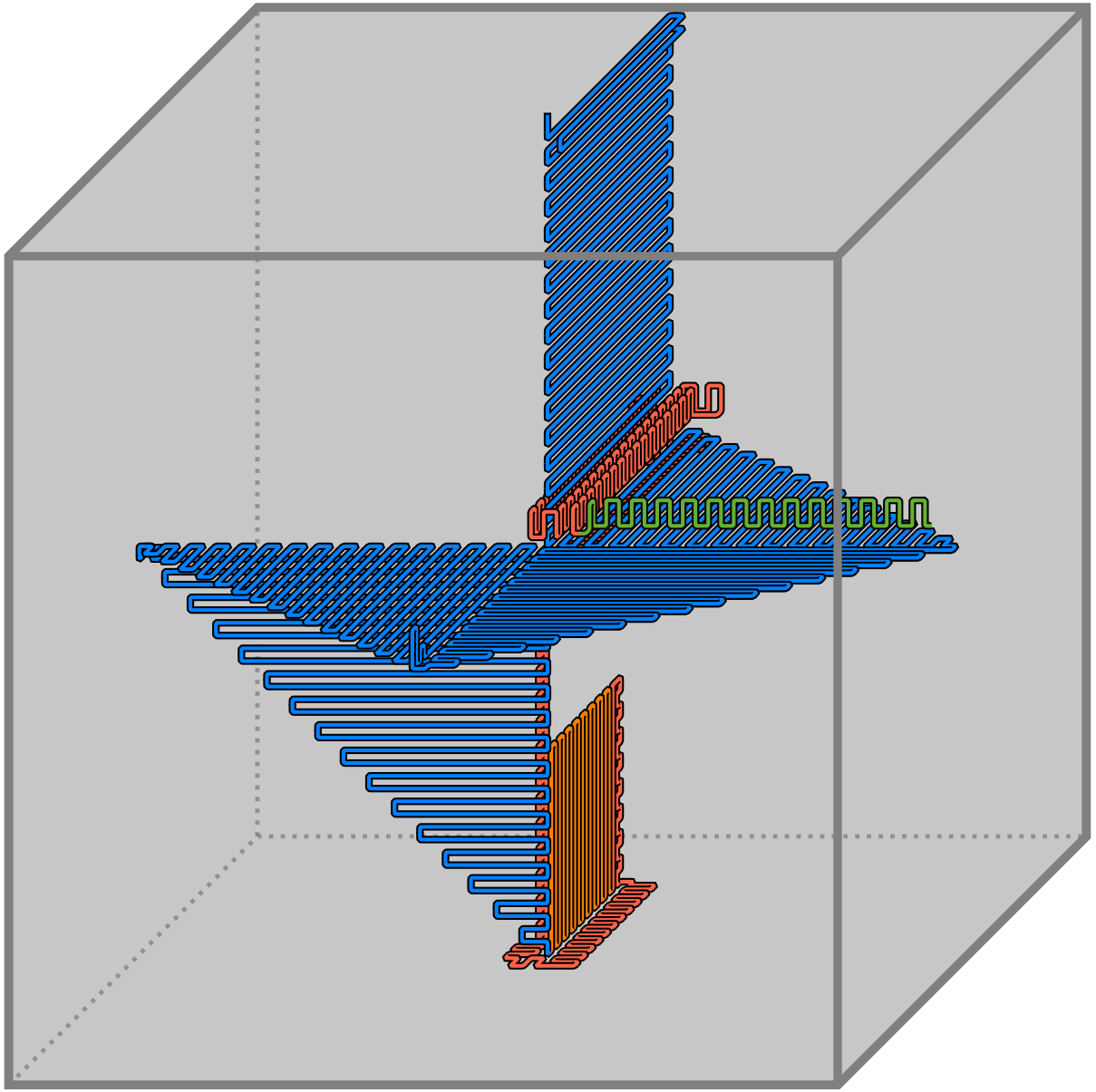
The 3D advantages: a radius 1 simulating any radius 1



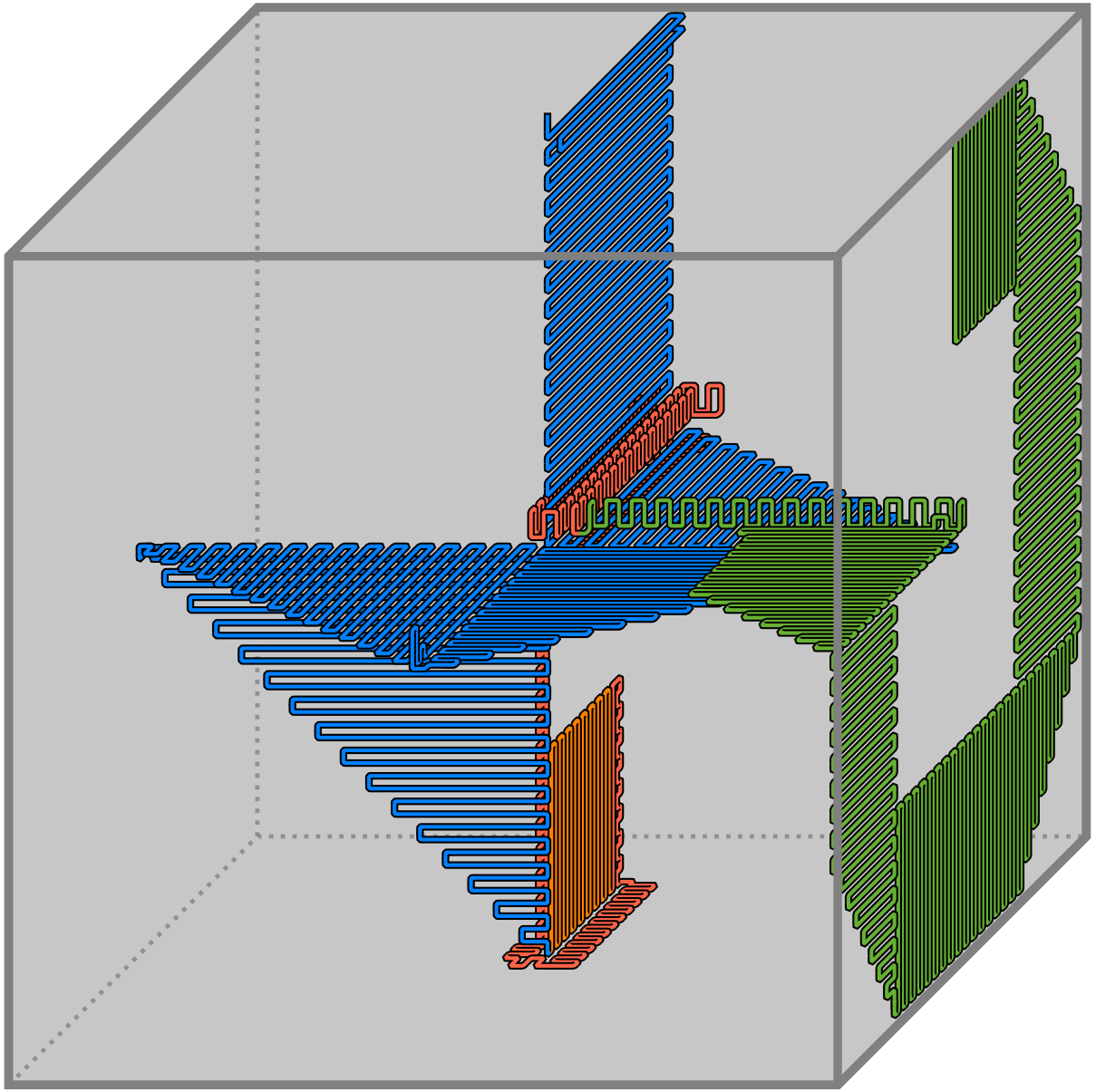
The 3D advantages: a radius 1 simulating any radius 1



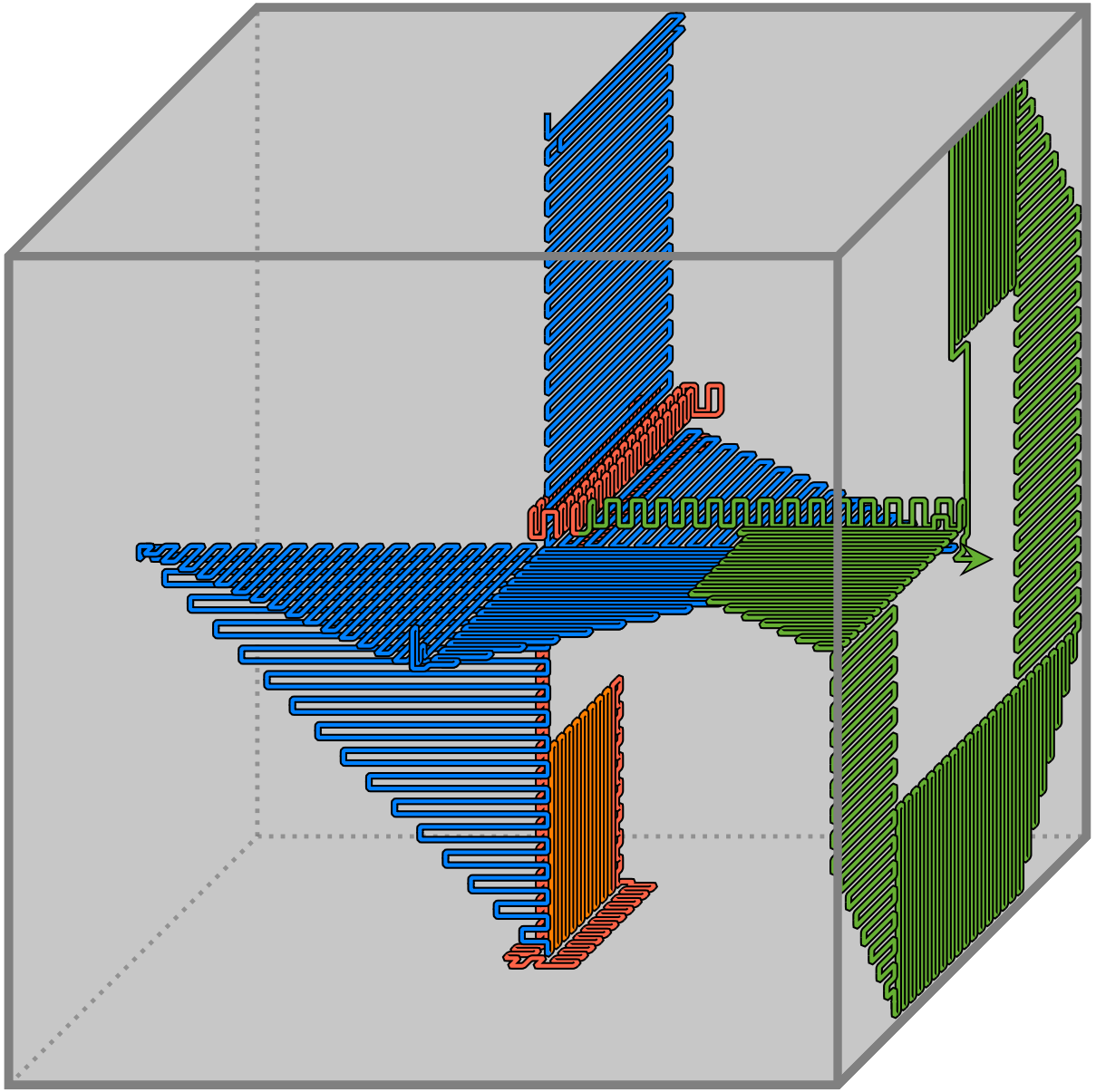
The 3D advantages: a radius 1 simulating any radius 1



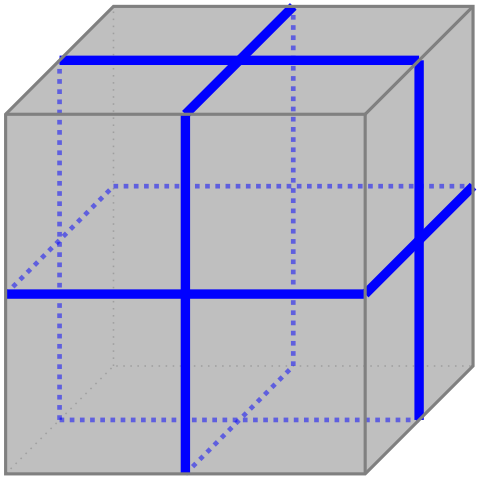
The 3D advantages: a radius 1 simulating any radius 1

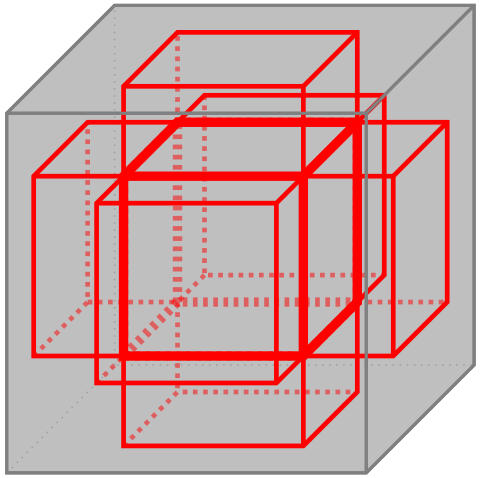


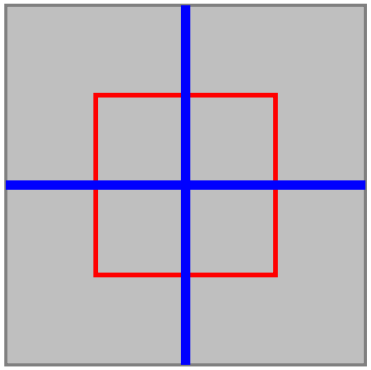
The 3D advantages: a radius 1 simulating any radius 1



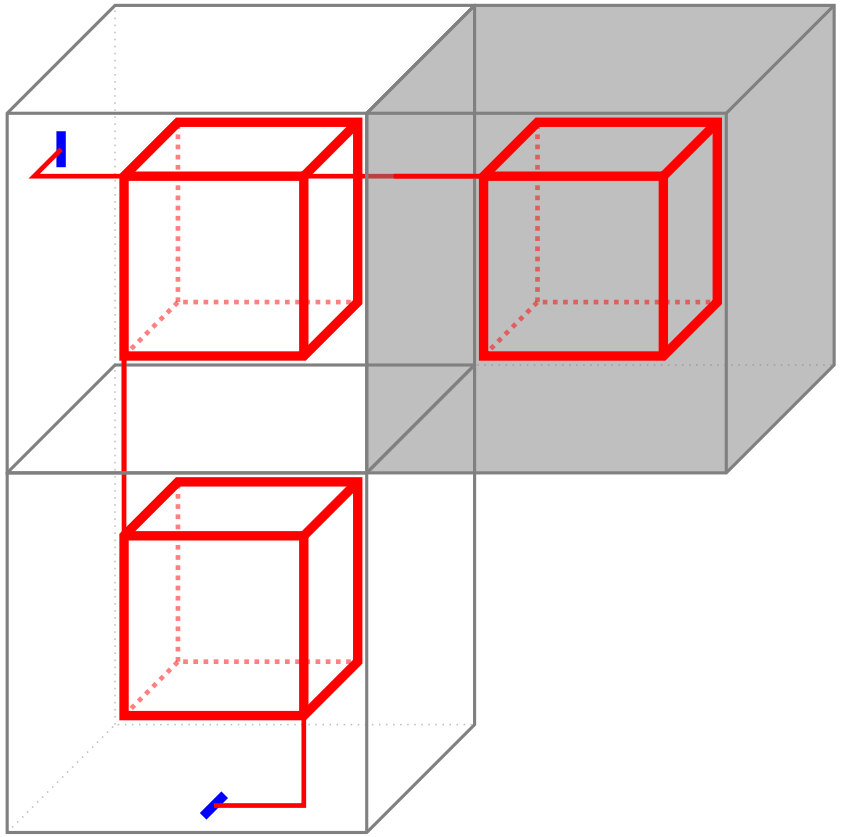
The liberal power:



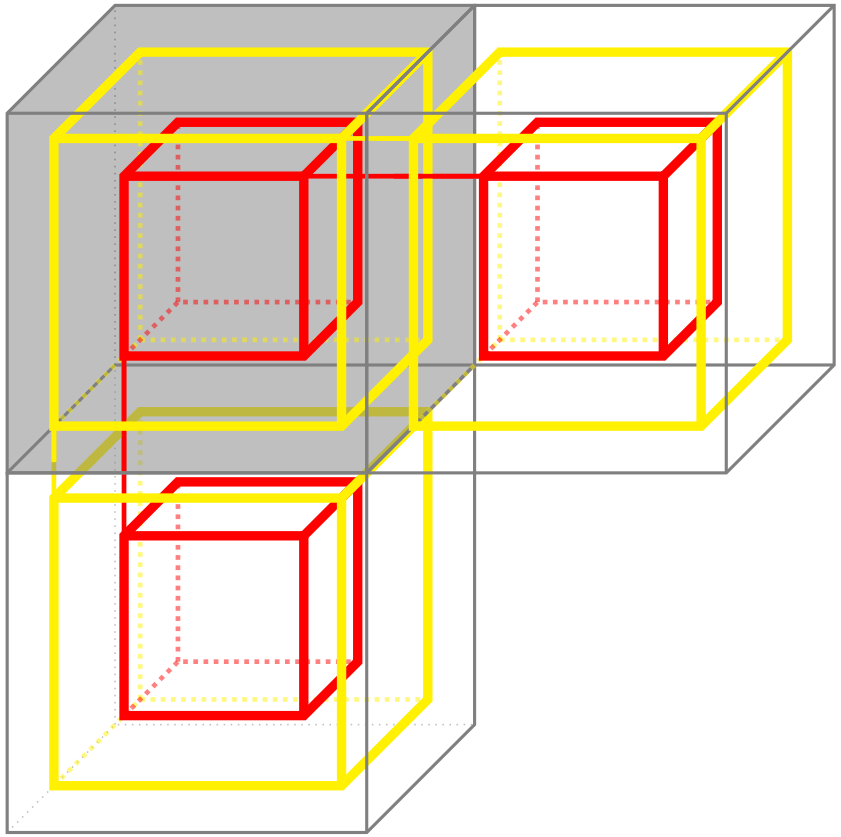




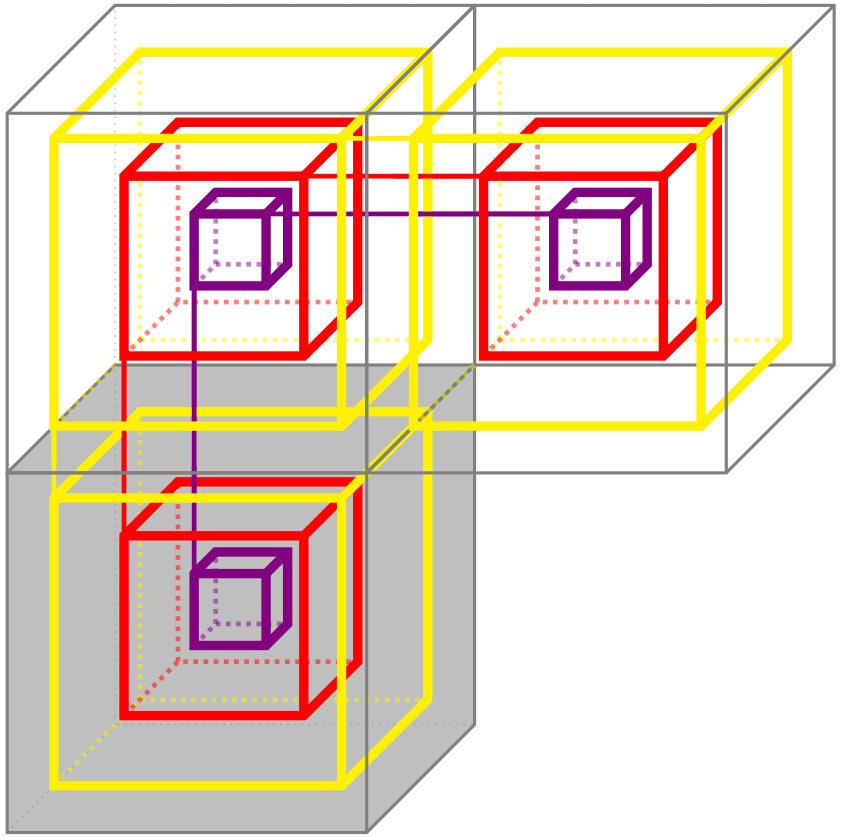
The liberal power:



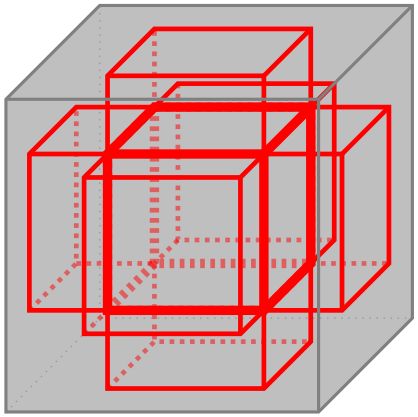
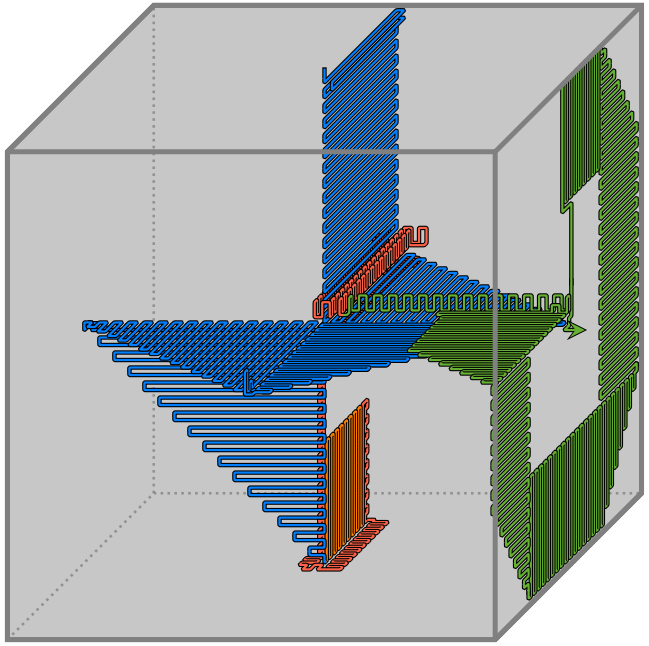
The liberal power:



The liberal power:



3D + liberal simulation: a complete universality



+