

Finding shortest walks in Kuru Kuru Kururin

Mickael LAURENT

Maher MALLEM

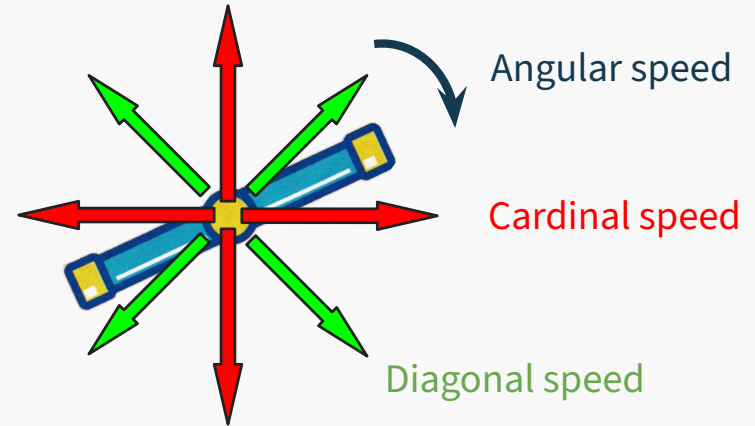
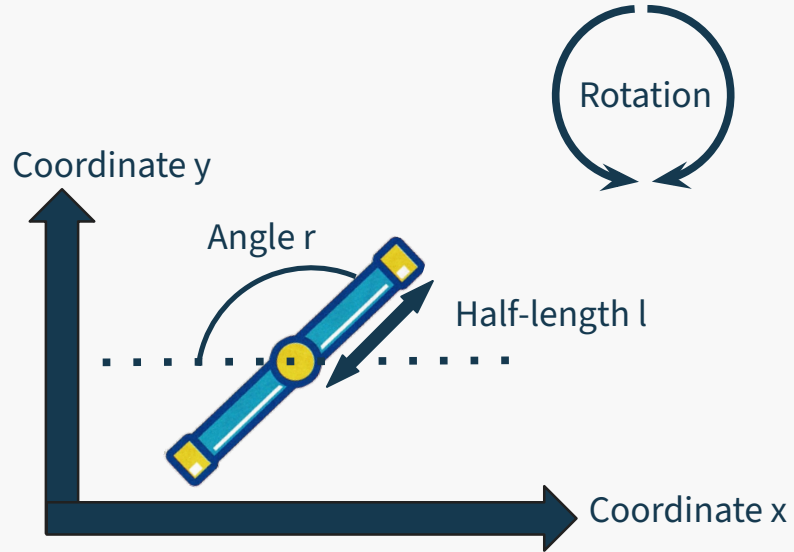


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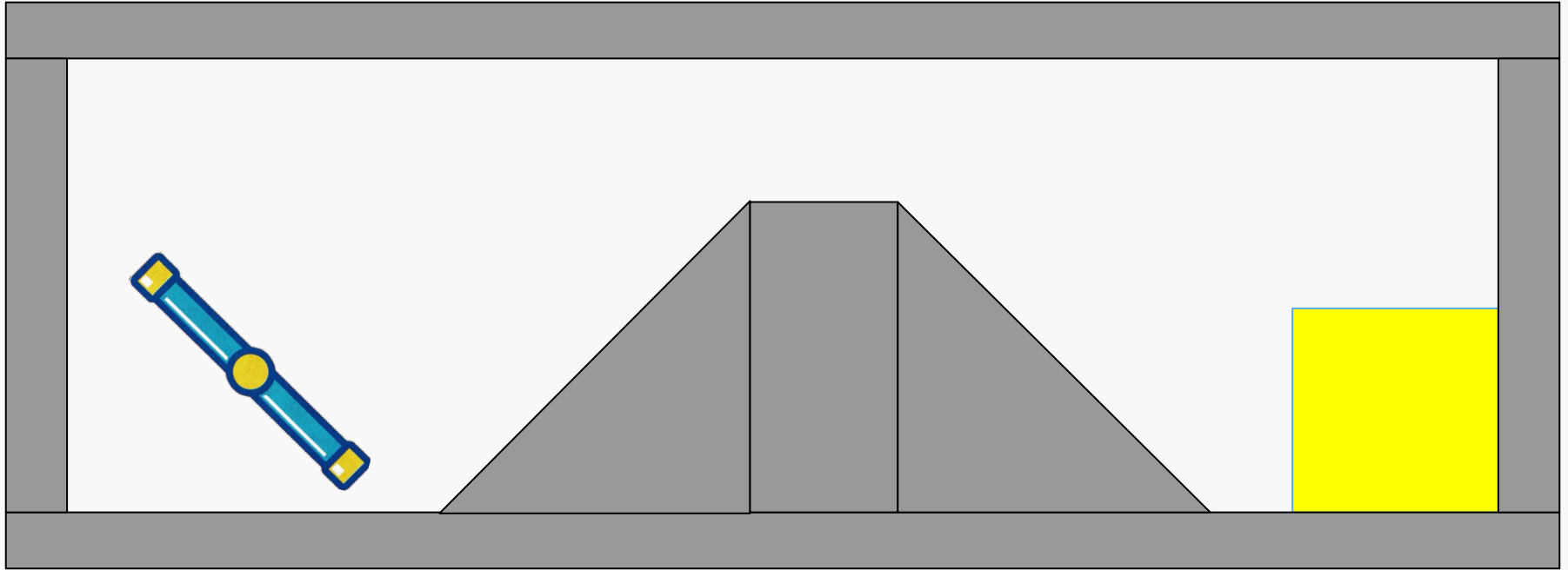
Model and complexity

The boring part

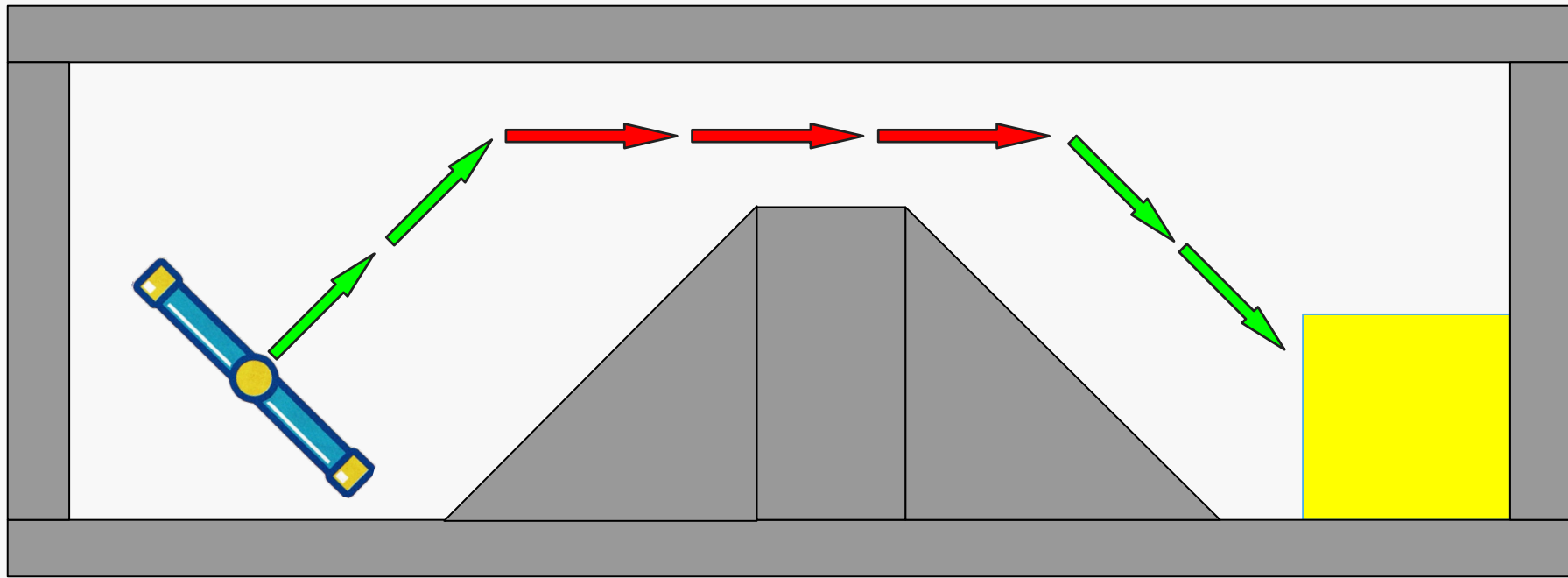
The Helirin



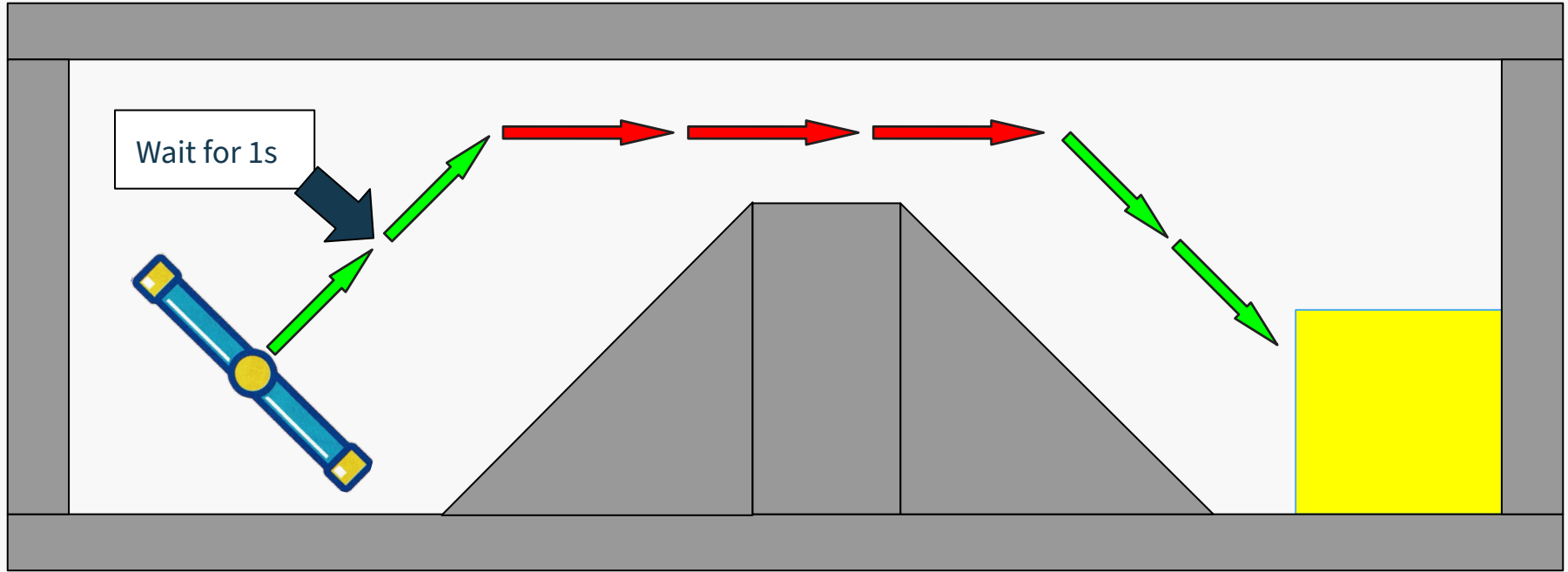
The problem



The problem

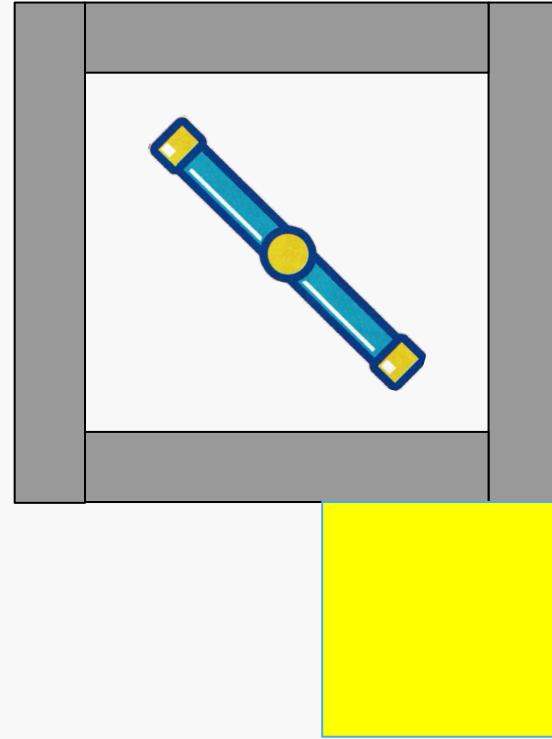
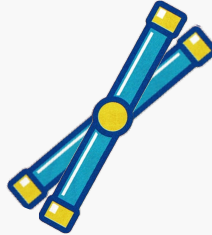
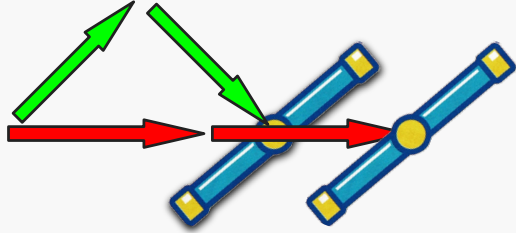


The problem



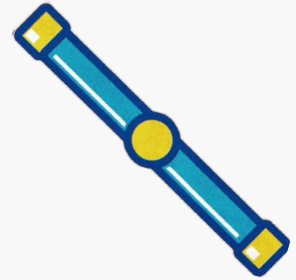
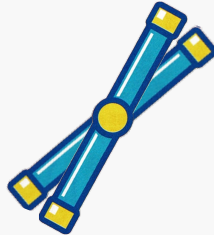
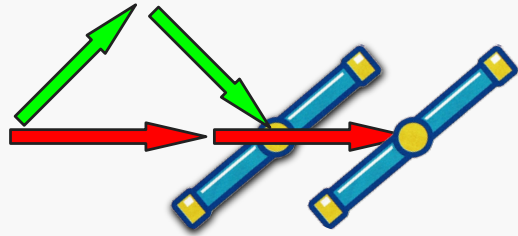
Hardness

- Pseudo-poly time; in PSPACE; NP-hard.
- Offset-based reductions.



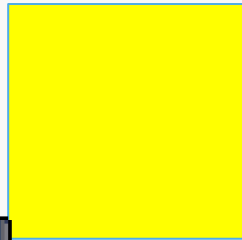
Hardness

- In PSPACE; NP-hard; pseudo-poly.
- Offset-based reductions.



- No walls? No problem!

- Extra game mechanics: springs , spiked balls , pistons 
- NP-hard and co-NP-hard: not in NP?!



2

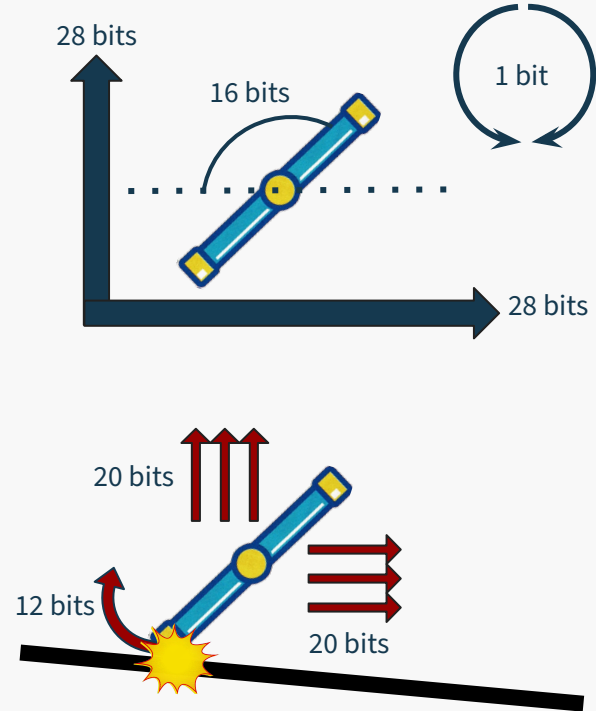
Practical resolution

Algorithmic techniques to reduce the search space (the fun part)

State space

	Quantity	Size
Resting state	Position	56 bits
	Angle	16 bits
	Rotation direction	1 bit
Collision state	Bump speed	40 bits
	Rotation bump speed	12 bits
Total		125 bits

About $6 \cdot 10^{37}$ states!



Approximate resolution

STEP 1 : Cost map (gives a global direction)

- Helirin represented as a **point**.
- Position precision is reduced (**pixel-precision**).
- **No reaction** to collisions (untraversable walls).

About 16 million states.

	Quantity	Size	New size
Resting state	Position	56 bits	24 bits
	Angle	16 bits	0
	Rotation direction	1 bit	0
Collision state	Bump speed	40 bits	0
	Rotation bump speed	12 bits	0
Total		125 bits	24 bits

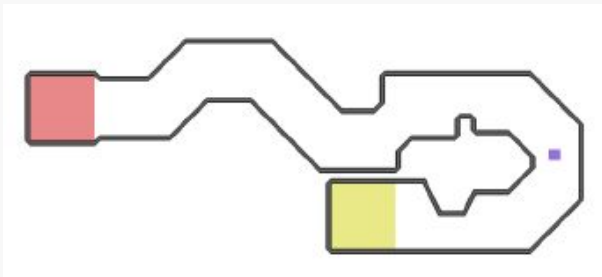
Approximate resolution

STEP 1 : Cost map (gives a global direction)

About 16 million states.



Dijkstra algorithm can be used to compute the distance to the end for each pixel of the map.



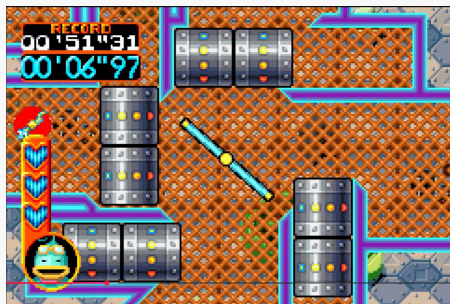
Approximate resolution

STEP 2 : Search with A* algorithm

We now tackle the real problem (full precision + collisions).

⇒ The cost map is used to guide the search overall.

Still, too many states are explored in sections that require a "maneuver" (waiting, controlled collision, etc.).



Here, the helirin must *wait for moving pistons to clear the way* — this additional cost is *not captured by the cost map*.

Approximate resolution

STEP 2 : Search with A* algorithm

To avoid exploring states which are "very close", we define **equivalence classes** of states.
Eq. classes are **parameterized by a resolution**:
for pixel resolution, the eq. class is defined by shifting the position 16 bits to the right.

State	Equivalence class
x=0x0012A7B5 y=0x0015B889	x=0x0012 y=0x0015
x=0x0012CAA0 y=0x0015D922	x=0x0012 y=0x0015
x=0x0013A055 y=0x0015B889	x=0x0013 y=0x0015

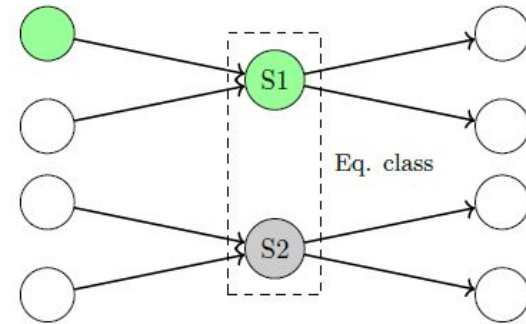
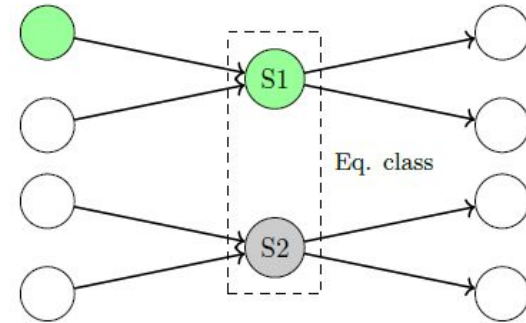
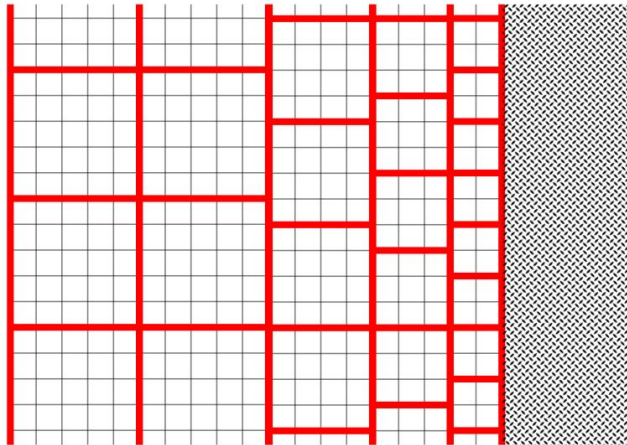


Figure 13 Path finding: node S2 is disabled because S1 has been reached first

Approximate resolution

STEP 2 : Search with A* algorithm

To avoid exploring states which are "very close", we define **equivalence classes** of states. Eq. classes are **parameterized by a resolution**: for pixel resolution, the eq. class is defined by shifting the position 16 bits to the right.



■ **Figure 13** Path finding: node S2 is disabled because S1 has been reached first

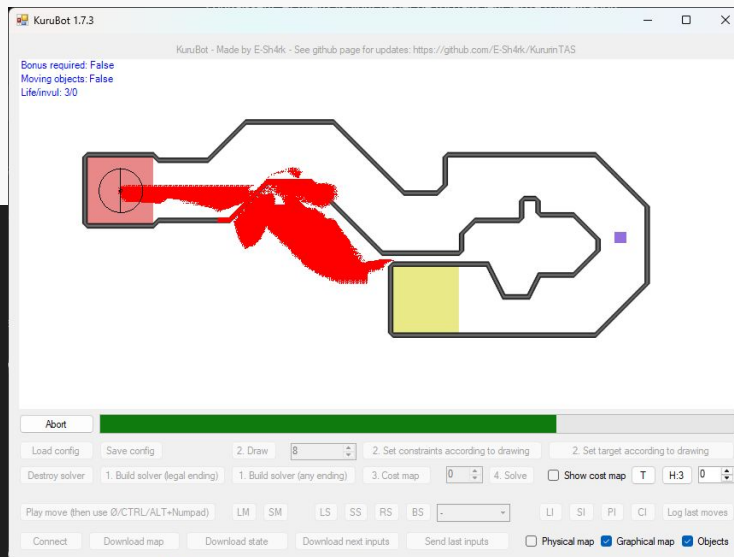
Implementation: KuruBot

KuruBot: Implementation (C#, 4000 loc)
replicating the exact physics of the game.

```
// 1. Set input speed (XS and YS) depending on inputs
int[] speeds = input_speeds;
if (e.x != Direction1.None && e.y != Direction1.None)
    speeds = input_speeds_2;
int speed = speeds[(int)e.speed];
int xs = (int)e.x * speed;
int ys = (int)e.y * speed;

// 2. Reduce bump speed / bump rotation (XB, YB and Rot_rate) / invulnerability
short rot_diff = (short)(st.rot_srate - st.rot_rate);
if (rot_diff < -rotation_rate_decr)
    rot_diff = -rotation_rate_decr;
if (rot_diff > rotation_rate_decr)
    rot_diff = rotation_rate_decr;
st.rot_rate = (short)(st.rot_rate + rot_diff);
st.xb = st.xb * bump_speed_decrease_numerator / bump_speed_decrease_denominator;
st.yb = st.yb * bump_speed_decrease_numerator / bump_speed_decrease_denominator;
if (st.invul > 0)
    st.invul--;

// 3. Move depending on speed (bump+input), rotate depending on rotation rate (Rot_rate)
st.xpos += xs + st.xb;
st.ypos += ys + st.yb;
st.rot += st.rot_rate;
```



It turns out the physics
can be abused to cross walls!

Categories

We want to beat the game following different sets of rules:

Category	Rules
Damageless	Cannot take damage (no collision with walls except in safe areas)
Regular intended	Can take damage and hit walls to gain time, but no out-of-bounds
Regular unrestricted	Can exploit the physics to cross walls and go out-of-bounds



Taking a hit
(forbidden in
damageless)



Going out-of-bounds
(only allowed in
regular unrestricted)

Categories

Each category has its specific cost-map configuration and search resolution.

Category	Cost Map	Resolution (base)	Resolution (near walls)
Damageless	No wall crossing	2 px	2 px
Regular intended	No wall crossing	2 px	1 px
Regular unrestricted	Wall crossing at a fixed cost	1 px	$\frac{1}{8}$ px



Tool-assisted speedruns

Enjoy!



Questions?



Recap

4-/8-neighbor grid?	No rotation?	Notes	Complexity	
x	x	No walls	in P	in PSPACE pseudo-poly
	o	-	NP-h	
o			in P	
	x	co-NP-h?		
		With springs	NP-h	
o	With pistons or spiked balls	NP-h co-NP-h		

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Title here

1

Saturn

Saturn is a gas giant and has several rings

2

Neptune

Neptune is the farthest planet of all them

3

Earth

Earth is the third planet from the Sun

4

Sun

The sun is in the middle of the Solar System

6

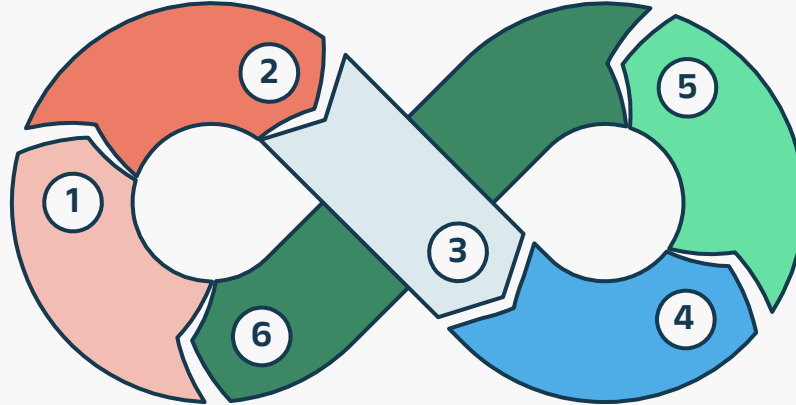
Jupiter

Jupiter is a gas giant and a big planet

5

Mars

Despite being red, Mars is actually a cold place



You can use this diagram



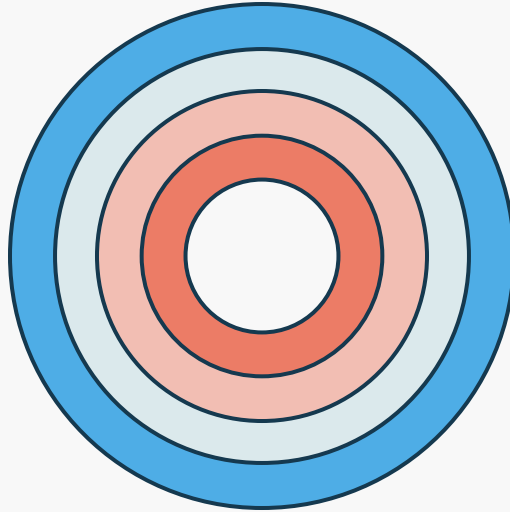
Mercury

Mercury is the smallest planet in the Solar System



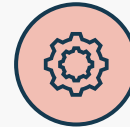
Mars

Despite being red, Mars is actually a cold place



Venus

Venus has a nice name and is the second planet to the sun



Jupiter

Jupiter is a gas giant and the biggest planet of them all

This is a cycle diagram

1

Mars

Despite being red, Mars is actually a cold place

2

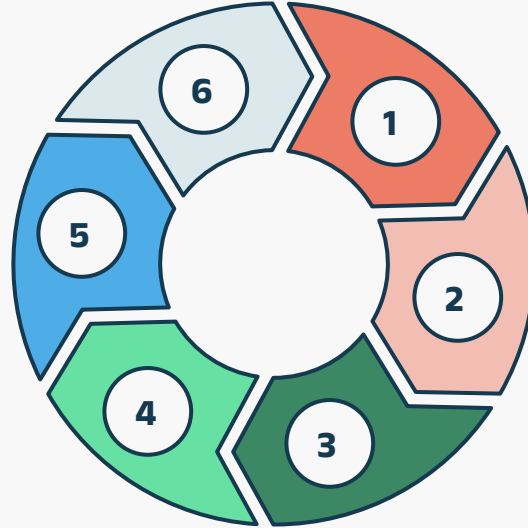
Venus

Venus has a beautiful name, but it's terribly hot

3

Saturn

Saturn is a gas giant and has several rings



Neptune

Neptune is far away from the the sun

4

Earth

Earth is the third planet from the Sun

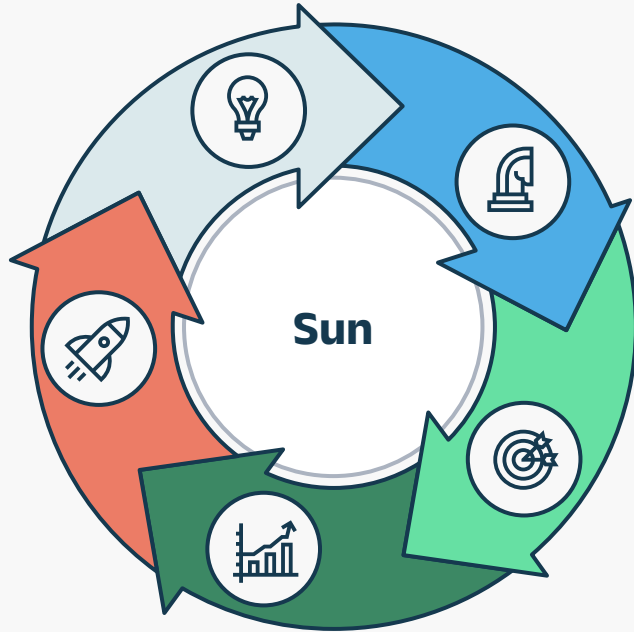
5

Mercury

Mercury is the closest planet from the sun

6

Make your idea understandable



Mercury

Mercury is the closest planet to the Sun



Earth

Earth is the third planet from the Sun



Venus

Venus is the second planet from the Sun



Jupiter

Jupiter is the biggest planet of them all



Saturn

Saturn is a gas giant and has several rings

Do you need more infographics?

Mercury is the closest planet to the Sun

Mercury



Jupiter is the biggest planet of them all

Jupiter



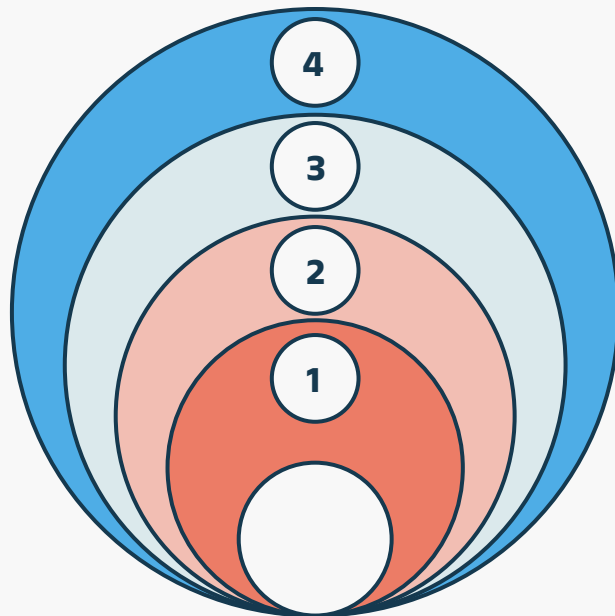
Despite being red, Mars is actually a cold place

Mars



Venus is the second planet from the sun

Venus



Title here

10

Neptune

Neptune is an ice giant

9

Earth

Earth is where we live

8

Moon

The moon is a satellite

7

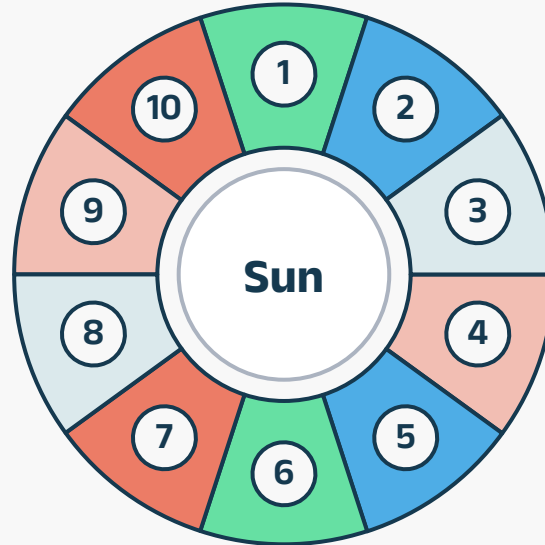
Pluto

Pluto is a dwarf planet

6

Mercury

Mercury is very small



Jupiter

1

Jupiter is very big

Venus

2

Venus is very hot

Mars

3

Mars is a cold place

Saturn

4

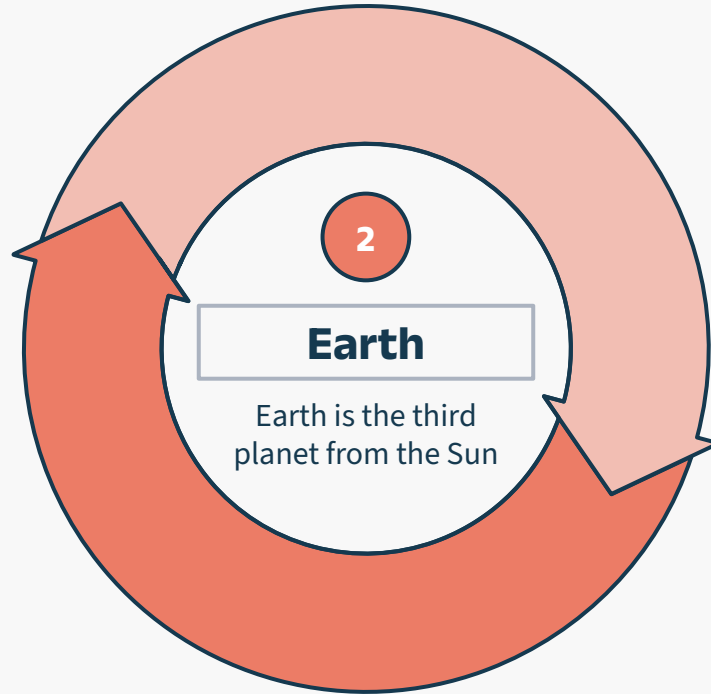
Saturn has many rings

Sun

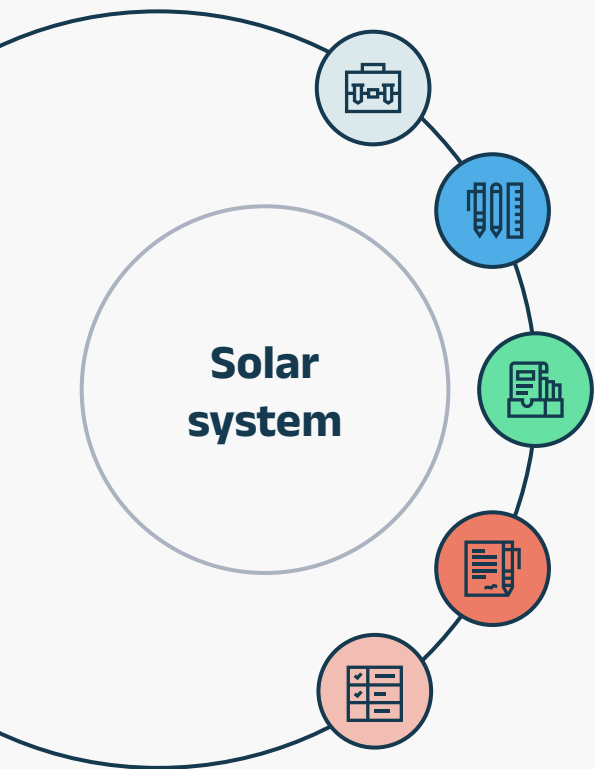
5

The sun is a star

Do you need another infographic?



This is another infographic



1

Jupiter is a gas giant and also the biggest in the Solar System

Jupiter

2

Mercury is the closest to the Sun and the smallest in the Solar System

Mercury

3

Despite being red, Mars is a very cold place full of iron oxide dust

Mars

4

Earth is the third planet from the Sun and where we all live on

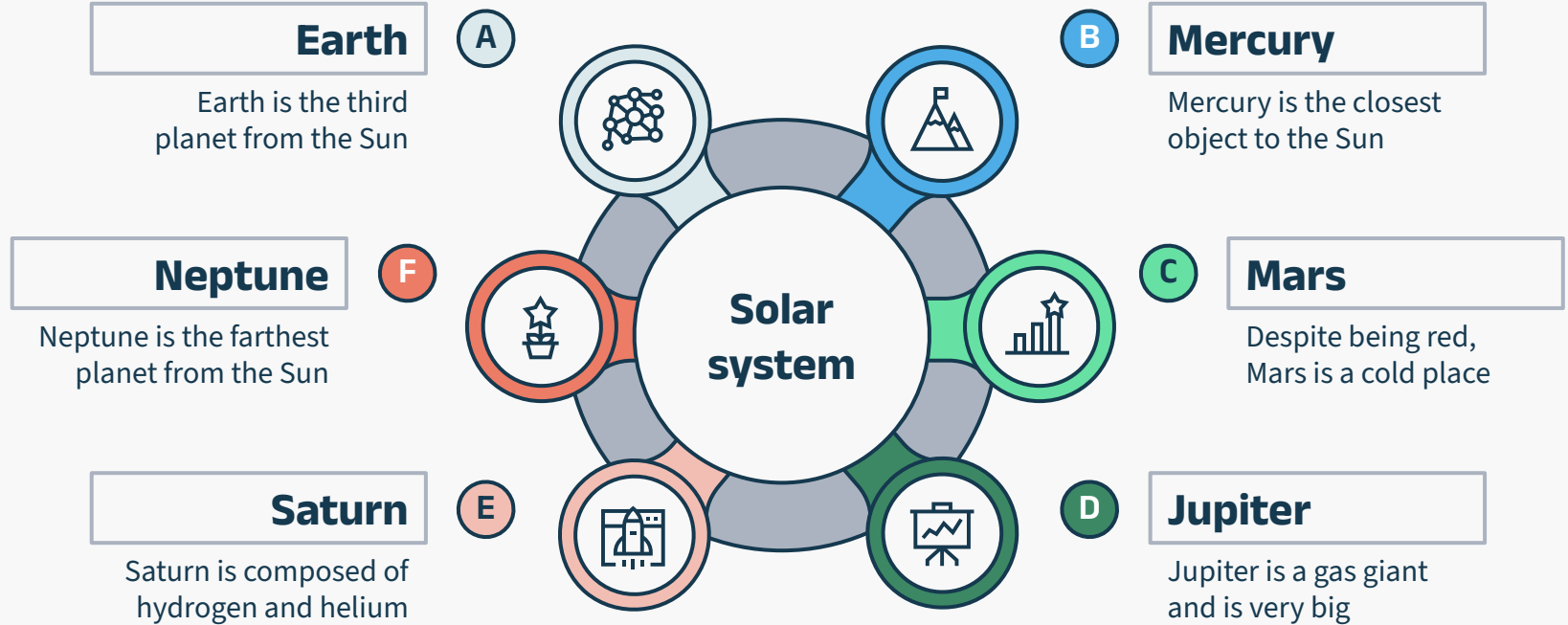
Earth

5

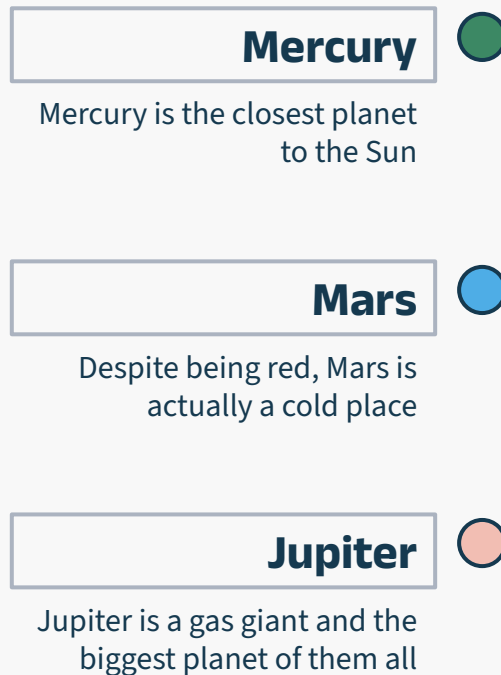
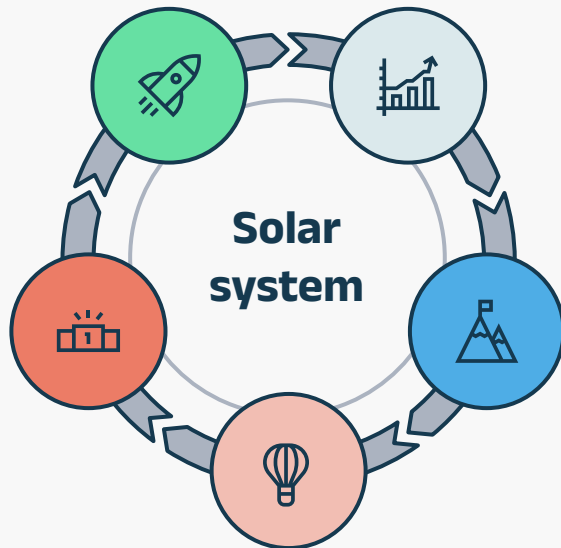
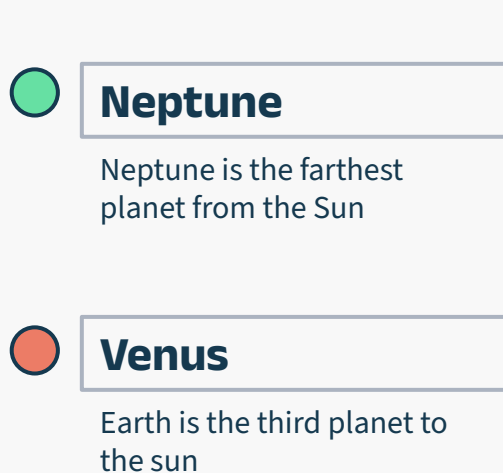
Saturn is composed mostly of hydrogen and helium

Saturn

Title here



This is also a cycle diagram



You can use this cycle diagram



Mercury

Mercury is the
smallest planet in
the Solar System



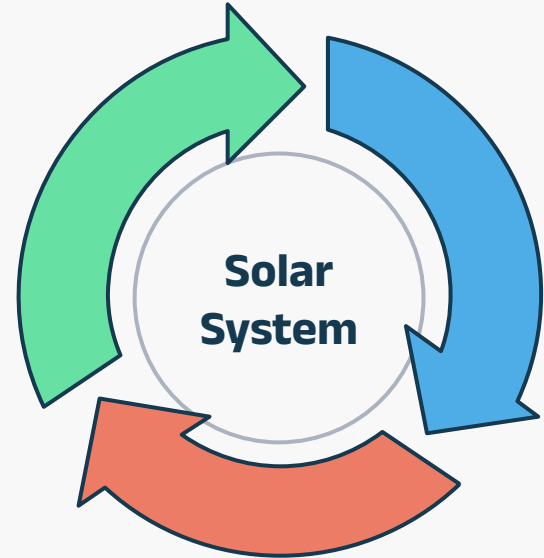
Jupiter

Jupiter is the
biggest planet in
the Solar System



Venus

Venus is the
second planet
from the sun



Make your idea understandable



Mercury

Mercury is the closest planet to the Sun



Mars

Despite being red, Mars is a cold place



Saturn

Saturn is a gas giant and has several rings



Neptune

Neptune is far away from the sun



Jupiter

Mercury is the biggest planet of them all



Venus

Venus is the second planet from the sun



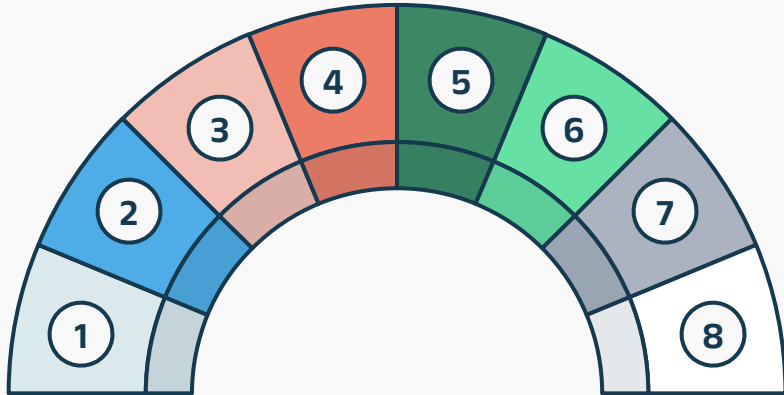
Sun

The sun is an enormous star



Earth

Earth is the third planet from the sun



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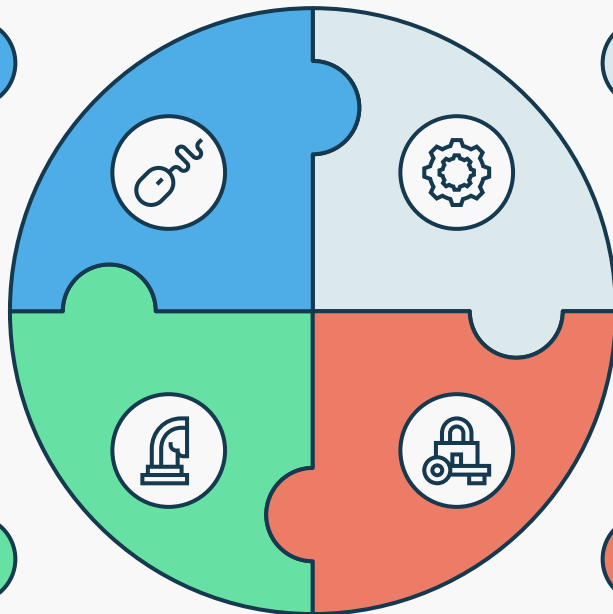
Mercury

Mercury is the smallest planet in the Solar System

Despite being red, Mars is actually a very cold place

Mars

1



2

Venus

Venus is the second planet to the sun and is very hot

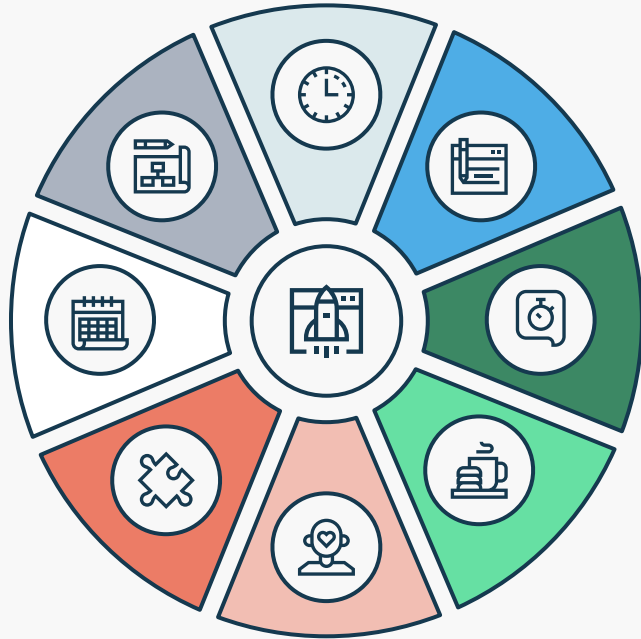
Jupiter is a gas giant and the biggest planet of them all

Jupiter

4

3

This is a cycle diagram



Neptune

Neptune is the farthest



Mercury

Mercury is very small



Sun

The Sun is a big star



Earth

Earth is a nice place



Jupiter

Jupiter is very big



Mars

Mars is a cold place



Venus

Venus is very hot



Pluto

Pluto is a dwarf planet

Do you need another infographic?

2

Saturn

Saturn is a gas giant and has several rings

3

Sun

The sun is in the middle of the Solar System

4

Jupiter

Jupiter is a gas giant and a big planet

1

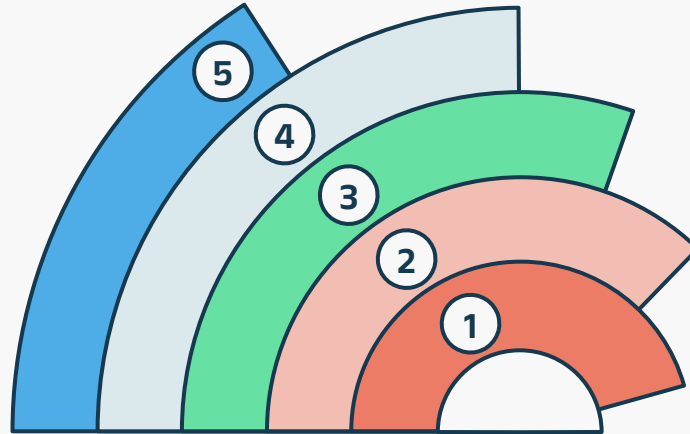
Neptune

Neptune is the farthest planet of all them

5

Mars

Despite being red, Mars is actually a cold place



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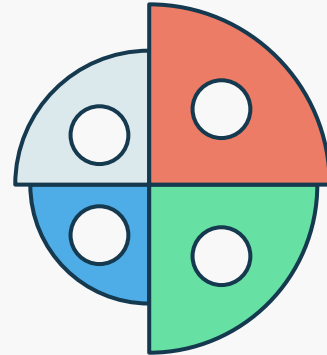
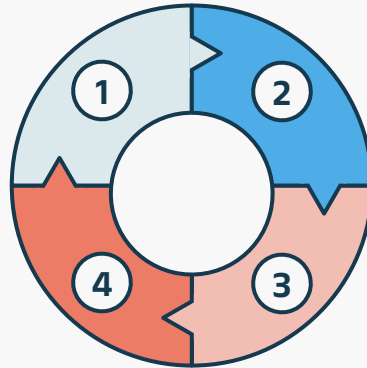
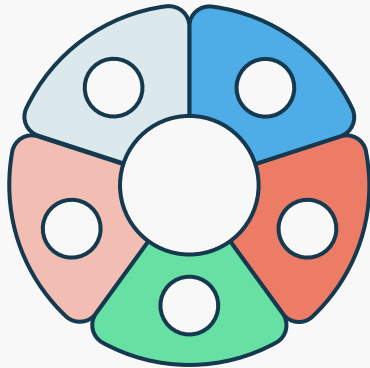


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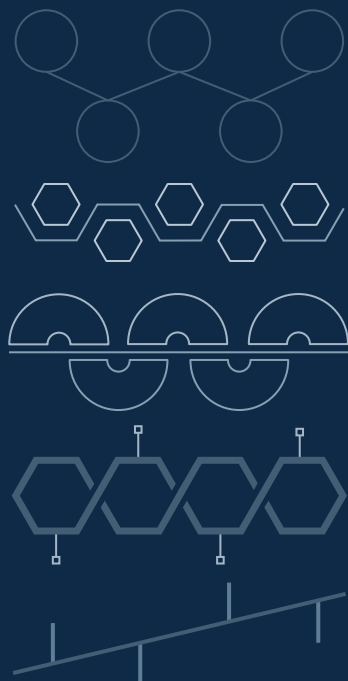
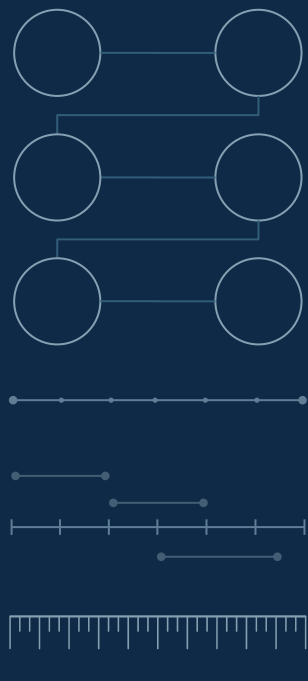
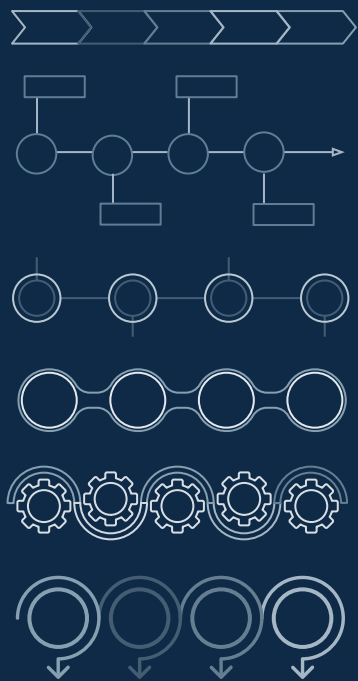
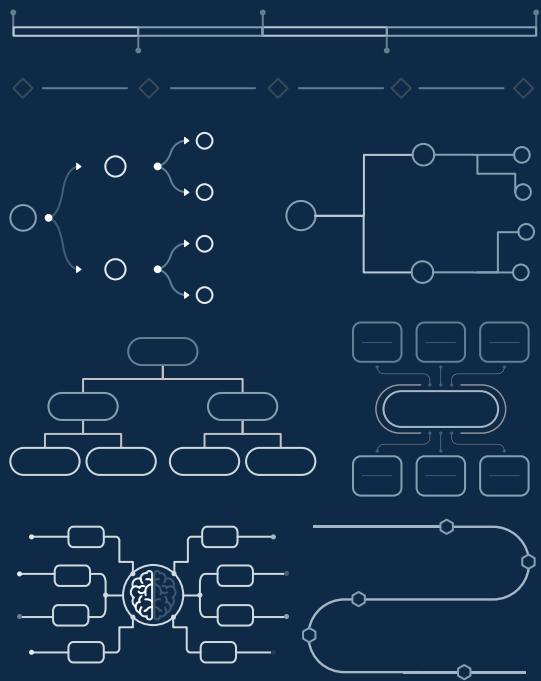
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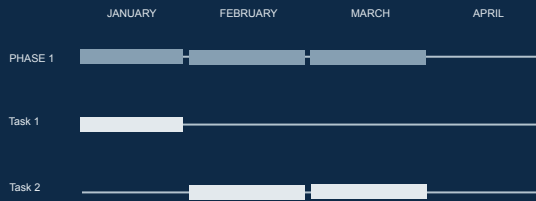
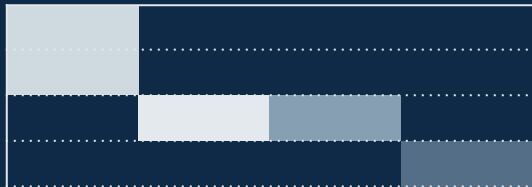
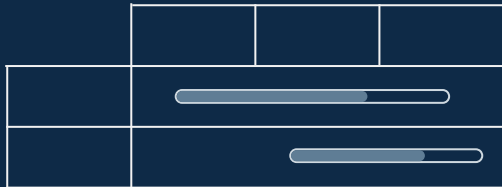
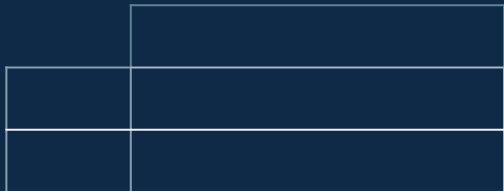
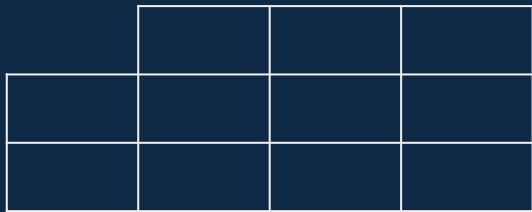
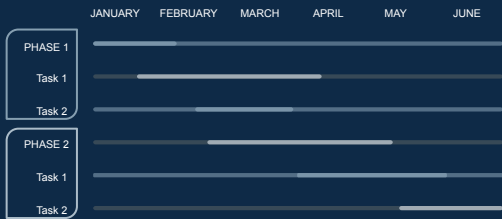
Use our editable graphic resources...

You can easily **resize** these resources without losing quality. To **change the color**, just ungroup the resource and click on the object you want to change. Then, click on the paint bucket and select the color you want. Group the resource again when you're done. You can also look for more **infographics** on [Slidesgo](#).











...and our sets of editable icons

You can **resize** these icons without losing quality.

You can **change the stroke and fill color**; just select the icon and click on the **paint bucket/pen**.

In Google Slides, you can also use **Flaticon's extension**, allowing you to customize and add even more icons.



Educational Icons



Medical Icons



Business Icons



Teamwork Icons



Help & Support Icons



Avatar Icons



Creative Process Icons



Performing Arts Icons



Nature Icons



SEO & Marketing Icons



