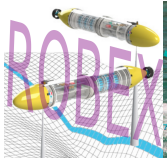
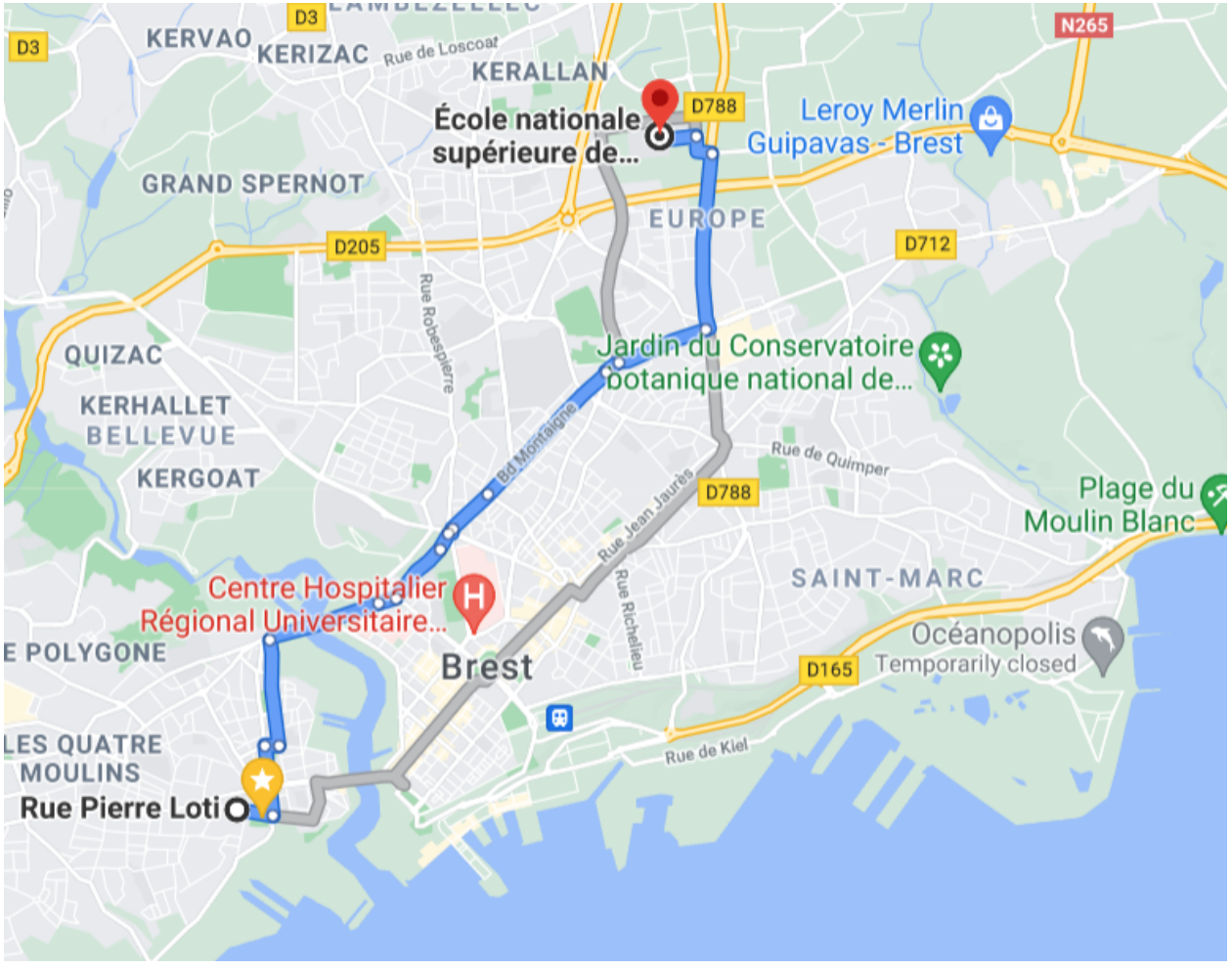
Underwater exploration by an autonomous robot with the method of stable cycles

L. Jaulin

Navigation and control of Underwater vehicles
SeaTechWeek, 2022, Brest



Modern navigation



Modern navigation

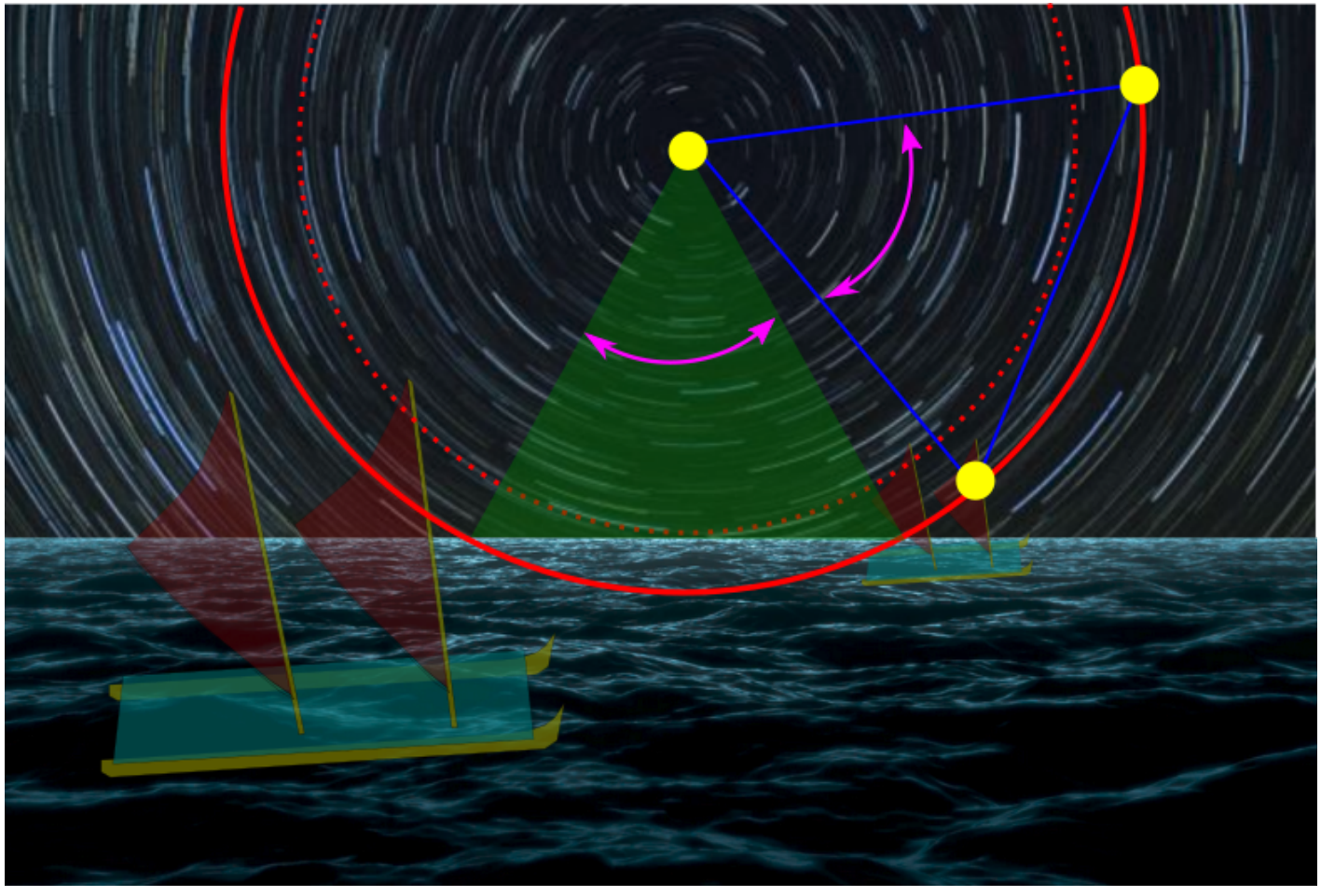
Route-based navigation

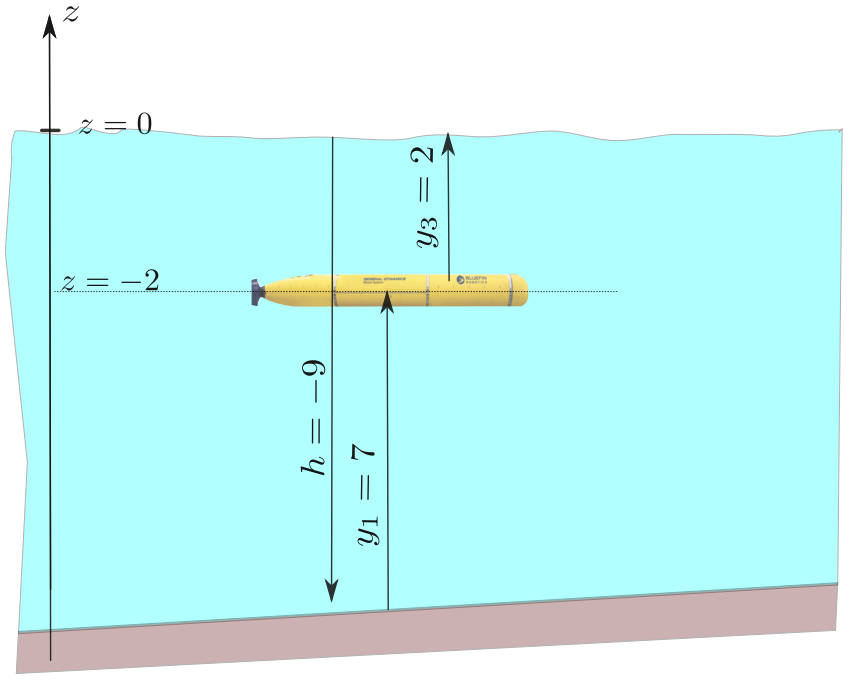
Submeeting 2018

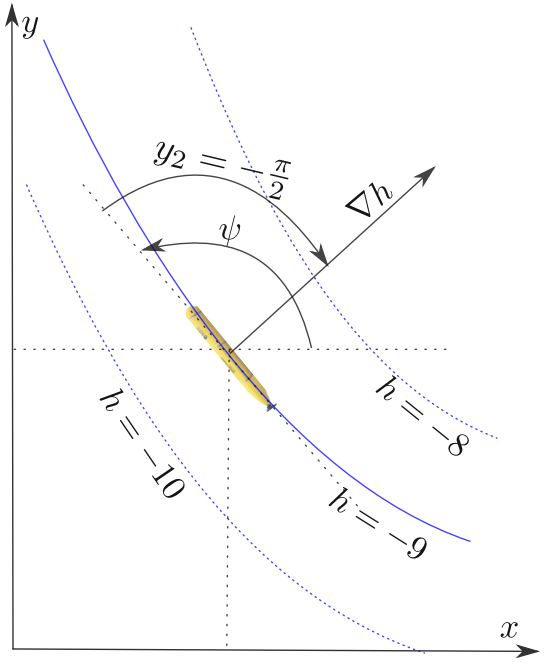
Find the route without GPS, compass and clocks with *wa'a kaulua[4]*

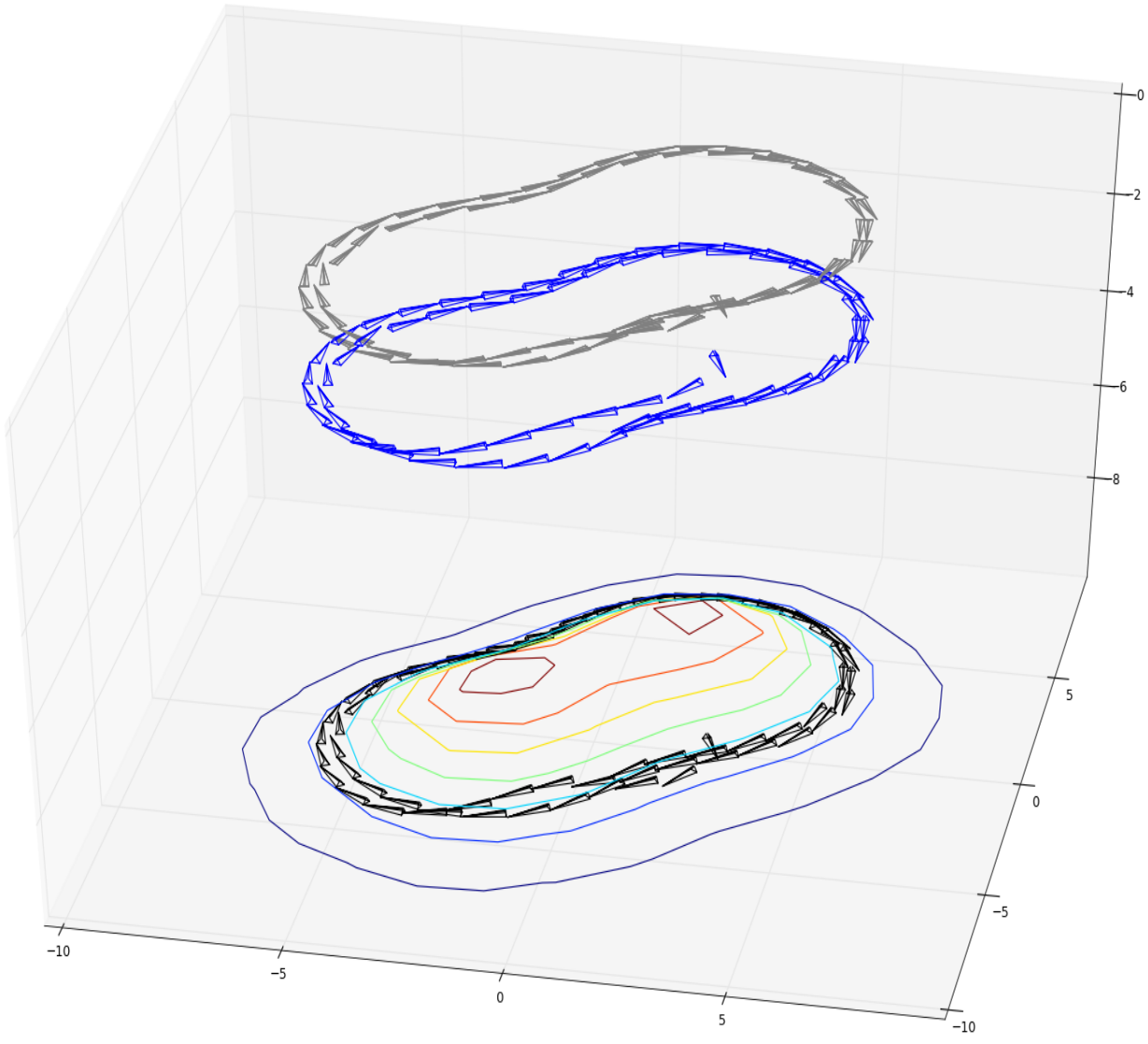
Follow a route

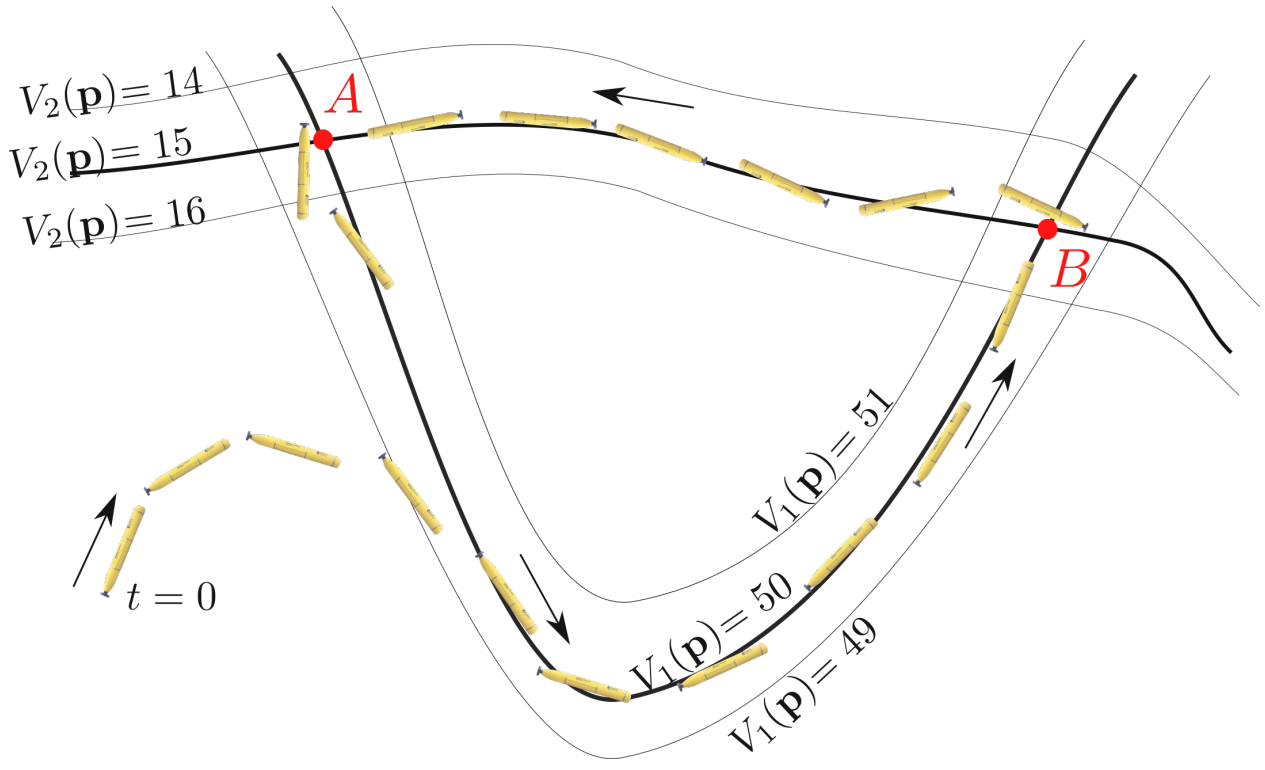
Given a function $h : \mathbb{R}^2 \mapsto \mathbb{R}$, a route in defined by $h(\mathbf{p}) = 0$.
h could be the temperature, the radiation, the pressure, the altitude, the time shift between two periodic events.

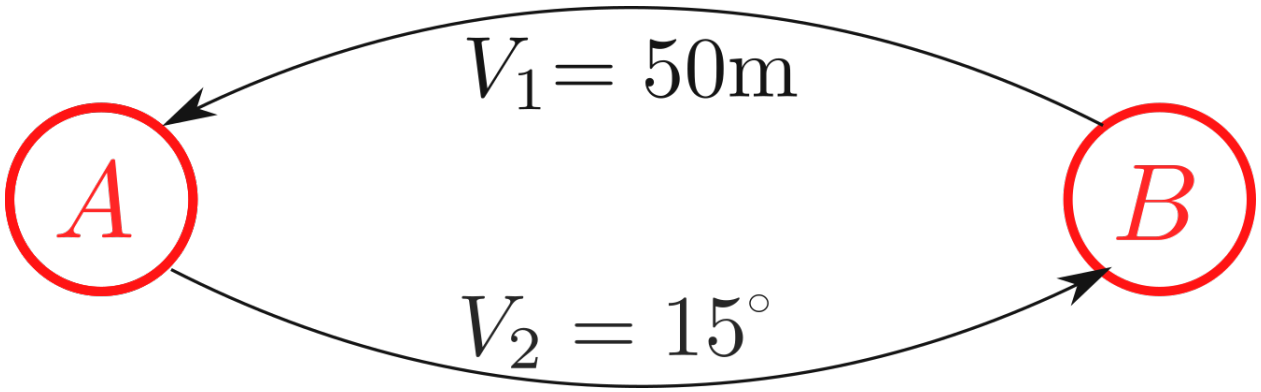



z
z = 0
z = −2
y3 = 2
h = −9
y1 = 7

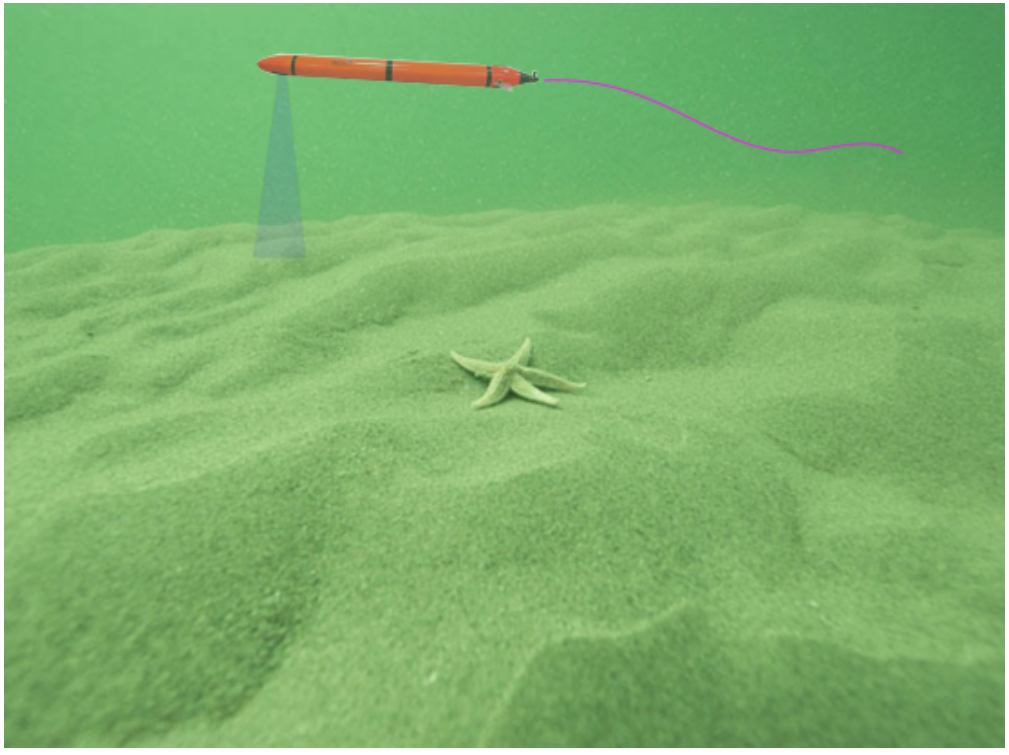

y
x
y2 = −π/2
ψ
∇h
h = −8
h = −10
h = −9


0
2
4
6
8
−10
−5
0
5
−10
−5
0
5

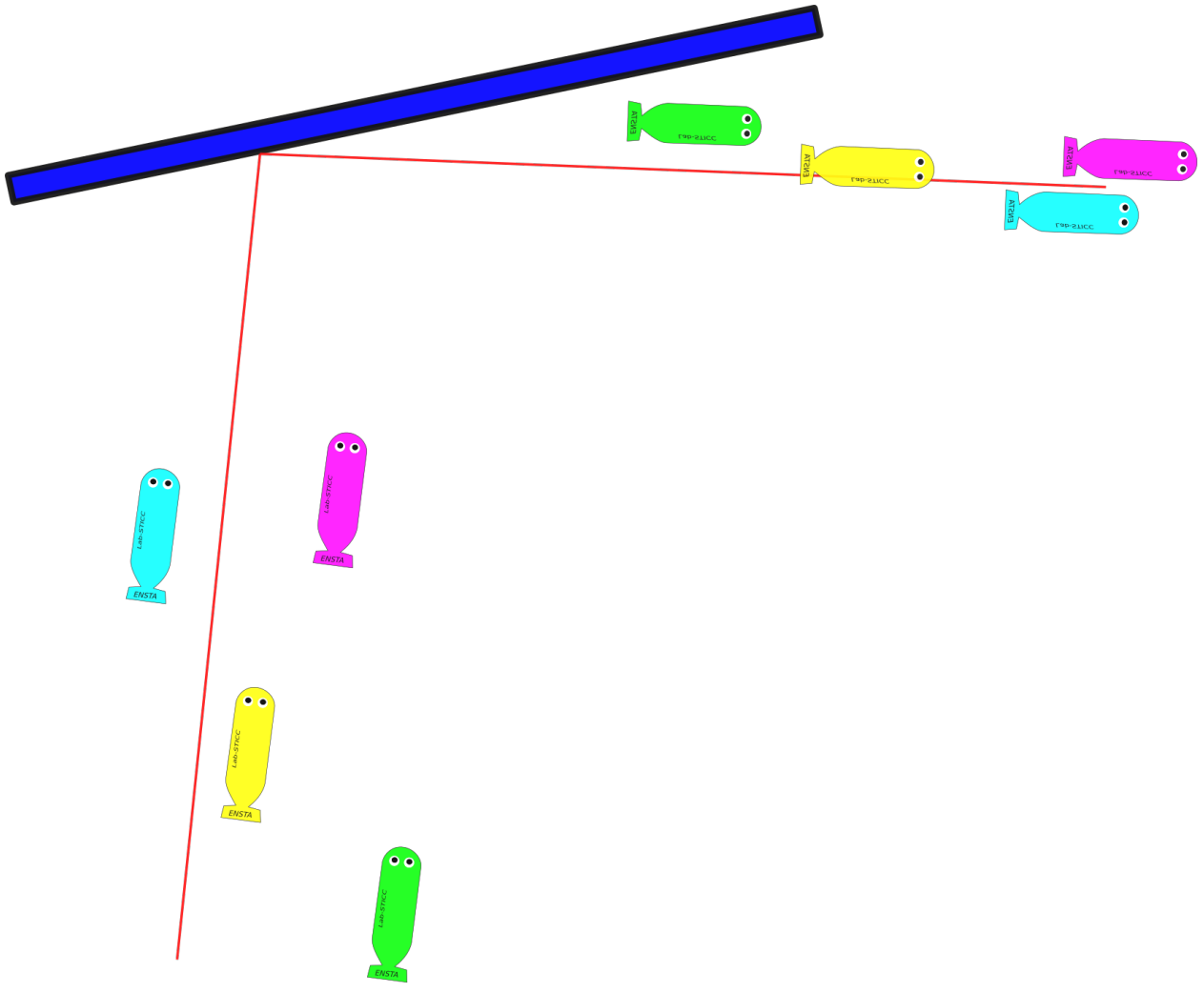

$V_2(\mathbf{p}) = 14$
$V_2(\mathbf{p}) = 15$
$V_2(\mathbf{p}) = 16$
A
B
$V_1(\mathbf{p}) = 51$
$V_1(\mathbf{p}) = 50$
$V_1(\mathbf{p}) = 49$
$t = 0$

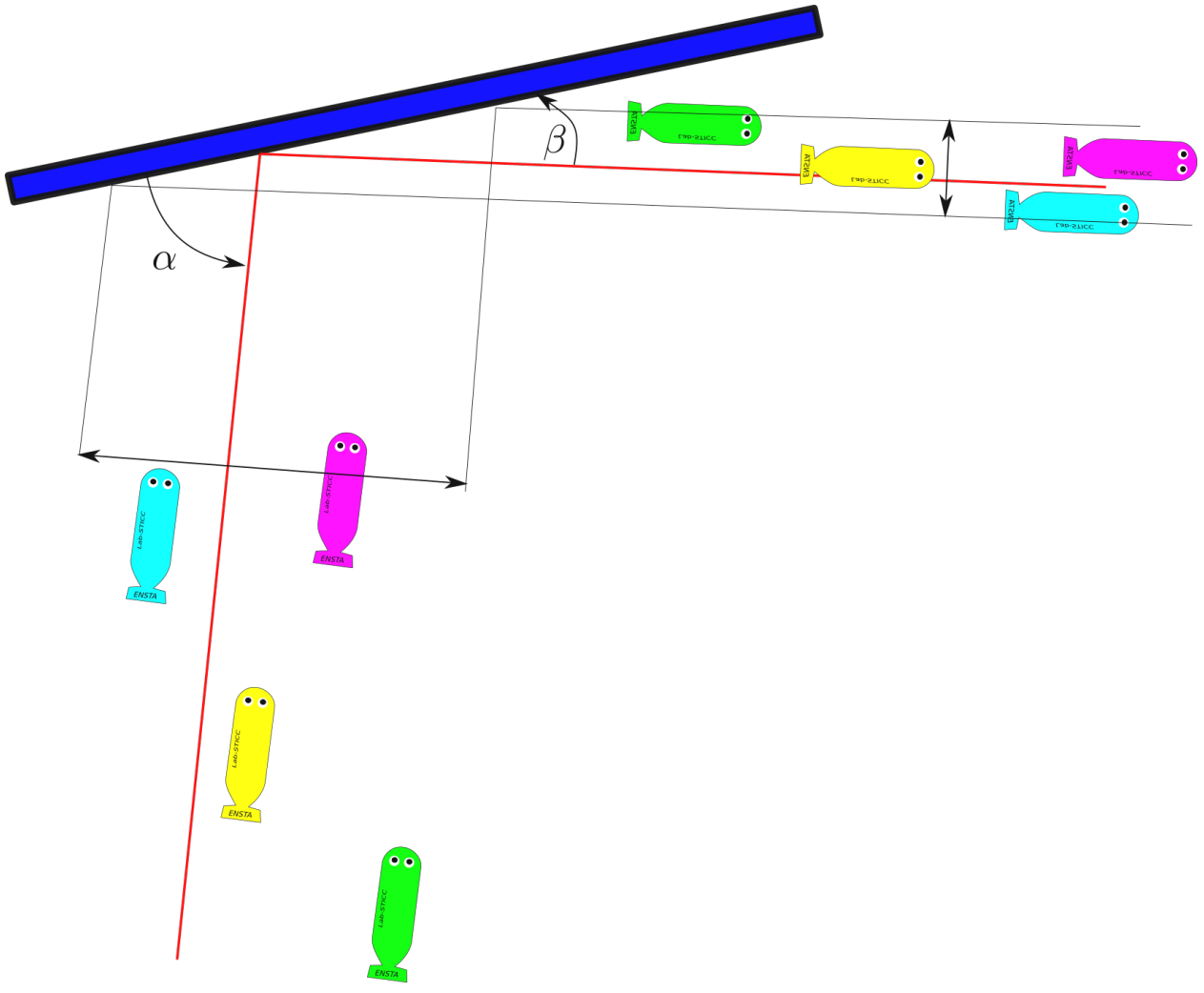

$V_1 = 50\text{m}$
A
B
$V_2 = 15^\circ$

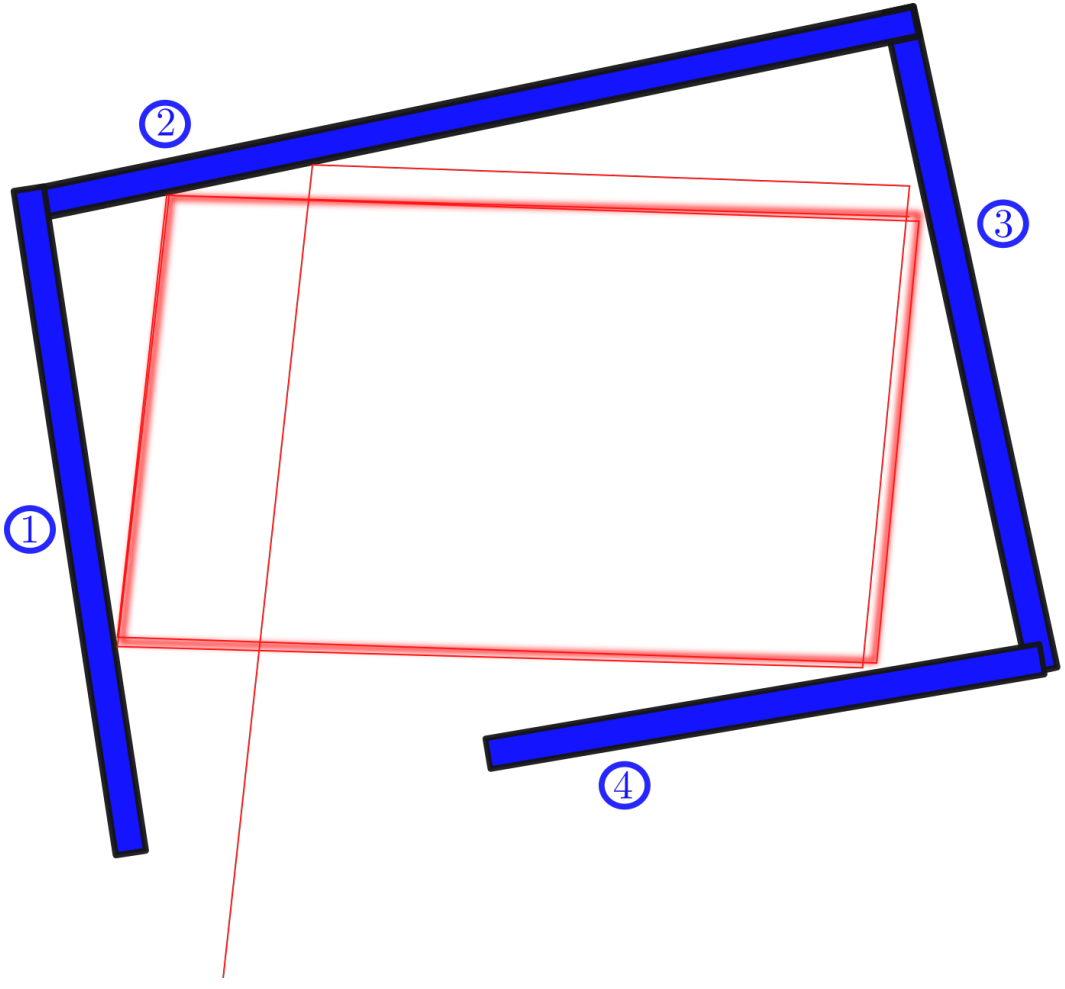
Stable cycles [3][1]

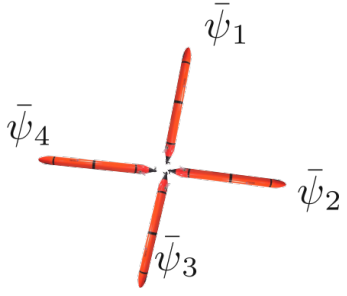


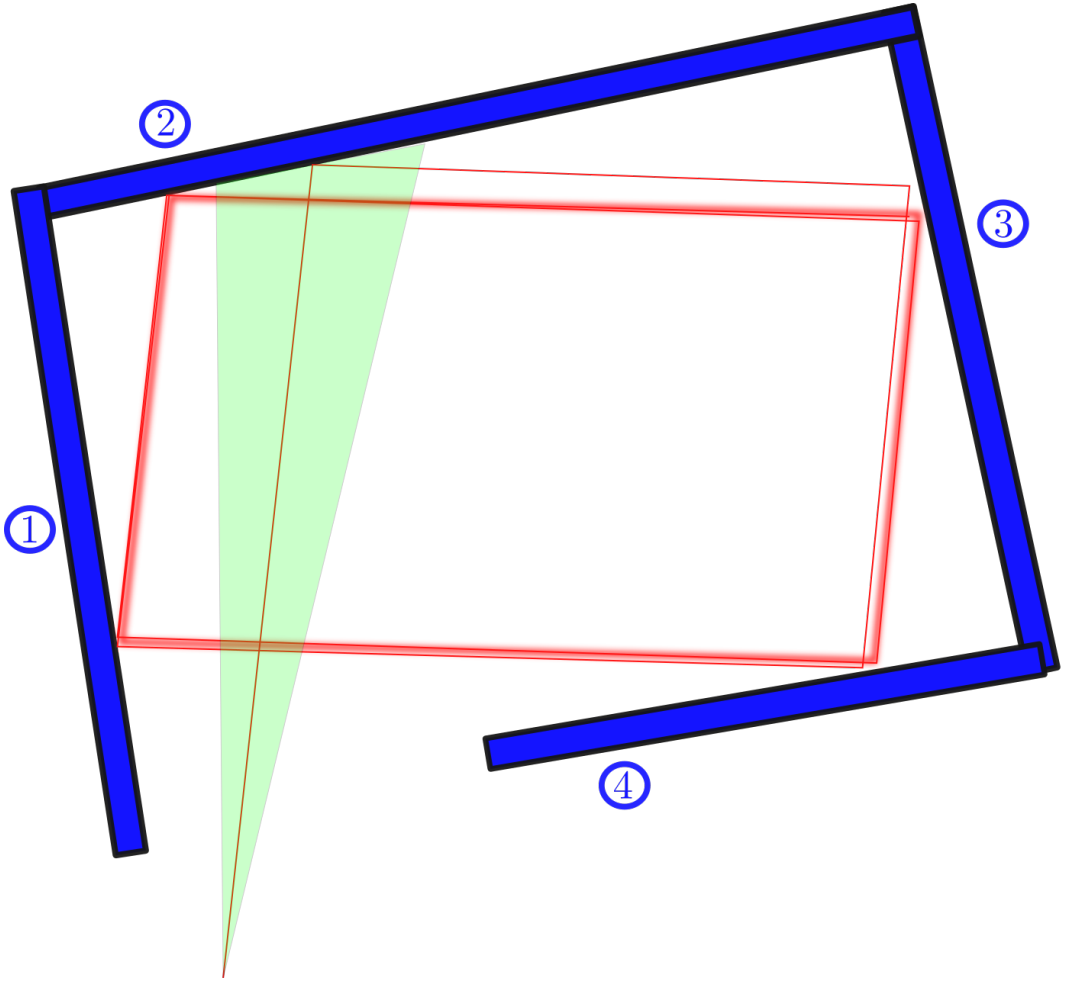
No route exists

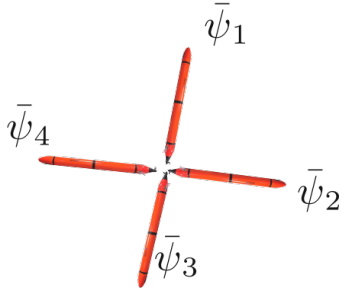

ENSTA
ENSTA
ENSTA
ENSTA
ENSTA
ENSTA
ENSTA
ENSTA
ENSTA


β
α


2
3
1
4


$\bar{\psi}_1$
$\bar{\psi}_4$
$\bar{\psi}_2$
$\bar{\psi}_3$


2
3
1
4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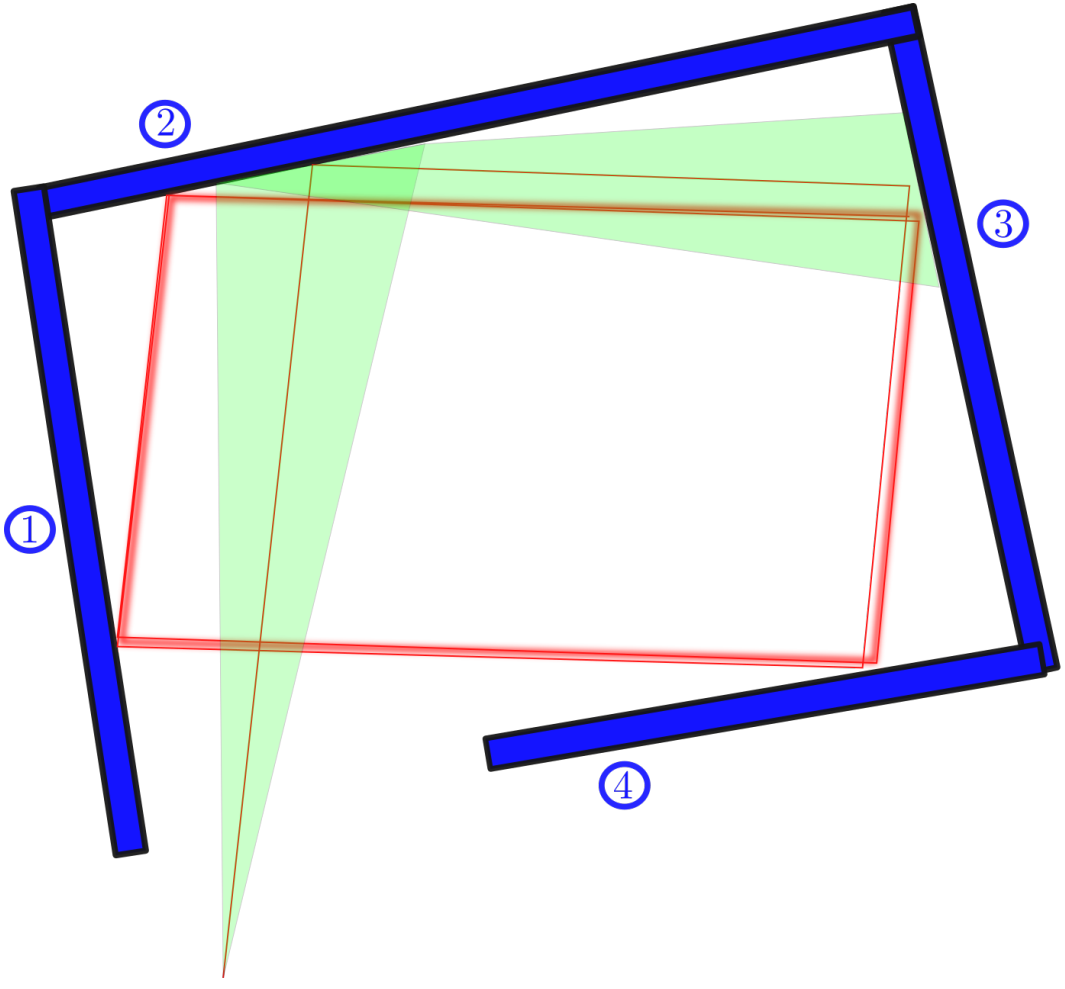
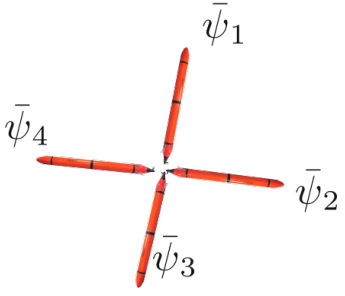
$\bar{\psi}_4$
$\bar{\psi}_2$
$\bar{\psi}_3$


2
3
1
4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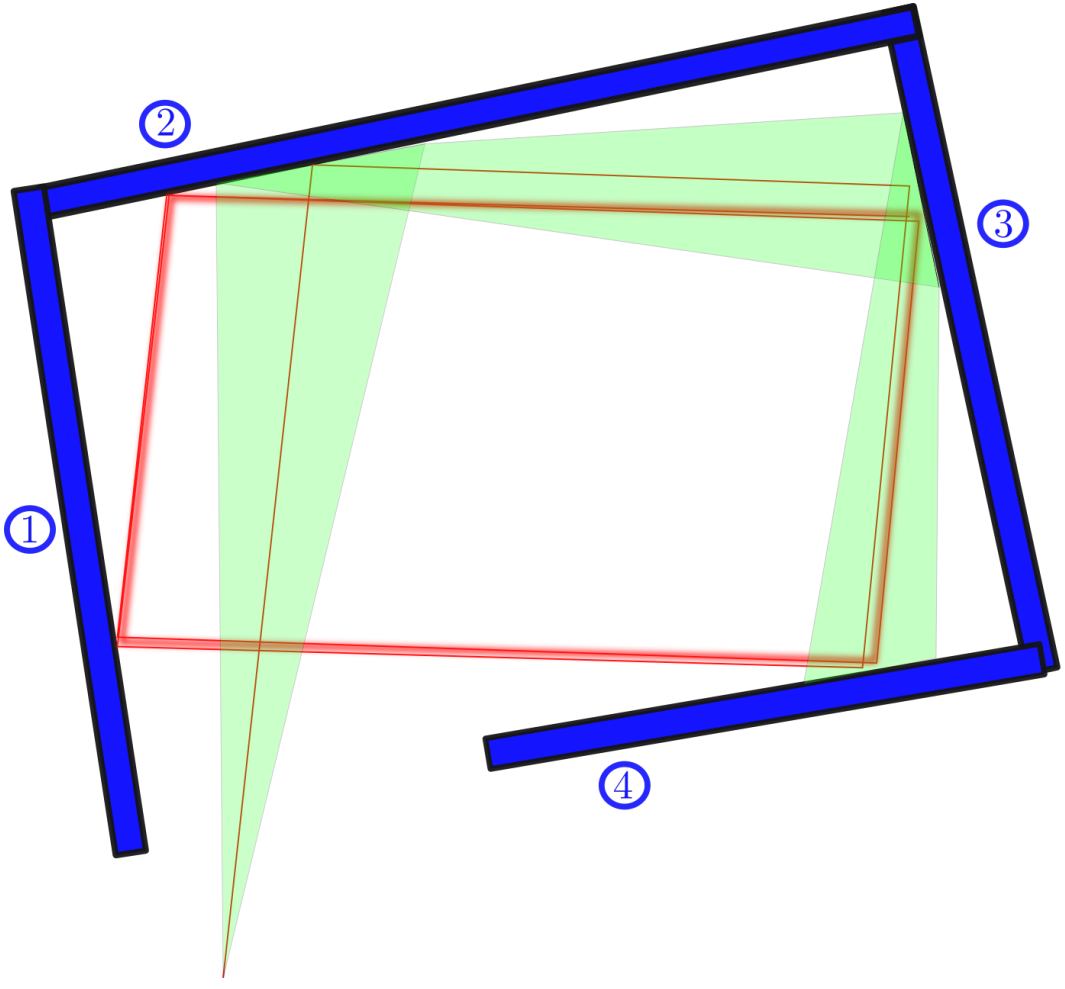
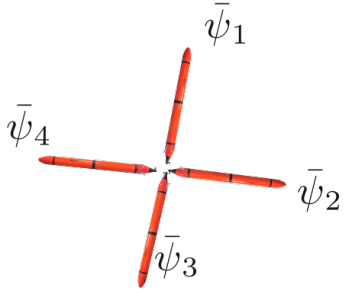
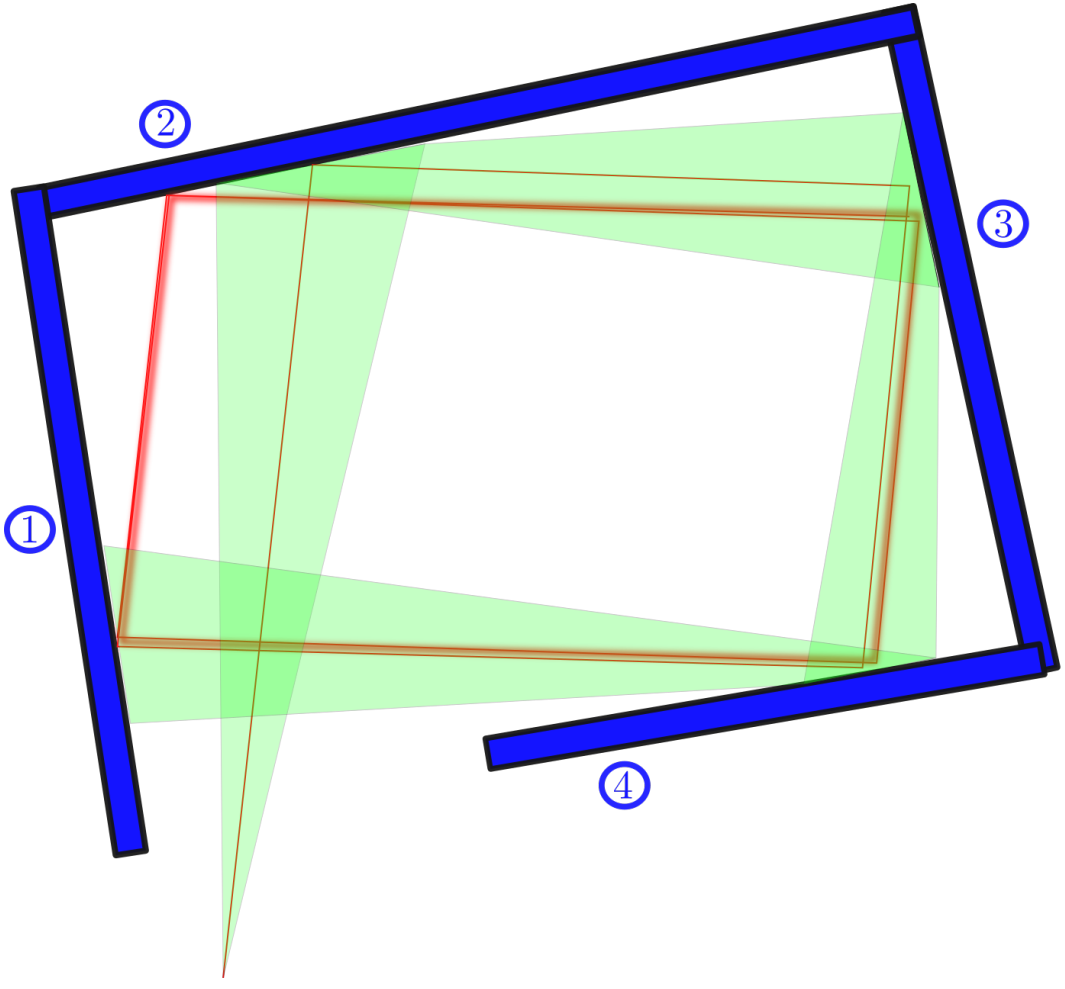
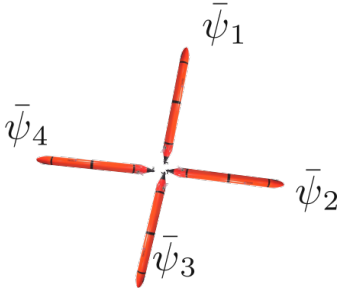
$\bar{\psi}_4$
$\bar{\psi}_2$
$\bar{\psi}_3$


2
3
1
4


$\bar{\psi}_1$
$\bar{\psi}_4$
$\bar{\psi}_2$
$\bar{\psi}_3$


2
3
1
4


$\bar{\psi}_1$
$\bar{\psi}_4$
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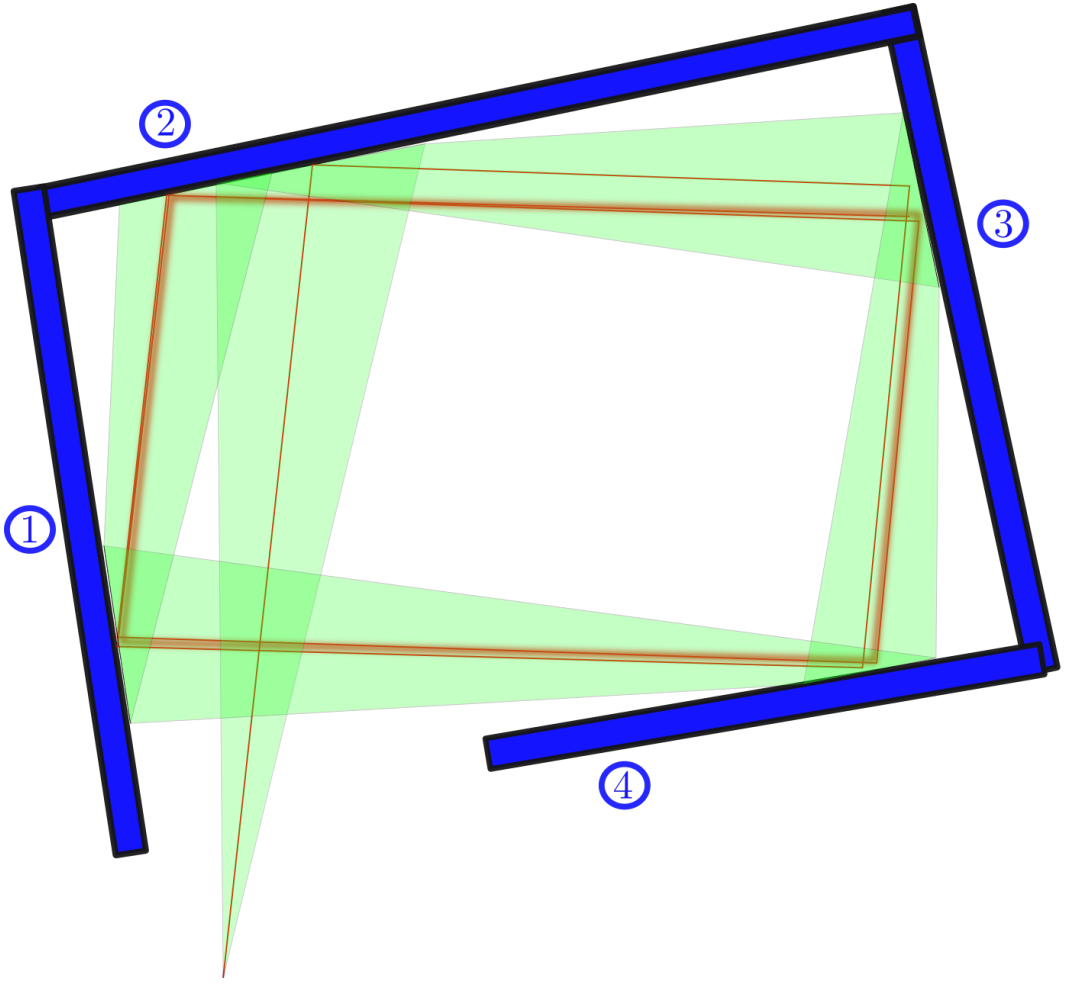
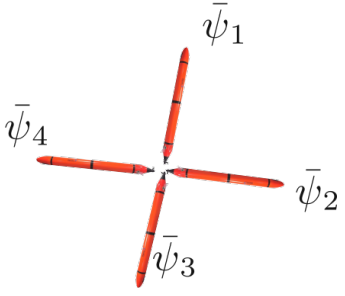

2
3
1
4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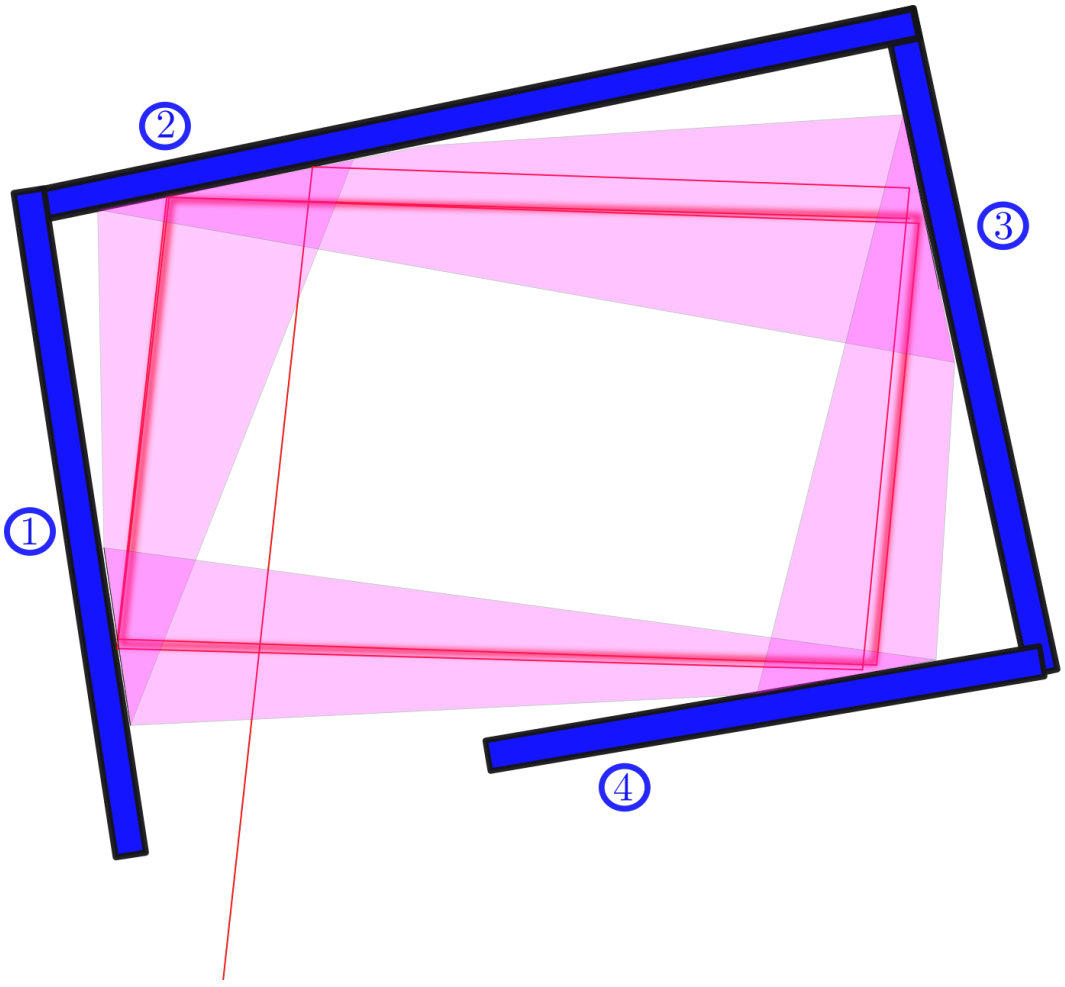
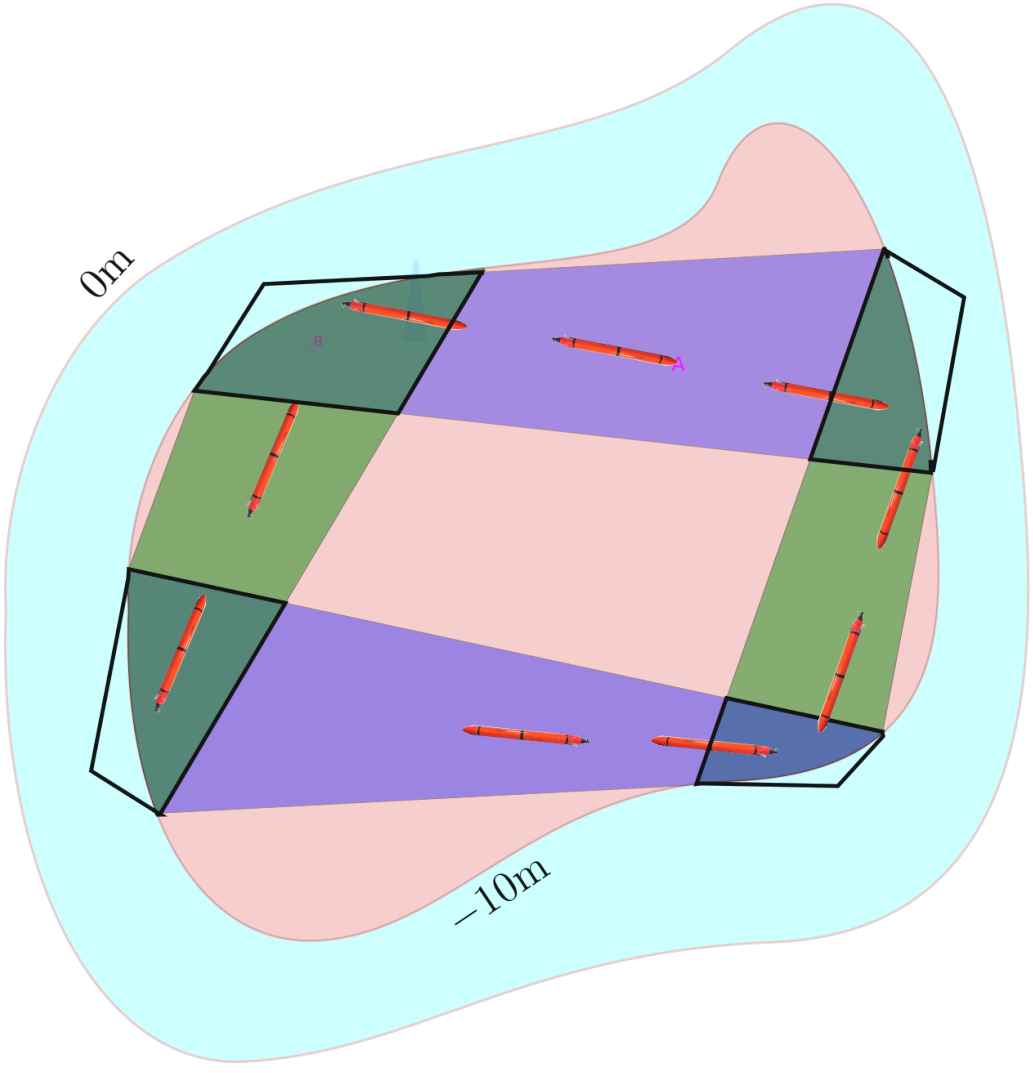
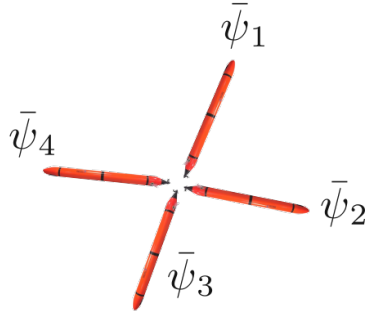
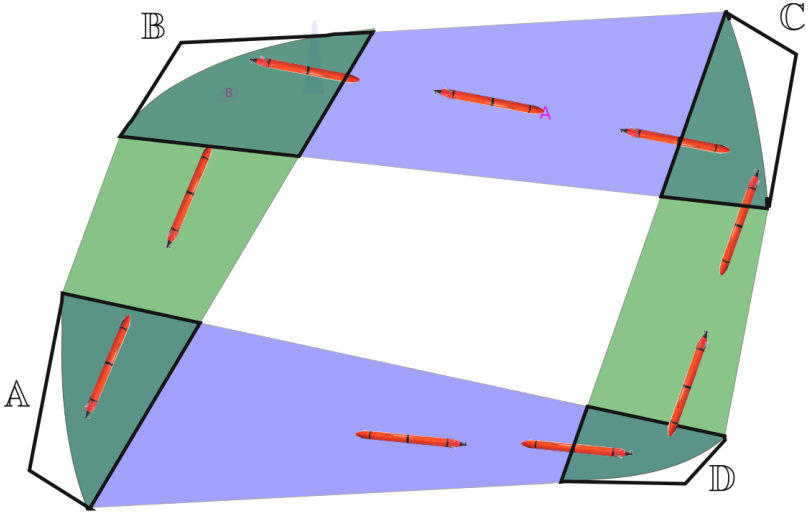
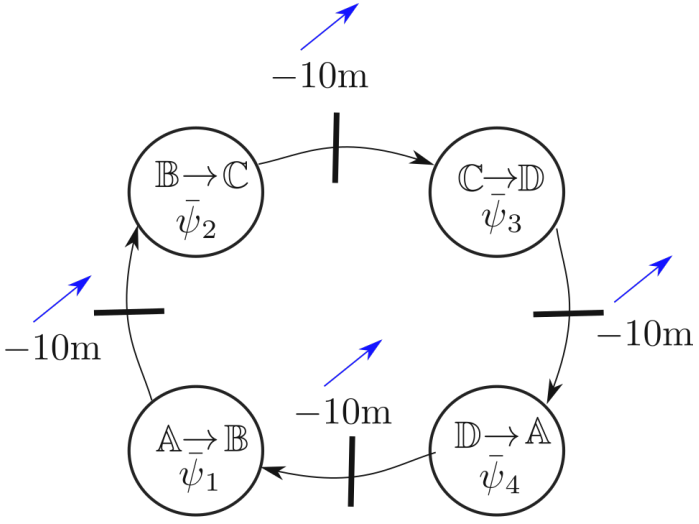
$\bar{\psi}_4$
$\bar{\psi}_2$
$\bar{\psi}_3$


2
3
1
4


0m
−10m


$\bar{\psi}_1$
$\bar{\psi}_4$
$\bar{\psi}_2$
$\bar{\psi}_3$


𝔹
ℂ
𝔸
𝔻

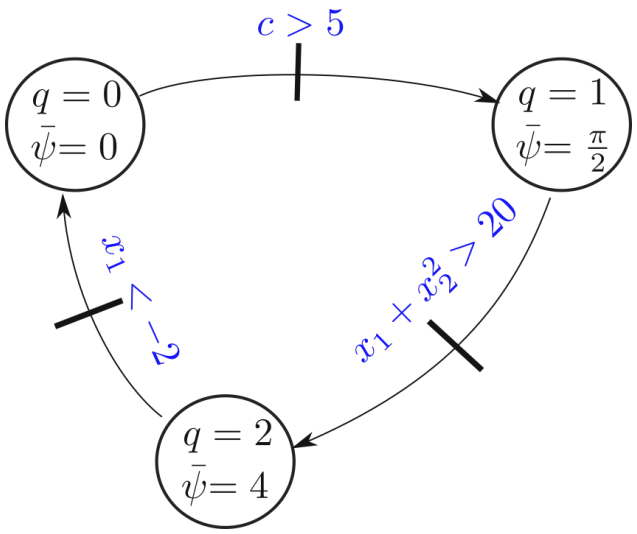

−10m
𝔹→ℂ
$\bar{\psi}_2$
ℂ→𝔻
$\bar{\psi}_3$
−10m
−10m
−10m
𝔸→𝔹
$\bar{\psi}_1$
𝔻→𝔸
$\bar{\psi}_4$

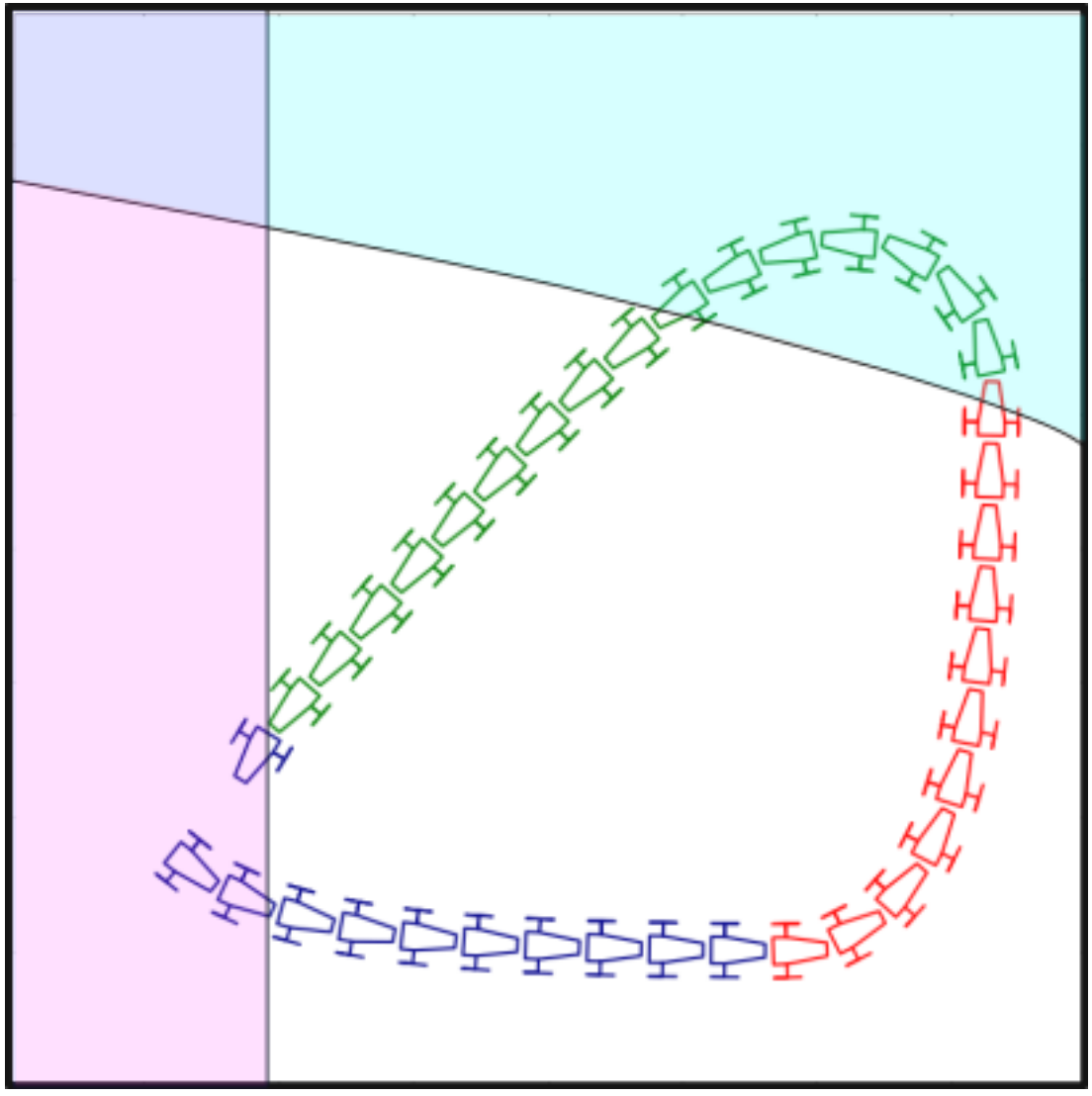
Test-case

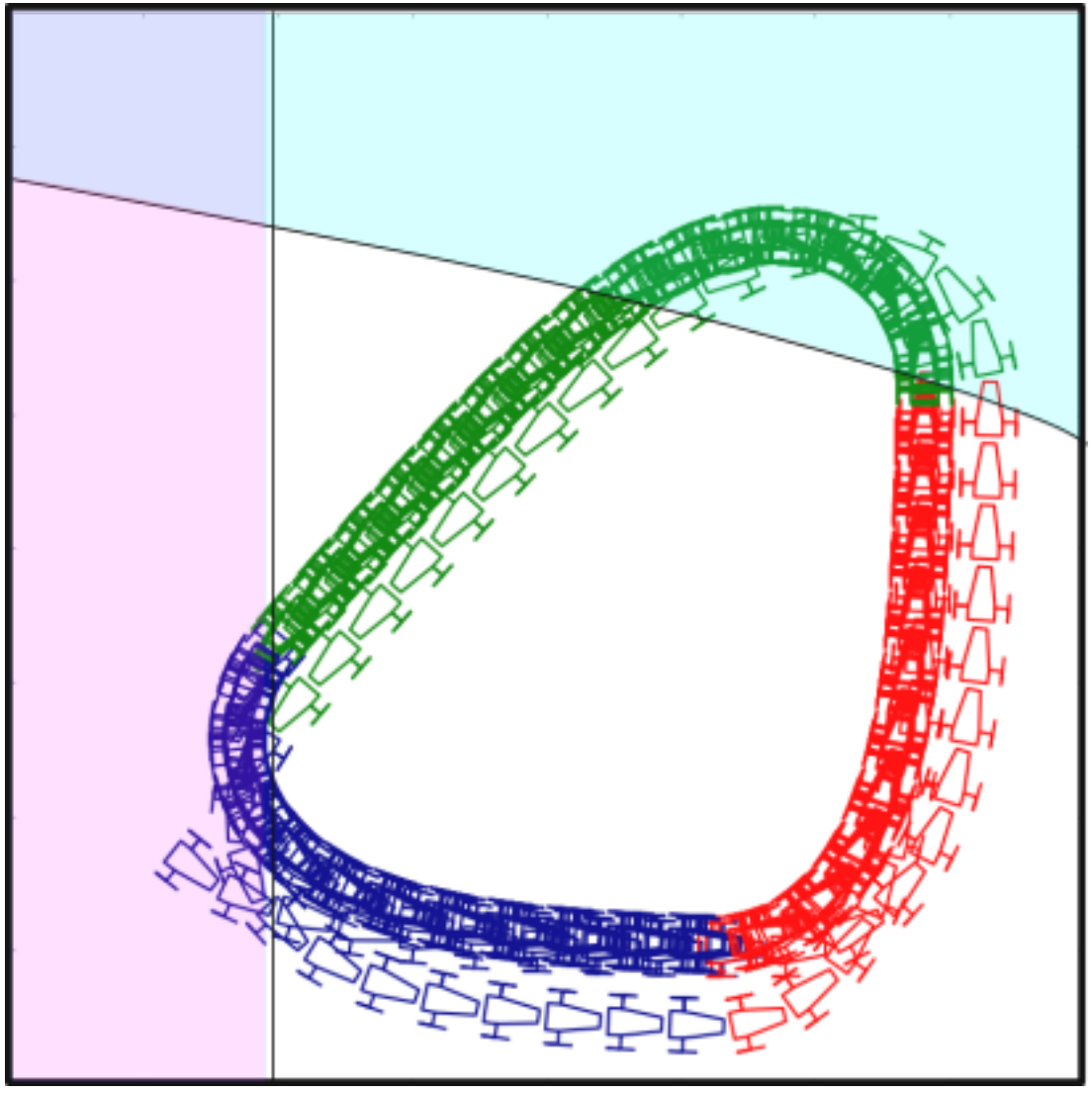
Consider the robot [2]

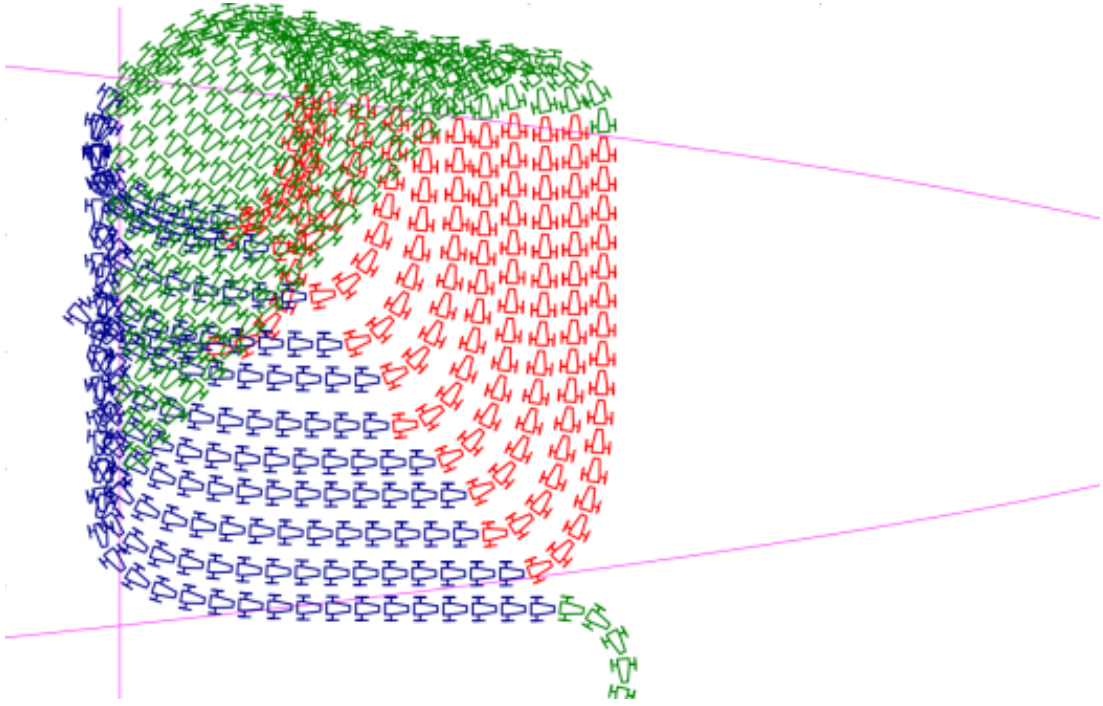
$$\begin{cases} \dot{x}_1 &= \cos x_3 \\ \dot{x}_2 &= \sin x_3 \\ \dot{x}_3 &= u \end{cases}$$

with the heading control $u = \sin(\bar{\psi} - x_3)$.







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