A. EL JAWAD, B. RAYMOND, E. ROUAULT,
F. LE BARS, P. ROUSSEAU

COMPLEX ROBOT BEHAVIOUR CREATION USING VECTOR FIELDS AT WRSC 2016

PLAN

I. Existing work

II. Construction method

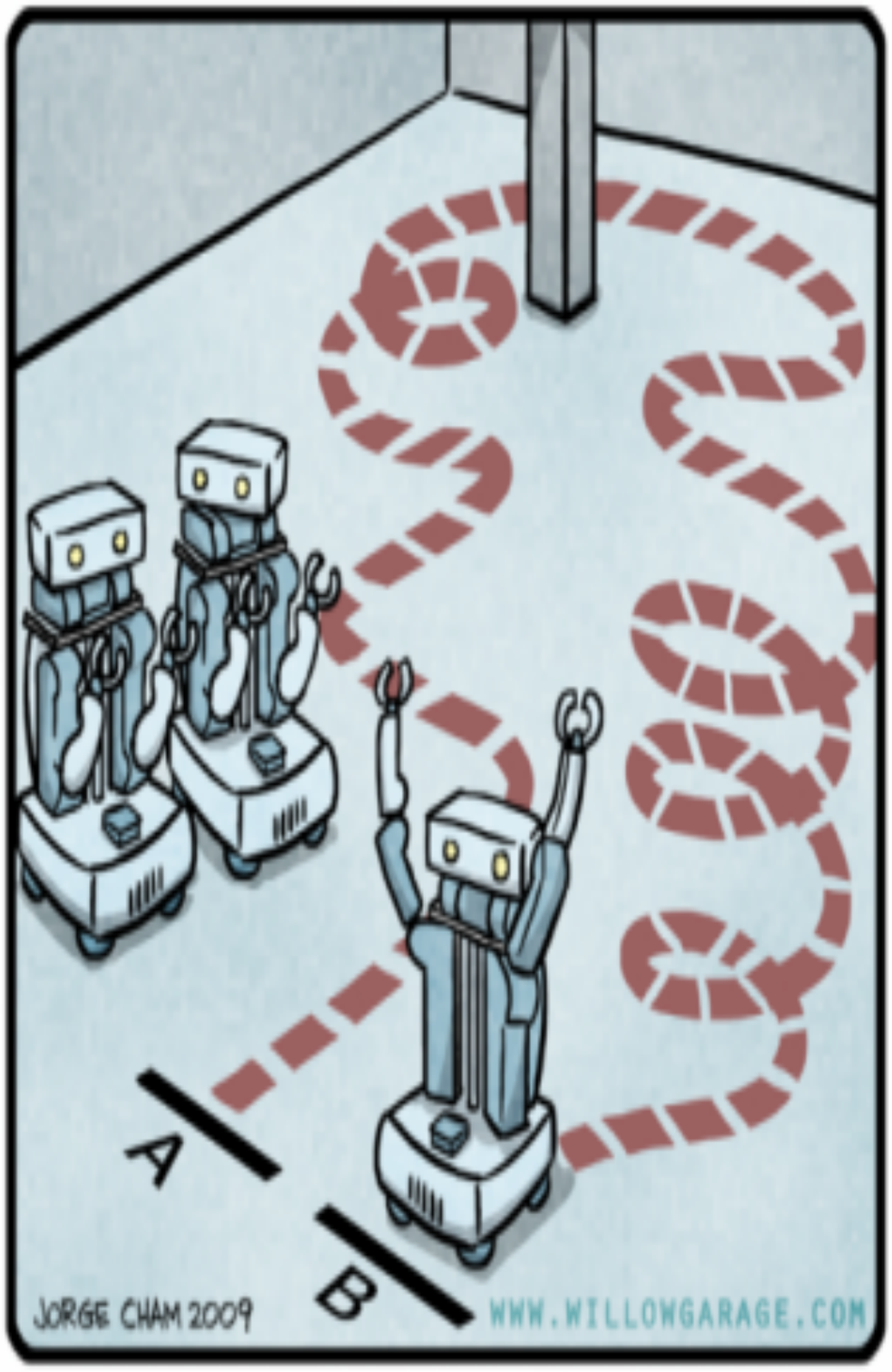
III. Implementation

1. Architecture

2. Simulation, Tests & Results

IV. WRSC 2016

V. Conclusion & Discussions



"HIS PATH-PLANNING MAY BE SUB-OPTIMAL, BUT IT'S GOT FLAIR."

MOTION PLANNING FOR COMPLEX BEHAVIOURS

EXISTING WORK

- Robot control is a complex task
- Generalised rules

"AT THE EXECUTION LEVEL IT CAN BE DESCRIBED AS A COLLECTION OF BEHAVIOURS "

C. ARKIN

SEVERAL SOLUTIONS

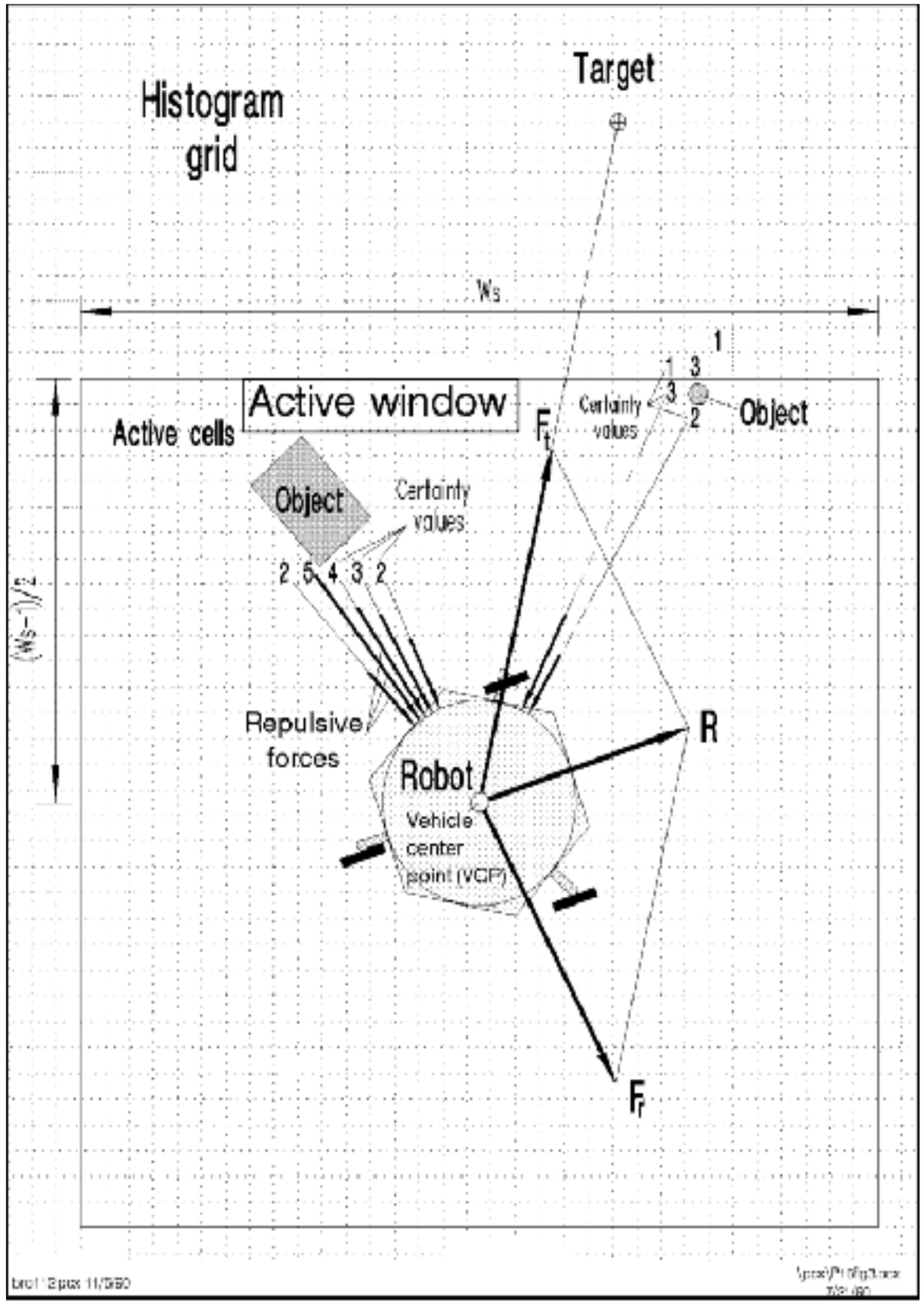
- Grid-based search
- Interval-based search
- Geometric algorithm
- Potential & Vector fields

SEVERAL SOLUTIONS

- Grid-based search
- Interval-based search
- Geometric algorithm
- Potential & Vector fields
  - Elegant
  - Simplicity of implementation

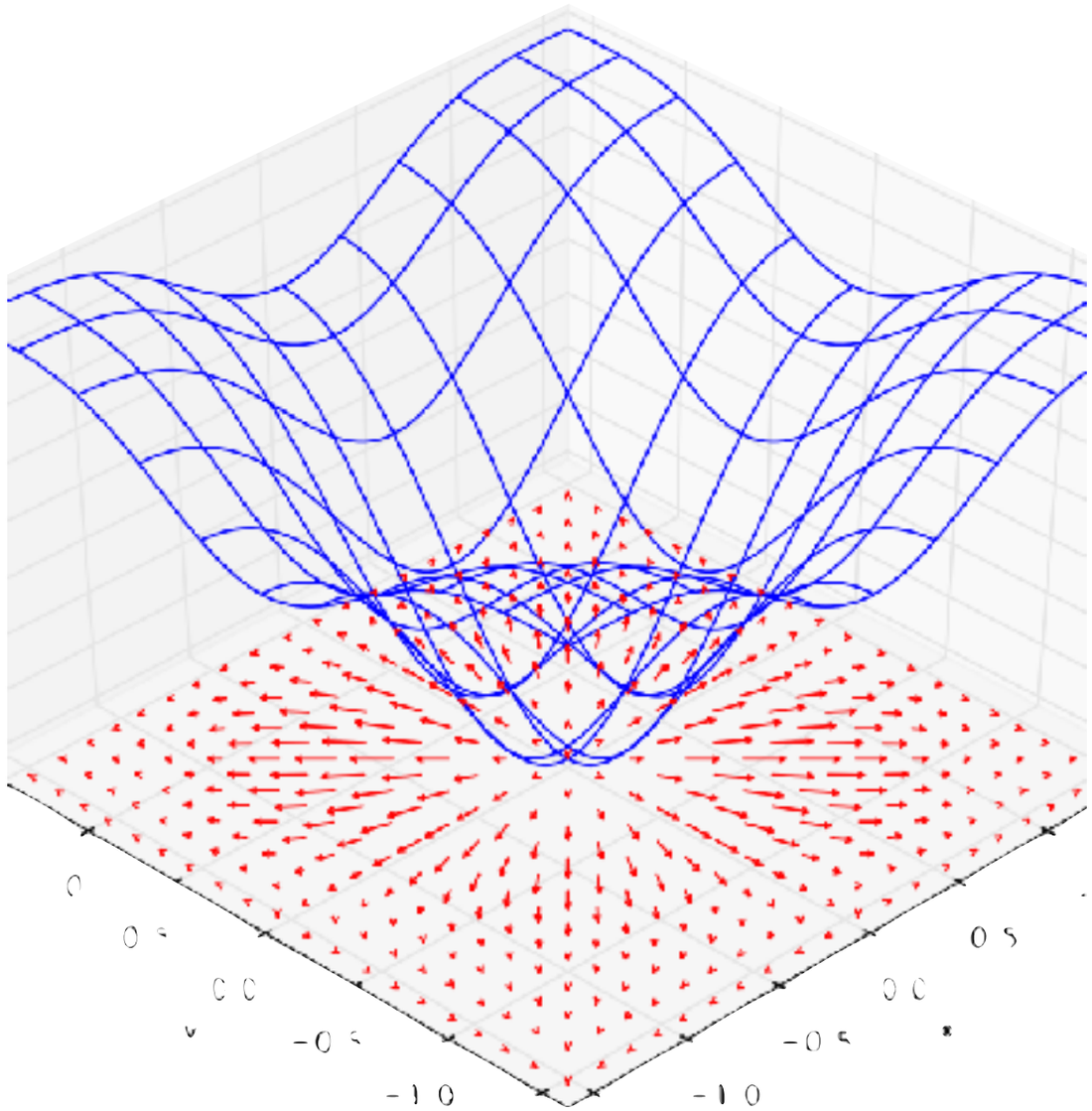
VIRTUAL FORCE FIELD

- 2D-Cartesian grid
- Each cell generates a repulsive force
- Target generates attractive field
- Total force



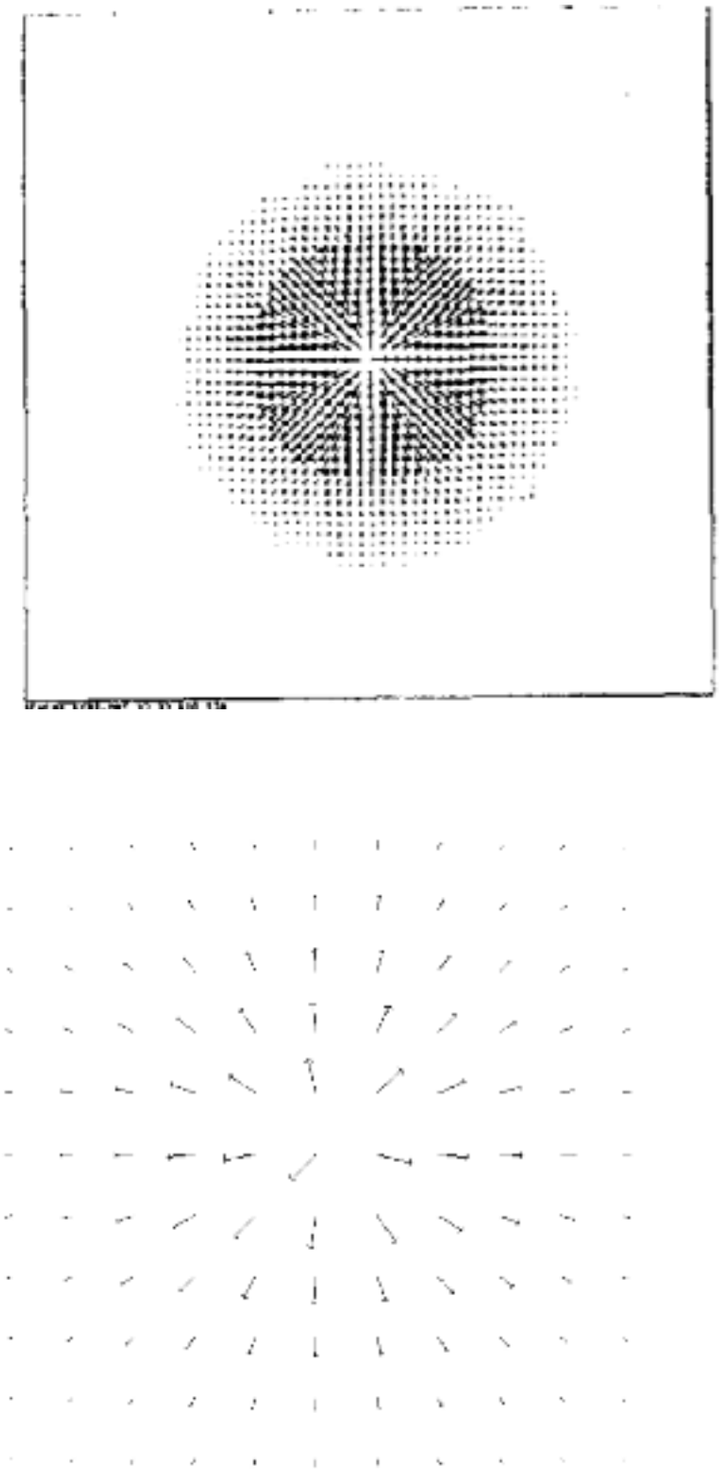
GRADIENT DESCENT

- 2D-cartesian grid for the potential field
- Doing a gradient descent on the 2D matrix to generate a vector field
- Use vector for steering and speed

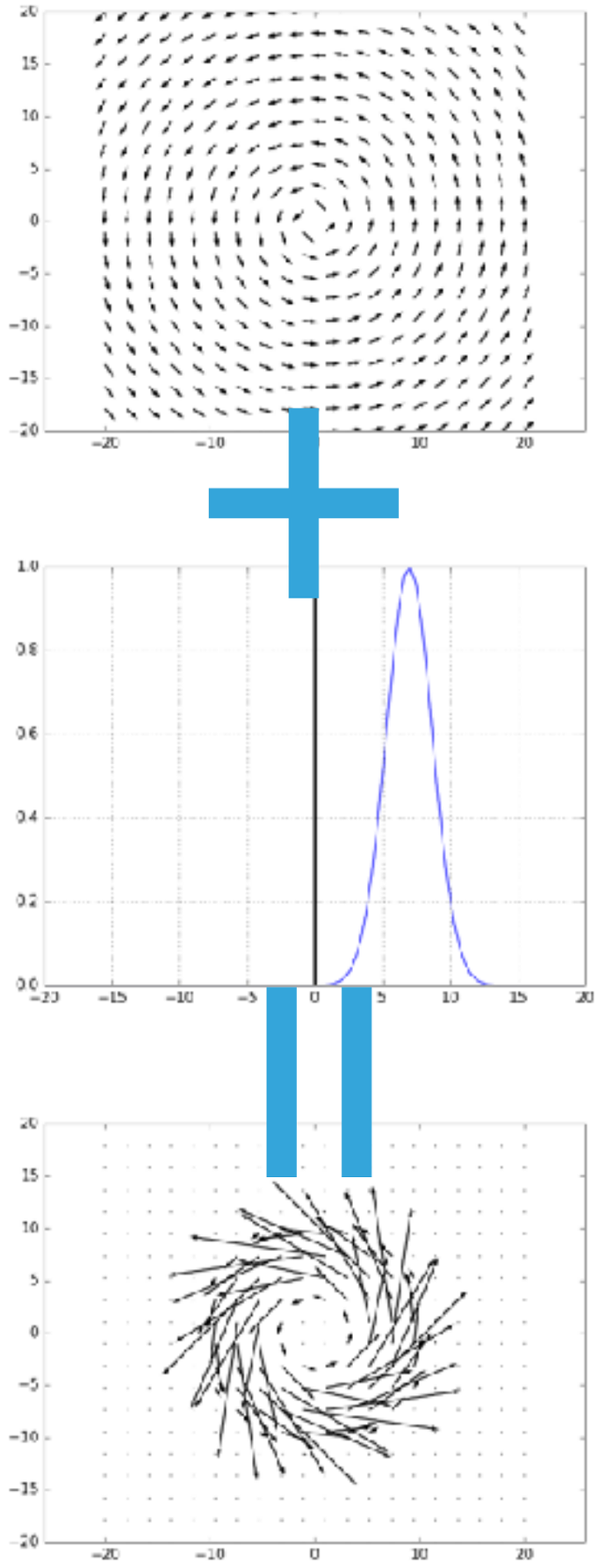


GENERATE VECTOR FIELD DIRECTLY

- Generic functions for each behaviour
- More flexibility
- More various fields



(b) Repulsive Point



CONSTRUCTION METHOD

VECTOR FIELD CONSTRUCTION

S. SCHMITT IMPLEMENTATION

- General solutions for obstacle avoidance
- Ocean environments - less vector field limitations
- Complex vector fields = combination of '*atomic*' fields
  - addition
  - rotation
  - translation
  - scaling

INTRODUCTION TO OUR IMPLEMENTATION

- Using R.O.S.
- Modularity to create complex fields
- Focus on velocity control
- Vector fields instead of potential fields

VECTOR FIELDS DEFINITION

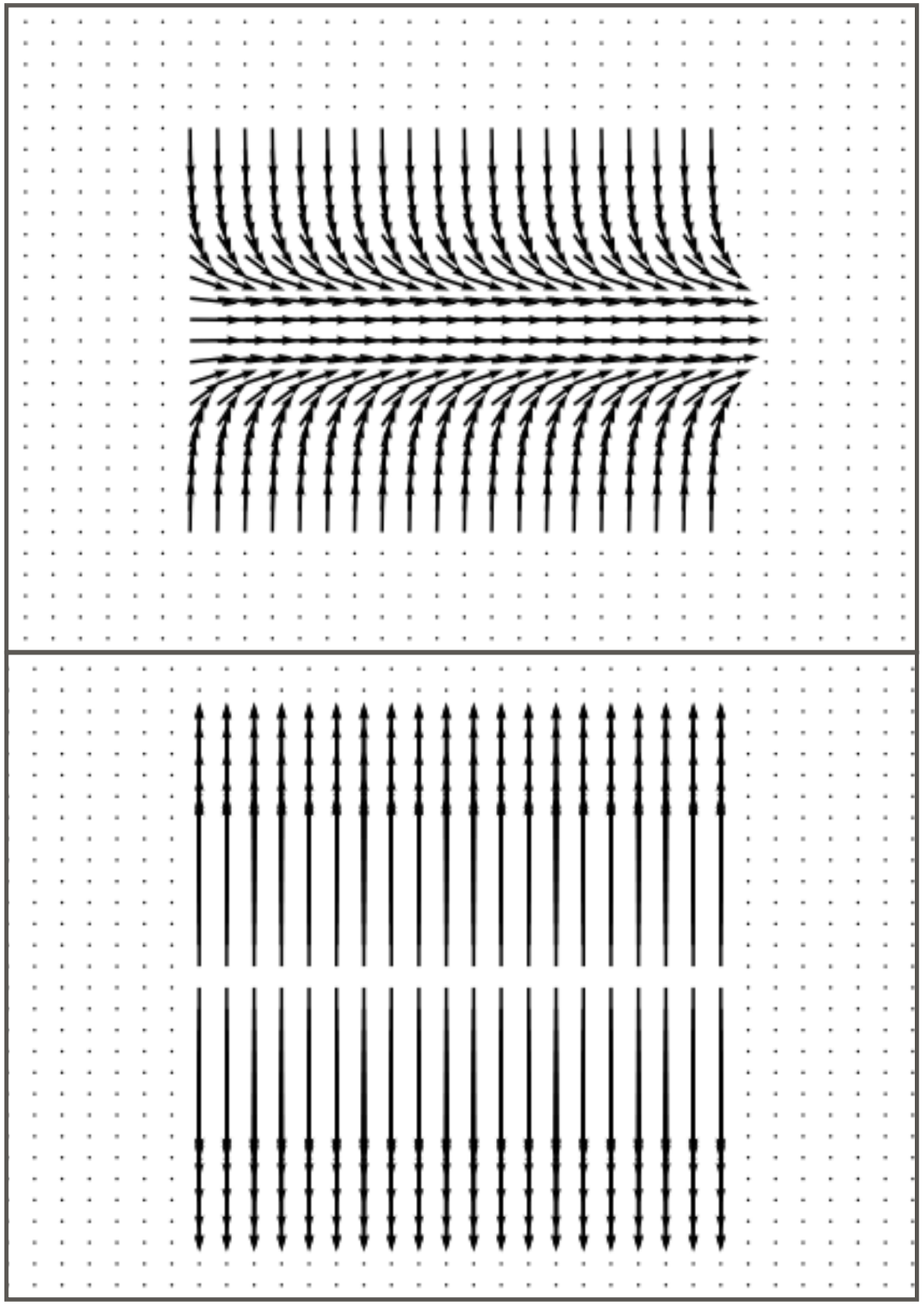
- Function

$$f : \mathbb{R}^2 \to \mathbb{R}^2$$
$$(x, y) \mapsto f(x, y)$$

- $\|f(x, y)\|$ is the desired speed to within a constant
- $tan^{-1}(\frac{y}{x})$ is the desired heading

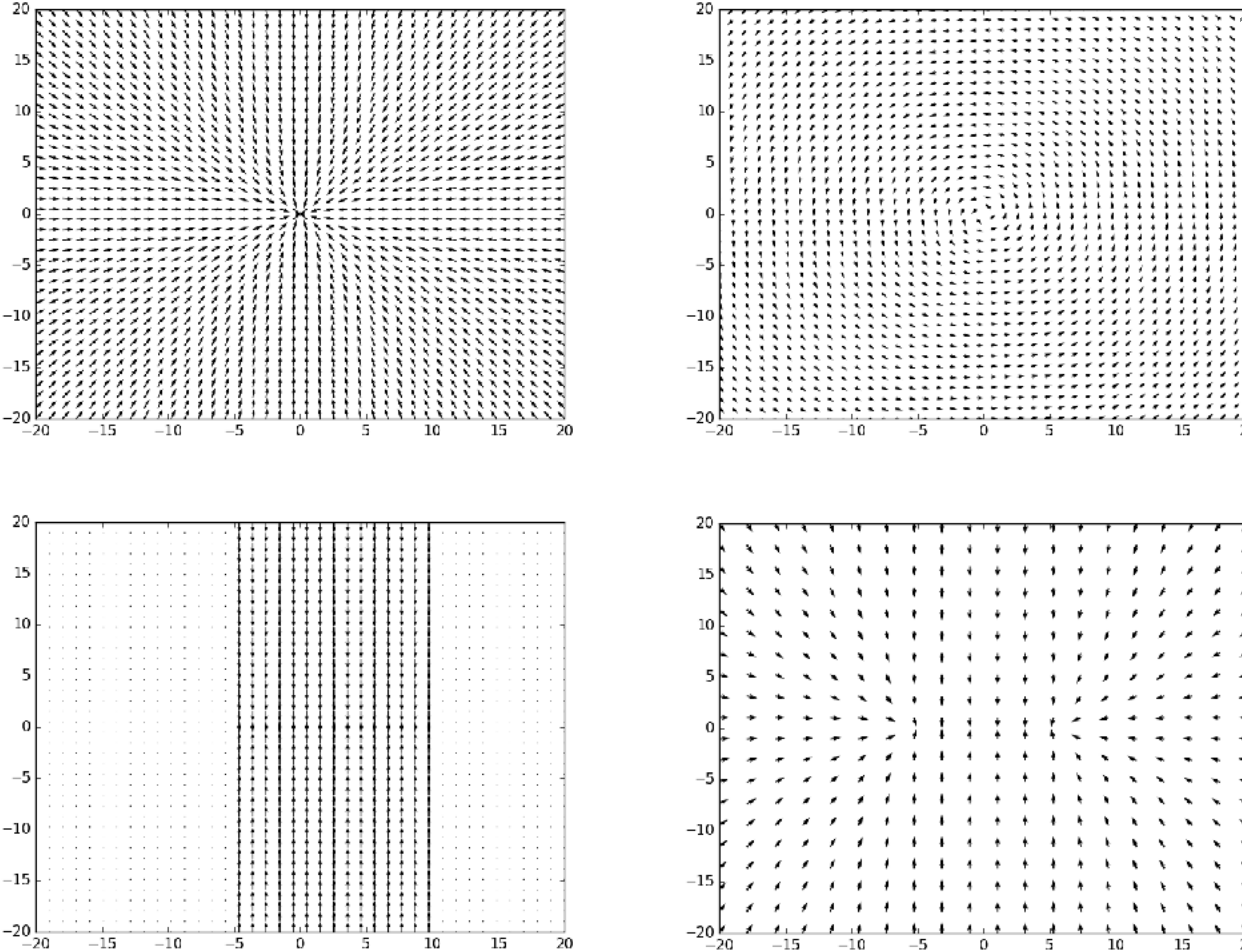
BLOCKS FOR MODULARITY

- Similarities in field construction:
  - Direction
  - Intensity modulation
- Simple blocks



FIELD DIRECTION

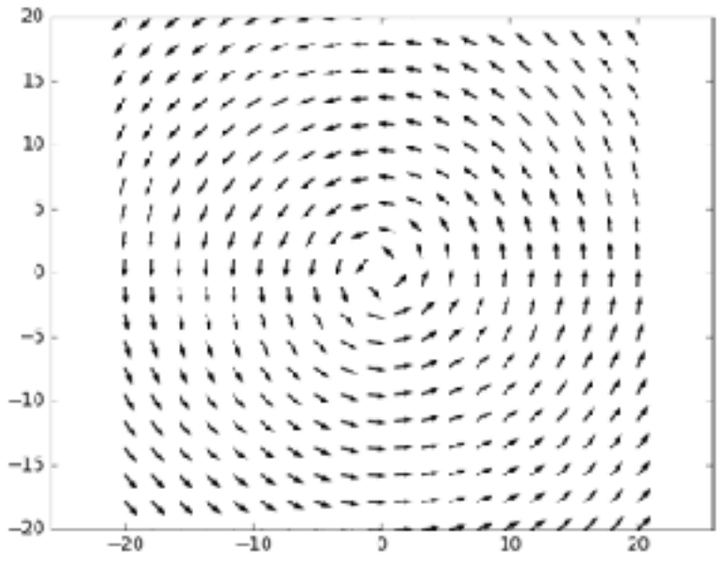
- Generate fields towards common behaviour shape:
  - point
  - line
    - segment
    - rotating
- Information about the position of the behaviour
- Methods for each simple field

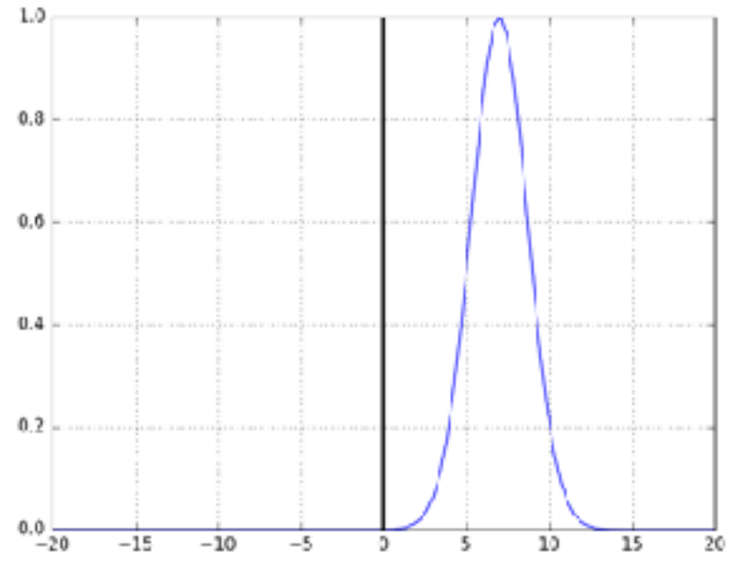

20 15 10 5 0 −5 −10 −15 −20
−20 −15 −10 −5 0 5 10 15 20

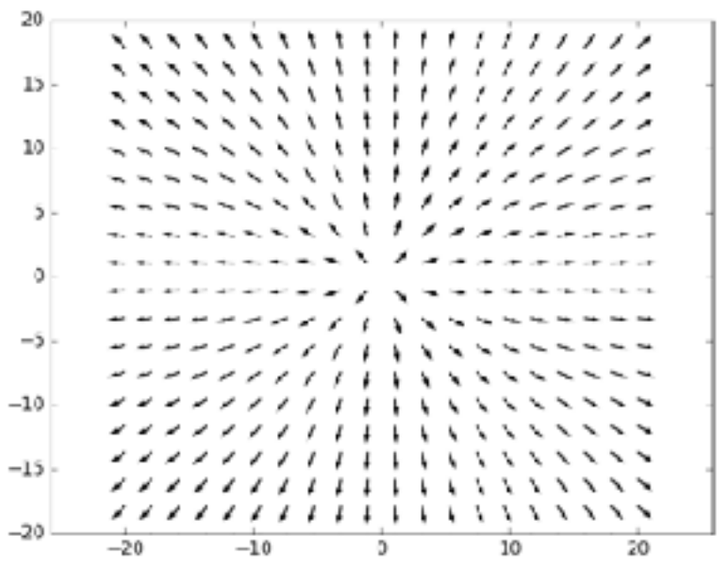
FIELD MODULATION

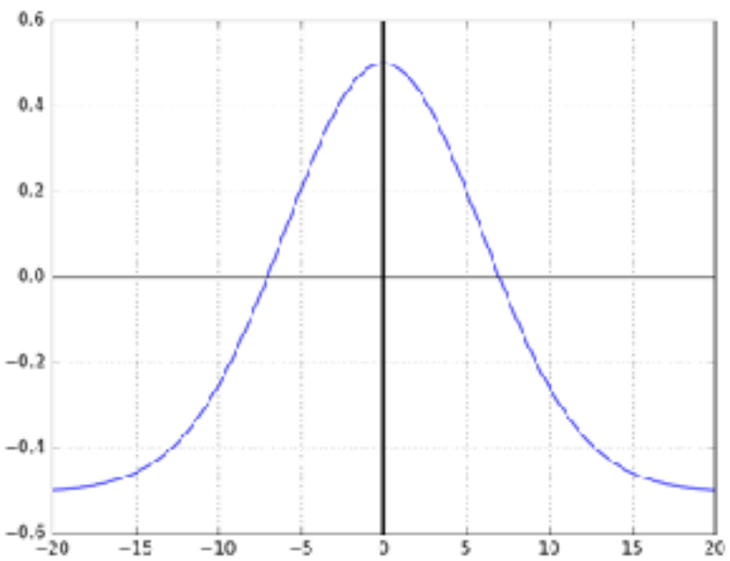
- Function of the distance to the behaviour location
- Calculation method for distance to behaviour shape
- Information about the velocity
- Various modulation = various fields

FIELD COMBINATION – EXAMPLE

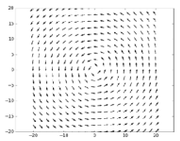


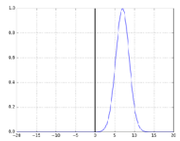


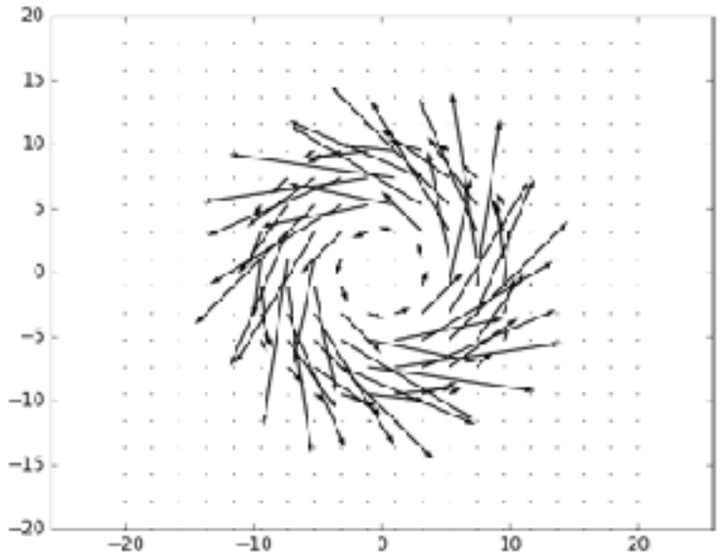


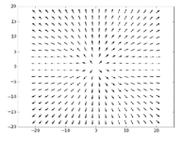


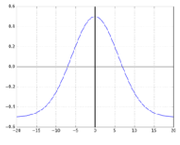
FIELD COMBINATION – EXAMPLE

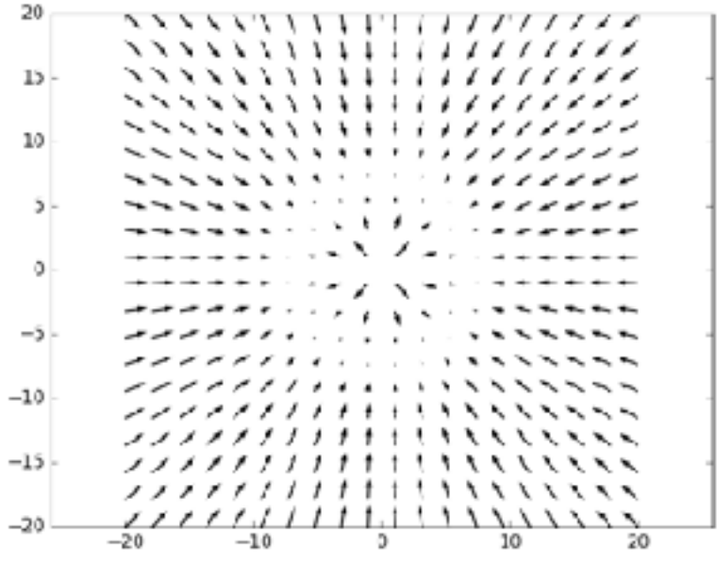


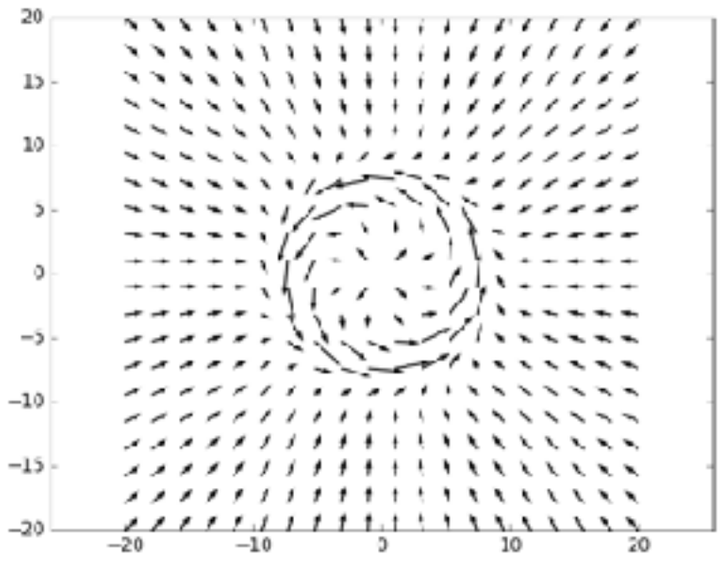


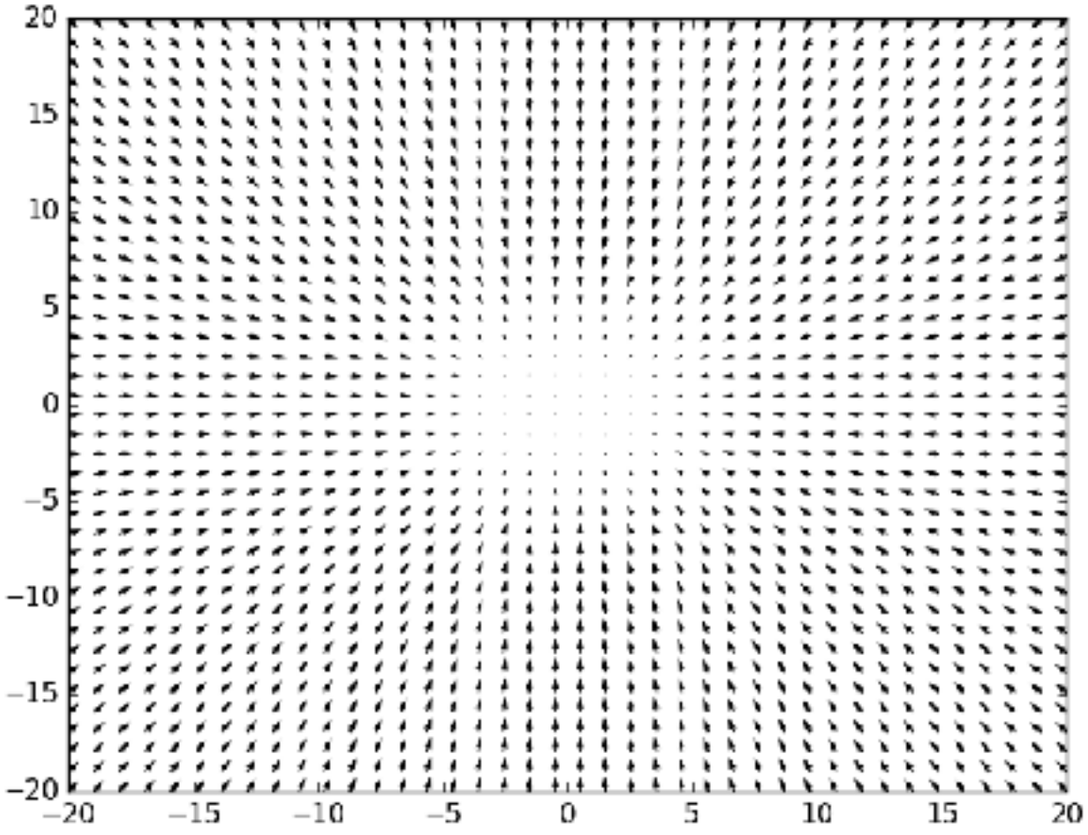








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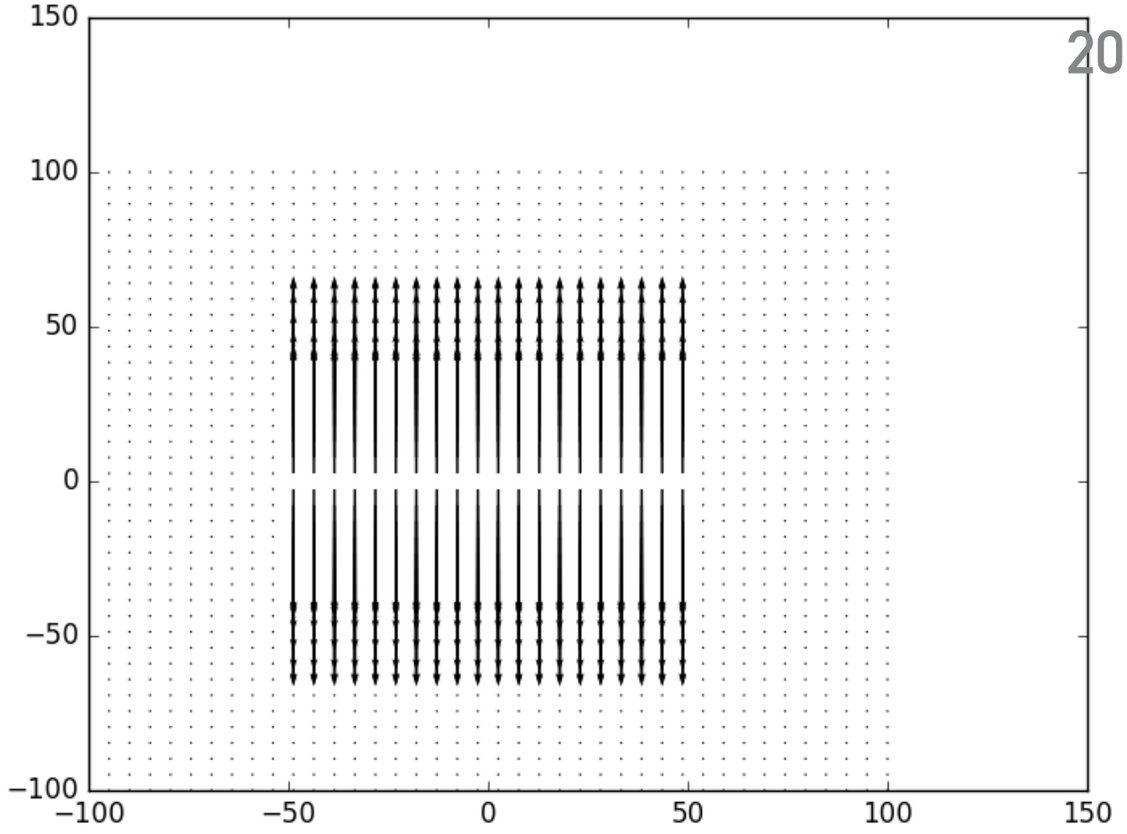
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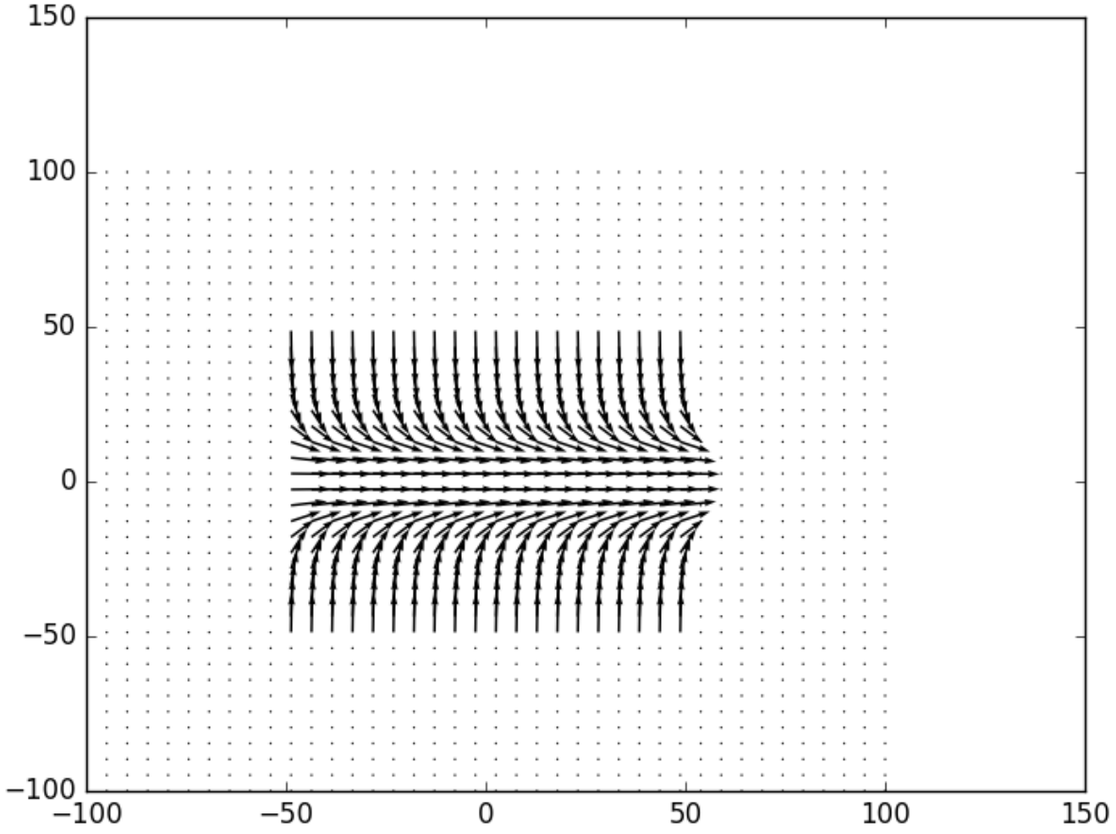
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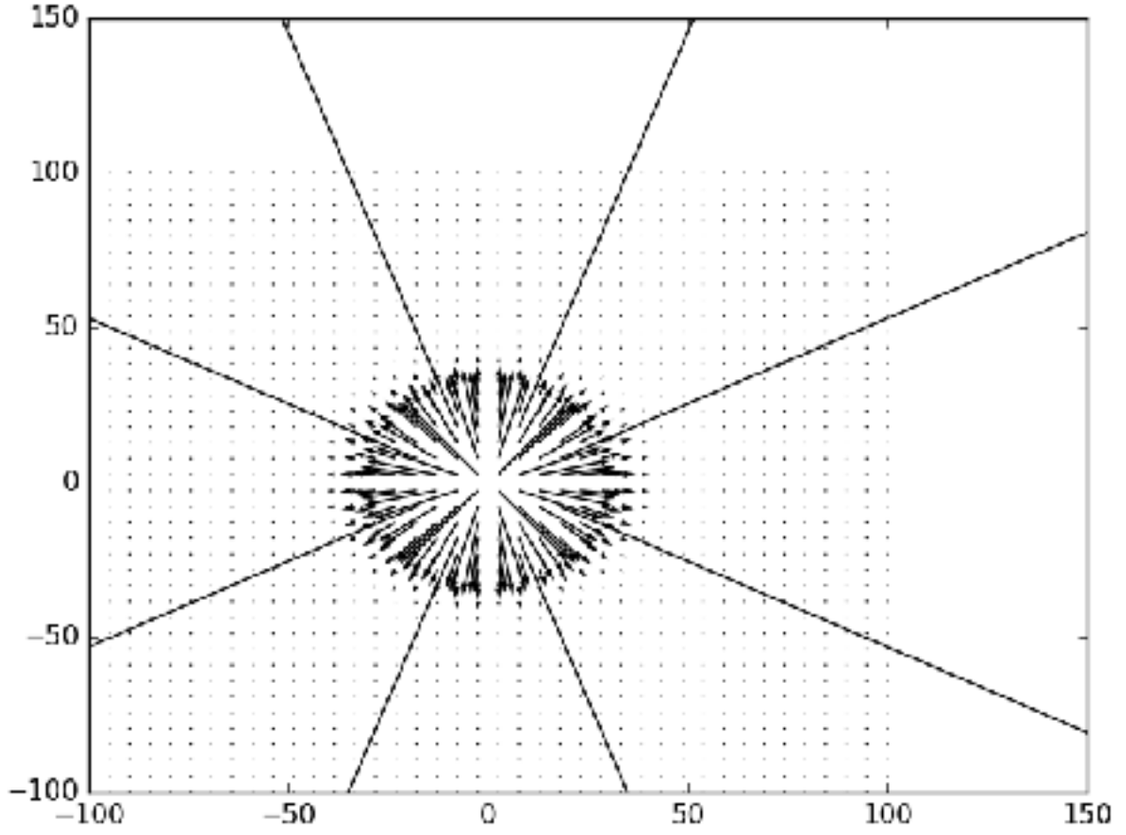
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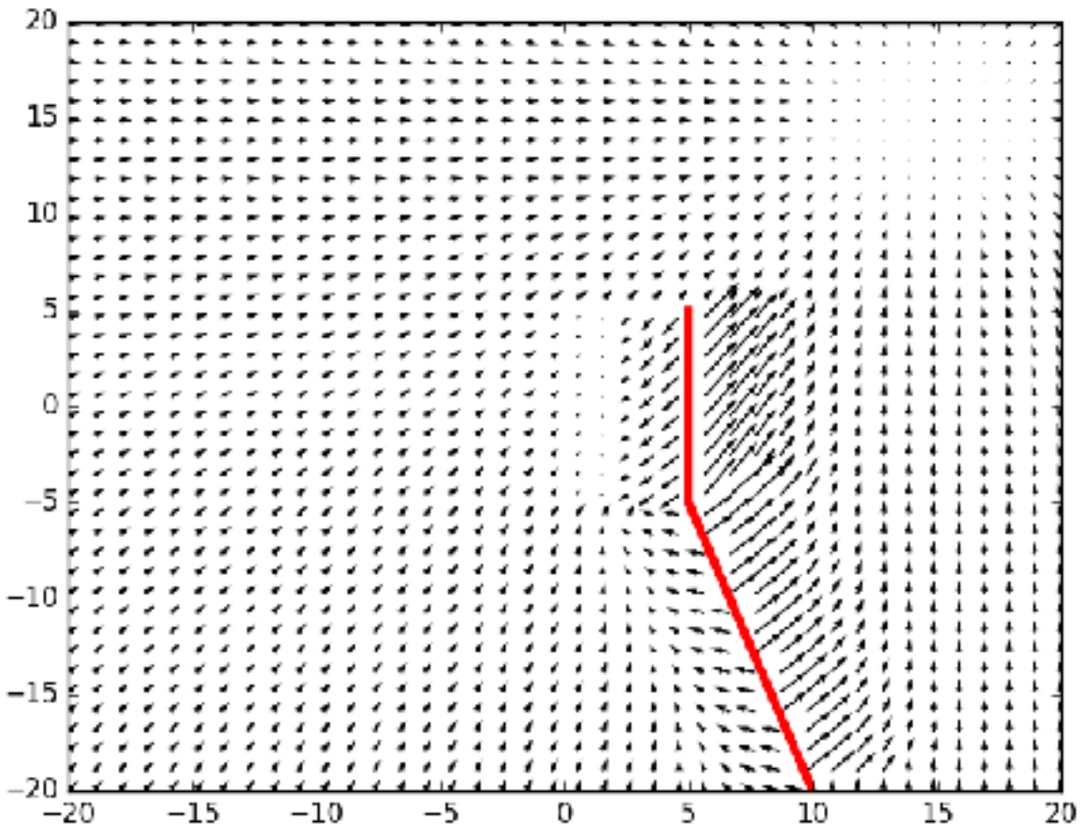
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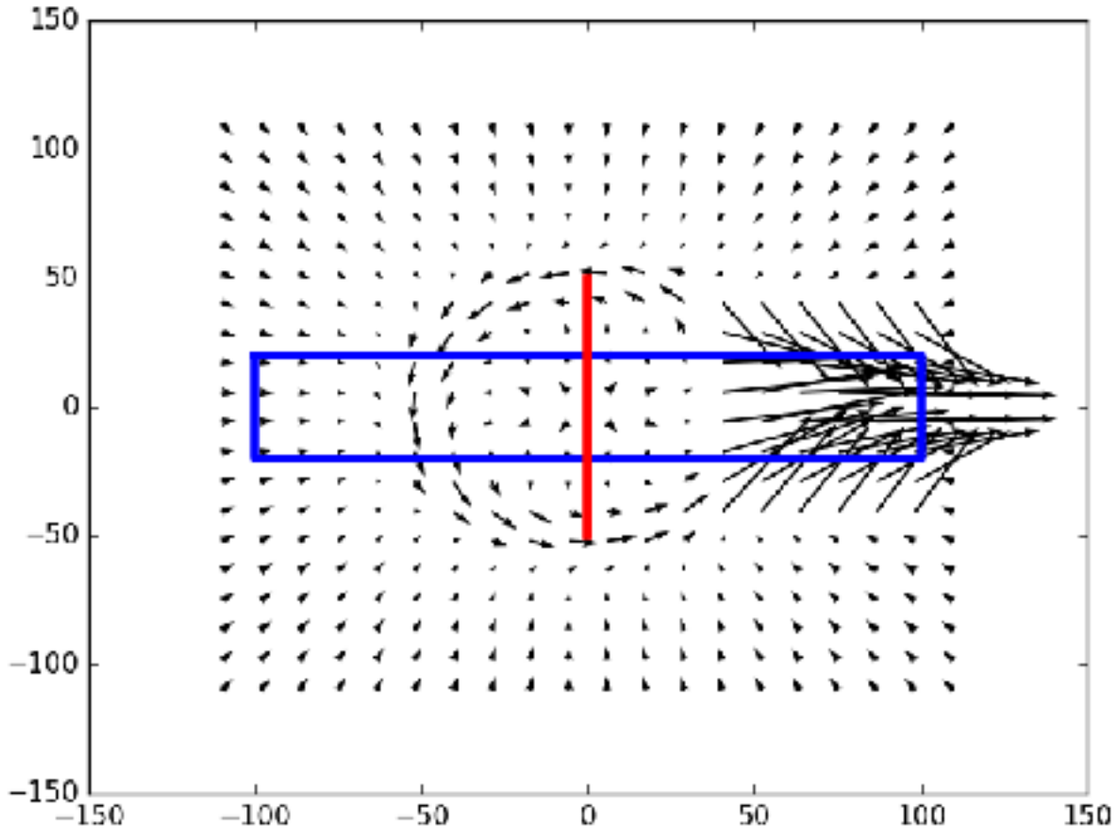
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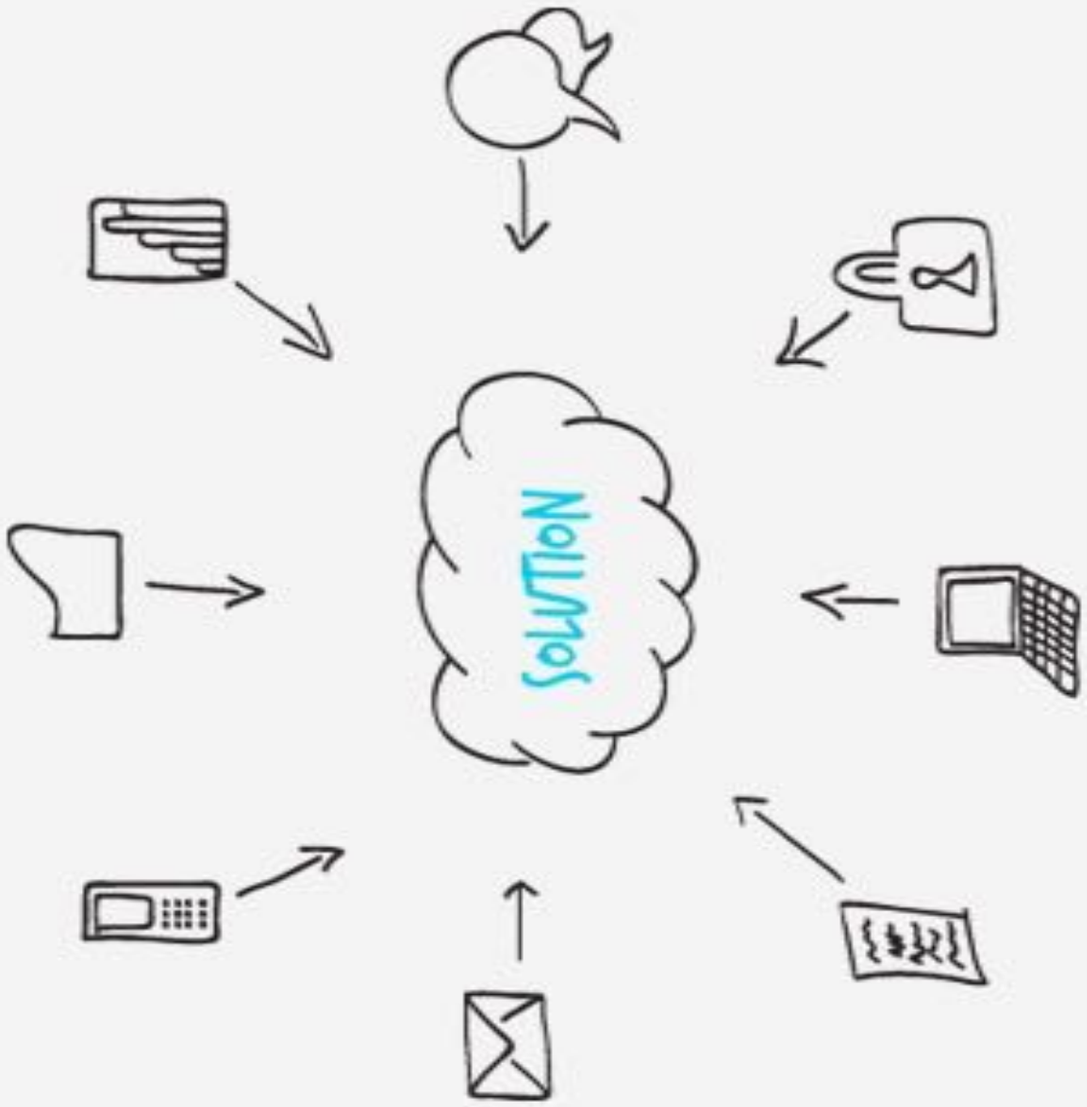
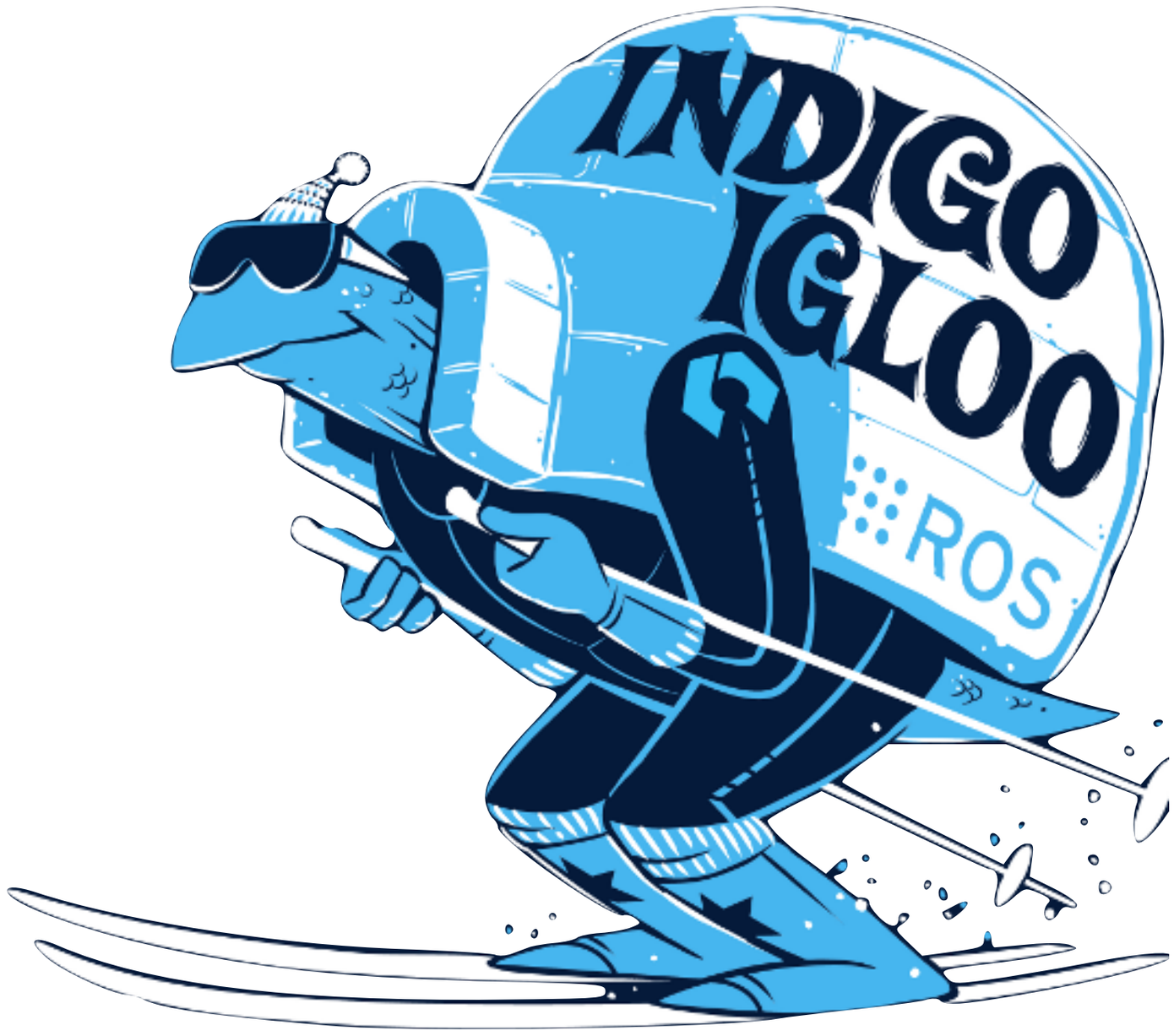


IMPLEMENTATION

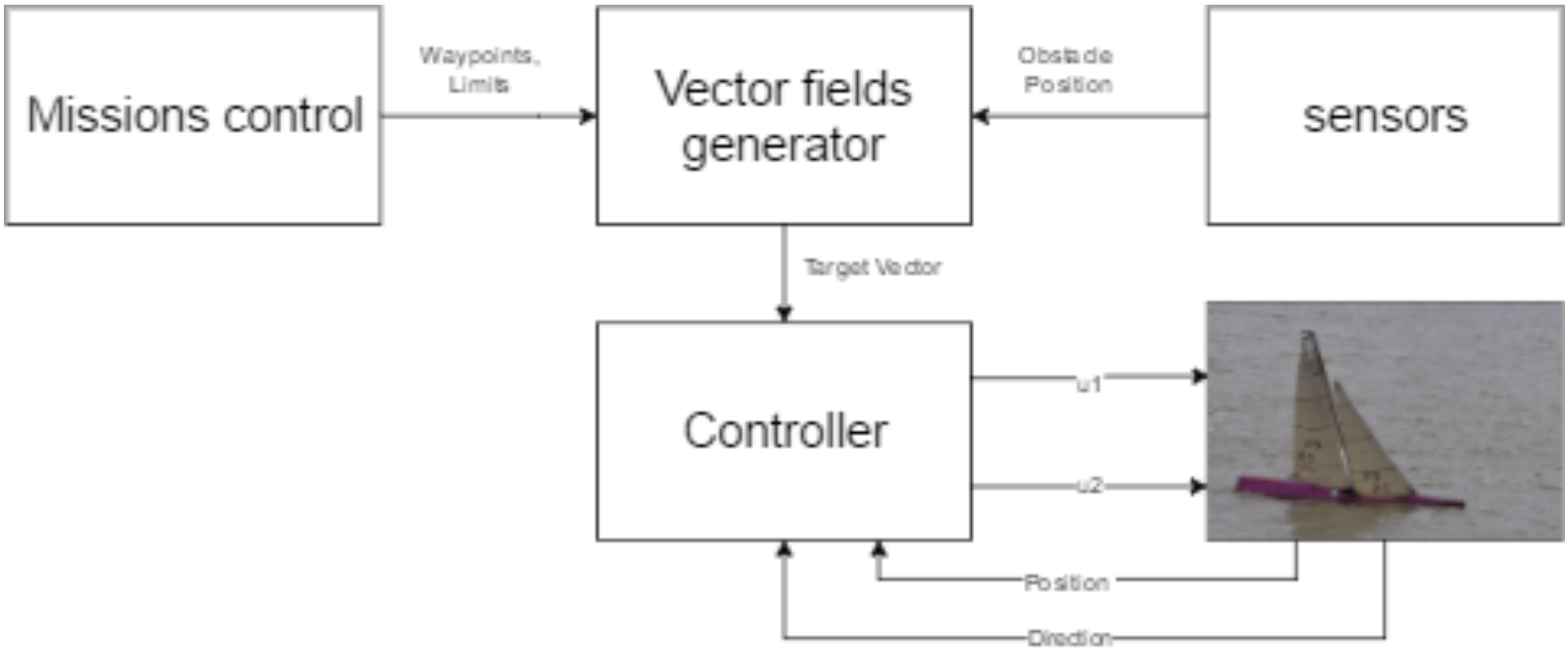
ARCHITECTURE , SIMULATION & RESULTS

ROS MIDDLEWARE

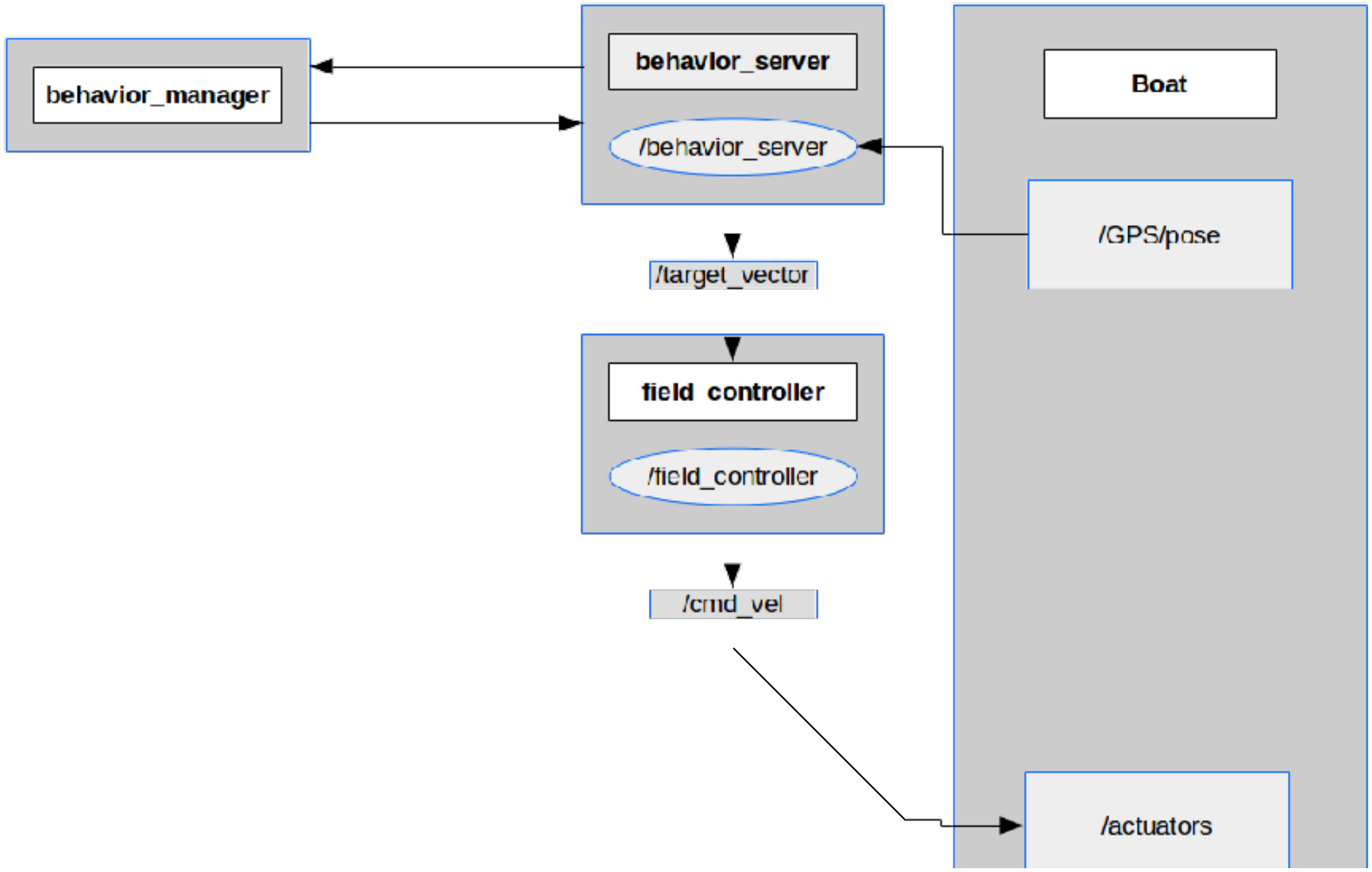
- Flexible framework
- Tools, libraries & conventions
- Complex & robust system
- Publish-subscribe architecture
- Rapid iteration
- Parallelisation of process



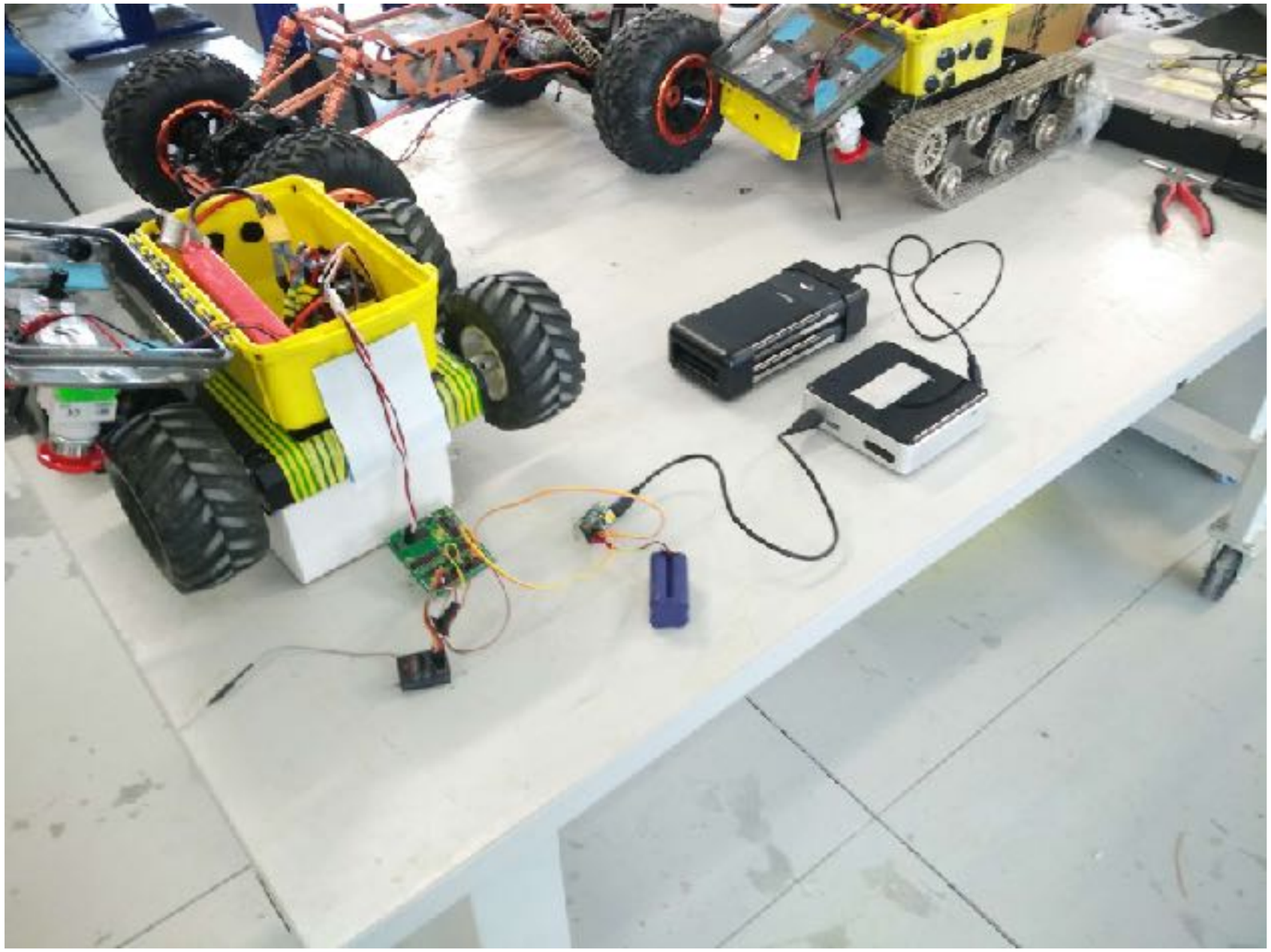
ARCHITECTURE



ROS – ARCHITECTURE

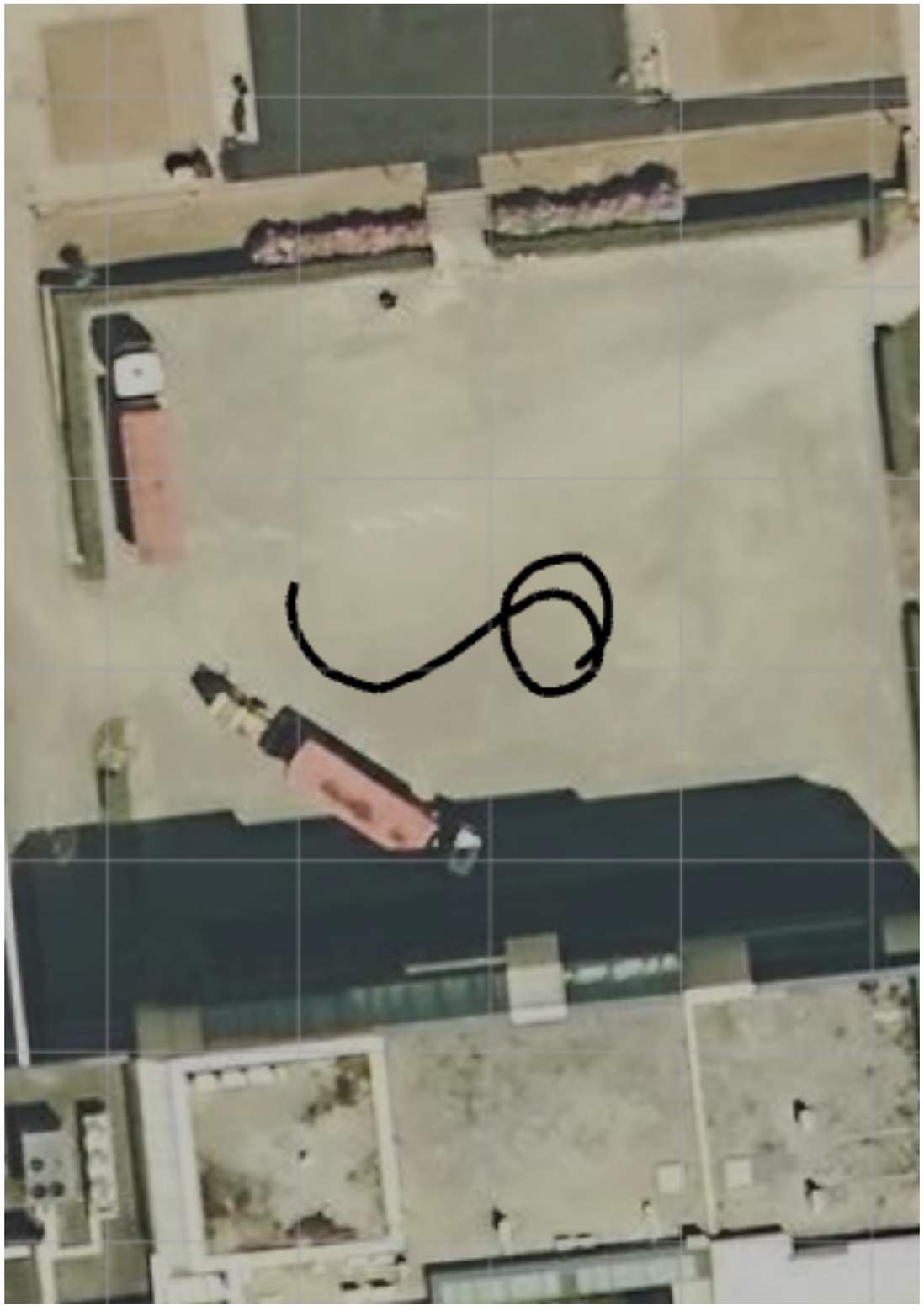


TEST 1



TEST 1 CONCLUSION

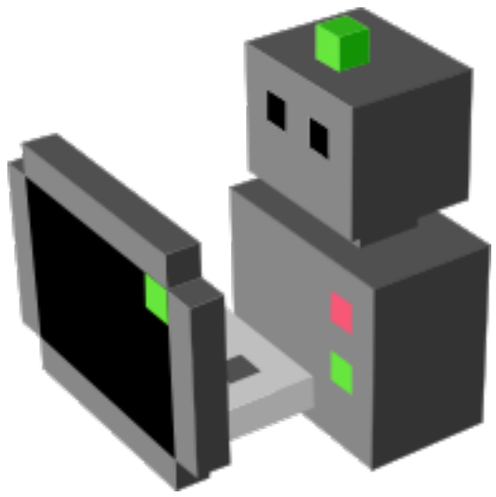
- Buggy = Dubin's Car
- Waypoint = station keeping
- Good results



ADVANTAGE OF SIMULATION

- Avoid technical problems
  - battery
  - wifi connectivity
  - sensor imprecision
- Environment easy to change

SIMULATION UNDER MORSE



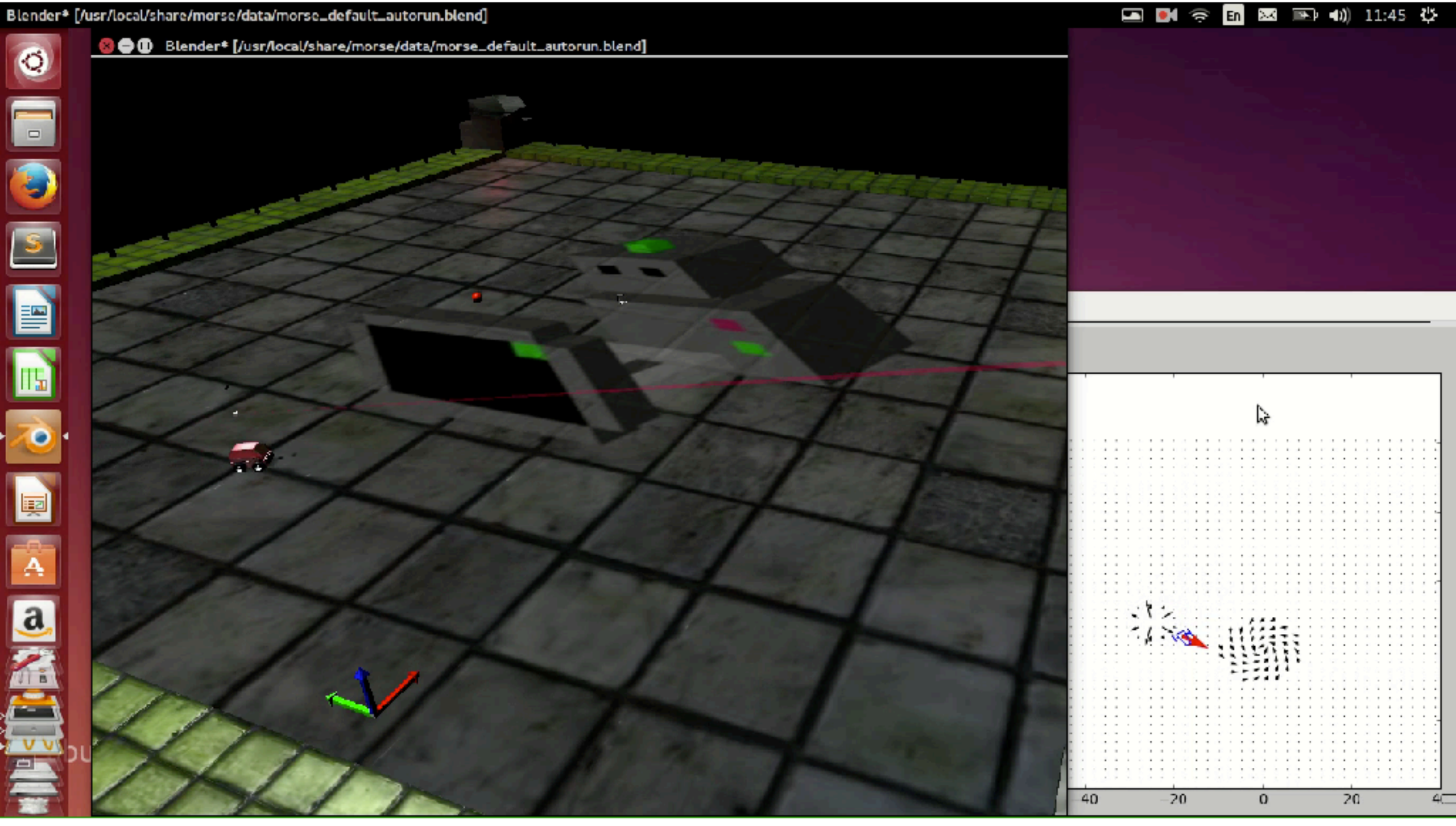
blender™

python powered

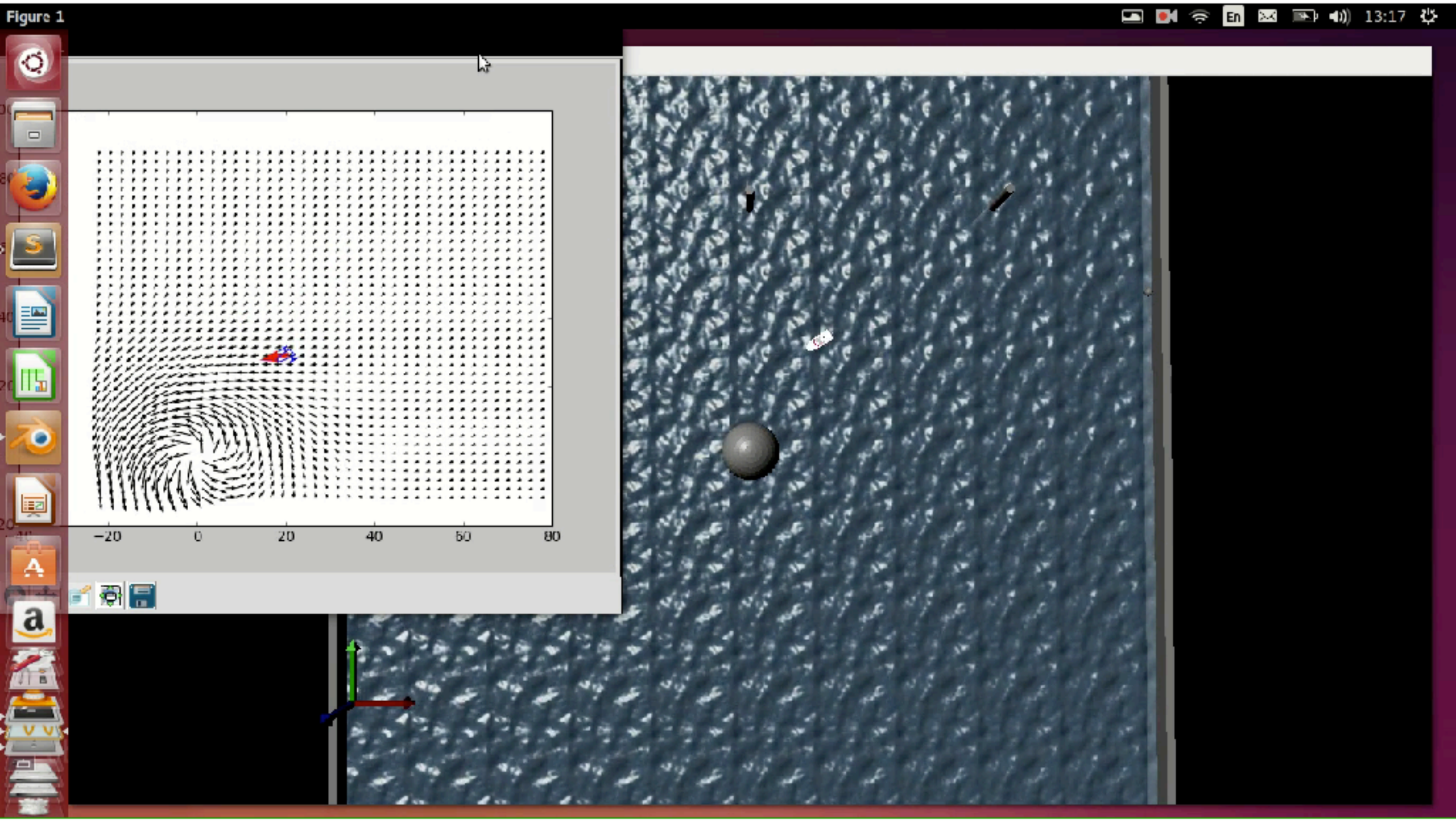
```
print("Hello, world!")
```

BULLET PHYSICS LIBRARY

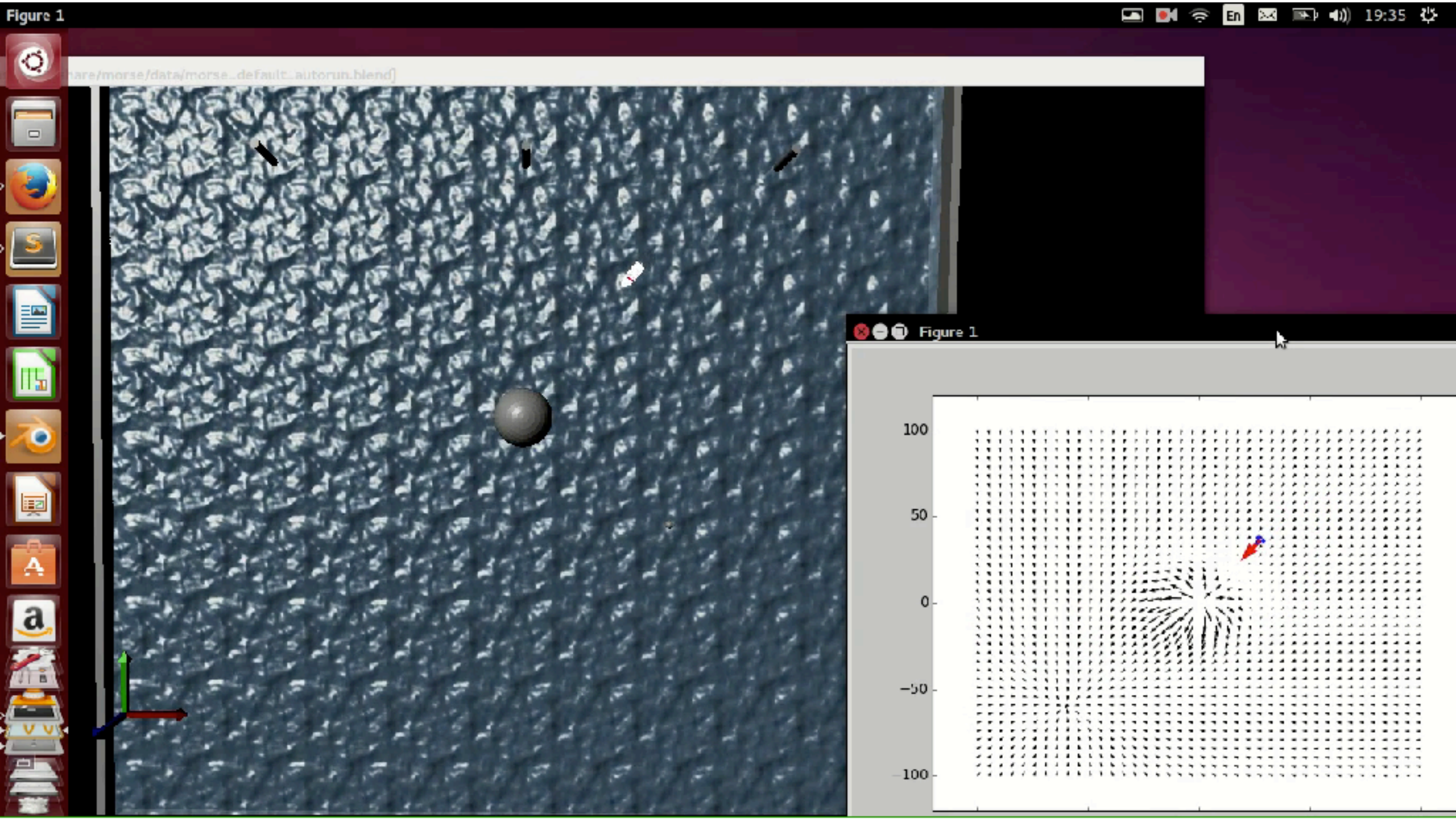
TEST 2 – SIMULATED GROUND ROBOT



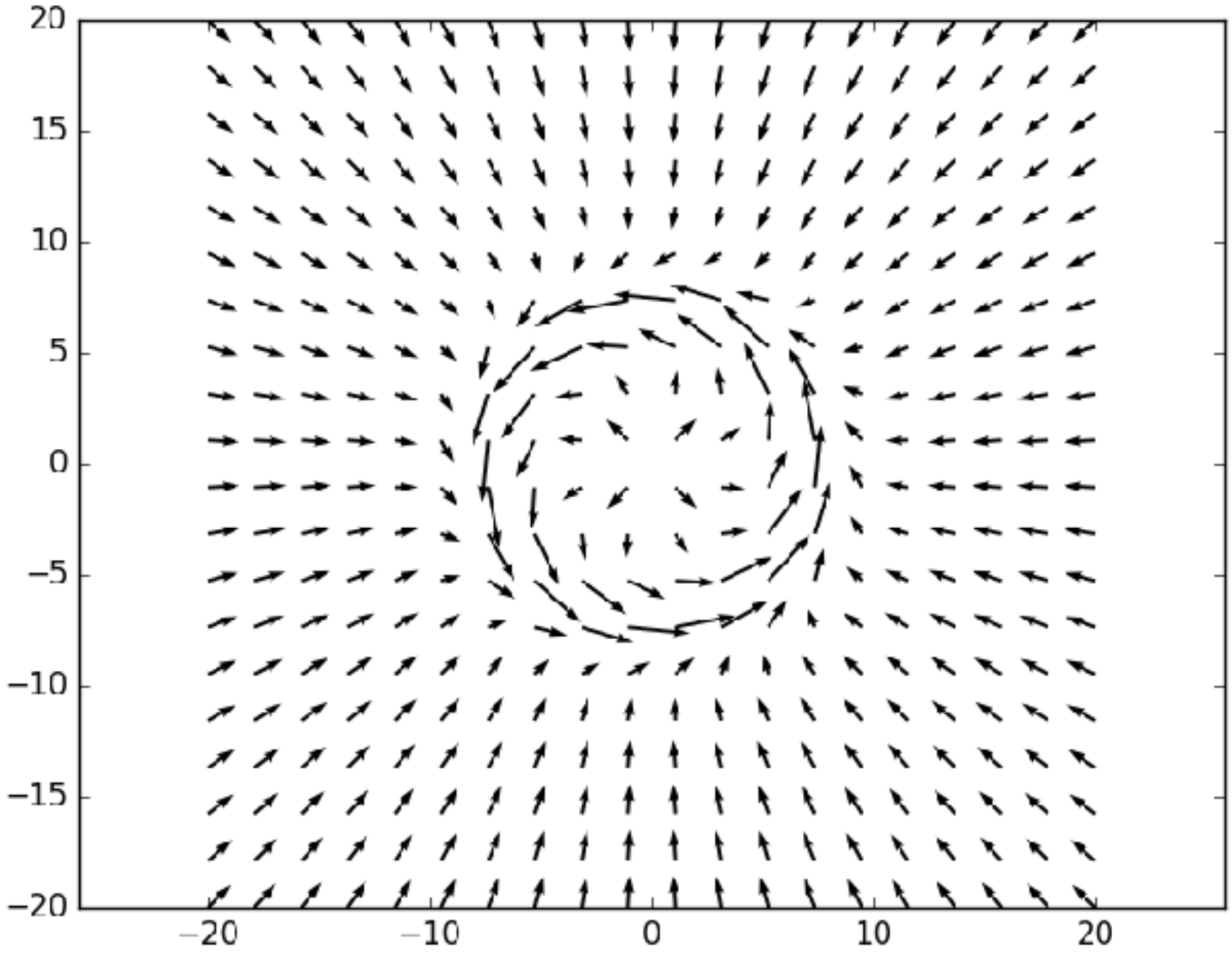
TEST 3 – SIMULATED BOAT



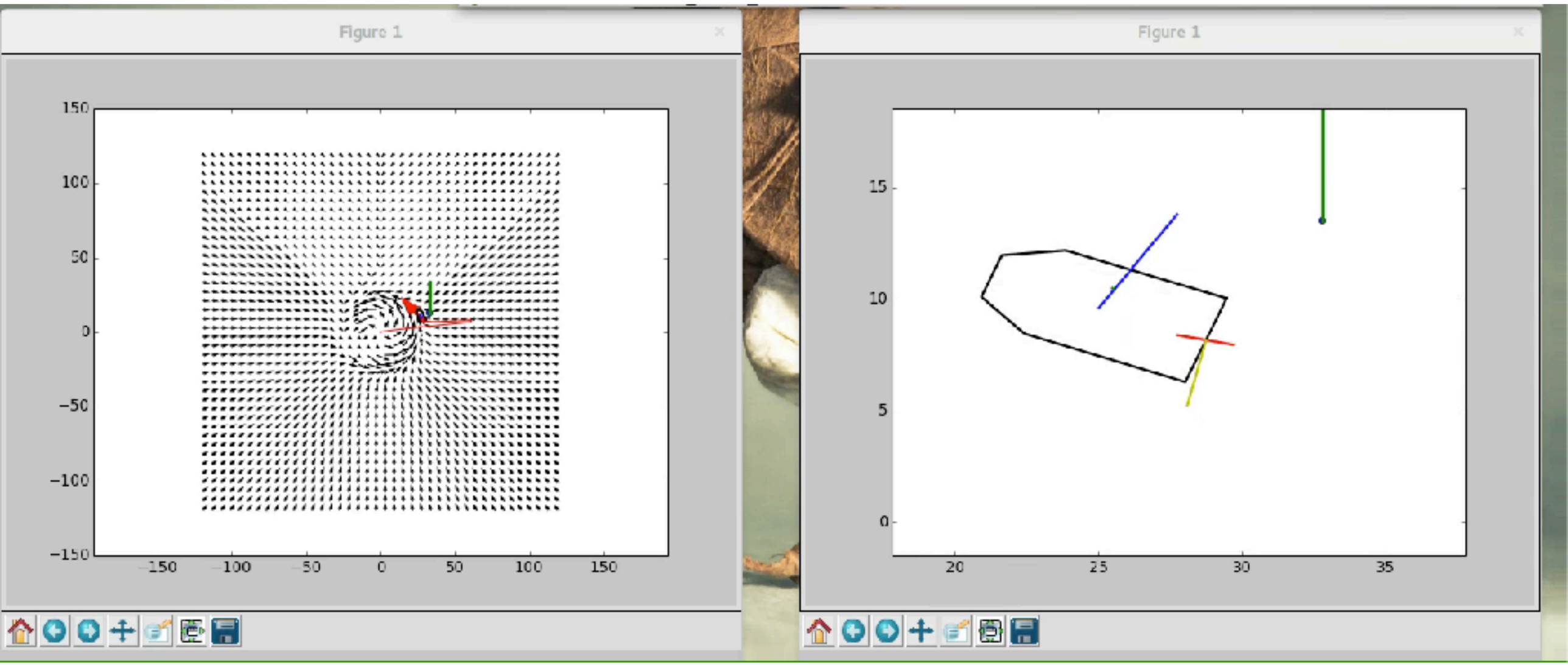
COMPARISON WITH PREVIOUS FIELD



APPLICATION TO A SAILBOAT



APPLICATION TO A SAILBOAT



PRESENTATION & RESULTS

WRSC 2016

PRESENTATION

- **WRSC**: World Robotic Sailing Competition
- **IRSC**: International Robotic Sailing Conference

- Around 12 International teams
- 2 categories
  - Microsailboat (<1.5m)
  - Sailboat (1.5 to 4m)

MISSIONS

- 4 missions
  - Fleet race (1st)
  - Station keeping
  - Area scanning
  - Obstacle avoidance

WRSC 2016
VIANA DO CASTELO · PORTUGAL
SEPTEMBER 5-10

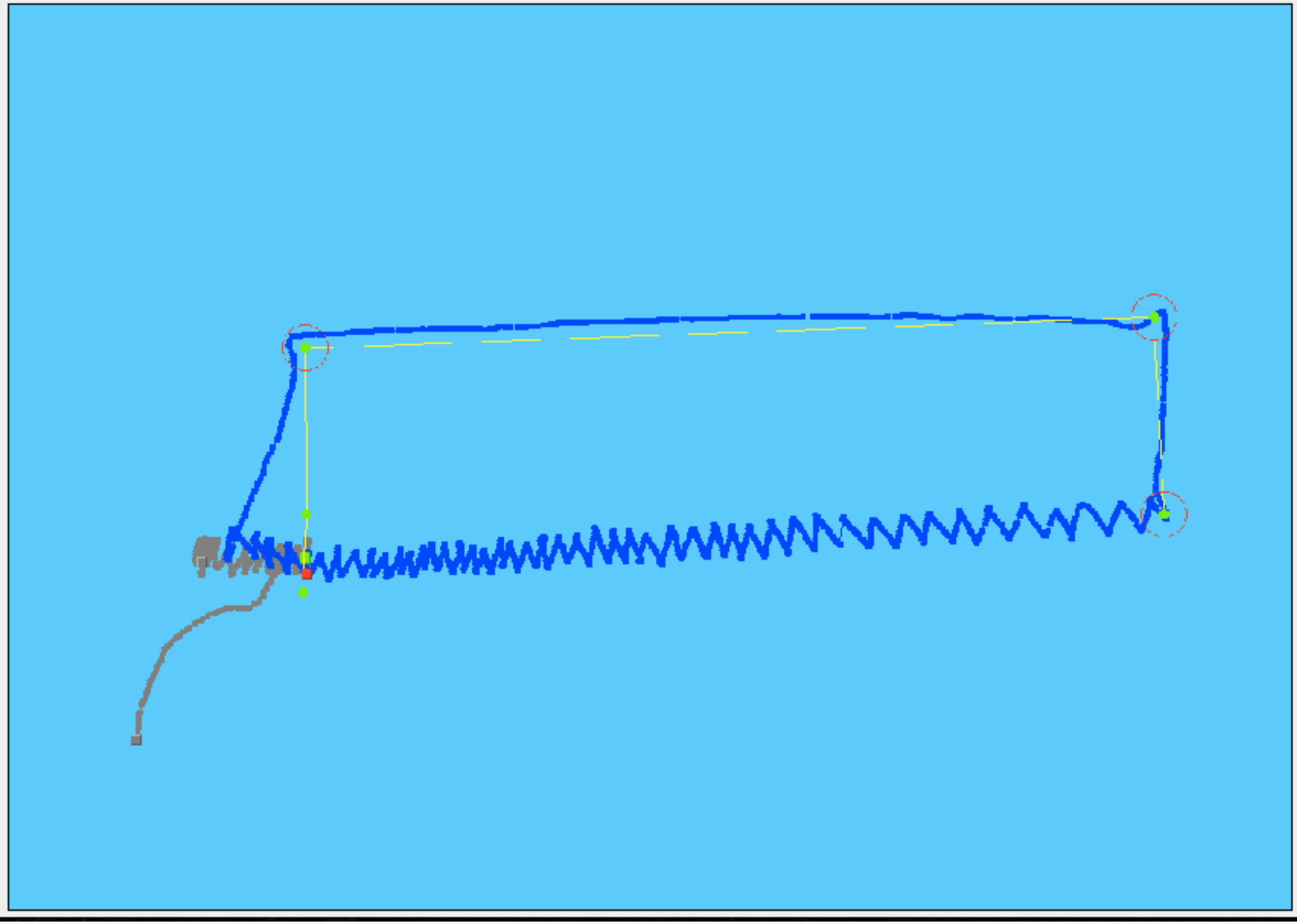
Fleet Race

HA-EB_fr

Reached all marks

Run Time: 32:13.0

Valid Complete Run

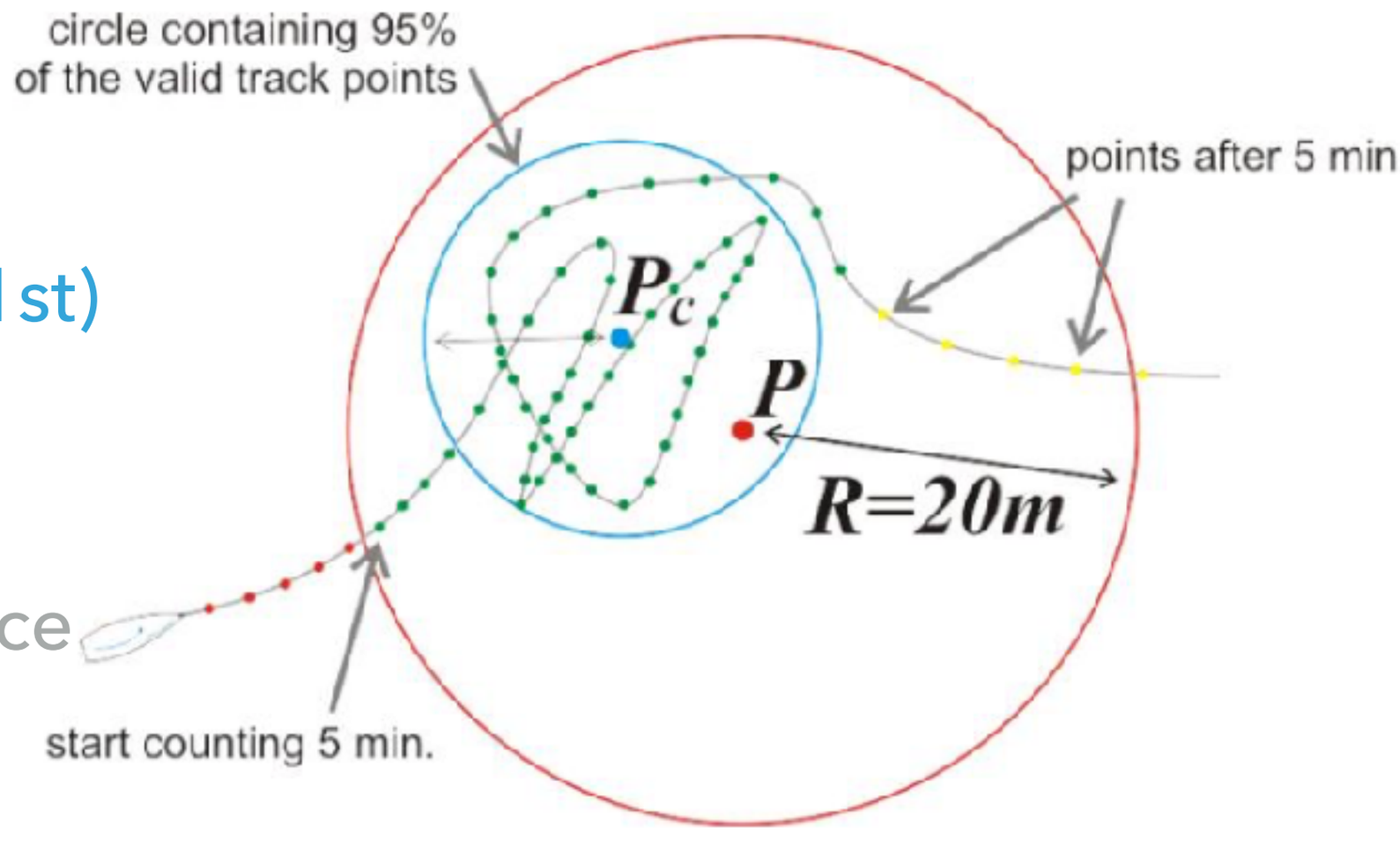


Show Full Route

Back

MISSIONS

- 4 missions
  - Fleet race
  - Station keeping (1st)
  - Area scanning
  - Obstacle avoidance



WRSC 2016
VIANA DO CASTELO - PORTUGAL
SEPTEMBER 5 - 10

Station Keeping

HA-EB_sk1

LOA: 1.85

Radius: 11.48m

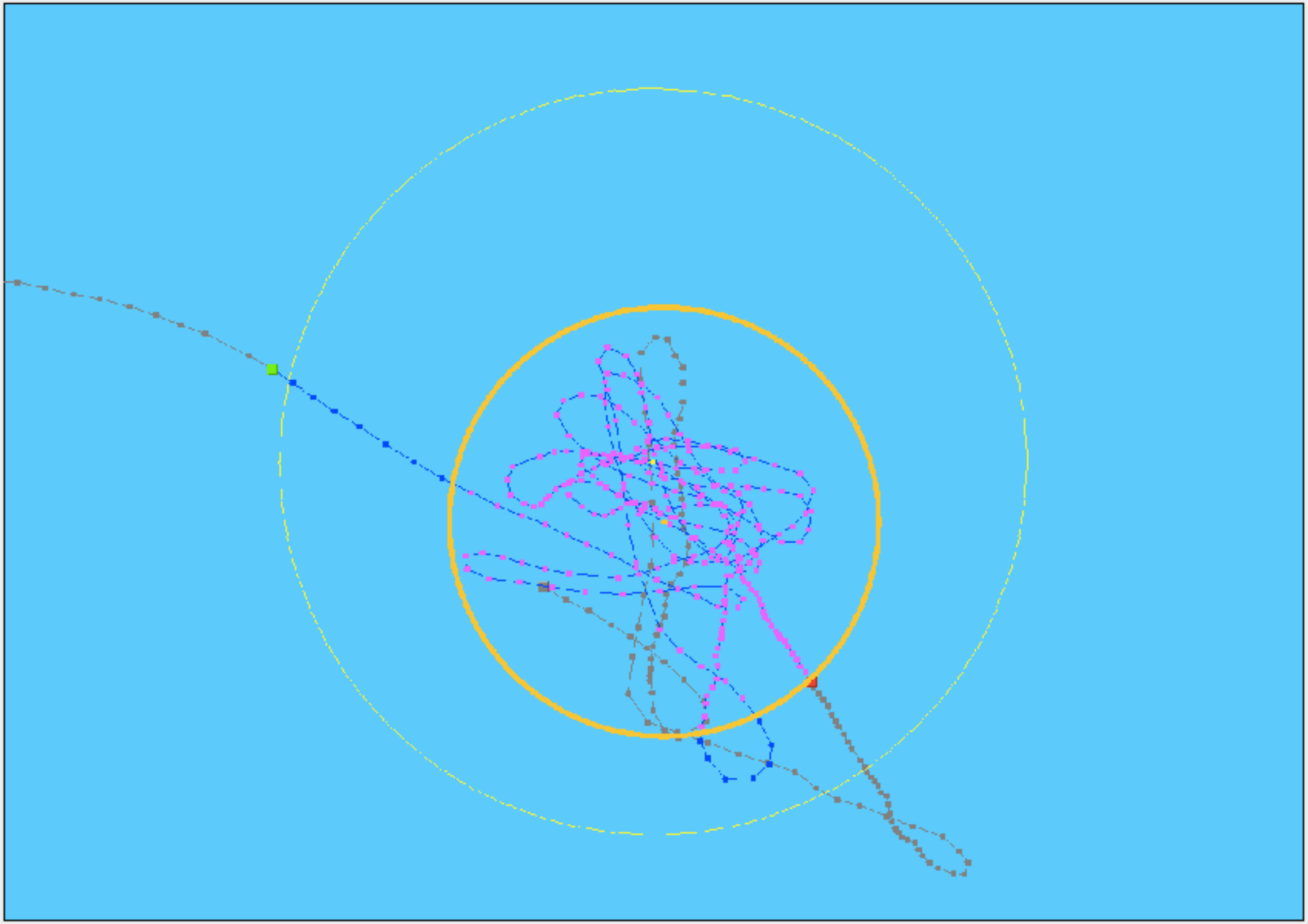
Score: 6.205405

Run Time: 5:1.0

Valid

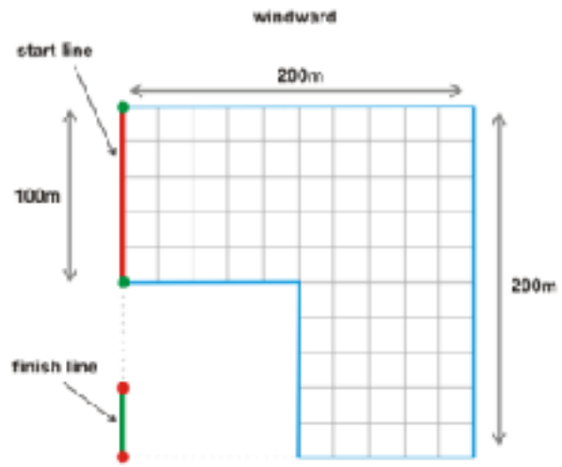
Show Full Route

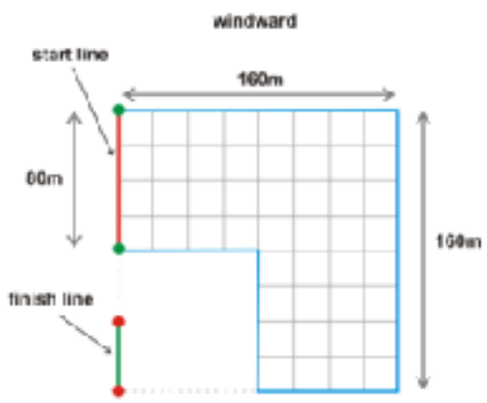
Back

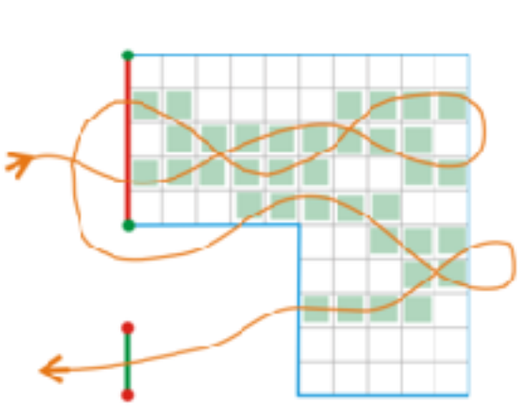


MISSIONS

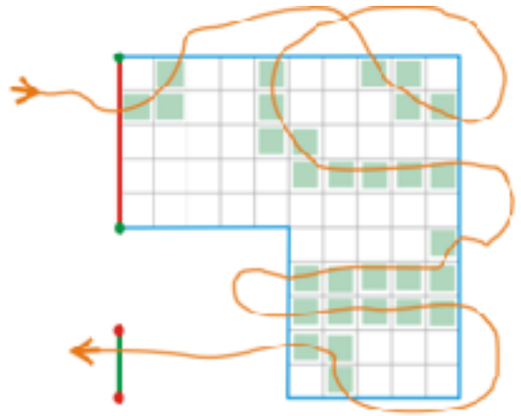
- 4 missions
  - Fleet race
  - Station keeping
  - Area scanning (3rd)
  - Obstacle avoidance







score: 36 squares



score: 30 squares

WRSC 2016
VIANA DO CASTELO - PORTUGAL
SEPTEMBER 5 - 10

Area Scanning

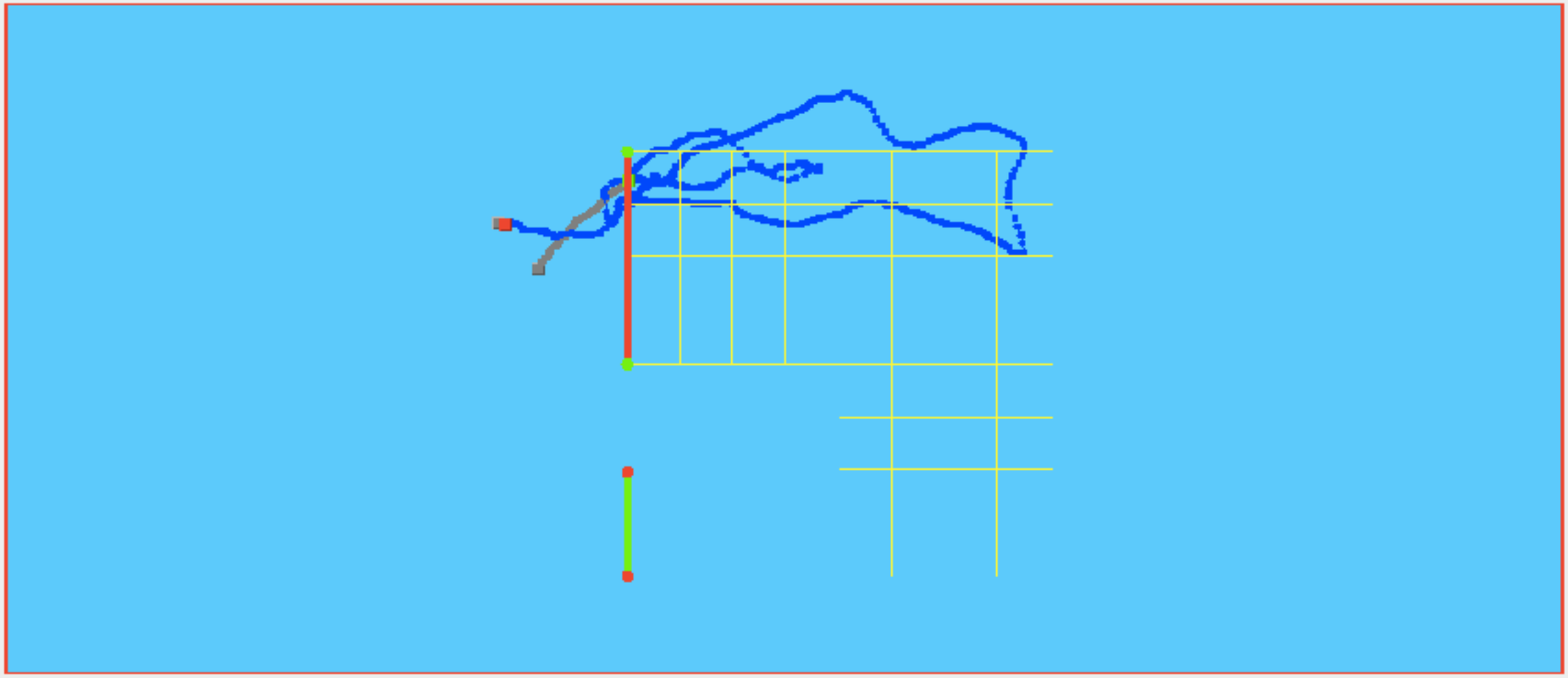
HA-EB_as1

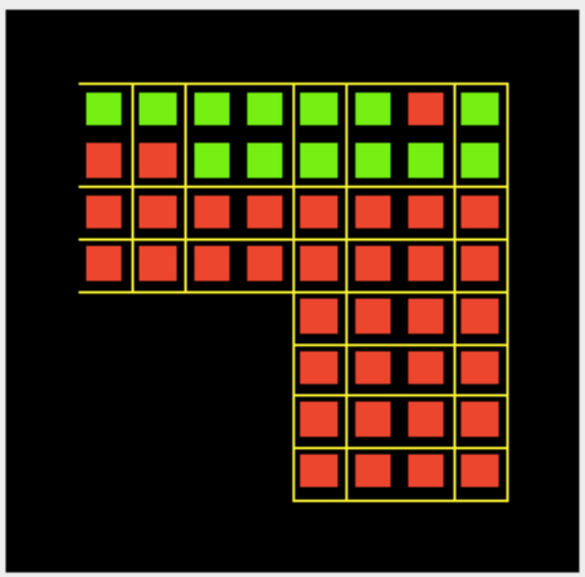
Score:

- 13/48
- 62.5% (inside)

Run Time: 8:44.0

Valid





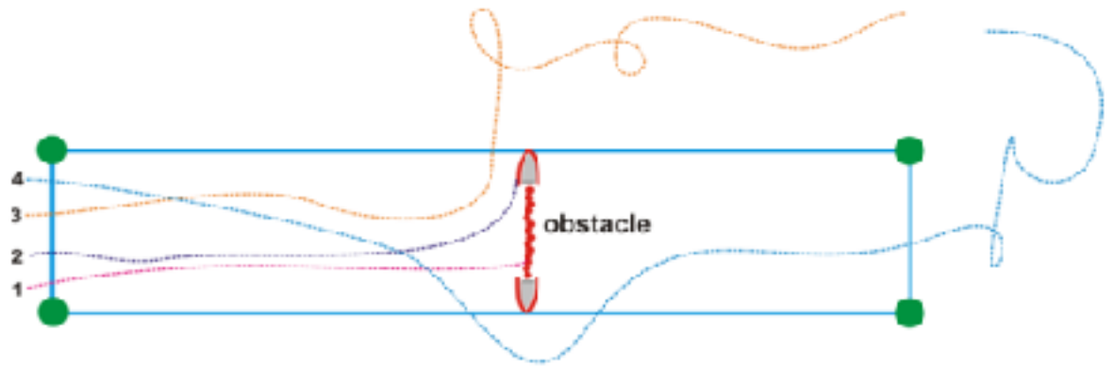
Square Height: 19.99m

Square Width: 19.99m

Back

MISSIONS

- 4 missions
  - Fleet race
  - Station keeping
  - Area scanning
  - Obstacle avoidance



WRSC 2016
VIANA DO CASTELO - PORTUGAL
SEPTEMBER 5-10

Collision Avoidance

HA-EB_ca1

Obstacle in leg 3

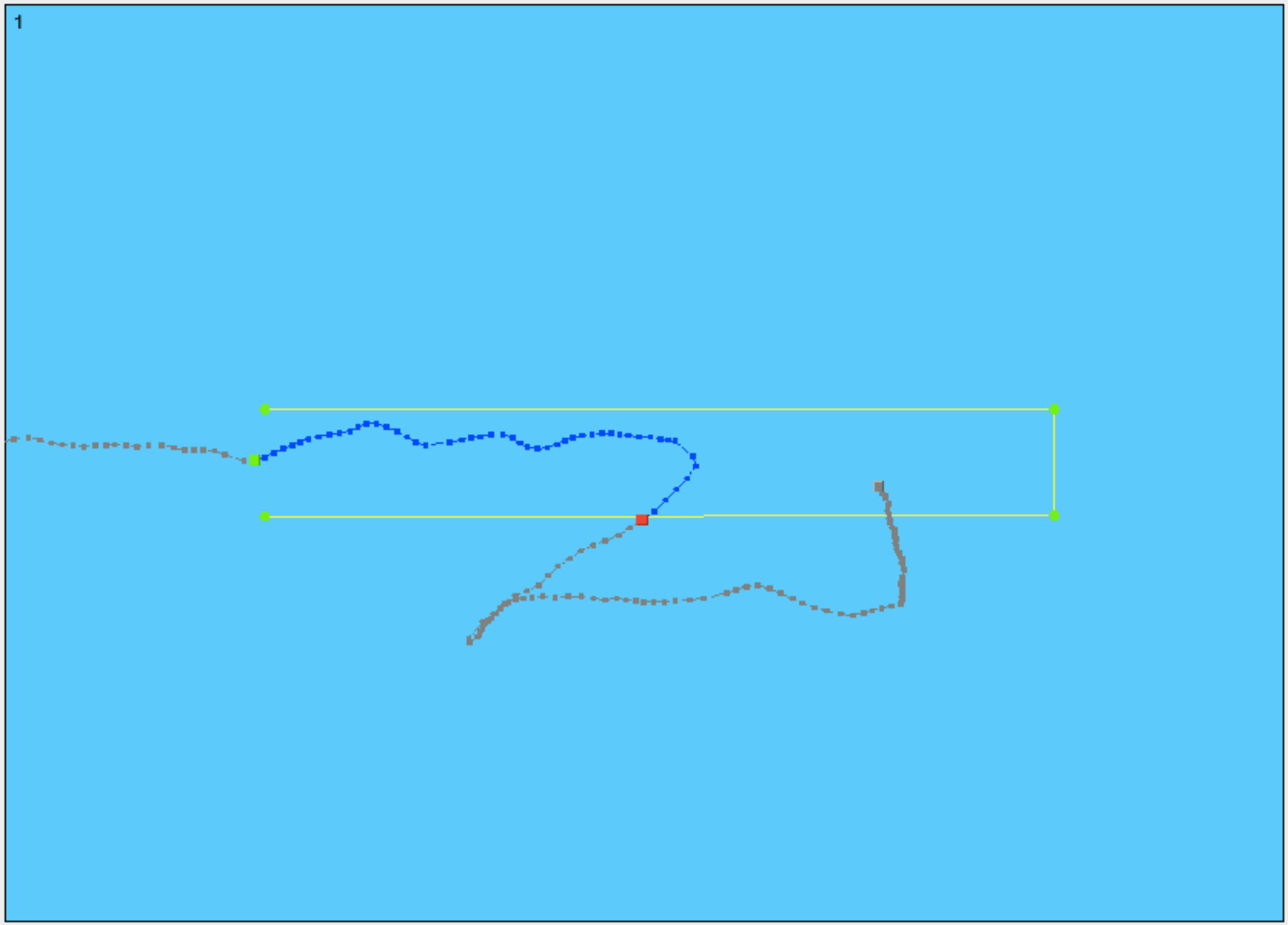
- % (inside)

Run Time: 0:52.0

Invalid: left area in leg 1

Show full route (last leg)

Back



WRSC2016
Final results Class "Sailboat"

	Team	Fleet Race	Station Keeping	Area Scanning	Collision Avoidance	Total
1st	ULPGC	6	2	1	1	**10**
2nd	HÅ-EB	1	1	3	6	**11**
3rd	Univ Porto – INESC TEC	6	6	2	6	**20**
4th	USNA	6	6	4	6	**22**
5th	CINAV – Escola Naval	6	6	5	6	**23**

CONCLUSION & DISCUSSIONS

- Still under implementation
- Correct some problems (normalisation, addition…)
- Did not tested everything on a real sailboat
- 2nd position at WRSC 2016

FUTURE WORKS

- Simulation of sailboat under M.O.R.S.E.
- Test on real sailboat
- WRSC 2017