VINEYARD SCENARIO GENERATION AND OPTIMAL CONTROL FOR AUTOMATED OPERATIONS IN VIRTUAL ENVIRONMENT

CO-SIMULATION OF VEHICLE DYNAMICS, ENVIRONMENT AND IN-FIELD SENSORS ACCORDING TO THE LATEST PRECISION FARMING TECHNOLOGIES

Elisabetta Leo
Claudio Maroni
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OUTLINES

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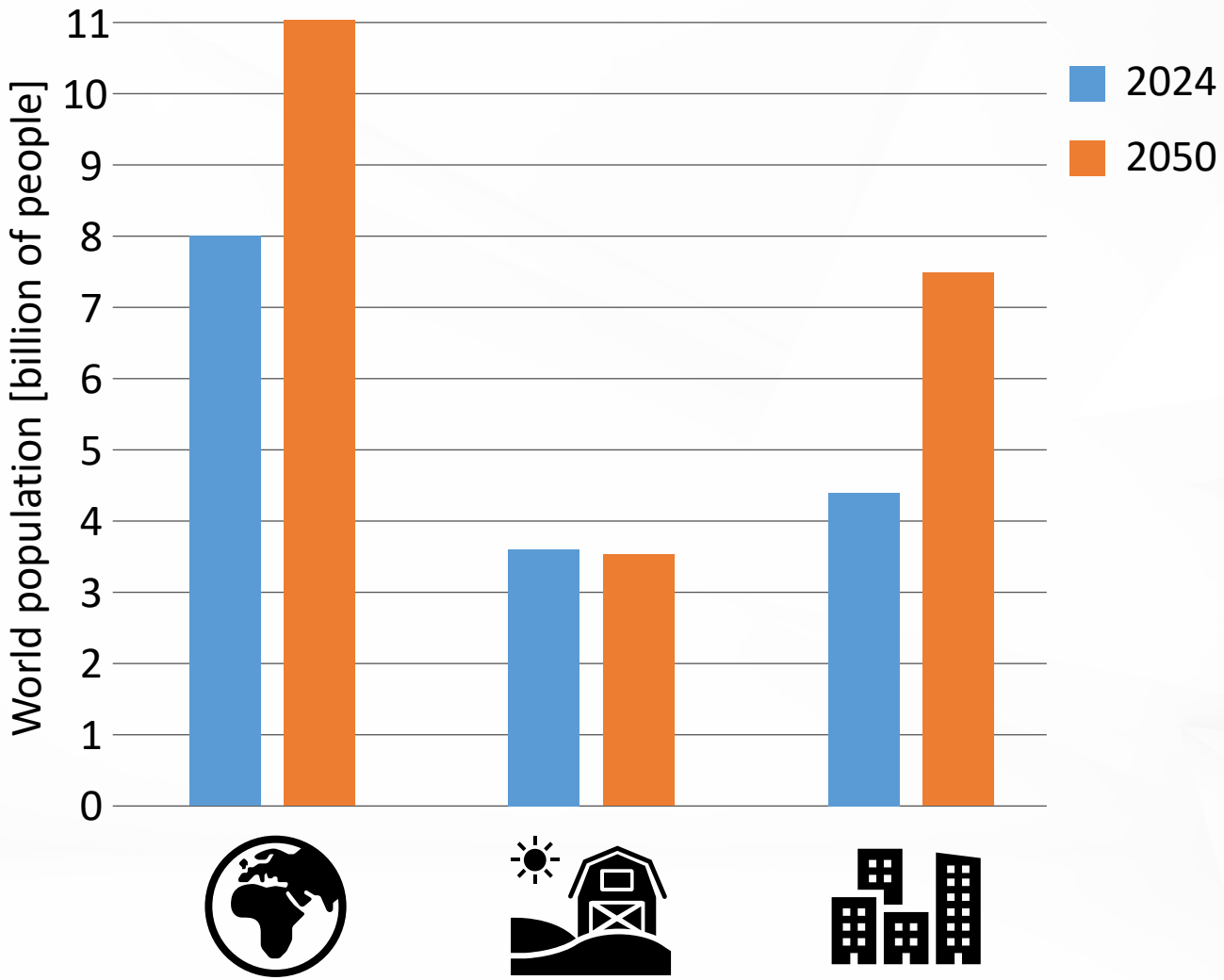
MOTIVATIONS



- 3 billion more mouths to feed
- 50% increase in food demand
- Depopulation of rural areas
- Fewer agricultural workers
- Sustainability problem
- Reduction of water, fertilizers, pesticides, …

UN SOURCE, https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

MOTIVATIONS

FARM INNOVATION IS MANDATORY

PRECISION FARMING

a farming management strategy, based on observing, measuring and responding to temporal and spatial variability of the soil, to improve agricultural production and sustainability.

MOTIVATIONS

PRECISION FARMING

+

VITICULTURE

- TRAJECTORY CALCULATION
- AUTONOMOUS DRIVING
- PLANTS INSPECTIONS
- IMPLEMENT ACTUATION

- ❑ REDUCE LABOR COST
- ❑ IMPROVE CROP HEALTH
- ❑ ENHANCE PRODUCTIVITY

HOW TO DEVELOP AND TEST THIS KIND OF SYSTEMS?

MOTIVATIONS

HOW TO DEVELOP AND TEST THIS KIND OF SYSTEMS?

EXPERIMENTAL

- ❑ SEASON AND WEATHER DEPENDENT
- ❑ IMPACT ON PRODUCTION
- ❑ SOMETIMES NOT REPEATABLE
- ❑ DIFFICULT REPLICATION OF EDGE SITUATION
- ❑ SAFETY RISK

Good only for the last mile of development

SIMULATION

- ❑ SEASON AND WEATHER INDEPENDENT
- ❑ NO IMPACT ON PRODUCTION
- ❑ ALWAYS REPEATABLE
- ❑ EASY REPLICATION OF EDGE SITUATIONS
- ❑ NO SAFETY RISK

BUT…

MOTIVATIONS

BUT…

A RELIABLE SIMULATION PLATFORM CAPABLE OF REPLICATING A VINEYARD SCENARIO WOULD BE NEEDED:

- ❑ TRACTOR/ROBOT VEHICLE MODEL
- ❑ GEOREFERENCED REAL FIELD
- ❑ REALISTIC FIELD MORPHOLOGY
- ❑ SOIL IRREGULARITY
- ❑ INTERACTIONS WITH PLASTIC SOIL

?

- ❑ ROWS OF VINES
- ❑ DIFFERENT MATURITY LEVEL

TARGETS

TO DEVELOP A ROBUST, VIRTUAL ENVIRONMENT WHERE WE CAN SIMULATE AND OPTIMIZE AUTONOMOUS OPERATIONS IN VINEYARDS.

TO DEMONSTRATE THE EFFECTIVENESS OF THIS ENVIRONMENT, IT HAS BEEN USED TO DEVELOP TWO PROTOTYPE CONTROL LOGICS: ONE FOR AUTONOMOUS DRIVING AND ONE FOR PLANT INSPECTION.

OUTLINES

VINEYARD SCENARIO GENERATION

QGIS

.shp

FIELD BOUNDARY

.shp

VINES ROW

https://www.qgis.org/

VINEYARD SCENARIO GENERATION

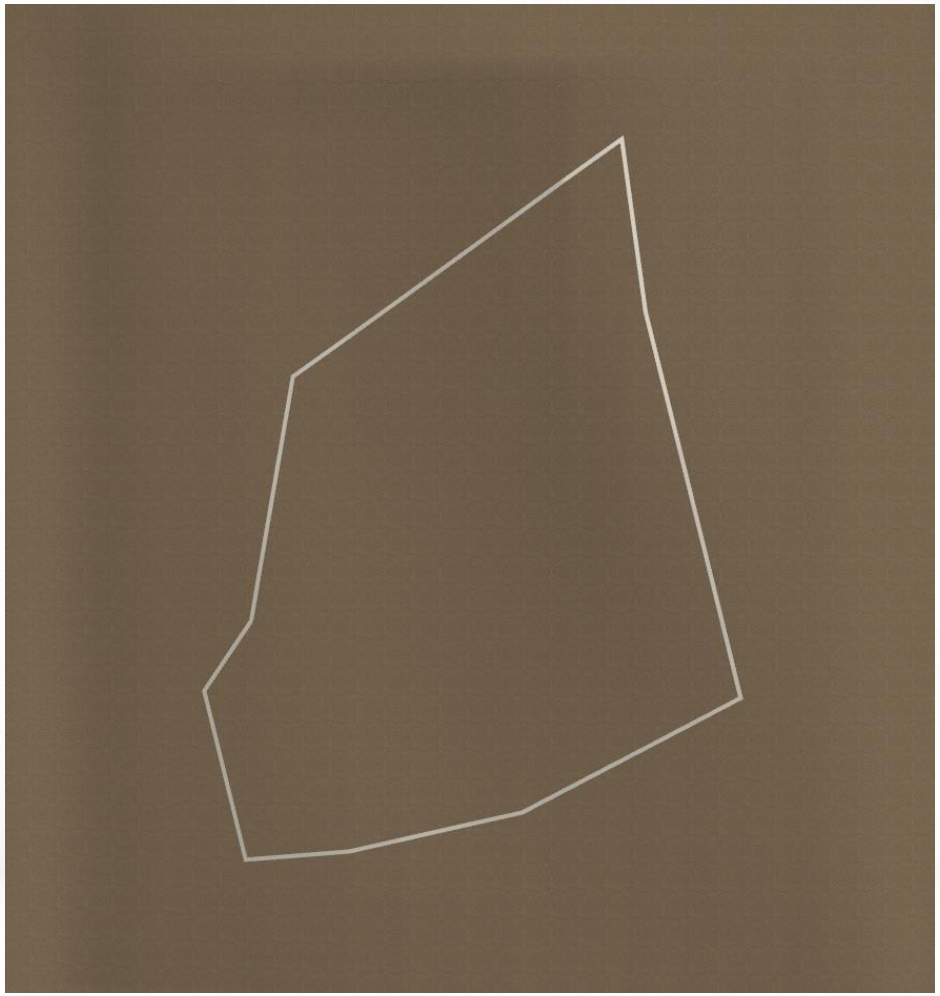
FIELD BOUNDARY

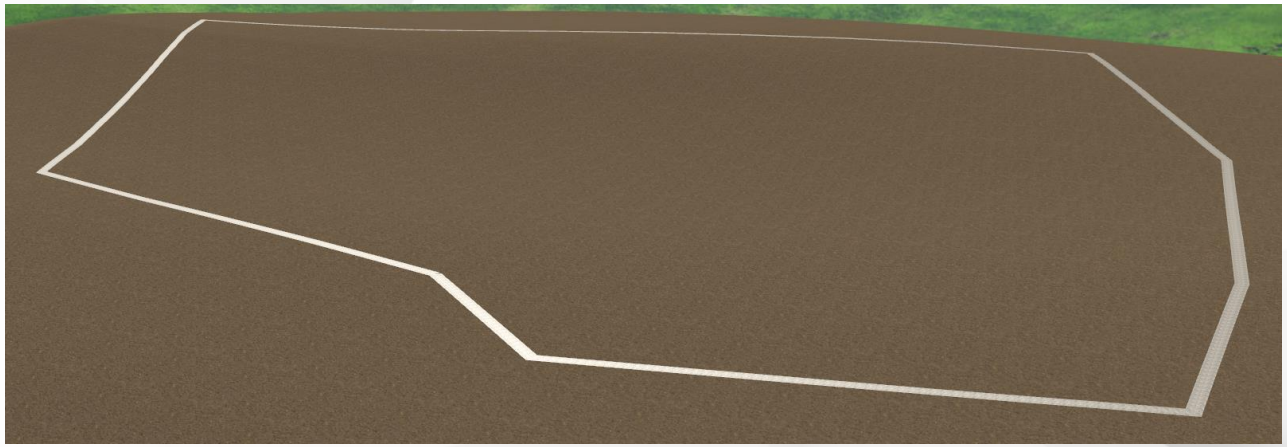
SCENARIO GENERATOR

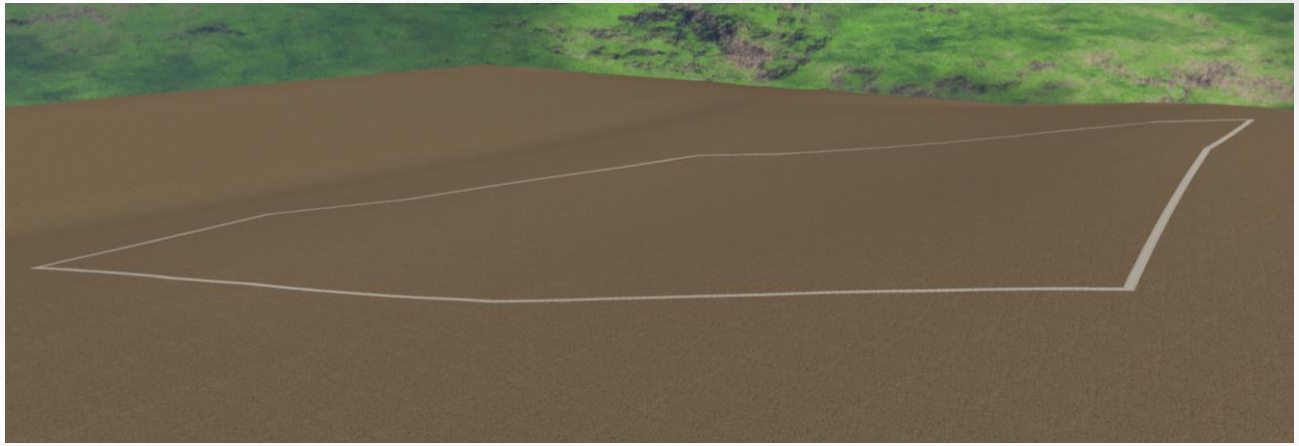
FIELD

- ❑ GEOREFERENCED
- ❑ DRIVABLE AREA (SOIL TEXTURE)
- ❑ BOUNDARY (DIRT ROAD TEXTURE)
- ❑ REALISTIC ELEVATION PROFILE

VINEYARD SCENARIO GENERATION







VINEYARD SCENARIO GENERATION

FIELD BOUNDARY

SCENARIO GENERATOR

FIELD

- ❑ GEOREFERENCED
- ❑ DRIVABLE AREA (SOIL TEXTURE)
- ❑ BOUNDARIES (DIRT ROAD TEXTURE)
- ❑ REALISTIC ELEVATION PROFILE

FIELD

VINES ROW

VINEYARD GENERATOR:

- DISTANCE BETWEEN LINES (UI)
- MATURITY LEVEL (UI OR RANDOM)

VINEYARD

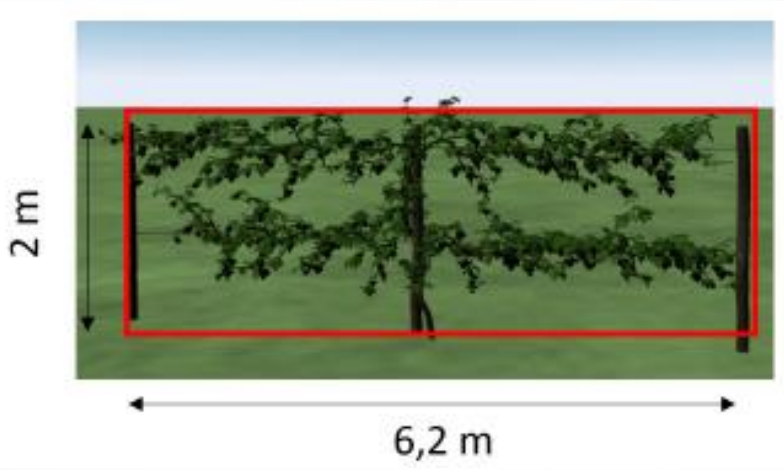
- ❑ GEOREFERENCED
- ❑ DRIVABLE AREA (SOIL TEXTURE)
- ❑ BOUNDARIES (DIRT ROAD TEXTURE)
- ❑ REALISTIC ELEVATION PROFILE
- ❑ ROWS OF VINE PLANTS WITH DEFINED MATURITY LEVEL

?

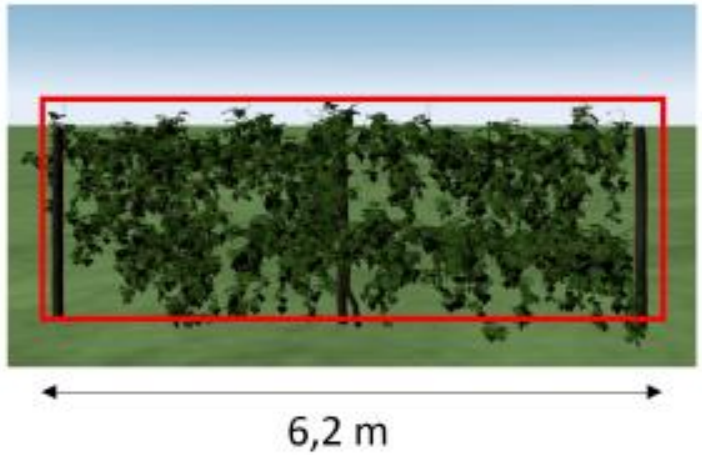
VINEYARD SCENARIO GENERATION

DIFFERENT MATURITY LEVELS ARE OBTAINED USING DIFFERENT GEOMETRY OBJECTS (.obj)

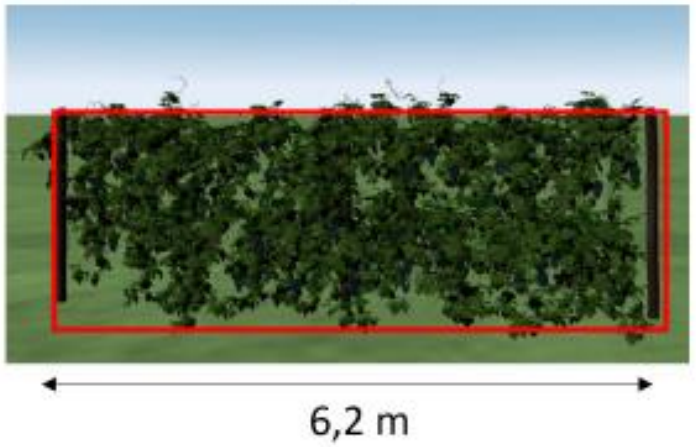
LOW MATURITY



MEDIUM MATURITY



HIGH MATURITY



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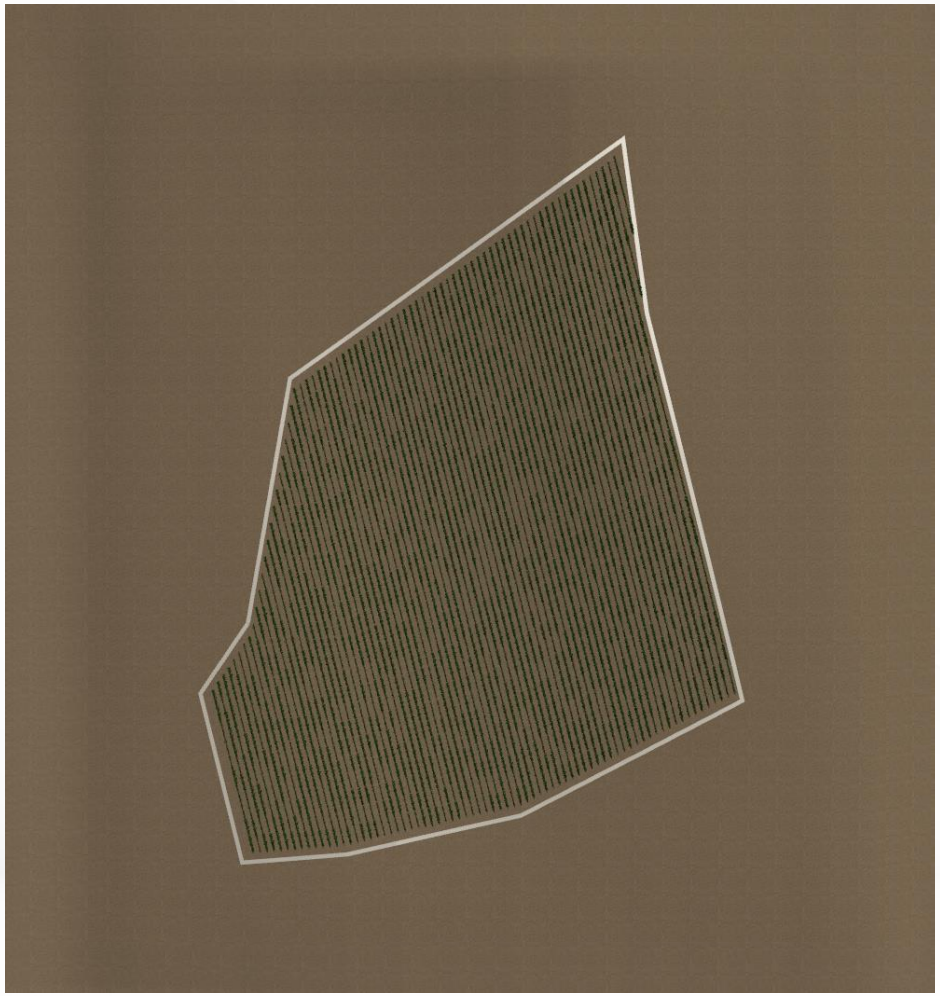

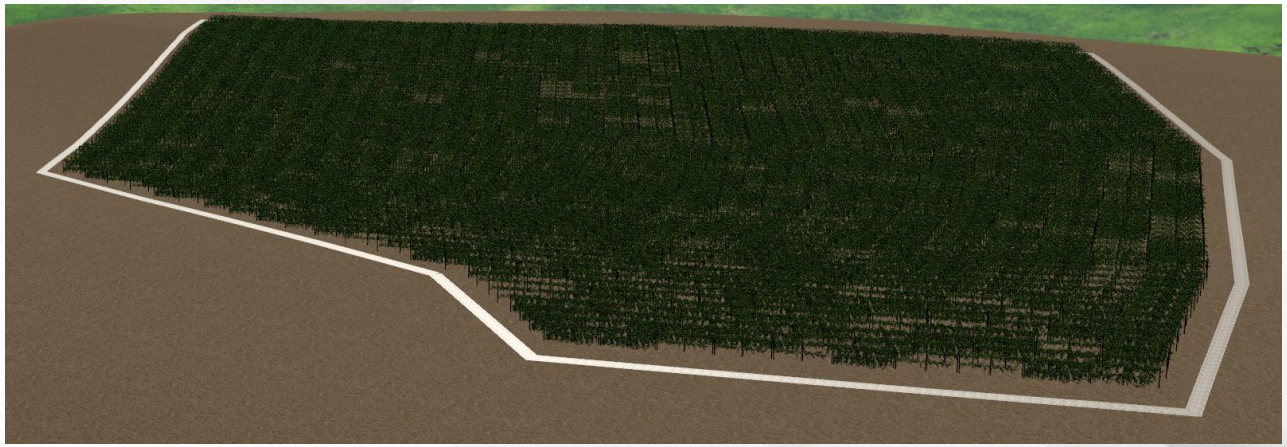

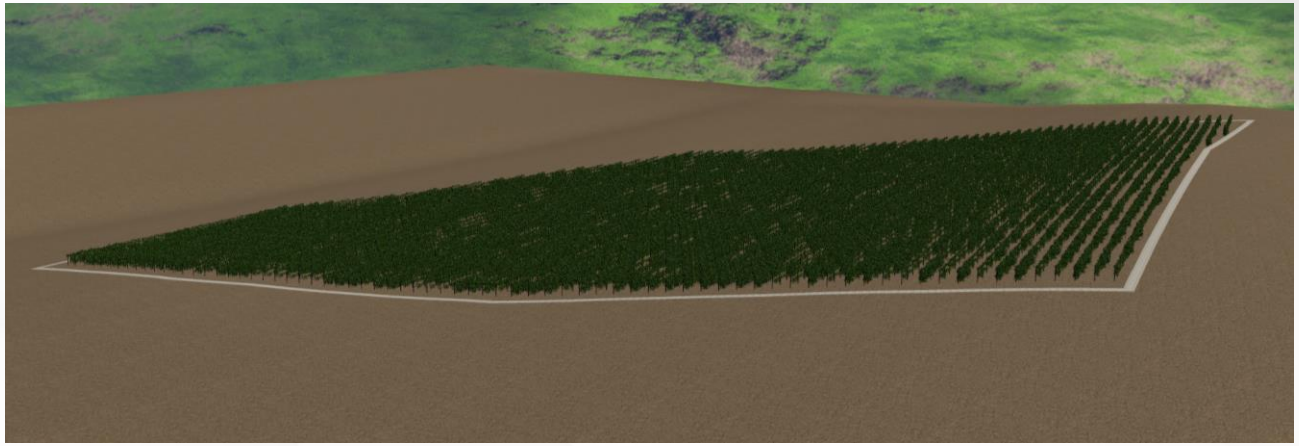

OUTLINES

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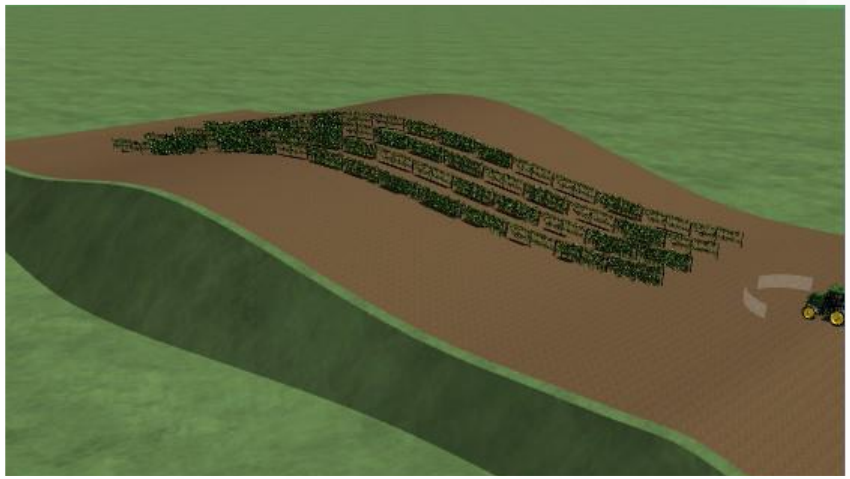
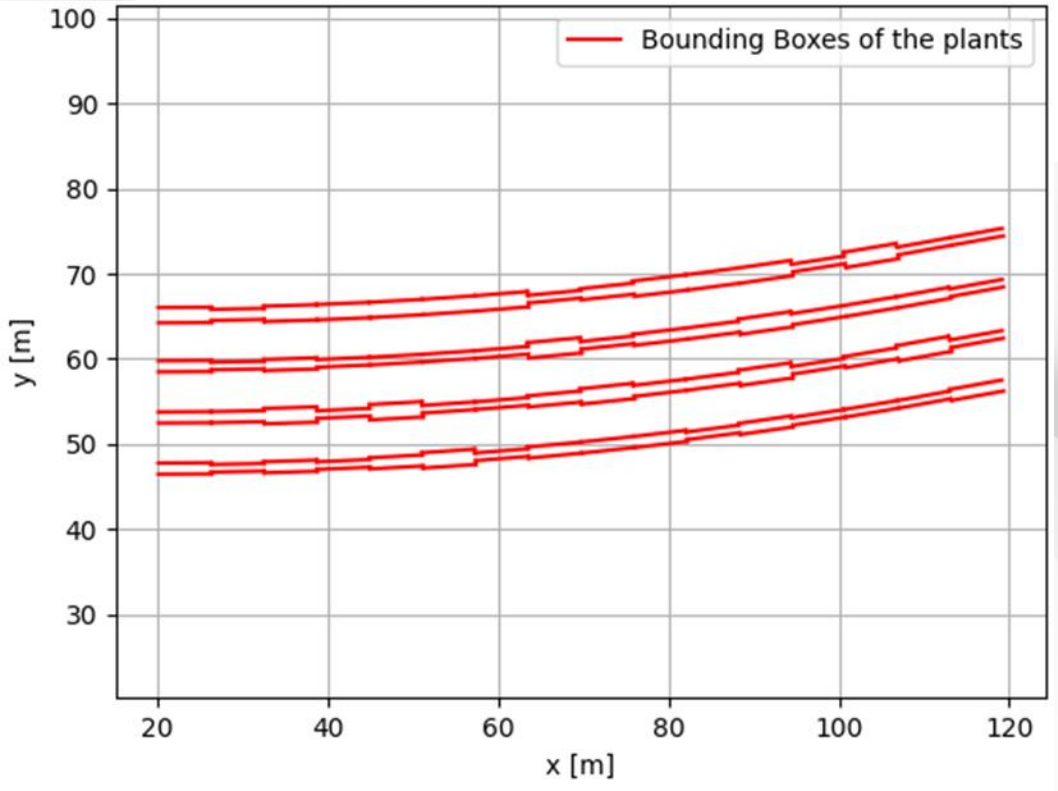
AUTONOMOUS DRIVING LOGIC





- SIMPLE SCENARIO TO BE USED AS A LOGIC DEVELOPMENT TRAINING GROUND.
- THE ROWS OF PLANTS ARE NOT STRAIGHT BUT THEY HAVE A SLIGHT CURVATURE (MORE CRITICAL)
- DIFFERENT VEGETATIVE CONDITION, SO DIFFERENT BOUNDING BOXES FOR THE PLANTS

AUTONOMOUS DRIVING LOGIC

DRIVING IN VINEYARD:
TWO PHASES

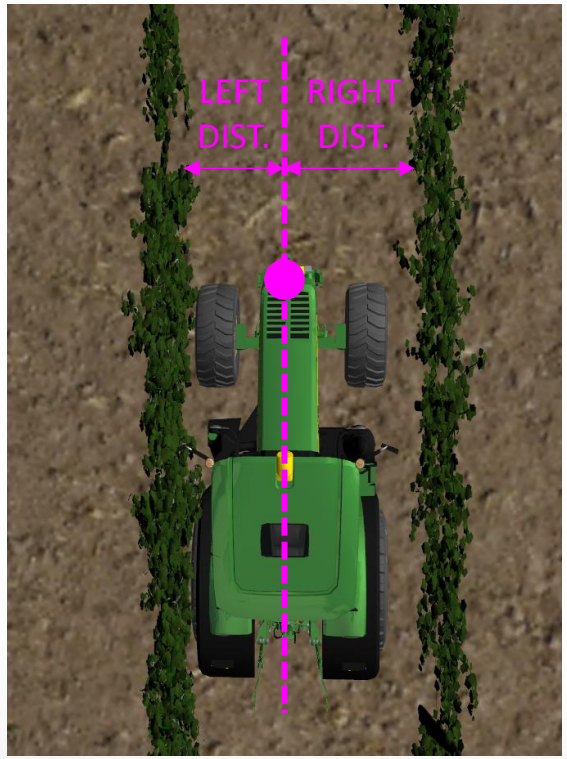
STRAIGHT

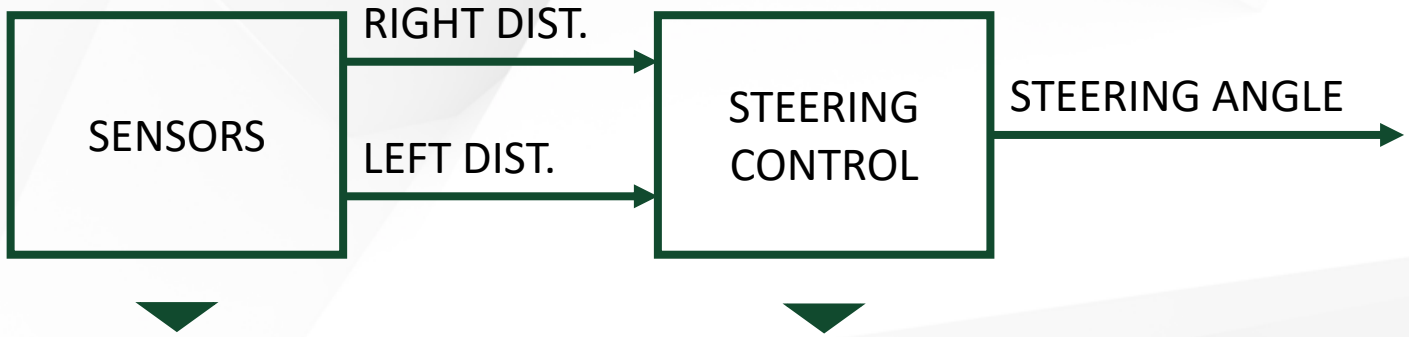
- TRACTOR IN A CORRIDOR
- CONSTANT SPEED
- ROWS OF PLANTS DETECTION
- STEERING CONTROL TO MAINTAIN THE VEHICLE IN THE CENTER

U-TURN

- TRACTOR AT THE END OF THE FIELD
- SPEED REGULATION
- MINIMUM TURNING RADIUS
- STEERING AND LONGITUDINAL CONTROL TO EXIT FROM A CORRIDOR AND ENTER IN A NEW ONE

AUTONOMOUS DRIVING LOGIC



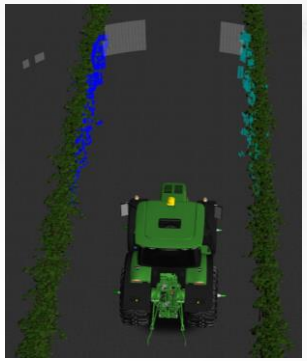


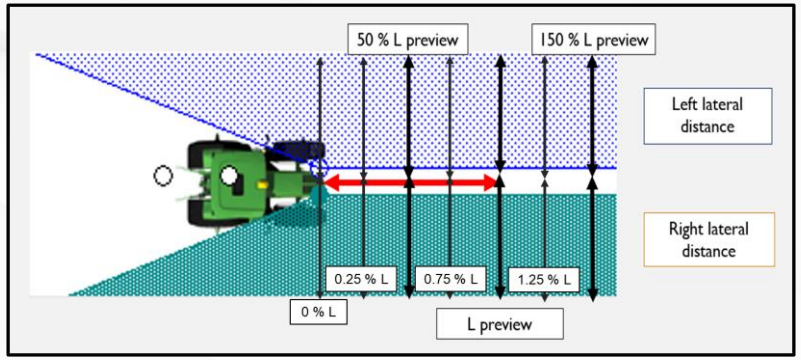
HYPOTHESIS OF IDEAL SENSORS

Once the vehicle is inside a corridor, the relative position between it and the rows of plants is always known and accurate.

MPC CONTROLLER

The trajectory to be followed by the controller is sensor based





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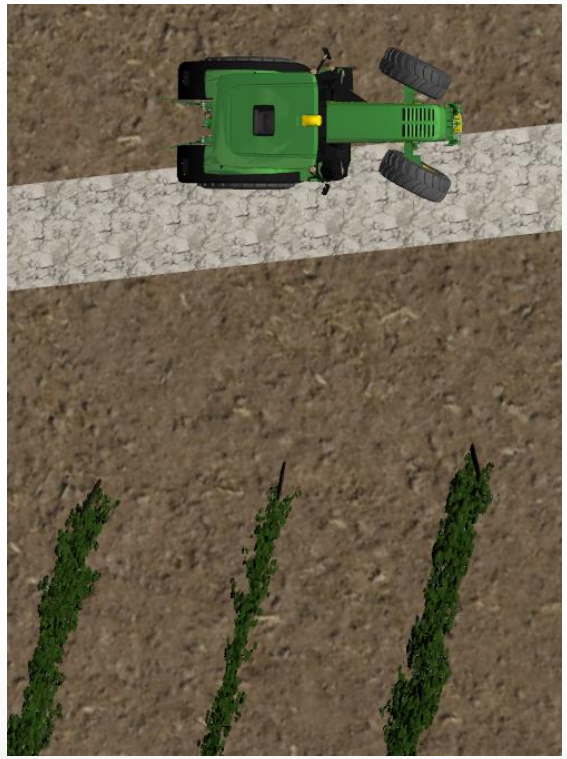

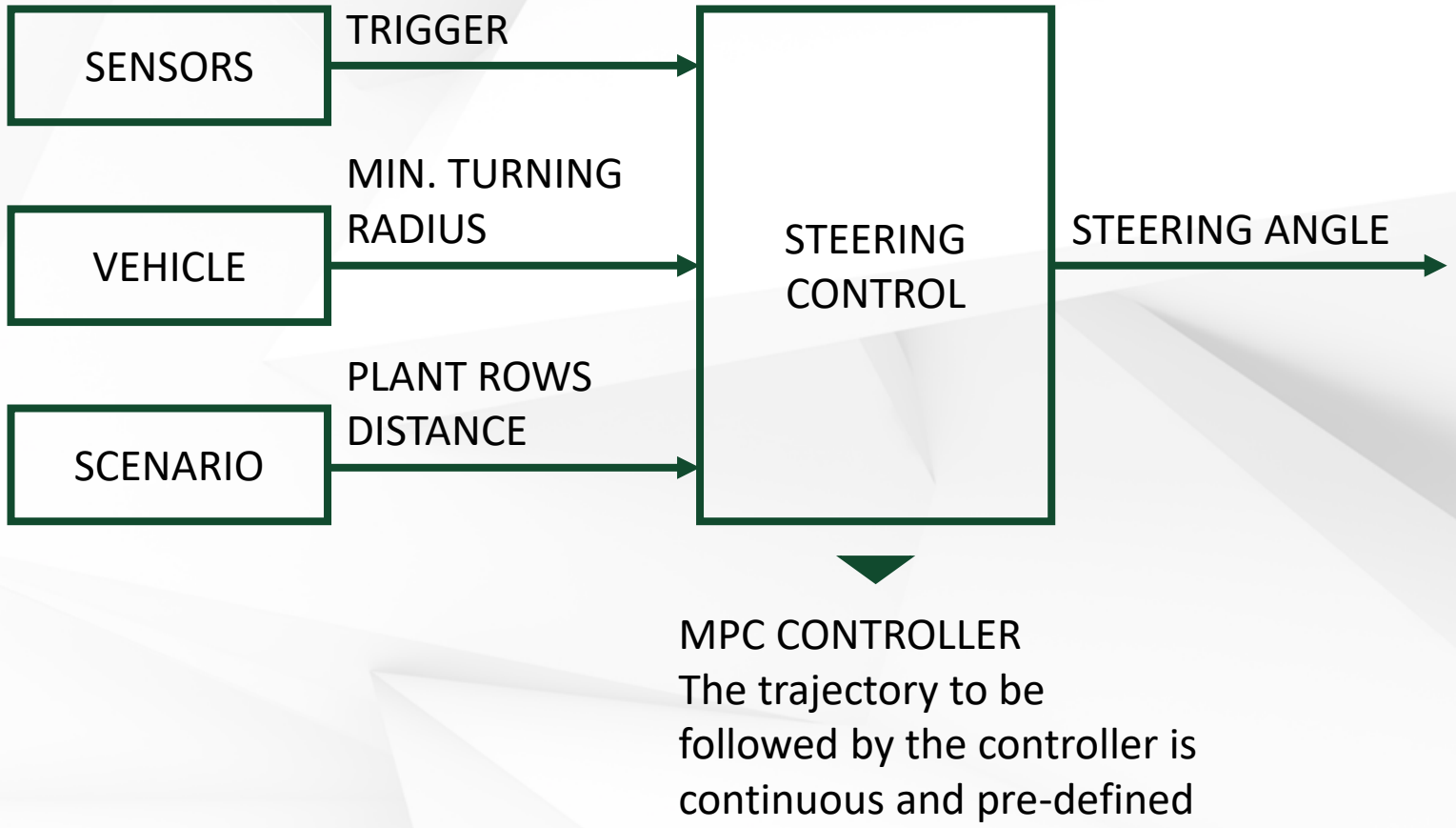

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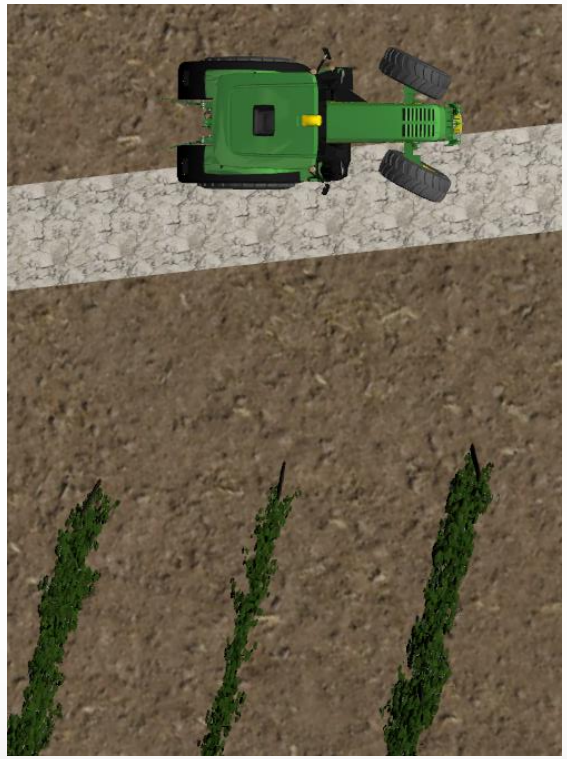

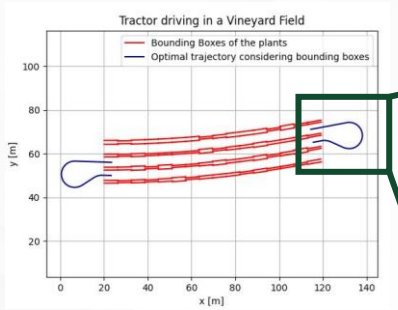

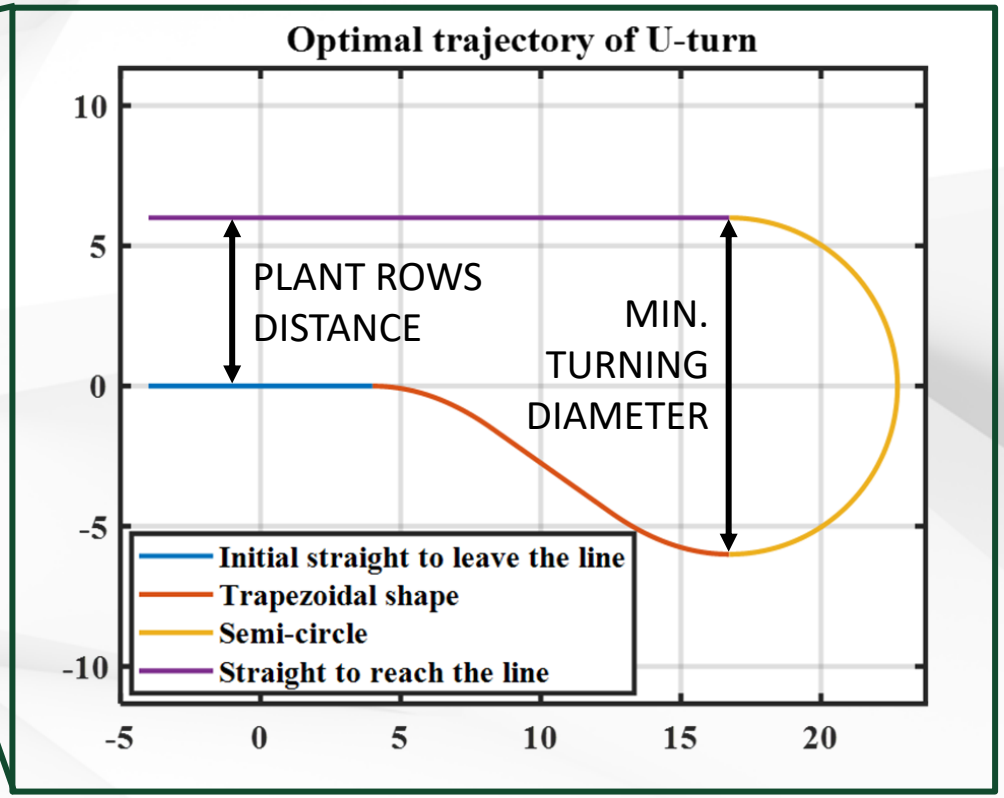

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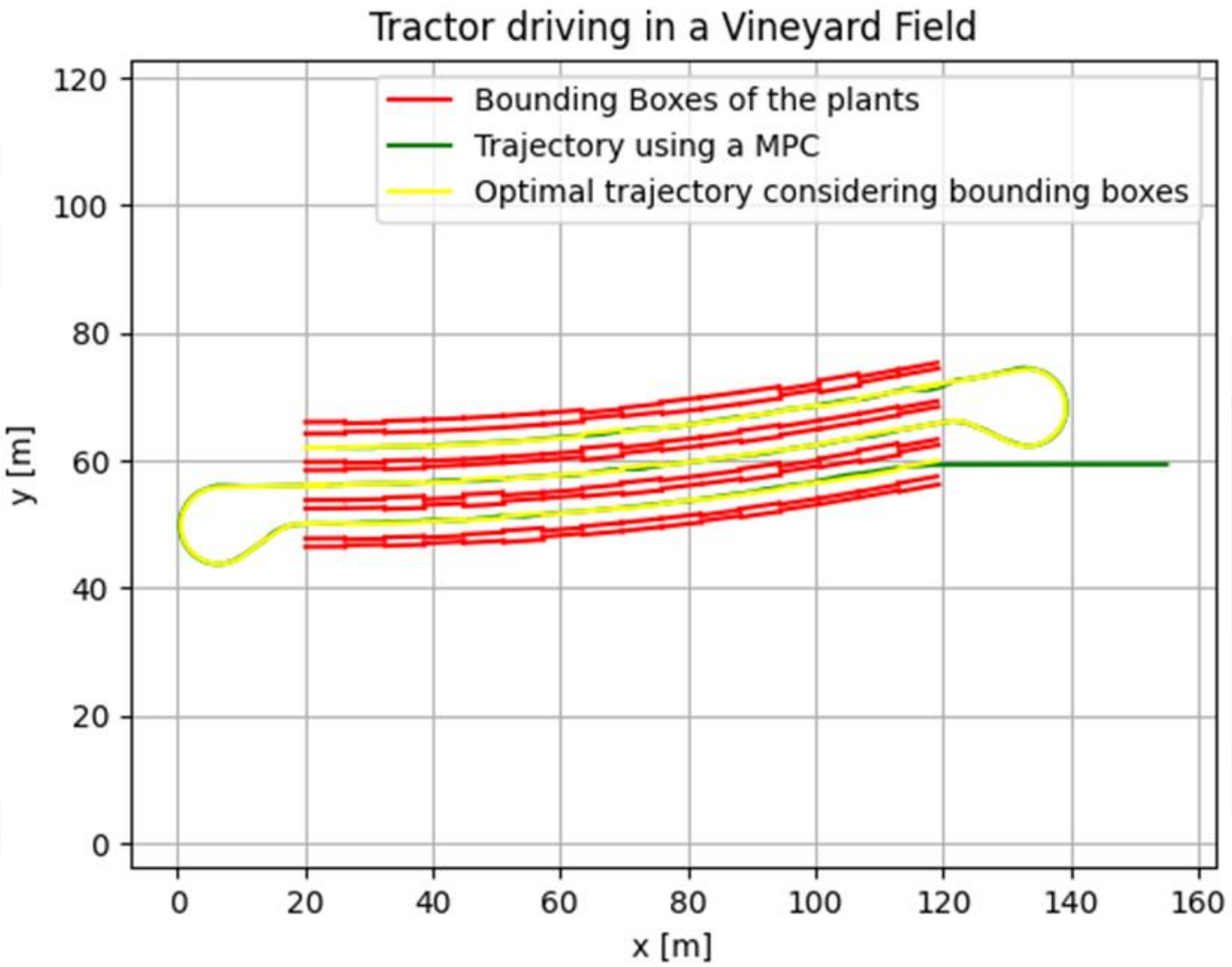

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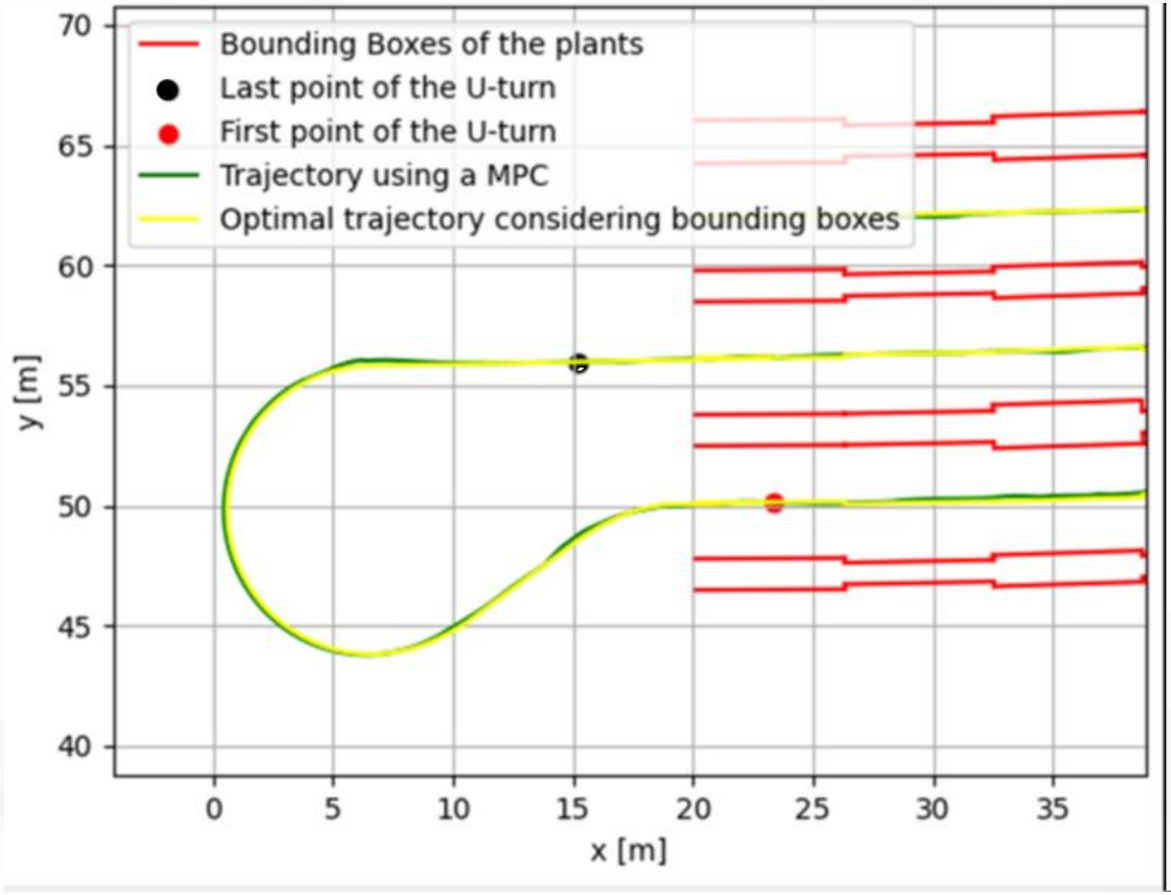

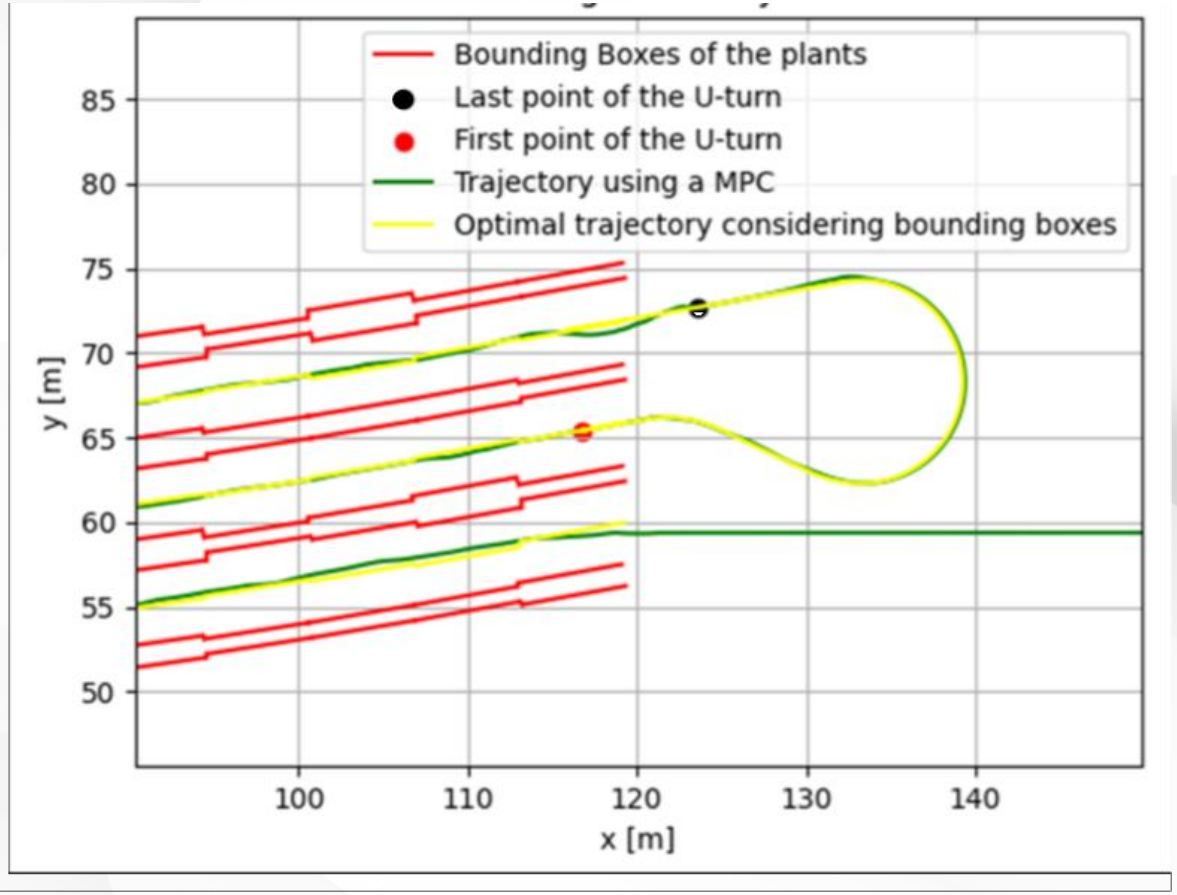

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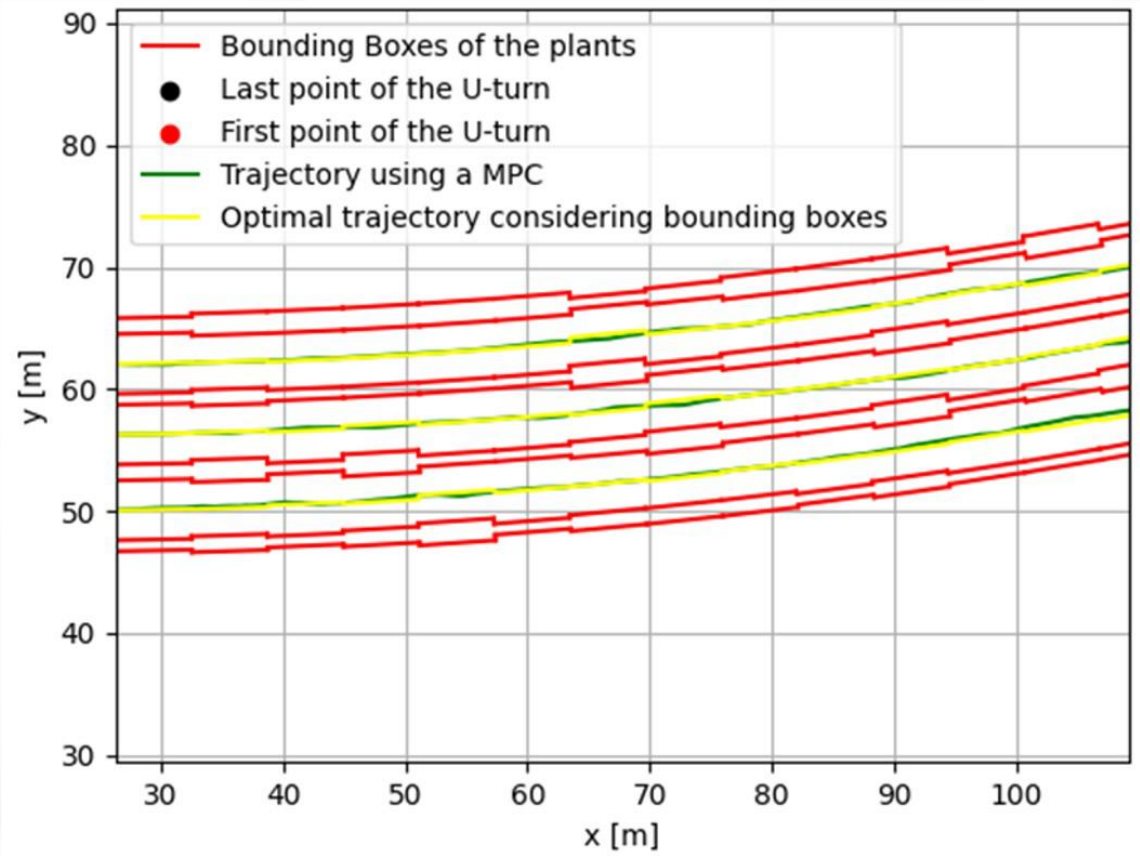

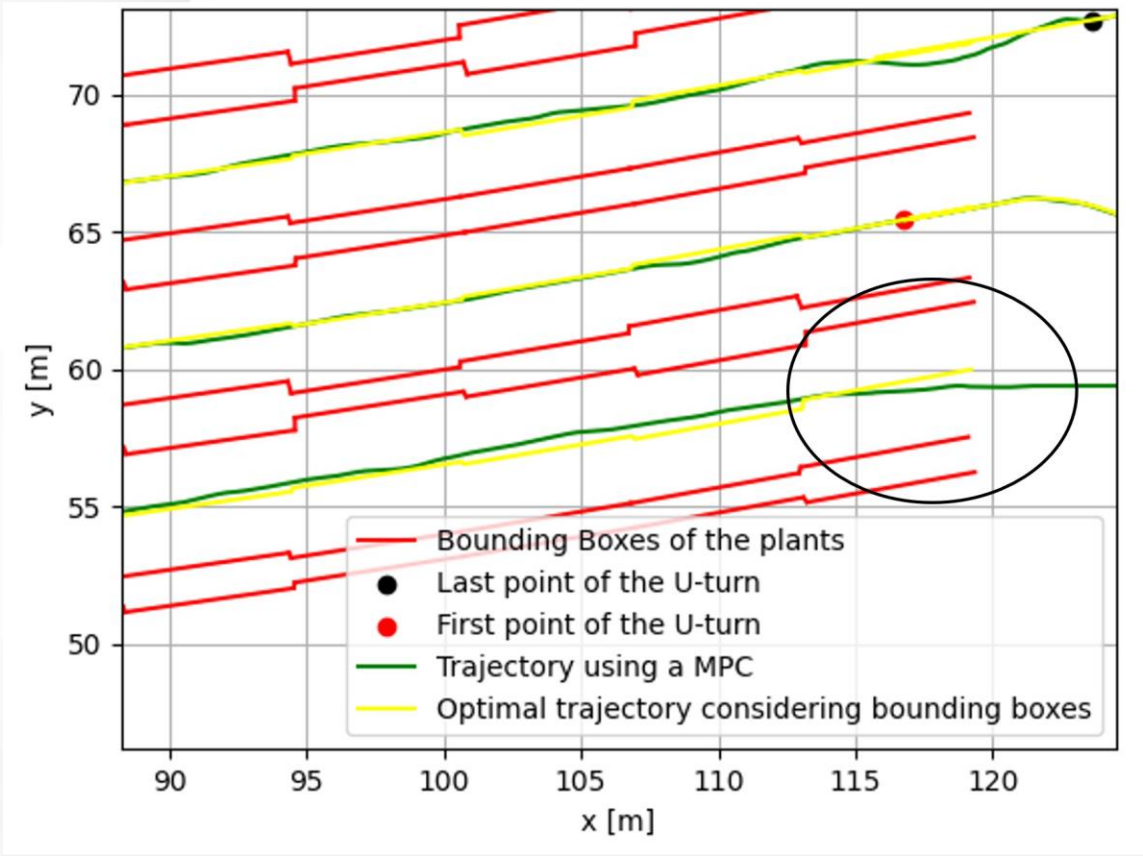

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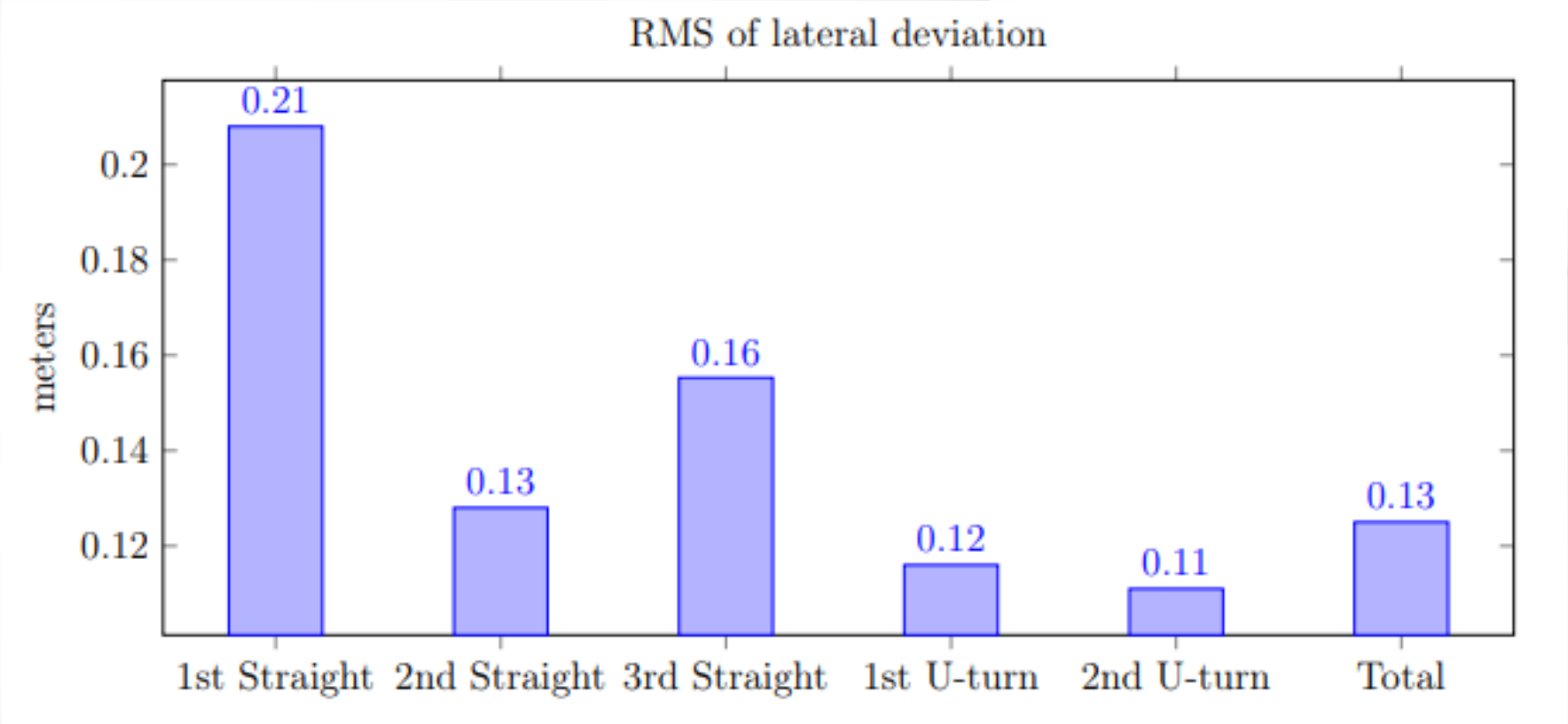

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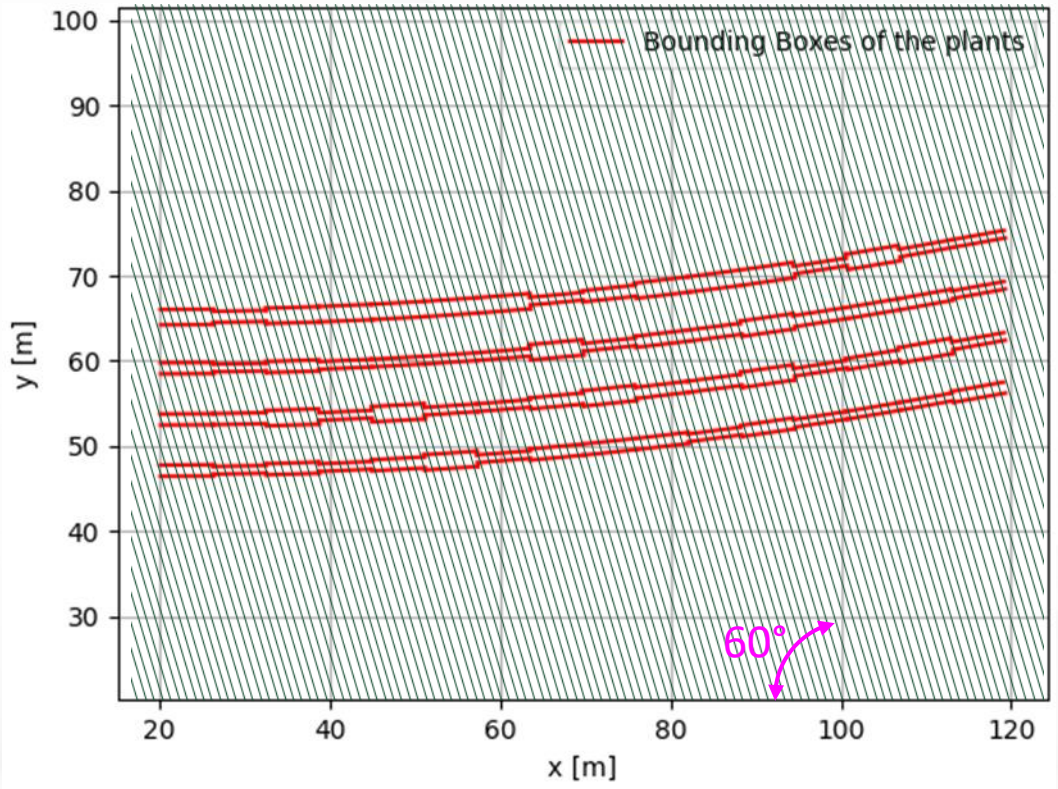
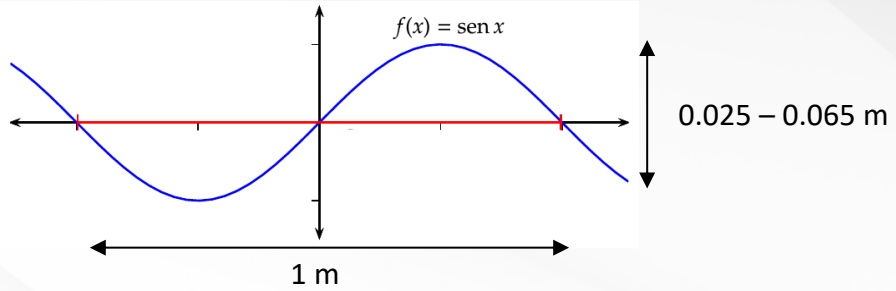


BUMP WAVE IRREGULARITIES
WITH FOLLOWING PARAMETERS

Parameter	Value
Rotation [deg]	60
Height [m]	0.025 – 0.065
Period length [m]	1



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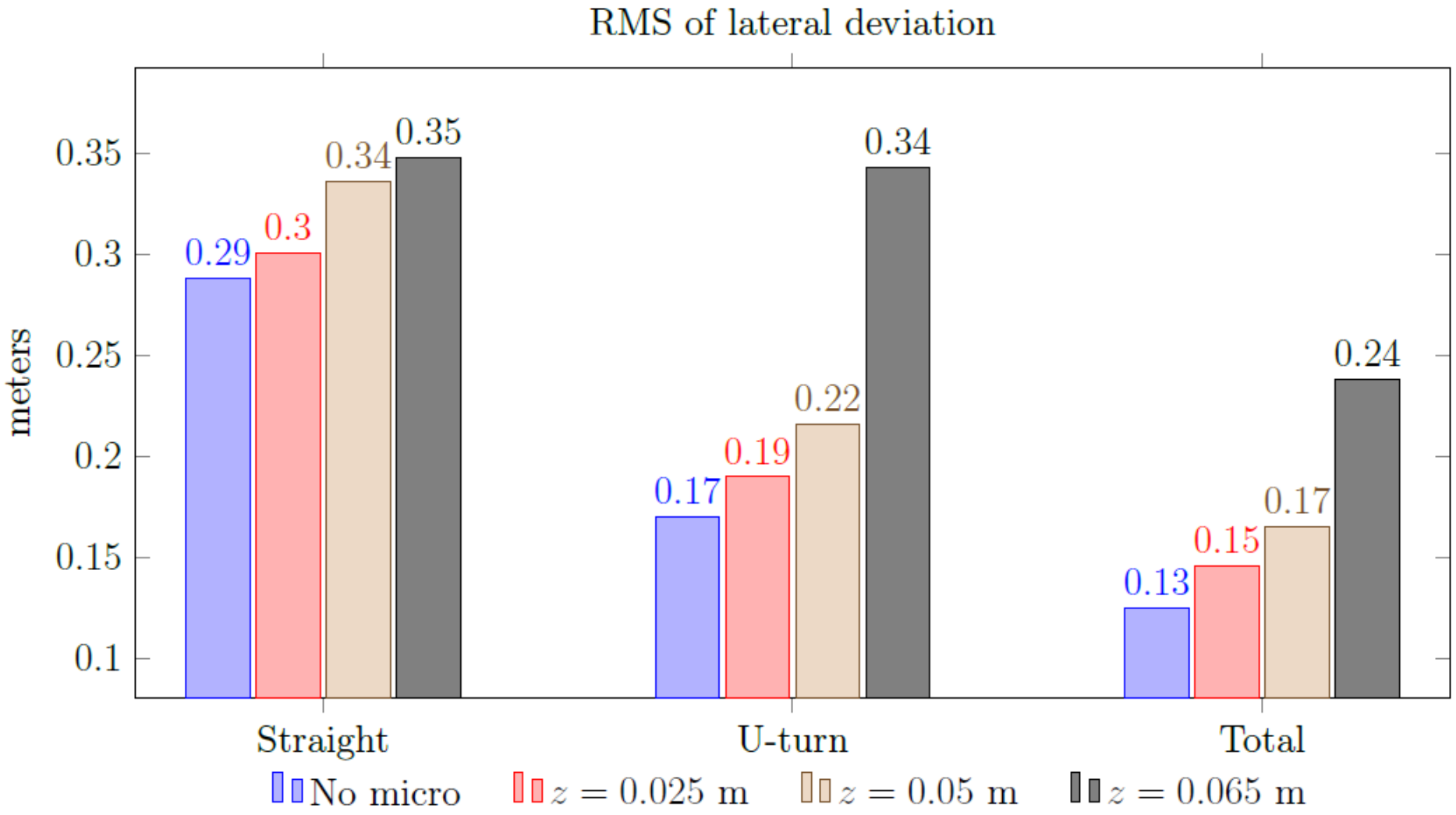

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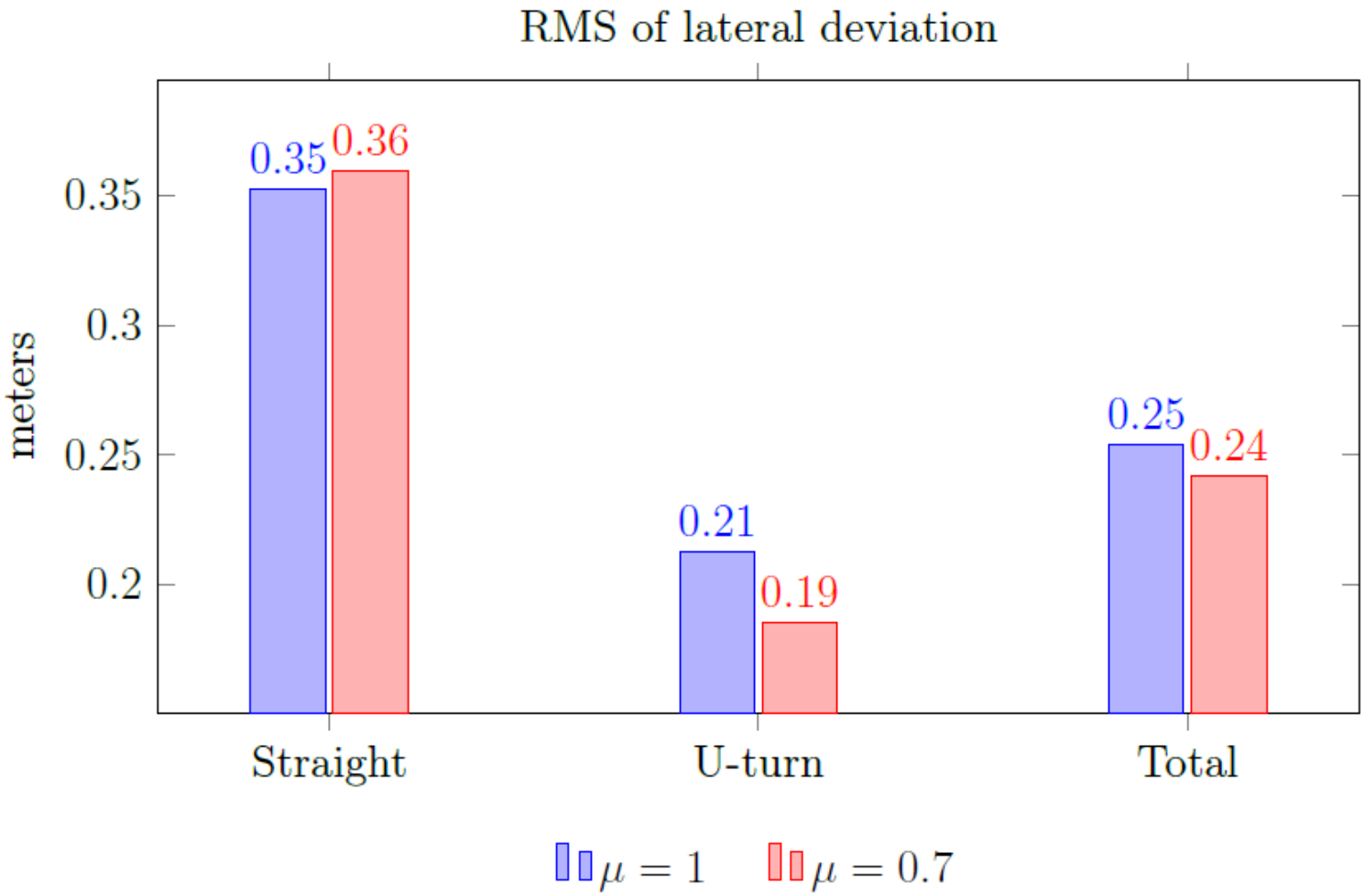

OUTLINES

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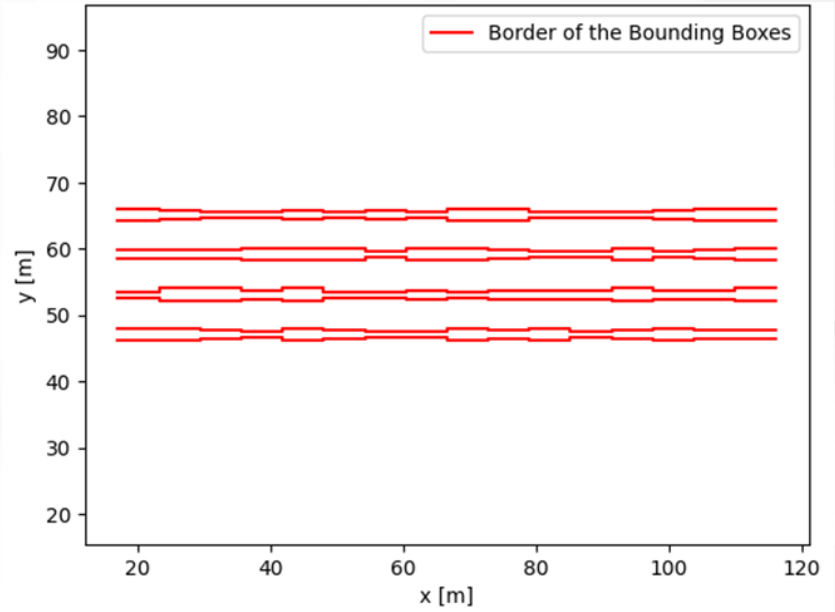
PLANTS INSPECTION LOGIC

- SIMPLE SCENARIO BUILT STARTING FROM A REAL VINEYARD (SUBSET)
- DIFFERENT VEGETATIVE CONDITION, SO DIFFERENT BOUNDING BOXES FOR THE PLANTS



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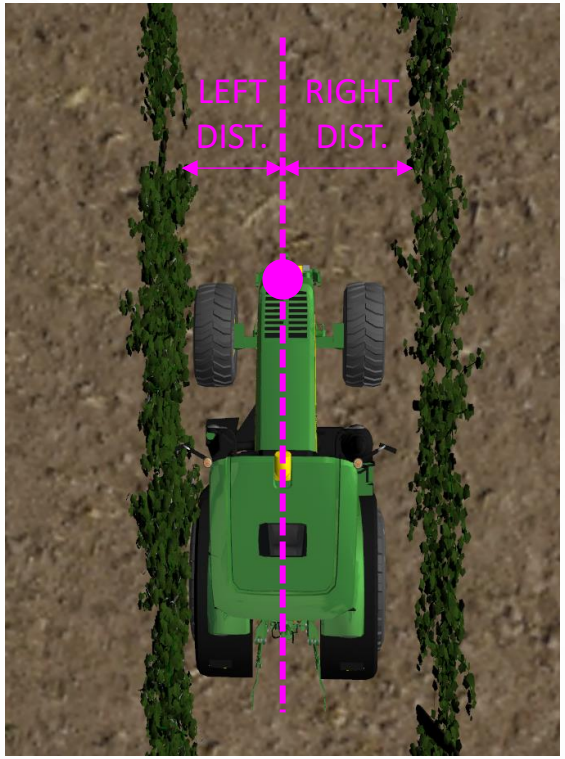

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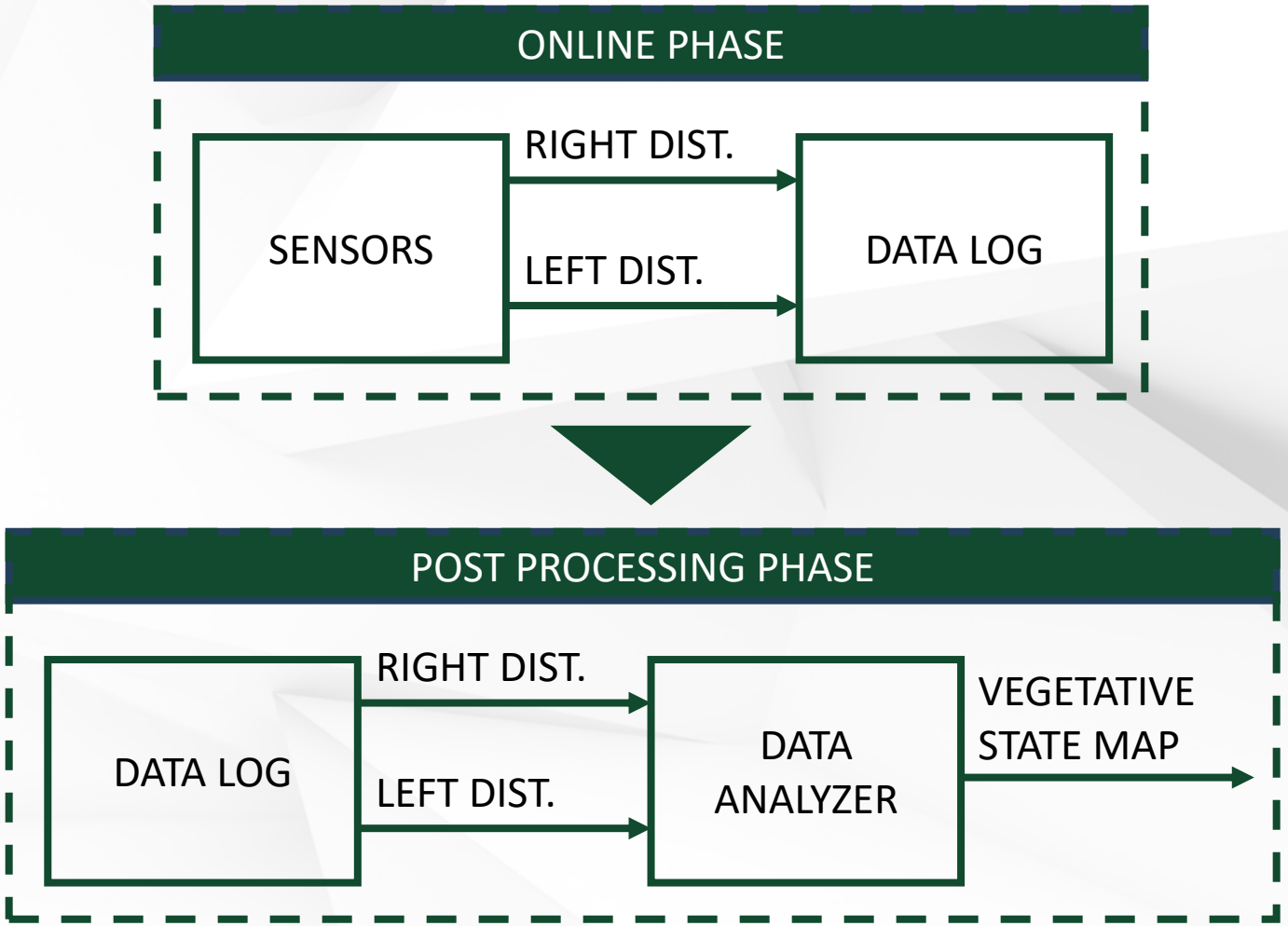

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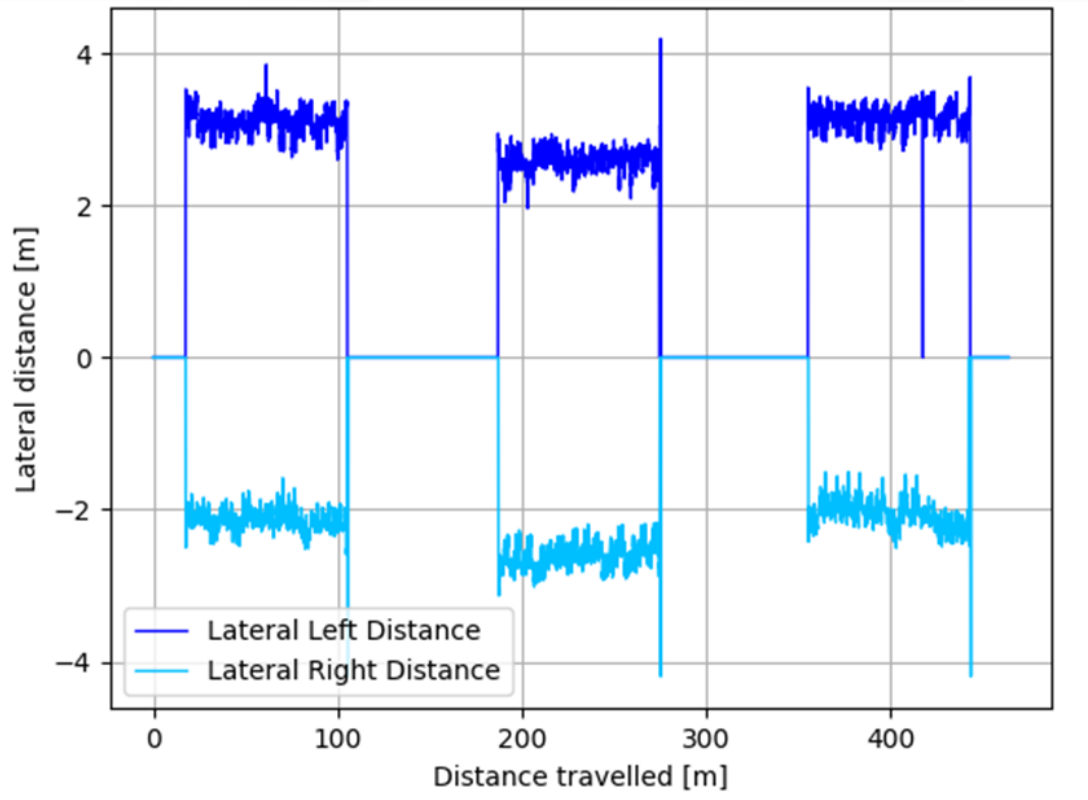

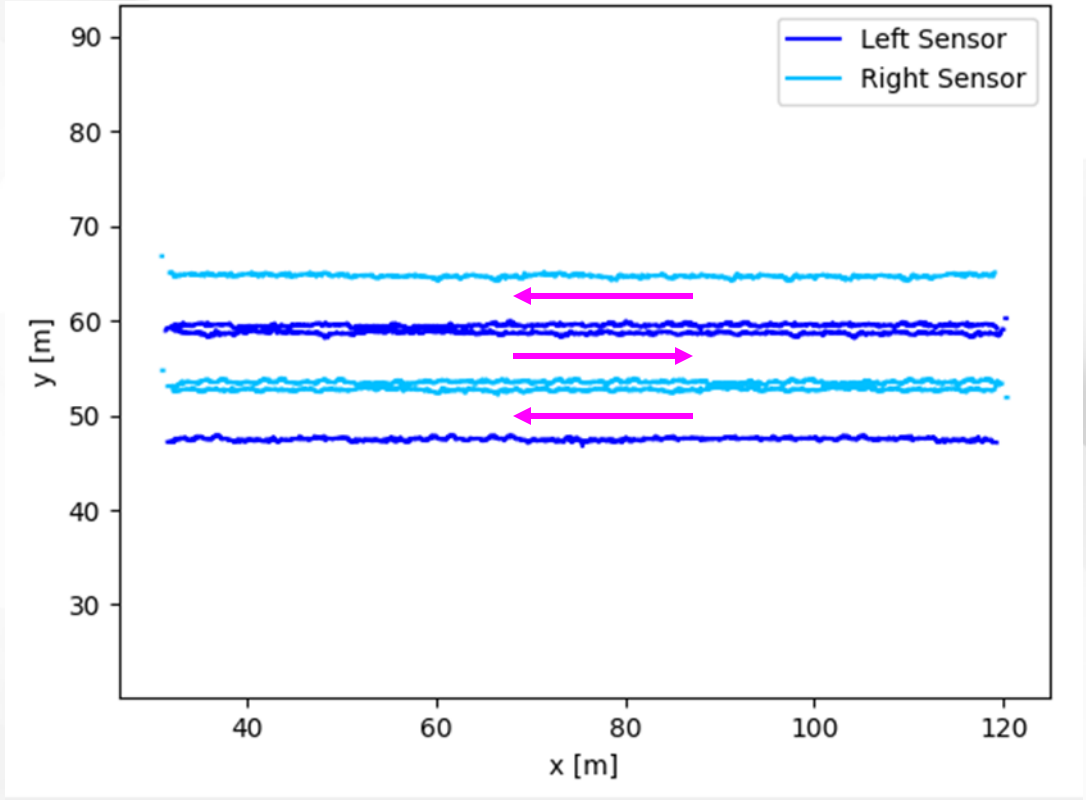

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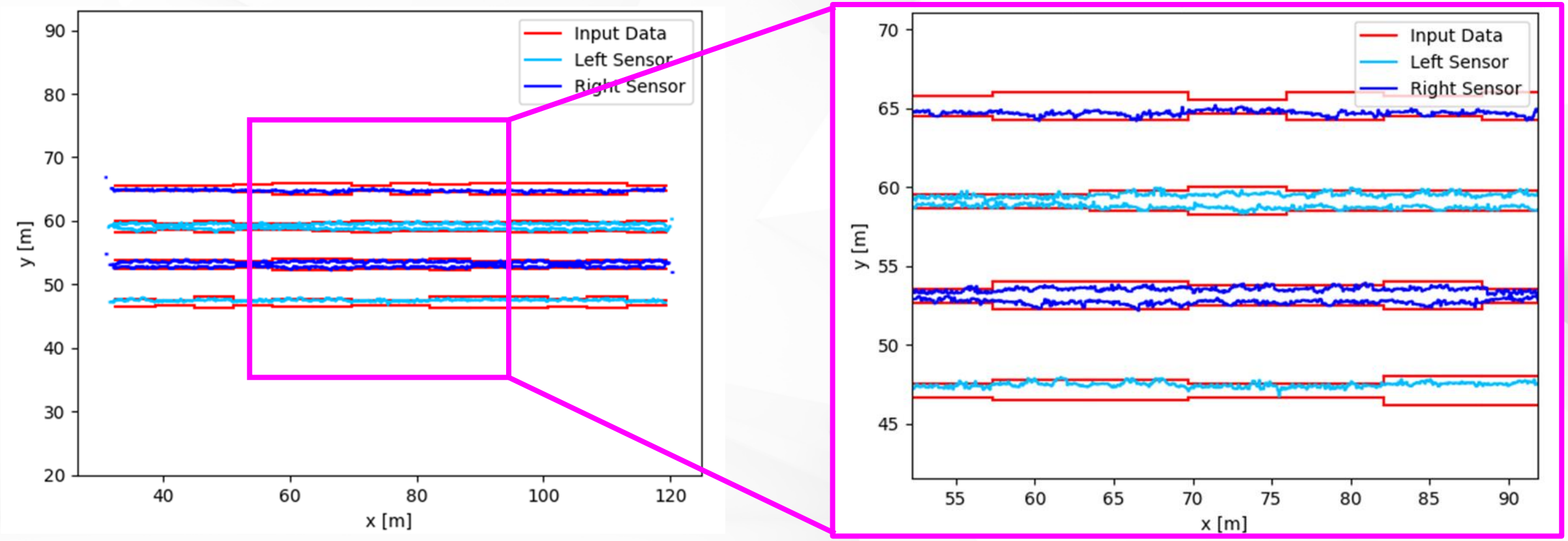

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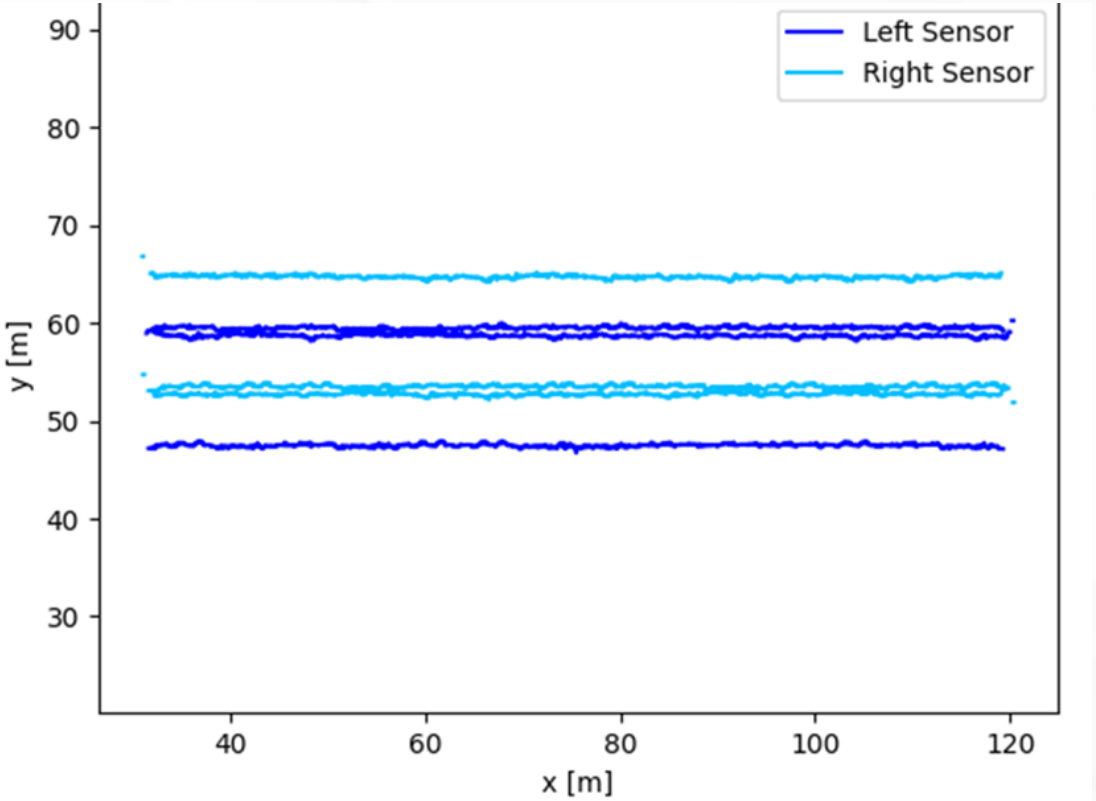

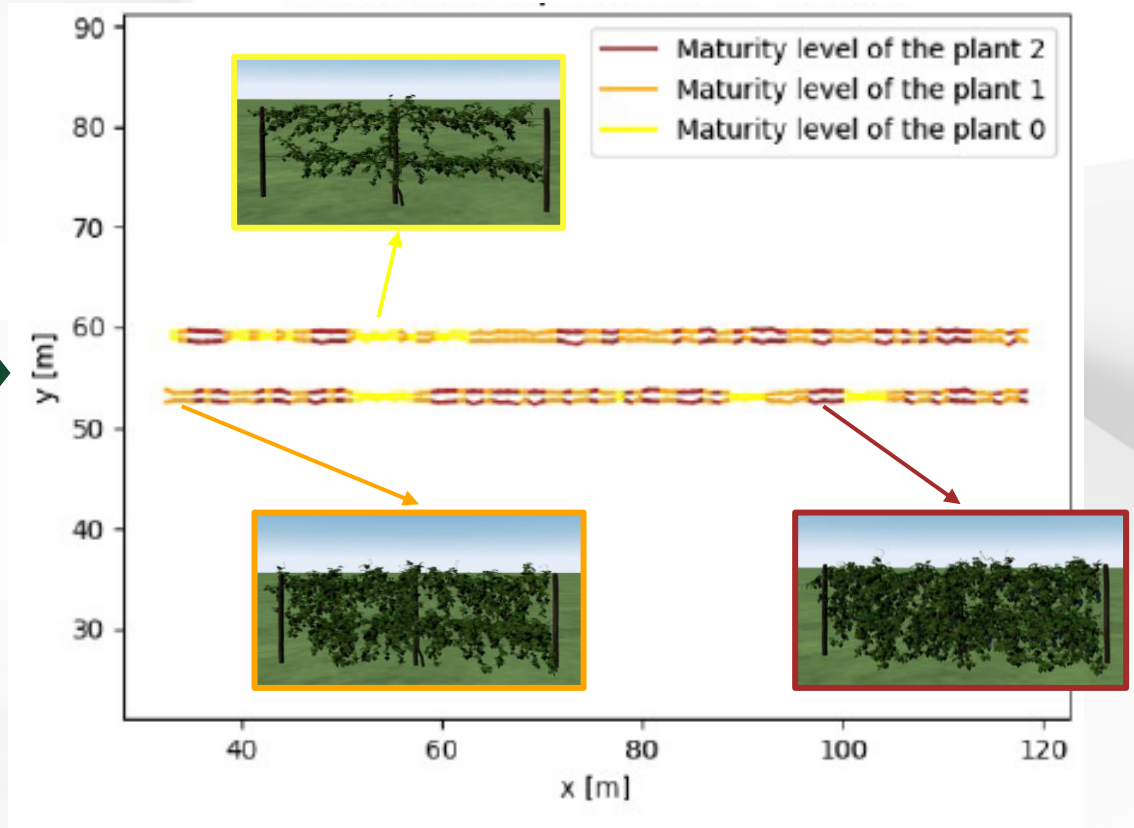

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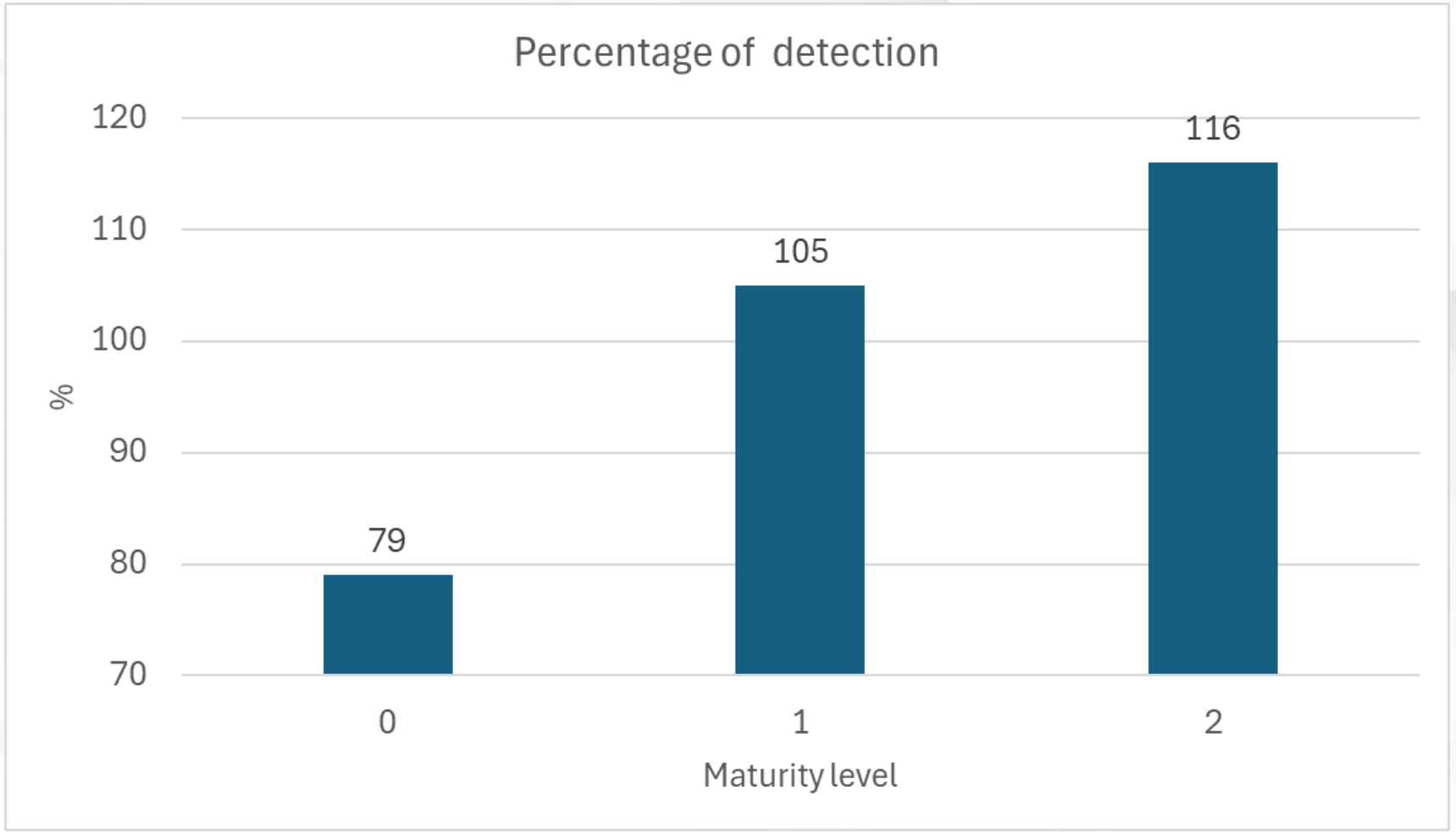
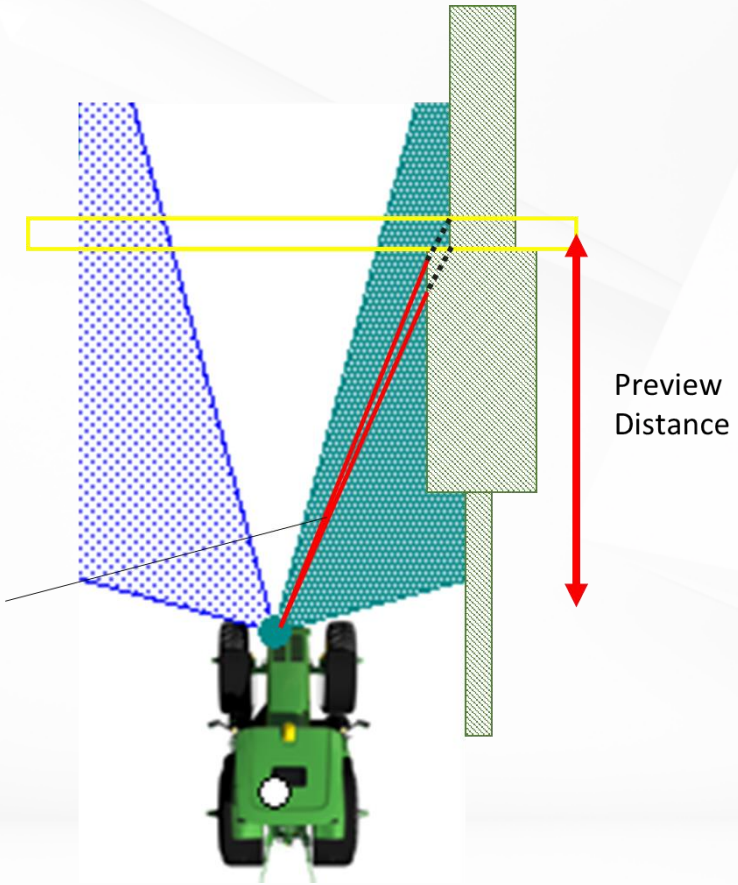
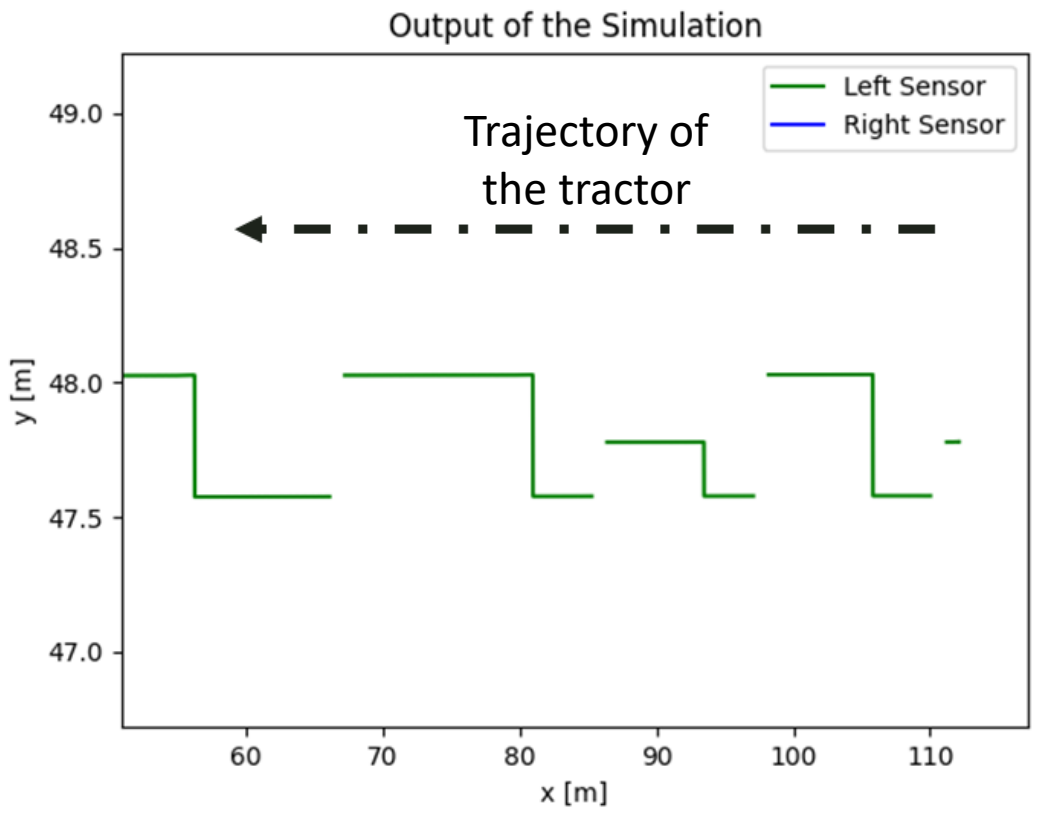


AUTONOMOUS DRIVING LOGIC





OUTLINES

1 TARGETS & MOTIVATIONS

2 VINEYARD SCENARIO GENERATION

3 AUTONOMOUS DRIVING LOGIC

4 PLANTS INSPECTION LOGIC

5 **CONCLUSIONS**

CONCLUSIONS

AN ALGORITHM HAS BEEN DEVELOPED TO GENERATE A GEOREFERENCED SCENARIO THAT REPLICATES AN EXISTING VINEYARD. STARTING FROM DATA OBTAINABLE FROM COMMON GIS SOFTWARE, THE SCENARIO FILE IS AUTOMATICALLY GENERATED FOR IMPORT INTO AgriSI SIMULATIONS.

THE EFFECTIVENESS OF USING A GENERATED VINEYARD SCENARIO FOR THE DEVELOPMENT OF CONTROL LOGICS HAS BEEN DEMONSTRATED. AS EXAMPLES, THE SETUP OF TWO PROTOTYPE ALGORITHM HAS BEEN SHOWN:

- AN MPC CONTROLLER FOR AUTONOMOUS DRIVING WITHIN THE VINEYARD
- AN AUTOMATIC EVALUATION OF THE MATURITY LEVEL OF THE PLANTS

AgriST

THE AGRICULTURAL VEHICLE DYNAMICS AND PRECISION FARMING SIMULATION PLATFORM