ICSE 2022
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Paper Award



Efficient Online Testing for DNN-Enabled Systems using Surrogate-Assisted and Many-Objective Optimization

Fitash Ul Haq[1], Donghwan Shin[1], and Lionel Briand[1,2]

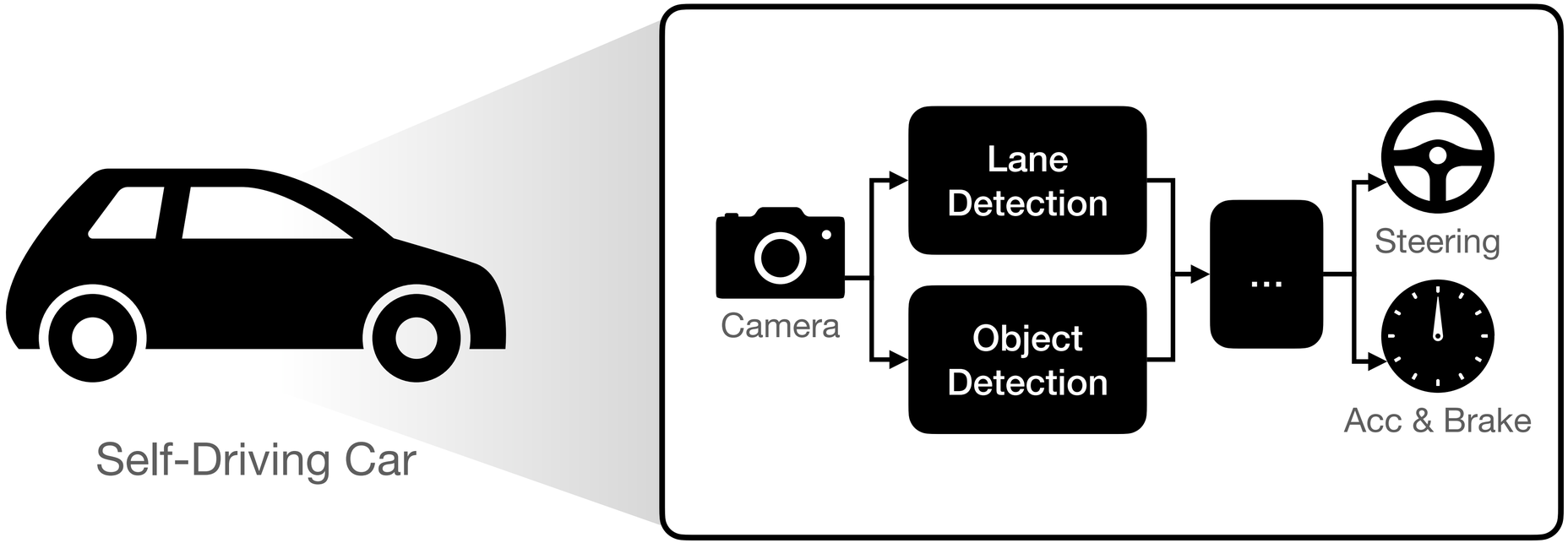
1. University of Luxembourg
2. University of Ottawa



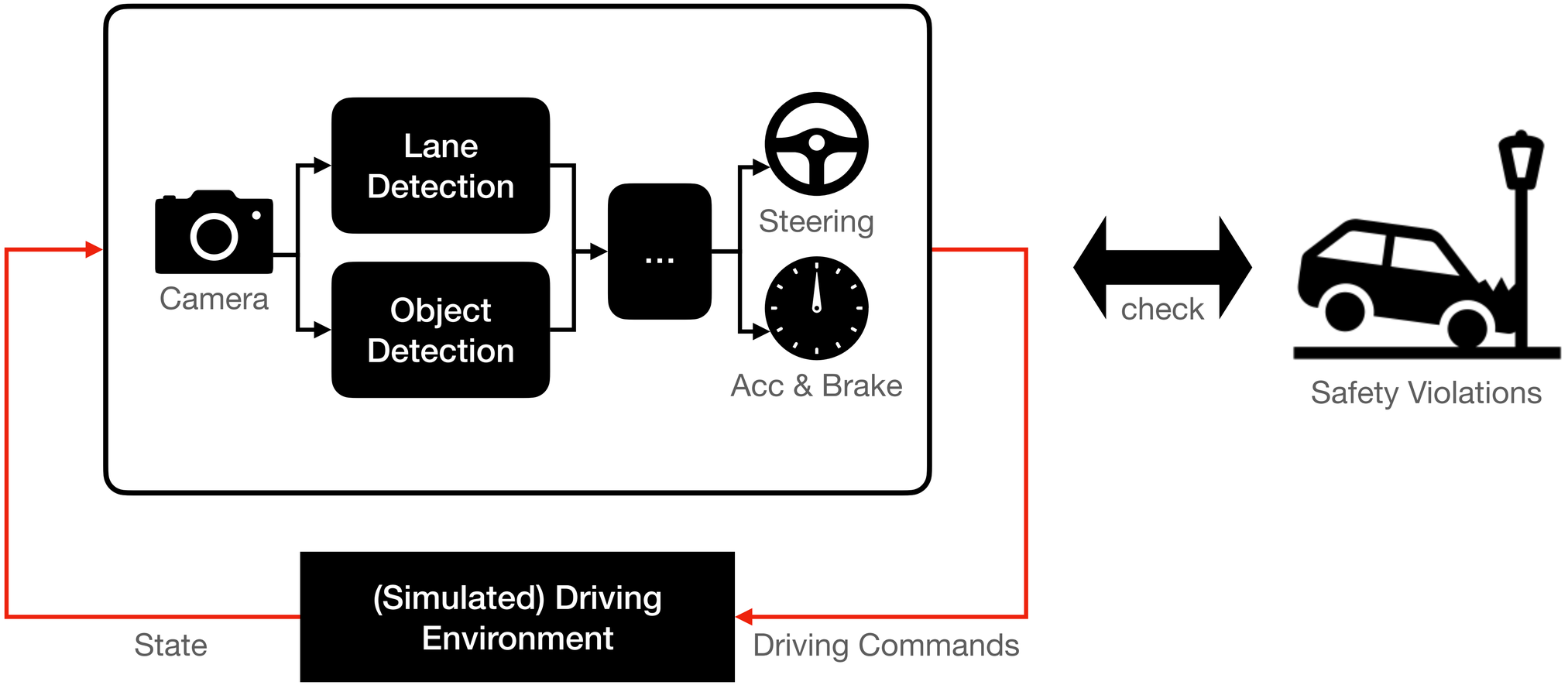




DNN-Enabled Systems (DES)



Online Testing for DES



Challenges for Online Testing

Large Input Space

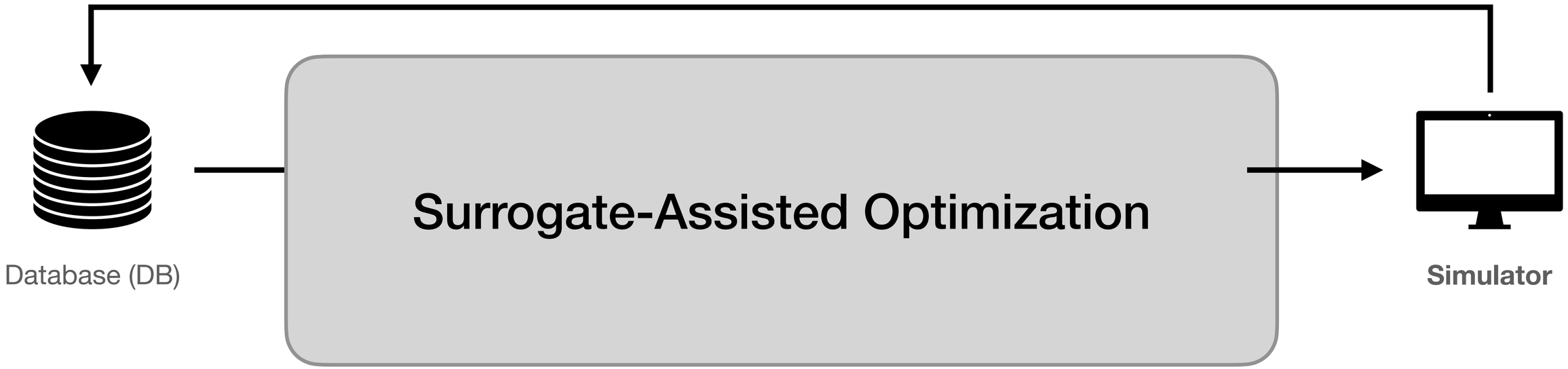
Multiple Safety Requirements

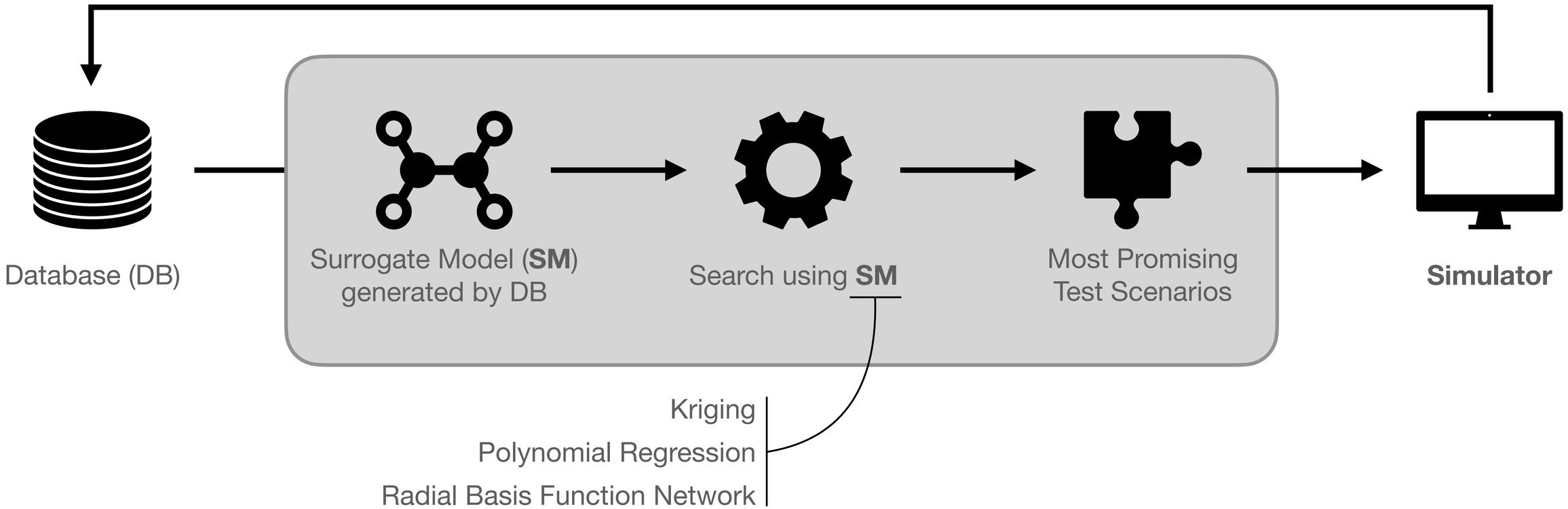
Computationally-intensive Simulation

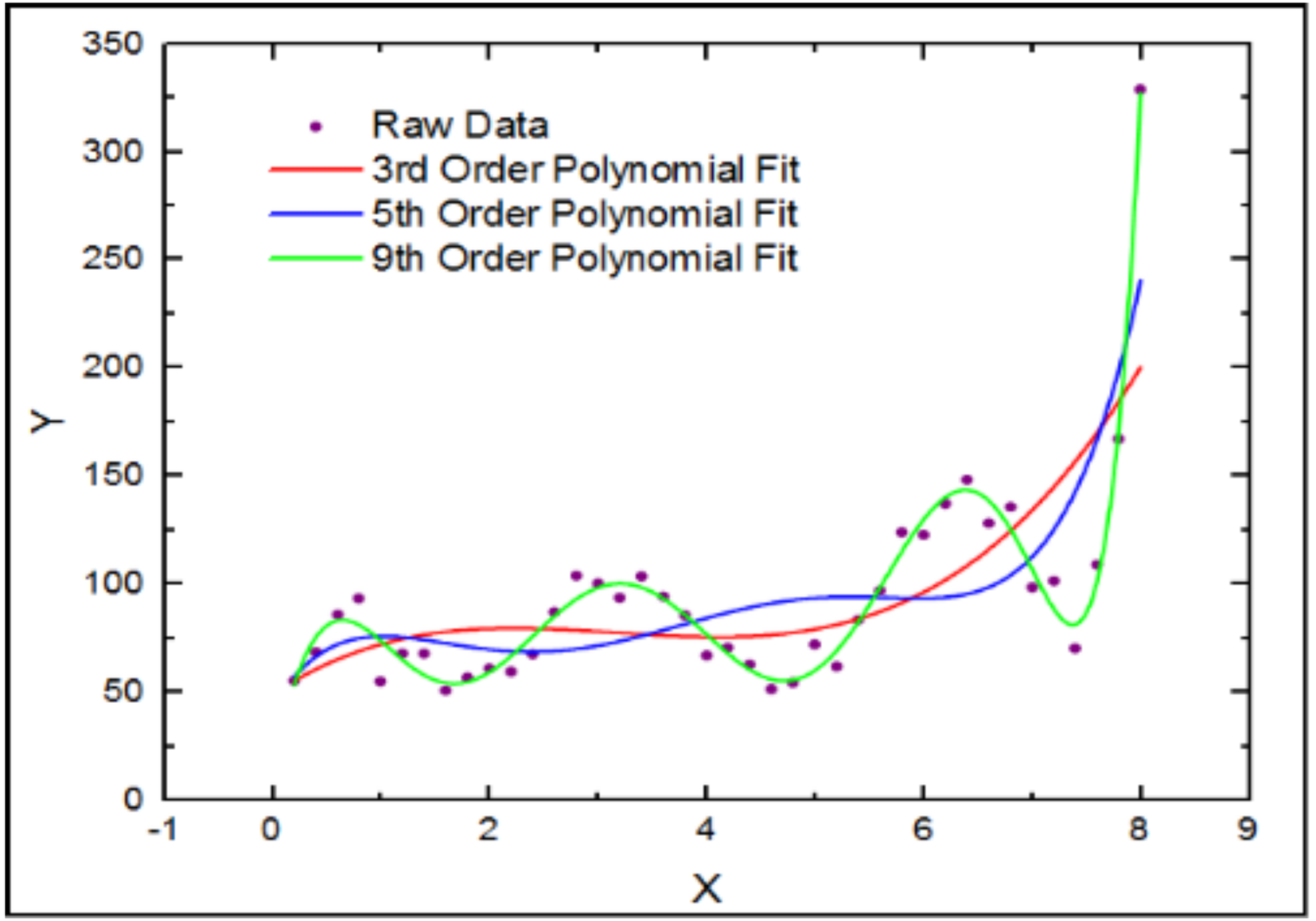
3rd Party Components

SAMOTA

(Surrogate-Assisted Many-Objective Testing Approach)


Surrogate-Assisted Optimization
Database (DB)
Simulator

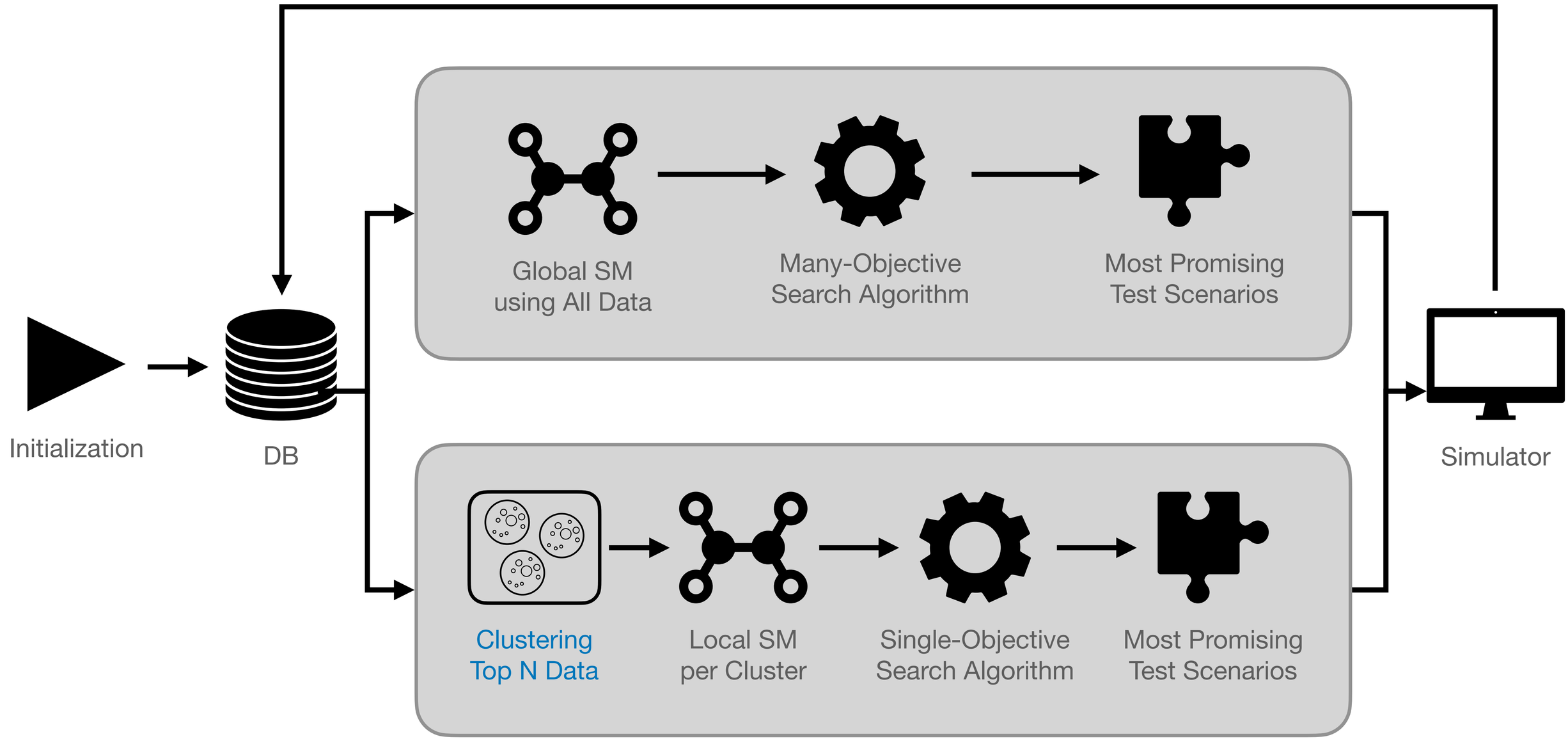

Database (DB)
Surrogate Model (**SM**) generated by DB
Search using **SM**
Most Promising Test Scenarios
Simulator
Kriging
Polynomial Regression
Radial Basis Function Network



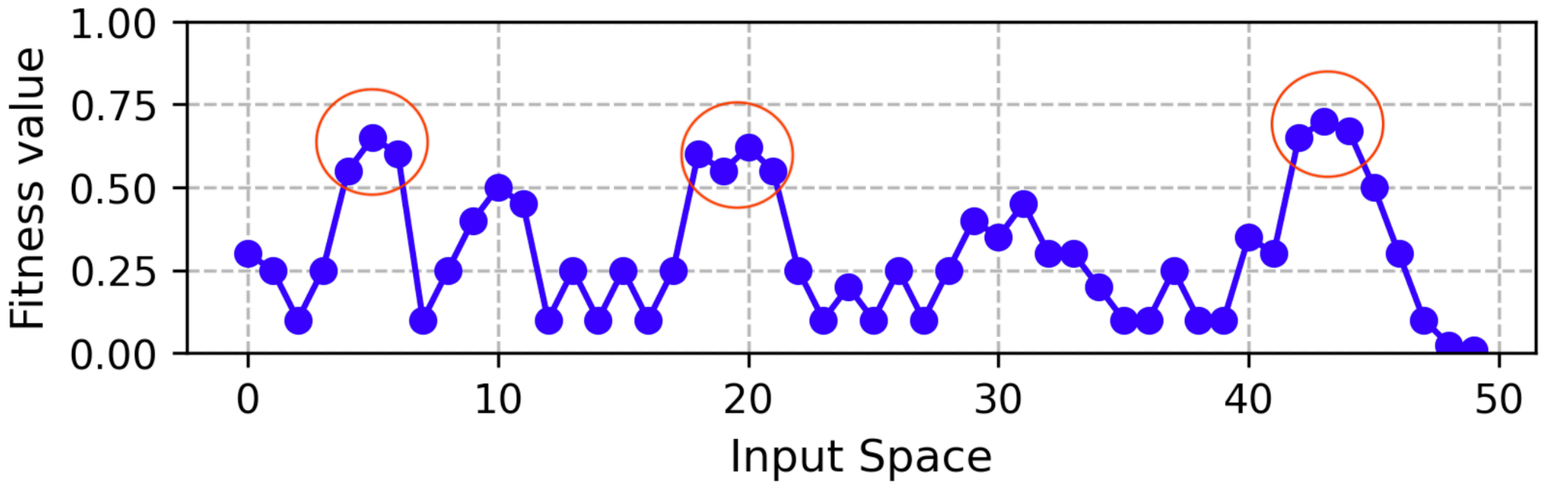
[image from WikiMedia by Shobha]

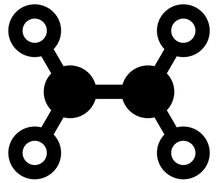


DB = Database
SM = Surrogate Model

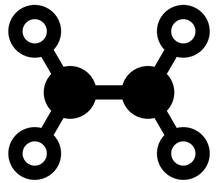


DB = Database
SM = Surrogate Model





Global SM
using **All Data**



Local SM using
top n% data

- One LSM for the top n%
- One LSM per cluster

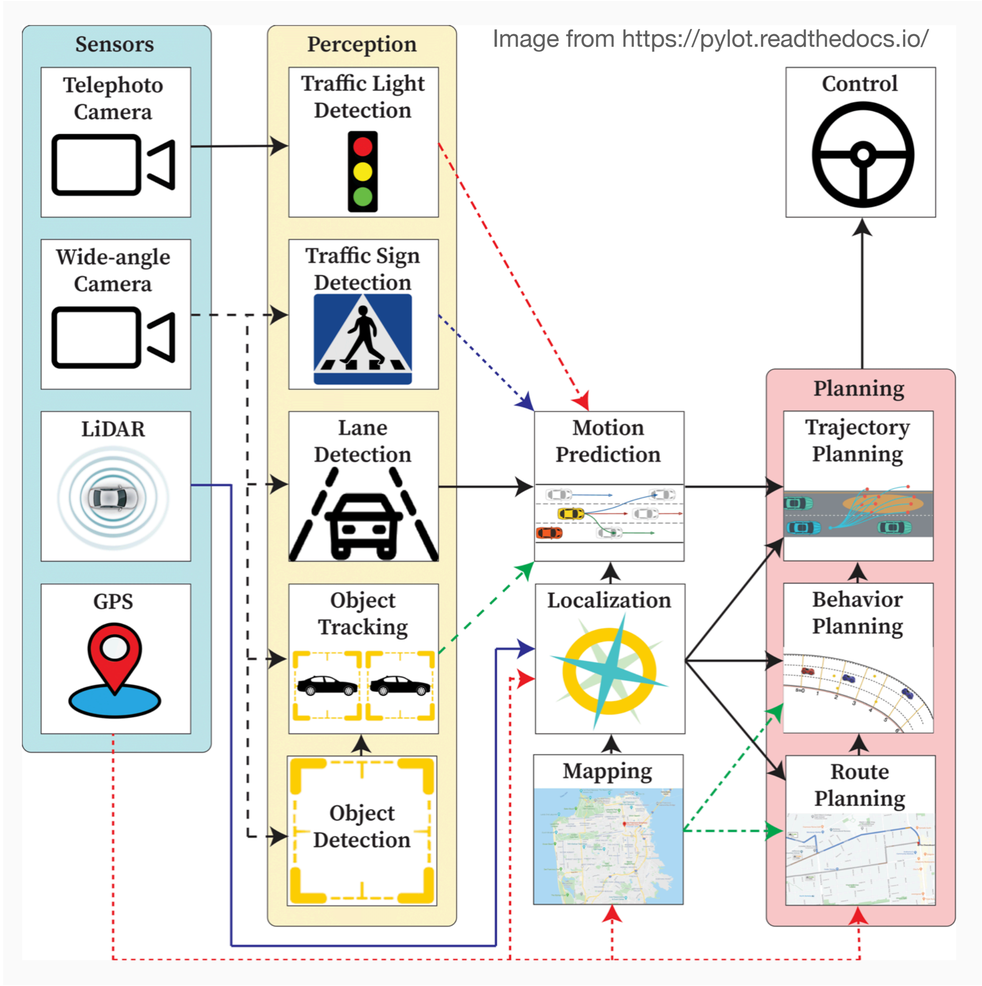
Empirical Evaluation

RQ1: What is the best configuration for Local Search (LS)?

RQ2: How do alternative approaches fare in terms of test effectiveness?

RQ3: How do alternative approaches fare in terms of test efficiency?

Case Study Subject



Pylot (DNN-enabled system)

Image from https://carla.org



CARLA (Driving Simulator)

Test Case (Driving Scenario)

- Road type
- Start/end-point on maps
- The presence of other vehicles in front/same/opposite lane
- Other vehicle types
- Vehicle speed
- The density of pedestrians
- The presence of trees and buildings
- Time of day
- Weather condition

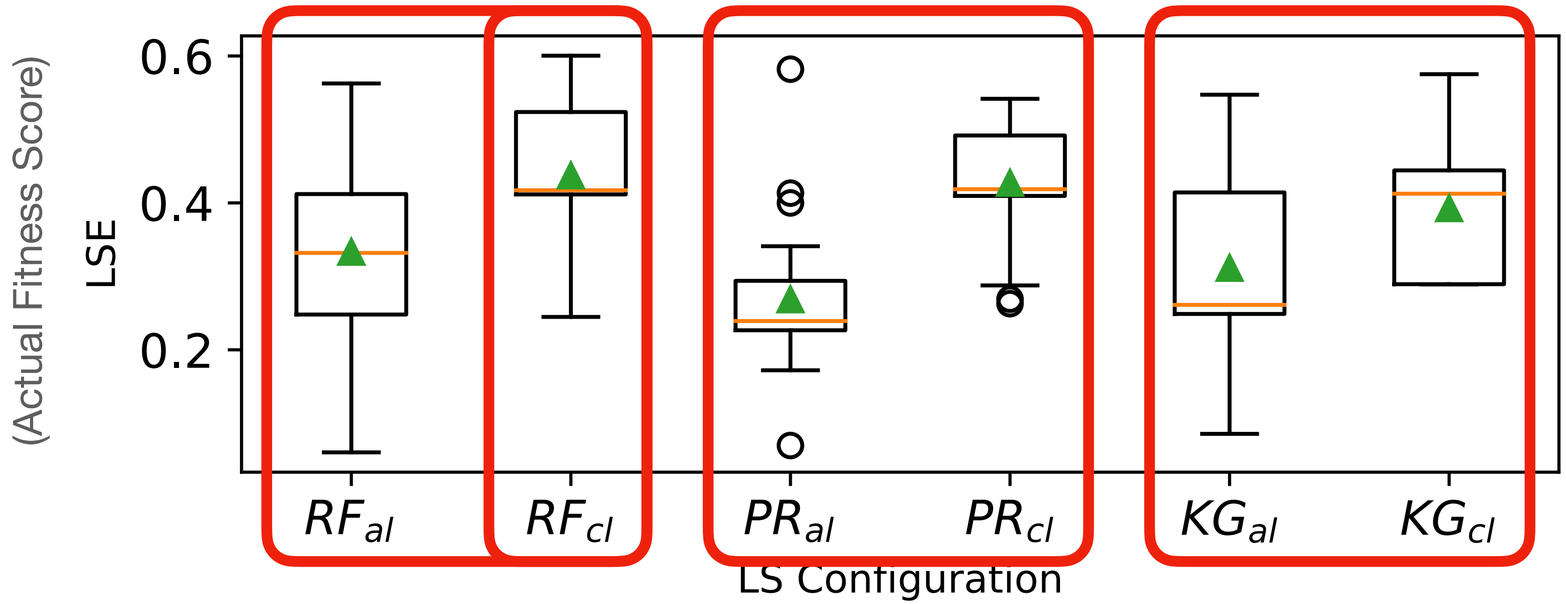
Image from https://carla.org



Safety Requirements

- Follow the center of the lane
- Avoid collision with other vehicles
- Avoid collisions with pedestrians
- Avoid collision with static objects (e.g., traffic signs)
- Abide by traffic rules (e.g., traffic lights)
- Reach the destination within a given time

RQ1: Best Configuration for LS



SM Type

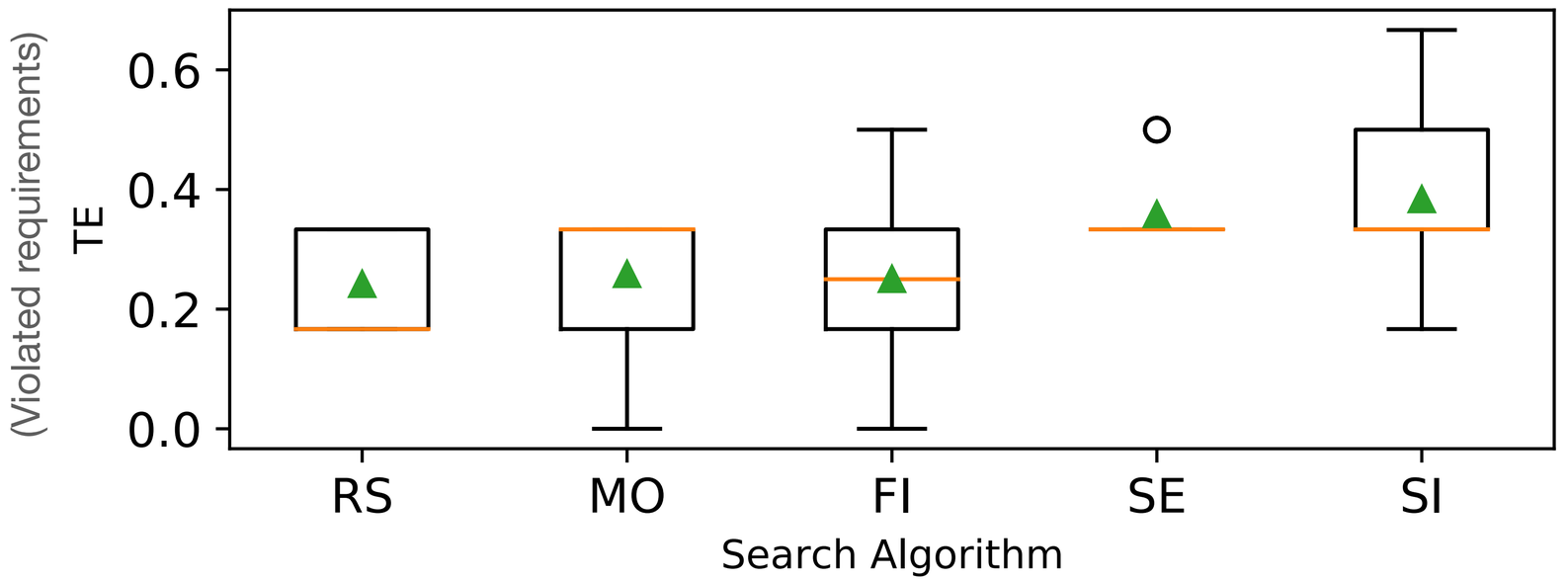
KG: KriGing
PR: Polynomial Regression
RF: Radial basis Function network

SM Generation Approach

al: one SM using all the top n% data points
cl: one SM for each cluster after clustering the data points

- ***cl*** is better than ***al*** in all cases
- RF_{cl} is the best on average

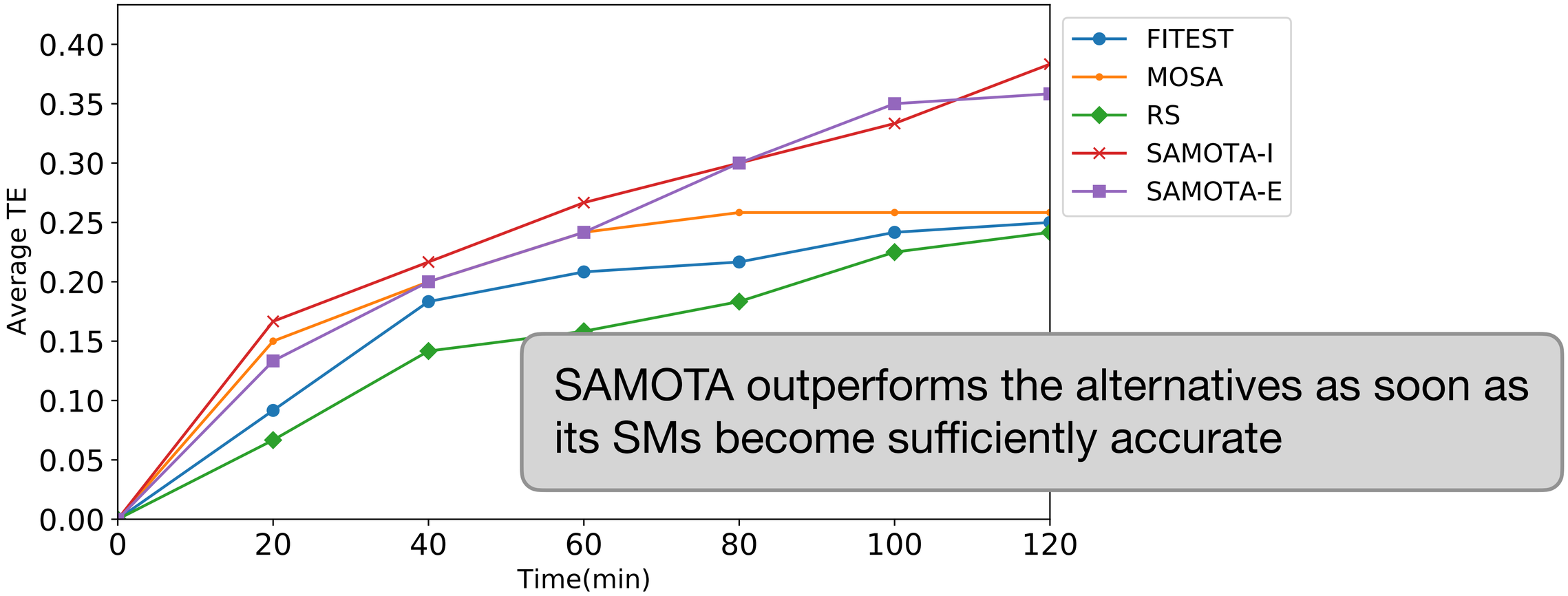
RQ2: Test Effectiveness



RS: Ransom Search
MO: MOSA (ICST 2015 & TSE 2018)
FI: FITEST (ASE 2018)
SE: SAMOTA with an Empty DB
SI: SAMOTA with an Initial DB

- SAMOTA outperforms the alternatives
- Using an initial DB further boosts the performance

RQ3: Test Efficiency



SAMOTA outperforms the alternatives as soon as its SMs become sufficiently accurate

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