

Automatic Generation of Safety-Critical Test Scenarios for Collision Avoidance of Road Vehicles

Matthias Althoff and Sebastian Lutz
Technische Universität München

Motivation



Creating dangerous situations from given, non-critical situations.

Main Algorithm

Require: Initial state x_0 , threshold ϵ , iteration limit it_{max} , binary search iteration limit μ , weighting matrix W , reference area profile a_{ref}

Ensure: critical scenario S

```

1:  $\kappa_{new} \leftarrow 0, \quad \kappa_{old} \leftarrow -\infty, \quad it \leftarrow 0, \quad x_{0,curr} \leftarrow x_0$ 
2: while  $|\kappa_{new} - \kappa_{old}| \geq \epsilon$  and  $it < it_{max}$  do
3:    $success \leftarrow true$ 
4:   while  $|\kappa_{new} - \kappa_{old}| \geq \epsilon$  and  $success = true$  do
5:      $\kappa_{old} \leftarrow \kappa_{new}, \quad x_{0,old} \leftarrow x_{0,curr}$ 
6:      $x_{0,curr}, S, success \leftarrow quadProg(solve)$ 
7:      $\kappa_{new} \leftarrow (\gamma(S) - a_{ref})^T W (\gamma(S) - a_{ref})$ 
8:   end while
9:    $x_{0,s}^v \leftarrow binarySearch(x_{0,old}, x_{0,curr}, \mu)$ 
10:   $S \leftarrow updateScenario(S, x_{0,s}^v)$ 
11:   $\kappa_{new} \leftarrow (\gamma(S) - a_{ref})^T W (\gamma(S) - a_{ref})$ 
12:   $it \leftarrow it + 1$ 
13: end while

```

Basic Idea

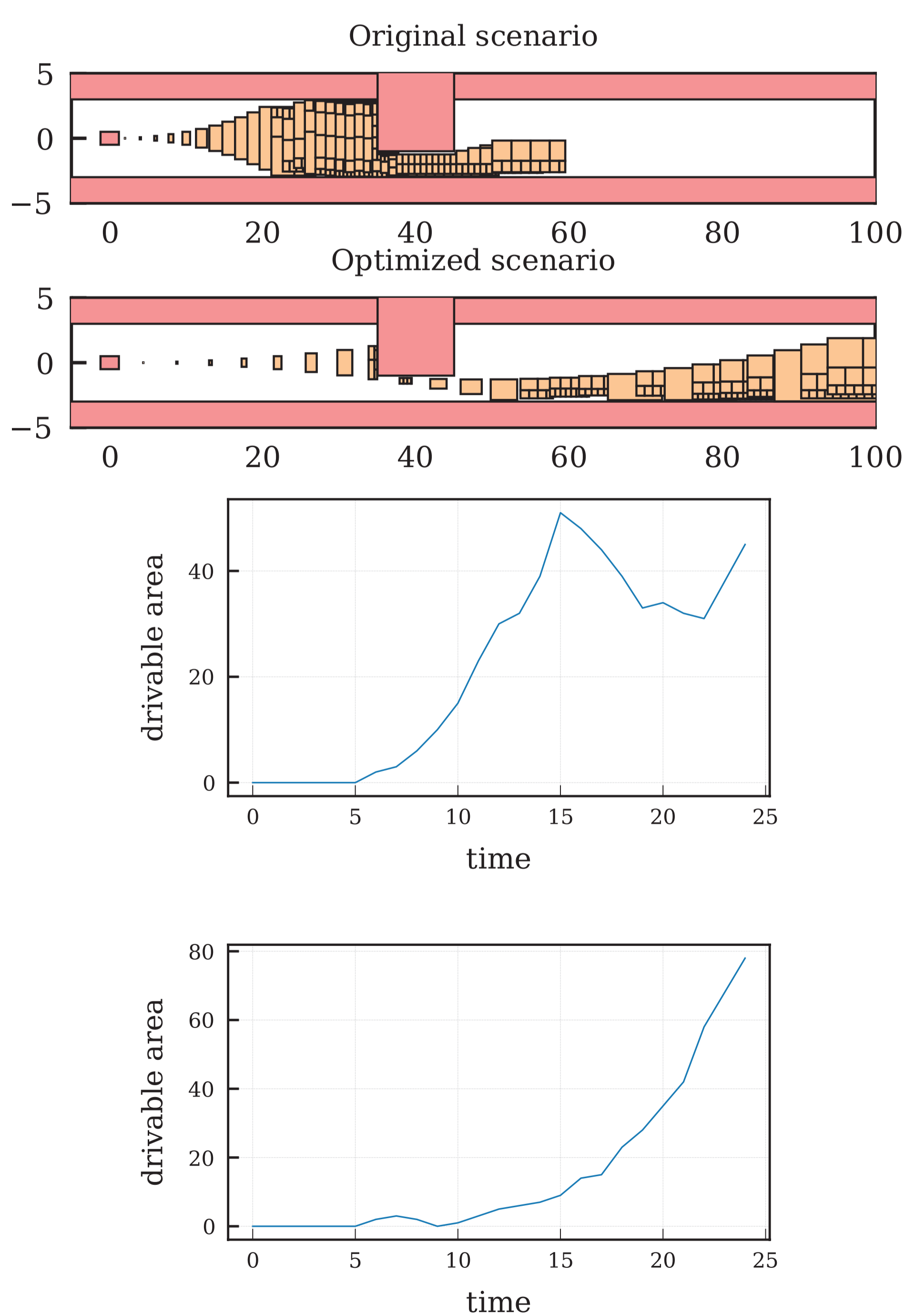
- Reduce testing effort in simulations by creating critical situations.
- Starting point: real traffic scenarios.
- Increase criticality by changing the initial position and velocity of each traffic participant (metric of criticality: reachable area of ego vehicle).
- Basic procedure:
 1. Compute the influence each vehicle has on the criticality.
 2. Find the optimal changes in position and velocity using sequential quadratic programming.
 3. Additionally, binary search is employed to recover from empty solution spaces.

Main Results

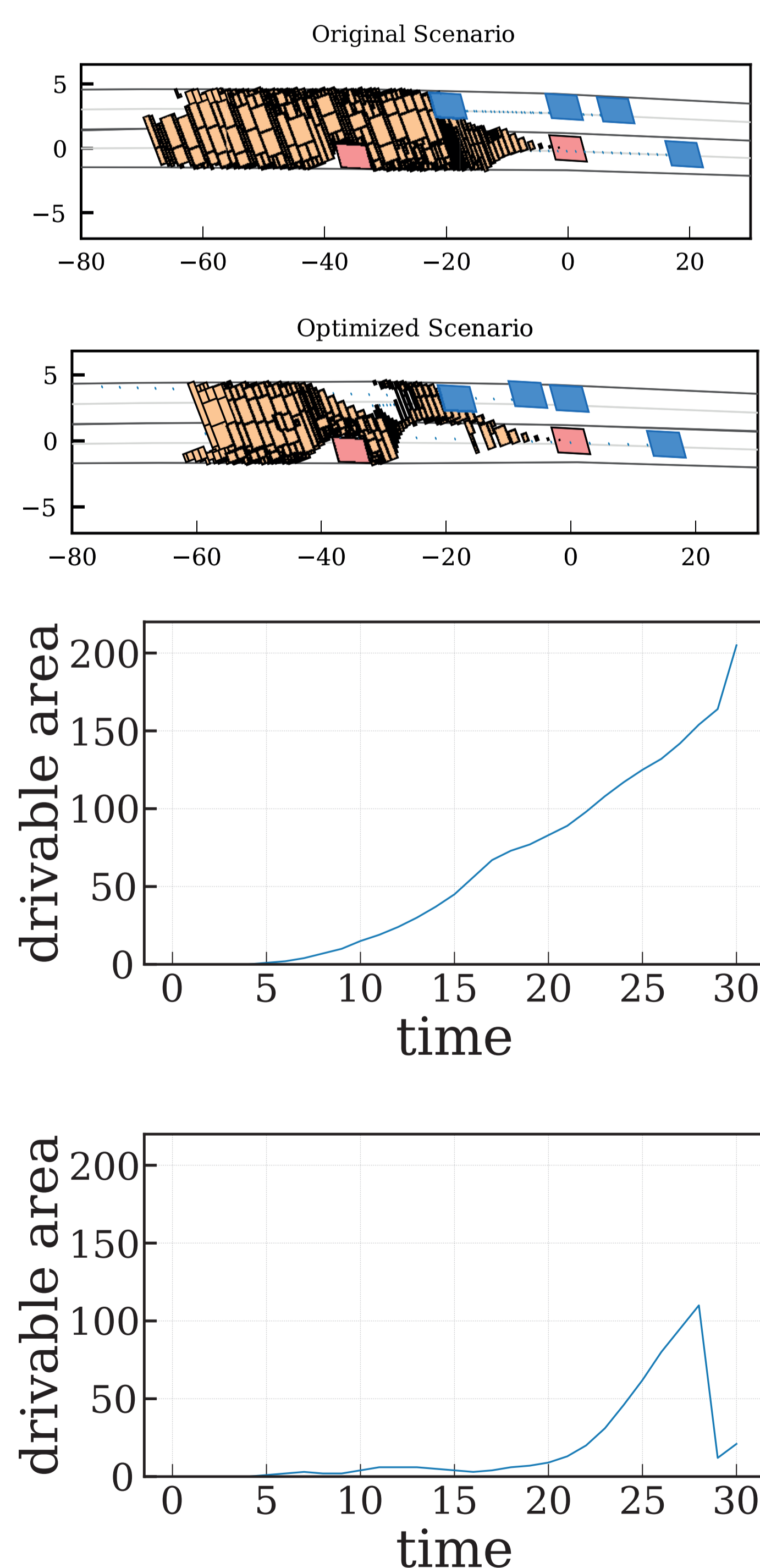
- Traffic situations can be automatically altered so that they become more critical.
- Solution space of the ego vehicle is a useful measure for criticality.
- Our approach does not require any user interaction.
- No guarantee for finding the most critical situation, but scenarios become significantly more critical.
- Computation time is within a few seconds.
- A critical scenario could save more than a thousand kilometers in a driving simulator.

Numerical Experiments

Scenario A:



Scenario B:



Scenario C:

