# Intelligent cars

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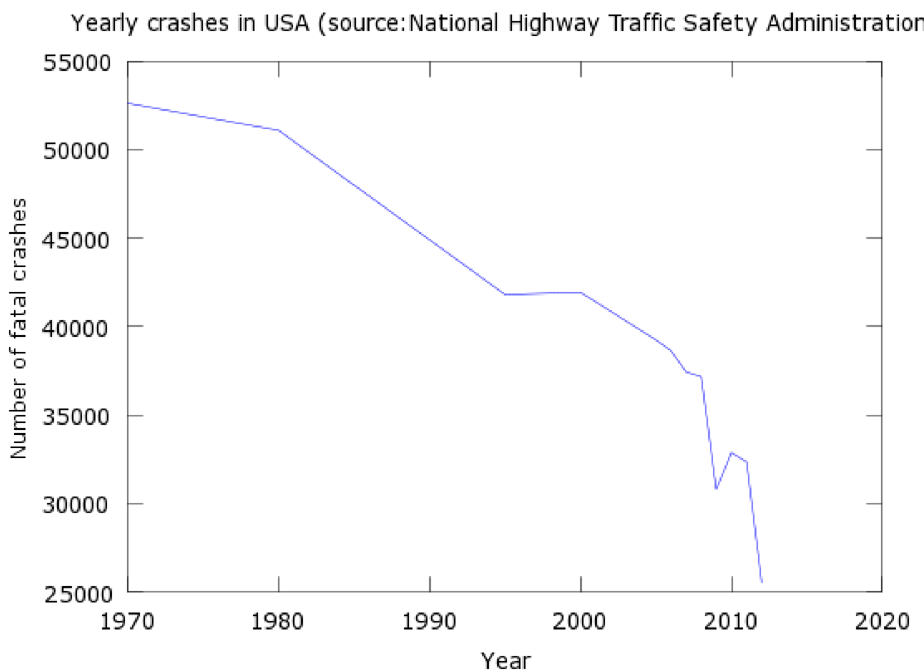
# Introduction

- Ever since automobiles were introduced to the mass market, safety has been an issue.
- In 1959 Volvo introduced the first three-point seat belt
- In the 1980s the first driver support system was introduced on a large scale
- The first ACC system was introduced in 1999 by Mercedes
- In 2002 Nissan introduced the first lane-keeping assist system
- Crash rate is decreased significantly with the advancement of technology



# What is an intelligent car?

- An **Intelligent car** should be able to perceive environment, analyze, and act upon it suitably in legitimate real-time.
- Lane change warning
  - Alerts the driver when changing or entering a lane about any potential threats by optical or acoustic warnings
- Lane keeping/tracking
- Parking assistance
- Automatic braking and collision avoidance
- Traffic sign surveillance
- Adaptive cruise control
  - Adapts to the velocity and distance based on the pace of the car in front

# What is an intelligent car?

- Vehicle tracking
  - Adapts to the velocity , distance and direction based of the car in front
- Decision making
- Safety is the main reason behind the evolution of Intelligent cars
  - Passive safety include seatbelts, airbags etc.
  - Active safety include lane tracking, adaptive cruise control, collision avoidance etc.
- Intelligent car classification
  - Semi Autonomous
  - Autonomous

# Collision Avoidance

- Collision can either be avoided by braking or by steering.
- **ABS** is typically achieved by sensors that monitor forward zone of the vehicle. Senses objects and warns before an impact and applies autonomous braking if the applied brake is insufficient


- ABS is usually applied when time-to-collide(TTC) becomes less than a predefined time.

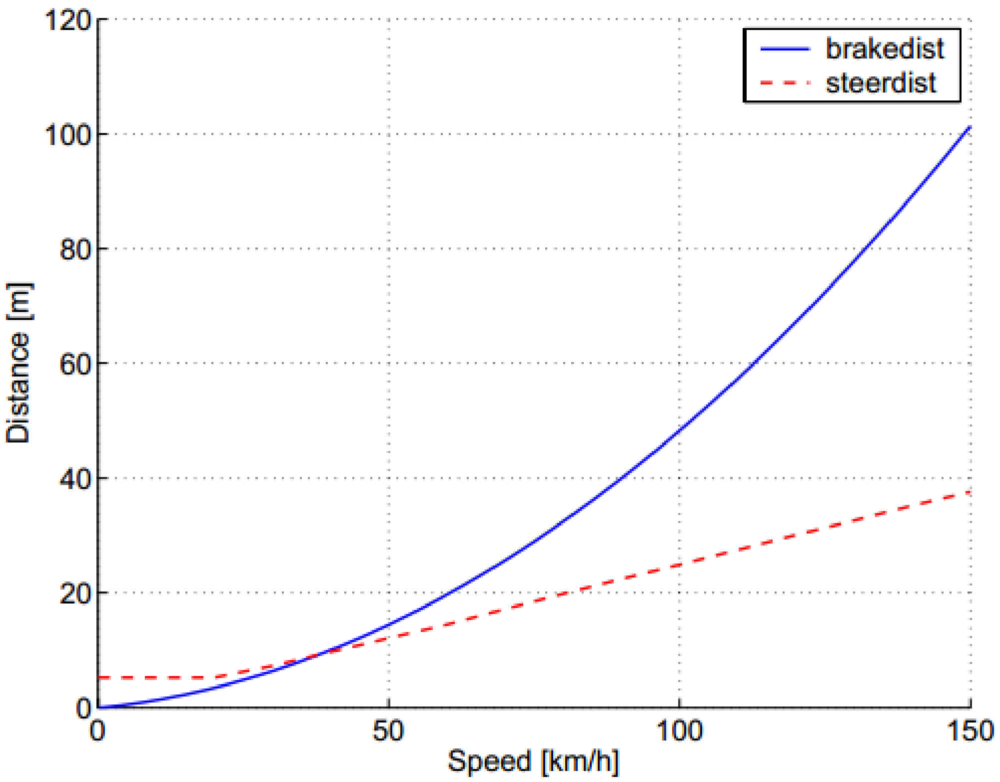
***TTC= -d/v***

*Where d= distance between the host and the obstacle*

*And v=relative velocity between the host and the obstacle*

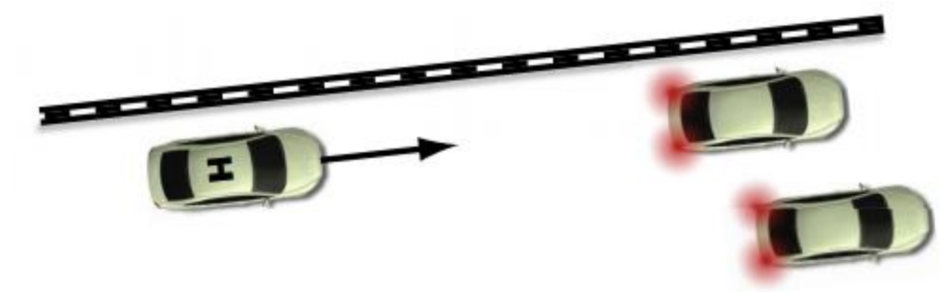
# Collision Avoidance ABS vs Steer

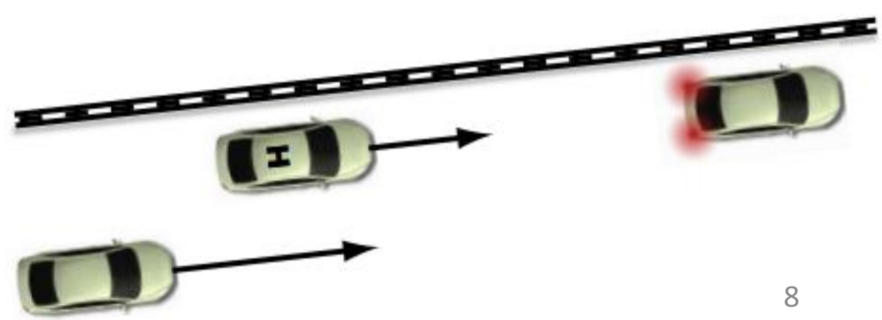
- In low speeds(40km/h), braking can be commenced later than steering. In high speeds, braking should be commenced before steering



# Collision avoidance-Introducing multi target threat assessment.

- By processing multi targets simultaneously, better collision avoidance can be achieved. i.e., when steering is not an option because
  - Another vehicle is blocking the steering path
  - Another faster moving vehicle is entering the steering path
- In that case ABS in the vehicle could take these objects into consideration and commence braking much earlier





# Threat assessment(single target)- When to commence an intervention?

- An intervention is called only when the collision is unavoidable(almost) to minimize the number of incorrect of false interventions
- One way to achieve this is by calculating Brake Threat Number(BTN) and Steering Threat Number(STN)

$$\text{BTN} = \frac{a_{\text{long,req}}}{a_{\text{long,max}}} \quad \text{and} \quad \text{STN} = \frac{a_{\text{lat,req}}}{a_{\text{lat,max}}}$$

where , $a_{long,req}$=required deceleration to avoid collision

$a_{long,max}$=maximum available deceleration

$a_{lat,req}$=required lateral acceleration to avoid collision

$a_{lat,max}$=maximum available lateral acceleration

- When BTN or STN equals 1. The auto-brake system may intervene

# Threat assessment-multi target

- In case of multi targets an algorithm is used to get an "optimal" maneuver, which can be formulated by

$$\min_{m \in \mathcal{M}} C_m(m)$$

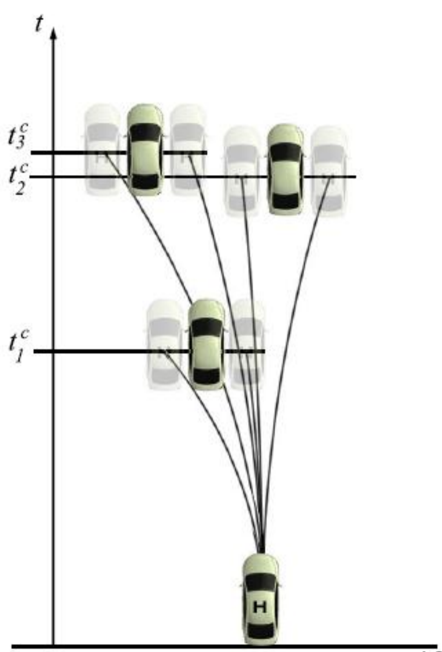
where *m* is a real function *m(t)* which defines the maneuver, *M* is the set of conflict free maneuvers and $C_m$ is the "cost" function.

# Algorithm

- Optimal maneuver will be of cost zero. i.e., to go straight forward
- Since an object can be passed either by left or right, we have 2 maneuvers per object
- The result is a kind of search tree, with each branch ending when either all objects are cleared, or when no escape path is found, i.e., when the path is blocked.
- Input to the algorithm is state of all objects. Eg, position, velocity, TTC
- Algorithm ends if an optimal path or no escape path is found

# Algorithm

1. If there are no objects or barriers, then abort the algorithm and return the cost zero.
2. For each object i, compute the maneuver/time pairs $p^R_i = (m^R_i, TTC_i)$ and $p^L_i = (m^L_i, TTC_i)$. Form sets $M^R=\{p^R_i, i=1\ldots\}$ and $M^L=\{p^L_i, i=1\ldots\}$
3. For each barrier j, compute the maneuver/time pairs $p^R_j = (m^B_j, TTC_j)$. Form set $M^B=\{p^B_i, i=1\ldots\}$ .
4. Form the common set of maneuvers $M = M^R \cup M^L \cup M^B$.



# Algorithm

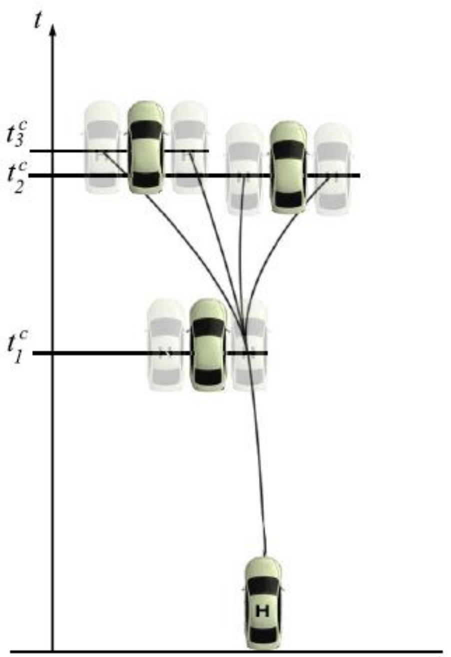
5. Add a maneuver/time pair $p_0 = (m_0, t_0)$ to the set M where $m_0$ is the cheapest possible maneuver not considering any objects or barriers and $t_0 = \infty$ .

6. Remove all conflicting maneuver/time pairs i.e., if a pair (m, t)∈M lead to a conflict with an object i with $TTC_i < t$ or any of the barriers, then remove the pair from M.

7. If the maneuver $p_0$ is still in the set M, i.e., if $p_0$ is conflict free, then abort the algorithm and return the cost $C_m(p_0)$. Typically $C_m(p_0) = 0$.

# Algorithm

8. If the M is empty, then there are no escape paths, return the cost $\infty$ .
9. For all remaining maneuver/time pairs $p^k = (m^k, t^k)$ in the set M, repeat:
   a) Predict the state of all objects at time $t_k$, i.e., compute $x^{tk}_i = P_{obj}(x^0_i, m^k, t^k)$.
   b) Predict the state of all barriers at time $t_k$, i.e., compute $y^{tk}_j = P_{barrier}(y^0_j, m^k, t^k)$.
   c) Predict the host vehicle state at time $t^k$, i.e., compute $z^{tk} = P_{host}(z^0, m^k, t^k)$.
   d) Remove all objects with TTC < $t^k$.



# Algorithm

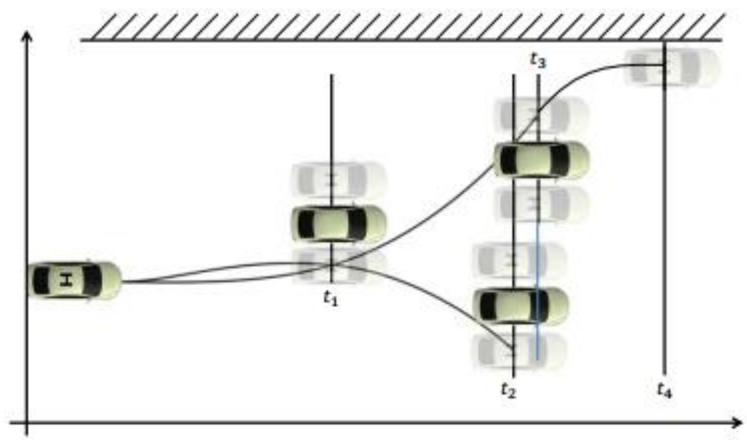
e) Call the algorithm again with the reduced set of objects and all predicted states $x^{tk}_i$, $y^{tk}_j$ and $z^{tk}$ . For each maneuver, the algorithm will generate new maneuvers for the second step in the sequence. The algorithm returns a cost, say $C_k^{pred}$ associated with each predicted scenario.

f)Form $C_k = \max(C_m(p_k), C_k^{pred})$

10. Return $\min_k(C_k)$.

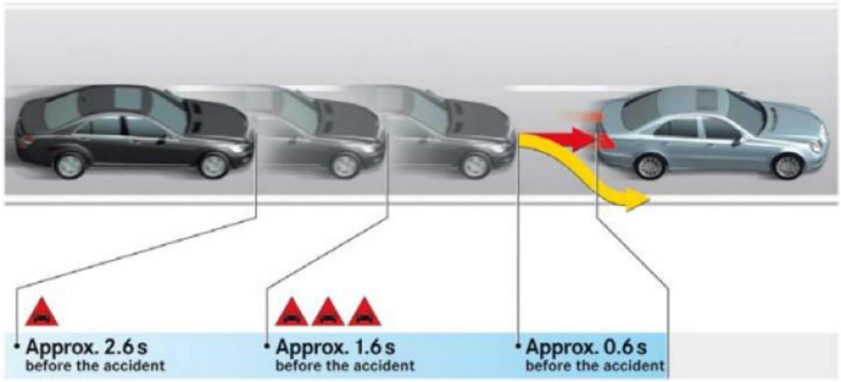
# Algorithm-complexity and enhancements

- Computational cost: If the number of obstacles is n, then the number of maneuvers can be approximately $2n^3/3$.
  - This means with 5 objects, around 80 maneuvers has to be computed.
  - Up to 10 objects is not a problem for current hardware
- One of the disadvantage is jerk.
- Smoothing Splines can be used to have smoother trajectory



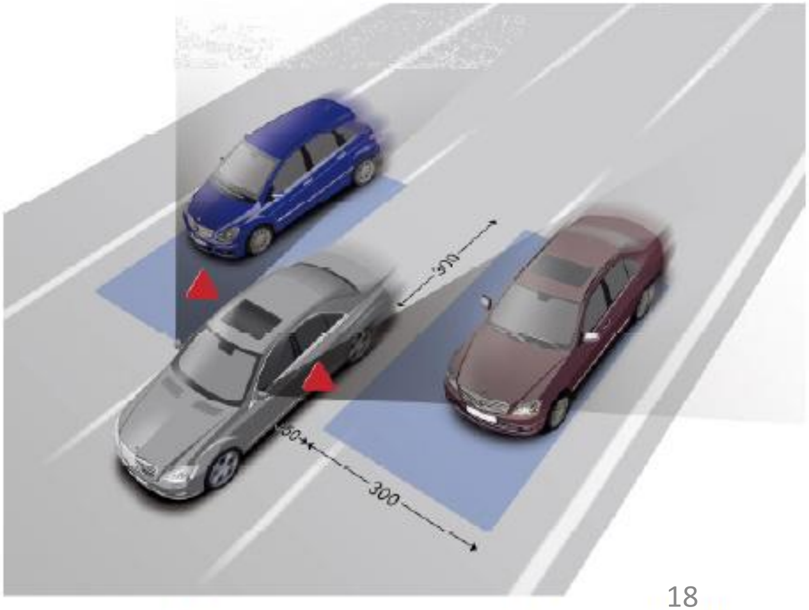
# Example: Mercedes Benz

- Mercedes-Benz uses two short-range radars (SRR) in the front and two in the rear bumper, one mid-range radar (MRR) and one long-range radar (LRR) to realize the following functions:
  - Brake Assist and Brake Assist PLUS
    - Uses 2 UWB SRR sensor working at 24GHz and 1 LRR working at 76.5GHz to monitor the front zone
    - Disadvantage is the system works only if the driver gives brake command stepping on the brake
  - DISTRONIC PLUS for Adaptive Cruise Control and Stop&Go
    - Operates speeds between 0 to 200km/h and therefore coping with the Stop&Go traffic policy
  - PRE-SAFE Brake



# Example: Mercedes Benz

- Blind Spot Assist
  - Uses 2 SRR sensors housed on the side-rare of the vehicle to alert driver while changing the lane
- Lane Keeping Assist
  - A camera is used to detect road markings.
  - Image processing unit sends data to electronic control unit which analyses if the car is leaving the lane intentionally
  - Operates at speed 60-250km/h

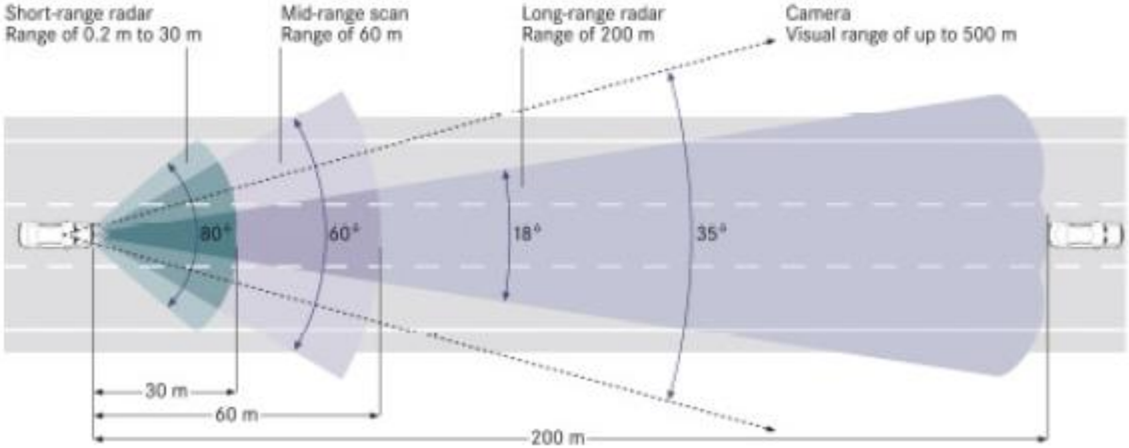





Blind Spot Assist with two sidelooking UWB-SRRs

# Example: Mercedes Benz

- Mercedes Benz uses Ultra wideband Radars because of the advantages like,
  - Direct distance and speed measurement
  - Robust against weather influences and pollution
  - Unaffected by light
  - Measurement of stationary and moving objects on and in the vicinity of the road
  - Invisible integration behind electromagnetically transparent materials (for example bumpers).



# Summary

- Safety
- At high speeds collision can be avoided by steering
- Multi target threat assessment is done to foresee steering maneuver is possible
- ABS is applied only if there is no escape path
- Smoothing splines are applied to the trajectory to minimize jerk
- Radars have advantage over Lidar and cameras in automotive industry

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Thanks and questions..?