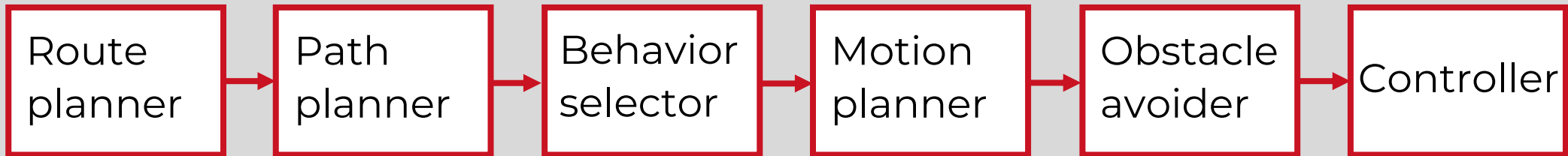


DECISION MAKING IN AUTONOMOUS DRIVING

embotech*



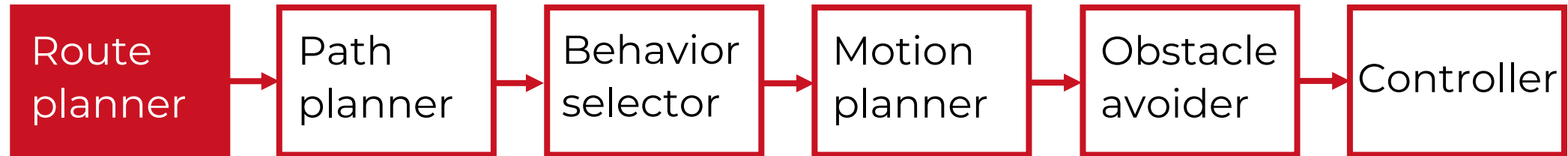
Decision making



ACKNOWLEDGMENTS

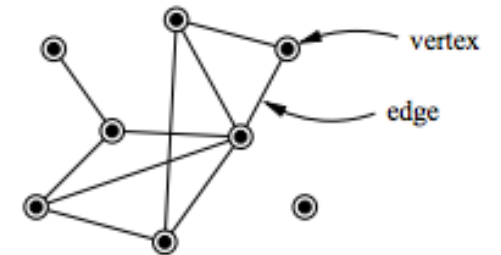
Based on the work of Badue et al., <https://arxiv.org/abs/1901.04407> and the references within

ROUTE PLANNER



ROUTE PLANNER

- Computes the route, like a SatNav system
- A sequence of waypoints, in x-y coordinates
- For a road network defined as a graph
 - Vertices are waypoints
 - Edges are costs of travelling that segment



[https://en.wikipedia.org/wiki/Vertex_\(graph_theory\)](https://en.wikipedia.org/wiki/Vertex_(graph_theory))

ROUTE PLANNER

Methods

- Goal-directed
- Separator based
- Hierarchical
- Bounded hop

ROUTE PLANNER

Methods

- Goal-directed
- Separator based
- Hierarchical
- Bounded hop

- Search from source to target vertex
- A* is a classic

ROUTE PLANNER

Methods

- Goal-directed
- Separator based
- Hierarchical
- Bounded hop

- „Coarsify“ the graph via vertex separators
- A vertex separator is a small subset of vertices
- Creates an overlay graph, which is much smaller
- Faster than searching the full graph

ROUTE PLANNER

Methods

- Goal-directed
- Separator based
- Hierarchical
- Bounded hop

- Exploit hierarchy of road networks
- If far away, larger roads are considered first

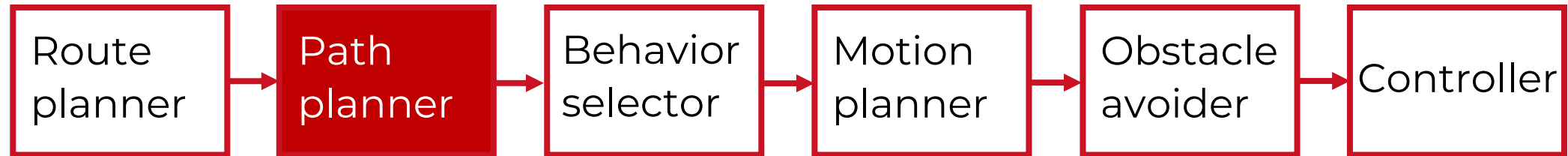
ROUTE PLANNER

Methods

- Goal-directed
- Separator based
- Hierarchical
- Bounded hop

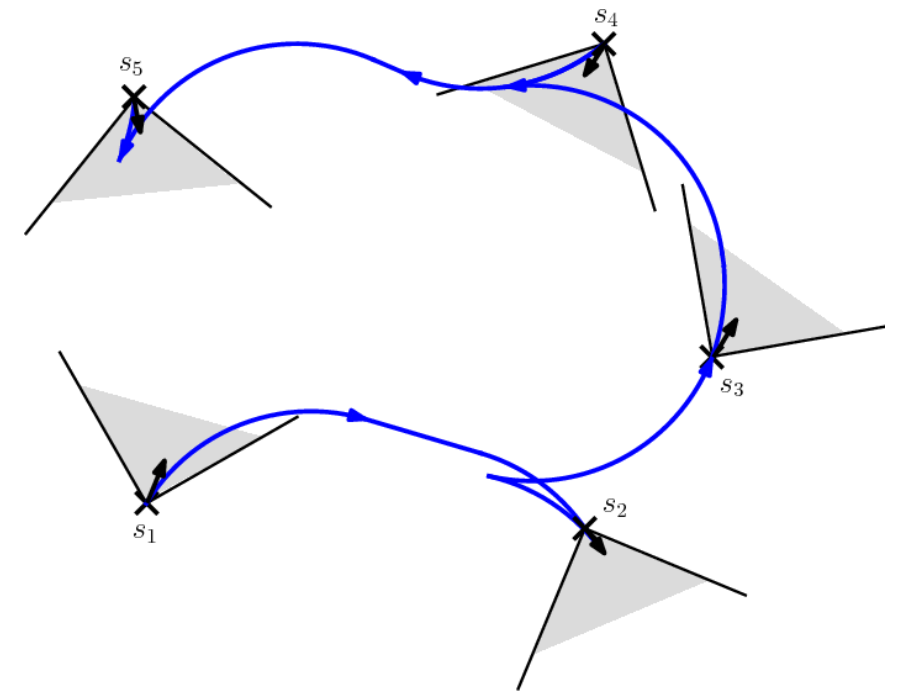
- Adds virtual shortcuts
- Precompute distances between vertices

PATH PLANNER



PATH PLANNER

- Computes paths for the route
- A path is a sequence of poses
- A pose is an x-y position plus orientation



Rathinam, Sivakumar et al. "Path Planning Algorithms for a Car-Like Robot visiting a set of Waypoints with Field of View Constraints."

PATH PLANNER

Methods

- Graph search
- Curve interpolation

PATH PLANNER

Methods

- Graph search
- Curve interpolation

- Find best path between current and goal state
- Search space is discretized
- A graph is imposed on an occupancy grid map
- Dijkstra and A* are common methods for the graph search

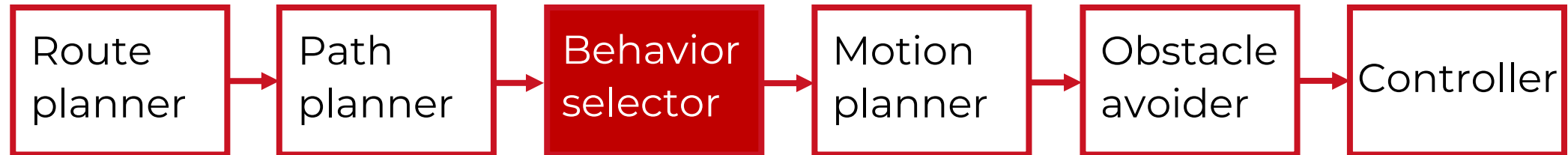
PATH PLANNER

Methods

- Graph search
- Curve interpolation

- Find a set of points by interpolating between two waypoints
- Splines are often used
- Result is not optimal

BEHAVIOR SELECTOR

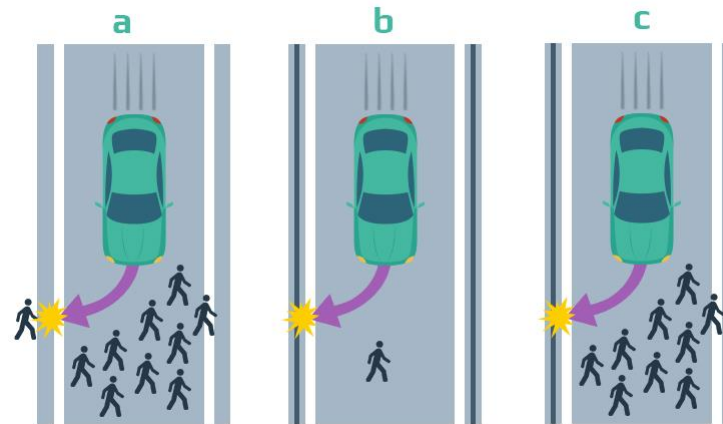


BEHAVIOR SELECTOR

- Decides on driving behavior
 - Lane keeping
 - Intersection handling
 - Traffic lights, etc.
- ... By selecting a path

BEHAVIOR SELECTOR

- Considered an „ethical“ element
- Usually a combination of heuristics and finite state machines



<https://www.intellias.com/it-s-time-to-give-autonomous-cars-an-ethics-lesson/>

BEHAVIOR SELECTOR

Methods

- Finite state machines
- Ontology-based
- Markov decision processes

BEHAVIOR SELECTOR

Methods

- Finite state machines
- Ontology-based
- Markov decision processes

- Discrete rules based on traffic
- Difficult to model the uncertainty of complex scenarios

BEHAVIOR SELECTOR

Methods

- Finite state machines
- Ontology-based
- Markov decision processes

- Ontology is a framework for knowledge representation
- Consider rules of the road and makes decisions such as „stop“, „go right“
- Complex model at each location that needs to be built manually

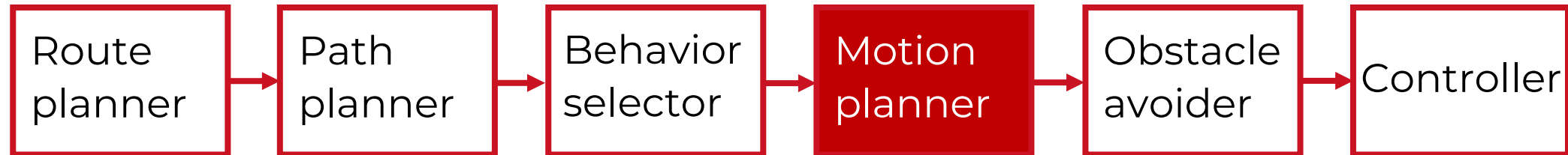
BEHAVIOR SELECTOR

Methods

- Finite state machines
- Ontology-based
- Markov decision processes

- Widely used
- Can handle uncertainties in action transition
- Can also handle uncertainties in perception
- The assumption is that other vehicle follow rules

MOTION PLANNER



MOTION PLANNER

- Computes a trajectory from current state to current goal
- The trajectory follows the path selected by the behavior selector

MOTION PLANNER

- The trajectory satisfies:
 - Kinematic and dynamics constraints
 - Other constraints (actuators)
 - Safety
 - Can also consider comfort and eco-driving

MOTION PLANNER

- A trajectory can be defined as
 1. A sequence of actuators commands
 2. A sequence of states
- Important to distinguish
 - Structured space (e.g. road with lanes)
 - Unstructures space (e.g. open areas)

MOTION PLANNERS

Methods

- Graph search
- Sampling-based
- Curve interpolation
- Numerical optimization

MOTION PLANNERS

Methods

- Graph search
 - Sampling-based
 - Curve interpolation
 - Numerical optimization
- Extention of technique used for path planning
 - Commonly used methods are: state lattice, elastic band and A^*

MOTION PLANNERS

Methods

- Graph search
 - Sampling-based
 - Curve interpolation
 - Numerical optimization
- Random sample of the state space to look for a trajectory
 - Commonly used is the Rapid-exploring Random Tree (RRT)

MOTION PLANNERS

Methods

- Graph search
 - Sampling-based
 - Curve interpolation
 - Numerical optimization
- Interpolate to find smooth trajectories
 - Clothoid curves commonly used (smooth transitions)

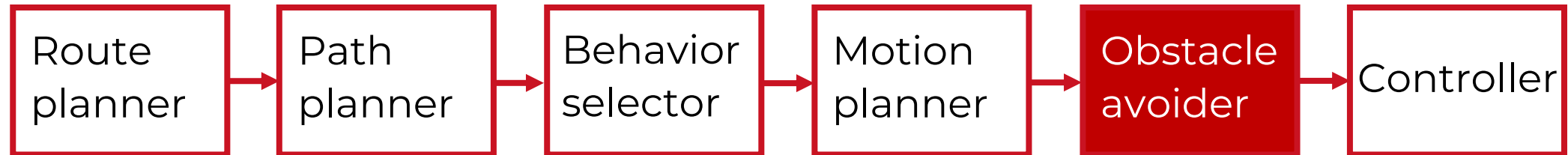
MOTION PLANNERS

Methods

- Graph search
- Sampling-based
- Curve interpolation
- Numerical optimization

- Solve an optimization problem for given objectives and constraints
- Nonlinear Model Predictive Control commonly used
- Easy to consider dynamics and constraints
- Can have high computational cost

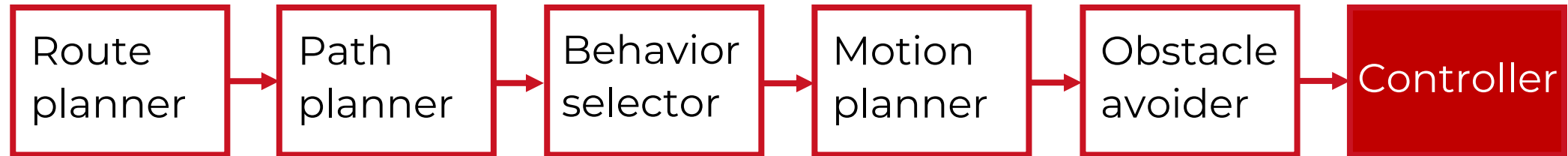
OBSTACLE AVOIDER



OBSTACLE AVOIDER

- Twicks a trajecory to avoid collisions
- Often, it simply reduces speed
- Uses information directly from the perception to assess risks
- Safety-critical component: the simpler, the better

CONTROLLER



CONTROLLER

- Uses the trajectory as set point, and calculates and sends commands to actuators (steering, accelerating, braking)
- Can be a simple PID loop, but also a nonlinear model predictive controller

CONTROLLER

Methods

- Direct actuation
- Path tracking

CONTROLLER

Methods

- Direct actuation
 - Path tracking
- When the trajectory is already a sequence of commands
 - Provides fast feedback control loop to track commands

CONTROLLER

Methods

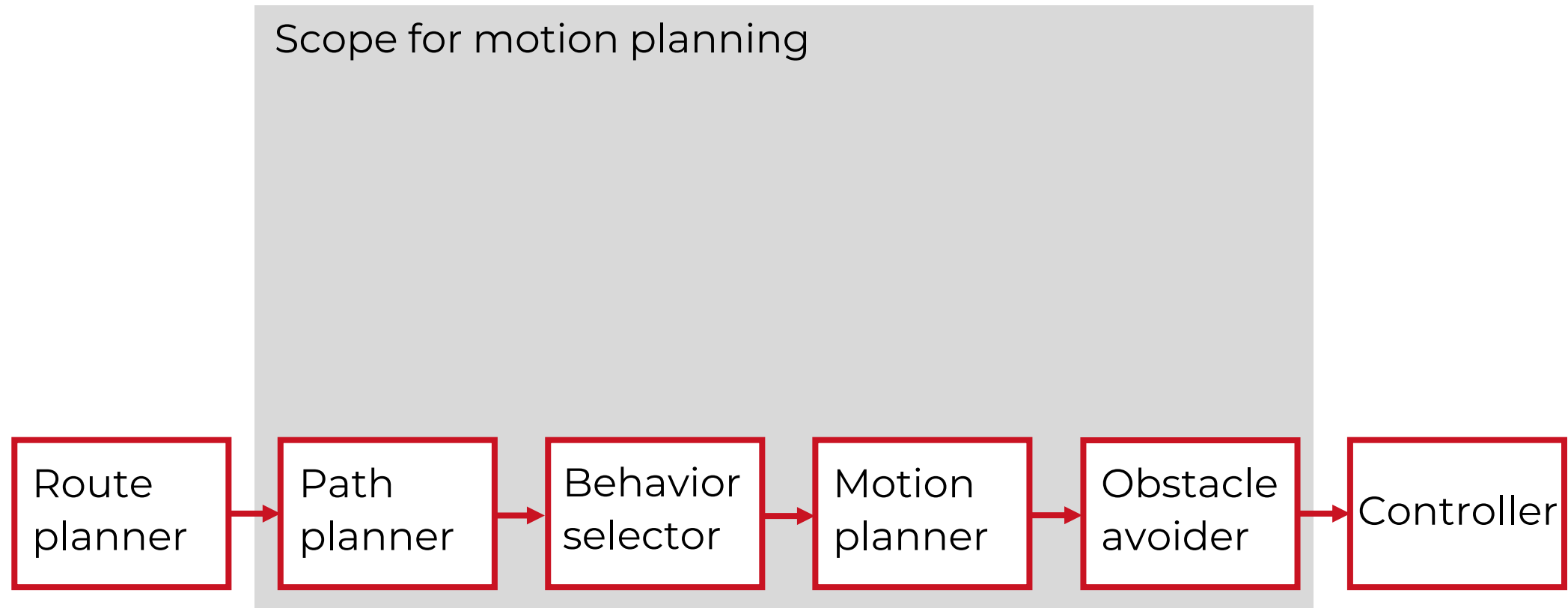
- Direct actuation
- Path tracking

- When the trajectory is a sequence of states
- Provides fast feedback control loop to track states
- Pure pursuit is a common method
- MPC is a more advanced method

TAKE AWAY POINTS

- Decision making in AD is a cascade of functions
- Boundaries between such functions are quite arbitrary
- Algorithm choice is a compromise between
 - computational speed
 - accuracy
 - safety levels required

NEXT





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