Ever since the creation of the first car there has been a safety concern that refuses to go away, the driver. Most car accidents are caused by human error and even those that are not, such as those caused by weather or mechanical failure, could easily be mitigated by taking the right course of action (like pulling over to the side of the road during a sandstorm). Vehicles which drive themselves could fix this problem with prototypes already proving their reliability and safety. While there are still many issues that need to be worked out, we seem to be moving closer and closer to a world driven by machines. The first and foremost issue to overcome in creating an autonomous vehicle is the selection of sensors to use and the development of algorithms to detect obstacles and drive the car. Various methods have to be used in order to avoid collisions, stay in the correct lane, follow traffic laws, and keep track of where the vehicle is and where it is going. There are other issues involved as well, such as many humans unwillingness to accept and trust autonomous drivers. However, the benefits of autonomous vehicles are clearly evident and research has brought this amazing advancement shockingly close to fruition. This is shown through the algorithms, architecture and theory that will make autonomous vehicles commonplace in the near future.

Many different architectures and designs have been created in order to produce an autonomous car. One such attempt is described in the paper, “Intelligent Robotic Car for Autonomous Navigation.” The team took a small car, dubbed “CaRINA I,” and retrofitted the steering wheel, gas, and brakes to be controlled by an onboard computer via a system of pulleys and linear actuators. An array of mounts was also created for lasers, cameras, and other sensors. Four lasers were installed on the mounts, two in front and two for the sides and back, as well as a stereo camera in front-center. The lasers keep track of the geometry of the road while the camera keeps the car on track and watches for obstacles. Finally, a GPS, compass, and inertial monitor were installed to keep track of its location, direction, and acceleration. The figure below shows how these sensors are set up on CaRINA.
To detect the road in front of the car, it uses the front laser scanner, which is better explained by LRM. “Using a sweeping 2D laser scanner (planar scan) mounted in a pitch down view is possible to reconstruct the terrain surface ahead the vehicle and identify the road by features extraction and classification from raw data. For each obtained scan, resultant points sets represent the intersection between laser and terrain planes (slices). Knowing the laser angle and vehicle pose along the trajectory, is possible to build a tridimensional representation of terrain shape by integrating over time the successive points sets.” (15) This representation of the terrain can then be analyzed in order to figure out where the “navigable” and “non-navigable” parts of the terrain as shown below.

Collision detection is handled using the stereo camera with a “cone-based” algorithm. The car also uses a mapping algorithm with the GPS, compass, and inertial drivers to keep track of where it is and to navigate a path to its destination. This allows the car to take the shortest path to its destination and make sure it stays on the correct road. All of the methods used above allow CaRINA to safely navigate almost any type of road without any human influence. [1]

One of the problems with the approach used by the CaRINA is that it is very reliant on known roads. In rural and off-road environments, there is often no clear road and even if there is, the road may literally be off the map. For this reason, cars in off-road and rural environments cannot make much use of convenient global mapping algorithms. Without the mapping information, it becomes difficult to detect the best path to the goal. However, with the use of LIDAR’s (laser based radar sensors)
along with stereo cameras, several algorithms can be developed to mitigate this problem and navigate unknown terrain safely.

One such algorithm, the classification algorithm, uses LIDAR mapping of its environment and designates each point of the scan as the ground or an obstacle where it “uses the deviation of height z against lateral position y. If the position of the detected points x and z does not change, although the lateral position y changes, those points can be assumed to be ground.” (977) Another algorithm, the height-difference-based algorithm, also uses LIDAR scans and detects high height difference points. “If the distance between two given points is smaller or equal to a specific predefined range and the z position difference exceeds a critical vertical distance, those two points can be assumed to be dangerous.” (978) This detects any smaller but still dangerous obstacles or bumps which the classification algorithm misses. Then, each algorithms points are weighted by their possible error and summed together to create an overall risk map. The risk map shows the probability of there being an obstacle at each point in the scanned area. This allows the autonomous car to safely move towards its destination with a very small probability of an accident and without the help of a mapping system. Off-road tests were completed with the risk map and driving path shown below.

In this scenario, the autonomous car successfully navigated around obstacles and was able to reach its destination. This shows the algorithm successfully can navigate unknown and uneven terrain. [2]

However, in order to avoid collisions, a driver must keep track of other vehicles on the road as well as stationary obstacles. While many algorithms, such as the ones discussed above, keep track of stationary obstacles very well, they do not take an obstacle’s movement into account. Using a probabilistic algorithm, one can predict the stochastic movement of other vehicles. The proposed
algorithm takes into account the planned path for the autonomous vehicle and the probable position of any moving obstacles at different future time frames in order to detect a possible collision.

(300)
For example, the figure above shows how the algorithm would detect and prevent a collision with another vehicle at $\tau_2$. This algorithm shows that autonomous drivers can be as good as or better than human drivers at predicting collisions with moving vehicles.[3]

Even if a car did have full-proof algorithms and a reliable architecture, it doesn't mean it will be successful. The problem is that human passengers have difficulty accepting an autonomous driver. “The reasons are mainly twofold: autonomous cars drive robotic-like when following planned trajectories which often feels unnatural compared to human driving. The second reason is, that the passengers have no idea if the autonomous vehicle recognizes and evaluates traffic situation correctly or if a critical maneuver has to be performed.” (635) These problems may make it difficult for autonomous vehicles to be commercially successful. If the customers don’t trust a product, they won’t buy it. So, in order to solve these problems, the designers should incorporate humanity and emotion into the car. Using algorithms like the probabilistic algorithms explained above, one can derive the probability of an accident at any given point in time. This probability can be used to describe the emotional state of the car. The example used is where two lanes merge into one in busy traffic. This is a situation that not only has a higher probability of an accident, but also is often very stressful. Communicating to the passengers that the car is also aware of the situation and possibly “unhappy,” would do wonders for trust of an autonomous driver. [4]

In a future of autonomous cars, people are going to want an easy way to interface with their vehicle. For this, the AI Group at Freie Universität in Berlin created what they call iDriver. iDriver, in essence, is an iOS app which can interact with, and even control an autonomous vehicle. One of the main benefits to this is the ability to have your car pick you up. The iDriver app takes the iPhones GPS coordinates and sends them to the car, which sets that as its destination. The car then sets a path to your location and drives there as a taxi would. There is also the ability to directly control your vehicle. Using the flexibility of the multi-touch interface, users are able to accelerate, brake, and steer using their iPad or other iOS device using real time video. Fortunately, the vehicle will take control and brake if the driver seems to be in danger of crashing.
This seems to be a good prediction of where autonomous driving is going. An interface with a user's phone or other device seems a logical next step for autonomous vehicles. [5]

In the end, autonomous cars are the future of driving and that future is fast approaching. Theory and speculation have given way to implementation and testing. The sensors, cameras, and other hardware are getting cheaper, allowing more groups to research the technology and bringing affordable autonomous cars ever closer. This research leads to the algorithms becoming more and more accurate, allowing autonomous drivers to become better than humans at collision avoidance, navigation, and off-road driving. It also allows for research to make autonomous cars to be more viable such as the iDriver app and the research into emotion in driving. All of this research will result in an autonomous car that will be safe, cheap, and trustworthy, leading to safer roads and simpler lives.


