

SELF-DRIVING CARS WITH MARKOVIAN MODEL-BASED SAFETY ANALYSIS

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Abstract: At present, the development of Self-Driving Cars systems has been increasing. The need for man to control all possible scenarios has led to the inclusion of theories such as human perception. This means identifying how the human brain recognizes its environment and translating it into data that a machine can learn and make decisions. For this, great doubts have been generated concerning safety; in the present work, a Markovian model is used, a stochastic method for randomly changing systems. These models show all possible forms and the transitions, the rate of changes, and the probabilities between them. Markovian models can also recognize patterns, make predictions, and learn sequential statistics.

Key Words: Markovian, Perception, Safety, Self-Driving Cars, Stochastic.

1. INTRODUCTION

Self-Driving robotics vehicles are cars or trucks in which human drivers are never required to take control of the vehicle safely operating. An Internet of Things (IoT) ecosystem consists of web-enabled intelligent devices that use microprocessors, sensors, and technology to store, processing and act in their environments [1-4].

Internet of Things is also very present in the automotive world. Our cars are becoming more intelligent (Connected Car) thanks to intelligent sensors that go far beyond calculating a route: they save fuel, they notify emergency services, our geolocation in case of accident or breakdown, they receive and interpret incidents or safety notices that affect our trip and communicate it to us in real-time. Through time we have two stages of security inside the vehicle: passive and active systems [5-9]. Markov defined a way to represent real-world stochastic systems and processes that encode dependencies and reach a steady state over time. From a mathematical point of view, safety scenarios are a discrete state space stochastic process without after-effects to be modeled as a Markov Chain.

The paper is organized as follows: In Section 1, the Introduction is given. In Section 2, the Driver Assistance Technologies are considered. In Section 3, the Self-Driving Robotic Cars are considered. In Section 4, the Intelligent Cities and Automotive Transportation are presented. In Section 5, the Markovian Model is considered. Conclusions are given in Section 6 and References.

2. DRIVER ASSISTANCE TECHNOLOGIES

For the safety of the passengers and pedestrians, the designers have established an 'incremental' technological development. Historically, all the critical points of the vehicle have been developed; today, these advances have focused on more sophisticated and intelligent systems, so the results are less physically dazzling. For this reason, can describe two safety systems stages, passive and active safety [10-15].

2.1 Passive Safety

Before World War II, passive safety was established; Hungarian engineer Bela Barenyi designed structures capable of absorbing impact energy called non-deformable cabins, using the concept of programmed deformation where the outer structure (chassis) must have high rigidity and gradually decrease towards the inside of the vehicle, creating a survival cell, e.g., Belt, Headrest, Front airbag, ABS (Antilock braking System), BAS (Brake Assist System), ESP (Electric Stability Program), etc.

a. Active Safety

The active safety stage has been gaining strength since 2005, based on the implementation of microelectronics and control systems for vehicle stability, designs capable of correcting driver errors. Concepts of vehicle autonomy are handled in their fullness, providing the machine with Intelligence to recognize the environment in which the vehicle circulates and make decisions [16-20].

Since 2012, the development of systems capable of anticipating an eventual accident has begun; the term "perception" is introduced for a joint work of several sensors for safer navigation and to act independently in an emergency, e.g., AFS (Adaptive Front Lighting System), TPMS (Tire Pressure Monitoring System), LKS (Lane Keeping Support), DRL (Daytime Running Lights), eCALL (Emergency CALL), DDM (Driver Drowsiness Monitoring), SBR (Sit Belt Remembering), EBR Automatic Braking Emergency, etc.



Figure 1. *Passive Safety Systems*

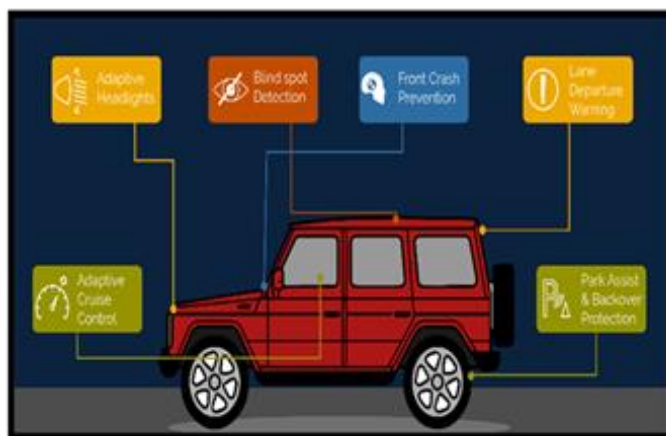


Figure 2. *Active Safety Systems*

3. SELF-DRIVING CARS

Self-driving robotics vehicles are AI (Artificial Intelligence)-based cars that will take information about the environment around them into account before making each decision in which human drivers are never required to take control of the vehicle safely operating. The main challenge in self-driving cars is the synergy between predictive AI, imaging technology, sensors, and actuators. The sensors create a 3D picture around the vehicle; the AI interprets the current vehicle situation, and actuators respond safely; driving a car requires manipulating the direction and the speed. The imaging technology is overriding; it has become the most significant limiting factor to the wide-scale production of self-driving cars. Development in sensor technology has historically combined video, radar, ultrasonic sensors, and Light Detection and Ranging LiDAR [21-26]. This approach, however, has not been successful.

3.1 Perception

Currently, developers use various theories, mechanisms, and techniques to give the vehicle a level of Intelligence to make decisions. Following this line, they have been based on human behavior and its interpretation of an unexpected phenomenon, perception. Human perception is defined as the set of processes and activities related to a constant flow of information, through which we can determine the environment in which we find ourselves, the actions we perform in it, and our internal state, Figure 3. The perception process in autonomous cars is in charge of recognizing the vehicle's environment in real-time, using a combination of image acquisition technology (cameras and sensors), 3D modeling systems, and intelligent algorithms [27-35].

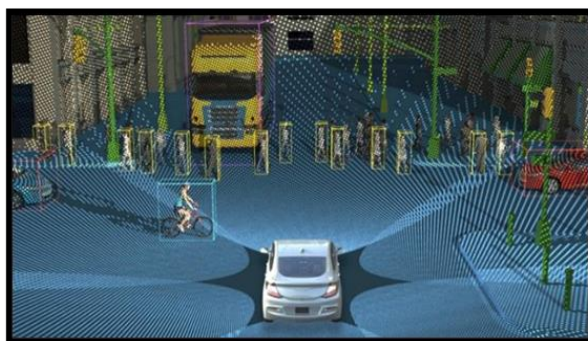


Figure 3. *Perception Inside Self-Driving Cars*

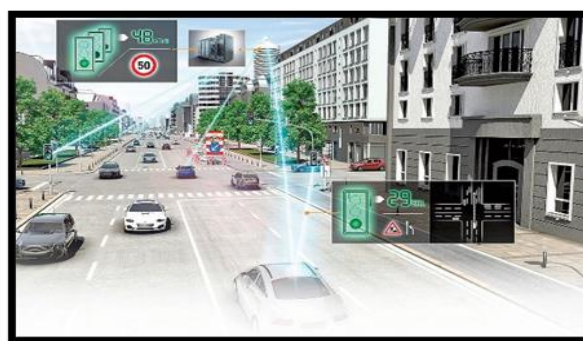


Figure 4. *Connecting Traffic Lights*

4. INTELLIGENT CITIES AND AUTOMOTIVE TRANSPORTATION

Autonomous vehicle technology enables automobiles to understand the environments in which they operate and execute safe and efficient commands based on this understanding. Autonomous vehicles can assume decision-making and operational tasks, enabling drivers to become passengers, entirely disengaged from driving demands. Citizens engage with innovative city ecosystems in various ways using smartphones and mobile devices and connected cars and homes. Sceneries of implementation: Connected traffic lights receive data from sensors and cars adjusting light cadence and timing to respond to real-time traffic, reducing road congestion, Figure 4. Connected cars can communicate with parking meters and electric vehicle (EV) charging docks and direct drivers to the nearest available spot. Intelligent garbage cans automatically send data to waste management companies and schedule pick-up as needed versus a pre-planned schedule. And citizens' smartphone becomes their mobile driver's license and ID card with digital credentials, which speeds and simplifies city and local government services. Analyze the data: Focus on two types of analysis: immediate analysis and long-term modeling.

5. MARKOVIAN MODEL

Markov model is a stochastic process used for estimating categorical time series. The approach has been used in the transportation domain and other fields such as computer science for speech recognition and social science for life-course trajectory analysis [33-35]. A Markov model is used to model systems that randomly change states over time. Further, a first-order Markov model is assumed, i.e., future state at time $t+1$ only depends on the current state at time t (and not any previous periods). Assume the activity-travel behavior state of an individual i is represented by $X_{(i,t)}$. Where i is an index for individuals and can take values from $1, \dots, N$ and t is an index for time and can take values from $1, \dots, T$. $X_{(i,t)}$ can take values from m categories $\{1, \dots, m\}$ representing the different activity and travel episodes that they can pursue. The first-order Markov model is characterized by two parameters $\theta = (\delta, q)$. δ is an m dimension vector of initial probabilities where an element δ_j denotes the probability that the individual starts their day by conducting activity j at period 0:

$$\delta_j = P(X_{(i,1)}=j); \quad j \in \{1, \dots, m\}$$

q is an $m \times m$ matrix of the transition probabilities, where an element $q_{(j,h)}$ indicates the probability of switching to activity h at time t given the individual was pursuing activity j at time $t-1$.

$$q_{(j,h)} = P(X_{(i,t)}=h | X_{(i,t-1)}=j); \quad j, h \in \{1, \dots, m\}$$

$q_{(j,h)}$ is assumed to be constant over time t . This assumption leads to a homogeneous first-order Markov model.

5.1 Markovian Models

Markov chain - used by systems that are autonomous and have fully observable states. The Hidden Markov model is used by autonomous systems where the state is partially observable. Markov decision processes - used by controlled systems with a fully observable state. Partially observable Markov decision processes - used by controlled systems where the state is partially observable

Every model consists of a structure and parameters that be defined for the model to be meaningful. The structure of the model defines dependencies among the various parts of the model. Parameters are values often, but not necessarily numerical values required by the model. Parameters are fixed, in which case they constitute model assumptions, or they may be variable.

5.2 Markov chain

Markov chains are mathematical systems that hop from one "state" (a situation or set of values) to another. The system is modeled as a sequence of states and, as time goes by, it moves in-between states with a specific probability. Since the states are connected, they form a chain.

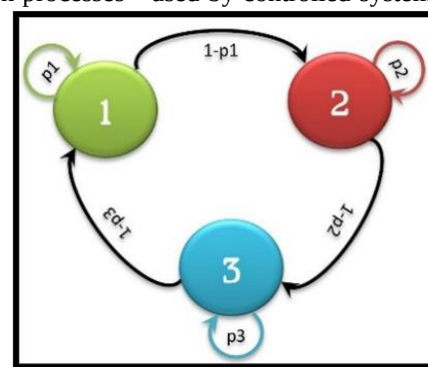


Figure 5. Markov Chain Example

6. CONCLUSIONS

In Markov model, if can reach all states in the chain, the probability of moving to a particular state will converge to a single steady value in the long run. In the development of algorithms for autonomous cars, it is not enough to have the conditions of the car in real-time; it is necessary to consider driving conditions (weather, traffic, etc.) and the behavior of passengers and pedestrians. Algorithms capable of monitoring these conditions in real-time are generated, increasing vehicle efficiency, saving resources, adjusting fuel consumption, and directing vehicle control to a safe point without the need for driver interaction.

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