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# EVOLUTION OF THE CRUISE CONTROL

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ABSTRACT

In this paper we discussed the evolution of Cruise Control systems, from the most rudimentary systems to the adaptive systems. Different Cruise Control systems are presently implemented in vehicles on the market today and the prospects for development of them.

KEYWORDS

CRUISE CONTROL; ADAPTIVE SYSTEM; AUTOMATIC BRAKING; SIGN RECOGNITION; IMAGE PROCESSING.

## 1 Introduction

The cruise control appeared just as any other product: responding to an existing need. In this case, a need to increase the driver's comfort and safety.

The first system recognized as Cruise Control was created by James Watt and consisted in the use of a centrifugal valve regulating the position of a butterfly valve which, in turn, regulated flow of steam admitted into the machine. If the machine speed rise, the centrifugal valve’s rotation caused the butterfly valve to close which reduced the steam flow, thus reducing the machine speed. This system was purely mechanical.

In 1944, Ralph Teetor, created the first prototype of a Cruise Control which he named the Speedostat (Simpson & Sehgal, 2014). He noted, on a trip with his lawyer, that he reduced the car's speed as he spoke and accelerated as he listened, Ralph decided to create a system that controls the speed. Ten years later, the first patent for a cruise control system arose. This system was developed by Perfect Circle, and was first marketed by Chrysler (Vahidi & Eskandarian, 2003).

Figure 1 - *Ralph Teetor.*

After the invention of the cruise control system, two projects were created to help advance the technology and control. These projects were the Eureka Prometheus Project, active from 1986-1995 and the Argo project, active from 1996-2000. The Eureka project was supported by various car manufacturers with the intent of improving traffic safety. The outcome of the project was a sensor that sensed that a slower object was presents in its path a therefore decelerated the car. The Argo project added generic object and lane detection functionality to the cruise control system (Simpson & Sehgal, 2014).

Presently Cruise Control systems are already highly evolved, ranging from systems that maintain a pre-set speed to systems with add-ons like safely braking systems and obstacles detention among others.

## 2 Traditional Cruise Control

Firstly, it is important to realize how cruise control works. This system allows the driver to set the vehicle speed without having to break or accelerate. The cruise control then has the function to increase driver comfort while driving. To increase driver safety this system is switched off immediately if the accelerator, brake or clutch is touched (Adaptive Cruise Control with Steer Assist., n.d.).

Typically, Cruise Control systems most used by various brands consist of a program that maintains the vehicle speed. The driver only needs to accelerate the vehicle to the desired speed and turn on the system. Broadly speaking, these systems consist of 4 buttons: "Set", which, once pressed, assumes the vehicle's instantaneous speed as the cruising speed, thereby maintaining the vehicle at the same speed; "+ 1" and "- 1 ", allow the driver to increase or decrease 1 km / h at the speed set in" set ", thus becoming the new set speed; "Off" to turn off the system.

The Cruise Control is useful in situations where the vehicle speed does not need to vary (driving on the motorway), so, as a rule it can only be activated when at speeds above 50 km / h, in the case of stick-shift, only when the vehicle is in the high gears.


Figure 2 - Cruise Control buttons.

These systems only have the function of maintaining the vehicle speed, interacting with the engine control unit (ECU), increasing or decreasing the engine load, so that the vehicle meets the various disturbances which tend to vary its speed (wind, road gradient, etc.). For security reasons, if the driver trigger any of the car's pedals (accelerator, brake or clutch) the system turns off automatically. Of course, in a manual transmission vehicle, the system cannot interact with the gearbox, whereby it is limited to the gear change. Therefore, situations may arise where the vehicle does not have the capacity to maintain the desired speed, e.g. while driving up a steep slope, the car may not have enough power to be able to maintain the desired speed. In this case the system only places the maximum engine load, and the speed falls (Adaptive Cruise Control DISTRONIC PLUS | Daimler Technology & Innovation Safety Prevention, n.d.).

These systems can be used for more efficient use of the motor fuel, by avoiding abrupt accelerations. This system is the most used in the market. All major brands use this system as standard or optional equipment in their vehicles. With respect to electronic components, this type of cruise control is relatively simple. It only utilizes speed sensors and a system controller which receives the constant speed readings and act on the engine load to maintain constant speed, these components are already present in every car.

## 3 The Adaptive Cruise Control

The Adaptive Cruise Control system is a more recent system in which various sensors and actuators interact to keep the vehicle under certain conditions. These systems are found only in vehicles with medium / high range, since its implementation requires the use of a wide variety of sensors and actuators, as well as highly complex programs. These factors have high costs, making it infeasible to implement such lower end systems and vehicles (Adaptive Cruise Control DISTRONIC PLUS | Daimler Technology & Innovation Safety Prevention, n.d.) (O Que é O ACC Ou Controlador De Velocidade Ativo?, 2014).

A majority of adaptive cruise control systems present in today’s vehicles are systems that control the accelerator, engine powertrain and vehicle brakes to maintain a desired time-gap to the vehicle ahead. (Marsden, McDonald, & Brackstone, 2001) But advancements are continuously implemented into the system that add more functionality, versatility, options, cost effectiveness and comfort to the driver.

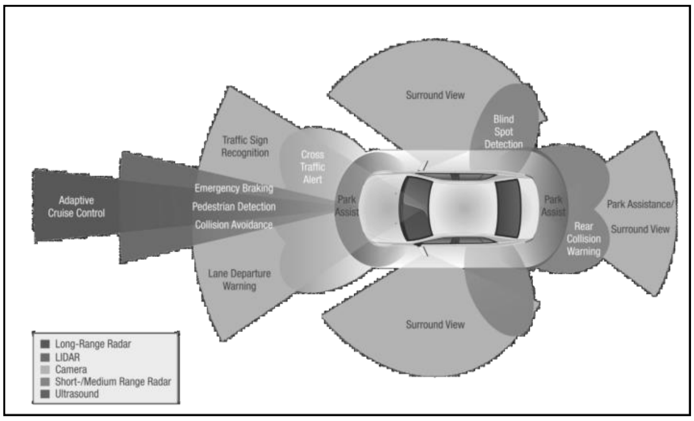


Figure 3 – Sensors and respective ranges (Adaptive Cruise Control DISTRONIC PLUS | Daimler Technology & Innovation Safety Prevention, n.d.).

### 3.1 Automatic Braking System

One of the features integrated in adaptive systems is the automatic braking system. In this system the vehicle is equipped with radar sensors that measure the distance from the front of the vehicle (Russell, et al., 1997) (Tokoro, Kuroda, Kawakubo, Fujita, & Fujinami, 2003) or detect the appearance of any obstacles. The sensors send information to the controller which processes and acts on the ECU of the vehicle or on the brakes, so that the desired distance is maintained (Adaptive Cruise Control DISTRONIC PLUS | Daimler Technology & Innovation Safety Prevention, n.d.). Since the average reaction time of a human being is approximately 1 second, if the vehicle is moving at 90 km / h during the driver's reaction time the car moves 25 meters. It is thus important to have a system which reacts as quickly as possible, so that the distance traveled during the response time is as short as possible. The sensors, controllers and actuators used in adaptive systems have very short response times (approximately 15 ms), the distance traveled during the response time is approximately 2% of the traveled during the time of human response. This difference reduces the likelihood of accidents, making the vehicle safer.

This feature is found mainly in high-end vehicles because of cost, all the system components and a highly complex program make it an expensive system.

### 3.2 Safety distance System

Vehicle following and the effects on traffic flow has been an area of much research. A humans driving skills involves reaction times, delays, and human errors that all affect traffic undesirably. A way to eliminate human errors, delays and reduce reaction time in vehicle following is to assist the human driver with a computer control system and sensor package (Loannau & Chien, 1993).

This system is used to maintain a distance from the vehicle ahead (Palmquist, 1993) (United States of America Patent No. US 5230400 A, 1993). Similarly to the automatic braking system, the vehicle checks the distance from the front vehicle and acts on the brake or ECU to maintain the distance to the vehicle ahead. This system, in addition to increasing the vehicle safety, makes driving more comfortable but is mainly projected for highway applications (Mercedes-Benz TechCenter: DISTRONIC PLUS, n.d.).

Stop and go cruise control is basically the same concept as described above but with the capability to react in more traffic congested areas. According to Dr. Paul Venhovens et al. "[Stop and go cruise control] requires extensive knowledge about driver and traffic behavior. New sensor concepts for detecting the driving environment will need to be developed and the acquired information needs to be transformed into an assessment of the traffic situation. Models are necessary in order to identify the traffic state and determination of the appropriate actions for each situation needs to be established." (Venhovens, Naab, & Adiprasito, 2000)

Ichiro Masaki proposed in his patent an image processing algorithm that periodically takes repetitive live images of the car to follow and compensates for horizontal and vertical shifts scaling and steering which allows the vehicle to be followed and maintain distance around highway curves (United States of America Patent No. US 4987357 A, 1991).

## 3.3 Signal Recognition System

The traffic sign recognition system uses a camera and an image processing program which detects the presence of certain objects and recognize traffic signs detected. These signs are then presented to the driver on the instrument panel (Palmquist, 1993). In more advanced systems, the system controller can even act on the vehicle so that it complies with the rules established by the signs (Adaptive Cruise Control DISTRONIC PLUS | Daimler Technology & Innovation Safety Prevention, n.d.) (Bishop, 2005).This system allows the driver to see all the currently active road signs and view any missed signs due to distraction.


Figure 4 – Traffic Sign Recognition.

B. Asadi proposed the use of traffic signal information in the vehicle's adaptive cruise control system in a way to reduce idle time at stop lights and fuel consumption thus increasing efficiency. To achieve this goal an optimization-based control algorithm is formulated that uses short range radar and traffic signal information accurately to define an optimum velocity curve for the vehicle. This control could ultimately time and apply the "perfect" approaching speed so that there is minimal braking before having to accelerate at green light, all this while still maintaining a safe distance between vehicles, and cruising at or near set speed (Asadi & Vahidi, 2010).

## 3.4 Pedestrian Detection System

Pedestrians detection of was implemented in the Volvo cruise control systems (Volvo Lança Sistema Detector De Peões Capaz De Travar O Carro, n.d.). This function is achieved by combining a radar mounted on the front area of the vehicle, and a camera placed in the rearview mirror (United States of America Patent No. US

7149613 B2, 2006). The RADAR function is to detect objects and the distance to which they are from the car (Russell, et al., 1997) (Tokoro, Kuroda, Kawakubo, Fujita, & Fujinami, 2003), the camera along with advanced image treating functions define the type of objects present (Volvo Lança Sistema Detector De Peões Capaz De Travar O Carro, n.d.).

These features can be revealed to be vital, for example, a situation where a pedestrian or a cyclist suddenly emerge in front of the car, the cruise control system realizes the existence of the obstacle and immediately activates the brakes to immobilize the car (Bishop, 2005).

### 3.5 RADAR Operation

RADAR is a word that appeared in English and stands for Radio Detection and Ranging and allows object detection over long distances (Russell, et al., 1997). This ability comes from the fact that this device works with electromagnetic waves where the waves are emitted by the radar and then reflected by the object (Russell, et al., 1997) (Tokoro, Kuroda, Kawakubo, Fujita, & Fujinami, 2003). Wave propagation Speed simply measure the time that has passed since the wave was issued until it was received be the radar and then uses those variables to calculate the distance from the object (Adaptive Cruise Control DISTRONIC PLUS | Daimler Technology & Innovation Safety Prevention, n.d.).

This measuring instrument uses the Doppler Effect as the physical principle, to achieve a high accuracy value in its results, the wave must have a very stable frequency (Russell, et al., 1997). To control the waveform characteristics, the radar uses an oscillator which emits a wave with a desired length and produce a signal which can vary in frequency and amplitude. Radar generally uses microwave or radio waves (Tokoro, Kuroda, Kawakubo, Fujita, & Fujinami, 2003).

The Doppler principle says that when a light or sound wave is emitted, as the source approaches a reference point the effects are increasingly felt, as soon as the source passes the reference point the effects decrease dramatically.

### 3.6 Image Processing Operation

According to US patent US 6958683 B2 "A multipurpose sensing system for a vehicle includes an optic that is directed at multiple viewing areas. A vision sensor is coupled to the optic and generates multiple object detection signals corresponding to the viewing areas. A controller is coupled to the vision sensor and generates multiple safety system signals in response to the object detection signals." (United States of America Patent No. US 6958683 B2, 2005)

A video image processor (VIP) is a combination of hardware and software that extracts desired information from images obtained by image sensors (United States of America Patent No. US 7149613 B2, 2006). Image sensors can be anything from a TV camera to an infrared camera (Fancher, 1998). Typically the camera is a CCD camera and is normally mounter in the rear-view mirror of the car (Handmann, Kalinke, Tzomakas, Werner, & Seelen, 2000). The VIP system can detect speed, presence and can count objects. The VIP system operates generally in the following manner, the operator selects the detection areas where objects appear in the camera image. A processing algorithms is then run which analyzes and detects objects in the pre-selected areas.

Some advantages of VIP systems is that they are mounted above the road, the detection zone may be selected by the user and the system can be used for following vehicles. Disadvantages include that the system misinterprets objects due to shadows, bad weather and road reflections. But these disadvantages can be overcome by improving the hardware and algorithms used in the image analysis (Handmann, Kalinke, Tzomakas, Werner, & Seelen, 2000).

## 4 Conclusion

Cruise Control systems have undergone major technological advances over the years (Bishop, 2005). Since its beginning, various systems were added like distance control systems, recognition of traffic signals, pedestrian detection, etc. These systems are no longer limited to the simple establishment of a speed and persistence in the same speed without having to use the accelerator. The convenience, safety and comfort of these systems evolved to a very high level. Since these systems can be used so that the vehicle has the lowest possible fuel consumption, the cruise control plays a big role in a car's environmental factors.

With increasing accuracy of global positioning systems (GPS), their use in the Cruise Control systems can, in the near future be a reality, allowing the vehicle to receive information on the upcoming path, thus having the ability to anticipate and adapt to what is ahead on the road (Bishop, 2005).

## 5 References


*Adaptive Cruise Control DISTRONIC PLUS | Daimler Technology & Innovation Safety Prevention*. (n.d.). Retrieved December 17, 2014, from https://www.daimler.com/dccom/0-5-1210218-1-1210321-1-0-0-1210228-0-0-135-0-0-0-0-0-0-0-0.html

*Adaptive Cruise Control with Steer Assist.* (n.d.). (Volvo Car Group Global Media Newsroom) Retrieved December 17, 2014, from https://www.media.volvocars.com/global/en-gb/media/videos/49628/adaptive-cruise-control-with-steer-assist

Asadi, B., & Vahidi, A. (2010). Predictive Cruise Control: Utilizing Upcoming Traffic Signal Information for Improving Fuel Economy and Reducing Trip Time. *IEEE Transactions on Control Systems Technology, 19*(3), 707-714.

Bishop, R. (2005). *Intelligent Vehicle Technology and Trends.* Norwood: Artech House Publishers.

Fancher, P. (1998). *INTELLIGENT CRUISE CONTROL FIELD OPERATIONAL TEST.* Ann Arbor: University of Michigan, Transportation Research Institute, Ann Arbor MI Remarks.

Handmann, U., Kalinke, T., Tzomakas, C., Werner, M., & Seelen, W. V. (2000). An image processing system for driver assistance. *Image and Vision Computing, 18*(5), 367-376.

Kakinami, T., Saiki, M., & Sato, J. (1993, July 27). *United States of America Patent No. US 5230400 A.*

Loannau, P. A., & Chien, C. C. (1993). Autonomous intelligent cruise control. *IEEE Transactions on Vehicular Technology, 42*(4), 657-672.

Marsden, G., McDonald, M., & Brackstone, M. (2001). Towards an understanding of adaptive cruise control. *Transportation Research Part C: Emerging Technologies, 9*(1), 33-51.

Masaki, I. (1991, January 22). *United States of America Patent No. US 4987357 A.*

*Mercedes-Benz TechCenter: DISTRONIC PLUS*. (n.d.). (Mercedes-Benz TechCenter: DISTRONIC PLUS) Retrieved December 17, 2014, from http://techcenter.mercedes-benz.com/en/distronic_plus/detail.html

Mills, A. L., Engleman, G. H., Xu, L., & Beydoun, S. M. (2005, October 25). *United States of America Patent No. US 6958683 B2.*

*O Que é O ACC Ou Controlador De Velocidade Ativo?* (2014, January 25). (circulaseguro) Retrieved December 15, 2014, from www.circulaseguro.pt/seguranca-activa/o-que-o-acc-controlador-velocidade-ativo

Palmquist, U. (1993). Intelligent cruise control and roadside information. *IEEE Micro, 13*(1), 20-28.

Russell, M. E., Crain, A., Curran, A., Campbell, R. A., Drubin, C. A., & Miccioli, W. F. (1997). Millimeter-wave radar sensor for automotive intelligent cruise control (ICC). *IEEE Transactions on Microwave Theory and Techniques, 45*(12), 2444-2453.

Simpson, P., & Sehgal, N. (2014). *The Future of Autonomous Cars.* Tackk.

Stam, J. S., Pierce, M. W., & Ockerse, H. C. (2006, December 12). *United States of America Patent No. US 7149613 B2.*

Tokoro, S., Kuroda, K., Kawakubo, A., Fujita, K., & Fujinami, H. (2003). Browse Conference Publications > Intelligent Vehicles Symposiu ... Help Working with Abstracts. *Intelligent Vehicles Symposium, 2003. Proceedings. IEEE*, 304-309.

Vahidi, A., & Eskandarian, A. (2003). Research advances in intelligent collision avoidance and adaptive cruise control. *IEEE Transactions on Intelligent Transportation Systems, 4*(3), 143-153.

Venhovens, P., Naab, K., & Adiprasito, B. (2000). *Stop and Go Cruise Control.* Seoul: FISITA World Automotive Congress.

*Volvo Lança Sistema Detector De Peões Capaz De Travar O Carro*. (n.d.). (Green Savers) Retrieved December 17, 2014, from http://greensavers.sapo.pt/2013/03/11/volvo-lanca-sistema-detector-de-peoes-capaz-de-travar-o-carro/