Adaptive Damping Control using RFID: Design & Optimization

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Abstract
This communication presents the design, implementation and optimization of the Variable Damping System, explaining RFID role as an automated protocol for Smart Luggage Transportation. The research combines Radio-Frequency Identification as main entry to our Variable Damping System, which's purpose being to regulate the transportation's vehicle suspension levels, depending on the nature of transported items, making each product's trip optimally specified on security and road comfort levels, in order to insure the desirable transport conditions for sensible products.

Keywords
Variable Damping Systems, Radio-Frequency Identification, Smart Transportation

1. Introduction
Tracking via RFID technology allows enormous portals on a large platform of applications, and Damping in a multitude of engineering applications has a variable threshold requirement based on system excitation. Since system excitation is also variable, dampers are such that an adequate amount of damping is provided, opposed to an optimal amount as a function of excitation. In that context, our proposed Applicative scenario is an Intelligent Transportation application, combining both complementary technologies, including a complex network of variable suspension sensors and actuators, RFID Tags and readers, along with the main suspension ECU. The adaptive suspension system's purpose is to regulate the transportation's vehicle suspension levels, depending on the nature of transported items, making each product's trip optimally specified on security and road comfort levels, to insure the desirable transport conditions for sensible products. While the RFID role is to automatically, detect the optimally adequate suspension mode, based on already-scripted data printed on the transported items tags.

In this paper, we start by defining the concept of variable suspension on both mechanical and electronic basis, while explaining the system's role in optimizing transportation experiences. Secondly, we explain the system's synoptic and define network's components, functioning schematization, implantation and realization steps & we eventually underline RFID automated identification role in optimizing the Transportation Process.

2. History & Evolution of Suspension Systems
The first suspension system has been designed for the light chariots of RamsesbI1 around the year of 1296 B.C. But this suspension system was not accurate, due to its unstable condition. At that time, one suspension system has been found that was practically comfortable for driving power and suspension. However, there were problems for that design in which it reduces the speeds and the rapid wear of the component and needs to be changed frequently. By that time, the history witnessed a rapid evolution of suspension system design with several problems that have been discovered and identified. Regardless of the positive development of suspension system design, there still problems pertaining to the system such as noisy attempts at an iron chain suspension. A new suspension system design was found by William Brush in 1906, after his brother had a car accident at unpaved road with the speed of 30 mph.

The impression is that the car's right wheel started shimming violently and the entire car vibrated furiously. Brush has designed a suspension system for the Brush Two-Seat Runabout car model. The feature of the model was different with front coil springs and devices at each wheel that dampened spring bounce (shock absorber) mounted on a flexible hickory axle. After 25 years, the independent coil spring front suspension has been introduced. Automobiles were initially developed as self-propelled versions of horse-drawn vehicles. However, horse-drawn vehicles had been designed for relatively slow speeds, and their suspension was not well suited to the higher speeds permitted by the internal combustion engine. The first workable spring-suspension required advanced metallurgical knowledge and skill, and only became possible with the advent of industrialization. Obadiah Elliott registered the first patent for a spring-suspension vehicle; each wheel had two durable steel leaf springs on each side and the body of the carriage was fixed directly to the springs which were attached to the axles. Within a decade, most British horse carriages were equipped with springs; wooden springs in the case of light one-horse vehicles to avoid taxation, and steel springs in larger vehicles. These were often made of low-carbon steel and usually took the form of multiple layer leaf springs. Leaf springs have been around since the early Egyptians. Ancient military engineers used leaf springs in the form of bows to power their siege engines, with little success at first. The use of leaf springs in catapults was later refined and made to work years later. Springs were not only made of metal; a sturdy tree branch could be used as a spring, such as with a bow. Horse-drawn carriages and the Ford Model T used this system, and it is still used today in larger vehicles, mainly mounted in the rear suspension. Leaf springs were the first modern suspension system and, along with advances in the construction of roads, heralded the single greatest improvement in road transport until the advent of the automobile. The British steel springs were not well-suited for use on America's rough roads of the time, so the Abbot-Downing Company of Concord, New Hampshire re-introduced leather strap suspension, which gave a swinging motion instead of the jolting up and down of a spring suspension. In 1901 Mors of Paris first fitted an automobile with shock absorbers. With the advantage of a damped suspension system on his 'Mors Machine', Henri Fournier won the prestigious Paris-toBerlin race on 20 June 1901. Fournier's superior time was 11 hrs 46 min 10 sec, while the best competitor was Léonce Girardot in a Panhard with a time of 12 hrs 15 min 40 sec. Coil springs first appeared on a production vehicle in 1906 in the Brush Runabout made by the Brush Motor Company. Today, coil springs are used in most cars. In 1920, Leyland Motors used torsion bars in a suspension system. In 1922, independent front suspension was pioneered on the Lancia Lambda and became more common in mass market cars from 1932. Today, most cars have independent suspension on all four wheels. In 2002, a new passive suspension component was invented by Malcolm C. Smith, the inerter. This has the ability to increase the effective inertia of a wheel suspension using a geared flywheel, but without adding significant mass. It was initially employed in Formula One in secrecy but has since spread to other motorsport.

3. Variable Suspension System Types & Characteristics

Variable suspension or Active suspension is a type of automotive suspension that controls the vertical movement of the wheels relative to the chassis or vehicle body with an onboard system, rather than in passive suspension where the movement is being determined entirely by the road surface. So called active suspensions are actually divided into two classes: real active suspensions, and adaptive/semi-active suspensions.

While adaptive suspensions only vary shock absorber firmness to match changing road or dynamic conditions, active suspensions use some type of actuator to raise and lower the chassis independently at each wheel. These technologies allow car manufacturers to achieve a greater degree of ride quality and car handling by keeping the tires perpendicular to the road in corners, allowing better traction and control. An onboard computer detects body movement from sensors throughout the vehicle and, using that data, controls the action of the active and semi-active suspensions. The system virtually eliminates body roll and pitch variation in many driving situations including cornering, accelerating, and braking.

4. Presentation of our Adaptive Suspension system

The controlled suspension system with variable damping makes it possible to anticipate the deformations of the road and to adapt the damping level of the wheels to contain the movements of the vehicle. The system consists of the following elements:

- 4 height sensors
- 3 Accelerometer sensors
- 2 front shock absorbers
- 2 Rear-mounted shock absorbers

- 1 RFID reader
- 1 multifunction video camera
- 1 variable amortization calculator

A basic schematization of the system is shown in figure1.

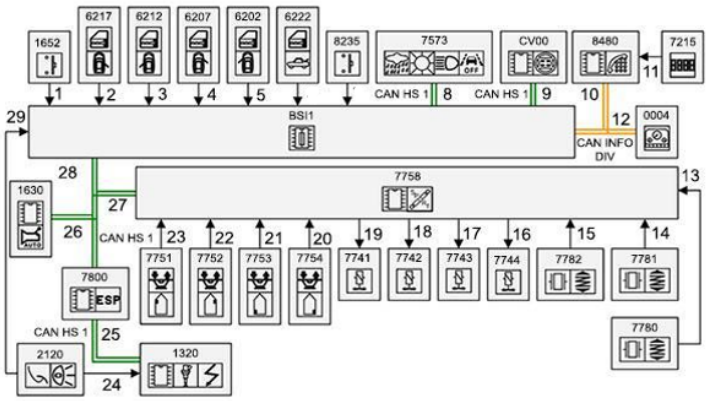

Figure 1. Schematization of Variable Damping System

4.1. Activation & Deactivation conditions

The variable damped controlled suspension function is activated if the following conditions are met:

- Request for activation of the variable damping-controlled suspension function.
- The vehicle speed is between 13 and 130 km / h.
- The engine is turning.
- The front, rear and trunk doors are closed.
- Multifunction video camera operational and not in fault.
- The engine control computer is operational and not in fault.
- The height sensors are operational and not in fault.
- The RFID reader is functional, and communication is established.
- The dynamic stability control computer is operational (not inhibited and not in default).
- No fog, snow, heavy rain.
- Daytime driving NOTE: If all the activation conditions are not fulfilled, the driver is informed of the unavailability of the function.

The damped controlled suspension function is disabled if one of the following conditions is true:

- Request to deactivate the variable damping-controlled suspension function.
- The variable damped controlled suspension function is faulty.
- The vehicle speed is less than 13 km / h.
- The vehicle speed is greater than 130 km / h.
- Loss or absence of information about the ride height.
- Loss or absence of information relating to the nature of the items being transported.
- Loss of information relating to the state of the road.
- Loss of trajectory control on strong solicitation.

- The engine control computer is faulty.
- Engine stopped.
- Opening one of the fronts, rear or trunk doors.
- Impossibility of evaluating the occurrence or loss of information from the driver.
- In case of fog, snow, heavy rain.
- Night driving NOTE: The request to activate or deactivate the variable damping-controlled suspension function is done via the telematic calculator or through the driving mode selector and / or the polysensor mode.

The controlled suspension system with variable damping makes it possible to adapt the law of damping of the anticipated vehicle to contain the movements of the vehicle according to the obstacles of the road detected by the multifunction video camera. The system's components are related by different signal protocols, mainly PSI5, PWM, CAN and wired links. Figure 2 shows our system's architecture.

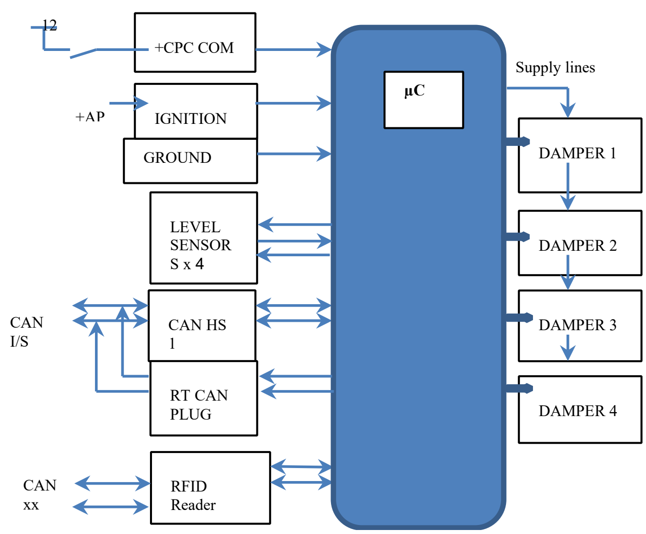

Figure 2. Variable Damping System Architecture

4.2. Principle of Operation of the Adaptive suspension system

The controlled suspension system with variable damping consists of adopting a law of anticipated damping of the suspension according to the obstacles of the road, the utility of the RFID technology is to define the mode of suspension to be used, based on the nature transported elements. The damping law is controlled and calculated independently for each wheel by the variable damping calculator according to the information sent by:

- The multifunction video camera
- Dynamic stability control computer
- The engine control computer
- The intelligent servitude case
- The RFID central reader

4.3. Regulation and control of depreciation

The variable damping suspension computer controls each independently controlled damper according to:

- Road condition information provided by the multifunction video camera.
- The suspension mode chosen by the RFID Reader (hence the nature of the property).
- nformation on the average ride height and suspension travel provided by the ride height sensors.

- Vehicle acceleration information provided by variable damping accelerometers.
- Information provided by the Dynamic Stability Control Calculator.

4.4. Different Modes of the Variable Damping Controlled Suspension Function

driver can choose from 3 possible suspension modes, which can only be possible when the engine is running. Following a selection of a suspension mode, the driver is informed that his request has been taken into account. The mode selected by the driver is memorized and becomes the default active mode until his request is modified, or until the RFID automatic mode is chosen. The variable damping suspension computer sends the corresponding information to the intelligent service box (via the CAN HS 1 network). The intelligent service box requests the display of the appropriate message to the handset (via the CAN INFO DIV network). NOTE: Certain driver assistance systems have an impact on the longitudinal dynamics of the vehicle by acting on braking and acceleration. The variable damped controlled suspension function must therefore give priority to occupant safety by activating the safest mode. The available modes depending on the carried luggage are stated below:

- Mode 1 is a flexible suspension mode. The variable damping suspension computer acts on the dampers controlled in the sense of optimizing transportation comfort. The mode's algorithm is made specifically for items classified as Not-sensible.
- Mode 2 corresponds to an intermediate suspension mode. The variable damping suspension computer acts on the dampers controlled so as to satisfy the best comfort / behavior compromise. NOTE: Mode 2 is the default active suspension mode.
- Mode 3 is a hard suspension mode. The variable damping suspension computer acts on the controlled dampers in the direction of greater sensitivity. This mode's algorithm is made to transport the most sensible items.

5. Components Roles and Functioning

5.1. Role of the Variable suspension Computer

The main functions of the variable damping calculator are the following:

- Feed the height sensors
- Feed the variable damping accelerometers
- Acquire the information delivered by the ride height sensors
- Acquire the information delivered by the variable damping accelerometers
- Power the RFID reader
- Acquire the information delivered by the RFID reader
- Send and receive information on the CAN HS multiplex network 1
- Order hydraulic suspension solenoid valves

5.2. Role of Body Height Sensor

The body height sensors send the average ride height and suspension travel to the variable damping suspension calculator. A change in ride height varies the ride height sensor angle, which changes the output voltage of the sensor. The negative value of the ride height sensor angle is the compression of the suspension and the positive value of the angle of the ride height sensor corresponds to the relaxation of the suspension.

5.3. Information acquisition function

Vehicle height information acquisition: By default, the height sensors are a provision in the scope of the system. This chapter is applicable only in case of one or more unit measurement with level sensor. When the vehicle is already equipped with height sensor (eg equipped with dynamic lighting control system - 2 sensors aligned along x vehicle axis), these height sensors could be used and would be in this case outside the scope of the delivery. The use of already existing height sensors in the transportation vehicle shall be allowed, and in particular, as long as it ensures compatibility towards:

- Their implementation is a compatible information requested by the system.
- Their numbers need to be a compatible system. Otherwise, one or more sensors will be added to specification.

- The impacts (harness changes, local organic architecture...) negative induced by the use of these sensors do not generate constraints or cost more than the gain provided.

Depending on vehicle equipment, the type of system suspension or other system and / or location constraints, the vehicle may be equipped with a set of measurement including:

- One height sensor on a single axle, in this case the rear axle,
- Or two height sensors on a single axle, one at each of the wheels, in this case the rear axle,
- Or two height sensors, one on each axle,
- Or three sensors, one sensor on one of the axles and two sensors on each wheel of the second axle,
- Or four sensors, one at each of the wheel

The system must acquire the electrical information from the sensor height so as to provide the following configuration:

- Information “axle height” and / or “high wheel”,
- Information “axle deflections” and / or "wheel deflections”,
- The “speed axle deflections” and / or “wheel travel speed” information.

To ensure system performance, the recommended resolution for the acquisition, computation and retrieval of information or clearance height is less than or equal to 0.1 mm. The measurement made by the sensor is obtained as follows: the linear movement of the sensor is 70° (i.e. 58.33 %) for the maximum deflection travelled: 240 mm. The system must make this transfer data tunable, Figure 3 illustrates vehicle height information acquisition.

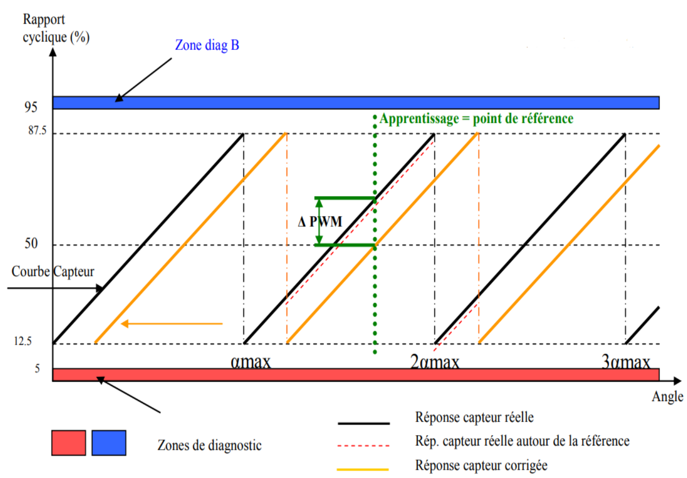

Figure 3. Vehicle Height Information Acquisition

In the case of a single sensor per axle, it is located Preferably put centrally, so that the playback of information travel is within + / - xx mm from the axis of symmetry of the vehicle (+ / - 10 mm default). It is positioned so as to read the movements between the body and the axle or the anti-roll bar and the body, or the anti-roll bar and axle.In case of one sensor by wheel, sensor will be positioned such that the point of deflection is read in the X-axis closer to the wheel center, the wheel itself and left-right symmetric.

The system must be compatible to each of the configurations described above by simple configuration: it will be able to manage each sensor, with for each a specific cartography and mapping. Mounted on the vehicle, to ensure the accuracy of the information height, and eliminate process variations related to the implementation and / or the characteristics of the components, the system will be able to make a height learning to match the true height of the vehicle and the value of (the) sensor (s) at the time of learning.

6. Damping law for different driving inputs

6.1. Damping law for lateral driver inputs (cornering)

For positive lateral driver inputs, The system must make for limit the car body roll angle and velocity between Arr_mini and Arr_maxi (for the roll angle) and between Vrr_mini and Vrr_maxi (for the roll velocity). These values depend of the vehicle speed. The system must make for limit the car body roll angle and velocity with a damping factor between Tx_roulis_cond_mini and Tx_roulis_cond_maxi. These values depend of the vehicle speed.

For negative lateral driver inputs, The system must make for limit the car body roll angle and velocity between Arr_mini and Arr_maxi (for the roll angle) and between Vrr_mini and Vrr_maxi (for the roll velocity). These values depend of the vehicle speed. The system must make for limit the car body roll angle and velocity with a damping factor between Tx_roulis_cond_mini and Tx_roulis_cond_maxi. These values depend of the vehicle speed.

6.2. Damping law for longitudinal driver inputs (braking/acceleration)

Braking and acceleration need different calibrations to guaranty independent damping law in function of the longitudinal driver inputs. Supplier will precise his functional architecture and if there is independent modules. For positive longitudinal driver inputs (acceleration), the system must make for limit the car body pitch angle and velocity between A_tg_mini and A_tg_maxi (for the roll angle) and between V_tg_mini and V_tg_maxi (for the roll velocity). These values depend of the vehicle speed. The system must make for limit the car body roll angle and velocity with a damping factor between Tx_tg_cond_mini and Tx_tg_cond_maxi. These values depend of the vehicle speed.

For negative longitudinal driver inputs (braking, gear change), the system must make for limit the car body pitch angle and velocity between A_tg_mini and A_tg_maxi (for the roll angle) and between V_tg_mini and V_tg_maxi (for the roll velocity). These values depend of the vehicle speed. For automatic gearbox, the gear change is managed automatically (no clutch pedal, automatic hydraulic clutch decoupling) The system must make for limit the car body roll angle and velocity with a damping factor between Tx_tg_cond_mini and Tx_tg_cond_maxi. These values depend of the vehicle speed.

Based on the RFID reader's entry data, the conductor's choice of modes, and sensor's entry data, the system proposes 3 different transportation modes,

- State 1 – "Comfort" When this state is selected by the driver the parameters in the different functions are chosen to optimize the passengers comfort. These parameters will be defined during the tuning period.
- State 2 – "Nominal" When this state is selected by the driver the parameters in the different functions are chosen to optimize the compromise between comfort and handling. These parameters will be defined during the tuning period.
- State 3 – "Dynamic" When this state is selected by the driver the parameters in the different functions are chosen to optimize the handling. These parameters will be defined during the tuning period. When the mode is active, and when vehicle speed goes over V_Overboost_TH threshold for first time, the nominal values of damping forces are amplified. The amplification will be realized by applying an overboost on the nominal current of dynamic mode during a period T1 seconds, and will be gradually decreased during a period T2 seconds until overboost is null again. V_Overboost_TH , amplification, duration T1 and T2 will be tuneable. They will be defined during the tuning period.

Conclusion

In this research, we showed how controlled suspension system with variable damping makes it possible to adapt the law of damping of the anticipated vehicle, to contain the movements of the vehicle according to the obstacles of the road, detected by the multifunction video camera. The integration of RFID technologies allowed automated adaptation of the transportation modes, depending on the precision scripted on transported items tags. This integration insured better transportation quality for delicate products, while reducing human intervention in the mode choice, as modes are automatically activated for each specific merchandise, making the transportation process independently intelligent, and optimizing the existing solutions.

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Biography

Kenza OUFASKA is an assistant professor at the International University of Rabat - Morocco and attached to « Ecole Supérieure d’Informatique et du Numérique » and member of TICLab. She obtained a PhD in Mathematics (Operations Research and Logistics option) at Moulay Ismail Meknes University. Her research work focuses on multi objective mathematical programming applied to the fields of intelligent transport, intelligent mobility, optimization of supply chains, green and sustainable logistics and humanitarian logistics.

Khalid EL YASSINI holds a PhD and MSc in Mathematics (Operations Research) from University of Sherbrooke - Canada (2000 and 1994). Previously, he had a degree in Applied Mathematics (Statistics) at Abdelmalek Essaadi University - Morocco (1991). During his academic career, he has taught in several Canadian institutions such as University of Sherbrooke, Univesité du Québec à Rimouski or St-Boniface University at Winnipeg; and in various Moroccan institutions such as Moulay Ismail University, International University of Rabat, ENSAK, ESTM, ENSAM or Royal Military Academy. He has taught various courses in mathematics, computer science, operations research and logistics. His current research activities focus on mathematical programming, artificial intelligence, information systems, security in computer networks, telecommunications, intelligent systems, and logistics engineering with applications in hospital field or medication domain. Currently, he is a Professor at the Faculty of Sciences - Moulay Ismail University, Morocco. Its main current research activities focus on mathematical programming (linear and multiobjective optimization), artificial intelligence, information systems, security in networks, telecommunications, intelligent systems (smart cities and smart vehicles), logistics engineering, and green logistics with applications in hospital field or medication domain.

Yassir ROUCHDI is a Mechatronics Engineer and PhD in Software and Mechatronics, researching new tracking methods and solutions. His current work is optimizing RFID middleware and studying its combination, along with Wireless Sensor Networks, Variable Damping Systems or Vehicular ad-hoc Networks.