OBSERVER DESIGN FOR ACTIVE SUSPENSION SYSTEM USING SLIDING MODE CONTROL

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Dedicated to my mother, father, husband, sisters and my dear friend
With my deepest love and appreciation

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ABSTRACT

The purpose of this project is to construct to design an observer for active suspension system by using sliding mode control. The sliding mode control was chosen as a control strategy, and the road profile is estimated by using an observer design. It will be demonstrated theoretically and by computer simulations that the proposed controller enhanced road handling performances for the active suspension system compared to the passive suspension. And the performance of the proposed controller will be compared to the linear quadratic regulator by using the MATLAB and SIMULINK toolbox. A mathematical modelling and simulation study will illustrate that SMC with disturbance observer strategy has better performance than LQR control system and the ability to absorb disturbance for SMC is much better than LQR controller.

ABSTRAK

Tujuan projek ini ialah merekabentuk pemerhati untuk sistem gantungan aktif menggunakan kawalan ragam gelincir. Teknik kawalan ragam gelincir dipilih sebagai pengawal, sementara profil jalan dianggarkan dengan menggunakan pemerhati. Projek ini akan membuktikan secara matematik dan computer simulasi bagaimaan pengawal yang dicadangkan berupaya meningkatkan keupayaan pengendalian jalan oleh sistem gantungan aktif berbanding dengan sistem gantungan pasif. Keupayaan pengawal yang dicadangkan juga akan dibandingkan degan pengatur sukuan linar dengan menggunakan perisian MATLAB dan SIMULINK. Kajian secara simulasi menunjukkan kawalan ragam gelincir lebih berkeupayaan menyerap gangguan jika dibandingkan dengan pengatur sukuan linar.

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CHAPTER 1

INTRODUCTION

1.1 Definition of Suspension System

A system which supports a load from above and isolates the occupants of a vehicle from the road disturbances is called a suspension system. The flexible elements in the suspension system are springs. These components have an ability of storing the energy applied in the form of loads and deflections. The spring is able to absorb energy and bend when it is compressed to a shorter length. It is forced upward and the spring absorbs energy of this upward motion, when a tire meets an obstruction.

On the other hand, this energy is observed by spring for a short time only and the energy will release by extending back to its original condition by it. When stored energy is released by spring, it does so with such quickness and momentum that the end of the spring usually extends too far. Until all of the energy in the spring is released the spring will go through a series of oscillations, contractions and extension. The speed of the oscillations will be determined by the natural frequency of the spring and suspension.

The energy that spring released, will be changed to heat and dissipated partly by friction in the system via damper. Generally Dampers are in the form of piston working in cylinders which filled with hydraulic fluid. A force which they apply is proportional to the square of the piston velocity. To restrain undesirable bounce characteristic of the sprung mass is the function of damper. Furthermore it used to make sure which the wheel assembly always contact with the road by being excited at its natural vibration frequency.

Other mechanical elements in a suspension system are the wheel assemblies and control geometry of their movement. Some of these elements are simple links and multi-role members such as transverse torsion bars used to stabilize the vehicle in corners by restricting roll. A suspension system comprises many elements that include spring, damper, tires, bushes, locating links and anti-roll bars are shown in Figure 1.1. [1].

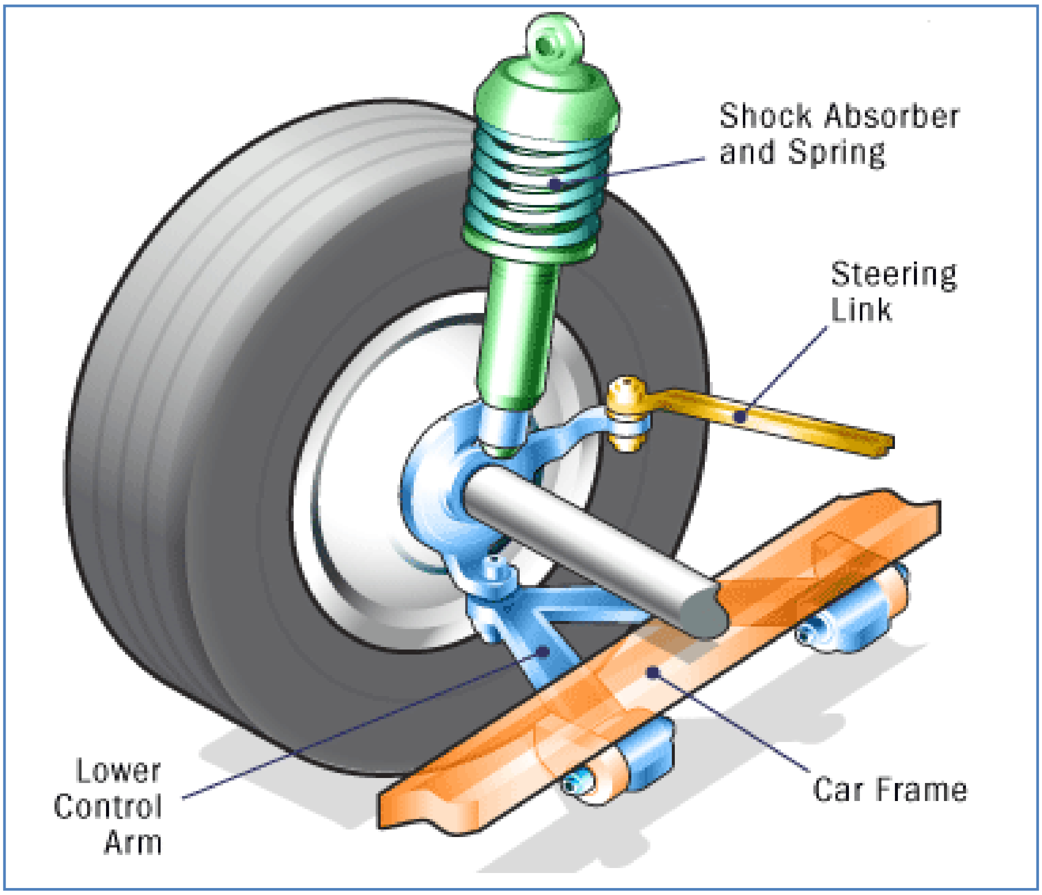

Figure 1.1 A suspension system

1.2 Functions of a Vehicle Suspension

A complicated system as it has to fulfill a large number of partly contradictory requirements is vehicle suspension system. Among the most important requirements that have to fulfill are Ride comfort, safety, handling, body leveling and noise comfort.

The acceleration of the vehicle body can determine ride comfort. As a disturbance, the passengers experience acceleration forces and set demands on the load and the vehicle. The task of the suspension system is to isolate these disturbances from the vehicle body, which the uneven road profile caused It.

The wheels ability to transfer the longitudinal and lateral forces onto the road can determine the safety of the vehicle during travelling. The necessity of the vehicle suspension system is to keep the wheels as close the road surface as possible. Wheel vibration must be dampened and the dangerous lifting the wheels must be avoided. If between the wheels and the road surface, dynamic forces happening are small, the braking, driving and lateral forces can be transferred to the road in an optimal manner. The cause for the recognized conflict of aims among comfortable and safety tuning is the requirement of dampening the tire system.

The isolation of the vehicle body from high frequency road disturbances is a further purpose of the suspension system. In the car, the passengers acoustically note these disturbances and therefore the noise comfort decrease. The suspension system, while there are changes in loading, has to remain the vehicle level as stable as possible therefore for the wheel movements the complete suspension travel exists. In addition, a good suspension design is a lower suspension travel; it means that lower suspension working space. In order to fulfill all these contradict desires confident marginal situation considered [1].

1.3 Types of Suspension System

In general, there are three types of the suspension system. They are:

1) Passive suspension
2) Semi-active suspension
3) Active suspension

1.3.1 Passive Suspension

The conventional suspension system is passive suspension system. It has two elements one of them is damper and another is spring. In this passive suspension, the purpose of the dampers is to dissipate the energy and the spring is to store the energy. Often a spring design function is expressed in terms of energy storage capacity. In machines, springs are frequently used to store kinetic energy from moving components during deceleration and release this energy during acceleration to reduce peak loads. If a load exerted to the spring, it will compress until the force produced by the compression is equal to the load force. , the spring will oscillate around its original position for a period of time when the load is troubled by an external force. Dampers can absorb this oscillation; therefore, it would only jump for a short period of time. For this type of suspension system damping coefficient and spring stiffness are fixed characteristics therefore this is the main weakness as parameters for ride comfort and good handling vary with different road surfaces, vehicle speed and disturbances. [1]

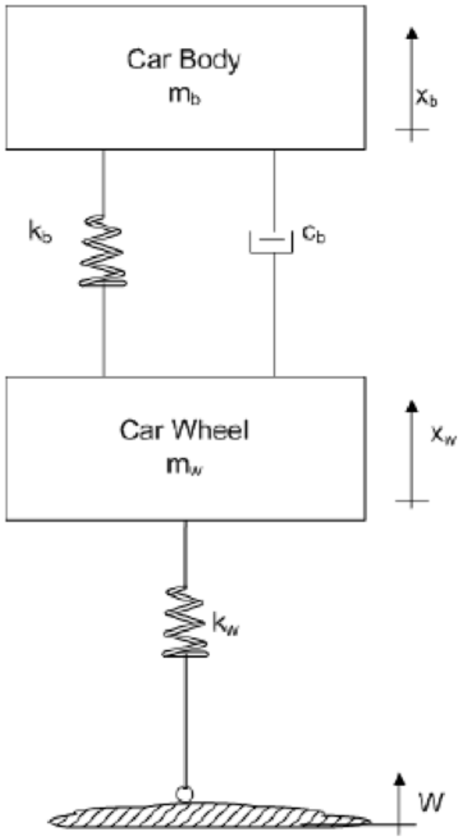

Figure 1.2 Passive suspension systems

The performance of passive suspension system can be improved by using the semi-active suspension system. [2]

1.3.2 Semi-active Suspension

The component in the semi-active suspension system is similar with passive suspension system and where external energy is needed in the system, it uses the same function of the active suspension system. The differentiation with passive suspension system is that the damping coefficient can be controlled .The fully active suspension is modified thus the actuator is only capable of dissipating power rather than supplying it as well. The actuator then becomes a continuously variable damper which is theoretically capable of tracking force demand signal independently of instantaneous velocity across it [3]. While having low system cost, light system weight and low energy consumption this suspension system exhibits high performance.

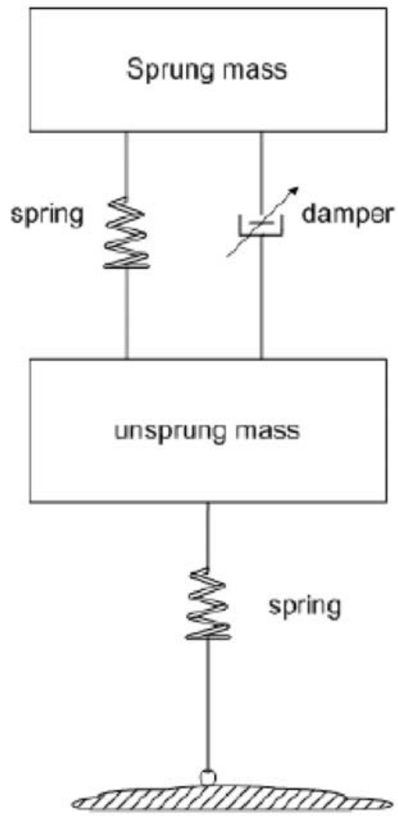

Figure 1.3 The semi-active suspension system

Disadvantage of semi-active suspension: The high frequency harshness that has been observed in road tests and reported in analytical studies of semi active suspension is a significant feature that the performance of 'semi active' suspension is not suitable [4].

To get good body isolation for low frequency inputs a good semi active system should provide high damping, for good comfort, low damping in the mid - frequency range , adequate damping to control the wheel hop, especially under conditions of motion that requires the development of lateral forces and finally increased damping of structural modes. Semi active suspension that use feedback of modal variables reduces structural vibrations in comparison to the corresponding systems with rigid body based controllers [4].

1.3.3 Active Suspension

As early as 1958, the conception of active suspension system was introduced. The differentiation compare to conventional suspension is active suspension system able to add energy into vehicle dynamic system by the use of actuators rather than dissipate energy. Active suspension can use further degrees of freedom in assigning transfer functions and therefore get better performance. The active suspension system consists an additional element in the conventional suspension, which the main component of it, is an actuator that is controlled by a high frequency response servo valve and which involves a force feedback loop. A control law, which is normally obtained by application of various forms of optimal control theory, govern the demand force signal, which typically generated in a microprocessor [3].

In theory, this suspension provides best possible ride and handling characteristics. By maintaining an around stable tire make contact with force, maintaining level vehicle geometry and by minimizing vertical accelerations to the vehicle it is done. On the other hand, due to its complication, cost and power requirements, it has not yet put into mass production [1].

In analysis of suspension system, there are varieties of performance criterion, which require becoming optimal. In designing a suspension system there are three performances criterion, which we should consider carefully; they are body acceleration, suspension travel and wheel deflection. By introducing the appropriate controller into the active suspension system, the performance of the system can be more improved [2].

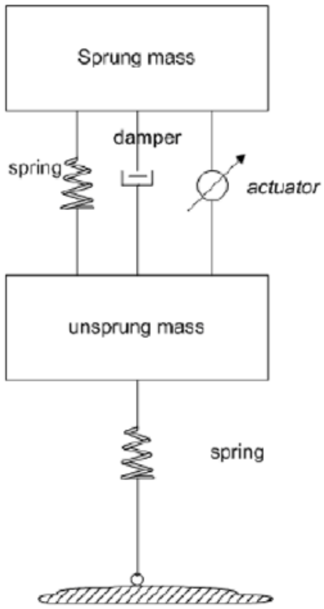

Figure 1.4 The active suspension system

1.4 Active Suspension System Control Strategies

In general, the duty of sensor in active suspension systems is to measure suspension variables such as body velocity, suspension displacement, and wheel velocity and wheel or body acceleration. In an active suspension system, actuators that supply additional forces improve the passive elements. A feedback control law via data from sensors attached to the vehicle determines these additional forces. Good riding comfort to passengers in high speed is proffered by the active suspension system and the additional advantages of this system are a negative damping can be produced and at low velocities, a larger range of forces can be generated. Therefore, the suspension system performance potentially will increase.

Improve the suspension system performance via directly controlled the suspension forces to match with the performance characteristics is the purpose of the active suspension system. Earlier researchers in the design of the active suspension system have established different linear control strategies. Amongst them are a fuzzy reasoning [5], robust linear control [6],∝H[7], and adaptive observer [8]. The results of the study have presented which in comparison with passive suspension system; active suspension system is more useful in the vibration isolation of the car body. The reason of this project is to make use of the idea of sliding mode control in active suspension system by observer design used for road estimator [2].

1.5 Objective of study

The objectives of this study are as follows:

i. Establish the mathematical model of quarter car active suspension system with an observer.
ii. Design an observer, which act as a road profile estimator for active suspension system.
iii. Design a Sliding Mode Control (SMC) for the quarter car active suspension system.
iv. Evaluate the performance of the Sliding Mode Control (SMC) with a disturbance observer.

In theory, by using a Lyapunov's second method will achieve confirmation of the planned controller and observer on its stability. The Performance of the active suspension system will be observed by using Computer simulation, MATLAB software and SIMULINK [2].

1.6 Scope of work

The scopes of work for this study are as follows:

I. Become familiar with a quarter car active suspension system by Sliding Mode Controller

II. Mathematical derivation of an observer for a quarter car active suspension system.

III. Design an Observer for a quarter-car active suspension system by using Sliding Mode Control technique.

IV. Demonstrate a simulation works by using a MATLAB/Simulink to observe efficiency of the observer.

V. Compare the performance of the proposed Sliding Mode Control with Observer design with a Linear Quadratic Regulator (LQR) technique [2].

1.7 Research Methodology

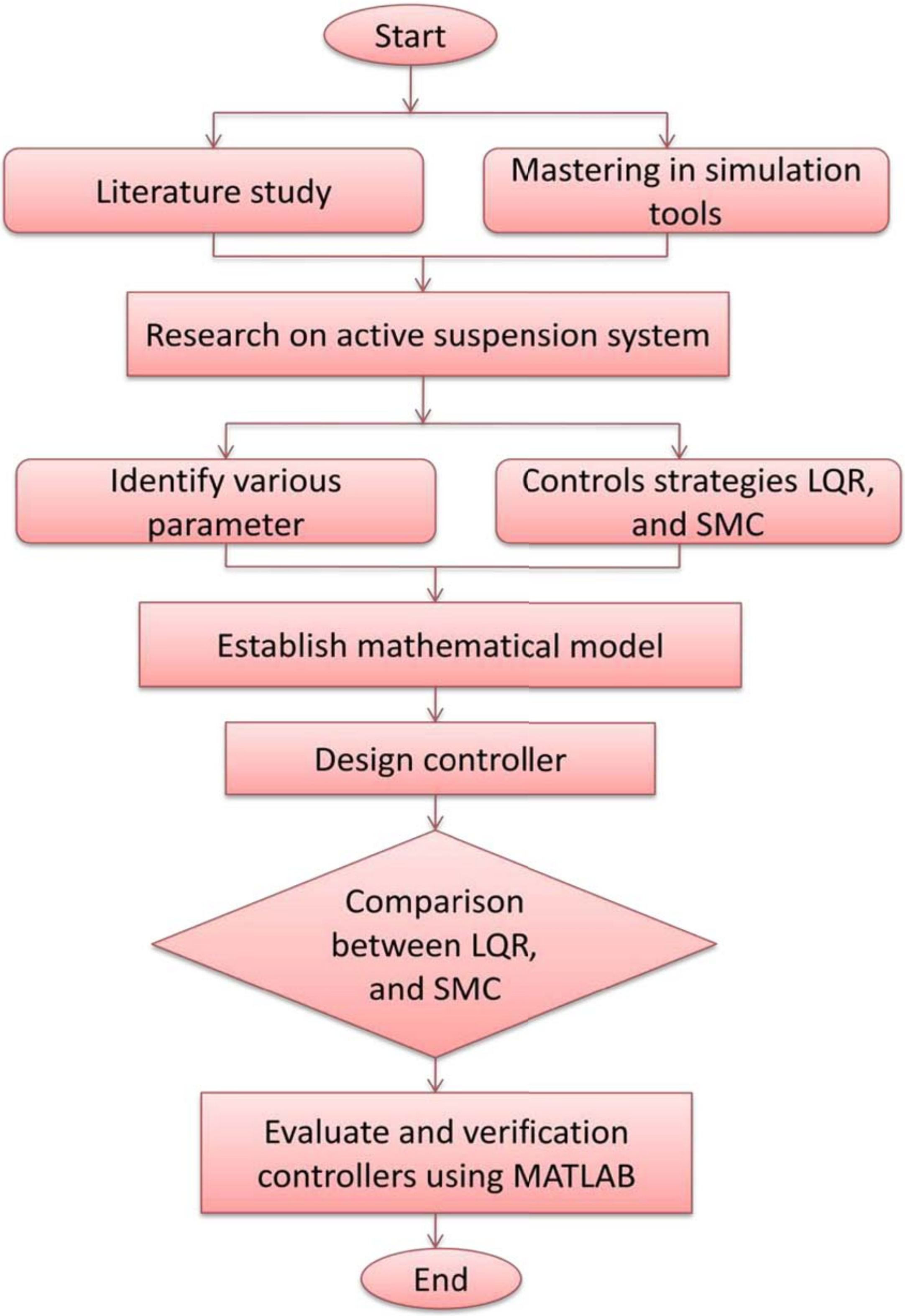

Figure 1.5 Research methodology flow chart

1.8 Structure and Layout of Thesis

For achieving purpose of the study, the required components are given in the following chapters. The mathematical modeling of a quarter cars is derived in chapter 2 and The state space demonstration of the dynamic model of the passive, semi active and active suspension system are outlined. The literature review and mathematical model will discuss in this chapter.

In chapter 3, sliding mode control, the proposed controller with disturbance observer is shown. By using a Lyapunov's stability theory, it will be presented that the system is bounded stable for the system with mismatched uncertain.

In chapter 4 discussion on an observer design is performed.

In chapter 5, the performance of road handling and ride comfort will be compared with the LQR controller. In this chapter, demonstrate the computer simulation for the proposed observer and controller.

The summary of the results and suggestion for future work based on this study will be shown in chapter 6.