# Implementation of a Controller into Prototype Vehicle.

## Homework#1

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A controller is a device or method that modifies the inputs to a system in engineering and control systems to produce a desired output behavior. Whatever the application, some mega engineering firms like Porsche Engineering provide a hardware and software platform based on specifications that offer the ideal solution. The behavior of other devices or systems is managed, ordered, directed, or regulated by a controller, which is a device or system. For instance, a controller in a car might take inputs from sensors that measure things like speed, acceleration, and steering angle and use that data to regulate actuators like the throttle and brakes.

The controller guarantees real time stability and safety by altering the inputs based on the system's present state and desired behavior. Control algorithm development, implementation on a micro-controller or other control hardware, and mathematical modeling of the system are all possible components of controller design. The purpose of a controller is to influence a system's behavior by using feedback from the output to modify the inputs when in practice out in the real world.

**Major Goals:**

- To assure the vehicle's stability and safety.
- To optimize the vehicle's motion efficiency.

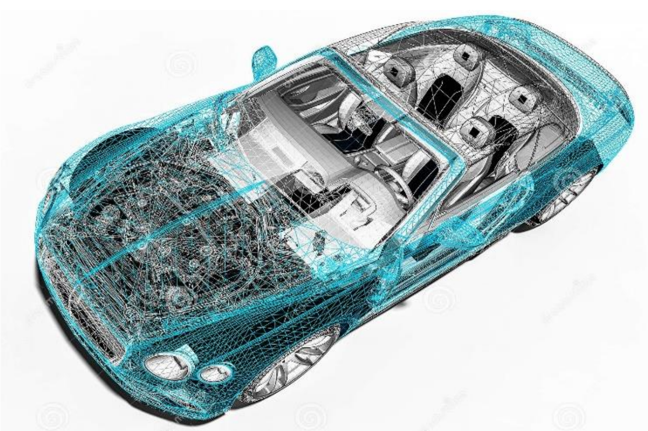


Fig-1 (Prototype Vehicle Concept)

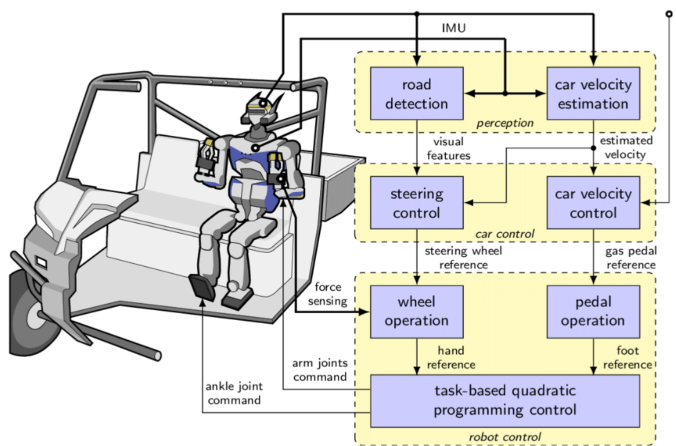



Fig-2 (Controller visualization)

**Necessary Assumptions:**

- The prototype vehicle already includes the sensors and actuators required to provide input to the controller and receive output from it.
- A micro-controller with appropriate processing power and memory will be used to implement the controller.
- The environment and operational circumstances of the vehicle are specified and do not vary much.
- The engineering team has the necessary technical competence to complete the implantation.

**Key Questions:**

- What is the vehicle's desired state?
- What kind of control algorithm will be applied to reduce the discrepancy between the desired and actual state?
- What limitations on the control outputs are there to maintain the vehicle's stability and safety?

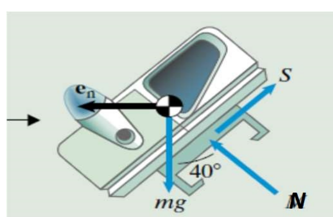
- Are there any constraints on the control algorithms (e.g., computational complexity, hardware limitations)?

**Pseudocode**

```
%Read sensor data
sensors_dara = read_sensors(x,a); %where x is the current position and a is the
current acceleration
%Calculate control outputs
control_outputs = calculated(sensors_data);
% Apply control output to actuators
output_1 = calculated(control_outputs);
%Calculate desired vehicle state
[alpha,m] = positioning(x,y);%where alpha is the tilt angle and m is the mass

N = force normal to the point of contact
S = force exerted in the lateral direction
v = minumum or maximum velocity
m = mass of the body
R = radius of curvature
alpha = angle of tilt
u_s = coefficient of friction
g = 9.81
while
    %%using free body diagram and the outputs from sensors
    %balancing vertical forces
    N = ((m*g)- S*sin(alpha))/cos(alpha);
    %balancing lateral forces
    v = ((R/m)*(N*sin(alpha)+S*cos(alpha)))^1/2;%v is the velocity of the vehicle
 end
  if friction_force == 0
    v_max = (tan(alpha)*g*R)^0.5;  end
  if S == 0 %zero lateral force

    %FBD equation
    %balancing vertical forces
    N*cos(alpha) = m*g;
    %balancing lateral forces
    N*sin(alpha) = (m*(v^2))/R;
    v = ((R/m)*N*sin(alpha))^0.5;
 end
```




**Case I- When do we get the maximum tilt?**

We get the maximum tilt when the radius of curvature of the turn is minimum. In other words, the lower the angle, alpha, the more the tilt and hence lower the radius, R.

**Case II- When the lateral force(S) is zero, how the controller responds?**

If we keep the values of R and m constant and vary the value of alpha alone, then the velocity will increase as alpha increases.

**Case III- What is the behavior of the masses?**

The square of the velocity of the mass is directly proportional to the angle of tilt.

$$v^2 \equiv \text{alpha}$$

**Problem 2.**- Take measurements of accelerations in a moving vehicle All of our phones have accelerometers that can be accessed, either directly or with apps that can be purchased quite reasonably (your team's choice). You are to acquire a dataset of vertical and lateral accelerations. It may be useful for you to acquire simultaneous mapping and video of the route/occupants for later correlation with your data. See below for a reference on obtaining accelerometer data from an iPhone. You need not be limited to this approach. The apple app store also has an interesting app called "Vibration" which may be of use, but this is up to your group to evaluate and decide.

**Major Goals:**

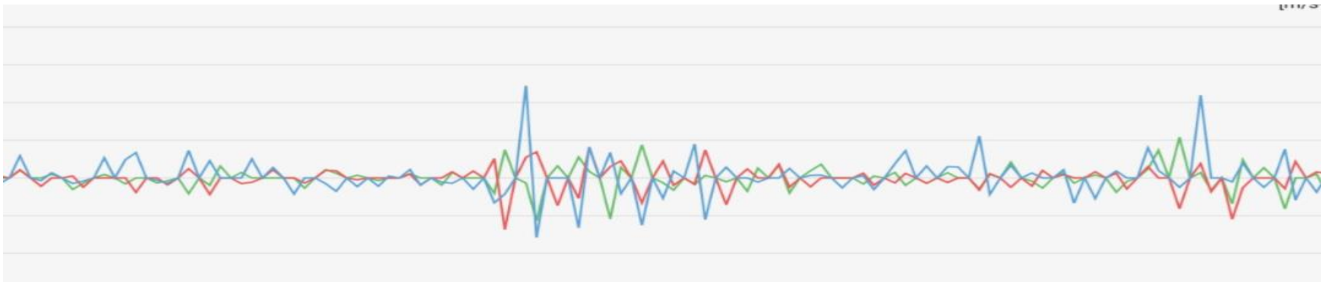
1. Take measurements via mobile phone and perform statistical analysis to evaluate the results.
2. Understand what level of acceleration we believe is addressable with physical actuation, and how is sound(noise) perceived by the driver.

**INITIAL STEP (DATA gathering and analysis)**

First, we start by taking the measurement by Vibration meter app on the play store, through which we took accelerometer data in x, y, and z directions (fig.1) while driving the vehicle through the parking lot measuring events such as Steady State Velocity, Acceleration, Braking, and Bump.

**The nomenclature for the signal is as follows:**

X-axis represents an acceleration in m/s^2 and Y-axis represents the time.
Green, Red & Blue simultaneously represent X, Y & Z-axis data.
Looking at the signal at below(fig2) we can conclude the following from the top:



(*data is susceptible to human error)

The data is noisier than one could have expected even though the accuracy of phone accelerometers is nowhere near the professional types of equipment used by the auto industry while testing & tuning. Mostly Z throughout the data will be vibrating as it is connected to vehicle motion but as per ISO 2631, any vertical acceleration less than 0.8 does not create any discomfort.

**Scenario 1:**

(*The data for the time-stamp during acceleration 1m/s$^2$)

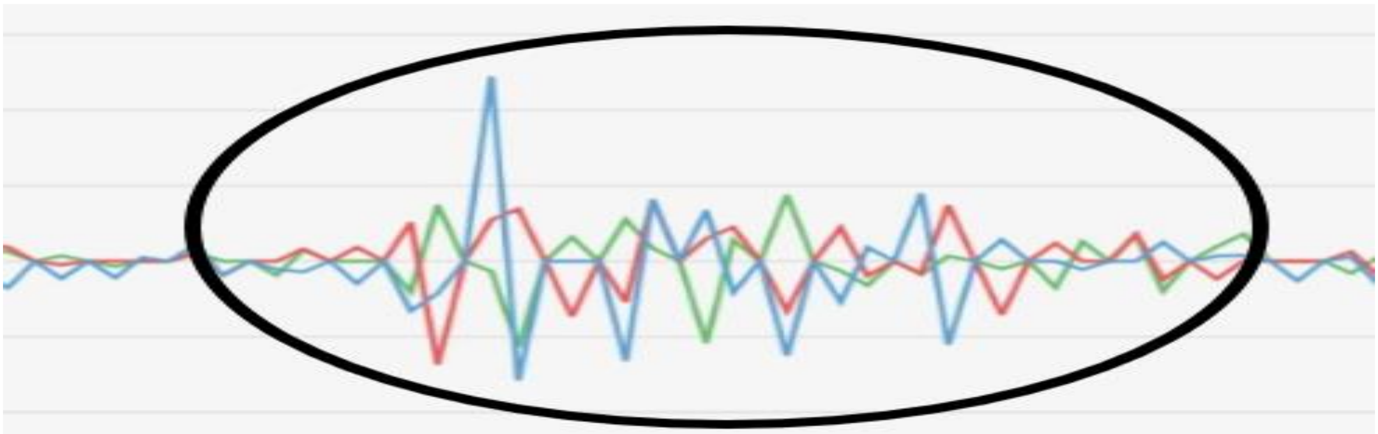
Here it can be seen that signal for some unknown reason goes in acceleration, which may be due to measurement error or due to the sudden jerk one feels while accelerating. Max acceleration can be calculated by seeing the peak value for a given direction.

**Scenario 2:**

(*data for the time-stamp during de-acceleration 2m/s$^2$)

Here it can be seen that signal is better to compare to acceleration in terms of noise, which can correlate to human factors as well as perceiving that braking is easier to achieve than acceleration in each time. Max de-acceleration can be calculated by seeing the peak value for a given direction.

**Scenario3:**



(*data for the time-stamp while encountering bump 3m/s$^2$)

Here can be clearly seen the excitation in Z-axis while going over the bump. Moreover, the main thing to notice is that it excites in both directions i.e. positive and negative. Also, the magnitude of the peak for the Z axis slowly dies down which signifies the damping out of vertical excitation. Trying to correlate with the physical feeling the overall value of the Z axis in both directions can be called a jerk felt by the passenger.

**FINAL STEP (Conclusion)**

- Physical actuators in suspension making active or semi-active suspension, mainly only incorporate when encountering large adulation (>0.3m/s^2 approx.) i.e., which leads to only improving the ride when encountering a measurable bumpy road and not the micro-vibration which created while in motion. This is not possible as this micro-vibration leading and noise which lies well above 100Hz are much high than the capacity through which the physical actuator can act to mitigate by eliminating them. Also, when dealing with high-frequency changes of resonance while elimination is more than often possible leading to even worse ride and comfort.
- Noise perceived by drivers is a completely different phenomenon when compared to the comfort of drivers, as comfort is measured at the physical level while noise is perceived at the hearing level. Comfort lies below 100 or mostly below 50Hz while noise lies well above 400Hz. Due to this an active suspension has much less influence on the noise characteristic of the driver than compared to the comfort part.