EXPERIMENTAL CALIBRATION OF RACING CAR

P.S. KRASIN[1], N.A. VOLCHENKO[2]

[1]Oxford Brookes University,
Headington Campus Gipsy Lane, Oxford OX3 0BP UK,
e-mail: peter.krasin@mail.ru
[2] Kuban State Technological University,
2, Moskovskaya st., Krasnodar, Russian Federation, 350072

Racing car advances a large amount of different loads. Since roll is a "movement" quantity, the primary effects are movements in the vehicle as well. Secondary effects are force based. Considering the primary effect, the wheel angles are the most important for handling, particularly camber. Generally speaking roll moves the wheels away from the initial position in a corner in terms of camber. Therefore yaw sensor is a good definition of the displacement of the big number of suspension parts. One of the better ways to calibrate such a sensor is to use a known time instead of the number of turns, since the time is one of the basic units as mass or a length, which can be unchangeable compare to the turn distance as it can be different every time as the stopwatch stops. Since the acceleration sensor is a linear it has an accurate results and it has fast response. However this sensor has a disadvantage of the use of one and only axis. Therefore there would be need in 3 sensors.
Keywords: sensors, calibration, acceleration sensor, data acquisition systems

Racing car advances a large amount of different loads. Since roll is a "movement" quantity, the primary effects are movements in the vehicle as well. Secondary effects are force based.

Considering the primary effect, the wheel angles are the most important for handling, particularly camber. Generally speaking roll moves the wheels away from the initial position in a corner in terms of camber. This will have an effect on the overall grip capability of the vehicle and possibly the balance too. The obvious solution here is to reduce roll to nothing. While this will improve your wheel angles, it will greatly increase the warp stiffness if not the overall stiffness of the suspension to the levels of that found in a go-kart which is no good for grip on anything but a completely flat road. In fact it will defeat the purpose of having a suspension in the first place. Therefore yaw sensor is a good definition of the displacement of the big number of suspension parts.

For the experiment: тhe wires (red - +supply, black - -supply) must be connected to positive 12V and negative input of power supply, for motor; тhe wires (red - +supply, black - -supply) must be attached to positive 12V and negative input of power supply, for sensor; sensor yaw-rate cable (Pink) must be attached to the Voltmeter input; ground cable (black - -supply) of power supply must be connected to voltmeter input; the control switch has three positions: motor is off (middle), motor goes clockwise (one side) and anticlockwise (another side).

Set the power supply voltage to about 2 Volts and check everything works correctly and motor can go clock wise and anticlockwise. At zero rate of turn, the voltmeter should read about 2.5 Volts. Set the power supply to 0.5 Volts. Use the stopwatch to time 5 turns clockwise, at the same time the sensor voltage measurements are taken. Repeat above steps for anticlockwise measurements

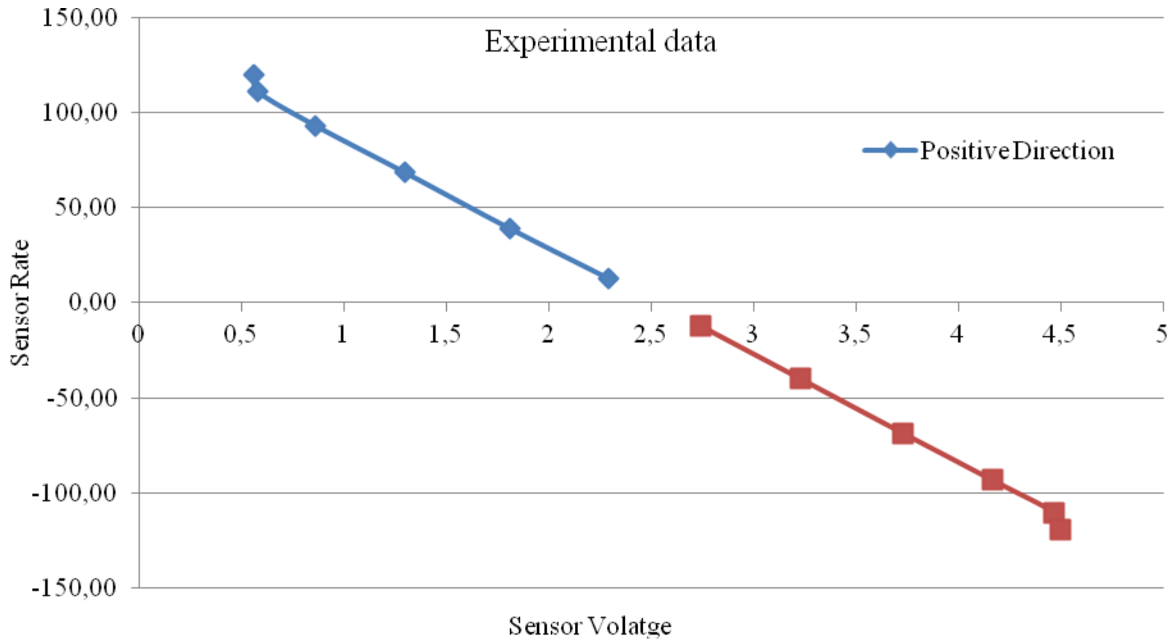
Measurements are conducted at 0.5, 1.0, 1.5, 2.0, 2.3, 2.5 volts in each direction

Data is compiled in the Table 1 Graph is plotted using the data

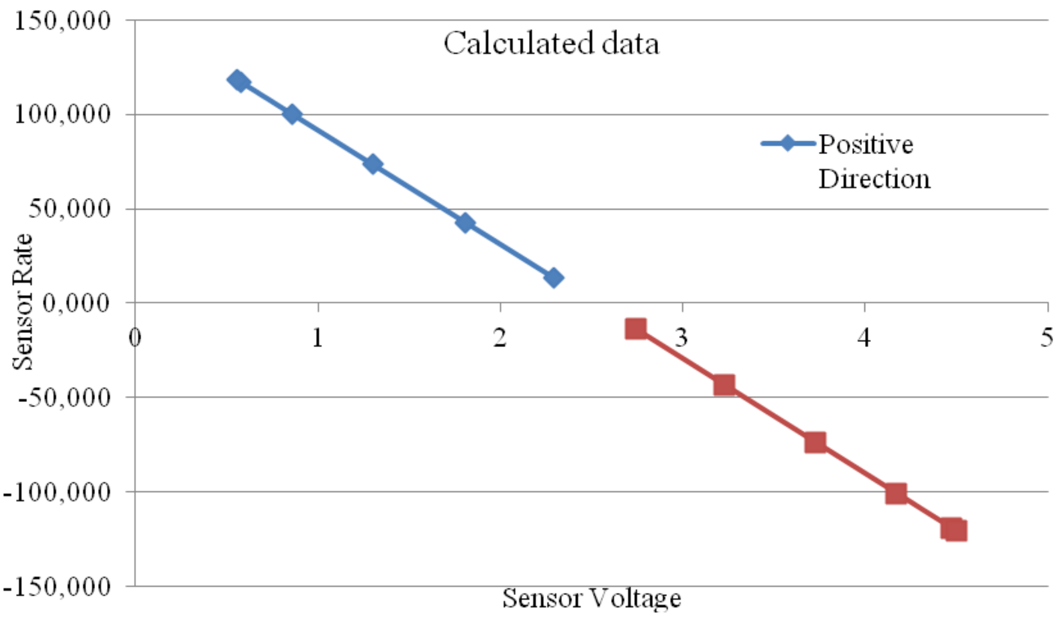
Table 1

Supply Voltage / Volts	Number of turns	Time / Second	Rate of turn / degrees per second	Sensor voltage / Volts	Calculated Rate of turn	Linearity Error / f.s.d	Error in Rate	Polynomal 5th order equation
0,5	5	138,9	12,96	2,29	13,356	0,331	0,397	7,029
-0,5	5	151,7	-11,87	2,74	-13,963	-1,748	-2,098	-5,6
1,0	5	46,0	39,13	1,81	42,497	2,806	3,367	36,275
-1,0	5	45,2	-39,82	3,23	-43,712	-3,241	-3,889	-29,9
1,5	5	26,3	68,44	1,30	73,460	4,182	5,019	67,3854
-1,5	5	26,3	-68,44	3,73	-74,067	-4,688	-5,626	-53,6
2,0	5	19,3	93,26	0,86	100,173	5,757	6,908	92,93
-2,0	5	19,3	-93,26	4,17	-100,780	-6,263	-7,515	-73,3
2,3	5	16,2	111,11	0,58	117,172	5,050	6,060	110,98
-2,3	5	16,3	-110,43	4,47	-118,993	-7,136	-8,563	-86,4
2,5	5	15,0	120	0,56	118,386	-1,345	-1,614	119,88
-2,5	5	15,1	-119,21	4,50	-120,814	-1,341	-1,609	-94,7

The graphs and trend line equations



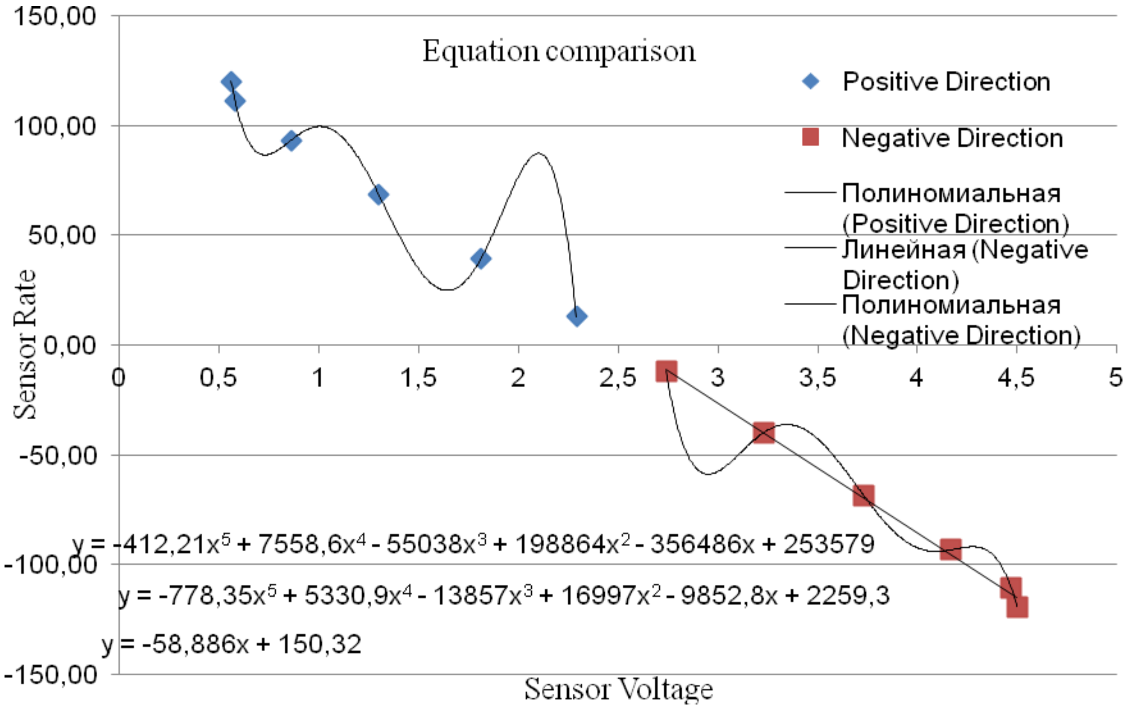
Graph 1



Graph2

Table 2

Output Voltage Range	0,56 to 4,50
Rate of Turn Range	-119,2 to 120
Sensitivity	-0,01647
Zero Offset	2,51
Max Linearity	8,60%



Graph 3

Sensitivity is a Voltage output per change in Measurand

Sensitivity = ΔV / ΔR,

ΔV – Finite difference of sensor voltage

ΔR – Finite difference of the rate of sensor turn

Yaw-rate sensor sensitivity = (4.50-0.56) / (-119.2-120) = 1.73/-107.04 = -0.01647 Volts/Degrees per sec.

Zero Offset is a Voltage output at zero Measurand

Zero Offset = 2,51 Volts

Measurand = (Voltage – Zero Offset) / Sensitivity

Magnitude of linearity errors is a percentage of full – scale – deflection

Linearity error = (Error in rate / Max Value of the Scale)*100

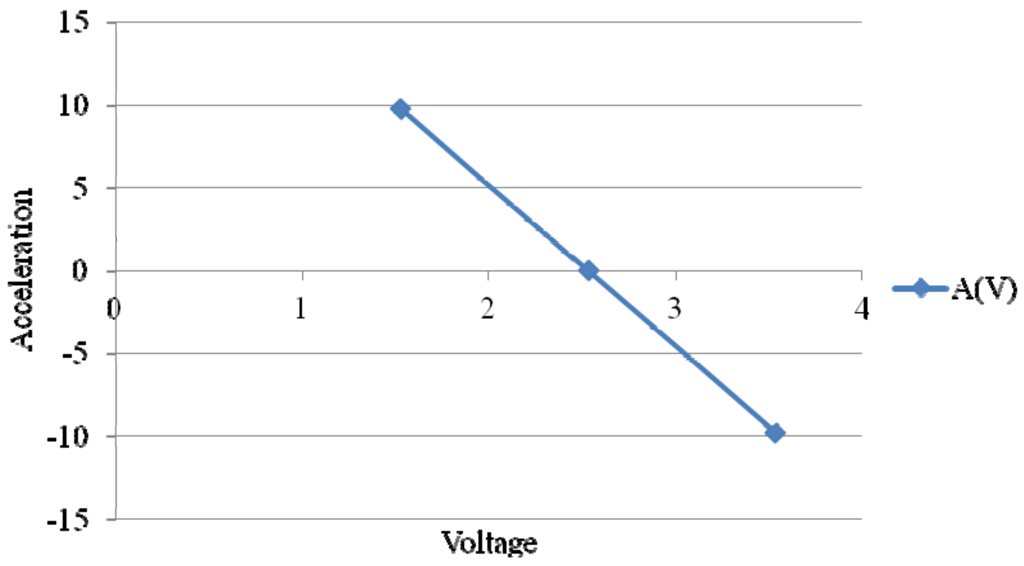
Remove Bosch Duo Sensor from the motor/ Connect the red wire to +12V power supply, connect the black wire to the negative, join negative of power supply with a negative of Voltmeter, sensor acceleration wire (white) must be connected to the Voltmeter, check the Voltage change by tilting the sensor, at the flat position

Voltage output should be around 2.5. Sensor should be place in three different orientations (-9.8 m/s^2, 0, 9.8 m/s^2) for the experiment

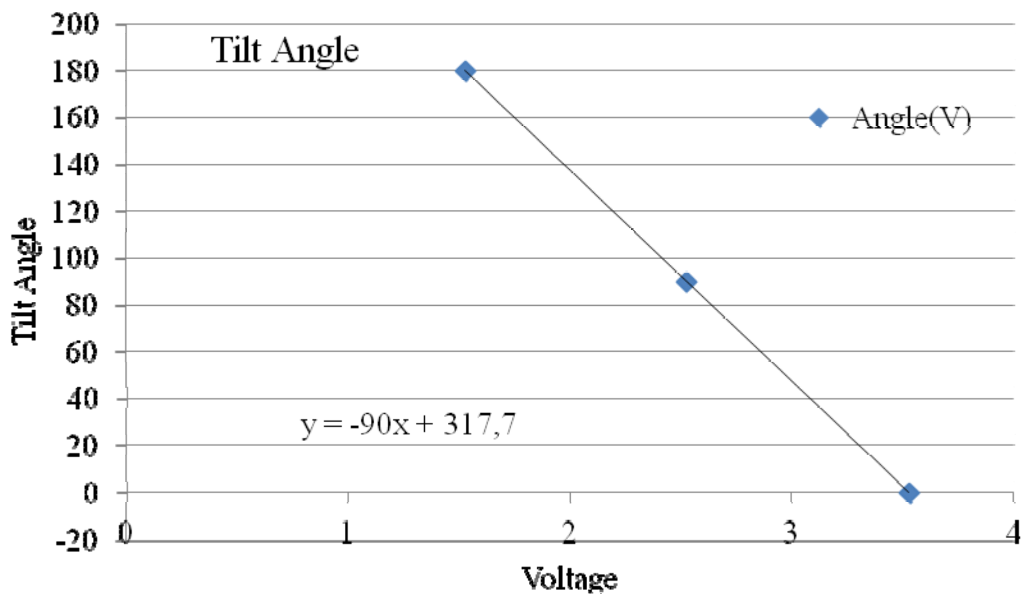
Table 3

Acceleration / m/sec^2	Voltage / Volts	Angle / Degrees
-9,8	3,53	0
0	2,53	90
9,8	1,53	180

The graphs and trend line equations (graph 4 and 5)



Graph 4



Graph 5

Table 4

Output Voltage Range	1,53 to 3,53
Acceleration	-9,8 to 9,8
Sensitivity	-0,102
Zero Offset	2,53

Acceleration sensor sensitivity = ΔV / ΔA

Sensitivity = (1.53 – 3.53) / (9.8 – (-9.8)) = -2 / 19.6 = -0.1

Zero Offset = 2.53

Acceleration = (Voltage – Zero Offset) / Sensitivity

Acceleration sensor is linear and acceleration will change respectively to Voltage. Accuracy is defined in terms of systematic and random errors. The measurement system is considered valued if it is accurate and précised. Therefor the system is not précised since we have had sensor Voltage measured only once for every 5 turns in the negative and positive direction at the same motor power. Accuracy can be defined by the errors in the Table 1. Although the errors are of the actual experiment data and calculated me asurand, it is more likely that they would be lesser in terms of larger number of experimental attempts. Graphs 1 and 2 shows that the sensor is not fully linear. Further on comparing of them indicates that deviations are small. However to reach the conclusion, maximum linearity error was defined as 8.6 %, therefor the accuracy is low.

There are different sources of the errors as calibration is made. Despite of the error source in the motor response, especially at the low Voltage, there is imperfect method of observation. Taking a reading of the time is not the same every time and can vary, however the difference at starting time position is not accidentally large. Furthermore there is a partial difference in starting and ending position of the sensor turn which affects time as well. There are more sources such as stopwatch response that affects time. Compare the time in the Table 1 for the 0.5 Volts supply of the motor, it shows the huge difference in time for clockwise direction and anticlockwise. Therefor the motor influence on the errors presents. Although there are factors which are to influence errors, there are errors which may be present as a result of the estimate based on the mathematical model. Graph 3 shows that polynomial trend line of the 5^{th} period suits better than linear, furthermore it has a more accurate equation for presented output Voltage. However there are deviations which are not suitable for this kind of graph. Therefore a bigger range of the data should be introduced to minimize the errors.

Overall to get a better accuracy and a minimum magnitude of errors there should be a lesser human factor. One of the better ways to calibrate such a sensor is to use a known time instead of the number of turns, since the time is one of the basic units as mass or a length, which can be unchangeable compare to the turn distance as it can be different every time as the stopwatch stops.

Since the acceleration sensor is a linear, there is a place to the Tilt angle to Voltage equation to be expressed. As well as for the acceleration of the sensor angle will change linear to Voltage. Therefor as to define sensor orientation as 0, 90 and 180 degrees, the graph can be plotted and equation produced from a linear trend line. However it can be accomplished for the one axis Tilt sensor as introduced in the experiment. Graph 3 shows the comparison of the Angle and Voltage and a following equation of established data is created:

$y = -90x + 317.7$

y – Tilt angle

x – Voltage

However there are some concerns, since the Zero Offset is not at 0 Degrees. Therefor as to set angles -90, 0, 90 there will be a similar function but negative angle is something odd. Furthermore angles can be change to 270, 0, 90 as if to try to set them in 360 degrees, but since the sensor operates in 180 degrees there will be no point of placing such degrees.

Overall there are several ways to measure the angle and as for me function above fits better of all discussed.

Since the acceleration sensor is a linear it has an accurate results and it has fast response. However this sensor has a disadvantage of the use of one and only axis.

Therefore there would be need in 3 sensors. Despite this it is much more important in some areas (as an example phone) to have a fast response.

Although linearity is important there are can be created different types of graphs and equations like polynomial in the various choice of programs such as Excel. However there are a lot of times when such program cannot find a perfect solution to the graph. Furthermore it can create a trend line with a huge deviations which is not acceptable in most of experiments.

ЭКСПЕРИМЕНТАЛЬНАЯ КАЛИБРОВКА ДАТЧИКОВ ГОНОЧНОГО АВТОМОБИЛЯ

П.С. КРАСИН, Н.А. ВОЛЬЧЕНКО

Кубанский государственный технологический университет,
350072,Российская Федерация, г. Краснодар, ул. Московская, 2;
электронная почта: peter.krasin@mail.ru

Гоночный автомобиль испытывает большое количество различных нагрузок при движении. Основной движущей силой является крутящий момент, при этом колеса автомобиля работают на изгиб. Для контроля смещения большого числа деталей подвески используется датчик развала-схождения. Один из лучших способов калибровать такой датчик состоит в том, чтобы использовать известное время вместо числа поворотов, так как время - одна из основных единиц как масса или длина, которая может быть неизменной. В работе приведены данные об экспериментальной калибровке датчика. Установлено, что этот датчик является линейным, быстрореагирующим и имеет высокую степень отклика. Определено, что для точных измерений необходима установка трех таких датчиков на автомобиль.

Ключевые слова: датчики, калибровка, датчик ускорения, система сбора данных