Lane Change Simulation with Vehicle Driver Model using ADAMS

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ABSTRACT

In vehicle dynamic analysis, there are two ways of simulation to investigate the vehicle handling performance. One is the open loop control with fixed steering input such as step steer, the other is the closed loop control with driver for which the driver model is necessary to control the steering wheel angle. In this paper the driver is modelled as a preview controller. For efficiency the bicycle model with driver is first used to determine the proper control gains for lane change maneuver and these gains are applied to the full vehicle model. The simulation results show the driver model achieves successful tasks.

INTRODUCTION

For the vehicle design verification, the dynamic simulation with comprehensive vehicle model based on the multi-body dynamic analysis has become useful to investigate the vehicle handling performance before building the prototype car. The vehicle has two aspects in its dynamic property. These aspects depend on how the system boundary is defined. In the simulation for the vehicle only system, the designer examines the vehicle dynamic response, while for the vehicle-driver system the designer examines the driver's response as well as the vehicle response. In general the designer considers the vehicle-driver system, since all the cars are basically driven by the human driver. When one simulates the dynamics of the vehicle-driver system by the closed loop control, one needs to define the road path which the driver wants to follow and the driver as a controller in the vehicle model. Although there has been a numer of papers about this subject with mathmatical expressions, this papar intends to describe the vehicle-driver model by ADAMS[1] and to show the lane change simulation using this model.

VEHICLE-DRIVER MODEL

Fig.1 shows the vehicle-driver system diagram, where Y(t) is the desired road path, y(t) is the vehicle position at simulation time t, e(t) is the error between Y(t) and y(t), and δsw is the correction of steering wheel angle by the driver in order to reduce the error.

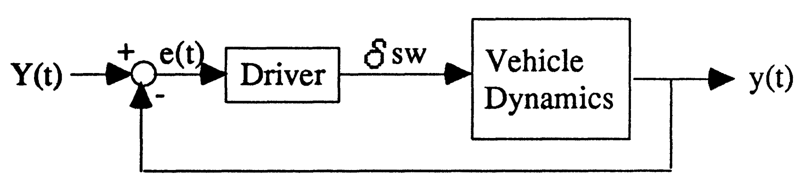

Fig.1 Vehicle-Driver System

The well known 2-d.o.f linear bicycle model is used to efficiently determine the proper control gains of driver's steering control. Fig.2 shows the bicycle model with driver. The ADAMS data set for this model is listed in the appendix. ADAMS bicycle model consists of 5 parts; vehicle body, front wheel, rear wheel, steering wheel, and dummy part. The dummy part is used for driver modelling and application of control force to steering wheel motion. Note that the MOTION in ADAMS is a function of time only. So we can't directly describe the driver's control action to steering wheel motion by a function of error in Fig.1. To solve this, we first express a control force on dummy part by a function of error and then couple the movement of dummy part with that of steering wheel.

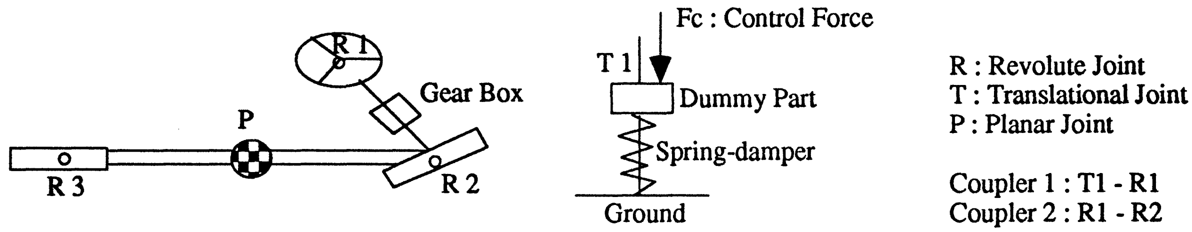

Fig. 2 Vehicle-Driver Model in ADAMS

The driver is regarded as PD(proportional and differential)-controller in the closed loop control system and is shown in Fig.3. The proper control gains, Kp and Kd, are detirmined by trial and error and will be a reference to the full vehicle model. We used STEP functions of forward distance to describe the real road path and the desired road path which is shifted by leading distance from the real road. That is why we model the driver as a preview controller, which well represents normal driving pattern. Fig.4 shows the road path from ISO/TR 3888[2].

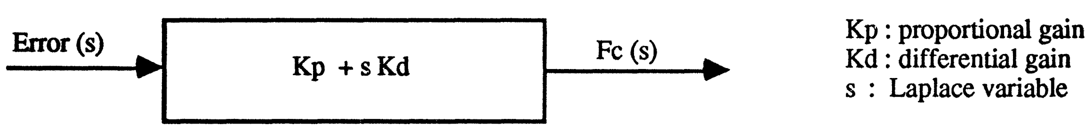

Fig. 3 Driver Model as PD-controller

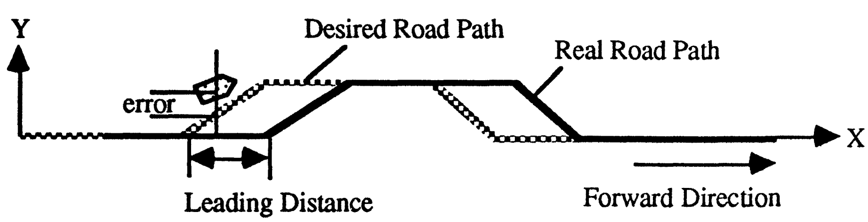

Fig. 4 Road Path for Lane Change Simulation

SIMULATION and RESULTS

For the simulation with the bicycle model, the vehicle parameters of bicycle model are originated from full vehicle model. It has been known that the values of the control gains of driver depend on the vehicle speed and the leading distance[3]. In this simulation the vehicle speed is 100 kph and the leading distance is 15 m. After the simulation with several combinations of Kp and Kd, we recognized that Kd is dominant in the control system performance. It is found that the best combination is when Kp = -1 and Kd = 8.

For the simulation with the full vehicle model, an MPV is modelled as in Fig. 5 . The suspension is double wishbone type with torsion bar in front and 5 link rigid axle type with coil spring in rear and the steering system is rack and pinion type. This full vehicle model has 80-d.o.f. We expressed the same driver model of the full vehicle as that of bicycle model. For the control gains in the full vehicle, first we used the same values as those of bicycle model. However the control performance was not acceptable, so these values were adjusted. It is found that the best combination is when Kp = -1 and Kd = 12. The nonlinearites of the suspension geometry and compliance and tire characteristics, and the more degree of freedom in the full vehicle model may cause the difference in the best control gains of the bicycle model and the full vehicle model.

As the simulation results, Fig.6 shows the vehicle trajectory, Fig.7 shows the lateral displacements, Fig. 8 shows steering wheel angle by the driver, Fig.9 shows yawrate responses, and Fig.10 shows lateral acceleration responses. In these figures we can see the driver model achieves good task in severe lane change maneuver.

CONCLUSIONS

- The well known 2 d.o.f vehicle model is built by ADAMS and works well.
- The present driver model is useful for the study of vehicle-driver system.
- The driver model can be enhanced by substituting the DIF statement with control elements in ADAMS

REFERENCES

[1]. ADAMS reference manual (version 6.0), MDI, Nov, 1991
[2]. Road Vehicle - Test procedure for a severe lane change (ISO/TR 3888), ISO, 1975
[3]. Abe, Vehicle Motion and Control, Japan, 1979

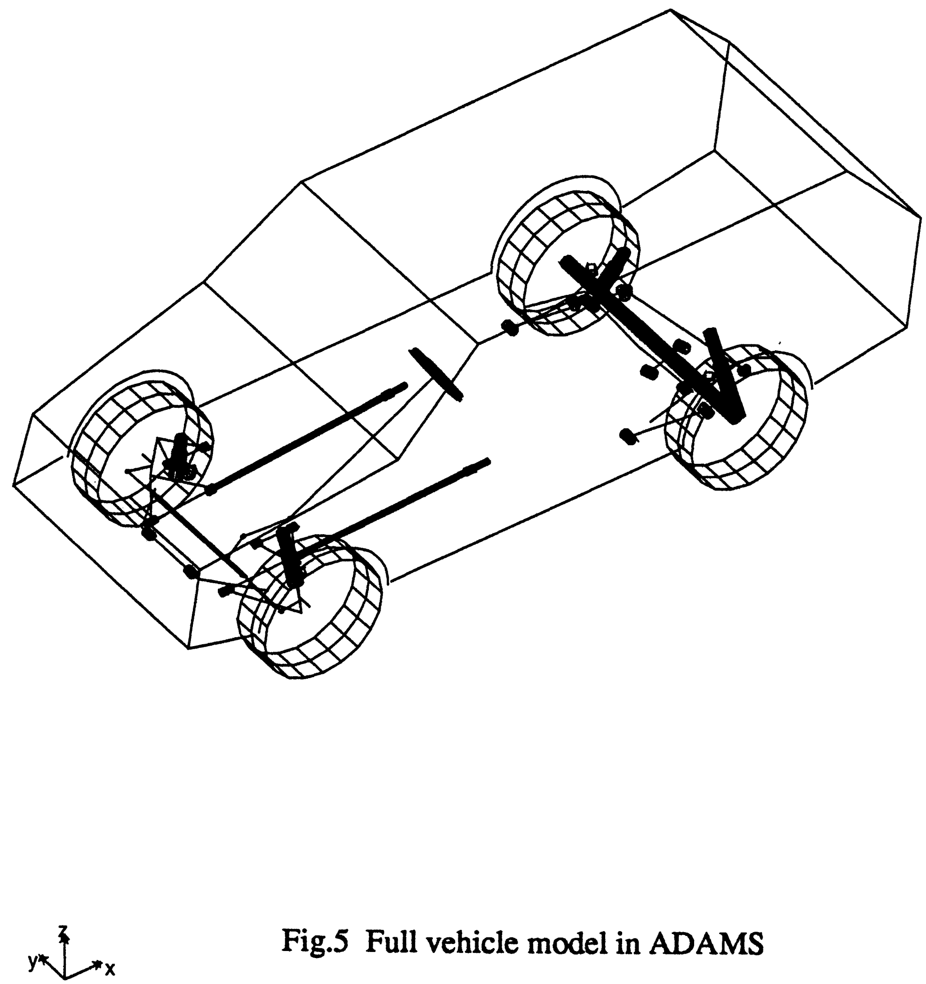

Fig.5 Full vehicle model in ADAMS

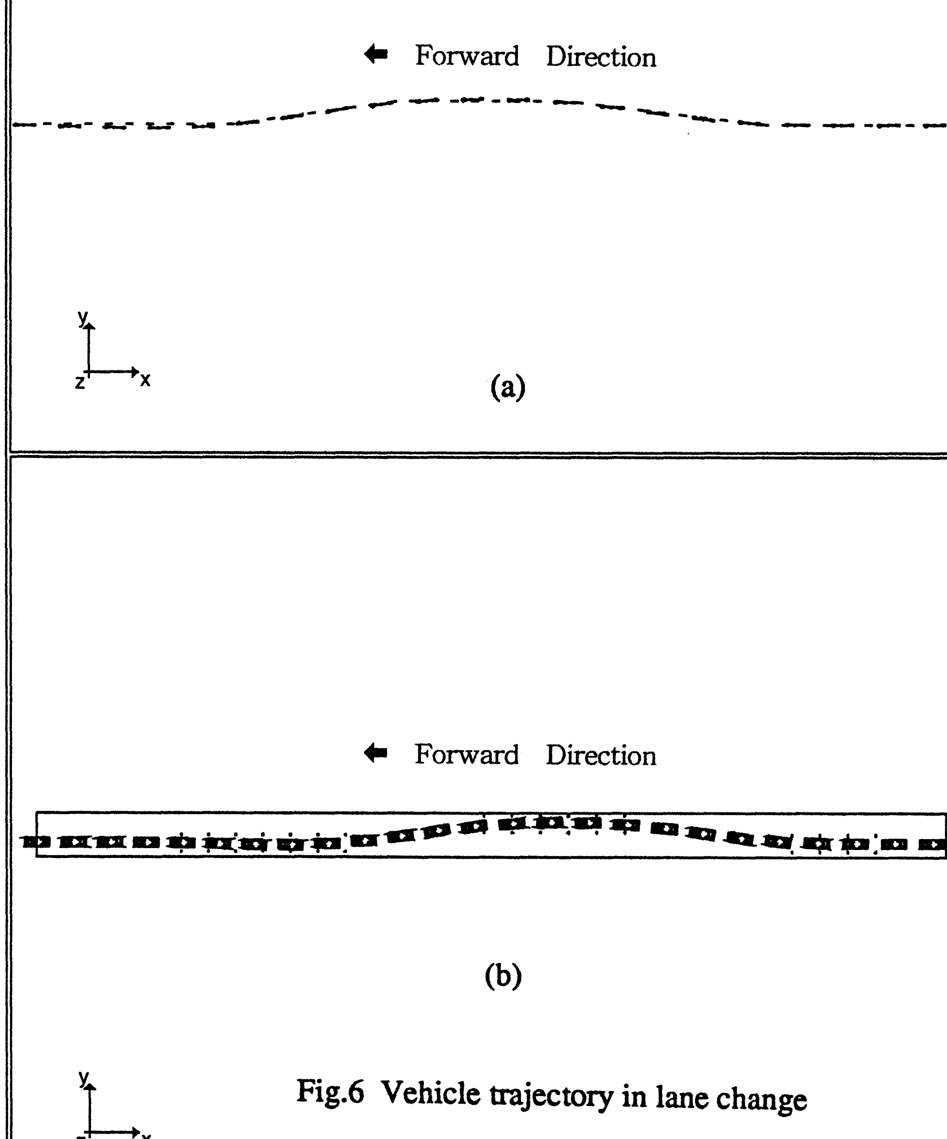

Fig.6 Vehicle trajectory in lane change

(a : bicycle model , b : full vehicle model)

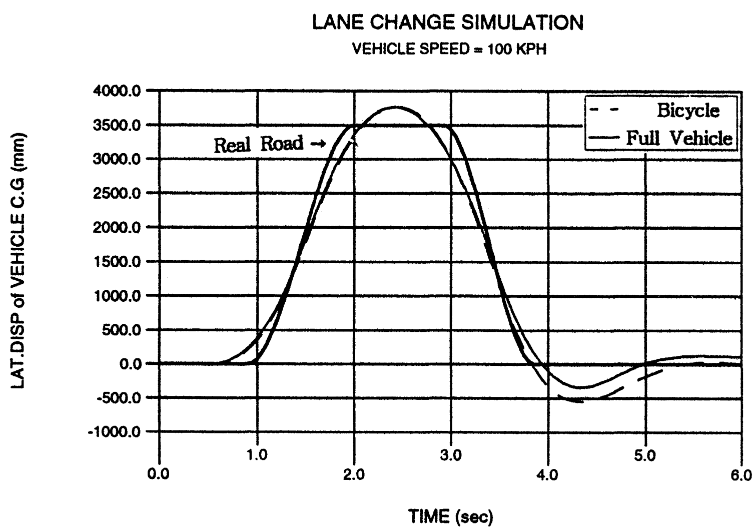

Fig.7 Lateral displacement of vehicle C.G

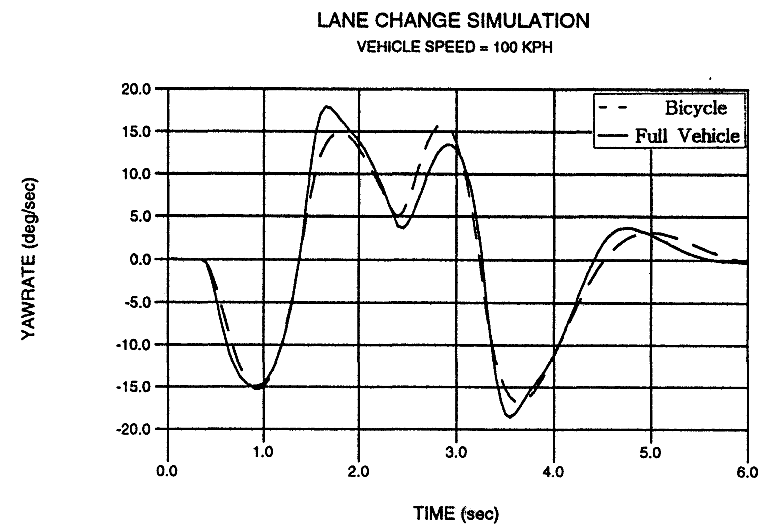

Fig.9 Yawrate responses

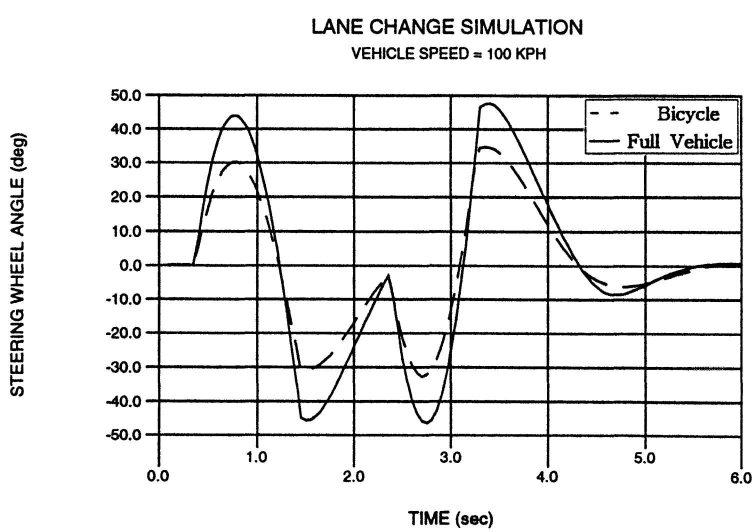

Fig.8 Steering wheel angle by the driver

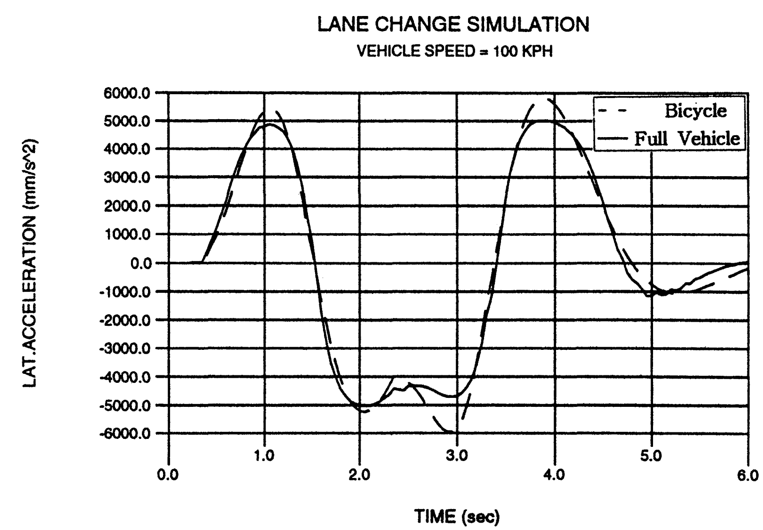

Fig.10 Lateral acceleration responses

APPENDIX

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  BICYCLE MODEL---ADAMS 7.0
! LANE CHANGE SIMULATION

                  <<< parts >>>

pa/99,ground                             ! Ground
ma/990
ma/991,qp=0,1000,0,reu=0,-90d,0
ma/992,reu=0,-90d,0
ma/993,qp=1250,0,0
ma/9901,qp=1250,0,0
ma/9902,qp=-23750,0,0
ma/9903,qp=-53750,3500,0
ma/9904,qp=-78750,3500,0
ma/9905,qp=-103750,0,0
ma/9906,qp=-133750,0,0
gra/991,cyl,cm=993,rad=100,len=100
gra/992,out=9901,9902,9903,9904,9905,9906

pa/10,cm=100,ma=1940,ip=1,1,2558e6       ! Vehicle Body
,vx=-27777.8
ma/100,qp=1250,0,0
ma/101
ma/102,qp=2630,0,0
ma/103
ma/104,reu=0,-90d,0
ma/105,qp=2630,0,0,reu=0,-90d,0
ma/106,qp=2630,0,0,reu=90d,90d,0
gra/100,out=101,102
gra/101,cyl,cm=101,rad=50,leng=20
gra/102,cyl,cm=102,rad=50,leng=20
gra/103,cir,cm=100,rad=100

pa/20,cm=200,ma=1,ip=1,1,1               ! front Wheel
,vx=-27777.8
ma/200,reu=0,-90d,0
ma/201
gra/200,cyl,cm=200,rad=300,leng=100
gra/201,cyl,cm=200,rad=300,leng=-100
gra/202,cyl,cm=201,rad=40,leng=-50

pa/30,cm=300,ma=1,ip=1,1,1               ! rear Wheel
,vx=-27777.8
ma/300,qp=2630,0,0,reu=0,-90d,0
ma/301,qp=2630,0,0
gra/300,cyl,cm=300,rad=300,leng=100
gra/301,cyl,cm=300,rad=300,leng=-100
gra/302,cyl,cm=301,rad=40,leng=-50

pa/40,cm=400,ma=1,ip=1,1,1               ! steering wheel
,vx=-27777.8
ma/400
ma/401
gra/400,cir,cm=400,rad=150
gra/401,cir,cm=401,rad=150,seg=3

pa/50,cm=500,ma=1,ip=1,1,1               ! dummy for driver
ma/500,qp=0,1000,0,reu=0,-90d,0
ma/501,qp=0,1000,0

                  <<< joints >>>

joint/1,rev,i=201,j=101   ! frt wheel steer
joint/2,rev,i=301,j=102   ! rr wheel steer
joint/3,rev,i=401,j=103   ! steering wheel rotation
joint/4,pla,i=100,j=990   ! body planar motion
joint/5,tra,i=500,j=991   ! dummy / ground
coupler/1,jo=1,3,type=r:r,sc=17,-1   ! steering gear ratio (strg whl & frt whl
coupler/2,jo=3,5,type=r:t,sc=1,-1d   ! dummy / strg wheel


                  <<< motion >>>

motion/1,jo=2,rot,fun=0              ! rear wheel steer freezing ...

                  <<< forces >>>

var/1,fun=(vy(101,990,100)/(vx(101,990,100)+1e-3)-az(201,101))  !frt_tire_slip
var/2,fun=(vy(102,990,100)/(vx(102,990,100)+1e-3)-az(301,102))  !rr_tire_slip

sforce/1,tra,i=101,j=200,ac,fun=2.0*varval(1)*53404       ! frt cornering forc
sforce/2,tra,i=102,j=300,ac,fun=2.0*varval(2)*49335       ! rr cornering force
spring/1,tra,i=501,j=992,k=1000,c=1,len=1000    ! dummy /ground


                  <<< road path & driver >>>


! lane change track ( ISO/TR 3888 : 15m-30m-25m-25m-30m )
var/3,ic=0,fun=step(dx(993,100),25e3,0,55e3,1)  ! real road
,*step(dx(993,100),80e3,1,105e3,0)*3.5e3
var/4,ic=0,fun=step(dx(993,100),10e3,0,40e3,1)  ! desired road leaded by 15 m
,*step(dx(993,100),65e3,1,90e3,0)*3.5e3

dif/1,ic=0,im,fun=dif(1)-(varval(4)-dy(100,993))
var/5,ic=0,fun=dif(1)                            ! error for Kp
var/6,ic=0,fun=dif1(1)                           ! diff-error for Kd


sforce/3,tra,i=500,j=992,ac                     ! control force (Kp,Kd)
,fun=-(-1*varval(5)+8*varval(6))
! reference Kp=-1,Kd=8

                  <<< request >>>

req/1,d,i=100,j=990,com=body disp
req/2,v,i=100,j=990,rm=100,com=body velocity
req/3,a,i=100,j=990,rm=100,com=body acc
req/4,d,i=500,j=991,rm=991,com=dummy disp:strg whl ang
req/5,f2=varval(1)\f3=varval(2)\                  ! tire slip angles in rad.
req/6,f2=varval(3)\f3=varval(4)\f4=varval(5)\f6=varval(6) ! road path,error(P,

output/reqsave,grsave,ypr
acc/k=-9806,gc=1000
end
```