Altair

HyperWorks

Altair MotionView 2019 Tutorials

MV-8001: Path and Velocity Following

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In this tutorial, you will learn how to:

- Define a path and velocity or acceleration profile
- Set up a feedforward steering controller to follow a path
- Set up a feedforward traction controller to follow a velocity or acceleration profile

Feedforward Controllers

- In a feed-forward system, the control variable adjustment is not error-based. Instead it is based on knowledge about the process in the form of a mathematical model of the process and knowledge about or measurements of the process disturbances.
- In simpler words, controller that uses the knowledge about the vehicle, to compute the signals
- Assume, a driver who knows that the vehicle weighs 1000 Kg and 30% throttle produces 1000 N of force in forward direction. If asked to produce 1 m/s2 of acceleration would simply give 30% throttle.

Defining a path for the driver

Multiple methods can be used to provide the desired path:

- **Table of centerline points:** Path is provided as a table of equally spaced cartesian coordinates of centerline points. These points are provided in a separate file, DDF or Driver Demand File.

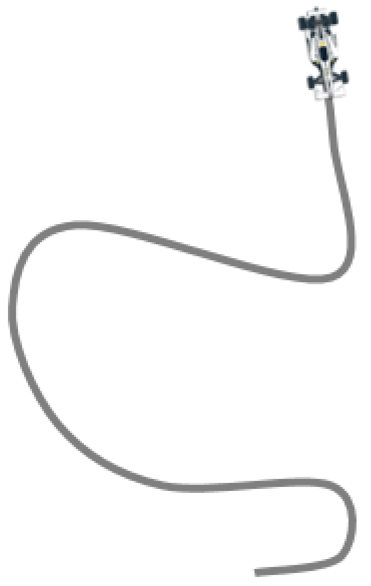
```
$Example DDF

[ALTAIR_HEADER]

FILE_TYPE          = 'DDF'

FILE_VERSION       = 1.0

FILE_FORMAT        = 'ASCII'

$--------------------------------------------------UNITS

[UNITS]

(BASE)

{length  force    angle     mass   time}
```

'm' 'newton' 'degrees' 'kg' 'sec'

$--------------------------------DEMAND_VECTORS

[DEMAND_VECTORS]

{X	Y	Z}
0	0	0
-4	0	0
-1	0	0
-2	0	0
-5	0	0
-3	0	0



- **Sequence of straights and arcs:** Path is provided as a table of straights and circular section.

KEY	PAR0	PAR1
ST	Length of the straight section	Unused
ARC	Radius of curvature	Angle of the arc • Positive angle means anti-clockwise arc • Negative angle means clockwise arc

[PATH]

{KEY PAR0 PAR1}

'ST' 100.0 0

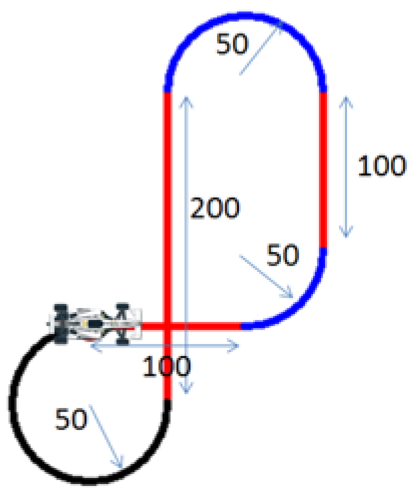
'ARC' 50.0 1.57079

'ST' 100.0 0

'ARC' 50.0 3.14159

'ST' 200.0 0

'ARC' 50.0 -2.35619



- **Predefined path**: Path is one of the predefined paths visualization (Constant Radius, Single lane change, Double lane change, and Slalom).

  $Example block for constant radius path

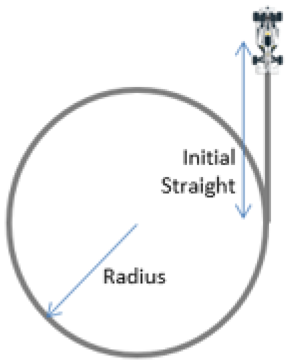
  [PATH]

  TYPE = 'CONSTANT_RADIUS'

  RADIUS = 30

  INITIAL_STRAIGHT = 45

  TURN = 'LEFT'



Defining a velocity or acceleration profile for the driver

- Demand velocity or acceleration profile is similar to open loop signal explained in tutorial 1. All methods – constant, expression and curve are valid for demand signal definition as well.

Exercise

Step 1: Assembling the vehicle.

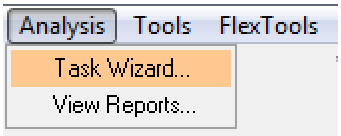
1. Follow the instructions in Step #1 of MV-8000 to create the vehicle with the topology as provided below.

Page	Label	Selection	Default (Yes/No)
1	Model type	Full vehicle with advanced driver	No
2	Driveline configuration	Front wheel drive	Yes

Page	Label	Selection	Default (Yes/No)
3	Vehicle body	Body	Yes
3	Front suspension	Frnt macpherson susp (1 pc. LCA)	Yes
3	Steering linkages	Rackpin steering	Yes
3	Rear subframe	None	Yes
3	Rear suspension	Rear quadlink susp	Yes
3	Powertrain	Linear torque map powertrain	Yes
3	Signal generator	Driver signal generator	Yes
3	Tires	FIALA/HTIRE	Yes
4	Steering column	Steering column 1 (not for abaqus)	Yes
4	Steering boost	None	Yes
5	Front struts	Frnt strut (with inline jts)	Yes
5	Front stabilizer bars	None	Yes
5	Rear struts	Rear strut (with inline jts)	Yes
5	Rear stabilizer bars	None	Yes
6	Front jounce bumpers	None	Yes
6	Front rebound bumpers	None	Yes
6	Rear jounce bumpers	None	Yes
6	Rear rebound bumpers	None	Yes
7	Disk brakes	Disk brakes	Yes
7	Front driveline	Independent fwd	Yes
8		Next	No
9		Finish	No

Step 2: Adding driver analysis.

1. Use the Task Wizard to load the driver analysis.



Step 3: Specifying vehicle parameters

1. We are going to use feedforward controllers for path and velocity profile following. Feedforward controllers model the vehicle and therefore, require vehicle parameters. Vehicle parameters need not be precise for controllers to work. Most of the vehicle parameters required by the driver can be automatically calculated from the vehicle model.

Step 4: Writing an Altair Driver File (ADF) driving event.

Example #1 Constant Radius with Constant Velocity Event

1. Open any text editor and copy and paste the following text into it. **Important: All blank lines must be removed prior to saving the file!** Be sure to read through the comments for a better understanding on what is written in the ADF.

$---ALTAIR_HEADER

$ This block is required for version control

[ALTAIR_HEADER]

FILE_TYPE = 'ADF'

FILE_VERSION = 1.0

FILE_FORMAT = 'ASCII'

$--UNITS

$In this block we specify the units in which this file should be read

[UNITS]

(BASE)

{length force angle mass time}

'meter' 'newton' 'radians' 'kg' 'sec'

$--VEHICLE_IC

$In this block we specify the initial conditions specifically initial speed of the

$vehicle with respect to the vehicle IC marker in the driver attachments

[VEHICLE_INITIAL_CONDITIONS]

VX0 = -15.0

VY0 = 0.0

VZ0 = 0.0

$--STEERING_STANDARD

$This block specifies the saturation and cutoff frequency for the low pass filter for

$steering output signal. These signals are global and are active for the entire event

[STEER_STANDARD]

MAX_VALUE = 3.141593

MIN_VALUE = -3.141593

SMOOTHING_FREQUENCY = 10.0

INITIAL_VALUE = 0.0

$--THROTTLE_STANDARD

$This block specifies the saturation and cutoff frequency for the low pass filter for

$throttle output signal

[THROTTLE_STANDARD]

MAX_VALUE = 1.0

MIN_VALUE = 0.00

SMOOTHING_FREQUENCY = 10.0

INITIAL_VALUE = 0.5

$---BRAKING_STANDARD

$This block specifies the saturation and cutoff frequency for the low pass filter for

$brake output signal

[BRAKE_STANDARD]

MAX_VALUE = 1.0

MIN_VALUE = 0.0

SMOOTHING_FREQUENCY = 10.0

INITIAL_VALUE = 0.0

$---MANEUVERS_LIST

$This block provides the list of all the maneuvers, simulation time for each maneuver

$maximum solver step size (hmax) and print interval

[MANEUVERS_LIST]

{ name simulation_time h_max print_interval}

'MANEUVER_1' 15.0 0.005 0.01

$---MANEUVER_1

[MANEUVER_1]

$This block provides the ties controllers to each driver output

TASK = 'STANDARD'

(CONTROLLERS)

{DRIVER_SIGNAL PRIMARY_CONTROLLER ADDITIONAL_CONTROLLER}

STEER FEEDFORWARD_STEER NONE

THROTTLE FEEDFORWARD_TRACTION NONE

BRAKE FEEDFORWARD_TRACTION NONE

$---STEER

$This is controller block containing all the information required by

$the driver to construct the controller. Different controllers have

$different requirements. Here we are using feedforward steering

$controller.

[FEEDFORWARD_STEER]

TAG = 'FEEDFORWARD'

LOOK_AHEAD_TIME = 0.5

PATH = 'PREDEFINED'

BLOCK = 'PATH'

$---PATH

$Block containing the information about the path to be followed

[PATH]

TYPE = 'CONSTANT_RADIUS'

RADIUS = 40

INITIAL_STRAIGHT = 20

TURN = 'LEFT'

$---THROTTLE & BRAKE

[FEEDFORWARD_TRACTION]

TAG = 'FEEDFORWARD'
TYPE = 'FOLLOW_VELOCITY'
LOOK_AHEAD_TIME = 0.5
DEMAND_SIGNAL = 'DEMAND_SPEED'
$---DEMAND_SPEED

$Block containing all the information about the velocity profile to be followed

[DEMAND_SPEED]

TYPE = 'CONSTANT'

VALUE = 15.0

2. ***Save*** the ADF.
3. ***Run*** the simulation .
4. Observe the results.
5. Next let's try the same path using another method - Sequence of straight and arcs.
6. Change the ***PATH*** attribute in the **FEEDFORWARD_STEER** block in the ADF to ***SEQUENCE_OF_ST_CRV***.

[FEEDFORWARD_STEER]

TAG = 'FEEDFORWARD'

LOOK_AHEAD_TIME = 0.5

PATH = '~~PREDEFINED~~ SEQUENCE_OF_ST_CRV '

BLOCK = 'PATH'

7. Replace the path block in the ADF with the following text.

[PATH]
{KEY PAR0 PAR1}
'ST' 20 0
'ARC' 40 6.28318

8. Rerun the simulation. This is simply a change in the method of providing the same path and therefore, should make any difference in the results.

Example #2 Straight Line Acceleration Event

In this example we will create an event to follow a straight line while accelerating the vehicle constantly with 2 m/s2.

1. Open any text editor and copy/paste the following text into it. **Important: All blank lines must be removed prior to saving the file!**

```
$---------------------------------------------------------------ALTAIR_HEADER

[ALTAIR_HEADER]

FILE_TYPE = 'ADF'

FILE_VERSION = 1.0

FILE_FORMAT = 'ASCII'

$-----------------------------------------------------------------------UNITS

[UNITS]

(BASE)

{length force angle mass time}

'meter' 'newton' 'radians' 'kg' 'sec'

$------------------------------------------------------------------VEHICLE_IC

[VEHICLE_INITIAL_CONDITIONS]

VX0 = -20.0

VY0 = 0.0

VZ0 = 0.0

$-----------------------------------------------------------STEERING_STANDARD

[STEER_STANDARD]

MAX_VALUE = 3.141593

MIN_VALUE = -3.141593

SMOOTHING_FREQUENCY = 10.0

INITIAL_VALUE = 0.0

$-----------------------------------------------------------THROTTLE_STANDARD

[THROTTLE_STANDARD]

MAX_VALUE = 1.0

MIN_VALUE = 0.00

SMOOTHING_FREQUENCY = 10.0
```

```
INITIAL_VALUE                 = 0.2
$------------------------------------------------------------BRAKING_STANDARD
 [BRAKE_STANDARD]
MAX_VALUE                     = 1.0
MIN_VALUE                     = 0.0
SMOOTHING_FREQUENCY           = 10.0
INITIAL_VALUE                 = 0.0
$--------------------------------------------------------------MANEUVERS_LIST
[MANEUVERS_LIST]
{ name               simulation_time  h_max  print_interval}
'MANEUVER_1'         10.0             0.01   0.01
$------------------------------------------------------------------MANEUVER_1
[MANEUVER_1]
$This block provides the ties controllers to each driver output
TASK = 'STANDARD'
(CONTROLLERS)
{DRIVER_SIGNAL       PRIMARY_CONTROLLER     ADDITIONAL_CONTROLLER}
 STEER               FEEDFORWARD_STEER                 NONE
 THROTTLE            FEEDFORWARD_TRACTION              NONE
 BRAKE               FEEDFORWARD_TRACTION              NONE
$-------------------------------------------------------STEER
$This is controller block containing all the information required by
$the driver to construct the controller. Different controllers have
$different requirements. Here we are using feedforward steering
$controller.
[FEEDFORWARD_STEER]
TAG                  = 'FEEDFORWARD'
LOOK_AHEAD_TIME      = 0.5
PATH                 = 'PREDEFINED'
```

```
BLOCK           = 'PATH'

$-----------------------------------------------------PATH

$Block containing the information about the path to be followed

[PATH]

TYPE                  = 'CONSTANT_RADIUS'

RADIUS          = 40

INITIAL_STRAIGHT      = 20

TURN                  = 'LEFT'

$-----------------------------------------------THROTTLE & BRAKE

[FEEDFORWARD_TRACTION]

TAG                   = 'FEEDFORWARD'
TYPE                  = 'FOLLOW_VELOCITY FOLLOW_ACCELERATION'
LOOK_AHEAD_TIME       = 0.5
DEMAND_SIGNAL         = 'DEMAND_SPEEDDEMAND_ACC'
$-----------------------------------------------------DEMAND_ACC

$Block containing all the information about the acceleration profile to be followed

[DEMAND_SPEED]

TYPE                  = 'CONSTANT'

VALUE                 = 2.0
```

2. Run the simulation and study the results.

Example #3 Path as a Table of Cartesian Coordinates of Centerline Points Event

In this example we'll give path as a table of Cartesian coordinated of centerline points. We'll define the velocity profile as well along the path.

1. Open text editor and copy/paste the following text into it. **Important: All blank lines must be removed prior to saving the file!**

```
$---------------------------------------------------------------ALTAIR_HEADER
[ALTAIR_HEADER]
FILE_TYPE                = 'ADF'
FILE_VERSION    = 1.0
FILE_FORMAT     = 'ASCII'
$------------------------------------------------------------------------UNITS
[UNITS]
(BASE)
{length  force           angle      mass   time}
'meter'   'newton'        'radians'  'kg'     'sec'
$------------------------------------------------------------------VEHICLE_IC
[VEHICLE_INITIAL_CONDITIONS]
VX0 = -20.0
VY0 = 0.0
VZ0 = 0.0
$------------------------------------------------------------STEERING_STANDARD
[STEER_STANDARD]
MAX_VALUE                      = 3.141593
MIN_VALUE                      = -3.141593
SMOOTHING_FREQUENCY            = 10.0
INITIAL_VALUE            = 0.0
$------------------------------------------------------------THROTTLE_STANDARD
[THROTTLE_STANDARD]
MAX_VALUE                      = 1.0
MIN_VALUE                      = 0.00
SMOOTHING_FREQUENCY            = 10.0
INITIAL_VALUE                  = 0.2
$-------------------------------------------------------------BRAKING_STANDARD
 [BRAKE_STANDARD]
MAX_VALUE                      = 1.0
MIN_VALUE                      = 0.0
SMOOTHING_FREQUENCY            = 10.0
INITIAL_VALUE                  = 0.0
$---------------------------------------------------------------MANEUVERS_LIST
[MANEUVERS_LIST]
{ name                 simulation_time  h_max  print_interval}
'MANEUVER_1'           10.0                0.01     0.01
$-------------------------------------------------------------------MANEUVER_1
[MANEUVER_1]
TASK = 'STANDARD'
(CONTROLLERS)
{DRIVER_SIGNAL         PRIMARY_CONTROLLER       ADDITIONAL_CONTROLLER}
 STEER                 FEEDFORWARD_STEER                    NONE
```

```
 THROTTLE            FEEDFORWARD_TRACTION          NONE
 BRAKE               FEEDFORWARD_TRACTION          NONE
$-------------------------------------------------------STEER
 [FEEDFORWARD_STEER]
TAG                  = 'FEEDFORWARD'
LOOK_AHEAD_TIME      = 0.5
$Instruction to the driver that the path is of type DDF
PATH                 = 'DDF'
$Path of the ddf file, data lies in same folder in file named snet.ddf
FILE                 = 'snet.ddf'
$----------------------------------------------THROTTLE & BRAKE
[FEEDFORWARD_TRACTION]
TAG                  = 'FEEDFORWARD'
TYPE                 = 'FOLLOW_VELOCITY'
LOOK_AHEAD_TIME      = 0.5
DEMAND_SIGNAL        = 'DEMAND_SPEED'
$-------------------------------------------------------DEMAND_SPEED
$Block containing all the information about the acceleration profile to be followed
[DEMAND_SPEED]
TYPE                 = 'CURVE'
$Velocity profile information is in the file snet.ddf in the same folder
$Velocity profile is defined under the column name DV in the DDF
${X      Y      Z      DV}
FILE                 = 'snet.ddf'
DEMAND_VECTOR        = 'DV'
```

2. Place `snet.adf` in the same folder as the ADF.

3. Run the simulation and study the results.

4. Alternatively, edit the **DEMAND_SPEED** block to be a curve as a function of distance traveled along the centerline. Replace the **DEMAND_SPEED** block in the ADF with the following text.

```
[DEMAND_SPEED]
TYPE = 'CURVE'
BLOCK = 'DEMAND_CURVE'
$------------------------DEMAND_CURVE
[DEMAND_CURVE]
INDEPENDENT_VARIABLE = 'PATH_S'
DEPENDENT_VARIABLE = SIGNAL
INTERPOLATION = 'LINEAR'
{PATH_S SIGNAL}
0   30
250 35
400 10
584 10
680 25
780 10
942 10
1300    40
1695    10
```

1868	10
1958	10
2040	15
2109	15
2173	15
2300	20
2409	15
2524	15
2647	10
2811	10
3500	50