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Authors
Hongola, Bruce
Chan, Ching-Yao

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Bruce Hongola
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Simulation and Animation Tools for Analysis of Vehicle Collisions: SMAC (Simulation Model of Automobile Collisions) and Carmma (Simulation Animations)

Bruce Hongola
Ching-Yao Chan

California PATH
Institute of Transportation Studies
University of California, Berkeley

ABSTRACT

This document describes part of the work conducted under MOU324, related to the studies of vehicle collisions in vehicle-following operations. The goal of the study is to conduct vehicle dynamics and control analysis and to explore display methods so that analytical results can be visualized.

This working paper is a description of the functional capabilities of a series of computer programs that can be used to investigate the consequences of vehicle collisions. The core element of the simulation tools for vehicle collision dynamics is SMAC (Simulation Model of Automobile Collisions) program. It has been used extensively in recent work at PATH to investigate the consequences of vehicle collisions and the effects of vehicle-following parameters on collisions. Another main tool is Carmma, which possesses animation capability for simulations. It has been used at PATH to create highway scenarios and to generate and/or animate vehicle simulations.

In this project it was deemed desirable to have an interface between the simulation and animation programs so that users can observe the vehicle movement profiles before and after a collision given the input scenarios for vehicle operations. Program functions and the interfaces between programs are outlined. Some simulation run cases are shown for various SMAC options implementing user-specified feedback controllers. The visual images captured during the case studies are also illustrated in this report. This document constitutes a simple yet thorough manual for the research tools developed for the subject matter.
EXECUTIVE SUMMARY

This report contains part of the work conducted under MOU324 during the fiscal year of 1998-1999. The research project centers around the analysis of vehicle-following collisions, which includes
(1) the investigation of vehicle dynamics under various collision scenarios,
(2) the feasibility of utilizing steering control to maintain vehicle trajectories under collision situations, and
(3) the portability of computer source codes to UNIX platform and the image display to enhance the visualization of simulation results.

This documentation describes the accomplishments of part (3).

In this report, the descriptions of two main computer programs are given to help understand the capabilities and the parameters in the analysis. First is a computer program for simulating vehicle collision dynamics. The program, SMAC (Simulation Model of Automobile Collisions), has been used extensively in previous studies at PATH to investigate the consequences of vehicle collisions and the effects of vehicle-following parameters on collisions.

The second tool is a simulation and animation program (Carmma). Carmma was developed by PATH and used to perform animations of vehicle simulations as part of the National Automated Highway Systems Consortium (NAHSC) effort. Carmma can be used to define and then animate a simulation or accept output from a simulator such as SMAC. The source code was written in Tcl/Tk (Tool Command Language). Tcl/Tk is a scripting language used on UNIX platforms to develop and display animations and the associated graphical user interface. Revisions to the program were made to accommodate the needs of this study.

Other programs include Hwydata, which accepts simulation output from SMAC and converts it into a form that can be accepted by Carmma, i.e. the highway scenario format.

With the completion of the revisions to these programs, these simulation tools are now available for the studies of advanced vehicle control in collisions.

1.0 INTRODUCTION

In studies related to vehicle collision safety, there are mainly two phases with respect to the occurrence of accidents. One area of interest is the warning and avoidance of accidents prior to the accident, while the other deals with the mitigation of accident consequences. This study falls into the second area, in which we attempt to understand the behaviors of vehicles after a collision and explore strategies to minimize the potential hazards and damage caused by a collision. In particular, the work reported in this report focuses on the tools that have been developed under the research project, MOU 324.

In recent years, a number of studies have been conducted at PATH to investigate vehicle dynamics in vehicle-following collisions. The understanding of this subject is important because one of the concerns in automated vehicle operations has been the consequences of collisions when system failure or component malfunctions cause closely-spaced vehicles to collide. It became apparent from observations in recent studies [1-3] that vehicles would lose control and veer out of the designated lane if no control was applied after a collision in highway operating conditions. However, earlier ad-hoc approaches [4-6] showed that vehicles could be steered to remain in the designated lane if timely steering inputs were applied. Subsequently, this project began a systematic evaluation of the feasibility in utilizing control strategies to stabilize vehicle trajectories. Some of the research outcome are presented and summarized in recent publications [7-8].

Along the course of this study, several simulation tools were developed to achieve the objectives of the project. This report contains the descriptions of procedures and tools utilized in the study. Besides general outlines of the computer programs, a flow chart was given to illustrate the procedure for using the tools. Through the presentation of this documentation, readers should be able to grasp the development approach taken by the authors. Furthermore, the source codes and related documentation are available at the PATH web site:
http://www.path.berkeley.edu/pub/path.
2.0 BACKGROUND INFORMATION

In this section, brief descriptions are given for the two main computer programs used for the study. The first is a vehicle dynamic and collision model, SMAC (Simulation Model of Automobile Collisions). The second is Carmma, a simulation and animation program. Readers can refer to other related publications given below for detailed explanations of these two tools.

2.1 SMAC

The analysis of vehicle collisions is conducted with a simulation program, SMAC (Simulation Model of Automobile Collisions) [9-13]. SMAC is initially developed by Calspan Corporation for National Highway Traffic Safety Administration (NHTSA). SMAC uses a set of assumed or estimated parameters, including vehicle and roadway properties to predict the outcome of a collision. Engineers have been using this simulation program to analyze vehicle dynamics and the damage resulting from crashes. [14-19]

SMAC analyzes the longitudinal and lateral movements of vehicles as well as the rotational motion about the vertical axis of vehicles on a horizontal plane. If a contact between vehicles is detected, the collision phase is analyzed. The external forces can be applied either at the tire/road interface or between the vehicles.

A copy of the source code of SMAC was obtained from the University of Michigan Transportation Research Institute (UMTRI). Revisions to the program were made to incorporate the option of exercising feedback control in collision situations. After these revisions, control algorithms can now be tested in crash scenarios to examine the feasibility and effectiveness of vehicle control in emergency conditions.

The features added to the source codes include the specification of straight and curved roads, the availability of wheel angle offset and time delay, the choice of control types and the options of turning on and off the control actions on either vehicle. The control gains can be interactively changed as the program is executed. Reference [20] contains a detailed description of added options in the SMAC program.

2.2 CARMMA

Carmma was developed by PATH, at UC Berkeley Institute of Transportation Studies, as part of the National Automated Highway Systems Consortium Project. It was used to animate simulations of vehicles as part of the investigation of the feasibility of implementing future automated highway systems (AHS). It can be used to create and animate vehicle simulations or to animate data from other simulators such as SMAC. A graphical user interface can be used to create a highway scenario file, which defines the highway length, number of lanes and the initial states of the vehicles. It can also be used create animations using data from a highway scenario file with the vehicle trajectories created by other simulators. Revisions to the program were made to define the animation for either a straight or curved road depending on the vehicle trajectories determined by SMAC. Reference [21] contains a description of the Carmma Program.

3.0 PROGRAM STRUCTURE AND FLOW CHART

In addition to SMAC and Carmma there are additional functions to aid the user in defining the input parameters and in preparing the necessary data for animations. A brief description of each function follows. A flow chart is shown in Figure 3-1.

3.1 SMAC – Simulation Model for Automobile Collisions

The SMAC program is separated into several main parts:
1. Input phase: This portion receives the information regarding the integration and output time steps, the vehicle parameters, state variables such as position and speed, steering and tire torque inputs from an input file.
2. Trajectory phase: A subroutine and associated functions calculate the trajectories of the subject vehicles while the vehicles are not in a collision.
3. Collision phase: The collision routines determine if the vehicles are in contact and calculate the contact forces and its direction, which is then used to determine the subsequent motions of the vehicles.
4. Output phase: The states of the vehicles are printed at specified intervals.
The SMAC simulator determines the distance/velocity profiles of two vehicles using input parameters including initial lateral and longitudinal positions and velocities. The simulation continues after the vehicles collide until both vehicles are at rest. The input parameters are defined in file INPUT.DAT and the output files are OUTPUT.DAT, VEH1.DAT and VEH2.DAT. The simulation is run by typing the name of the executable (smac). Reference [20] provides a detailed description of SMAC.

3.2 Posvel - Set vehicle positions and velocities in file INPUT.DAT

This function is not necessary if the user wishes to set all data in INPUT.DAT directly using an editor. The Posvel function prompts the user for the positions and velocities of the vehicles in meters and meters/sec. It leaves the other parameters in file INPUT.DAT at the original values. This function must be run before SMAC is run. The program is run by typing the name of the executable (Posvel).

3.3 Hwydata - Set vehicle scenario data for Carmma program animation

The Hwydata function uses the vehicle position and velocity data provided by SMAC in VEH1.DAT and VEH2.DAT to create the highway scenario file. This file contains the simulation data in a format usable by Carmma. Hwydata uses the vehicle simulation profile information in VEH1.DAT and VEH2.DAT and also the vehicle trajectory parameters from INPUT.DAT. The trajectory parameters determine the type of trajectory, either a curved or straight road. The program is run by typing "Hwydata filename.hwy". The file name should be different for each SMAC simulation case, i.e. different versions of files VEH1.DAT and VEH2.DAT. The highway scenario file for Carmma must have the suffix "hwy".

3.4 Carmma - Vehicle simulation animation program

Carmma is an animation program with a menu-driven user interface. It is used to animate simulations that have data defined in the highway scenario format. Carmma is executed by typing in the command "Carmma". Reference [21] provides a detailed description of Carmma.

3.5 Source Code and Executables for SMAC, Posvel, Hwydata and Carmma

The source code for SMAC is in FORTRAN 77. Posvel and Hwydata source code is written in the C language. Carmma source code is written in Tcl/Tk. For the UNIX operating system there are makefiles that can be used to create the executables for SMAC, Posvel, Hwydata and Carmma. makefile1 can be used to compile SMAC, Posvel and Hwydata source code. makefile2 can be used to compile the Carmma source code.
4.0 SAMPLE RUNS

The following figures show the final positions of 2 vehicles after a collision has occurred for several simulation cases. Carmma was used to animate the output for each case. Each vehicle has the same initial position and velocity in all cases. The difference in each case is whether or not feedback control is used for the vehicles. The vehicle control options are defined on Row 17 of the input file INPUT.DAT [20].

Case 1  No feedback control for either vehicle
Case 2  Feedback control for the following vehicle but not the lead vehicle

Case 3  Feedback control for the lead vehicle but not the following vehicle
Case 4  Feedback control for both vehicles

5.  CONCLUDING REMARKS

This report summarizes the functional capabilities of computer programs used for investigation of vehicle collisions. The tools include SMAC and Carmma, and the interface between the two main programs. By combining the simulation, animation and other tools into a coherent set of programs a user who conducts simulation studies can gain insight into vehicle behavior from the generation of detailed simulation output and the visual observations of the animations of vehicle trajectories.

This documentation provides a concise explanation of the procedures and the tools that have been developed and utilized in the course of the study. The tools and the associated documents will also soon be made available form the PATH website, thus giving all interested readers and researchers access to these tools. Any further improvements or revisions to the programs will be updated on the website.

This work is part of the research project conducted under MOU-324. Readers can refer to previous publications [1-6] for earlier studies utilizing SMAC. Newer publications for studies addressing the use of vehicle feedback control can be found in [7-8]. One can also refer to the code documentation for SMAC [20] and the Carmma User Guide [21]. Future work of this project will continue the testing of control algorithms in various scenarios and the validation of control robustness under various system parameters.

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This work was performed as part of the California PATH Program of the University of California in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration.

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REFERENCE