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THE LEEDS ADVANCED DRIVING SIMULATOR: THREE YEARS IN OPERATION

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CONTENTS

1. Introduction

The Leeds Advanced Driving Simulator (LADS) at the University of Leeds is a medium cost fixed-base simulator and its development has been funded by the Science and Engineering Research Council (now EPSRC). It has been fully operational since mid-1993 for rural-road scenes (Carsten and Gallimore, 1993) but currently simulation of urban environments and vehicle interactions are possible too. This paper focuses on the recent development of LADS. Also detailed other recent research projects carried out in the simulator to date.

2. Main Characteristics

All the software used in the system is purpose-built as there was no ready-made driving simulator software on the market when the work started at Leeds. The roads are created from 3 basic types of road segments: a) fixed width straights b) fixed width constant radius curves and c) straights that vary in width by a constant amount along their length. These road segments can automatically be placed one after each other. The path the road takes can temporarily be diverted, for instance by turning 90° to create an intersection (Gallimore, 1993). There is a very flexible road marking and road signing system and it is also possible to simulate fog. Recently it has been upgraded both in terms of software and hardware to the point where it is possible to create complex and realistic urban driving scenes, including other vehicles that comply with the rules of the road and that can interact intelligently with the “car”.

3. Design and functionality

The vehicle which the subject drives, is a full car, a Rover 216 GTi donated by Rover Cars. The engine and the fuel system have been removed, but the generator has been reinstalled with new bearings on the end of the flywheel drive shaft. An electric motor now drives the gear box at a constant speed so that gear changes feel natural. Having the clutch cable attached to the gearbox makes the clutch pedal feel normal as well, although there is currently no sense of a clutch “biting point”. The cabin controls remain operational, including items such as the stereo system and the ventilation. The main driving controls, that is the steering position, accelerator, clutch, brake, gear selection, hand brake and ignition position are sensed and this data is collected by a PC fitted with analogue and digital I/O expansion cards. Other controls, for instance the lighting system and indicators, control their dashboard lights but have no other effect.

A SILICON GRAPHICS 4D/440 Reality Engine runs the vehicle dynamics model and the visualisation code. It is a real time simulation of a Rover 216 GTi, the same car the driver sits in. The model simulates both longitudinal (performance and ride) and lateral (handling and concerning) modes of motion. The longitudinal simulation uses an engine model based on performance data and gearbox, braking and clutch specifications provided by Rover. The suspension model assumes the vehicle is a twin mass, one sprung and one unsprung. The lateral simulation is based on mathematical model originally developed by Segel (1956). This model allows drivers to skid in extreme conditions and simulators to understeer while cornering at high speed.

The single projector gives a 50° field of view directly in front of the driver, but there is a provision for two further projectors to be placed either side of the current one so that a image covering the whole screen (120°) can be created. The perspective of this view is calculated from the position of the driver in the car and is adjusted by the PC with a frequency of between 20 and 30 Hz (frames per sec) depending on the complexity of the scene. The time between actions in the car and a completed adjusted projection on the screen is 0.05 sec for the worst case (20 Hz).

4. Design of the traffic environment

A logical road network is created by numbering path ends and junctions; a logical connection is made between two points. A connection can either be made in both or in just one direction. For each connection an ordered list of road segment descriptions corresponding to the graphical descriptions of the road is created. These are used by other autonomous vehicles to travel through the road network. The database compiler also creates a cyclic graph of the road network which can be used by autonomous vehicles to make arbitrary route choices. Signs and objects are referred to by a name which identifies an object defined in a separate database of graphical objects. This makes it very easy to add new objects to the system as they are needed by experiments. The use of the "C++" language pre-processor and its file inclusive features allow the creation of libraries of predefined road sections in separate files and use them in different scenes. This gives the ability to specify small changes to the scene while keeping the same basic road network. The landscape around the road network is created by using a Fourier synthesis algorithm (Watts, 1989). The current parameters create landscape very similar to areas of moor land. A scene database preview program has been created to aid the building of scenes, showing consecutive views of the simulated world. The first is a plan view where the height above the road can be varied from 5 Km to 10 Km which allows the overall structure of the road system to be seen, as well as being able to zoom in on any part of the road. The second is a 3D perspective "fly through" which gives a driver's eye view of the scene. The two views can be linked so that clicking the mouse on the plans view will move the 3D to that position in the world.

5. Scenarios

At the start of each simulated run, a scenario is entered by the experimenter. This currently consists of the name of the scene database, a logical path and the position along it from which the simulation will start.

6. Applications

The simulator (LADS) has been used on numerous research projects. Under the DRIVE II (V2065) program and GEM (Generic Evaluation Methodology for Integrated Driver Support Applications) project a study was conducted to investigate the effects of a range of visual and non-visual variables on performance in the standard time-to-collision task.

Pyne et al (1995) investigated the effectiveness of different innovative road markings for reducing drivers' speed on single carriageway rural roads. The aim was to identify practical and cost-effective remedial treatments in order to reduce the frequency and severity of accidents on such roads. The simulator experiment involved subjects driving in three different scenarios: along straight road sections, along sharp bends and approaching and leaving residential areas (villages), each time with different road markings. Their speed, lateral position and overtaking manoeuvres were recorded and compared with genuine road users' behaviour and the same subjects driving behaviour along the real road (with the existing road markings). The results showed substantial reduction in speed and speed variance for all three scenarios and the most effective treatment (or combination of treatments) was identified for each scenario.

In the same project, a validation study took place to determine the external validity of the simulator, i.e. if the results obtained on the simulator are transferable to the real world. The speeds of subjects driving the simulator were compared with the speeds of the same subjects driving on the real road and with the speeds of genuine road users in the real road. Also the speed of the subjects driving on the real road were compared with those of the genuine users of the road. The speed on the real road was measured using Golden River "Archer" tube classifiers. Speeds were measured at three points, these being between two very sharp bends (about 80m radius), between two less sharp bends (about 630m radius) and in the middle of a long straight. The results showed that:

a) the subjects' speeds on the real road were higher than the speeds on the simulator for the straight sections, but were the same for the sharp bends (not tested for the smooth bends due to lack of data).
b) speeds of subjects and genuine road users when driving on the real road were the same for all three points
c) speeds of subjects on the simulator were the same for the sharp bends as those of the genuine users of the real road, but significantly faster for the straight and gentle bends.

The overall conclusion was that "speeds adopted on the driving simulator are significantly faster than those adopted on a real road at points where speeds are not constrained by horizontal alignment of the road".

Until this stage the LADS was only able to simulate rural environment involving a featureless landscape and a primitive road network and no interaction with other cars in the scene was possible. The "Urban simulation on an advanced driving simulator" project enabled development in five particular areas.

i) the redesign of the road network compiler to allow for a logical description of a network. This allowed for the tracking of the simulator car within the scene and traffic lights to be developed;
ii) the logical road network also allowed for realistic behaviour to be added to the drone cars and make their movements more intelligent. They now assess priority and give-away rules when necessary to other drones and the simulator car;
iii) improvement to the visual scene to allow urban environments to be simulated by the introduction of photo-realistic "texture maps";

iv) implementation of realistic, digital sound; and
v) further improvement to the vehicle dynamics model to add a sensation of "directness" to the feedback to steering response.

A route guidance evaluation study was conducted last year (1995) in LADS. The aim of this project was to study the effects of route guidance systems under closely controlled circumstances, as a complement to on-road studies where this was not achievable. The project was part of the EC DRIVE programme (DRIVE II project V2002 HOPES). It included three separate experiments: a) to study the effects of driving with route guidance information on the visual search of drivers and the effects of display complexity b) to study the effects of driving with route guidance information as compared to map-based information on vehicle control and driver workload and c) to study the effects of different types of route guidance systems on driver interactions and conflicts. The Institute for Transport Studies carried out the last experiment. In particular, subjects had to drive with route guidance that either did or did not present lane information. The indicators used were i) workload measures, ii) driver comfort measures and iii) driver interaction and conflict measures. The results of the third experiment were that the provision of lane information increased both speeds and the likelihood of conflicts.

Sound Alert Ltd, a commercial company, conducted a study on novel sound patterns for emergency vehicle sirens and other devices using the LADS in 1995. Existing emergency vehicle sirens are poorly localised by road users since they operate in a relatively narrow frequency range of 0.5 - 1.8 kHz. The aim of the study was to generate such a tone that the pedestrians or other vehicles will be able to identify the direction of the approaching emergency vehicle. The results showed an improvement in front/back localisation of the new sound pattern compared to existing sirens. The new siren was composed of a sound pattern which is both localisable and alerting. The next stage of the project is to establish the response of road users to the new and existing sirens by recording their reactions and movements towards both sound patterns.

The next project (started July 1995 and will finish June 1996) was the investigation of drivers’ behaviour to automatic speed control in urban areas. Automatic speed control is a form of system that controls the maximum speed of motorised vehicles in urban areas and has been widely discussed as a means of enforcing adherence to speed limits and for reducing accidents. The driving environment was a simple urban network which forced subjects to interact with other traffic at junctions. Two types of speed control were investigated (general speed control and additional speed control on the approach to a junction) with three levels of system penetration (no vehicles equipped, 50% equipped and all vehicles equipped). In addition to conflicts, measurements were made of speed on links, speed at junctions, following distances, braking and gap acceptance behaviour and mental workload.

An evaluation of driver response to road user charging systems is carried out on LADS this moment (May, 1996). The aim of the research is a) to study drivers' responses to a range of road charging structures, b) to identify and assess ways of reducing any negative impacts of
real-time road user charging systems and c) to produce more accurate estimates of the benefits, and likely revenues, from such systems. The simulator was used to determine at what level (if at all) real-time time-based and congestion-based charges induce evidence of increased risk taking (such as acceleration, gap acceptance, overtaking, lane selection). The experiment will enable to decide whether real-time charges can be included in the field experiments using ADEPT-equipped vehicles.

A validation study of the Leeds simulator will be carried out this year (1996). The study will first deal with the operator and then with the overall simulator/operator performance assessment. The first will be accomplished by requiring subjects to complete perceptual tasks on the simulator and by the administration of a questionnaire relating to the realism of the simulator. To assess overall simulator/operator performance, real world and simulator results will be compared, i.e. uncontrolled observational real road data (genuine road users driving behaviour will be monitored using hidden video cameras along a nine kilometres stretch of a rural road) will be compared with simulator behavioural data. Finally the issue of the methodology used to assess the validity of a driving simulator will be addressed, since it seems that there is no standardised procedure for the behavioural validation of a driving simulator. The research is separated into three main experiments: the real road experiment, the perception experiments and the simulator experiment (which will be a replication of the real road experiment). The sample size will be at least 100 genuine road users. For the driving simulator experiment, a similar number of subjects will be used.

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