Driver Behaviour Analysis in a Simulated Environment

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Abstract

Building a navigation system within a 3-dimensional virtual computer world is challenging. Further, building our navigable virtual world corresponding to real world facts (such as a map or a landscape of a given area) magnifies this challenge. This research investigates on possibilities of modeling a 3D navigable world corresponding to real world facts via mathematical constructs derived using the provided information of a given area. Thereafter, this realism augmented 3D navigation system is transformed into a 3D virtual driving simulator.

Our driving simulator is used as a tool for measuring driver behaviour under different types of varied conditions. The final output of this simulator after a single driving session is a sample data set indicating predefined metrics; those can be used to state observations for a typical human factors experiment. Hence the observations after a driving session in a simulated environment are used to derive useful inferences with respect to real driving. The metrics include; number of wall collisions, number of traffic cone collisions, time taken per driving session and speed detected during different times (can be used to obtain a speed graph later). The sample human factors experiment tested on our driving simulator is about inferring the relationship between driver behaviour vs. consumption of alcohol, which is simplified to driver behaviour vs. drowsiness for the sake of demonstration.

Keywords

Driver Behaviour Analysis, Driving Simulator, 3D Modeling, Virtual Navigation

1. Introduction

Road traffic crashes are one of the worlds largest threats related with public health and injury prevention. With rapid motorization, this ’neglected epidemic’, is forecast to escalate by 83 percent in some low-middle income countries and to become the third leading cause of death and disability by 2020[1]. Therefore developing measures, to prevent road traffic crashes is more crucial than ever before. There are 2 types of users in a typical road infrastructure; drivers and pedestrians. Most of the time, a road traffic crash occurs due to a contradictory behaviour from either of these users with respect to already established rules and policies to ensure road safety[2]. One of the initial steps of road crash prevention is to identify root causes for occurrence of driver behaviours leading to danger through research. But the problem lies on generating such contradictory driver behaviour within a real testing environment; while ensuring the safety of users and minimizing relevant property damages.

The main objective of this paper is to investigate the possibility of generating and studying these dangerous driver behaviours within a simulated environment by means of a computer generated program and simulation equipments (a driving simulator). Hence the required dangerous driver behaviours are generated in a safer and no property damaging manner. Although, the *relationship between driver behaviour vs. consumption of alcohol* [18] is the original problem intended; due to practical restrictions for this experiment within university, our initial study focus on a closely related problem, the *relationship between driver behaviour vs. drowsiness*[3].

The rest of the paper is arranged as follows. Section 2 provides background knowledge on research conducted with the use of driving simulators and current attempts taken to model 3D systems. Section 3 introduces design and implementation steps on building a 3D navigation system and converting it to a driving simulator. The major objective, which is the study of driver behaviour based on a human factors experiment, its evaluation and inferences, is presented under Section 4.

2. Background

Driving Simulators are used as a training tool for amateurs, evaluate new vehicles, test new advanced driver assistance systems and entertainment purposes [4]. But apart, our focus is towards its use in the area of human factors and medical research; to monitor driver behaviour [4].

2.1 Driver Behaviour Analysis vs. Driving Simulators

An evaluation of driver behavior in narrow running lanes was a study undertaken to access the impact of lane width on driving performance; using the Leeds Advanced Driving Simulator [5]. The objectives focused on evaluating driver behaviour in narrow running lanes (operating under simulated motorway conditions) in particular the relationships between lane width, traffic safety and highway capacity. *Interaction between speed choice and road environment* was another simulation study [6] based on identifying the most effective speed reducing measures for urban and rural environments. *Driver behaviour analysis for improving negotiation patterns of a driver at non-signalized intersections* using a driving simulator was a study on how drivers behave when entering a non-signalized intersection without right of way [7]. The negotiation patterns of skilled drivers and unskilled drivers were compared during the study. Later, these simulation results can be used to develop a methodology to improve the negotiation pattern of an unskilled driver during entering a non-signalized intersection.

The significance of driver behaviour study is that, even already performed experiments with user involvement may not be applicable to any human behaviour. Some countries have more strict rules and policies. The psychology, behaviour of the subject (driver) may vary according to his/her family, surrounding environment, culture and occupation. For instance, in a driver behaviour test with respect to consumption of alcoholic beverages (our sample problem in this paper), different countries in different parts of the world will expect different amount of consciousness from the driver according to their level of thinking. Different alcoholic beverages are used in different parts of the world. These different beverages will react in different amounts in terms of decreasing a driver's consciousness. With all these varying parameters, our global inference is at high level such as: 'too much alcohol is bad for driving'. This is not practically applicable since we can't define 'too much' quantitatively.

2.2 Modeling a 3D Simulated Environment

One of the simplest methods for modeling a 3D road infrastructure is using a *grid based approach* [9], [8]. The roads of an area are created in the pattern of a uniform grid. The city road grid is regular and size of each block is constant. More realistic models are created by random merging of components separated by the grid with random heights for each component. Another approach includes modeling 3D objects as *L-Systems* [10]. This approach [11], [8] focuses on the growth of a road network over the years from its initial stage of a single road and applies the theory of L-Systems for generating a realistic road network. *Standard templates* [12], [8] can be used to model road networks. For instance, the population density of an area can be used as a template to derive its road network, under the assumption that the complexity of a road network increases with the increase of population density. The *agent based approach* [8] follows an entirely different perspective to model cities. City models are generated by simulating agents (city developers, planning authorities and road builders) who involve in urban planning. The software thinks from the perspective of each agent; areas with minerals bias towards relevant industries, flat areas create houses and reservoirs are biased towards farming.

3. Design and Implementation of Driving Simulator

This section is an overview on the steps followed in terms of building the *simulated environment*, which is used for our pilot study on driver behaviour.

3.1 Modeling Roads as Mathematical Functions

Owing to prior research work and existing technology it is possible to obtain satellite images for: the extracted road network [13] and image based height map (as in Figure 1) of a particular area. Our design starts by obtaining two such images of the area of concern. The image based height map is used to model the landscape (by introducing y axis to represent heights, see Figure 1).

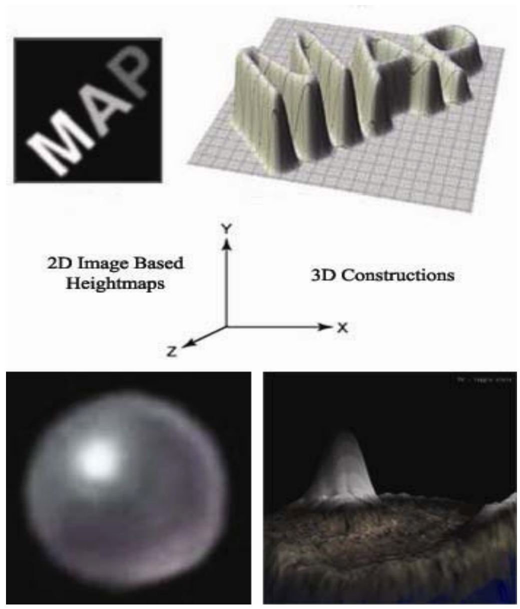
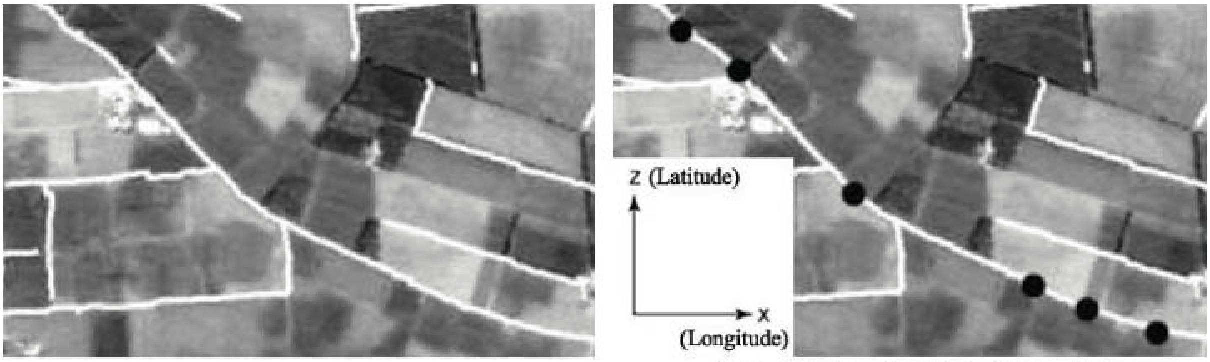


Figure 1: Construction of Landscape from an Image-based Heightmap

For each road, the most significant points on the road (especially sharp bends) are marked as in Figure 2 (marked as black dots). Any such point on a selected road can be given with (x, z) (or in latitude or longitude) co-ordinates (since we used axis y to represent height). With basic interpolation techniques, if such a set of significant points (x, z) is known: a function of the form $z = f(x)$ can be constructed, which passes through every significant point in our point set (road). Lagrange interpolation [17] was used to generate road functions during our sample implementations. Therefore our roads correspond to real roads on the map (since they are represented by generated road functions and an image-based height map).



(a) Extracted Roads (as white lines) (b) Most Significant Points (as black spots)

Figure 2: Constructing a road's function

A sample demonstration was created by using a generated road function, placing lines of traffic cones in random on the road with fences (walls) placed in both sides. This demonstration was used as the simulated environment for our driver behaviour experiment (see Figure 4).

3.2 Implementing Road Traffic

The concept of modeling roads as functions can be used to implement other extensions in our driving simulator. One such extension is modeling road traffic with self-behaving vehicles on roads. The idea behind this implementation is: since a road's function is known, its derivative can be obtained. The derivative provides the direction pointed by the road at a given point. Hence the direction obtained from derivative is used to instruct our self-behaving vehicle (in Figure 3) on which direction to turn towards at a given point on the road. Simulation of several such vehicles in a periodic manner can be used to generate variations of road traffic.

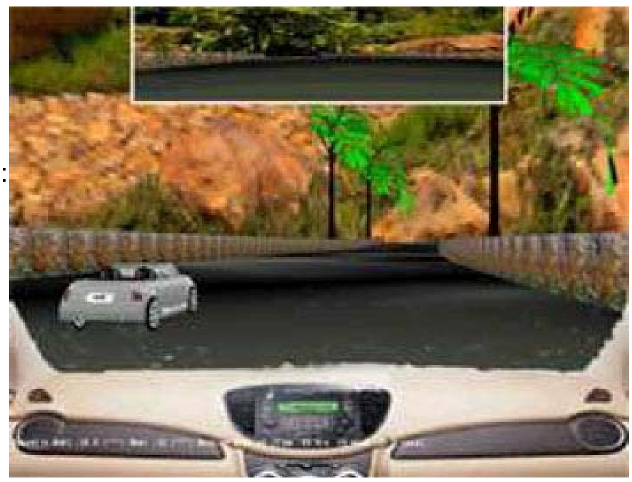


Figure 3: Demo - Road Traffic Simulation

3.3 Extensions towards a Driving Simulator

A first-person camera was introduced to our 3D navigation system. The camera changes with time according to the inputs provided with 4 basic functions: forward, backward, turn left and turn right. These 4 navigation functions were reused to create general functions related with driving: acceleration, braking, turn, increase gear and decrease gear. This software system was integrated with a Genius SpeedWheel Steering Kit, to provide the end user an immersion of a driving simulator via incorporating simulation hardware. Finally a logging mechanism was added to collect metrics during each driving session, by creating a log file during end of session with its associated metrics.

4. Driver Behaviour Analysis

This section presents the study on *driver behaviour vs. drowsiness* within our *simulated environment*. The discussion is carried further, with the methodology on reusing this study for our original problem, which is the study on *driver behaviour vs. consumption of alcohol*.

4.1 Drowsiness

Drowsiness is generated in the human body from a biological process known as the sleep-wake cycle [3]. This cycle is governed by homeostatic and circadian factors[3]. These 2 factors create a predictable pattern of two sleepiness peaks. The first occurs about 12 hours after the mid-sleep period (during the afternoon) and second peak before the next consolidated sleep period (most commonly at night before bedtime).

A study conducted in Sweden [14] to investigate effects of high-carbohydrate (HC) and high-fat (HF) diet on cognitive performance and sleepiness has revealed that: the HC-diet is significantly associated with an increase of subjective sleepiness. The HC-diet causes larger oscillation in performance and increased sleepiness compared to HF-diet, throughout day and night [14]. From Sri Lankan context, the heaviest meal of the day is lunch with main food item being rice, which is a HC-diet. Therefore, application of above studies based on drowsiness with Sri Lankan food habits yields that: post-lunch time period is subjected to generate drowsiness within an individual.

Figure 4: Demo - Driver Behaviour Experiment

In terms of drowsy driving, no measures currently exist for measuring drowsiness in the immediacy of a car crash [3]. However, a typical sleep related crash has the following characteristics [3]:

1) The problem occurs during late night/early morning or mid-afternoon.
2) The driver does not attempt to avoid a crash.
3) The driver is alone in the vehicle.

Although no driver is immune to crashes due to drowsiness: young people (ages 16 to 29 and especially males) is identified as one of the three population groups at highest risk, based on evidence from crash reports of sleep behaviour and driving performance[3].

4.2 Designing the Experiment

Our pilot study consisted of a sample of 10 individuals (subjects). With relevance to above findings on drowsiness; our sample was restricted to same age, same gender (male) and same level of computer gaming skills; who are my (the author) batch mates (age between 23-26) at the university.

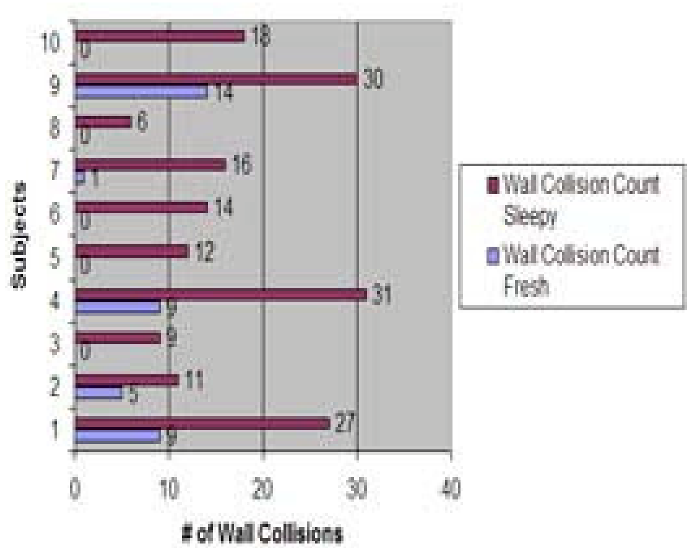


Figure 5: Comparison between Frequency of Wall Collisions

The demonstration integrated with steering kit, incorporating lines of traffic cones in random placements on both sides of the road (see Figure 4); was used as the *simulated environment* for the experiment. The individual (driver) was instructed to attempt for a safe drive by ignoring traffic cones and not colliding with fences on both sides of the road.

Each individual was given a single turn to practice within this simulated environment (i.e. a single driving session). Thereafter each individual was subjected to drive alone for 2 separate driving sessions conducted in 2 distinctive times of the day.

1) During the morning (between 10.00am - 11.00 am)

2) During drowsy time just after lunch (between 1.30pm – 2.30pm)

The following metrics were taken from each individual, during each driving session.

1) Total number of collisions with fences (walls) on both sides of the road

2) Total number of collided traffic cones

3) Total time taken to complete a driving session

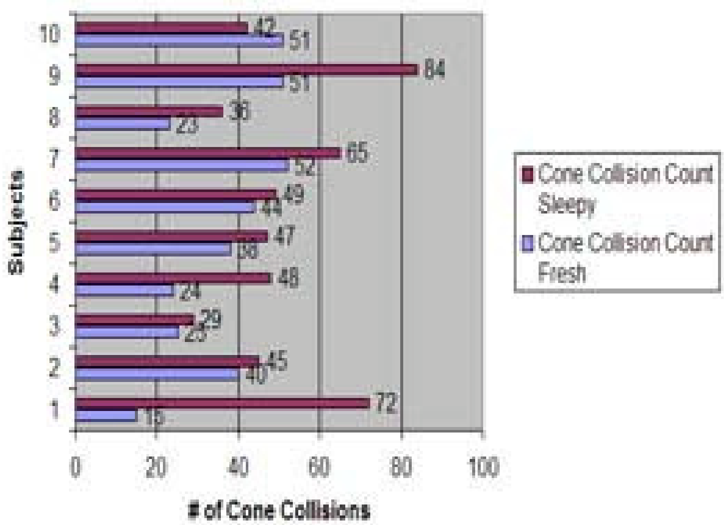


Figure 6: Comparison between Number of Traffic Cones Collided

Therefore, by coming up with this experiment: we used *drowsiness generated after a heavy meal* as the varying factor instead of *unconsciousness occurred due to consumption of alcohol*, which we wanted to consider originally.

4.3 Analyzing Results

In terms of comparing number of wall collisions occurred for each individual during 2 distinct modes (the fresh individual in the morning and the drowsy individual after lunch): Figure 5 illustrates the set of bar graphs derived for frequencies exhibited by each individual during each driving session. The frequencies obtained for wall collisions are different from individual to individual, even within the same mode of driving. However considering all 10 individuals, for each case, the frequency of wall collision at drowsy (sleepy) mode is greater than the frequency during fresh mode.

Figure 6 illustrates the collection of bar graphs derived for each individual by considering the number of traffic cones collided by him during each driving mode. The results for number of traffic cones collided indicate the same pattern similar in frequency of wall collisions except for the last case. But for a majority of 90% individuals the cone collision has increased during drowsy mode comparing with fresh mode.

Time taken by each individual for completing a driving session during fresh and drowsy modes (see Figure 7) indicates that: we can't find a similar relationship by means of time, like in the cases for wall or cone collisions. A possibility for these results could be: although in the drowsy mode with weaker driving capabilities, the driver attempts to drive within the same time span incurring more damages, thus affording a careless drive. On the other hand in fresh mode the driver tries to drive with less damages (or collisions) and hence consumes additional time due to cautiousness.

The experimental results indicate that there is significance in terms of driver behaviour between fresh and drowsy modes of driving. Further this significance is detectable with our *simulated environment* (driving simulator) via the use of its implemented metrics: *wall collision count* and *total number of traffic cones being collided*.

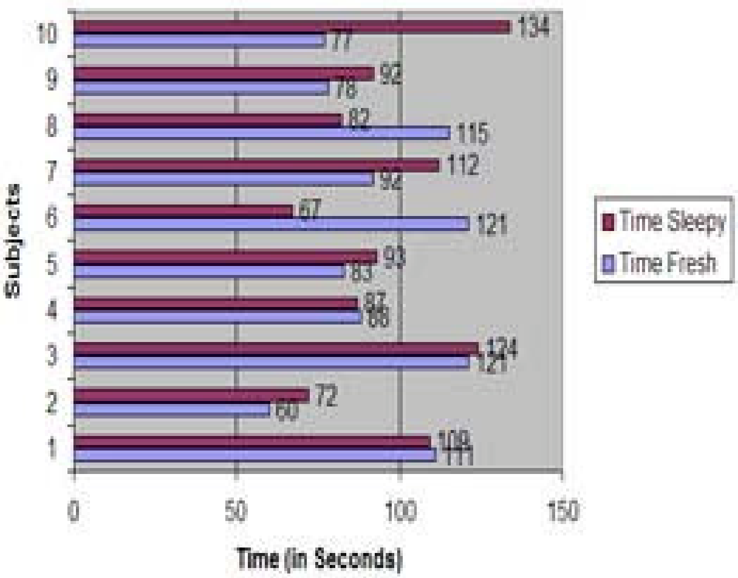


Figure 7: Comparison between Time taken per Driving Session

4.4 Study of Drunk Driving in a Simulated Environment

Similar to effects of alcohol: drowsiness slows reaction time, decreases awareness, impairs judgment and increases your risk of crashing [15]. Therefore we can reuse our *experiment on drowsy driving* (with our simulated environment) for testing against *drunk driving*. The only alteration is considering individuals (drivers) in fresh vs. alcoholic modes; instead of individuals in fresh vs. drowsy modes.

Unlike drowsiness; there exists blood, breath and other objective tests for determining level of alcohol consumed by a driver [3]. Our experiment can be done for each individual with no consumption of alcohol vs. consumption of different amounts of alcohol from different alcoholic beverages.

Drunk driving is closely related with aggressive driver behaviour, where alcohol is one of the root causes leading to aggression [16]. Impatience is one of the major characteristics of aggressive driving. Therefore in addition to our metrics in drowsy driving study: we can use the speed graph derived, per each driving session (by considering driving speeds logged periodically by our driving simulator) as a tool for determining the level of aggression produced under effects of alcohol.

For a real world study, the selection of individuals (subjects) can be diversified such as gender, age group, job categories, day/night workers. The experiment can be performed separately for each group. Collecting experimental results from a sample of at least 30 individuals from each such group; enables deriving inferences based on inferential statistics.

The inferences become useful in cases such as *'policy making for drunk driving'*. For each alcoholic beverage, the largest amount consumable by an individual can be determined, where the individual is still able to ensure safe driving. Based on these threshold amounts, policies can be formed in a local context such as: *'driving after taking more than x milliliters of Vodka is not permitted'*.

4.5 Fidelity vs. Validity

Fidelity addresses the question on: how truthful the experience created by a driving simulator, with respect to the experience obtained during real driving [4]? Validity inquires whether results obtained using a simulator can be directly applicable to real-world driving which is possible to have at least a minimal difference with the simulator environment, most of the time[4].

The basic solution is to come up with a hybrid approach, where simulator studies are recreated on a real pilot test track using a minimum number of real vehicles. Thereafter, our driving simulator can be calibrated with results obtained from real driving. Our driving simulator supports calibration via availability of following metrics as configurable constants, within its implementation.

1) Weight
2) Gear Count
3) Minimum vs. Maximum Speeds under each Gear
4) Acceleration
5) Braking
6) Minimum Turn Radius

5. Conclusion

Unlike traditional methods for driver behaviour analysis (i.e. with the use of real vehicles and road infrastructure): use of a simulated environment is a safer and cost-effective approach.

Drowsiness provides a significant contribution to promote dangerous driver behaviour. This significant change in driver behaviour is proven under use of a simulated environment via our human factors experiment. Since drunk driving produces the same behavioural patterns generated by drowsy driving, the same experiment for studying drowsy driving is applicable for study of drunk driving. Thus effects of drunk driving can be studied under the presence of a simulated environment, without relying on conventional methods which require the presence of real vehicles and road infrastructure.

Road segments can be modeled as mathematical functions generated via interpolation methods. This approach enables the exact road of a particular area to be modeled (by means of significant bending points on the road, extracted from a map of the area) inside a simulated environment.

6. Acknowledgement

We gratefully thank for all the resources and support provided by University of Colombo School of Computing, Sri Lanka.

References

[1] Road Crashes - An unfolding national crisis
http://www.salimandsalimah.org/crashes.htm
[2] Driver/Pedestrian Understanding and Behaviour at Marked and Unmarked Crosswalks by David R. Ragland, Meghan Fehlig Mitman
http://repositories.cdlib.org/its/tsc/UCB-TSC-RR-2007-4/
[3] Drowsy Driving and Automobile Crashes - NCSDR/NHTSA Expert Panel on Driver Fatigue and Sleepiness
http://www.nhtsa.dot.gov/people/injury/drowsy_driving1/Drowsy.html
[4] Driving Simulator - Wikipedia
http://en.wikipedia.org/wiki/Driving_simulator
[5] Leeds Driving Simulator – Previous Research
http://www.its.leeds.ac.uk/facilities/uolds/previous_research.php
[6] Leeds Driving Simulator – Current Research
http://www.its.leeds.ac.uk/facilities/uolds/current_research.php
[7] Driver Behavior Analysis for Improving Negotiation Patterns of a Driver at Non-signalized Intersections by Kosaka Hiroaki, Higashikawa Nobuhisa, Morioka Toshiyuki, Noda Masaru, Nishitani Hirokazu, Uechi Masaaki, Sasaki Kazuya
http://sciencelinks.jp/j-east/article/200701/000020070106A0853624.php
[8] A Survey of Procedural Techniques for City Generation by George Kelly, Hugh McCabe
http://www.gamesitb.com/SurveyProcedural.pdf
[9] Undiscovered Worlds - Towards a Framework for Real-Time Procedural World Generation by Stefan Greuter, Jeremy Parker, Nigel Stewart, Geoff Leach
http://www.infinitylab.com.au/research/dac2003.pdf
[10] L-System - Wikipedia
http://en.wikipedia.org/wiki/L_Systems
[11] Procedural Modeling of Cities (CityEngine) by Yoav I H Parish, Pascal Müller
http://www.cs.berkeley.edu/~sequin/CS285/PAPERS/Parish_Muller01.pdf
[12] Template-based Generation of Road Networks for Virtual City Modeling by Jing Sun, Xiaobo Yu, George Baciu, Mark Green
http://portal.acm.org/citation.cfm?id=585747
[13] Automatic Road Extraction from IRS Satellite Images in Agricultural and Desert Areas by Uwe Bacher, Helmut Mayer
http://www.isprs.org/congresses/istanbul2004/comm3/papers/423.pdf
[14] Performance and Sleepiness during a 24 h Wake in Constant Conditions are affected by Diet by Arne Lowden, Ulf Holmbck, Torbjrn Kerstedt, Jeanette Forslund, Maria Lennerns, Anders Forslund
http://www.sciencedirect.com
[15] Drowsy Driving - National Sleep Foundation
http://www.drowsydriving.org
[16] Psychiatric and Behavioral Problems in Aggressive Drivers by Loretta S. Malta, Edward B. Blanchard, Brian M. Freidenberg
http://www.sciencedirect.com
[17] Lagrange Interpolation Polynomial – Wolfram MathWorld
http://mathworld.wolfram.com/LagrangeInterpolatingPolynomial.html
[18] Dept of Transportation (US), National Highway Traffic Safety Administration (NHTSA). Traffic Safety Facts 2006: Alcohol-Impaired Driving. Washington (DC)
http://www-nrd.nhtsa.dot.gov/Pubs/810801.PDF