Advances in Engineering Software 40 (2009) 1000–1010

Contents lists available at ScienceDirect

Advances in Engineering Software

journal homepage: www.elsevier.com/locate/advengsoft

Object-oriented methodology for intersection simulation model under heterogeneous traffic conditions

Asaithambi Gowri, Kanagaraj Venkatesan *, Ramaswamy Sivanandan

Transportation Engineering Division, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai 600036, India

ARTICLE INFO

Article history:
Received 7 August 2008
Received in revised form 20 February 2009
Accepted 23 March 2009
Available online 24 April 2009

Keywords:
Heterogeneous traffic
Mid-blocks
Intersections
Traffic simulation
Object-oriented programming

ABSTRACT

In developing countries like India, the traffic on roads is highly heterogeneous in nature, with vehicles of widely varying static and dynamic characteristics. In this type of traffic, vehicles do not follow lane discipline and they move freely over the entire width of roadway based on availability of space. To study this type of complex traffic flow and associated vehicular interactions, simulation is considered as an effective tool. An object-oriented methodology (OOM) for heterogeneous traffic simulation is proposed in this paper with focus on mid-block and intersection flow modeling. The paper presents the basics and advanced features of object-oriented programming (OOP) in detail in the context of traffic flow. The sample C++ code is discussed in detail to demonstrate the implementation of OOP features, such as encapsulation, inheritance and polymorphism. The contribution of this research work is the development of software objects for various components such as vehicle, traffic, link and node. This software can be adopted for heterogeneous traffic simulation programs, in general.

1. Introduction

The difference between homogeneous and heterogeneous traffic at mid-block sections can be illustrated by comparing the photographs shown in Fig. 1. Homogeneous traffic (Fig. 1a) has traffic entity types, whose physical dimensions do not vary much. The vehicles also follow lane discipline in heterogeneous traffic (Fig. 1b and c). The vehicular composition include vehicles with widely different characteristics, such as motorized two-wheelers (MTW), cars (including jeeps and small vans), buses, auto-rickshaws (three-wheeled motorized vehicles), light commercial vehicles (LCV), trucks, and non-motorized vehicles such as bicycles and tricycles. Due to highly varying physical dimensions and speeds, it is difficult to impose lane discipline. Hence, the vehicles occupy any lateral position on the available road space. Small sized vehicles (MTW, bicycle) often utilize gaps between larger vehicles in the traffic stream. Due to complex driver behaviour, vehicular interactions and their manoeuvres, it is very difficult to model the traffic flow through analytical methods. So, modeling of road traffic flow through simulation technique is often resorted to.

In traditional procedural programming, the behaviour of the system is completely decoupled from the characteristics or attributes of the system, which reduces the one-to-one matching between the physical system and the software model. In this context of increasing complexity of physical system, software programming faces challenges and it is difficult to develop a robust model. This is where the object-oriented modeling can offer a better solution. Software objects in object-oriented modeling represent the physical components, which build the physical system. Object is an entity, which encapsulates both the characteristics and behaviour of the component. So, the physical system can be considered as a composition of such objects. This paper deals with traffic simulation system, which was implemented using object-oriented programming and modeling as specified by unified modeling language (UML) [1,2]. Complex software designs that would be difficult to describe textually can readily be conveyed through diagrams. Unified modeling language is a visual language for specifying, constructing, and documenting the artifacts of systems UML can be used with all processes, throughout the development lifecycle, and across different implementation technologies.

In recent years, object-oriented programming (OOP) has gained popularity in the development of scientific codes [3–5]. The programmer produces more intelligible, maintainable and expandable codes with less effort and at less expense using powerful and flexible characteristics of OOP [6]. For studying homogeneous traffic flow characteristics, various commercial software such as VISSIM, PARAMICS, NETSIM, FRESIM, INTRAS, CORSIM and INTELSIM are available [7–9]. Most of the literature related to the present study deals with homogenous traffic conditions using OOP concepts [10–13]. The versatility of these software and models to simulate heterogeneous traffic is however, unknown. For example, it is hard to say how well they can simulate non lane-based traffic, non

* Corresponding author. Tel.: +91 9444328429.
E-mail addresses: gowri_iitm@yahoo.co.in (A. Gowri), venkatesankanagaraj@yahoo.co.in (K. Venkatesan), rsiva@iitm.ac.in (R. Sivanandan).

0965-9978/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.advengsoft.2009.03.015

Fig. 1. Homogeneous and heterogeneous traffic characteristics.

lane-based vehicle entries and undisciplined flow at intersections. The model developed and presented in this paper has the capability to incorporate the above features. The implementation details of the developed model are explained in greater detail. Some research studies have been made on modeling of heterogeneous traffic flow. Some traffic simulation models were developed for heterogeneous traffic using FORTRAN language [14–16]. Rao and Rengaraju [17] and Chandra and Parida [18] developed simulation models using C language. Some studies have been carried out on development of simulation models to understand the heterogeneous traffic using C++ language [19,20]. From the above review, it is believed that most of the heterogeneous traffic simulation models are developed using the traditional waterfall algorithm-driven structured programming approach for some specific traffic analysis. Unfortunately, little information about the implementation of heterogeneous traffic simulation in object-oriented environment is published in the literature. This paper deals with object-oriented modeling of heterogeneous traffic simulation with focus on mid-block modeling and intersection modeling. Detailed study on queue formation, weaving, and interactions near signalized intersections areas are made. Reusability and expandability of the code using existing classes is a feature of the work.

2. Simulation framework

The basic idea in simulation modeling is to build a computer program that mimics the real-world conditions. Once the model is built, a traffic engineer could experiment with different design configurations, control strategies and traffic flow conditions, and determine their impacts on the system. The advantage of the model is that it eliminates the need for field testing of controls/strategies before their implementation, thereby obviating the disruption of traffic operations during field experiments. It is also much faster and cheaper than field experiments. A microscopic traffic simulation model for urban mid-block section under heterogeneous traffic flow conditions was developed by Venkatesan et al. [21]. The modeling framework is outlined here to provide the background for this paper. The simulation model uses the interval scanning technique with fixed increment of time. The entire road space is

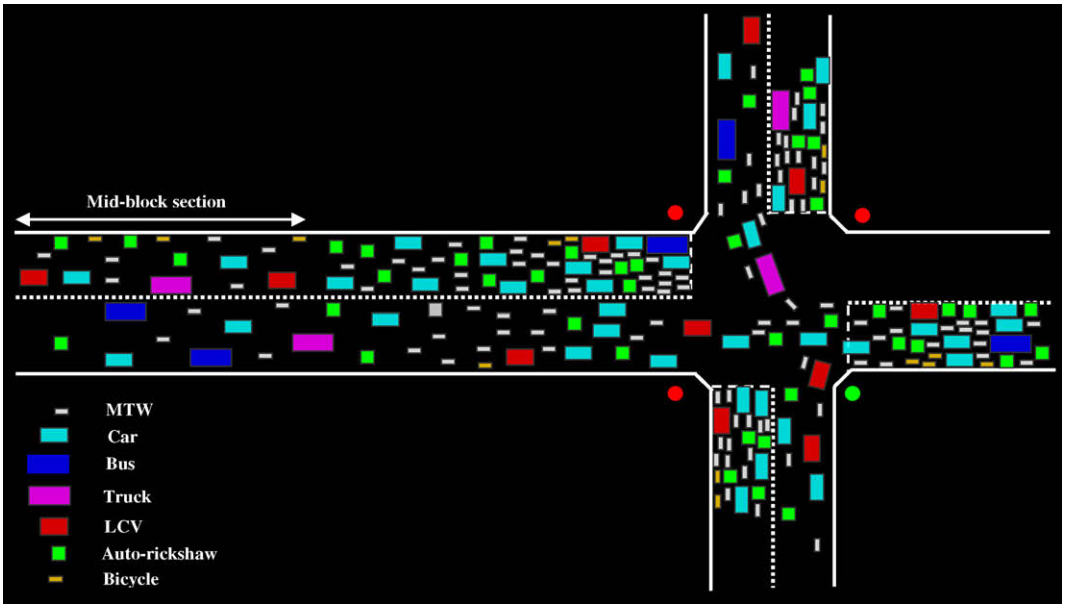

Fig. 2. Graphical representation of vehicles on a road.