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A Software Environment to Integrate Urban Traffic Simulation Tasks

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Abstract

This paper describes the CATIA software environment, which is oriented to tool integration. The main functionality provided by CATIA is the ability to support the traffic engineer throughout several phases and tools that are demanded to analyze urban traffic systems. An open architecture combined with an object-oriented data model of the application domain provides for advantageous features when compared to classical tools and engineering environment for CATE (Computer Aided Traffic Engineering). The modeling, implementation and obtained results are described, emphasizing the architecture of the inter-tool communication facilities.

Keywords: Computer aided engineering, interactive simulation, object-oriented.

1 INTRODUCTION

The evolution of complex urban agglomerates has posed significant challenges to the city planners in terms of optimizing traffic flows in a normally congested traffic network. Such planning and optimization relies on advanced CAE/CAD tools to model, simulate, design and operate complex urban traffic systems. Simulation and analysis of such systems require modeling the behavioral, structural and physical characteristics of the road system, which include at least the mobile agents themselves and the roads and intersections.

A large number of variables are used to characterize the flux of traffic, and its behavior can be forecast and optimized by very complex simulations, which require sophisticated software tools. The urban planner has to rely on a large number of tools, each one dealing with specific models and related variables of the systems. Among the several types of analysis to be dealt with in the traffic simulation, one can point the study of individual intersections, the evaluation of traffic management and allocation schemes, performance evaluation of road sections, and the study of traffic area control schemes. Tools such as

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CONTRAN [8], SATURN [9,10], SIDRA [1], TRAF-NETSIM [5], TRANSYT [11, 12, 13] are traditional in the trade. TRANSYT, for instance, is applicable to traffic control area modeling, SIDRA models and simulates individual intersections to optimize local intersection flows through lights, and SATURN models global traffic allocation throughout the network using coarse models of origin and destination demanded by urban commuters.

An important evolution, required for the sake of productivity by the urban planner, is the integration of tools, models and analysis methods, which have been developed for individual domains, into a common simulation framework. Such framework has to support inter-tool communication and a common visual interface to drive the modeling, simulation and result analysis phases. There are environments proposed in the literature, such as ASTERIX [2], targeted to address in part some of these requirements, and tools which target the human-machine interface improvement for a given application for traffic simulation, as in the case of INGRATA [3].

In this paper the specification and implementation of the software environment CATIA are presented. This system is dedicated to Computer-Aided Traffic Engineering (CATE). The main functionality provided by CATIA is the ability to support the traffic engineer throughout several phases and tools that are demanded to analyze urban traffic systems. CATIA has been implemented under a PC Windows 95 O.S. in DELPHI object-oriented programming language [6]. A common user interface, a unique data model that is integrated in a general model frame for the entire city objects, as well as powerful inter-tool communication facility intended to support several simulators, are a few of the distinct characteristics of the software environment implemented at UFRGS university. A proof of the concept of open interface to commercial black-box simulators was implemented using SATURN, a commercial tool of wide acceptance that has been used to model traffic allocation. The CATIA environment model supports both microscopic as well as macroscopic traffic simulation tools, and the black-box interaction is important to preserve the investment on widely used legacy systems that were built with traditional software engineering and Fortran programming languages.

Challenges and optimization goals that are recurring in current practice of urban traffic planning and operation, as well traditional simulation techniques are briefly described. Following suit, the data models for the CATIA environment, its basic structure and finally examples of integrated use with third party tools are presented in this paper.

In traffic systems analysis and planning one has to deal with models of the entire city, which include population density, road network, land usage, land development, demand profile from traffic sources to sinks, intersection controls, encompassing a large set of geo-referenced data. The vehicle flow monitoring and data gathering are facilities very seldom integrated into such simulator systems, which demand control system facilities that are not addressed in this paper. Integrating information from city plan data to traffic flow today is a real challenge, since the traffic engineer has been dealing with separate tools to address each specific analysis task; non integrated tools, inconsistent data models, and widely different computer interface environments add more difficulties to the final task of the simulation engineer. An integration of several modeling domains is a starting point for the development of an integrated environment such as CATIA.

2 AN INTEGRATED DATA MODEL

Accurate data modeling is required to describe in a clear and organized way the entities of an urban traffic system. In CATIA an object-oriented modeling technique is used, such that its implementation approach provides an organized and hierarchical structure in different levels of abstraction to describe the system entities. Such a structure facilitates the system viewing in many detailed levels from a macroscopic to a microscopic model, as the movement is dealt with consistently both in a global as well as in an isolated way. OMT was chosen as the object-oriented technique [7]. The basic class diagram is incrementally detailed in Figure 1 and Figure 2.

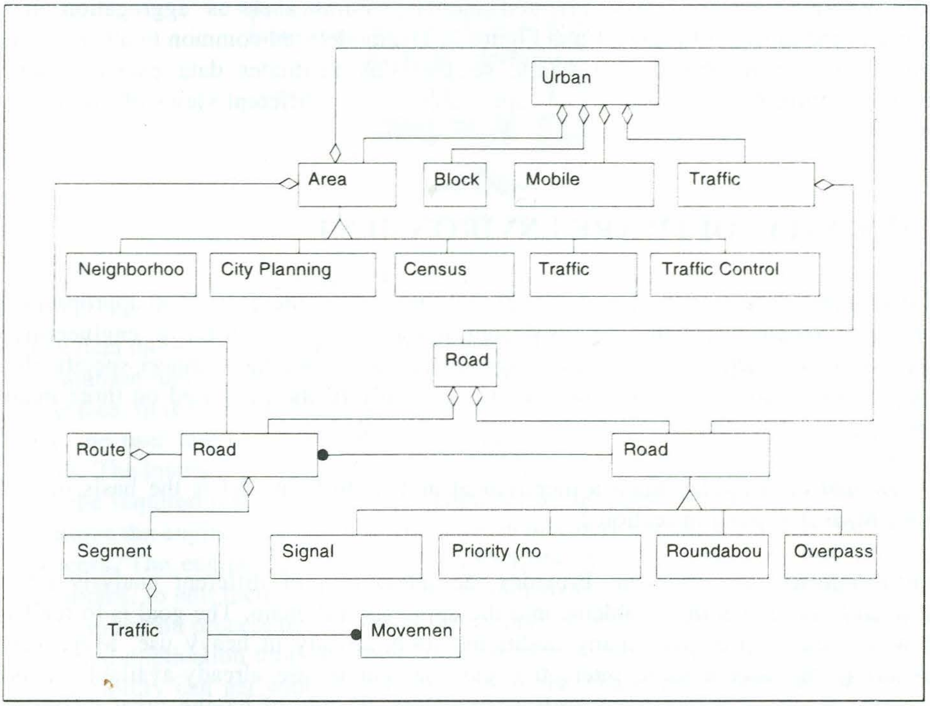

Figure 1 - The basic class diagram.

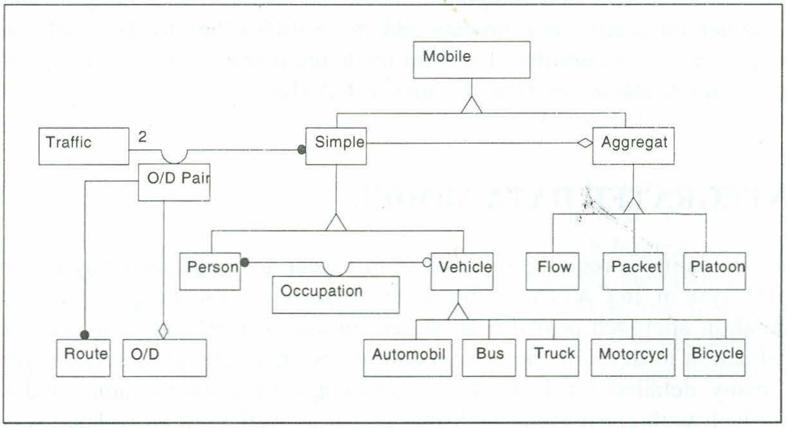

Figure 2 - Basic class diagram – the mobile element hierarchy.

An intuitive as well as formal description of the system entities and the relation among them are provided by the object-oriented model features such as aggregation and inheritance of the objects of Figure 1 and Figure 2. The models are common to all software tools driven by or integrated to CATIA, so that this facilitates data exchange and intercommunication among analysis tools applicable to very different views of the traffic system.

3 THE CATIA SOFTWARE ENVIRONMENT

CATE (Computer Aided Traffic Engineering) tools aim to provide the user an appropriated software environment to aid the various design and analysis tasks in traffic engineering. The CATIA environment constitutes an integrated tool set to aid the engineer specifically in the urban traffic application domain. The CATIA specification is based on three main features:

Object oriented data model. Such a hierarchical and intuitive model is the basis of the environment, as described in section 2.

Integrated Software Environment. Provides the integration of different analysis tools aiming to address the various problems into the application domain. The goal is to render usable within the environment many traditional tools already in heavy use. Moreover, CATIA offers the user a more interactive environment to use already-available tools, adding value by the fact that many traffic simulators, despite of having great technical qualities, are poor in terms of graphics user interface. Used in this mode, the CATIA environment is not adding an analysis model, but in fact providing a support environment.

An integrated environment facilitates the addition and productive usage of new analysis tools, as the interface and the models are reused from the CATIA environment.

Interactive edition tools. The main goal of the interactive tools is to provide a friendly user interaction aiming to facilitate the various steps in the simulation process and to increase the productivity in the analysis phase. Furthermore the interactive tools must help to drive the user to a good understanding of traffic problems as well as to facilitate taking decisions towards more realistic simulation parameters.

The basic architecture of the CATIA software environment is represented as layers in a vertical structure, each layer supporting specific category of functionalities. The architecture is shown in Figure 3.

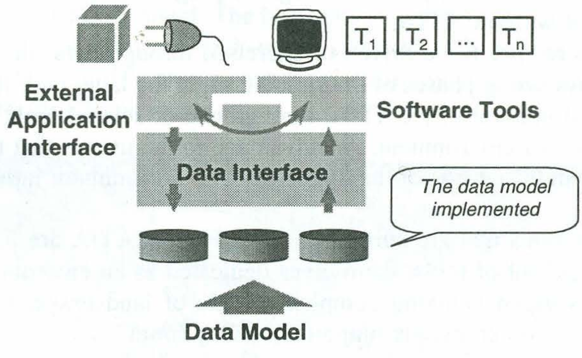

Figure 3 - The CATIA basic architecture.

The data model that describes the application domain, in the lower level is implemented in a database and becomes available to the integrated tools in an organized way. The data interface, in the intermediate level, manages the communication between the database level and the user interface levels that are either the edition tools or the external application tools. The interactive tools constitute the environment graphical user interface (GUI). They are the required resources to aid the engineer in the simulation process. By using CATIA features the engineer can rapidly and consistently perform the main steps in the simulation process. The engineer is aided by CATIA to browse the system entities, to access their attributes, to edit them – changing the system state – to prepare, to execute and to control the simulation process performed by some analysis tool integrated to the environment. The external application tools are those used to address the traffic analysis needs. The system applicability can get wider by adding new tools. The external application tools interface manages the applications integrated to the CATIA environment.

The applications could be either traditional ones based on older software engineering techniques, simulator-specific file I/O and file exchange techniques, or those implemented specifically for the CATIA environment following its specification and using both its API and GUI. The later ones use the object-oriented approach and are then integrated directly by the communication among such objects.

4 INTERFACING WITH EXTERNAL TOOLS - AN EXAMPLE

External tool integration to the environment follows two possible approaches:

1. for application software developed specifically on the CATIA models and API, inter-tool communication is supported through a plug-in that allow interaction among objects modeled within CATIA;
2. legacy systems require to be driven or exercised through data file exchanges in both pre and post-processing phases of the simulation. In the latter case file formats have to be exported and imported by CATIA, through one or several tools that are integrated in this tool-oriented environment. An advantage to the user is that there is no need to deal directly with the edition of the files that drive the simulator input.

Examples of applications that are currently integrated to CATIA are SATURN simulator and the CityZoom [4] set of tools, themselves dedicated as an environment to model and analyze cities in its urban planning complex models of land usage, lot occupation, city rules scenarios, among other models supported by CityZoom.

In the development strategy of CATIA a decision was made to make it fully integrated to the CityZoom tool, in a plug-in model of inter-tool communication. Communication among software objects is the contemporary paradigm used in this project.

The CityZoom environment aims to aid taking decisions related to the urban planning and design tasks. The system basic structure relies on the integration of different urban plant performance models, among them the traffic and transportation models. Key to the success of this environment is the ability to integrate different performance models that need to be considered consistently; a change in land usage criteria has to be dealt with in the traffic modeling and simulations in a consistent way, for instance. CityZoom has an interactive tool set to help in dealing with vastly different urban system entities, some of which are related or are a part of the city traffic network. CityZoom was implemented following the same modeling and implementation object-oriented approach and shares with CATIA the same data model to describe the urban traffic entities.

The first legacy simulation code supported by CATIA in its current implementation is SATURN, and black-box wrapping facilities are yet another set of tools developed for the environment. Supporting external tools of wide commercial acceptance such as, but not exclusively, SATURN is of paramount importance for successful simulation environments. Interfaces to third party tools are just another set of tools, from CATIA environment standpoint.

SATURN aids the analysis of applying different traffic management schemes. It was implemented in Fortran and it is a typical file exchanging based tool, since the users need to edit ASCII files as input parameters to the SATURN functional modules. SATURN simulations have been done in many cities throughout the world, e.g. Porto Alegre.

By integrating these tools into the same software environment, the user can easily benefit from the CityZoom interactive tools and interface in order to avoid an unfamiliar SATURN user interface. As another advantage, the user can apply the results from SATURN running into the common environment as input parameters to other integrated tools as they use the same urban traffic description model. The basic environment interface presented to the user is shown in Figure 4 and follows Windows 95 standards like pop-down menu, tool bars, and a graphic area where traffic entities can be visually selected and edited. All menus are presented in English for international use.

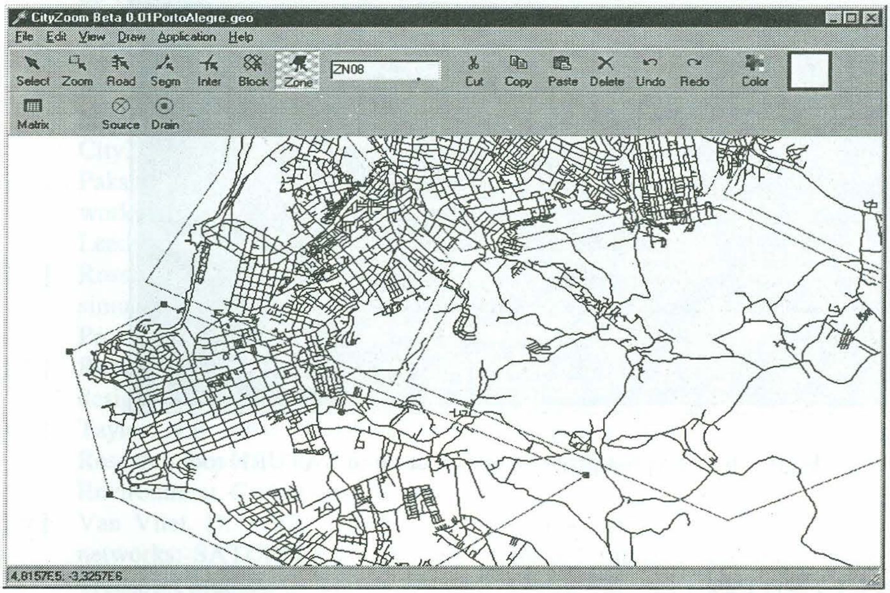

Figure 4 - The basic environment interface.

An example of executing integrated SATURN functions from the CATIA environment is shown in Figure 5. The edition of input files describing parameters of external tools becomes user-transparent as the system entities are edited graphically using the CATIA environment tools. One tool, for instance, is the 2-D network editor. Once the simulation parameters have been set, the SATURN can run from the integrated environment, as shown in Figure 5 and Figure 6.

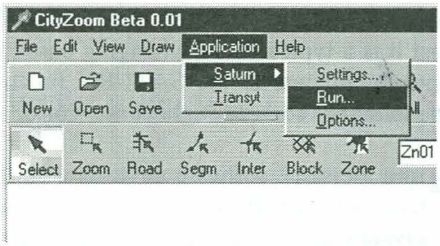

Figure 5 - Executing SATURN from the CATIA environment.

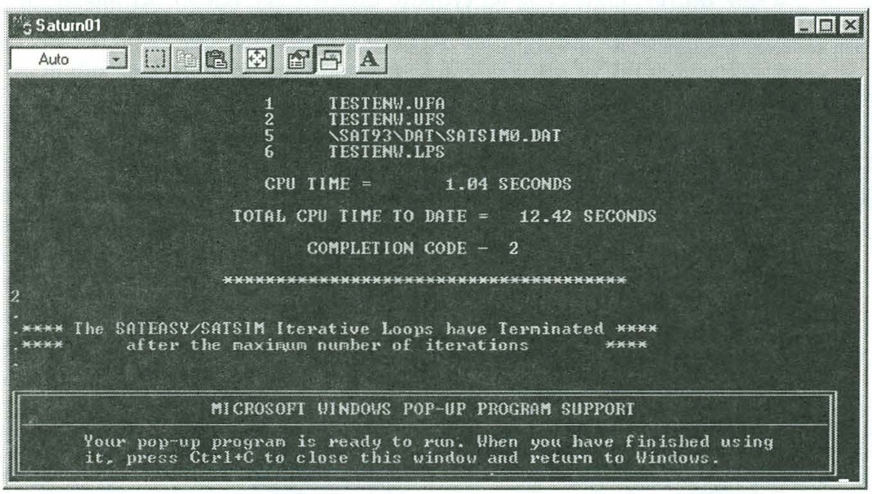

Figure 6 - The post-processing execution of SATURN tool.

5 CONCLUSIONS

The growing complexity of urban traffic models requires the use of a multitude of advanced software tools for various types of analysis. Although many of these tools are of wide commercial acceptance they are oriented to a specific problem. Actually they are efficient in terms of generated results but on the other hand they have great limitation related to their graphical interface. The concepts of the object-oriented approach, systems integration, and visual interactive simulation make the CATIA environment a powerful analysis tool for traffic systems studies. Black-box communication within CATIA facilitates using legacy code, while the plug-in communication approach makes the implementation of new tools easier and increases its applicability as a growing number of tools are integrated to the environment. This offers the engineers an appropriate way to test different policies of urban traffic management and control.

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