DEVS-Based Modeling and Simulation
For Intelligent Transportation Systems

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Contents:

❖ Background
❖ Design Methodology
❖ Case Study: I³D² Traffic Simulation System
❖ Conclusions
❖ Problems and Future Works
Background: Intelligent Transportation Systems

Motivation:
To maximize utilization rate of existing traffic equipments to reduce traffic congestion problems.

Collect Traffic Information
- Ultrashort waves Detector
- Image Detector
- Beacon

Manage and Analyze Traffic Information

Offers Processed Traffic Information
- Traffic Information Services
- Traffic Management Services
- Automatic Navigation Services
Background:
Research trends for ITS

- **Conventional**:  
  H/W-oriented (electronic, mechanical, civil engineering approaches)

- **Current**:  
  - There is a limitation in reducing traffic congestion from extending of existing traffic facilities.  
  - S/W-oriented approach is necessary for ITS  
  - ITS (Intelligent Transportation Systems)  
    - ATIS (Advanced Traveler Information System)  
      - user-oriented  
      - used for efficient traffic guidance  
    - ATMS (Advanced Traffic Management System)  
      - operator-oriented  
      - used for traffic system optimization
Background : Why Modeling and Simulation

for ATMS
- control policy analysis (efficiency, reliability).
- forecasting of congestion propagation depending on traffic accident, road construction ....
- optimal signal control algorithm generation.
- feasibility study of traffic effect.

for ATIS
- forecasting traffic congestions.
- dynamic travelling path finding.
- virtual driving.
Background: Conventional vs. DEVS Simulation

- **Conventional Traffic Simulation Approach**
  - mathematical analytic approach.
  - Mostly microscopic-oriented (where each car is separately injected to the road).

- **Discrete Event Simulation Approach**
  - support both microscopic & macroscopic.
  - provide hierarchical, modular system development environment.
  - fit the dynamic characteristics of traffic system where state transition occurs when light signal change (event).
  - allow level of abstraction
Layered approach for designing ITS simulation

**Layer IV**
- ITS Simulation Environment
  - Intelligent
  - Integrated
  - Interactive
  - DEVS-based
  - Discrete

**Layer III**
- Microscopic Traffic Modeling
- Macroscopic Traffic Modeling
  - Car-following
  - Lane-changing
  - Node & link network

**Layer II**
- Model Abstraction
  - Aggregation
  - Morphisms
  - Simplification

**Layer I**
- Hierarchical, Modular, and Distributed Modeling & Simulation Environment
  - Hierarchical & modular
  - Distributed
  - Object-oriented
Layer I: Hierarchical, Modular and Distributed Modeling & Simulation

- **System Entity Structure / Model Base**
  - Proposed by Zeigler
  - support hierarchical, modular discrete event modeling and simulation environment
  - system entity structure
    - AI-based tree-link knowledge representation scheme that combines the decomposition, taxonomic, and coupling relationships.
  - model base
    - Contains models that are procedural in character, expressed in DEVS (Discrete Event System Specification) formalism

- **DEVS/HLA**
  - DEVS/HLA based distributed simulation environment
  - use of multiple computers for model execution is fast becoming the predominant form of simulation
Layer II : Model Abstraction

Macroscopic Modeling (Street-level)

Macroscopic Modeling (Road-level)

Macroscopic Modeling (Cell-level)

Microscopic Modeling (Vehicle-level)

Real World
Layer III : Microscopic and Macroscopic Traffic Modeling

Microscopic Simulation Model

- Based on the discrete-time approach
- Generally applied and analyzed by the car-following model & the lane changing model. so as to trace the behavior of each vehicle at every time period.
  - Car-following
    - study of which how the driver of a following vehicle try to conform with the behavior of the lead vehicle
  - Lane-changing
    - the core of multi-lane microscopic traffic model in company with the car-following model
    - relatively complex because of the intervention of driver’s characteristics and decision making

Macroscopic Simulation Model

- Can be abstracted from the microscopic model, consists of nodes and links
  - CROSS, TRANSD (Transducer), GENR (Generator), ROAD
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### TRANSPORTATION SYSTEMS

#### VEHICLES
- **VEHICLE**
  - **MOTOR**
  - **PASSENGER**
    - **SUV**
    - **RV**
    - **VAN**
  - **TRUCK**
  - **BUS**

#### NETWORK
- **NODES**
  - **NODE**
    - **CROSS GENR**
    - **TRANSD**

#### LINKS
- **LINK**

#### MANAGEMENT SYSTEMS
- **MANAGEMENT-SYSTEM**
  - **SENSOR**
  - **SIGNAL-CONTROLLER**
  - **TRAFFIC CENTER**

### VEHICLES
- **VEHICLE**
  - **~state variable**
  - **~nature of driver**
  - **~response time**
  - **~gap-acceptance**
  - **~licensed date**
  - **~license type**

#### VEHICLE SPECIFICATIONS
- **license-speccareer-specclass-specemergency-speckenhance-specclass-speccommercial**
  - **MT10Y**
  - **MT5Y**
  - **MT2Y**
  - **LT2Y**
  - **commercial**
    - **non-commercial**
      - **CLASS-A**
      - **CLASS-G**
      - **CLASS-B**
      - **CLASS-D**
      - **CLASS-C**
      - **CLASS-M**

#### NETWORK SPECIFICATIONS
- **~name**
- **~location**
- **~link number**
- **~number of lane**
- **~limited speed**
- **~rear road**
- **~rear cross**
- **~strategy of signal control**
- **~signalizing time**

### DRIVER
- **DRIVER**
  - **~type**
  - **~max-speed**
  - **~max-power**
  - **~feature**
  - **~path-info**

#### DRIVER SPECIFICATIONS
- **~sex-spec**
  - **MALE**
  - **FEMALE**
- **~career-spec**
- **~license-spec**
  - **commercial**
  - **non-commercial**
  - **~number of lane**
  - **~strategy of signal control**
  - **~signalizing time**

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JongKeun Lee — 11
Conceptual Diagram of Traffic Modeling

Simulation model

Layer II : ITS Components

Layer I : Traffic Network & Vehicles

Real world

Modeling

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Conceptual Diagram of DEVS/HLA based Distributed Traffic Modeling
Layer IV: ITS Simulation Environment

- \( I^3D^2 \) Traffic Simulation System
Layer IV: ITS Simulation Environment
- NaeBu Freeway Traffic Simulation System
Performance Analysis

Simulation Model Structure of JOONGBOO Highway
The amount of vehicles generated between East Seoul T.G. and Gonziam I.C. according to collected real data. 

Real Data: Thursday, May 31, 2001, am 05:00 ~ pm 12:00

# of Vehicle
Traffic model’s ability to express

Average travel time of vehicles that drive from East Seoul T.G. to Gonziam I.C according to time period.

Although this has a little faster average travel time than real data, comprehensive traffic phenomena are expressed effectively.

Average Travel Time (m)
### Processing Time of Simulation

The result of simulation for 13 hours in 32Km block of JOONGBOO Highway. About four times faster than real-time.

But, processing time of simulation should be about 6 to 7 times faster than real-time (by Transportation Engineering)

Only so, it is efficient to apply the analysis of real world’s traffic phenomena to real world

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System: Intel Pentium III 500 MHz   RAM: 256MB
Distributed Simulation

Decomposition concept of the large scale traffic network

Sub-Network1

Sub-Network2

Sub-Network3

Sub-Network4

R : Road
c : Cross

RunTime Infrastructure (DEVS/HLA)
Distributed Simulation Result (Abnormal)

Distributed Traffic Simulation Result (abnormal situation)

(a) Time = 500
(b) Time = 600
(c) Time = 2000
(d) Time = 5000
Conclusions

† DEVS-based design methodology for the traffic simulation system has been discussed.
† Discrete event modeling technique can be employed to describe macroscopic model.
† Level of abstraction supports a coherent integration between microscopic and macroscopic traffic modeling.
† Four-layered approach provides a convenient means for evaluating the alternative signal control strategies at the operating level of ATMS as well as for generating the simulation-based forecasting information for ATIS.
† I³D² traffic simulation system has been successfully implemented and tested.
† Finally, it is showed whether DEVS/HLA-based distributed simulation technique can be applied to traffic simulation field effectively.
Some Problems of Our research

- To consider scalability of traffic simulation, DEVS/HLA-based distributed simulation is applied.
- There is a doubt if it effectively enhances the performance
  - The stabilized system structure non-sensitive to fluctuation of objects is necessary.
  - Enhancement of distributed processing speed of DEVS/HLA is required.
    - Reduce the size and frequencies of message for Distributed Traffic Simulation.
    - Apply Predictive Quantization Multiplexer method to Distributed Traffic Simulation.
Future Works

Objective

- Performance Enhancement on DEVS/HLA based Distributed Traffic Simulation

Idea

- Uses the Predictive Quantization Multiplexer method and performs the effective message filtering and compression between two Roads in distributed environment.
- Performs Distributed Traffic Simulation with reasonable communication overhead.
- This idea is based on proposed Methodology by Prof. Bernard P. Zeigler et al.
Data Communication of Distributed Traffic Simulation Envir.

- **Vehicle Information**
  - Transfers the information only when vehicles move to connected federate. But, there are relatively lots of information transferred.

- **Road Information**
  - Transfers information of the front road every time. But it has less data amount at one time than vehicle information.

![Diagram of traffic simulation environment with vehicle and road information communication paths.](image-url)
Moving of Vehicle Information

- Method that minimizes individual variables in each vehicle information is necessary.
- Individual transmission method of vehicle information is multiplexed and transferred.

In Federate A:
- Sender_Road₁
- Sender_Road₂
- Sender_Roadₙ

In Federate B:
- Receiver_Road₁
- Receiver_Road₂
- Receiver_Roadₙ

Network connection between Federate A and Federate B.
Moving of Road Information

As road information requires update of continuous information, Predictive Quantization Multiplex method should be used.
The End

Thank you very Much!