Development and Evaluation of a Hybrid Travel Time Forecasting Model with GIS

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Overview

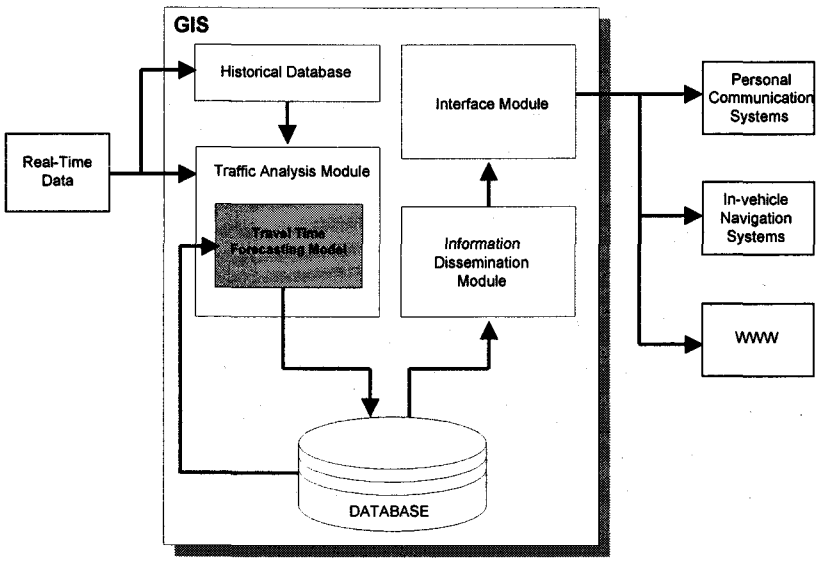
- ❑ Background and Motivation
- ❑ Foundation of a Hybrid Forecasting Model
- ❑ Nonparametric Regression Analysis
- ❑ Conceptual Forecasting System Framework
- ❑ Model Parameters
- ❑ Forecasting System Structure
- ❑ Travel Time Forecasting and GIS
- ❑ Preprocessing Traffic Data
- ❑ Parameter Readjustment: Machine Learning
- ❑ Forecasting System Development
- ❑ Case Studies: Arterial & Highway Traffic Data
- ❑ Contributions and Future Research

Background and Motivation

- ❑ Demand for Transportation Systems Improvement
- ❑ Strong Demand for future travel time information in ITS applications; particularly, in ATIS and ATMS
- ❑ Available Traffic data from early traffic surveillance systems (various vehicle detectors, closed circuit cameras, etc.)

➔ Eventually, future travel time information assist in traffic managers as well as travelers.

Travel Time Forecasting in a Traffic Management and Information Center

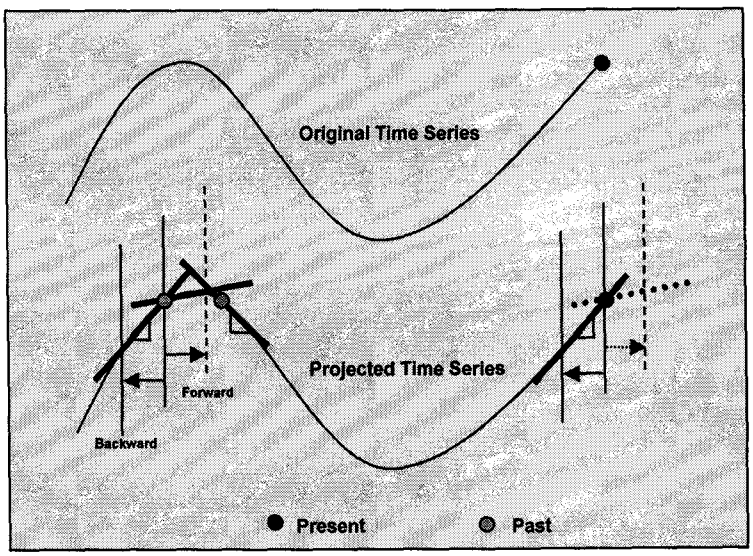


Forecasting Models: a Comparison

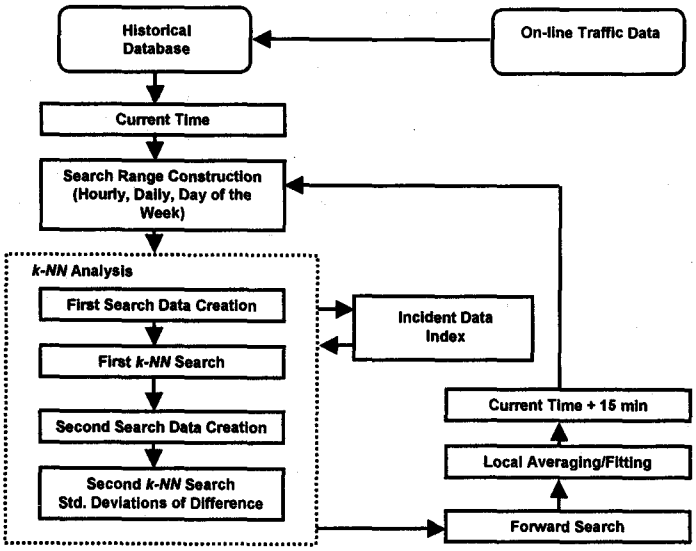
Model \ Evaluation Category	Utilization of Historical Database	Capability of Online Data Use	Transferability of Forecasting Algorithm	Effectiveness of Forecasting Algorithm	Accuracy of Forecasting Algorithm	Capability of Forecasting with Traffic Incidents
Historical Profile Approaches	O	×	O	O	×	×
Time Series Models	O	Δ	×	Δ	Δ	×
Neural Networks	O	Δ	×	×	O	Δ
Nonparametric Regression	O	O	O	Δ	O	×
Traffic Simulation	Δ	O	Δ	Δ	Δ	Δ
Dynamic Traffic Assignment Models	Δ	O	×	×	Δ	Δ

(O) Excellent; (Δ) Good; (×) Poor

Modified Nonparametric Regression



A Hybrid Forecasting Model
(for "15-Minute Ahead" Forecasting)



Model Parameters

- Forecasting Range
  - the prediction length in minute.
- Search Data Segment Length
  - the length of segment for searching traffic patterns from historical database.
- Day of the Week
  - separating weekday and weekend data.
- Search Range
  - limiting the size of the search space in the historical databases.

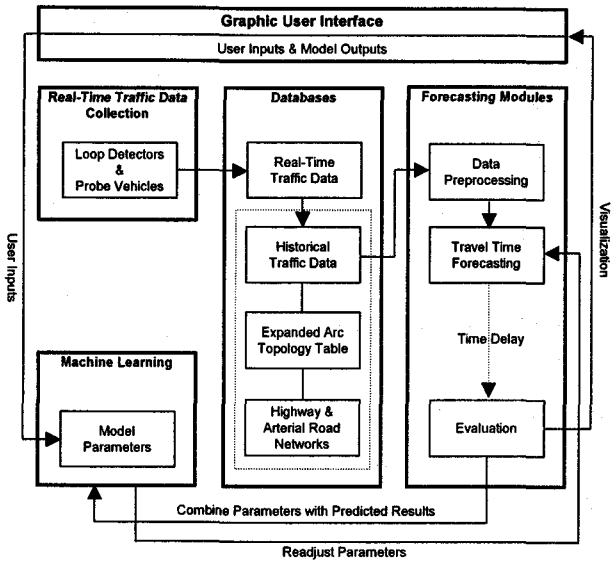
Model Parameters (Continued)

- Large K
  - limiting the number of similar patterns selected from past data.
- Small k
  - the subset of the large K to limit the number of similar patterns to the current condition within K.
- Local Estimation Method
  - calculating travel times from k sets of similar cases (Local Averaging and Local Fitting).
- Data Preprocessing
  - filtering noise from traffic data (wavelet transform or outlier detection)

Domain of Model Parameters

Parameters	Type	Domain	Unit
Forecasting Range	Discrete	{15, 30, 45, 60}	Minute
Search Data Segment Length	Discrete	{15, 30, 45, 60}	Minute
Day of the Week	Binary	{Consider, Ignore}	-
Search Range	Discrete	{1, 2, 3}	Hour
Large K	Discrete	{1, 2, 3, 4, 5, 6, 7, 8, 9, 10}	-
Small k	Discrete	{1, 2, 3, 4, 5, 6, 7, 8, 9, 10}	-
Local Estimation Method	Binary	{Local Averaging, Local Fitting}	-
Data Preprocessing	Binary	{Wavelet, Outlier Detection}	-

A Schematic Structure of Hybrid Forecasting Model

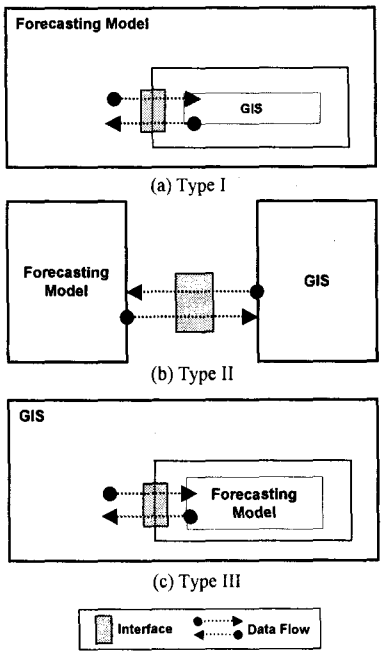


GIS and Travel Time Forecasting

- Roles of GIS
  - Data Management
  - Technology Management
  - Information Management
- Functions of GIS
  - Creating and editing traffic networks with topology,
  - Assisting in both managing and visualizing historical and online traffic data,
  - Providing graphic user interfaces (GUIs),
  - Supporting application development environments for the integration of forecasting algorithms,
  - Providing flexible spatial data analysis tools, and
  - Disseminating forecasted results for internal and external use.

Three Possible Types of Model Integration with GIS

- ❑ Type I: Forecasting Model "including" GIS
- ❑ Type II: Forecasting Model "connected to" GIS
- ❑ Type III: Forecasting Model "within" GIS



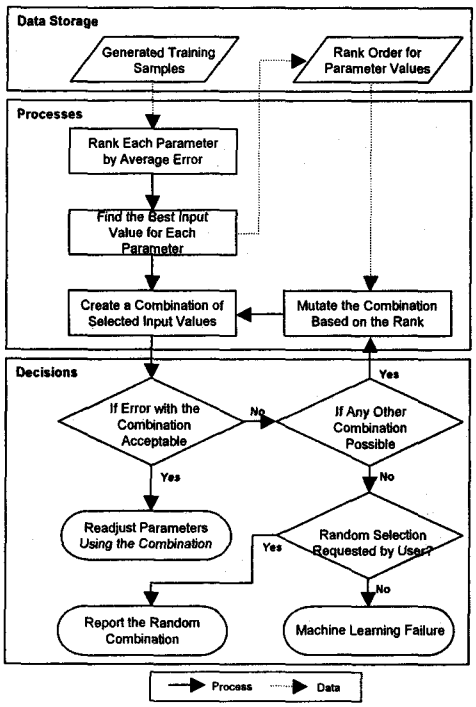
Development Tools for Type I Integration

Functions	Development Tools
• Supporting user inputs and system controls	Visual BASIC
• Displaying networks	ODE ARCPLOT ActiveX Control
• Managing real-time and historical data	ODE ARCPLOT ActiveX Control
• Representing traffic networks	ODE ARCPLOT ActiveX Control
• Simulating real-time data inputs	Visual BASIC
• Screening and filtering raw traffic data	MATLAB: Wavelet Transform Visual Basic: Robust Estimation
• Performing predictions	Visual BASIC and Visual C++
• Managing forecasting model executions	Visual BASIC
• Evaluating predicted results	OLE MSGraph Object

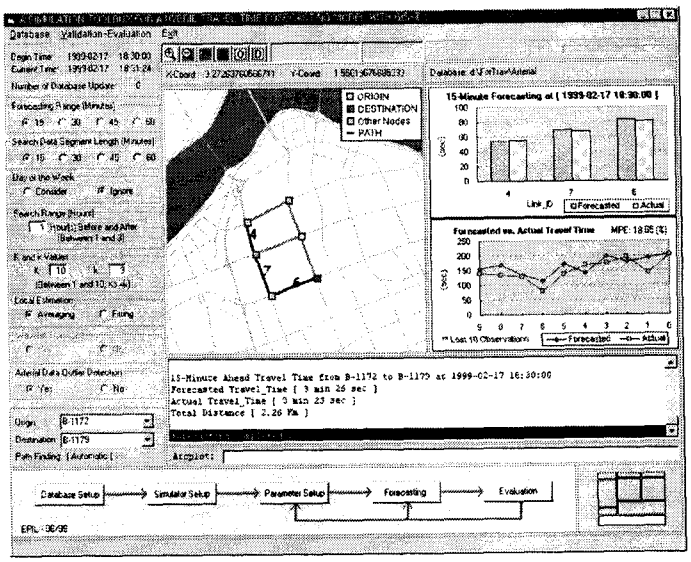
Data Preprocessing

- Wavelet Transformation Technique
  - Utilizing Moving Averages (Approximation) with Moving Differences (Details)
  - Useful for Noisy Highway Loop Detector Data
- Robust Estimation Technique
  - Utilizing Median Absolute Deviation (MAD)
  - Useful to Eliminate Extreme Outliers from Probe Vehicle Data

Parameter Readjustment: Machine Learning



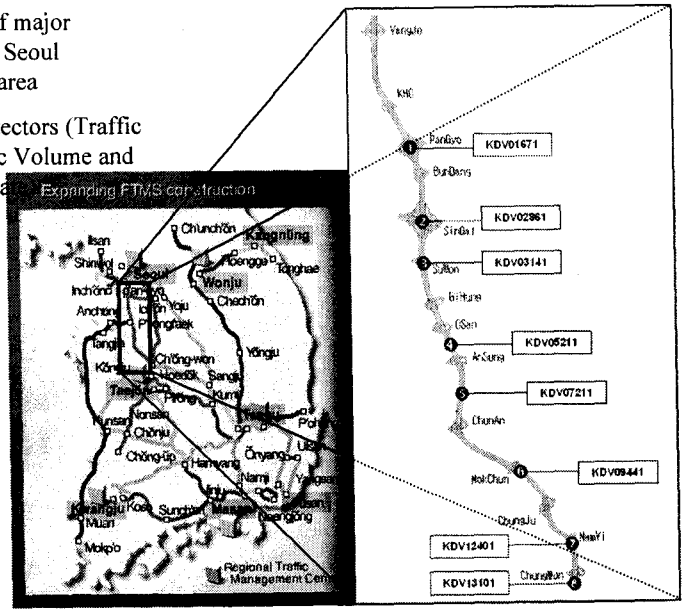
System Development



ForTrav (Type I)

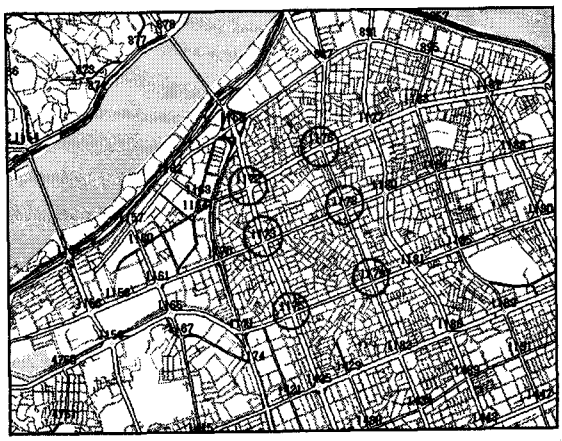
Study Area (Highway)

- A section of major highway near Seoul metropolitan area
- 8 Loop Detectors (Traffic Speed, Traffic Volume and Occupancy Ra
- 114.3 Km

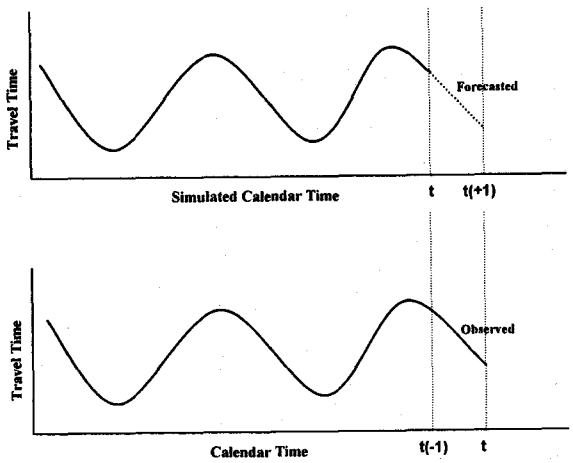


Study Area (Arterial)

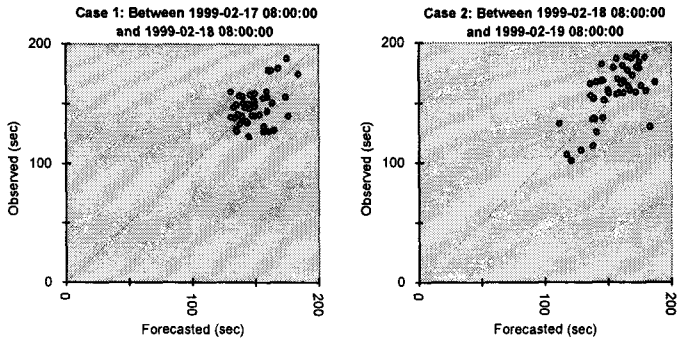
- 6 Roadside Beacons in South of Seoul
- 7 links on 5 major arterial roads
- Total length: 5.3 Km



Simulated Forecasting using Historical Database

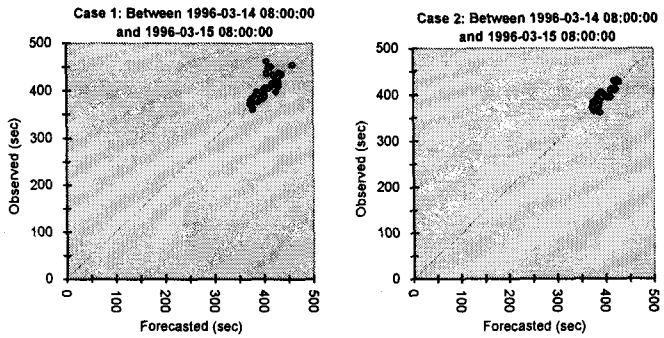


Forecasting based on Randomly Selected Discrete Time Points with Arterial Data (Origin: B1173; Destination: B1179)



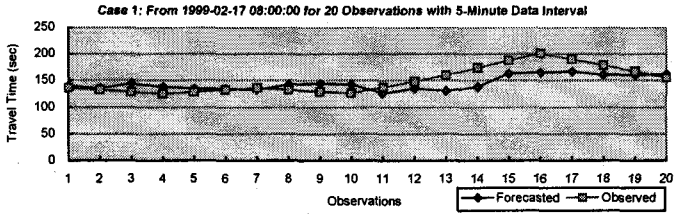
	RMSE (sec)	*MAPE (%)*	*ρ*	*Average Observed Travel Time*
Case 1	15.47	8.02	0.47	148.50
Case 2	19.63	9.88	0.66	161.67

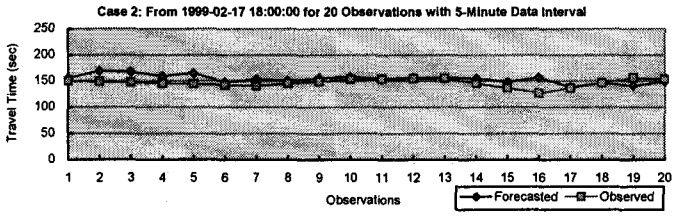
Forecasting based on Randomly Selected Discrete Time Points with Highway Data (Origin: PanGyo; Destination: SinGal)



	RMSE (sec)	*MAPE (%)*	*ρ*	*Average Observed Travel Time*
Case 1	14.27	2.22	0.83	404.48
Case 2	8.46	1.67	0.90	390.52

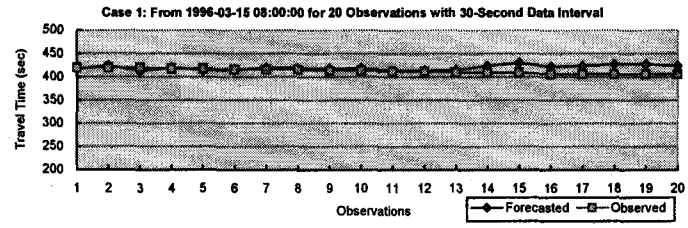
Forecasting based on Continuous Time Points with Arterial Data (Origin: B1173; Destination: B1179)

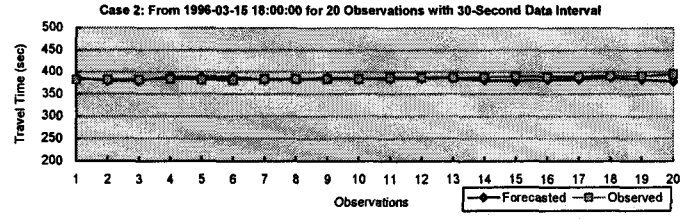




	RMSE (sec)	*MAPE (%)*	*Average Observed Travel Time*
Case 1	17.76	9.29	150.27
Case 2	12.50	6.68	146.55

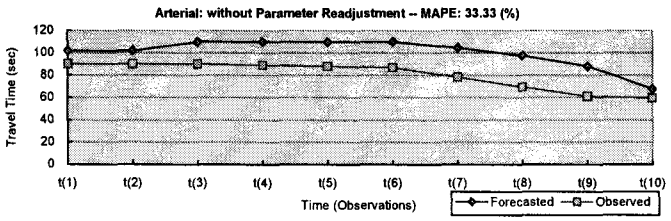
Forecasting based on Continuous Time Points with Highway Data (Origin: PanGyo; Destination: SinGal)

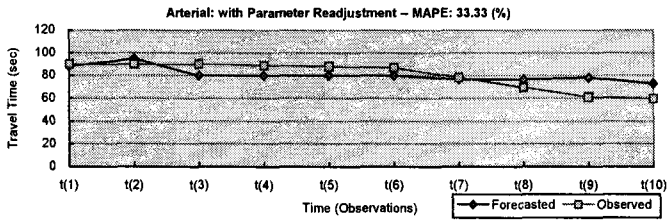




	RMSE (sec)	*MAPE (%)*	*Average Observed Travel Time*
Case 1	11.47	2.14	412.80
Case 2	6.03	1.23	385.34

Performance Evaluation for the Machine Learning Module





	RMSE (sec)	*MAPE (%)*	*Average Observed Travel Time*
Without Readjustment	20.90	25.44	80.27
With Readjustment	9.16	10.81	80.27

Contributions

- A nonparametric regression model has been formulated and developed for forecasting travel time on road networks.
- Type I model has been designed and implemented by embedding GIS functions.
- A machine learning module has been integrated with the travel time forecasting model, showing positive performance evaluation results.

Future Research

- Parallel Processing
  - The hybrid forecasting model requires various modules that perform intensive calculating, searching, sorting, etc.
- System Calibration
  - The hybrid forecasting model requires intensive system calibration in the system initialization stage when applying it to traffic information centers.
- Information Management
  - It is necessary to prepare strategies to disseminate predicted travel time information within traffic information centers and distribute it to public.