Evaluation of Advanced Mobile Information Systems (AMIS) for the Winter Olympic Games in Nagano, JAPAN 1998

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Summary

The 18th winter Olympic Games were held in Nagano Japan. These were the final Olympic Games of this century. As traffic management measures for this event, Nagano ITS such as the Advanced Mobile Information Systems(AMIS), Mobile Operation Control Systems(MOCS), Dynamic Route Guidance Systems(DRGS) and Public Transportation Priority Systems(PTPS) were developed and installed. In an effort to ease traffic congestion and moderate traffic flow during this event, the AMIS provided travel time, traffic congestion and regulation information through infrared beacons to drivers equipped with VICS in-vehicle units. The AMIS is a core system in the Nagano ITS. It uses infrared beacons that permit two-way communication between vehicles and the traffic control center. This paper describes an outline of the travel time and congestion information estimation techniques we developed and explains some of the results we obtained in our evaluation of their accuracy.

INTRODUCTION

The key to the success of the AMIS is its ability to provide accurate travel time data and congestion information in real-time according to varying traffic conditions. This system is indispensable for moderating traffic conditions and alleviating traffic congestion, especially during the Winter Olympic Games.(1) If more than ten percent of the vehicles on the road are equipped with VICS ready navigation systems, the accuracy of the travel time data will be enhanced. In the early stages of deployment, however, the percentage of vehicles likely to be equipped with navigation aids of this nature is expected to be fairly low. Therefore, even in this case, the AMIS should provide travel time information of tolerable accuracy using a sophisticated travel time estimation technique and existing traffic detector data.

During the Nagano Winter Olympic Games, the AMIS link travel time data was provided to MOCS and DRGS systems to enable them to provide travel time for their purposes. The AMIS was, therefore, the key system in the Nagano ITS.

CHARACTERISTIC OF THE AMIS

OUTLINE OF THE AMIS

This system gathers and provides travel time information around the downtown Nagano area, Hakuba area, Iizuna area, with a total of 309 locations using 414 infrared beacons to moderate traffic. The traffic data provided consists of travel time estimates and congestion information updated every five minutes on simplified diagrams(Figure 1) and navigation maps(Figure 2). Figure 3 shows an outline of the system. The AMIS also uses traffic data gathered by existing traffic information central processors. The AMIS in Nagano itself consists of a U-type information provision central processor and two U-type information front end processors which handle two-way communications through the use of infrared beacons. The information obtained from the beacons is called up-link information.

Figure 1 Examples of AMIS travel time information

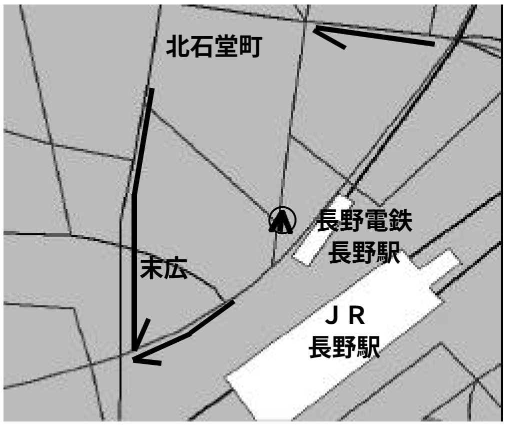


Figure 2 Example of AMIS traffic congestion information

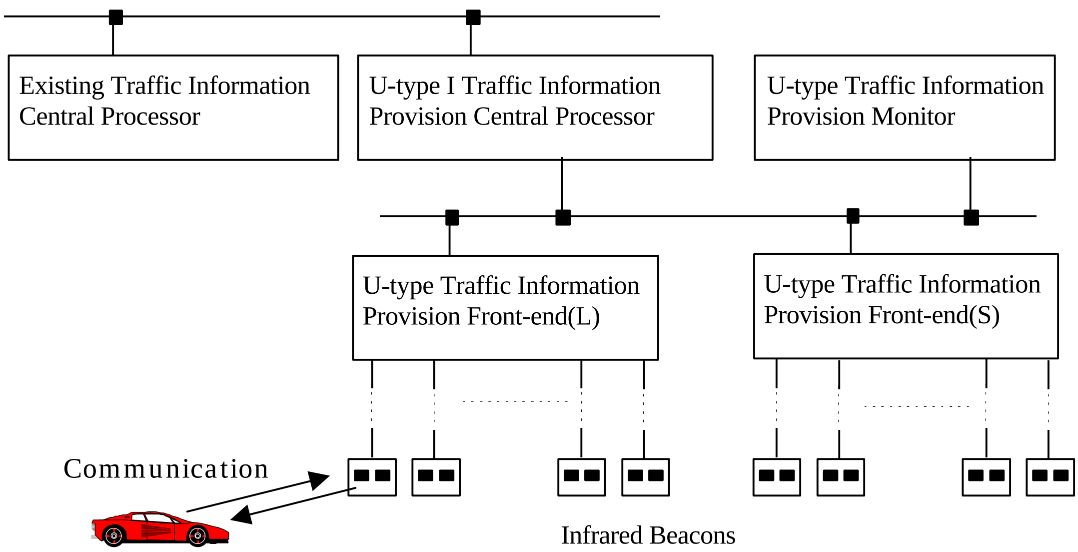


Figure 3 Outline of AMIS in Nagano

TRAVEL TIME ESTIMATION METHODS

In this system, traffic information, such as travel time and congestion status, are produced every five minutes for each link. A link is a minimum division of road sections. The travel time estimation method, as developed, is a hybrid method in which one of five methods in the following is selected to estimate the travel time according to the data available, which may differ from link by link. This hybrid method allows the system to behave in a graceful manner without suffering severe degradation as a result of insufficient information.

1. Travel time from infrared up-link information
2. Travel time from existing AVI(Automatic Vehicle Identification Systems)
3. Travel time from existing vehicle detectors(mainly, ultrasonic detectors)
4. Travel time database gathered from vehicles running beforehand.
5. Travel time calculated by regulation speed.

Method 1,2 and 4 use the travel time data actually measured. In one of these cases estimated travel time is calculated by linearly dividing the data by ratios of the link. In Nagano, travel time estimation using existing detector data(Method 3) played an important role in the overall system. We found that the sand clock method was difficult to apply because it requires a high density of detector installations. By also taking the processing speed into account, we decided to develop a linear combination model and a learning algorithm of the travel time using existing detector data. The estimation algorithm is a learning algorithm in which actual travel time data is used as training travel time data, and minimizes the errors between the training data and the travel time estimate from the linear model by tuning the parameters in the model. The existing detector data consists of traffic volume and vehicle occupancy information obtained at five minute intervals. From this base, velocity is estimated. The linear combination link travel time is estimated using the average velocity as a weighted sum of each base velocity within each link. The error between the linear combination link travel time and the training travel time may be minimized by adjusting the weights as described below.

link travel time estimate $$T_e(t_i) = bias + L / \sum_n a(n) v(n, t_i) \qquad \text{.........................(1)}$$

evaluation function $$E = \sum_i \left| T_e(t_i) - T_r(t_i) \right|^2 + \alpha \sum_n \left| a(n) - a_{mean} \right| \qquad \text{...............(2)}$$

In Equation(1), $v(n,t_i)$ is a base velocity given by detector n at time t_i, a(n) is the weight assigned to it and L is the link length. The parameter bias tries to represent local travel time consumed at intersections and because of other factors. The evaluation function E of Equation(2) represents the mean square error between the training data $Tr(t_i)$ and estimated data $Te(t_i)$. " a_{mean}" in Equation(2) is the average of all weights. The second term on the right-hand side of Equation(2) tries to use all possible detector data in order to distribute risk. α is a predetermined parameter used for this purpose. We decided to minimize E with a genetic algorithm, because the evaluation function may be reformed in the future.

CONGESTION LEVELS AND LENGTH

The AMIS also provides congestion level and length information. On a link where detectors have been installed sufficiently, such as a main road, congestion levels are calculated by utilizing the traffic volume and occupancy information from the detectors. Congestion length is estimated by using the length from the link end to the detector. However, wherever detector installation density is limited, it becomes difficult to estimate the congestion directly from the detector data alone. For these links, we use a method which estimates congestion from the link travel time data mentioned above.

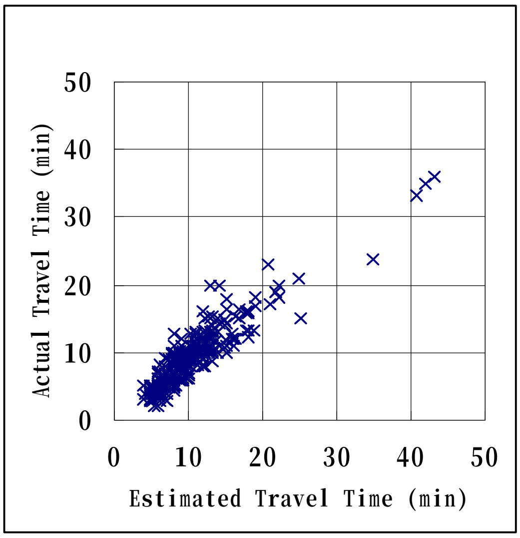
ELIMINATION OF FALSE DATA

In order to avoid accumulating excessive travel time caused by vehicles being illegally parked under a detector or for any other reason, false data must be need eliminated. Travel time data from on-road sensors are judged to be true or false in relation to given threshold values. If the data are judged to be false, another lower-ranked method among hybrid method mentioned above is adopted. In regards to congestion information, a similar process is also implemented. Moreover, we append the elimination filtering process in providing travel time information. This filter compares the current travel time to a historical record of recent travel time and, if the difference is too great, we try to substitute the current travel time value with a recent past representative value(the median of travel time for a typical 20-minute time period in the recent past). This filter eliminates false data and successfully tracks sharp increases in travel time during morning rush hour periods.

EVALUATION AND STUDY

EVALUATION OF TRAVEL TIME ESTIMATION

We evaluated the accuracy of travel time by comparing the estimated travel time with the actual travel time during the Winter Olympic Games (from Feb. 9^{th} to Feb.22^{nd} 1998). The evaluation was conducted in several sections on Route 18, the main road through Nagano bound for Tokyo. The results are shown in Figure 4, Figure 5 and Table 1. Figure 4(a) shows the total correlation graph of the actual travel time and the estimated travel time using our hybrid travel time estimation method. Figure 4(b) shows an enlarged graph of Figure 4(a) within 15 minutes. Figure 5 shows a histogram of travel time errors between the actual travel time and estimated travel time. Table 1 shows the results of the analysis of these data. 69% of the trips were within a 2-minute error range. From the analysis, the estimated travel time distribution slightly shifted from the actual one. This is because the provided travel time was intentionally increased by one minute in order to decrease the possibility of providing too short a travel time.



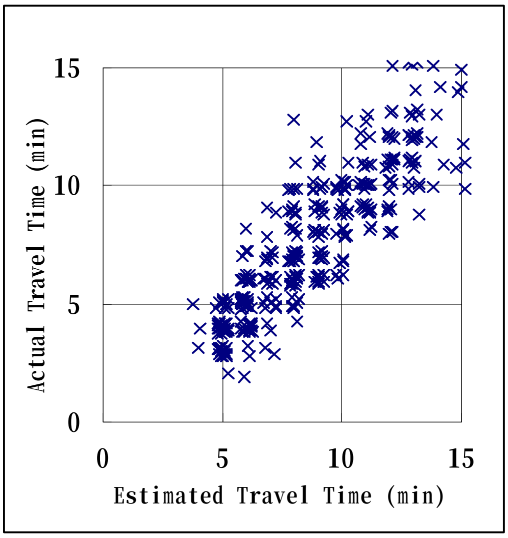


Figure 4(a) Correlation between actual travel time and estimated travel ti

Figure 4(b) Enlarged graph of Figure 4(a) (within 15 minutes)

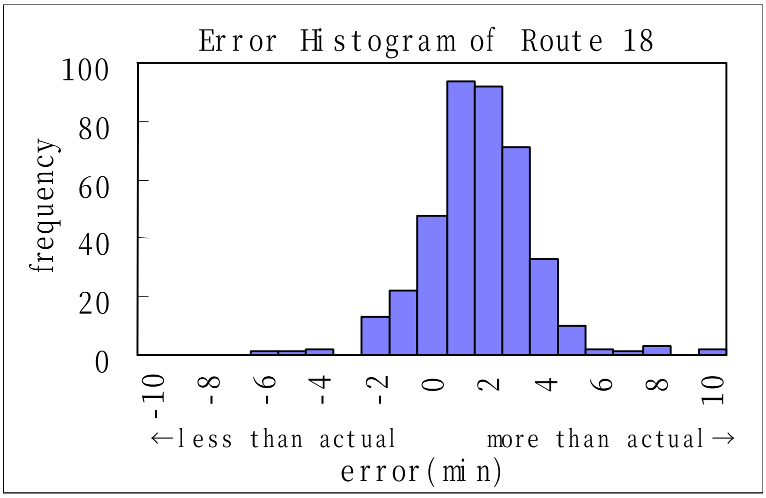


Figure 5 Histogram of travel time error

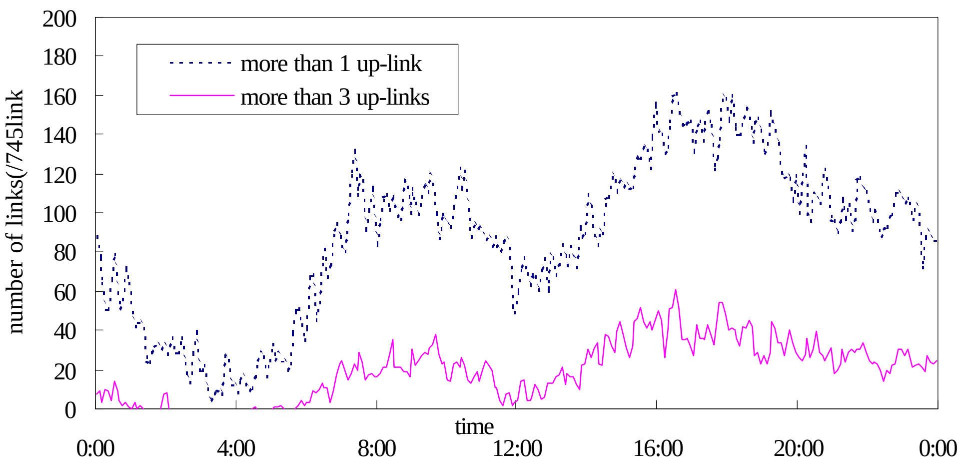
Table 1 Evaluation results

Number of Data	395
Average Travel Time	8.5 (min)
Ratio of Less Than 3 min Error	86 (%)
Average Absolute Error	1.7 (min)
Maximum Absolute Error	11 (min)
Correlation Value	0.92

EVALUATION OF UP-LINK TRAVEL TIME

We have also evaluated the up-link travel time characteristic of AMIS. Figure 6 shows the profiles of the number of links that received up-link information every five minutes on Feb. 7(the day of the Olympic opening ceremony). For utilization of up-link information, three or more data every 5 minutes are required. The maximum number of links which received up-link information every five minute interval was about 60(The total number of links was 745). This trend was applied over the whole period of the Winter Olympic Games.

Correlation between the accuracy of the estimated travel time and the number of up-links was evaluated. The data used for evaluation was the same data used in the previous section. Figure 7 shows a correlation between the mean number of up-links at one link and the travel time error. In spite of the low number of the total up-links, the error decreases as the number of up-links increases. Figure 8 shows a correlation between up-link rate and the travel time error. The travel time provision section consists of several links. The up-link ratio is defined as the ratio of the number of links which receive a sufficient number of up-links versus the total number of links included in the travel time provision section. In this case, the error was also reduced as the up-link rate increased. These results show that up-link information is effective for the provision of travel time information. In spite of the amount of up-link information, data including large error was occasionally observed. The reason may be that vehicles uploaded greater than the actual travel time information by stopping for a while and then driving



again.

Figure 6 Profile of number of inks which receive up-links

EVALUATION OF PROVISION OF CONGESTION INFORMATION

Because the estimation of congestion information, such as degree and length of congestion, changes dynamically and depends on personal feelings, the evaluation is difficult. In this paper, one congestion estimation data was picked as a reference. Figure 9 shows the profile of the estimated value of travel time and congestion length in a section from Kawaishinden-minami to Higashi-wada, (about 4 km) on Route 18 on Feb. 7. In this case, the profile of estimated travel time was nearly synchronized with that of congestion length. In the Nagano Prefectural Police Headquarters Traffic Control

Center, real-time images from observation cameras placed at main intersections are available. The state of congestion from these images coincided for the most part with the congestion information displayed on the information provision monitors. No complaint to this center about the difference between actual congestion status and congestion information provided during the Winter Olympic Games, or before or after, was made. Therefore, good results were produced with the provision of the congestion information.

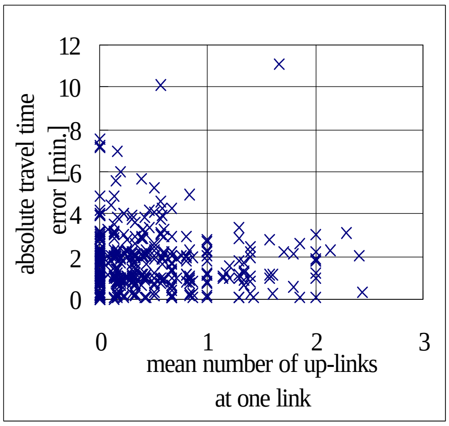


Figure 7 Correlation between mean number of up-links at one link and estimated travel time error

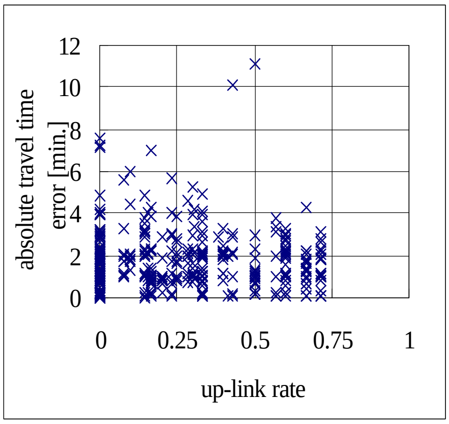


Figure 8 Correlation between up-link rate and travel time error

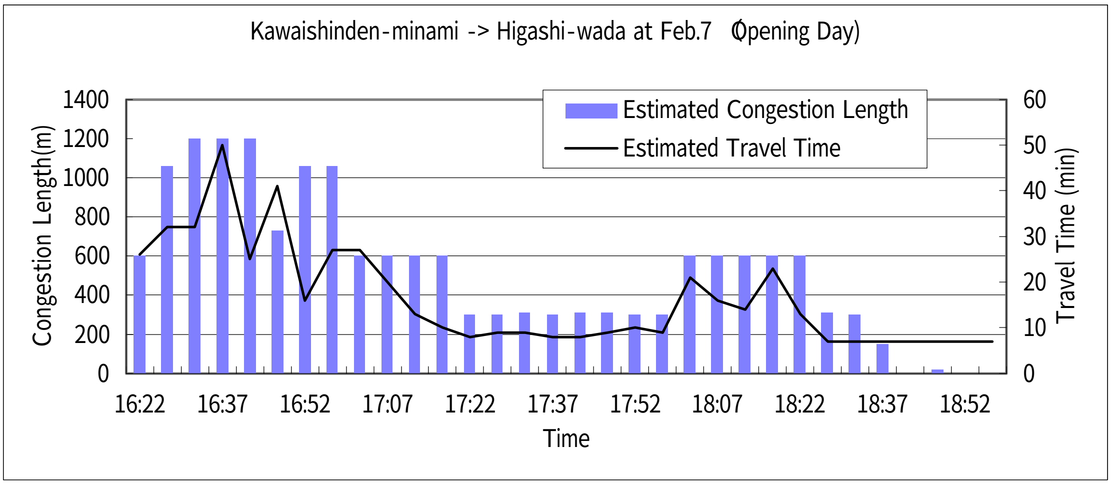


Figure 9 Profile of the estimated value of travel time and congestion length

CONCLUSION

During the Nagano Winter Olympic Games, over a period of 16 days, provision of travel time information with an error range of three minutes was achieved on almost all the routes in the presence of dynamically changing traffic conditions due to weather and game schedules. 24-hour continuous operation of the systems also contributed to smooth traffic management throughout the event. At the Nagano Prefectural Police Headquarters Traffic Control Center, a WWW site on traffic information utilizing AMIS was opened which provided the world with real-time information through the Internet.

The accuracy of estimated travel time was much higher than we had predicted. This may be because of:

1. the new estimation method utilizing proper compensation of existing detector information.
2. the large amount of up-link information from the over one thousand NAOC vehicles equipped with VICS-ready navigation systems.

After the event, the NAOC vehicles left Nagano and a decrease in the number of vehicles with navigation systems was predicted. Even in this situation, the estimation method tries to maintain its accuracy by shifting its mode down. In this case, the conventional detector data must be indispensable in obtaining accurate travel time information because of fewer up-link data has been obtained after the Winter Olympic Games. We evaluated the performance of the method utilizing conventional detectors before the event, when the NAOC vehicles were rarely seen. A little over 80 % of the total travel time data was covered in an error range of three minutes. Consequently, the method was thought to have a good performance after the event. The validity of up-link data was confirmed from the evaluation results. It is expected that the diffusion of VICS-ready navigation systems will be accelerated with these results.

Future subjects for investigation are listed below:

1. Higher accuracy of estimations of travel time and congestion information.
2. Valid utilization of up-link data in the case of a small amount of up-link data.
3. More advanced techniques for the elimination of false up-link data.

AMIS has been operating since the Winter Olympic Games and are providing traffic information. Further functional expansion is planned for the future.

ACKNOWLEDGEMENTS

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Reference

[1] Yoshimi Tanaka, “ITS Traffic Management for Nagano Olympic Winter Games in Japan”, 4th ITS World Congress, Berlin, 1997.