PAPER

A Study on Forecasting Road Surface Conditions based on Weather and Road Surface Data

Atsuhiro SAEGUSA[†], *Nonmember and* **Yoshitaka FUJIWARA**[††], *Member*

SUMMARY Thanks to recent improvements in road heating technology, traffic problems due to icy roads are decreasing. However, there has always been concern about the high operational and maintenance cost associated with road heating. One way to reduce the cost is to reduce the time when power is applied for preheating because it is often applied even when a road is not likely to be icy. The authors believe that, if it is possible to forecast accurately whether a road will become icy, unnecessary preheating can be greatly reduced. This paper presents an algorithm for forecasting physical road conditions. The algorithm divides the weather conditions that people perceive daily into 11 patterns. The comparison between the changes in road conditions as determined by our method and known changes in road conditions has shown a 12% increase over previous methods in forecasting accuracy.

key words: *Forecasting algorithm, Road heating*

1. Introduction

In Hokkaido, where the authors live, recent years have seen a dramatic improvement in the road infrastructure. This has encouraged people to move about and interact with people over a wider area in everyday life. However, since the use of studded tires was prohibited in 1991, slippery roads in winter have become a source of great concern, giving rise to increased demand for measures to improve road conditions in winter. The first and foremost measure that has been taken has been the heating of roads, which has indeed played a key role in ensuring road safety. However, the operation and maintenance costs of road heating have become a profound economic burden, forcing some communities to abandon heating in some places. A possible solution to this problem is to reduce preheating time. Preheating is heating a road before that road freezes. There have been many studies that focused on reduction in preheating time. Methods which have been reported include, for example, a method of confirming field conditions from images captured by a camera[1], a method of forecasting road freezing by obtaining weather forecast data and field data[2], and a combination of these two methods[2]. This paper proposes a new method of forecasting freezing conditions on roads by obtaining weather forecast data and field data. Our method differs from the previous method in the way road conditions are forecast. While the previous method identified one out of 44 situations based on the precipitation occurring in the previous one hour, and the temperature and other conditions of the road surface concerned, our method forecasts road conditions by categorizing weather conditions we can ordinarily identify into 11 patterns. Although a number of statistical methods of this type have been reported[3], they are not generic enough and cannot be applied effectively to other areas because predicting the weather trend of a specific area by using a correction function, multiple linear regression analysis, or pattern analysis based on multiple observed weather factors requires the collection of data relating to the area over a period of 2 or 3 years. In contrast, since the method proposed in this paper obtains the weather characteristics of a specific area using a mesh forecast and a weekly forecast data, it does not require the continual collection of data. Section 2 of this paper presents the basic concept of our approach. Sections 3 and 4 discuss the methods for forecasting ambient temperature and road surface temperature, which are needed for forecasting road conditions. Section 5 describes our goal of forecasting road conditions. Finally, Section 6 gives results obtained using our method.

[†]Shari-cho Agricultural Co-operatives
[††]Department of Computer Sciences, Kitami Institute of Technology

2. Basic concept

2.1 Basic ideas

In our method, road conditions are forecast by using "data from weather observations in the field" (hereafter referred to as *field data*), and "weather forecast data" (hereafter referred to as *forecast data*). The flows for obtaining these data for use in forecasting road conditions are shown in Fig.1.

As shown in Fig.1, forecast data are obtained from the Japan Weather Association via a leased line. These data are collected at a predetermined interval using dedicated data reception software. Field data are sent by mail from terminals that collect weather data of the locations where road condition forecasting is needed. The forecasting system collects these data by accessing a designated mail server every hour. At the forecasting system terminal, the collected forecast data are corrected using the collected field data. The corrected data are used to forecast the ambient temperature, road surface temperature and road conditions. Details of

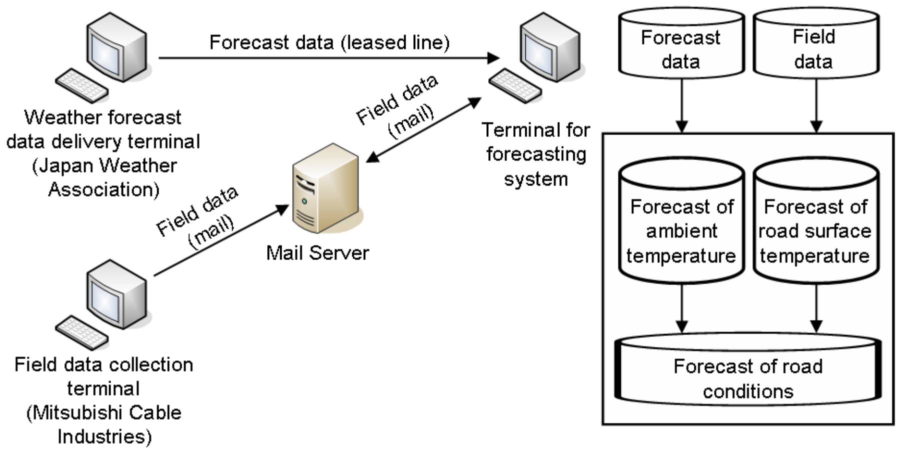

Fig. 1 Flow for obtaining data and forecasting

forecast data and field data are explained below.

2.2 Definition of forecast data

Forecast data are based on past weather data. There can be a great variety of past weather data. Our method relies on two sources: what we call *wide area mesh forecast data* and *weekly forecast data*.

2.2.1 Wide area mesh forecast data

Wide area mesh forecast data (hereafter referred to as *mesh forecast data*) are as follows. First, Japan is divided into 6 blocks: Hokkaido, Tohoku, Kanto and Chubu, Kansai and Shikoku, Kyushu, and Okinawa. Each block is broken into approximately 5-km square sub-blocks, each representing about 2.5 minutes of latitude and 3.75 minutes of longitude. A set of forecast data contains data for a 120 × 120 grid of such sub-blocks (Fig.2).

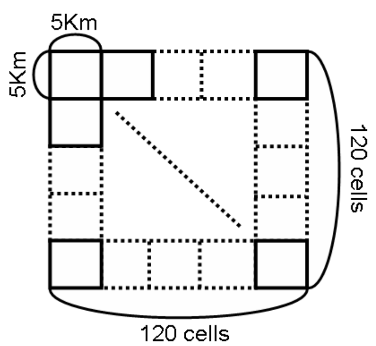

Fig. 2 Wide area forecast mesh model

Mesh forecast data are delivered twice a day. Each set of data provides forecast data for every hour over the next 51 hours. Mesh forecast data contains six items: ambient temperature, wind direction, wind speed, precipitation, humidity and sky condition (clear, cloudy, rainy, etc.). Of these, our method uses only ambient temperature and sky condition (which are hereafter referred to as *mesh ambient temperature* and *mesh sky condition* respectively).

2.2.2 Weekly forecast data

Weekly forecast data are forecast for each administrative area. These data are sent twice a day. Each set of data contains forecast data for every six hours in the next one week. Weekly forecast data contains three items: ambient temperature, precipitation and sky condition. Our method uses only sky condition (which is hereafter referred as *weekly sky condition*) Thus, we use both mesh sky condition and weekly sky condition. The intention is to compare road condition forecasting results based on these two different items of data.

2.3 Definition of field data

Field data are collected using different types of sensor located at observation points. Data are collected every hour and sent by mail. Each set of data contains 10 items: ambient temperature, wind speed, wind direction, humidity, sky condition, road surface temperature, road condition, etc. Of these, our method uses only ambient temperature, sky condition, road surface temperature, and road condition (which are hereafter referred to as *field ambient temperature*, *field sky condition*, *field road surface temperature*, and *field road condition* respectively).

3. Ambient temperature forecasting algorithm

This section presents the ambient temperature forecasting algorithm referred to in Fig.1. The Mesh ambient temperature is corrected using the field ambient temperature in order to forecast the ambient temperature more accurately. Figure 3 shows the mesh ambient temperature, $T_{am}(t)$ (-24 $\leq$ t $\leq$ 24), at a given time, t. $t = 0$ indicates the present time. Past time is indicated by a negative value, and future time by a positive value.

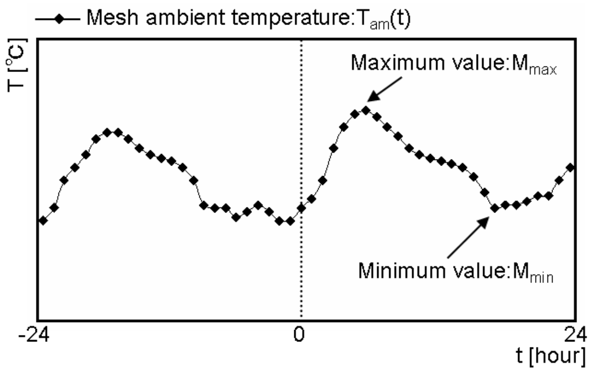

Fig. 3 Ambient temperature forecasting algorithm, step 1 (mesh ambient temperature is normalized)

First of all, we normalize the mesh ambient temperature, $T_{am}(t)$ (0 $<$ t $\leq$ 24). The normalized ambient temperature, $H(t)$, is derived from the maximum value, M_{max}, and the minimum value, M_{min}, of the mesh ambient temperature, $T_{am}(t)$, as follows:

$$H(t) = (T_{am}(t) - M_{min})/(M_{max} - M_{min}) \quad (1)$$

When the maximum and minimum ambient temperatures for the ambient temperature to be forecast are known, the forecast ambient temperature can be calculated using $H(t)$ as:

$$y(t) = H(t) \times (Y_{max} - Y_{min}) + Y_{min} \quad (2)$$

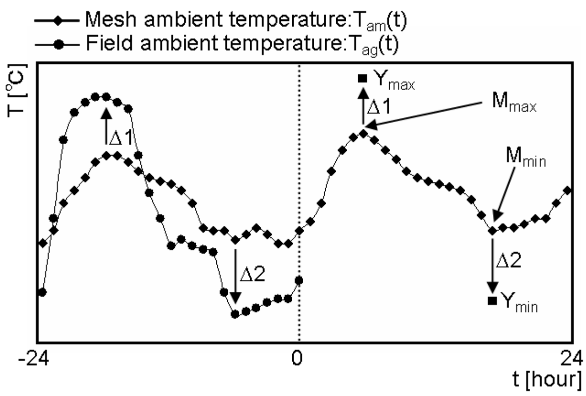

Fig. 4 Ambient temperature forecasting algorithm, step 2 (calculation of maximum and minimum forecast ambient temperatures)

where $y(t)$ is the provisional forecast ambient temperature. Next, we will derive the maximum and minimum values of $y(t)$. Let $\Delta 1$ and $\Delta 2$ be the differences in the maximum and minimum ambient temperatures respectively between the mesh ambient temperature, $T_{am}(t)$, and field ambient temperature, $T_{ag}(t)$ in the last 24 hours (-24 $\leq$ t $\leq$ 0). $\Delta 1$ and $\Delta 2$ can be given as follows:

$$\Delta 1 = T_{am}(t1) - T_{ag}(t1) \quad (3)$$

$$\Delta 2 = T_{am}(t2) - T_{ag}(t2) \quad (4)$$

These differences are used as correction values to correct the maximum and minimum values of mesh ambient temperature, as shown in Fig.4. Hence the maximum, Y_{max}, and minimum, Y_{min}, values of the temporary forecast ambient temperature are given as

$$Y_{max} = M_{max} + \Delta 1 \quad (5)$$

$$Y_{min} = M_{min} + \Delta 2 \quad (6)$$

The provisional ambient temperature, $y(t)$, can be obtained by substituting Y_{max} and Y_{min} given above into Eq. (2).

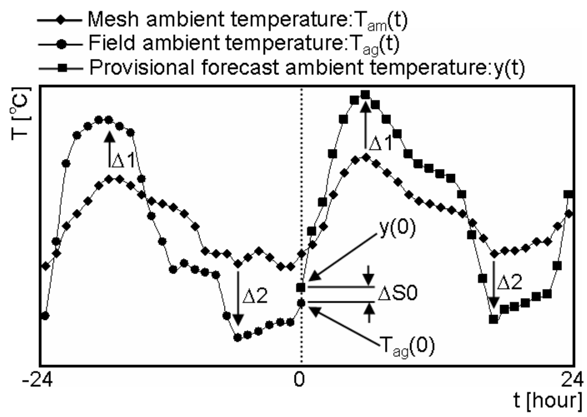

Fig. 5 Ambient temperature forecasting algorithm, step 3 (evaluation of provisional forecast ambient temperature)

Finally, the new provisional ambient temperature so obtained is corrected as shown in Fig.5. The difference, $\Delta S0$, between $y(0)$ at time ($t = 0$) and the field ambient temperature, $T_{ag}(0)$, is calculated, and then the provisional forecast ambient temperature $y(t)$ is corrected. $\Delta S0$ is given by

$$\Delta S0 = T_{ag}(0) - y(0) \quad (7)$$

The final forecast ambient temperature, $T_{ae}(t)$, can be calculated by correcting the provisional forecast ambient temperature, $y(t)$, with correction value, $\Delta S0$ (Fig.6). Hence, the final forecast ambient temperature is

$$T_{ae}(t) = y(t) + \Delta S0 \quad (8)$$

$\Delta S0$ serves to compensate even when the values of the final ambient temperature, $T_{ae}(t)$, and the field ambient temperature, $T_{ag}(t)$, begin to show different tendencies.

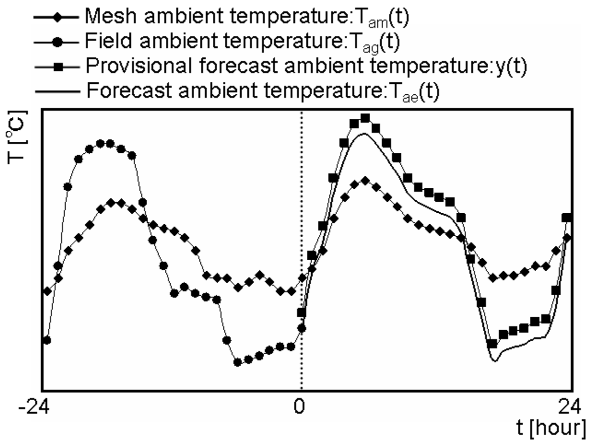

Fig. 6 Ambient temperature forecasting algorithm, setp 4 (calculation of forecast ambient temperature)

4. Road surface temperature forecasting algorithm

Factors that affect the road surface temperature include the ambient temperature and the short-wave radiation from sun and sky. Qualitative information that directly reflects the short-wave radiation from sun and sky is the sky condition. If it is clear, there is a lot of insolation, and if it is cloudy, the short-wave radiation from sun and sky is small. Our forecast algorithm thus takes account of the sky condition, and uses it to forecast the road surface temperature. To obtain the road surface temperature from the ambient temperature, it is necessary to use a classification made according to the sky condition and time information. Time information makes it possible to distinguish between day and night and thus determine whether there can be insolation or not.

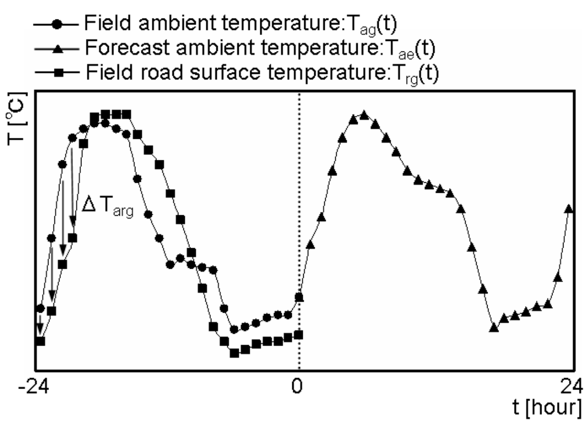

Fig. 7 Road surface temperature forecasting algorithm, step 1 (calculation of ΔT_{arg})

As shown in Figure 7, we examined the difference, ΔT_{arg}, between the field ambient temperature, $T_{ag}(t)$, and the field road surface temperature, $T_{rg}(t)$, for now and the past (t $\leq$ 0), and developed the ΔT_{arg} table shown in Figure 8. The ΔT_{arg} table was developed using the hourly data recorded over several days to give six types of average for each hour of the day, namely the hourly average for each of the five weather types (clear, cloudy, rainy, sleety and snowy) and the hourly ensemble average for all weather types, all calculated based on the received field data. For example, at 00:00, ΔT_{arg} is -2.7 when it is clear. No ΔT_{arg} has been calculated at 00:00 when it is rainy. In such a case, the average, -5.5, is used. Although using many patterns of data from the past in deriving the ΔT_{arg} Table may raise the forecast accuracy, it requires the additional time of developing the ΔT_{arg} Table. We have varied the period of data referred to to up to the past 10 days, and found that in practice data of just a few days can provide sufficient accuracy. We therefore developed the ΔT_{arg} Table using data for the past 3 days (-72 $\leq$ t $\leq$ 0).

Time	Average	Clear	Cloudy	Rainy	Sleety	Snowy
00:00	-5.5	-2.7	-6.0			-7.8
01:00	-5.9	-6.7	-5.1			
02:00	-5.8					-5.8
⋮	⋮	⋮	⋮	⋮	⋮	⋮
23:00	-5.0				-5.0	

Fig. 8 ΔT_{arg} Table

The road surface temperature is forecast using this ΔT_{arg} Table. As with developing a ΔT_{arg} Table, forecasting the road surface temperature requires forecasts of sky condition. There are two sources of data on sky condition: mesh forecast data and weekly forecast data. Both of them describe sky conditions in different ways from those used in field data. So, sky condition information in mesh forecast data and weekly forecast data are adjusted to conform to the classification used in field data as follows.

4.1 How to adjust sky conditions of mesh forecast data

The sky condition in mesh forecast data is classified into one of 11 categories as shown on the left side of Fig.9 while those in field data are given in only five categories (clear, cloudy, rainy, sleety and snowy). The correspondence is made as shown in Fig.9.

4.2 How to adjust sky conditions in week forecast data

Sky conditions in weekly forecast data are expressed in the same wording as is used in ordinary weather forecast (e.g., clear but occasionally cloudy). Each six-hourly set of data in the weekly forecast data is broken down into hourly data as follows. Suppose that the

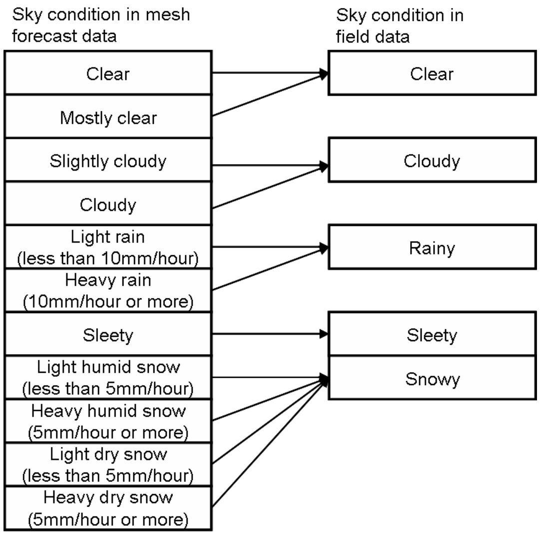

Fig. 9 Mapping of sky conditions in mesh forecast data

weekly forecast of the present time is "clear but occasionally cloudy". The past six-hour data that forecast "clear but occasionally cloudy" as well as their associated field data are searched for, and the field data of the matching six-hour data are sorted in chronological order as shown in Fig.10. Then, provisional adjusted hourly data is obtained by breaking the six-hour data of the present time (clear but occasionally cloudy) into "clear, clear, clear, clear, cloudy and cloudy". This is also added to Fig.10. Finally, from among the cases in the matching field data plus the provisional adjusted data, the one with the largest number of occurrences is picked as the adjusted hourly data. If there are more than one case that occurs the most often, the most recent one is selected. (In Fig.10, in the data of "four hours ahead", both *clear* and *cloudy* occur twice, but the most recent one is *cloudy*, so *cloudy* is chosen as the adjusted data.) The next time, the same sky condition is forecast in weekly forecast data, this adjusted data is used as provisional adjusted data, and the same process is repeated to arrive at the adjusted data for that occasion.

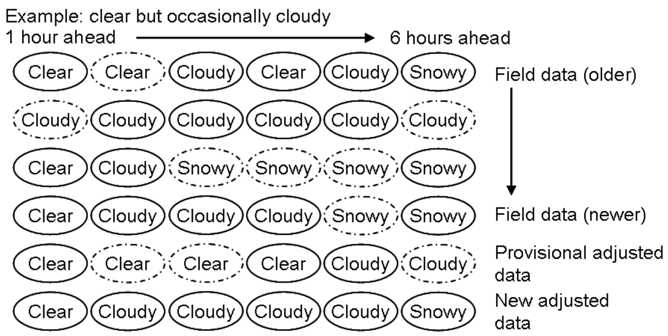

Fig. 10 How to adjust weekly forecast data

Using the three data items discussed above (field ambient temperature, field road surface temperature and either adjusted mesh forecast data or adjusted weekly forecast data), a provisional forecast road surface temperature, $r(t)$, is calculated as

$$r(t) = T_{ae}(t) + \Delta T_{arg} \tag{9}$$

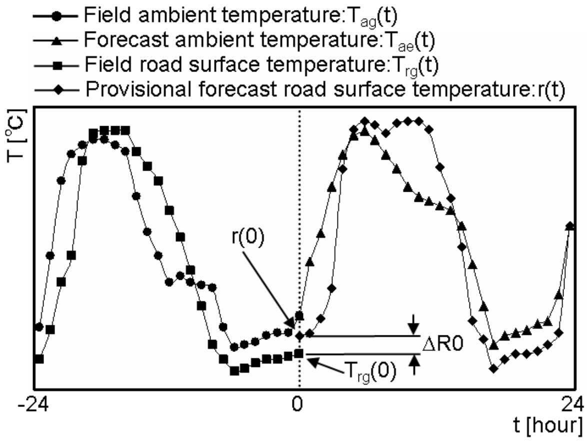

Fig. 11 Road surface temperature forecasting algorithm, step 2 (correction of provisional forecast road surface temperature)

As the final step, this provisional forecast road surface data is corrected in a manner shown in Fig.11. The difference, $\Delta R0$, between the temporary forecast road surface temperature, $r(0)$, and the field road surface temperature, $T_{rg}(0)$, is calculated as

$$\Delta R0 = T_{rg}(0) - r(0) \tag{10}$$

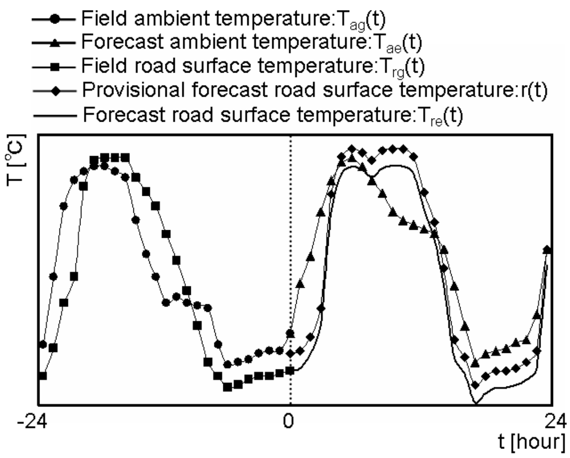

Fig. 12 Road surface temperature forecasting algorithm, step 3 (calculation of forecast road surface temperature)

This $\Delta R0$ is used to correct the provisional forecast road surface temperature, $r(t)$ (Fig.12). The final forecast road surface temperature, $T_{re}(t)$, is calculated as

$$T_{re}(t) = r(t) + \Delta R0 \tag{11}$$

This $\Delta R0$ serves to compensate even when the values of the final road surface temperature, $T_{re}(t)$, and the field road surface temperature, $T_{rg}(t)$, begin to show different tendencies.

5. Road surface state forecasting algorithm

The items of data needed for forecasting the road surface state are the ambient temperature, the road surface temperature and the short-wave radiation from sun and sky. As discussed in Section 4, the short-wave radiation from sun and sky is derived from the sky condition. Road surface states are classified into *dry*, *wet*, *icy* and *compacted snow*. Figure 13 shows a state transition diagram for transitions between these different states It has been assumed that not all transitions from one state to another state are possible, as shown in Fig.13. Certain limitations are imposed on transitions. The transitions that are not allowed are those from *compacted snow* to *dry*, from *dry* to *icy*, and from *icy* to *dry*.

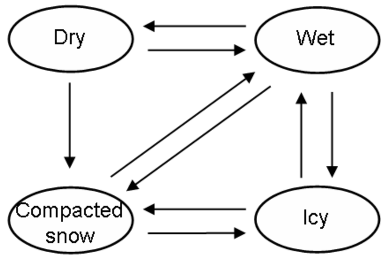

Fig. 13 Road surface state transition diagram

Since our concern is road surface conditions in winter, the critical transitions are those to *icy*. Transitions to *icy* are most likely to take place when the road state is *wet*, and the ambient and road surface temperatures are below zero Celsius. Let the ambient and road surface temperatures be T_a and T_r, respectively. Assume that the current road state is *wet*. The conditions of interest for determining whether a transition to *icy* takes place are as follows.

Condition 1 Both the road surface and the ambient temperatures are above zero Celsius.($T_r > 0$ and $T_a > 0$)
Result 1 The road surface is not icy.

Current road surface state	2 hours earlier			1 hours earlier			Present time			Next road surface state	
	Sky condition	Ambient temperature	Road surface temperature	Sky condition	Ambient temperature	Road surface temperature	Sky condition	Ambient temperature	Road surface temperature		
Dry							Rainy		+	Wet	
							Sleety		+	Wet	
							Snowy		+	Wet	
				Snowy	–	–	Snowy	–	–	Compacted snow	
Wet		–	–		–	–		–	–	Icy	
	Clear	+	+	Clear	+	+	Clear	+	+	Dry	*1
	Snowy			Snowy			Snowy			Compacted snow	
Icy		+	+		+	+		+	+	Wet	
	Snowy			Snowy			Snowy			Compacted snow	
Compacted snow		+	+		+	+		+	+	Wet	
	Clear	–	–	Clear	–	–	Clear	–	–	Icy	*2

*1: Applicable to 10:00-14:00; *2: Applicable to 16:00-19:00;
+: temperature is above zero Celsius; -: temperature is zero Celsius or below

Fig. 14 Road surface state forecasting table

Condition 2 The road surface temperature is above zero but the ambient temperature is zero or below.($T_r > 0$ and $T_a \leq 0$)

Result 2-1 If the ambient temperature is decreasing ($dT_a/dt < 0$), the road surface is likely to become icy.

Result 2-2 If the ambient temperature is increasing ($dT_a/dt > 0$), the road surface will not be icy.

Condition 3 Both the road surface and the ambient temperatures are zero or below.($T_r \leq 0$ and $T_a \leq 0$)

Result 3-1 If the ambient temperature is decreasing ($dT_a/dt < 0$), the road surface is icy.

Result 3-2 If the ambient temperature is increasing ($dT_a/dt > 0$) the road surface is icy, but the ice may be in the process of melting.

The authors have developed a road surface state forecasting table, shown in Figure 14, which forecasts the transition from the current state to the next state, taking account of the transitions described above. Normally, traffic volume is one of major factors that affect the road surface state. There was, however, no traffic in the test field where this forecast was made. Therefore, in Figure 14, traffic volume was zero. As shown in Figure 14, the next road surface state is forecast from the ambient temperature, road surface temperature and road surface state of the present time, one hour earlier and two hours earlier. For example, the road surface state five hours from now can be forecast from the ambient temperature, road surface temperature and road surface state of four, three and two hours from now. For ambient and road surface temperatures, forecast ambient temperature, $T_{ae}(t)$, and forecast road surface temperature, $T_{re}(t)$, described in Sections 3 and 4, are used. For the sky condition, the adjusted sky conditions of mesh and weekly forecast data are used.

6. Results

The ambient temperature, road surface temperature and road surface state are each forecast using the respective algorithms described above. These have been evaluated using field data from the North Tohoku Region from 2000 to 2003. There was no traffic in the test field where this forecast was made. Where the field data collected included data when snow was removed, the road surface state was changed to humid, and then the forecast was made using the road surface state forecasting table shown in Figure 14. The evaluation of ambient and road surface temperatures has focused on how correct the forecast is about whether the temperature is above or below zero Celsius. This is because only this above-or-below information is used for forecasting the road surface state, as shown in Figure 14. The road surface state has been evaluated in terms of the correctness of the forecast (*icy*, *compacted snow*, *dry* and *wet*).

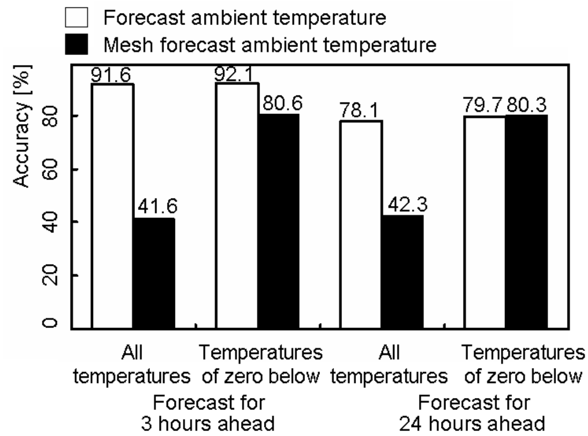

Fig. 15 Accuracy of forecasted ambient temperature

Figure 15 shows the evaluation of the ambient temperature forecast using the ambient temperature forecasting algorithm proposed in Section 3. It indicates a high accuracy for both forecasts of 3 hours ahead and 24 hours ahead. For comparison, the accuracy of the mesh forecast ambient temperature, which has been used to forecast the ambient temperature, is also shown in Fig.15. The figure indicates that the forecast of ambient temperature is as accurate as or more accurate than the mesh forecast ambient temperature, especially so in the forecast of 3 hours ahead, where the accuracy is higher than 90%.

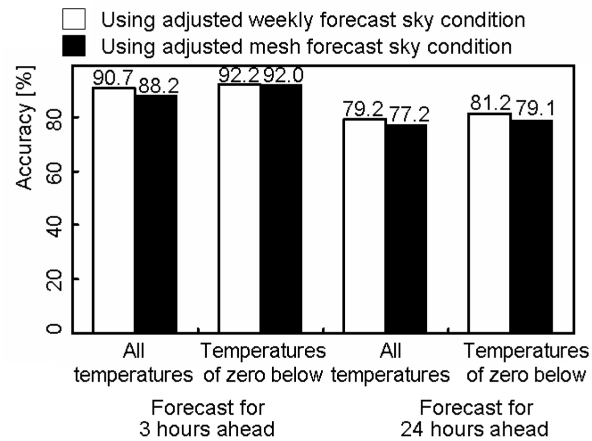

Fig. 16 Accuracy of forecasted road surface temperature

Figure 16 compares the prediction accuracy of the road surface temperature using the forecast ambient temperature data adjusted with mesh weather data, with that using the forecast ambient temperature data adjusted with weekly weather data.As was described in Section 4, the road surface temperature forecast is derived from the ambient temperature forecast and the weather data. Therefore, it can be derived for the following four possible combinations of weather data and ambient temperature forecast:

Combination 1	ambient temperature forecast and adjusted mesh weather data;
Combination 2	ambient temperature forecast and adjusted weekly weather data;
Combination 3	mesh ambient temperature and adjusted mesh weather data;
Combination 4	mesh ambient temperature and adjusted weekly weather data;

Since Figure 16 shows road surface temperature forecasts for Combinations 1 and 2, these results are not based on the mesh ambient temperature.As in the case with the forecast ambient temperature, a high accuracy has been recorded for both the forecasts of 3 hours ahead and 24 hours ahead. In particular, the accuracy of the forecasts for 3 hours ahead are higher than 90% whether the adjusted mesh sky condition data or the adjusted weekly sky condition data is used.

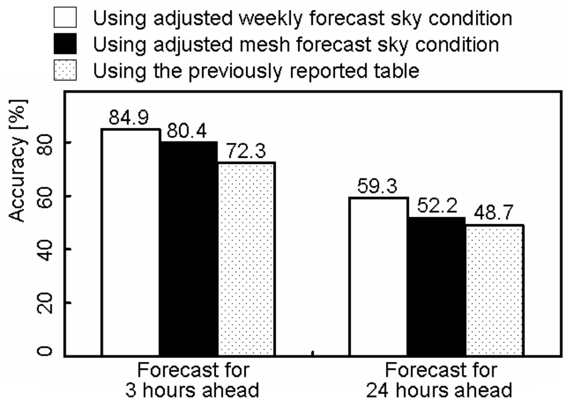

Fig. 17 Accuracy of forecasted road surface state

Finally, Figures 17 to 19 show the evaluation of the road surface state forecast using the road surface state forecasting algorithm given in Section 5. Since a road surface state forecasting table different to that in Figure 14 has been reported[2], the results obtained using this other table (hereafter referred to as *previously reported table*) have also be presented for comparison. As is the case with the forecast ambient and road surface temperatures, a high accuracy ratio has been recorded for the forecasts of road surface states for 3 hours ahead for

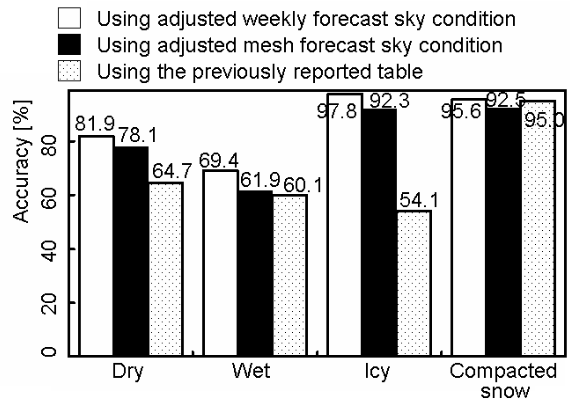

Fig. 18 Accuracy of forecasted road surface state (forecast for 3 hours ahead)

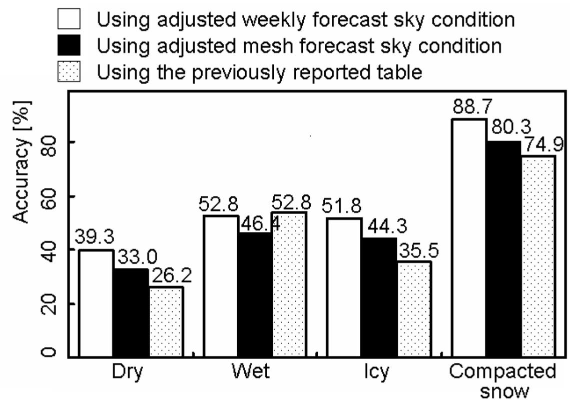

Fig. 19 Accuracy of forecasted road surface state (forecast for 24 hours ahead)

all road surface states shown in Figure 17. In comparison with the case using the reported table, the accuracy ratio is 8% higher when the adjusted mesh sky condition is used, and 12% higher when the adjusted weekly sky condition is used. Figures 18 and 19 show that there is a remarkable improvement over the previously reported method in the forecast accuracy of dry and frozen states in both forecasts for 3 hours ahead and for 24 hours ahead.

7. Conclusions

A new method of forecasting the road surface state has been developed. Evaluations based on past weather and road surface data have indicated that the accuracy of the new method is higher than those reported previously. It has also been found that the adjusted weekly forecast sky condition has led to greater accuracy for forecasts of road surface temperature and road state than the adjusted mesh sky condition.

Another important advantage of the new method is the length of period for which past weather data is needed. Conventionally, data from two to three consecutive years is needed to acquire knowledge about weather tendencies. In contrast, our method acquires this information from mesh forecast data or weekly forecast data, which are always available. Continuous collection of data is required only for developing a ΔT_{arg} Table (Fig.8), as discussed in Section 4. However, this only requires data from about the previous three days. Therefore, the initial investment for introducing a forecasting system can be greatly reduced.

Finally, one area where there is room for improvement in order to obtain a higher accuracy is the road surface state forecasting table (Fig.14). The evaluation results indicate that the accuracy of the forecast for 24 hours ahead is always lower than that of the forecast for 3 hours ahead, for all the forecast items: ambient temperature, road surface temperature and road surface state. A possible cause for this is that Fig.14 takes account of data relating only to the previous three hours. For a longer-term forecast, it may be necessary to use longer-term source data (e.g., 12 hours). To summarize, the method proposed in this paper is suitable only for a short-term forecast. For a longer-term forecast (e.g., 72 hours ahead), it is necessary to improve the road surface state forecasting table.

Acknowledgement

The authors wish to express their appreciation to people in Mitsubishi Cable Industries, Ltd. for providing the field data.

References

[1] Yokogawagiho: Web-based System for Determining and Forecasting Road Conditions, Yokogawagiho, Vol44 No.4 (2000)

[2] Yokogawa Denshikiki Co., Ltd, Road Condition Forecasting System, Published, Unexamined Patent Application 2002-196085 (P2002-196085A)

[3] Teruyuki Fukuhara, Akihiro Fujimoto, Hiroshi Watanabe: "Prediction Model of Snow - Ice State on Winter Road Surface -", Journal of Snow Engineering of Japan, Vol.22, No.1, pp.55-60, Jan. 2006.

[4] Atsuhiro SAEGUSA and Yoshitaka FUJIWARA: "Evaluation of Road Condition Forecasting Based on Knowledge about Weather - A study using weekly forecast -", General Conference of Hokkaido Sections of Engineering Associations related to Electricity, p.252, 2003.

[5] Atsuhiro SAEGUSA and Yoshitaka FUJIWARA: "Proposal for Road Condition Forecasting Based on Knowledge about Weather and Road Surface", Technical Report, Technical Group on Information System and Social Environment, Information Processing Society of Japan, 82-1, pp.1-8, 2002.

[6] Atsuhiro SAEGUSA and Yoshitaka FUJIWARA: "Proposed Algorithm for Temperature Forecasting Based on Knowledge about Weather for the Purpose of Forecasting Road Freezing",General Conference of Hokkaido Sections of Engineering Associations related to Electricity, p.299, 2002.

Atsuhiro SAEGUSA received the M.E. degree in Information Engineering from the Kitami Institute of Technology in 2004. He works as Shari-cho Agricultural Co-operatives and it is a doctor course student at the Kitami Institute of Technology. His research interests include knowledge base system.

Yoshitaka FUJIWARA is a professor in the Department of Computer Sciences at Kitami Institute of Technology. He received his BS and MS degrees in electronic engineering in 1966 and 1968, respectively and his Dr. Eng. degree in 1982, all from the Hokkaido University, Japan. He worked as a research engineer at NTT between 1968 and 1989. He joined Kitami Institute of Technology in 1989. His research interests include knowledge base system, probabilistic reasoning, intelligent tutoring system, and distance learning. He is a member IEEE, and the Information Processing Society of Japan.