센서네트워크 데이터를 이용하여 독성물질 누출속도를 예측하기 위한 신경망 기반의 역추적방법 연구

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A Neural Network-Based Tracking Method for the Estimation of Hazardous Gas Release Rate Using Sensor Network Data

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요 약

본 연구에서는 독성가스 중 가장 널리 이용되는 염소와 암모니아 가스 누출에 대한 누출속도 추정 방법을 제안하고자 한다. 우선, 독성 가스 누출이 자주 발생하는 위험 지역 주변에 펜스 형태의 광센서 네트워크를 설치한다. 센서가 규정 농도 이상의 위험물질을 감지하게 되면, 자동적으로 물질을 분석하고 그 물질의 농도정보를 얻게 된다. 기존의 역추적 모델들은 3개 이상의 센서 정보로부터 결과물을 요구하기 때문에, 하나의 센서정보로 누출속도를 구해야 하는 이 시스템에는 적합하지 않다. 이 연구에서 제안한 신경망을 기반으로 한 역추적 알고리즘과 농도정보 및 기상정보를 이용하여 누출원에서 누출속도를 구하게 된다. 관련 위험물 저장 설비의 공정정보, 물질정보, 기상정보 그리고 센서로부터 얻은 농도데이터 등 14개의 입력 데이터를 넣어 출력값인 누출속도를 구하게 된다. 이는 독성가스 저장시설 주변에 사는 주민들에게 위험시설에 대한 신뢰감을 향상시키며, 독성 가스 누출시 주변 지역 주민들에게 긴급상황을 신속히 전달할 수 있는 비상대응의 일환으로 활용 할 수 있을 것이다.

Abstract – In this research, we propose a new method for tracking the release rate using the concentration data obtained from the sensor. We used a sensor network that has already been set surrounding the area where hazardous gas releases can occur. From the real-time sensor data, we detected and analyzed releases of harmful materials and their concentrations. Based on the results, the release rate is estimated using the neural network. This model consists of 14 input variables (sensor data, material properties, process information, meteorological conditions) and one output (release rate). The dispersion model then performs the simulation of the expected dispersion consequence by combining the sensor data, GIS data and the diagnostic result of the source term. The result of this study will improve the safety-concerns of residents living next to storage facilities containing hazardous materials by providing the enhanced emergency response plan and monitoring system for toxic gas releases.

Key words : inverse tracking algorithm, hazardous gas release

I. Introduction

Economic development and ever-increasing adoption of technology for everyday life have unavoidably introduced many dangerous facilities inside and nearby city. Accidental discharges of hazardous gases, either

flammable or toxic, more likely to occur during manufacture, storage or transport can be considered as one of those cases. A feeling of insecurity for residents living nearby dangerous facilities increased, but response technologies are not accepted to be adequate [1,2]. Many studies on real-time monitoring is progressing. The research of monitoring system based on sensor-network is practical to be applied in

the field. However, existing methods are not easy to predict the release of toxic material using sensor-network information. Thus, this research proposes a tacking methodology for estimating release rates of toxic gases.

This paper focuses on releases of chlorine and ammonia which are highly toxic gases produced and used in large quantities around the world. In case of chlorine, due to its high oxidizing and germicidal potential, it is also widely used for water disinfection at drinking water treatment installations or at public swimming pools. For these uses, chlorine is generally transported and stored as a liquefied compressed gas. Many chlorine storage facilities are located in the area of dense population. Quantities of chlorine released to the atmosphere may vary from several hundreds of kilograms to tones. Even if the implicated quantities are small, a loss of containment accident may present a serious chemical hazard that has the potential to kill or injure large numbers of people, considering the high toxicity of this product. Meanwhile, anhydrous ammonia is widely used as refrigerant in many industrial facilities, e.g. food processing, dairy and ice cream plants, wineries and breweries, and cold storage warehouses. Each of these facilities has to take into account the risk of an ammonia release, sometimes associated with a fire or an explosion. Ammonia is considered a high health hazard because it is corrosive to the skin, eyes, and lungs. Therefore, we need to respond and cope quickly against releases of these chemicals.

In this study, we use a sensor network that has already been set up and operational surrounding an area where hazardous gas releases can happen. From the real-time sensor data, we detect and analyze harmful materials releases and their concentrations. Based on concentration data, the rate of release is estimated using the neural network. This model consists of 14 input variables (sensor data, material properties, process information, meteorological conditions) and one output (release rate). The dispersion model performs the simulation of the expected dispersion consequence by combining the sensor data, GIS data and the diagnostic result of the source term. The result of this study may improve the confidence of residents living next to storage facilities of hazardous materials, by supplying the improved emergency response plan and monitoring system for toxic gas releases.

II. Theory

This part we review existing tracking methodologies.

In addition, we searched neural network methods used for release rate estimation.

2.1. Tracking Method

Tracking methods have been studied in many fields. The popular methods are Multiple Hypothesis Tracking (MHT) method based on the Bayesian model and Kalman filter method. MHT algorithm is the optimal bayesian filter; the method makes the possible hypothesis based on observed information and calculates a probability of each hypothesis. The Kalman filter is an efficient recursive filter that estimates the state of a dynamic system from a series of incomplete and noisy measurements. Existing tracking methods, including the two mentioned, cannot be applied easily to a sensor-network of this research because it requires much information. The sensor network targeted for this research only measures the average value of concentration surrounding the hazardous area.

2.2. Neural Network

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. One can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements. In general neural networks are adjusted, or trained, so that a particular input leads to a specific target output. Such a situation is shown below. The network is adjusted based on a comparison of the output and the target iteratively until the network output matches the target. Typically a large number of input/target pairs are needed to train a network. Neual networks have been trained to perform complex functions in various fields, including pattern recognition, identification visions and control systems [7].
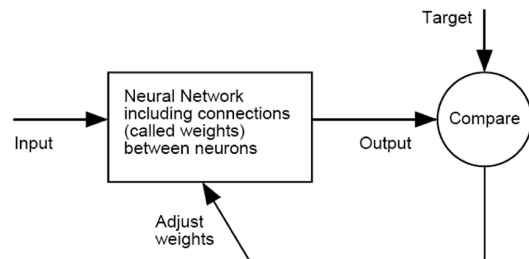

Fig. 1. Diagram of a neural network.

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III. Methodology

The purpose of atmospheric dispersion modeling is to provide the observed concentrations downwind of the source of release when all the input data are known. The source information, GIS data, and meteorological conditions are required for solving an atmospheric dispersion problem. For this study, we have concentration data from sensors, GIS information, and meteorological condition; we need a system for generating the source model from the concentration data.

In this study, we propose a new model for tracking of release rate from the concentration data of sensor. The newly proposed model was built using the 600 data (chlorine 300 + ammonia 300) obtained by using PHAST. We divided the raw data into three groups, one for training (360), validation (120), and test (120). We used the "mean node" for the replacement node since there were many values missing in the raw data. In addition, we set the 20 hidden units as networks, added the linear regression mode, and created a model by averaging the predicted values. Ensemble node can improve the performance for the generalization.

IV. Results and Discussion

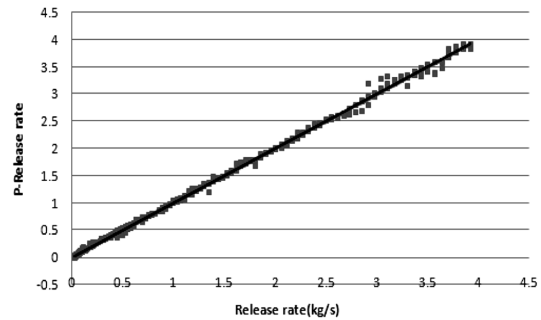The proposed tacking method using neural networks was used in predicting the release rate. The prediction
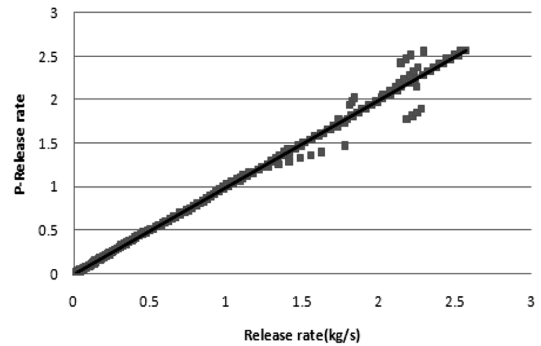
performance in the aspects of MSE (Mean Squared Error) and R Regression Values) is shown in Table 2. The predicted values of single material were found to match well against the target values, as shown in Figs. 2 and 3. In the case of chlorine (Fig. 2), the predictions of release rate fit within the error less than 1%. In contrast, the prediction and the data do not fit as well for the release of ammonia (Fig. 3). This is probably due to the fact that ammonia is light gas and thus more influenced by diverging atmospheric conditions. In the case of mixture (Fig. 4), we were able to obtain a result more reliable than one for ammonia alone. It is, however, less accurate than the prediction for single compounds since the result is

Table 2. Prediction performance to simulation result.

Material	MSE	R
Chlorine	3.239e-3	0.9989
Ammonia	4.324e-3	0.9961
Ammonia + Chlorine	8.664e-3	0.9799

Table 1. Input and output variables.

	Variables	Unit
Input	100 m Concentration	ppm
	Molecular density	g/l
	Molecular weight	g
	Boiling point	K
	Heat capacity	KJ/(mol · K)
	Heat of vaporization	KJ/mol
	Storage pressure	bar
	Storage temperature	K
	Relative humidity	%
	Atmospheric pressure	bar
	Atmospheric temperature	K
	Wind direction	1-8
	Atmospheric stability	1-6
	Wind velocity	m/s
Output	Release rate	Kg/s

Fig. 2. Fitness analysis in the estimation of the release rate (kg/s) of chlorine.

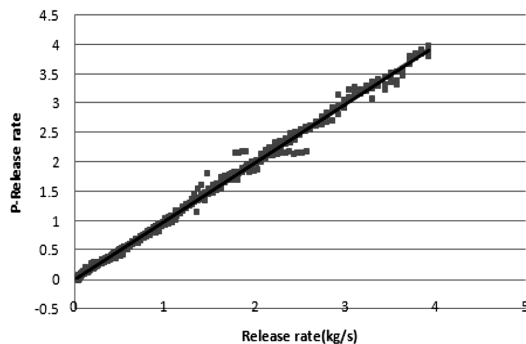**Fig. 3.** Fitness analysis in the estimation of the release rate (kg/s) of ammonia.

Fig. 4. Fitness analysis in the estimation of the release rate (kg/s) of chlorine + ammonia.

affected by physical properties of material: in this study, we considered 5 physical properties for prediction of the release rate of a mixture, but dispersion of hazardous materials is influenced by many more properties not considered here.

V. Conclusion

The system under development is expected to include a real-time, linked source emission modules, meteorological modules, transport and dispersion modules, and exposure and risk modules. There is a need for efficient communication of data, as well as for generation of model predictions across large distances. This work has been reported only for a single-source release, but more work is necessary on inverse modeling or source-finding, where observations are used to narrow down the suspected region (like triangulation in [6]) in identifying the location and magnitude of a release. Better parameterizations of mean flow vectors and turbulence for all time periods and surface types, improved methods of real-time modeling using limited and missing inputs, development of criteria for the best expected model in agreement with observations, and optimization of methods to be used in new sensor network systems, harnessing numerous number of sensors as ubiquitous sensor networks, also need further studies.

This study and more validation works will allow residents living near hazardous materials storage facilities to feel safer by providing them a better emergency response plan and real-time monitoring system against various hazardous gas releases.

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