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論文 / 著書情報
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題目(和文)	乱流環境下における匂い源探知戦略の開発と数値流体シミュレーションのフレームワークにおける評価
Title(English)	Development of Odor Source Localization Strategy in Turbulent Environment and its Evaluation under Framework of Computational Fluid Dynamics
著者(和文)	Muis Muhtadi
Author(English)	Muis Muhtadi
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	Computational Intelligence and Systems Science 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Philosophy)
学生氏名： Student's Name	Muis Muhtadi	指導教員（主）： Academic Supervisor(main)	Takamichi Nakamoto
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

An autonomous sensing system has long been envisaged to help in a source localization task. This task has been increasingly important in our modern life for various critical applications, such as searching for chemical leakage in a factory infrastructure, searching for a fire in the early stage inside a building, detecting and searching for drugs in airports and harbors, as well as humanitarian missions such as searching for human victims under building rubles. Hence, advancement of odor source localization is demanded to enable such autonomous sensing system.

Although the idea of an autonomous sensing system has been arising for more than two decades and numerous works have been attempted to build it since then, to date, the system development has not achieved a practical application. The problem of odor source localization is related with the environmental condition and the localization method. The problem related with the environmental conditions is generally owing to the complicated odor distribution. An odor distribution in real world is generally governed by turbulent airflow resulting in temporally and spatially fluctuating distribution of an odor. As for the problem related with the localization method is generally rooted from the limitation of the chemical sensor. One of the limitation of the chemical sensor in general is not able to follow quick changes in the chemical concentration resulting in the sensor response delay which should be considered in odor source localization strategy.

The objective of this study is to develop an odor source localization strategy in computer simulation considering common issues in the study of odor source localization, such as; the real world environment having a turbulent airflow, odor sensors having response delay, inconsistent environment for evaluating localization strategies. The development was carried out gradually in three phases.

The first phase, a localization technique based on Gaussian distribution was studied. A time-invariant testing environment with Gaussian time-averaged odor distribution was created using MATLAB programming. Using this static environment, an odor source location can be estimated remotely by fitting the Gaussian distribution to several sensor responses observed at different locations. The estimation using a formation of multiple sensor nodes was affected by distance between the sensor nodes in the formation, the formation orientation towards wind direction, and the formation position in crosswind direction towards the source location. An odor source localization strategy using multiple sensor nodes was developed for this environment. Using principle of *chemotaxis* and *anemotaxis*, the strategy divides the nodes to have two different tasks; *leading node* and *supporting node*. The leading

node has a task to track the plume toward the source using chemotaxis-anemotaxis strategy, whereas the supporting node moves zigzag while keeps up beside the leading node to collect odor information. The node which finds the highest odor concentration takes the role as the leading node and the others are the supporting nodes. This strategy, as simulated in MATLAB, showed its promising merit.

The second phase, a bio-inspired localization strategy was developed for a dynamic environment. For the testing environment, a turbulent environment was simulated using a Computational Fluid Dynamics (CFD) software. The environment is a closed room with an odor source on the floor and obstacles inside it. The localization strategy comprises searching for the plume centerline according to odor gradient (chemotaxis) and moving upwind along the centerline (anemotaxis). Direction to the plume centerline in crosswind direction is searched by using a zigzag scanning, i.e., collecting odor-concentration information to be used in an odor gradient estimation while moving zigzag. The odor gradient is estimated from a latest frame of time-series odor-concentration information obtained by a sensor node while moving. The estimation employs a regression technique to compute the model function from which the gradient function can be derived. To increase the accuracy of this estimation, a moving average filter is applied to the data before determining the model function. An estimation method based on an adaptive threshold was also developed and the efficacy was compared with the regression-based estimation. The performance evaluation shows that the strategy with regression-based estimation outperforms the strategy with adaptive threshold-based estimation with success rate above 95%.

The final phase, the strategy was further developed to consider odor sensor with response delay. To implement a realistic odor sensor with response delay, a sensor calibration model and a dynamic response model were applied in the sensing method. A new method for estimation of plume centerline was developed to exploit a transient sensor response. Similar regression technique as used in the previous phase was used here to determine the plume edges. The plume start and ending edges along the crosswind direction can be estimated accurately based on the gradient sign. The centerline can be estimated around the central points between the edges. Although the localization used sensor response which does not accurately represent the actual odor concentration, the gradient can still estimate the trend of odor concentration quite accurately and be used to navigate the localization with success rate above 71%.

In this study, the strategy of odor source localization with high efficiency for the dynamic environment with wind turbulence is demonstrated under the framework of computational fluid dynamics even when the sensor response delay is considered.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
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