전산/기계 학습을 통한 상부 기도 내에서의 유동 해석

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Computational/machine learning analysis of airflow dynamics in the upper airways

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Abstract : Obstructive sleep apnea (OSA) is a common sleep breathing disorder. Computational Fluid Dynamics (CFD) has become an widely used tool in investigating fundamental mechanism inside airway. Employing such technology, the geometry of the airway is a very important factor in flow characteristics, this study will provide quantitative standard for effective surgery and diagnosis based on an investigation of the relationship between geometry of airway and aerodynamic characteristics quantitatively. We created a predictive model using Gaussian process regression (GPR) through a dataset obtained through CFD. Support vector machine (SVM) model was used to determine the degree of OSA of a patient as normal-mild and moderate from GPR model.

1. INTRODUCTION

Obstructive Sleep Apnea (OSA), defined as the repeated complete or partial collapse of the upper airway during sleep, is a common sleep breathing disorder that The prevalence of OSAS in South Korea was 27% in men and 16% in women(1).

Invasive surgical methods are often used to treat obstructive sleep apnea. In order to improve probability of successful operation and precise treatment for OSA, several researchers have conducted investigation using computational fluid dynamics to better understand the mechanism of obstruction(2) Although the geometry of the airway is a very important factor in flow characteristics, the limitations of previous studies were only clinically analyzed for changes in airway geometry before and after surgery. In addition, only several patients have been compared; no comparison has been performed for a wide range of patients.

The main objectives of this study are to quantitatively investigate the relationship between airway geometry and aerodynamic characteristics through flow and structure simulation, and to build a model that quickly predicts flow characteristics through a machine learning algorithm. Furthermore, we have constructed a model to diagnose the degree of OSA symptoms based on the simulation results of the idealized model.

2. METHODOLOGY

2.1. Dataset

As the original airway geometry is too complicated, the geometries of the upper airway have to be simplified in order to focus on the main geometrical parameters. We selected 8 variables thorough CT data of 7 normal patients as shown in Fig.1. Based on the results of the main effect analysis, we selected three highly influential variables (CL, CS, and IS), and selected ML

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variables to confirm the flow properties distribution in the upper airway.

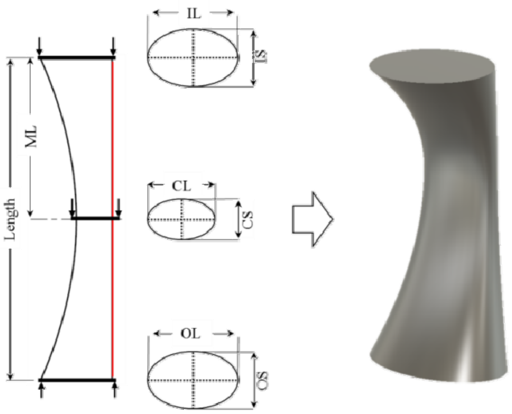

Fig. 1 Idealized airway with geometically parameters.

Datasets containing 160 samples for idealized upper airway model was constructed through the selected four parameters.

2.2. Numerical model

In order to simulate the air flow in the upper airway, the ANSYS CFX 18.1 was used. The Reynolds number in the airways may fall into laminar to transient region. For the calculation of the air flow structures, the Reynolds Averaged Navier - Stokes (RANS) model was selected as a turbulence model with the κ - ω model.

2.3. Machine learning algorithms

In this paper, Gaussian process regression (GPR) is used. A GPR defines a distribution over a space of function and it is completely specified by its mean function and covariance function. We used the SE kernel function with non-isotropic kernels. Also, to classify patients according to the severity of their OSA, we used support vector machine (SVM) with liner kernel function with scaling factor was set to be 0.5 and the box constraint was 1.

3. RESULTS

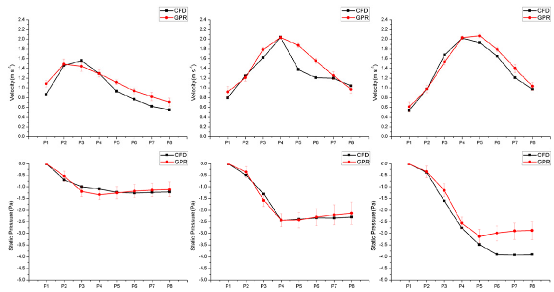

Fig.2 Velocity & Static pressure distribution comparison between the CFD data and the prediction data by GPR (a) Normal-mild patient; (b) Moderate patient; (c) Severe patient.

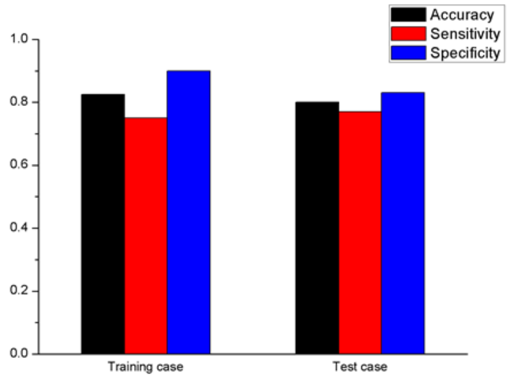

Fig.3 performance of classification using all feature extracted from GPR

Fig.2 is a graph comparing the results of the CFD and predictive models for 3 patients with normal-mild OSA symptoms, moderate, and severe. The average prediction accuracy at velocity was 86.19% for normal-mild, 90.07% for moderate and 90.75% for severe. And the mean prediction accuracy at pressure was 87.01% for normal-mild, 91.25% for moderate and 80.99% for severe. Fig.3 shows the result of classification performance from SVM model., based on the training case, the classification accuracy was about 82.5%, in the case of test case, classification accuracy was about 80%.

4. CONCLUSION

The models were developed to predict the flow characteristics in the upper airway through a machine learning algorithms. The prediction accuracy of the pressure and velocity distribution in the airway was 80 ~ 90% compared with the CFD result, and the accuracy for the classification of OSA was more than 80%.

GRANTS

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