Non-Contact Thermal Medium-Based Breathing Analysis

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***Abstract*— Respiration monitoring is an important physiological measurement taken to determine numerous health attributes of an individual. In clinical sleep studies, respiration rate is monitored to detect sleep disorders such as sleep apnea and respiratory conditions such as Chronic Obstructive Pulmonary Disease (COPD). Methods of respiration monitoring fall into two categories: contact methods, which monitor respiration by placing sensors on the patient's body, and non-contact methods, which monitor respiration without direct contact with the patient through remote sensors. Contact methods maintain higher accuracies than non-contact methods because they monitor respiration directly, but these methods often cause discomfort to the patient and alter natural breathing behaviors. One such device is the spirometer, which requires the patient to wear a clip on their nose and breathe forcefully through a tube. Not only is this method uncomfortable and strenuous, it also requires a conscious decision on the part of the patient to breathe in a particular manner, making it unfit for use with sleeping patients. Due to these factors, this device and other contact methods can only be used for a short period of time, making them unsuitable for long-term studies. Non-contact methods have an opposite tradeoff; while they are more comfortable and preserve natural breathing, they measure respiration indirectly, and therefore less accurately. To exploit this tradeoff for both comfort and natural respiration monitoring, we present a novel method of non-contact respiratory analysis that improves on current methods by measuring the exhaled air of a human subject through a medium-based exhale visualization technique. In this method, we place a thin medium perpendicular to the exhaled airflow of an individual, and use a low-cost thermal camera to record the heat signature from the exhaled breath on the opposite side of the material. Breathing rate and respiratory behaviors are then extracted from the thermal data using image processing techniques. Data collected from our experiments shows strong correlations between the exhale behaviors and the heat signature within the medium. As a proof of concept, we simulate exhaled air by using a fan to blow heated air onto a medium to validate the airflow to thermal imaging relation. We also test this technique on several human subjects to explore clinical feasibility. Like other respiration monitoring methods, this technique accurately reports breathing rate, but also provides metrics not obtainable through other non-contact methods, such as breathing strength, nose to mouth distribution, and tidal volume estimates. Nose to mouth distribution behavior is a metric not currently attainable from either contact or non-contact methods, and because nasal obstruction is known to increase the risk of sleep-disordered breathing problems, this measurement is highly valuable in sleep studies. This method can also be useful for a variety of medical applications where long-term respiratory analysis is necessary, and is particularly useful for applications that require additional information about breathing behavior.**

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