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A pilot study of online non-invasive measuring technology based on video magnification to determine skin temperature

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ABSTRACT

Much attention was paid on human centered design strategies for environmental control systems of indoor built environments. The goal is to achieve thermally comfortable, healthy and safe working or living environments in energy efficient manners. Normally building Heating, Ventilation and Air Conditioning (HVAC) systems have fixed operating settings, which can't satisfy human thermal comfort requirements under transient and non-uniform indoor thermal environments. Therefore, human thermal physiology signal such as skin temperature, which can reflect human body thermal sensation, has to be measured over time. Several trials have been performed by minimizing measuring sensors such as i-Button and mounting measuring sensors into wearable devices such as glasses. Infrared thermography technology has also been tried to achieve non-invasive measurements. However, it would be much more convenient and feasible if normal computer camera could record images, which could be used to obtain human thermal physiology signals. In this study, skin temperature of hand back, which has a high density of blood vessels and is normally not covered by clothing, was measured by i-button sensors. Images recorded by normal camera were amplified to analyzing skin temperature variation, which are impossible to see with naked eyes. The agreement between i-button sensor measuring results and image magnification results demonstrated the possibility of non-invasive measuring technology by image magnification. Partly personalized saturation-temperature model ($T = 96.5 \times S + b_i$) can be used to predict skin temperatures for young East Asia females.

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1. Introduction

About 30% of total final energy has been consumed by commercial and residential buildings in US in recent years [1]. Higher percentage of final energy has been consumed in area with severe outdoor environments such as Singapore recently, which used 52% of electricity [2]. Heating, Ventilation and Air Conditioning (HVAC) systems account for largest portion of building energy consumption. Reduction of HVAC energy consumption is necessary while human thermal comfort stays a design goal, which is energy efficient thermal comfort. Based on the concept of human centered design and demand controlled conditioning, new strategies including displacement, stratum, task/ambient were developed. Non-uniform thermal environments were created by displacement ventilation [3], stratum ventilation [4], personalized ventilation [5,6], under floor air distribution [7], personal comfort system [8–10], etc.

Human thermal sensation, which can be reflected by thermal physiological parameters such as skin temperature, can be used as feedback signal to control above mentioned HVAC systems. Invasive measuring technology has been used for human skin temperature measurements, which is mainly for laboratory experiments [11]. Several trials have been performed by minimizing measuring sensors such as i-Button and mounting measuring sensors into wearable devices such as glasses [12]. However, it would be much more convenient and feasible if normal computer camera could record images, which could be used to obtain human thermal physiology signals. Human skin color changes slightly with vasodilation or vasoconstriction especially under local thermal stimuli such as using hand warmer. The variation, while invisible to the

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naked eyes, can be extracted by image magnification [13–18]. This study is focused on non-invasive measuring technology by image magnification for hand skin temperature measurements, which can be used for demand control of HVAC systems.

Human visual system has threshold values on temporal-spatial sensitivity. There are a lot of information, which can not be observed by human visual system and need magnification technique. Motion magnification technique was pointed out, which measured small motions by a robust analysis of feature point trajectories and segment pixels based on similarity of position, color and motion [13]. Very small motions were analyzed according to correlation over time. The technique, which acted like a microscope, can achieve magnified observations for tiny motions. One parameter cartoon animation filter was demonstrated to simultaneously add exaggeration, anticipation, follow-through, and squash and stretch to a wide variety of motions [14]. Based on video imaging and blind source separation, a method of non-contact, automated cardiac pulse measurements was introduced [15]. The results extracted from webcam based videos were compared with the results from finger blood volume pulse sensor. High accuracy was achieved. Red, green and blue (RGB) signals of skin color from human face were magnified and extracted the first time. Independent component analysis was used to remove noise and separate cardiac pulse, which achieved automated cardiac pulse measurements. One vital signs camera algorithm was presented, which magnified variation rate of skin color to achieve non-contact pulse and breathing rate measurements accurately [16].

Above mentioned methods followed Lagrangian perspective, which paid attention to motion trajectories of each pixel and were sensitive to tiny motions. However, accurate motion prediction and image segment technique made the algorithm complicated. The effect of different temporal sampling kernels was studied, which demonstrated extended overlapping kernels can mitigate aliasing artifacts [17]. Temporal processing was used to extract invisible signals [15]. Based on Eulerian perspective, Eulerian video magnification (EVM) algorithm was pointed out [18,19]. Eulerian spatial-temporal processing was used for monocular video sequences to magnify tiny variations, which can't be seen by naked eyes. EVM algorithm can magnify spatial channels and temporal channels respectively, which is suitable for magnifying color variations of image pixels under temporal channels. This was the first time to magnify video color and motion by Eulerian method. Phase-based video magnification approach was introduced to overcome the limit that only small magnification factors were supported at high spatial frequencies [20]. Layer-based video magnification approach was presented, which can amplify small motions within large motions [21]. An examined layer was temporally aligned and subtle variations were magnified. Matting was used to magnify only region of interest while maintaining integrity of nearby sites.

Because of sensitivity for color variations of image pixels under temporal channels, EVM will be used to correlate skin temperature and skin color saturation in this study. Linear relationship between skin temperature and skin color saturation is envisaged, which is the research hypothesis. It is the first time to use video magnification approach to determine skin temperature and thermal sensation, which can be used to control HVAC systems. Non-invasive measuring technology will be achieved.

2. Practical application

In private office and open plan office where personal computers were used for each staff, video of human naked skin can be recorded by computer camera and skin color saturation can be analyzed by video magnification technique (Fig. 1). After user identification, the cohort of each user was identified. Saturation-temperature (ST) models for different cohorts were recorded in computer database. As one pilot study, ST model for young East Asian females was analyzed. ST models for different cohorts will be analyzed, based on age, gender and race. The database of ST models for different cohorts will be developed. By inputting skin color saturation to corresponding ST model, user skin temperature can be calculated and used as feedback signal for HVAC system control. The concrete steps are as follows.

2.1. User identification

User identification can be performed by identifying some personal information such as personal computer user account, radio frequency identification, fingerprint, human face, etc.

2.2. Online study

For personal computer in each workstation, ST relationship for the fixed occupant can be sampled and analyzed, which is called initialized study. Skin saturation, obtained by video magnification and analysis, can be used to calculate skin temperature by ST

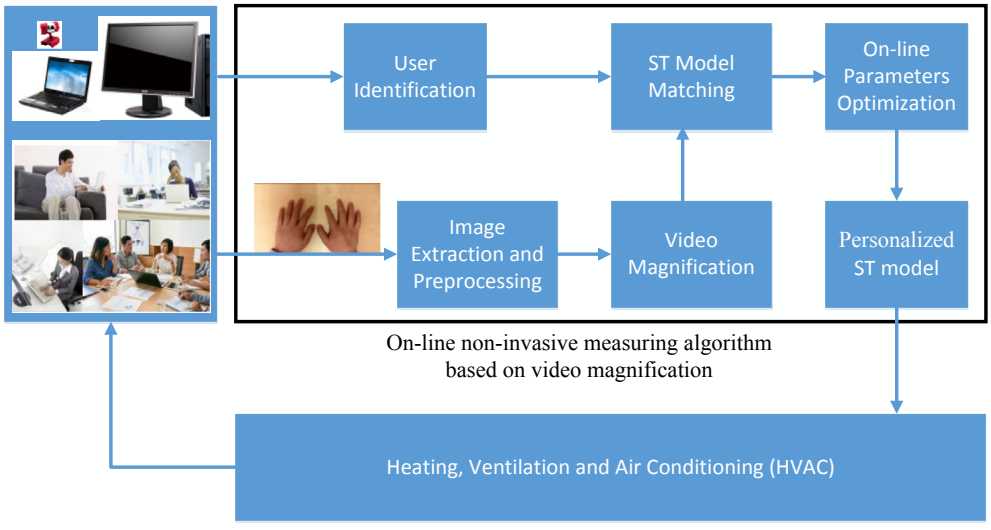

Fig. 1. Schematic of algorithm for practical application.

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