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論文の内容の要旨

In the past, consumer electrical products have evolved in response to the needs of users, such as “entertainment”, “convenience” and “comfort”, and in response to changes in society and living environments. More recently, there have been demands for products with more advanced functions, friendlier user interfaces, and lower energy consumption.

Regarding the need for comfort, we discuss how this can be achieved by optimally controlling the temperature and humidity to obtain an environment that is close to nature. This drive towards comfortable air-conditioned living environments is aimed at the use of air-conditioning as a comprehensive environment control technology. Each company has been promoting the development of energy-saving technology to implement air conditioning that provides comfort by satisfying various criteria such as the changing seasons, the differences in environmental conditions between Hokkaido in the north and Okinawa in the south, and the increasingly airtight nature of residential buildings.

While the development of energy-saving technology is in progress, as the performance of air conditioning improves, each company will use temperature detection sensors (thermopiles) and infrared sensors (pyroelectric sensors) to gather information such as entry/exit of people to/from a room, their positions inside the room, their level of activity, and the number of people in the room, and provide energy-saving air conditioning by controlling parameters such as the speed and direction of air flow based on this information. Due to these sorts of advances in air conditioning, the need has arisen for technology that can estimate the layout of a room (i.e., the positions of the walls, floor, beams, doors, etc.) and fine-tune the airflow speed and direction of accordingly.

In this article, we consider methods in which one or more cameras are mounded on domestic air conditioners, and the images captured by these cameras are used to detect the room layout. The

following three methods can be used for detecting the room layout:

- Using multiple cameras
- Using infrared sensors and/or ultrasound sensors
- Using a laser

One of the methods for detecting the room layout estimates the positions of objects by using the differences between pictures captured with multiple cameras. This method has had issues of high cost due to the need for multiple cameras, and the constraints imposed on the camera positioning and the size of the equipment housing. On the other hand, the cost issues can be solved by a method that uses infrared or ultrasound sensors, but since the number of pixels is small, there have been issues such as low resolution and short detection range. There is also a method that uses a laser, but the high cost and safety concerns have become issues.

Therefore, we worked on the research and development of a technique for room layout detection with a single camera to achieve both low cost and high precision. A room layout detection system using this technique detects the positions of objects and whether or not doors are open from images captured using a single camera. Also, since this technique was developed with a view to applying it to household appliances such as air conditioners, the processing of images captured using a single camera can be performed using little CPU processing power.

With this technique, the shape and size of rooms and whether doors are open or closed can be detected from a picture captured by a camera mounted on a domestic air conditioner, and the air flow direction and speed can be automatically controlled based on this information. This technique uses knowledge about the structure of a room given beforehand as a model to detect the interior structure of the building. For example, the air conditioner in a living room could automatically switch between single-room and double-room modes depending on whether or not the door between the living room and an adjoining room is open, or automatically adjust the blower swing orientation according to the size of the room.

An attempt to evaluate the thermal comfort was made by Dr. Fanger in 1973. Dr. Fanger proposed PMV (Predicted Mean Vote) that was based on heat exchange between environment and human. On the environment aspect, air temperature, mean radiant temperature, relative humidity and air velocity were included. On the human aspect, clothes and work were included.

The use of controlling supply air can allow changes in local heat exchange between environment and human. However, Dr. Fanger did not offer a method of estimating the local thermal sensation changes. In this study, we constructed the evaluation index of local thermal comfort based on the changes of human body temperature and air temperature. We also consider the basic model of thermal comfort based on the changes of room size and arrangement of furniture.

Keywords: PMV, Thermal comfort, Partition recognition, Layout recognition, Furniture detection

論文審査の結果の要旨

本論文は、空調機の送風により温度の制御を行う室内において、画像解析・画像認識により送風を遮蔽するオブジェクトの位置、形状特徴の抽出手法および人が知覚する温度に対する快適性の指標となるモデルを与え、これらに基づいた空調機制御手法を提案した。

本研究では、まず初めに複数の人間、家具、ドアなどが存在する人が居住する実空間を設定し、可視光および近赤外線カメラを用いて空間解析・認識を行って、この空間内の人間、家具の位置と形状、ドアの開閉および間取りを抽出する手法を与えた。特に人の移動やドアの開閉のような空間特性の時間変化に対応できるよう処理コストを低減してリアルタイムで特徴を抽出する手法を与えている。また、家具の形状にはテーブルや椅子のように長い脚を持つものがあり、脚などの隙間は送風が通過することが出来るから、単に家具を抽出するだけでなく形状特徴の抽出も必要となる。これらの空間特性を解析して空調機から人への送風経路を決定し、加えて人が知覚する快適性評価に基づいて送風の温度と風速などの空調制御を最適化する手法を与えた。

これまで空調の効いた室内での快適性の評価には体全体の平均的な体温が用いられてきた。しかしながら、肌が露出する顔、手、足などに温風や冷風が当たると快適さに大きな影響が生じる。このため本研究ではこれら局所的な部分での温度計測を行い、各局所部分に到達する送風の風速と温度に加えて主観評価実験の結果と合わせて快適性のモデルを構築している。本モデルにより、人が主観的に感じる快適さを良好に近似する評価値を与えることが可能となり、人の感覚を反映した効果的かつ効率的な空調制御を実現できた。

本研究成果の学会発表に対して３件の賞を受賞しており、学術的に高い評価を得ている。

本研究は居住空間特性の画像解析・画像認識という物理的、客観的な特性値と人が感じる快適性という主観的な特性とを空調制御により結びつけた研究と見なすことができ、学術的に貢献するところが大きい。更に、時間変化が伴う空間特性と人の快適性を評価値として空調制御を最適化することにより、人の感覚量を反映したエネルギー効率の高い制御を実現しており、高い実用性も認められる。よって博士（情報科学）の学位論文として充分価値あるものと認めた。