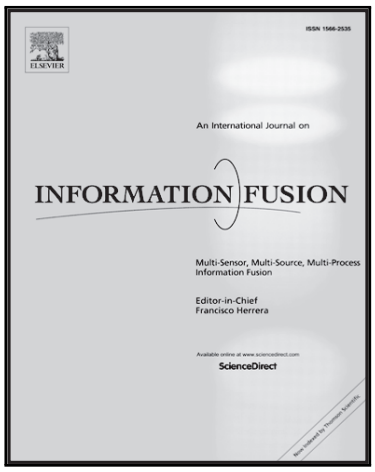

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Data Fusion and Multiple Classifier Systems for Human Activity Detection and Health Monitoring: Review and Open Research Directions

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ABSTRACT
Activity detection and classification using different sensor modalities have emerged as revolutionary technology for real-time and autonomous monitoring in behaviour analysis, ambient assisted living, activity of daily living (ADL), elderly care, rehabilitations, entertainments and surveillance in smart home environments. Wearable devices, smart-phones and ambient environments devices are equipped with variety of sensors such as accelerometers, gyroscopes, magnetometer, heart rate, pressure and wearable camera for activity detection and monitoring. These sensors are pre-processed and different feature sets such as time domain, frequency domain, wavelet transform are extracted and transform using machine learning algorithm for human activity classification and monitoring. Recently, deep learning algorithms for automatic feature representation have also been proposed to lessen the burden of reliance on handcrafted features and to increase performance accuracy. Initially, one set of sensor data, features or classifiers were used for activity recognition applications. However, there are new trends on the implementation of fusion strategies to combine sensors data, features and classifiers to provide diversity, offer higher generalisation, and tackle challenging issues. For instances, combination of inertial sensors provide mechanism to differentiate activity of similar patterns and accurate posture identification while other multimodal sensor data are used for energy expenditure estimations, object localisations in smart homes and health status monitoring. Hence, the focus of this review is to provide in-depth and comprehensive analysis of data fusion and multiple classifier systems techniques for human activity recognition with emphasis on mobile and wearable devices. First, data fusion methods and modalities were presented and also feature fusion, including deep learning fusion for human activity recognition were critically analysed, and their applications, strengths and issues were identified. Furthermore, the review presents different multiple classifier system design and fusion methods that were recently proposed in literature. Finally, open research problems that require further research and improvements are identified and discussed.

Keywords: Activity detection, Data fusion, Deep learning, Health monitoring, Multiple Classifier Systems, Multimodal Sensors

1. Introduction

The recent development in sensor technologies and decrease in the cost of sensor based devices have driven the implementation of health monitoring and human activity detection using mobile and wearable sensors. The implementation is vital to understand people's interaction with their environments which has become driving force for smart home and other cyber-physical applications[1, 2]. Human activity recognition has become significant in wide areas of researches and applications that include ubiquitous computing, military, health monitoring and elderly assisted living, life logging, computer interaction, surveillance and sports activity to mention but a few. Activity data collected with varieties of sensors in these areas are analysed to recognise simple and complex activities such as walking, sitting, running and other activities of daily living [3, 4]. These activities are very important to provide real time feedback for medical rehabilitations and to caregivers about patients' behaviour especially for elderly and those with special needs[5]. Other crucial applications are in the areas of fall detection and postural recognition[6, 7], where there are high risks of fall among the elderly populations and recognition of what constitute actual fall can help to prevent them with their negative health cost tendencies.

Based on devices and sensor types, human activity recognition can be classified into wearable, video, ambient and smartphone based approaches[1, 8]. Wearable devices are worn by the users for unobtrusive monitoring of body physiological signals such as accelerometers, gyroscopes and magnetometers. Video based approaches [9, 10] deploy video based sensors that capture images or surveillance camera features to recognise daily activities. Alternatively, ambient devices[8] capture the