

Robust Recognition of Reading Activity in Transit Using Wearable Electrooculography

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Abstract. In this work we analyse the eye movements of people in transit in an everyday environment using a wearable electrooculographic (EOG) system. We compare three approaches for continuous recognition of reading activities: a string matching algorithm which exploits typical characteristics of reading signals, such as saccades and fixations; and two variants of Hidden Markov Models (HMMs) - mixed Gaussian and discrete. The recognition algorithms are evaluated in an experiment performed with eight subjects reading freely chosen text without pictures while sitting at a desk, standing, walking indoors and outdoors, and riding a tram. A total dataset of roughly 6 hours was collected with reading activity accounting for about half of the time. We were able to detect reading activities over all subjects with a top recognition rate of 80.2% (71.0% recall, 11.6% false positives) using string matching. We show that EOG is a potentially robust technique for reading recognition across a number of typical daily situations.

1 Introduction

Activity recognition has recently emerged as a key area of research in building context-aware interfaces for mobile and pervasive computing. The problem of recognising physical activity in mobile situations, for example using body worn sensors, has been investigated by several researchers [17,21]. However, recognition of activities based on more subtle cues, such as user attention and intention - a far more difficult problem - remains relatively unexplored.

A rich source of information on user activity is in the movement of the eyes. The paths that our eyes follow as we carry out specific activities also reveal much about the activities themselves. This is particularly true for activities with very specific eye movements, such as reading. Reading is a pervasive activity, e.g. on computer screens at work, advertisements and signs in public, and books read at home or while travelling. Thus information on a person's reading activities can be a useful indicator of his daily situation as well as a gauge of task engagement and attention. Attentive user interfaces could comprise the current level of user interruptability or provide assistance to people with reading disabilities by automatically magnifying or explaining words or context in the text (for example see [15,10]).

We propose Electrooculography (EOG) as a novel measurement technique for recognition of user activity and attention in wearable settings. EOG, in contrast to well established vision-based eye tracking, is measured with body-worn sensors, and can be implemented as a wearable system. Although requiring facial skin contact, we believe EOG electrodes can be designed to be relatively unobtrusive, such as through integration into spectacles. A compact on-body device can then be used to process the incoming EOG signals.

The primary aim of this research is to assess the feasibility of recognising reading activity in different daily situations using wearable EOG. The wider goal of this is to gain insight into the potential of EOG for activity recognition. The specific contributions of the work are (1) an experiment involving data collection of subjects reading text while travelling to and from work, (2) a new method for saccade detection as a basis for reading recognition, and (3) an analysis of reading classification using string matching and Hidden Markov Models (HMMs).

The aim of our experiment is to capture reading in transit during different mobile situations. Despite the unavoidable fact that subjects wore sensing equipment on their faces, we took particular care to ensure that the chosen scenario - reading while travelling to and from work - was as realistic as possible. This scenario involved a continuous sequence of daily activities such as sitting at a desk, walking along a corridor, walking along a street, waiting at a tram stop and riding a tram. We recorded an 8 subject, ground truth annotated dataset, totalling nearly 6 hours of recordings - half of which involved reading.

Our work makes use of a new algorithm for detecting saccade features in EOG signals using Wavelet decomposition. Inspired by the typical characteristics of EOG signals during reading, we carry out a preliminary investigation into three different classification algorithms: a string matching algorithm on the horizontal saccade features; a discrete HMM also using the horizontal features; and a mixture of Gaussian HMM using the denoised signals from both horizontal and vertical EOGs. Our best result over all datasets was obtained using the string matching algorithm. Our main finding is that reading can be detected regardless of whether the subject is sitting, standing or walking, and in a variety of indoor and outdoor situations.

1.1 Related Work

In a recent work, Logan *et al.* aimed at recognising common activities in a “real world” setting using a large variety and number of common sensors such as wired reed switches, RFID tags and infra-red motion detectors in the environment [9]. They discovered that reading was one of the most difficult activities to detect and concluded that for covering all types of physical activity in daily life, additional sensors and improved algorithms need to be found.

All previous attempts to recognise reading have been based on vision to record eye movements. With the goal of building a more natural computer interface based on user activity, Campbell *et al.* investigated on-screen reading recognition using infra-red cameras to track eye movements [4]. The approach used was