論文の内容の要旨

Quantitative Analysis of Reading Behavior

to Recognize Personal and Text Characteristics

(読み方の定量的分析に基づく個人およびテキストの特徴認識)

氏名　　　マルティネス ゴメス パスクアル

(Pascual Martínez-Gómez)

Reading is a common method to consume information. Despite of its importance, the mechanisms underlying the reading process are not well understood. The reason lies in our incapability to directly observe the cognitive processes that occur during the reading act. For this reason, we resort to measurements of eye-movements as indirect observations of reading behavior. The objective is then to interpret measurements of eye-movements to understand the reading process. We concentrate on the analysis of two factors that may influence eye-movements. The first factor is linguistic characteristics of text, such as length of words, syntactic complexity of sentences or semantic ambiguity. The second factor is personal attributes, such as language skill or background knowledge of the reader. Psycholinguistic studies have investigated the relationships of these two factors and eye-movements, but experiments are often subject to controlled conditions and linguistic feature configurations. We aim to design methods to recognize linguistic features that influence reading behavior, and recognize personal attributes given measurements of eye-movements in natural reading tasks. There are three challenges associated to this work.

First, there is a need to recognize fixated words in eye-tracking studies on reading behavior. Although there are advances in eye-tracking technology, systematic errors prevent us from reliably obtaining the identity of fixated words. Current systematic error correction methods make strong assumptions on reading behavior, and do not perform well in unconstrained tasks.

We formulate the problem of systematic error correction as a text-gaze alignment, where fixation coordinates need to be mapped to the most plausible intended words. We use an image-registration technique, where the image representation of gaze samples is spatially transformed to match the image representation of text. Our method performs a global optimization using the structure of the text, and allows to recognize fixated words with an accuracy beyond sensor capabilities.

Traditional natural language processing techniques are capable to analyze linguistic characteristics of text or language. However, those techniques do not attempt to analyze how text is consumed by readers. Our second challenge is thus to discover text areas that demand higher cognitive effort, and identify the linguistic causes of cognitive demand. We show significant influences of linguistic features into cognitive effort, and find that the degree of linguistic influence depends on the type of reading task. Then, we use a Bayesian causal network to disentangle mixed effects of linguistic features into cognitive effort. We estimate the parameters of our Bayesian causal network using a corpus on readability, and find that our generative model identifies linguistic features that are consistent with cognitive evidence.

User-centered and adaptive systems benefit from fine-grained user profiles. In our third challenge, we aim to recognize latent personal attributes of readers and translators given measurements of eye-movements, text characteristics and typing events. To this purpose, we extract features from reading and typing behavior, and build non-linear functions that put them in correspondence with their personal attributes. We obtain significant error reductions in the recognition of reader's level of understanding and language skill, and show their characteristic patterns of eye-movements. We also obtain significant error reductions in the recognition of certified and non certified translators and their years of experience, and show the characteristic patterns of activity that distinguish expert and novice translators.

In this thesis, we present general methods to model the relationship of linguistic characteristics of text, personal attributes of readers and their eye-movements. Our methods are useful to quantify the degree of influence of different factors into eye-movements, and characterize readers and text according to the eye-movements they may produce.