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Editorial Article

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Representing and Inferring Dermatologists Perceptual Skill Based on Computational Behavioral Models

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Introduction

Perceptual skill is considered to be the crucial cognitive factor accounting for the advantage of highly trained experts [1]. It has been studied across various domains where it is profoundly exploited such as watching soccer games, playing chess, analyzing geo-spatial images, airport security screening, and examining photographical materials in clinical diagnosis [2-7]. Experts generate distinctively different perceptual representations when they view the same scene as novices. Rather than passively "photocopying" the visual information directly from sensors into minds, visual perception actively interprets the information by altering perceptual representations of the images based on experience and goals.

In knowledge-rich domains such as dermatology, experts' perceptual skill is a valuable yet effortless resource worth exploiting, particularly for training and designing decision support systems where knowledge regarding the basic diagnostic strategies and principles of diagnostic-reasoning are desired. Comprehension of the cognitive basis could benefit a wide range of research areas in medical informatics such as medical image retrieval, proactive human-computer interaction, and domain training. However, it is challenging to extract, infer, and represent dermatologists' perceptual skill for the applications.

Previous studies fill the gap between dermatologists' interpretation and the statistics of pixel values by dermatologists' manual annotation on segmented images and mapping into a domain knowledge ontology so as to perform medical image analysis at a semantic level [8,9]. However, there is great inter-variability between experts and intra-variability with which a single expert's performance changes from time to time also hinders this approach. Moreover experts' perception, as tacit knowledge, functions below the level of consciousness. The eye tracking technique allows researchers to study experts' subconscious image viewing behaviors by objectively measuring eye movements and is a promising way to address these challenges. Recently, more and more studies have tried to incorporate human perceptual skills into image understanding approaches, treating eye movements as a static process by directly mapping eye movement data into the image feature space or by weighting image segments. However, the fact that meaningful perceptual patterns sometimes exist only over time and that the observed eye movement data are noisy and inconsistent undermine the reliability and robustness of these methods. In particular, inferring latent patterns underlying these observable human behaviors is a critical intermediate step in terms of advancing image understanding.

One promising research direction is that developing state-of-the-art probabilistic machine learning methods and algorithms to understand, interpret, and predict dermatologist eye movement behaviors and their diagnostic reasoning decision-making [10,11]. By leveraging forward-looking predictive capability of probabilistic inference and learning, we can computationally discover and capture the spatial-temporal patterns in eye movement data. These studies require the researchers to work closely with dermatologists using human-centered experimental approaches to observe and record their overt perceptual and conceptual processing while inspecting medical images towards diagnosis. The inherent dynamic property and complexity of experts' diagnostic reasoning motivates the investigation into the temporal dynamics of this perceptual-conceptual-interleaving process.

The probabilistic dynamical models enable to discover certain aspects of dermatologists' domain-specific knowledge by summarizing their perceptual skill from their eye movements while diagnosing images [12]. The domain-specific knowledge unveils the meaning and significance of the visual cues as well as the relations among functionally integral visual cues without segmentation or processing of individual objects or regions. This will benefit the traditional pixel-based statistical methods for image understanding by evaluating perceptual meanings and relations of the image features which spatially correspond to the eye movement patterns.

This combination of expert knowledge and image features will help to generalize the approaches to images for which there is no experts' eye movements recorded. By analyzing the whole sequences of fixation and saccadic eye movements from groups with different expertise levels or no expertise, significant differences in visual search strategies between groups show that expertise plays a key role in dermatological image examination. It is shown that this subconscious knowledge can be acquired by extracting and representing experts' perceptual skill in a form that is ready to be applied.

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