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Automated screening aids diagnosis of diabetic eye disease

Ken Tobin and Edward Chaum

A low-cost computer-aided system in development could screen for early signs of diabetic retinopathy, a treatable disease that is the leading cause of blindness in working-age adults in the industrialized world.

The economic and social consequences of vision loss in people with the eye disease diabetic retinopathy (DR) could be reduced considerably if an inexpensive broad-based screening program existed for this disease. The World Health Organization estimates that 135 million people have diabetes mellitus worldwide and that the number of people with diabetes will increase to 300 million by the year 2025.[1] In the U.S., almost 20 million people are at high risk for developing diabetes. Diabetic retinopathy is the leading cause of new blindness in working-age adults in the industrialized world.

DR can be treated. The challenge lies in finding a cost-effective screening method: we need an approach—with high sensitivity and specificity—that can be applied to large populations in a timely manner, and identify those with the early stages of the disease. Jonathon C. Javitt and others at Johns Hopkins University estimated that up to 85,000 sight-years and as much as $167 million dollars could be saved annually in the United States alone by improving the screening methods for DR.[2] Through a National-Eye-Institute-sponsored research project, we are developing a novel approach to accurately describe and diagnose diabetic retinal disease from digital images of the back of the eye, the fundus.

Our project uses feature-based indexing and retrieval algorithms, which we previously used for applications in manufacturing[3] and geographic science.[4] Our goal is to automate the detection and diagnosis of diabetic eye disease from digital images taken in a primary-care setting (see Figure 1). The images are compared to a Web-based repository of historical images of healthy and diseased fundi. The diagnosis is determined by retrieving and comparing the image with visually similar images in the system. The more similar features of the patient's fundus are to historical images of diseased fundi, the higher the probability that the patient's eye is diseased.

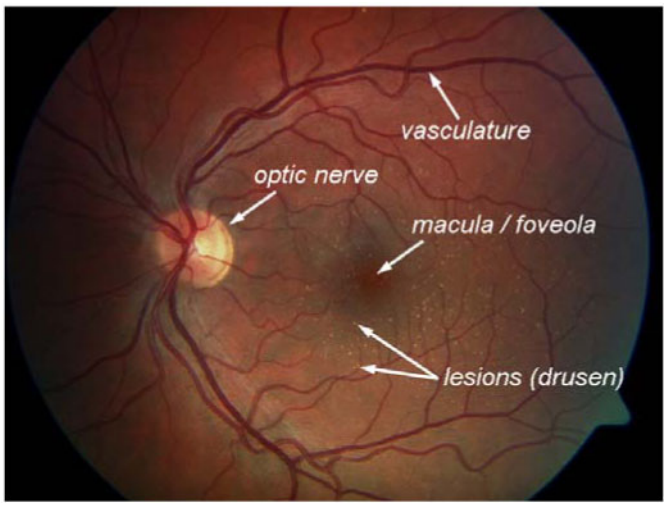

Figure 1. *A digital color image of the back of the eye reveals signs of the early stages of eye disease. This image shows telltale lesions, specifically, basal laminar drusen.*

Our approach to diagnosing DR hinges on the idea that visually similar content in a population of images can be related through physical cause.[3] For example, in semiconductor manufacturing, we gathered a repository of images that represented semiconductor-wafer defects. A query image is compared to the images in the repository. By finding similar images for which the defect cause was known, we were able to associate the query image with an errant manufacturing process. The repository contains both visual content associated with image pixels, and ancillary metadata. For semiconductors, this metadata includes product type, manufacturing process flow data, process layer, etc. For human retinas, metadata includes age, gender, ethnicity, diagnosis, duration of disease, relevant laboratory data, and manifestations associated with pathology. If we can prove that our visual-content hypothesis generalizes to other image domains, we can use this tool to diagnose both DR and other prevalent eye pathologies.

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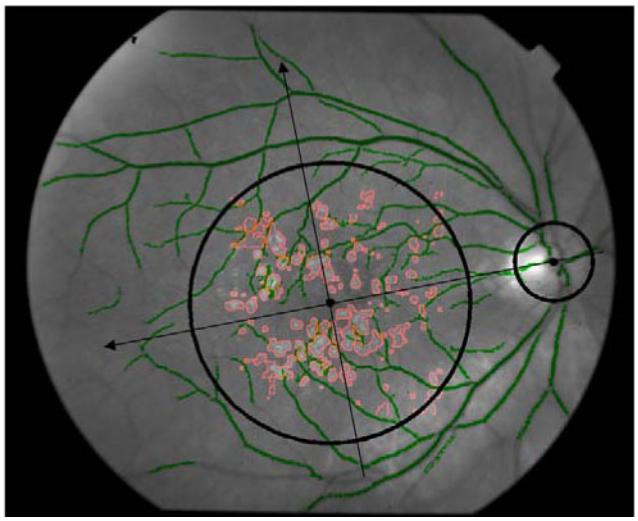

Figure 2. *This red-free fundus image shows automatic detection of the vascular arcades (green), optic nerve, macula region (black), and lesion population (red). These lesions indicate soft drusen in a patient exhibiting age-related macular degeneration.*

For electronic fundus imagery, we characterize visual attributes of the retina by first detecting important structures such as the vascular arcades, optic nerve, macula, and prevalent lesions, as shown in Figure 2.[5] We define a coordinate system centered on the macula—the highly-sensitive region of the retina responsible for detailed central vision—and then extract features that relate lesion types and distributions to the macula. Unlike other methods that attempt to classify manifestations and pathology through rule sets or supervised training,[6] our approach locates a statistically-similar population in the repository based on an index. This index is derived from image features. Our method infers manifestation and pathology from the image and metadata. That inference can be used to estimate of a probability of pathology based on extracted features. From a Bayesian point of view, we determine the conditional probability, ρ, of a given pathology, ω_i, given an observation of visual features, f. In other words, the probability is $\rho(\omega_i|f)$.

Although we are still in the early stages of this research, we have made significant progress in characterizing retinal structures across a wide variety of digital fundus images that represent many pathologies and associated disease manifestations.[5] We have succeeded in localizing our retina coordinate system and are currently researching relevant visual features of the retina topology and lesion populations. Our future work includes expanding our current data repository to incorporate data from additional DR studies. Eventually, we intend to determine the efficacy of this content-based-image-retrieval approach through a clinical study with the University of Tennessee Health Science Center, Mid-South Telehealth Consortium. Our long-term goal is to improve eye health on a societal scale through lower-cost, more-efficient and timely diagnosis and referrals, access to expert diagnosis in underserved populations, and high-throughput methods to meet the growing need for screening in the rapidly-expanding at-risk populations worldwide.

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