The eyes are one of the most important interfaces for us humans to interact with the world and also the best window into our minds. One way in which the eyes allow researchers to learn much about cognitive processes is by observing eye movements. Since the eyes only provide high-acuity detailed vision right where one looks, humans need to make frequent eye movements to take in their surroundings and perform many tasks of everyday life, such as driving and reading. Indeed, eye tracking, the recording of eye movements, has been used with much success by a wide array of research communities that include vision scientists, ophthalmologists, psychologists, neurologists, clinicians, and others, as well as by many industrial and commercial actors in neuromarketing, web usage studies, virtual and augmented reality, vehicle control, and safety, or human-computer interactions. Eye tracking not only provides much insight into cognition and brain mechanisms by determining where one looks while performing tasks, but observation of the movements of the eye is also an important diagnostic tool for many neurodegenerative diseases such as Alzheimer’s and Parkinson’s disease and vision disorders such as cataracts and age- or diabetes-related retinal degeneration.

Despite the long history of eye tracking, the current state-of-the-art eye trackers used for recording the movements of the eye all have significant limitations. These limitations however differ between eye trackers depending on the principle by which they determine eye movement. Eye trackers that use high-speed cameras to observe features on the front of the eye, such as the pupil or corneal reflections, often suffer from poor accuracy and/or precision. A different type of eye tracker instead images the retina at the back of the eye, thereby providing direct knowledge of how the light-sensitive surface of the eye is oriented in the visual world. While these recording techniques have sufficient resolution to observe even the smallest eye movements, they are often limited in terms of the range of eye movements that can be measured.

Importantly, data from eye trackers measuring different surfaces of the eye have different spatial and temporal properties, partly since the eye is not rigid and ‘wobbles’ more in some parts than others. However, since no eye tracker allows simultaneous recording of the front and the back of the eye, it is largely unknown how different parts of the eye move in relation to each other.

This project therefore will build an entirely new eye tracking platform that combines both a high-speed camera filming the front of the eye and a retinal tracker targeting the back of the eye that was built by the applicant’s group. This combined platform will, for the first time, provide simultaneous and synchronous measurements of the movement of both sides of the eye, allowing to determine the motion of the whole eyeball with unprecedented precision. Furthermore, since eye trackers using only the front or the back of the eye have non-overlapping limitations, new eye tracking techniques that combine tracking of the two sides of the eye will leverage the strong points of each while also mitigating many of the problems arising when using information from only one side of the eye. This new device and eye tracking techniques will allow us to break the limits in eye movement registration of current state-of-the-art eye trackers.

By crossing the technological gap with our new eye tracking platform, this project will also be able to bridge important knowledge gaps. First, we will for the first time create and validate a gaze estimation method that will take advantage of the information acquired concurrently from the two sides of the eye. Second, simultaneous recording of many parts of the eyeball will enable a better understanding of what the eye movement signals provided by an eye tracker recording from only a given surface of the eye actually reflect. Third, the limits to what information can be learned from tracking each of the eye’s surfaces will be elucidated, which also informs which tracking approaches are the most suitable in different situations and for addressing specific research questions.

The device, the new knowledge, and the new gaze estimation method created by this project will have a significant impact on many fields where eye trackers are used. Specifically, it will allow for the introduction of new experimental paradigms exploiting the significantly higher quality eye-tracking data accessible from our eye tracking platform, enabling investigations exploiting even the most minute eye movements that were heretofore not practically possible. This will allow for more precise research in many areas, from marketing, through vision science, to even medicine where this project’s outcomes could directly benefit patients by earlier and more precise diagnosis and better disease progression monitoring.