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Pradipta Biswas

Exploring the Use of Eye Gaze Controlled Interfaces in Automotive Environments

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Dedicated to my little Aarush

Preface

Eye gaze tracking is the process of measuring either the point of gaze (where one is looking) or the motion of an eye relative to the head. An eye tracker is a device for measuring eye positions and eye movement. Research on eye tracking dates back to the late eighteenth century when Louis Émile Javal investigated saccadic movements in reading tasks. Edmund Huey pioneered the building of the first eye tracker which was a contact lens connected with an aluminium pointer. Recent advancement in infrared-based eye gaze trackers has significantly increased research and industrial use of gaze tracking technology. Eye gaze trackers were mainly used for analysing ocular parameters for reading and a variety of human-machine interaction tasks. With the progress in processor speed and image processing algorithms, it is now also possible to use the gaze tracking technology in real time to control a screen pointer in a direct manipulation interface.

This book explores the use of eye gaze tracking as a direct controller of electronic displays inside a car and analysing drivers' cognitive load while driving. A couple of new algorithms are proposed to accommodate inaccuracy in eye gaze tracker for controlling an on-screen pointer and analysing micro-saccadic eye movements to detect cognitive load followed by a set of user trials to validate the algorithms involving a driving simulator. Important results have been obtained on gaze-controlled interfaces in vibrating environments and on visual perception while encountering oncoming road hazards.

Modern infotainment systems in automobiles add new challenges to human-machine interaction (HMI) while driving. Researchers have explored different input and output modalities like touchscreen, voice recognition, haptic feedback and so on to help drivers undertake secondary tasks involving the infotainment systems. The first section of the book explores the use of eye gaze-controlled interface so that drivers need not remove their hands from the steering wheel to control the dashboard. A series of user studies were undertaken to compare different input modalities and investigate the effect of vibration on gaze-controlled interface. Our initial study found that users found it difficult to home on target in a gaze-controlled interface and vibration along Y-axis of the screen further increases homing time on target. We have developed a new input modality combining eye gaze and finger

tracking technologies. We proposed and evaluated a neural network-based target prediction model that can expand users' intended target in a graphical user interface. A couple of user studies involving a driving simulator found that first-time users could operate a dashboard using their eye gaze in approximately 2.5 s for each on-screen item selection in different road conditions.

The second section of the book (from Chap. 5 onwards) has explored the use of saccadic intrusion to detect drivers' cognitive load and instantaneous perception of developing road hazards. Saccadic intrusion is a type of micro-saccadic eye gaze movement which was earlier found to be related to change in cognitive load. We have developed an algorithm to detect saccadic intrusion from a commercially available low-cost eye gaze tracker and conducted a series of user studies involving a driving simulator and cognitive and hazard perception tests. Our results show that average velocities of saccadic intrusion increase with increase in cognitive load, and recording saccadic intrusion and eye blinks for 6-s duration can predict drivers' instantaneous perception of developing road hazards.

Bangalore, India
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Glossary

Accelerometer A device that records instantaneous acceleration of its environment.

ANOVA Analysis of variance is a set of statistical models that is used to identify one or a set independent variables that significantly affect the variance of the dependent variable.

Automotive UI A set of user interfaces (for this book, mainly graphical user interfaces) inside an automotive.

Backpropagation algorithm Backpropagation, an abbreviation for ‘backward propagation of errors’, is a common method of training artificial neural networks used in conjunction with an optimization method such as gradient descent. The method calculates the gradient of a loss function with respect to all the weights in the network. The gradient is fed to the optimization method which in turn uses it to update the weights, in an attempt to minimize the loss function.

Bezier curve An algorithm to interpolate a curve through a set of points following the Bernstein polynomial function. It was initially used to draw automotive surface at Renault and Citroen and presently extensively used in computer graphics to draw curves and planes.

Cognitive load Cognitive load refers to the total amount of mental effort being used in the working memory while undertaking a task.

Dual-task study A user study where participants are instructed to undertake two tasks simultaneously.

Eye gaze tracker Eye gaze tracking is the process of measuring either the point of gaze (where one is looking) or the motion of an eye relative to the head. An eye gaze tracker is a device for measuring eye positions and eye movement.

Fitts’ law Paul M. Fitts proposed a model of rapid aiming movement that can predict movement time as a function of target width and distance to target. The law found extensive application in computer science for modelling, comparing and evaluating input pointing devices including input through physical and virtual keyboards.

Gaze-controlled interface Gaze-controlled interface is about operating a graphical user interface by changing the direction of one’s eye gaze movement, blinking or dwelling on an object.

Hazard perception test Hazard perception test is a part of the UK driving theory test that features everyday road scenes and contains at least one ‘developing hazard’. A developing hazard is something that may result in a driver having to take some action, such as changing speed or direction. The earlier a driver notices a developing hazard and makes a response, the higher he scores.

Index of difficulty Index of difficulty is a function used to measure a task’s difficulty in a rapid aiming movement using Fitts’ law. It is calculated as a function where the distance to the target is considered like a signal and the tolerance or width of the target is considered like noise.

Index of performance Index of performance (IP, in bits per second) is a measure of human performance in relation to rapid aiming movement, modelled using Fitts’ law and measured as the ratio of a task’s index of difficulty (ID) and the movement time (MT, in seconds) in selecting the target.

Midas touch problem The issue of selecting a target in an eye gaze-controlled interface is popularized as Midas touch problem. Generally, dwell time, blink, voice command or a hardware switch is used for selection.

Multimodal system An electronic system that can be operated using multiple input and output modalities.

N-back test An N-back test is a psychological test where participants are shown or made to hear a set of stimuli, and they have to remember the last N ($N = 2$ or 3) stimuli at any point of time. If at any point of time a stimulus is the same as the N th stimuli before, they need to respond by pressing a key.

Neural network Neural network is a mathematical model containing interconnected nodes (or neurons) inspired by biological neurons used as a classifier and pattern recognizer for complex data set.

Saccadic intrusion Saccadic intrusions are conjugate, horizontal saccadic movements which tend to be three to four times larger than the physiological micro-saccades and take the form of an initial fast eye movement away from the desired eye position, followed, after a variable duration, by either a return saccade or a drift.

Voice recognition Electronic technology to automatically recognize spoken voice command by an operator.