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Fang Chen • Jianlong Zhou • Yang Wang
Kun Yu • Syed Z. Arshad • Ahmad Khawaji
Dan Conway

Robust Multimodal Cognitive Load Measurement

Springer

Fang Chen
National ICT Australia (NICTA)
Sydney, NSW
Australia

Jianlong Zhou
National ICT Australia (NICTA)
Sydney, NSW
Australia

Yang Wang
National ICT Australia (NICTA)
Sydney, NSW
Australia

Kun Yu
National ICT Australia (NICTA)
Sydney, NSW
Australia

Syed Z. Arshad
National ICT Australia (NICTA)
Sydney, NSW
Australia

Ahmad Khawaji
National ICT Australia (NICTA)
Sydney, NSW
Australia

Dan Conway
National ICT Australia (NICTA)
Sydney, NSW
Australia

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Preface

The body of knowledge presented in this book is timely. As we enter the age of data, human capacities are increasingly the critical factor in determining the output of human-machine interactions. This has important implications not only in high reliability operations such as aviation, command and control and complicated industrial and commercial applications, but also in everyday device usage by the general population. In order to achieve optimal 'human-in-the-loop' system behaviour, it is therefore increasingly important to understand and adapt to the constraints of human cognitive abilities.

The research presented herein is the result of a unique combination of people and circumstances. A research group within NICTA had been carrying out research into interface technologies and for some years, producing both basic research and engineered applications. The team had a track record in the investigation of speech, linguistic features, gestures and then later physiological signals such as Galvanic Skin Response (GSR), eye-based signals, pen gestures and electroencephalography (EEG), all in the context of developing cutting-edge user interfaces. These investigations then evolved into a research focus on the advantages of multimodal interfaces and how cognitive architectures, when linked with technology, can be leveraged to provide more efficient and responsive Human-Computer Interaction (HCI).

Sometime in late 2004, during a site visit to a traffic emergency response facility, a manager asked me the following question: 'All my operators typically have multiple issues open that they are working on at any one time. When something dramatic and urgent occurs that requires immediate attention – who should I give the additional issue to?'

Armed with its previous experience, our team thus focused its attention on investigating and operationalizing the construct of cognitive load and its effect on user performance with the aim of providing robust, real-time quantification tools and methods. This work was then extended into the design of adaptive systems (both human and machine) that are able to compensate for the intersection of task demands and a user's cognitive capacities. Answering these questions has involved a 10 year research campaign involving 13 staff, 16 PhD students, numerous other researchers and along the way produced over 70 papers, four patent families (applied and granted in countries including the USA, Canada and Australia), finally culminating in this book.

A fundamental conceptual principle that emerged from this body of research is that the ability to observe and quantify the end-user through sophisticated data collection techniques enables systems to adapt to constantly changing work environments. This is achieved by learning about the intersection of multiple sources of variance such as the different characteristics of each feature evaluated for each task component and in each context. Furthermore, the data analytics expertise within the group allowed an unprecedented level of analysis of the complicated signals generated by both human behaviour and physiology.

It should be noted that the team that has carried out much of the research presented here is situated firmly within a data-driven approach and is at the vanguard of machine learning and algorithmic technologies, which manifests itself within this work in both methods and applications. Many analyses presented here are machine learning based, but are discussed in general terms, thus being accessible to those not familiar with the methods themselves. The text is aimed at researchers and engineers generally, including undergraduates in HCI, psychology and related fields. There is also an emphasis on practical problems and applied research, as a result of the ongoing mandate of our team to grapple with pressing issues in the real world.

This book reviews the current state of play in the literature as well as presents our own research into multimodal cognitive load measurement focusing on non-intrusive physiological and behavioural modalities, such as signals derived from the eye, GSR, speech, language, pen input, mouse movement as well as multimodal approaches. Factors which affect cognitive load measurement such as stress, trust and environmental factors such as screen illumination are also discussed. Furthermore, dynamic workload adjustment and real-time cognitive load measurement with data streaming are presented. Finally, typical application examples of cognitive load measurement are reviewed to show the feasibility and applicability of multimodal cognitive load measurement to situated applications. This is the first book to systematically introduce various computational methods for automatic and real-time cognitive load measurement and by doing so moves the practical application of cognitive load measurement from the domain of the computer scientist and psychologist to more general end-users ready for widespread implementation.

Whilst there is more work to be done in the field, the overwhelming message that should be taken away from this book is that many of the approaches outlined herein have now been validated and that useful and responsive measurement of human cognitive load is both achievable and an important factor in bringing about a more perfect union with our machines.

Sydney, NSW, Australia Dr. Fang Chen
January 2016

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We also thank many volunteer participants from universities such as UNSW, USYD and various NICTA groups who contributed their precious time for many different cognitive load measurement experiments conducted at NICTA. These people, in many instances, are students who are busy with their study and staff who have time pressure for their deliverables gave freely of their time and experiences thereby enabling us, as cognitive load researchers, to research this fascinating topic. Their great contribution makes our cognitive load measurement experiment successful.

We acknowledge our collaborators from around the world who have had various discussions and comments on our work.

Lastly, and most importantly, we would like to thank NICTA providing all kinds of support in the past years to make our research and experiments run smoothly and successfully.

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