Multimedia ergonomics

Drawing from a wide range of fields, the study of multimedia ergonomics is a highly interdisciplinary science. Here, **Dr Ivan V Bajić** discusses his research into the interactions between human and multimedia signals

Could you begin by explaining the term 'multimedia ergonomics'?

Ergonomics examines interactions between humans and 'things', so multimedia ergonomics studies interactions between humans and multimedia signals. There are many factors that impact this interaction. For example, in the case of video, the size and type of display device, ambient lighting, viewer's visual acuity, his or her mood, prior experiences and so on, are some of the relevant factors. Regarding the video signal itself, important parameters include its resolution, frame rate, whether it is a 2D or 3D video, the sort of compression used, etc. Each type of media has its own set of ergonomically relevant factors.

How did you come to develop an interest in this domain?

Although my academic background is in electrical engineering and mathematics, I have been interested in signal processing since my undergraduate studies and have been working on image and video processing and compression over the past 12 years or so. My attraction to multimedia ergonomics developed gradually during this time, driven in part by the appearance of computational models of human response to multimedia signals as well as the emergence of novel user interfaces such as touch screens that make interaction with multimedia more intuitive and natural.

Could you elucidate your research objectives, both in the long- and short-term?

The long-term goal is to develop a systematic approach to incorporate multimedia signals into the realm of ergonomics. This includes human-in-the-loop design methodologies for multimedia systems. In terms of short-term goals, our present work includes visual attention and its applications in image and video processing, compression and security, interaction with compressed video objects and ergonomic display.

To what extent do novel technologies provide you with new research opportunities?

The interaction between humans and multimedia signals is mediated by user interfaces, so advances in user interface technology create new avenues for multimedia ergonomics research. In the context of visual media, some of the technologies that are currently having an enormous impact on the field are gesture- and motion-based interfaces and touch screens. Looking ahead, ultra-high resolution, curved, flexible, high dynamic range and high frame rate displays will create new research opportunities. In audio and acoustic ergonomics, sound field control systems, which are an extension of surround-sound technologies, are likely to play a prominent role in the future.

How has the field changed in recent decades?

Multimedia ergonomics has been around, in some capacity, for many years. For example, the Bayer colour filter array, developed in the 1970s and used in most digital image sensors, is an arrangement of red, green and blue colour sensors that approximates the distribution of the corresponding cone cells on the human retina. In the Bayer array, there are twice as many green sensors as blue or red sensors, because the human eye is more sensitive to green light. But it is only recently that the knowledge existing in various disciplines relevant to multimedia ergonomics has started to be pooled together under a common framework.

Are there any particular advantages to working in conjunction with corporate sponsorship, as you do at the Multimedia Communication Laboratory at Simon Fraser University (SFU)?

Close collaboration with industry is an important aspect of engineering research and education at SFU. This is especially relevant in the field of multimedia, where industry has often been ahead of academia in terms of both technological and conceptual development. To give an example, the Bayer colour filter array was developed not at a university lab, but at Eastman Kodak. We see tremendous value in collaborating with industry, in terms of sponsorship, but also in joint R&D. That said, we also maintain a research programme independent from corporate sponsorship, directed at long-term objectives and involving higher risk and less conventional ideas. This 'blue skies' line of research is necessary for scientific progress, yet due to the current financial climate, industry is not in a position to pursue it.

Picture perfect

Research at **Simon Fraser University** into the manipulation of multimedia signals is providing useful insights into human viewing behaviour that could literally change the way analogue and digital images are viewed

AS HUMAN AWARENESS is mediated by sensory stimuli, the signals received from analogue and digital sources have a huge impact on shaping the way in which the multimedia environment is experienced. Traditionally, ergonomics has focused on the more tangible aspects of life to better understand the relationship between humans and their immediate physical surroundings in order to, for example, improve productivity in the workplace. Understanding the interactions between humans and multimedia signals is relevant and necessary in a world where analogue and digital images and electronic interfaces are ever more prevalent in daily life.

Being an intuitive part of product optimisation, the germ of multimedia ergonomics can be found in the design of multimedia systems and tools as well as in the sciences pertaining to the senses. Just a few of its related fields include signal processing, human factors and systems engineering, psychophysics and neuroscience, making multimedia ergonomics a highly interdisciplinary area of study. With the knowledge gleaned from these disciplines multimedia ergonomics is beginning to address issues in content viewing that are only now being characterised.

Studying the science behind multimedia ergonomics and its applications is Dr Ivan V Bajić, Associate Professor at Simon Fraser University's School of Engineering Science, British Columbia. Currently Chair of the Vancouver Chapter of the Institute of Electrical and Electronics Engineers (IEEE) Signal Processing Society, Bajić's research interests primarily focus on the applications of signal processing in image and video coding. Collaborating with colleagues from Dolby Laboratories, the National Institute of Informatics in Japan and Hong Kong's University of Science and Technology, Bajić's research into perceptual aspects of visual information processing is helping to advance what is currently known about the complex interactions between human beings and multimedia stimuli.

HIDDEN ARTEFACTS

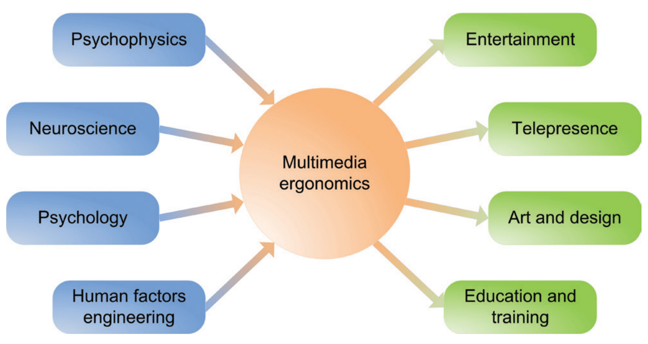
Though an individual observing a painting or a television programme might feel as though they are taking in the whole scene at once, the limited ability of humans to process information means the eye actually scans the image for points of interest. Baying for the eye's attention are variations in the visual features such as the orientation of an image, its intensity and its colour. These areas where attention naturally falls are salient regions. By manipulating these factors, Bajić has demonstrated that it is possible to guide the human gaze with considerable influence to and away from specific areas.

With consumer demands calling for ultra-high image resolution and faster streaming speeds of interactive and multiple-view video, network bandwidth constraints often result in errors causing image degradation. The most common problem in block-based video compression is the absence of macroblocks when packets of information are occasionally lost. For the most part, deblocking filters are not able to stop the proliferation as blocking artefacts carry over from one frame to the next ending up with a highly salient accumulation of artefacts and loss of visual quality.

Region-of-interest (ROI) video coding has employed computational models of visual attention to address this issue by encoding salient areas at a higher quality. A drawback of this method is that areas encoded at a lower quality can end up subject to blocking artefacts and actually divert attention from the naturally salient regions. Taking inspiration from the Itti-Koch-Niebur (IKN) saliency model developed in the late 1990s, Bajić's group has proposed a novel ROI-based coding method for improving video compression. By modelling the effects of compression on saliency, this method enables video compression to be saliency-aware. Therefore, in addition to reducing visually diverting blocking artefacts saliency is allowed to increase in ROI and decrease in non-ROI. Testing this technique against conventional video coding methods as well as the state-of-the-art Foveated Just Noticeable Difference (FJND) and Visual Attention Guided Bit Allocation (VAGBA) models showed consistent improvements in subjective video quality.

Sometimes, however, instances of missing Macroblocks (MBs) are simply too persistent. The low-saliency prior technique developed in Bajić's lab aims to address the problem of information loss during transmission in a two-pronged attack: firstly,

The relationship of multimedia ergonomics to some of the sciences it draws upon and some of the applications it impacts.



INTELLIGENCE

ERGONOMIC MULTIMEDIA

OBJECTIVES

Long-term:

- To develop a systematic approach to incorporate multimedia signals into the realm of ergonomics

Short-term:

- To find ways to utilise ergonomics-inspired signal processing in the design and development of improved multimedia systems and applications

KEY COLLABORATORS

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by helping to recover the relevant information for a clearer image and secondly, if the resulting picture is of low quality, by concealing the error. In earlier attempts at image recovery a low- and a high-resolution video were transmitted alongside each other. If MBs were lost during transmission of the high-resolution video then the low-resolution version served as a pool of replacements MBs to pick from. By adding the low-saliency prior, MBs are indentified and chosen on the grounds of best fit and lowest salience. In this way, a method of repair that is imperfect manages to draw as little attention to itself as possible. In a study comparing viewer response to videos with and without low-saliency, and at varying degrees of loss, the majority of participants consistently chose the former.

PULLING FOCUS

Though this area of research represents a useful tool in video coding, much of the lab's work is the result of blue sky ideation with a view to possible applications coming later, as Bajić explains: "Our thinking was that if you could influence the way people look at an image and video, that would in itself be a powerful new tool". A prime example is Bajić's work on orientation manipulation; just as an error can be concealed, so can desirable elements be highlighted. The manipulation of an image to make particular aspects draw the viewer's gaze is likely to find use as an effective tool for advertisers. Being one of the key factors competing for attention in an image, it has been demonstrated that altering the angles of specific regions can divert and attract attention accordingly. Using an image where its least salient regions have been mapped out using a control group, it is possible to compare where visual attention falls after rotating the angle of the dull areas in a modified picture. This study shows that not only is visual attention falling on the manipulated regions, but that eye movements are attracted to these areas in general and continue to linger.

Though likely to be useful in advertising, this research could be easily applied to graphic design and broadcasting scenarios too, with unforeseen applications likely to come about in the future as the computational models are developed further. With a background in electrical engineering and mathematics, Bajić was once not so confident that predictions could even be made regarding viewer attention, but the progress made in saliency modelling and manipulation has made it clear that not only can visual attention be accurately predicted, but it can be influenced with a considerable degree of control. Not only has multimedia ergonomics shown that this can be done but, states Bajić: "There are many ways to do it".

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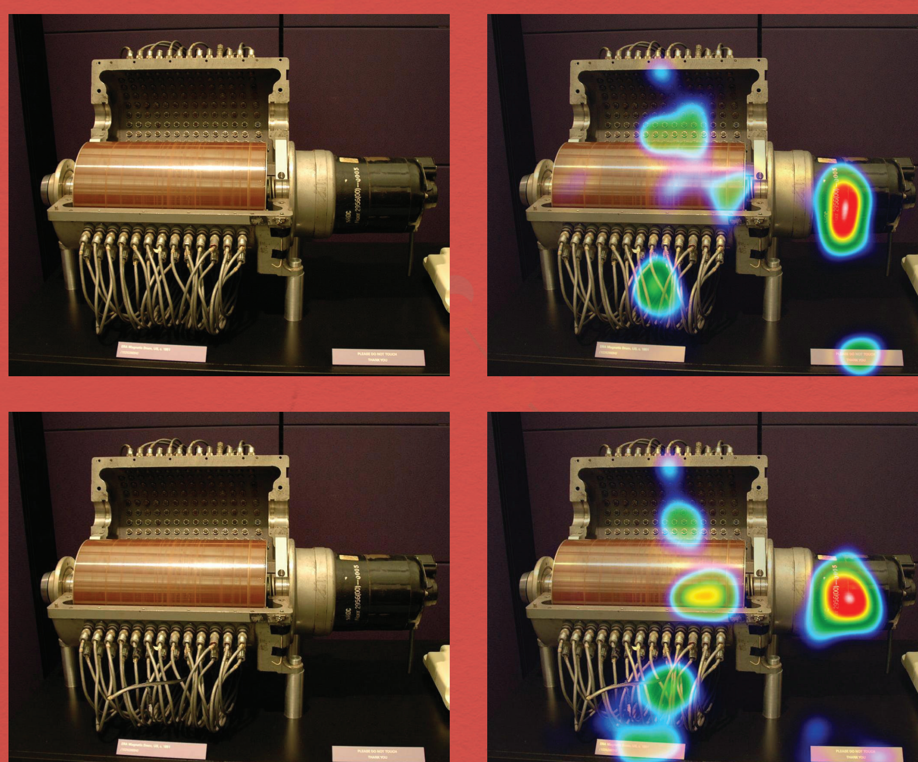

Illustration of how attention can be guided by careful manipulation of orientation. The **top left** image shows a photograph of a magnetic drum. The **top right** image shows a heat map of gaze points of a group of viewers recorded by an eye tracker, with warmer colours representing a larger concentration of gaze points. Note that none of the viewers looked at the plate beneath the cables. In the **bottom left**, a manipulated image shows which one of the cables has been optimally rotated in order to attract attention to that area. The corresponding gaze heat map in the **bottom right** confirms that viewers are now taking note of the plate beneath the cables.