Attention Management in Pervasive Computing

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The principles of HCI have reversed: previously, such principles focused on how humans actively approach ICT systems, but nowadays, ICT system designs also actively approach humans. Given this *human-computer confluence*, technologies such as Web-based news and advertisements, Internet Protocol TV, social network systems, mail and messaging systems, e-commerce, and logistics systems—big data in its broader sense—continuously wash floods of information over individuals. Both personal devices (mobile computers, smartphones, smart cars, and smart homes) and public ICT systems (digital signage and smart cities) create and share this data, making it difficult for the individual to allocate his or her attention to the right things at the rigt time.

Given this overabundance of information, attention management is of great interest to our community. Understanding how attention is allocated and how information is perceived and shared can lead to more informed decisions and behavioral change.

Formalizing Human Attention

Pervasive computing continues to leverage the miniaturization of electronics—embedding technology into literally everything—as well as multimodal (explicit) interaction design—where processor size and speed, wireless communication bandwidth, sensing capacities, and storage resources spawn the design space. Designers have come to realize that human attention is the single most critical resource for pervasive systems—yet it's also today's least understood pervasive systems design factor.

The study of attention in the pervasive computing domain is of both theoretical and practical importance. In the early 1900s, attention was viewed as a mental variable that couldn't be quantified or measured in metric terms. Consequently, it was considered outside the boundaries of scientific inquiry, although it constituted a fundamental element of psychological research. Today, everyone has an intuitive understanding of

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what attention is; how it can be assessed; and how it affects perception, memory, expectation, awareness, relevance, decision making, and consequently behaviors—on the individual as well as on collective and society levels. Yet, there's hardly any human capacity as complicated to describe.

Competing sensual stimuli, controlled via top-down (conscious) and bottom-up (unconscious) sensory and perceptual processes, and how we prioritize their importance makes it difficult to reliably assess attention. Formalizing human attention is extremely difficult, because it not only involves evidence-based research (such as the analysis of measurable, indicative signs of attention) but also theory-based research of human cognitive capacities (such as attention models). (For more information, see this issue's Spotlight department.)

In this light, the articles in this special issue focus on the introduction, presentation, and discussion of novel approaches to attention modeling, representation, recognition, estimation, and management as a theoretical and practical pervasive computing system design principle.

In This Issue

In "Sensor-Based Identification of Opportune Moments for Triggering Notifications," Benjamin Poppinga, Wilko Heuten, and Susanne Boll explore the most appropriate time to trigger alert notifications received via a smartphone, considering the fact that users are sometimes in situations where an interruption could be annoying or disruptive. Based on an empirical case in which the authors use a smartphone app as a research tool, they develop and validate a model for predicting appropriate moments for notification alerts.

In "Monitoring Attention Using Ambient FM Radio Signals," Shuyu Shi, Stephan Sigg, Wei Zhao, and Yusheng Ji analyze movement-related effects on received FM-radio carriers to understand the (loco)motion of individuals toward a stationary object in public places—such as a public display. The dynamics of locomotion effort (such as walking or standing) of people who pass a poster display is taken as a hint to understand the level of attention attracted by that poster. Features extracted from the ambient FM-radio signals help indicate changes in walking speed, velocity, and acceleration, which can help determine where the user is focusing his or her attention.

Finally, in "Using Augmented Reality to Help Children with Autism Stay Focused," Lizbeth Escobedo, Mónica Tentori, Eduardo Quintana, Jesus Favela, and Daniel Garcia-Rosas exploit notions of perceived attention to help children overcome difficulties induced by autism. The authors explore how augmenting physical objects with digital content can implement attractors to raise attention in specific situations of playful therapy, thereby increasing the selective and sustained attention of children with autism. Their contribution shows how important attention sensitivity is for therapy effectiveness, while at the same time identifying the need for models and algorithms that automate the recognition of human attention.

Foundational Attention Research Needed

To improve attention management for pervasive computing, we'll need foundational research that establishes theories and formal models of attention and conducts empirical studies to support and leverage such theories for future user interfaces. Theory-driven research must produce new theories based on observations of human behavior and validate them with designed user experiments, while data-driven research will try to find new attention models from mining big datasets, possibly creating new theories from facts found in the data. On the practical side, we'll need studies that can estimate attention from behavior using indicators such as eye and head gaze, speech, body pose, and effort and garner attention insight from perceived mental effort (for example, having people memorize things and then measure their response times and recall performance).

Furthermore, establishing design spaces and management architectures for attention—including models for human expectation, motivation, goals, plans, and decision making—will ultimately be necessary for attention-aware ICT systems. First, however, we need to better understand the matter of individual attention in terms of mechanisms for determining perceptual and cognitive load, recall performance, consciousness, overt versus covert attention, and focus versus periphery of attention. We'll also need to harness practical sensors—such as electroencephalography and electrooculography, blood-volume-pulse, and skin conductance sensors, visual gaze and pose tracking systems, positioning systems, accelerometers, and gyroscopes—and seamlessly integrate them into attention-aware systems. Then we can attack the issue of collective attention—including spatiotemporal information diffusion, novelty propagation, and consensus finding—by creating more complex sensors, which draw from social networks, microblogs, tweets, Web usage, and so on. A planetary nervous system of collective attention sensors could detect and understand collective societal phenomena, such as crowd movement, mass panic, financial crises, liquid democracy, the governance of commons, self-organization in traffic, human logistics, and energy systems.

Clearly, to fertilize a future generation of ICT systems based on the economics of human attention, we'll need to establish design, operational, and interaction principles and develop appropriate interface designs. We expect attention management system architectures, tools, and development frameworks to arise that include such principles.

Attention research will gain further momentum from challenging attention management showcases, success stories, and user studies in application domains of societal significance, such as healthcare systems, intense care and facility and operations control centers, electronic workplaces and electronic trading systems, mission-critical construction and engineering, avionic and automotive systems, energy and environmental protection systems, safety and security systems, monitoring and surveillance systems, and crisis observatories. Other domains of interest include sales systems and digital signage, art installations, public advertising, and public opinion building.

With such a wide-spanning spectrum of research challenges, and a broad span of application potential, we can almost be sure that attention research will hold our attention for years to come! P