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Editorial

Ambient intelligence: From interaction to insight

As the volume and complexity of information grows exponentially, information-overload becomes a common problem in our life. We find an increasing demand for intelligent systems to navigate databases, spot anomalies, and extract patterns from seemingly disconnected numbers, words, images and voices.

Ambient intelligence (AmI) is an emerging paradigm for knowledge discovery, which originally emerged as a design language for invisible computing (Norman, 2003) and smart environments (Pentland, 1996; Aarts and Marzano, 2004; Cai, 2005; Cai and Abascal, 2006; Cai et al., 2003). Since its introduction in the late 1990s, AmI has matured and evolved, having inspired the development of new concepts for information processing, as well as multi-disciplinary fields including computer science, interaction design, mobile computing, and cognitive science.

In a broad sense, AmI is perceptual interaction, involving common sense, serendipity, analogy, insight, sensory fusion, anticipation, aesthetics and emotion, all modalities that we take for granted in human interaction but have normally been considered out of reach in the computational world. We discover knowledge through the windows of our senses: sight, sound, smell, taste and touch, which not only describe the nature of physical reality but also connect us to it. Our knowledge is shaped by the fusion of multidimensional information sources: shape, color, time, distance, direction, balance, speed, force, similarity, likelihood, intent and truth. AmI is not only interaction but also perception.

We do not simply acquire knowledge but rather construct it with hypotheses and feedback. Many difficult discovery problems become solvable through interaction with perceptual interfaces that enhance human strengths and compensate for human weaknesses to extend discovery capabilities. For example, people are much better than machines at detecting patterns in a visual scene, while machines are better at detecting errors in streams of numbers.

As a branch of Artificial Intelligence, AmI is a subconscious process for ubiquitous computing, which inspires new theories and architectures for 'deep interactions', such as empathic computing (Cai, 2006). Common sense has been an immense challenge to AmI. For over 20 years, with over a 20-million-dollar investment, Douglas Lenat and his colleagues have been developing Cyc (Panton et al., 2006), a project that aims to create a reusable general knowledge base for intelligent assistants. Cyc essentially is an ontological representation of human consensual knowledge, which can construct a semantic web where meaning is made explicit, allowing computers to process information intelligently. One remarkable extension of the knowledge formalism in Cyc is its ability to handle default reasoning. In many cases, AmI often operates at a default level or below perceptual thresholds.

1. About this special issue

Originating from the ACM SIGCHI workshop on "AmI for Scientific Discovery," held in Vienna, April 25, 2004, this special issue is devoted to the cognitive aspects of AmI, such as serendipity, analogy, insight and sensory fusion.

Many great discoveries in history were made by accident and sagacity. True serendipity emerges from random encounters, such as in daydreaming (Mueller, 1990, 2000, 2003). In this issue, Beale (2007) introduces an intelligent system designed to maximize pseudo-serendipity (Roberts, 1989), which describes accidental discoveries of ways to achieve a desired goal. Beale introduces a synergistic interaction scheme that includes interactive data mining and a novel genetic algorithm to support serendipitous discoveries. He intends to answer questions such as: "what is interesting?" and "what is surprising?" In Beale's study, the highly dimensional data are mapped to a visual space where data are clustered by pseudo-physics properties, such as mass-spring relations. This method allows the user to interact with the data space from different perspectives and hypotheses.

Analytical models intend to reveal inner structure, dynamics or relationship of things. However, they are not necessarily intuitive to humans. Conventional scientific visualization methods are intuitive but limited by dimensions and resolutions. To bridge the gap, transformation algorithms are designed to map the data from an abstract space to an intuitive one, for example, a spectrogram maps an invisible sound to a visible frequency-intensity-time space. The convergence of scientific visualization and data mining creates a new domain for visual data mining. Seeing and understanding together enables humans to discover knowledge and deeper insight from a large amount of data (Wong, 1999). The approach integrates a human's AmI

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and analytical computation to form a coherent knowledge discovery environment. In this issue, Chakrabarti et al. (2007) present an insightful tool for mining and visualizing a large network, which has attracted growing attention in security, privacy and social science (Barabási, 2003; Watts, 2003). The tool, NetMine, analyzes a list of known patterns to detect anomalies in the graph (an abstract model that reveals patterns and laws), and then visualize the outliers in a two-dimensional image. The scalable algorithms allow a computer to handle arbitrarily large graphs. As the authors found, the tool discovered patterns that were not visible with known methods.

Human-like perception systems have potential for remote sensing, virtual reality, medical discovery, autonomous space exploration and artificial organs that extend our perception. The peripheral vision of the redundant information enables us to detect anomalies from seemly disconnected ambient data that we take for granted. For example, the human body is a rich ambient data source: temperature, pulses, gestures, sound, forces, and moisture; Also, many electronic devices provide pervasive ambient data streams, such as mobile phones, surveillance cameras, satellite images, personal digital assistants, wireless networks and so on (Cai, 2006). In this issue, Robertsson et al. (2007) present artificial sensor models for olfaction and manipulation, which enable ambient interfaces for knowledge discovery in a sensor web.

Finally, Krepki and his colleagues (2007) present the Berlin Brain–Computer Interface (BBCI) as a potential HCI channel for knowledge discovery. Derived from an interface for physically challenged people, the brain-computer interface enables information retrieval directly through the human brain. In addition, it provides feedback regarding human attention, interests and emotion directly to an integrated computer. For decades, information analysts have been searching for ways to incorporate expert's preference, style, attention, rhythm and other properties of intelligence into a knowledge discovery system. Unfortunately, most existing user-modeling methods are both invasive and indirect. A brain-computer interface provides a powerful approach to solving the issues and paradox of direct interaction with ambient information.

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References

Aarts, E., Marzano, S., 2004. The New Everyday—Views on Ambient Intelligence, ISBN 90 6450 5020.

Barabási, A.L., 2003, Linked, Penguin Group.

Beale, R., 2007. Supporting serendipity in data mining and information foraging. International Journal of Human-Computer Studies, to be published.

Cai, Y., 2005. . Ambient Intelligence for Scientific Discovery. Lecture Notes in Artificial Intelligence, vol. 3345. Springer, Berlin.

Cai, Y., 2006. Empathic computing. In: Cai, Y., Abascal, J. (Eds.), Ambient Intelligence for Everyday Life. Lecture Notes in Artificial Intelligence, vol. 3864. Springer, Berlin.

Cai, Y., Abascal, J., 2006. . Ambient Intelligence for Everyday Life. Lecture Notes in Artificial Intelligence, vol. 3864. Springer, Berlin.

Cai, Y., Snel, I., Bharathi, B.S., Klein, C., Klein-Seetharaman, J., 2003. Towards biomedical problem solving in a game environment. Lecture Notes in Computer Science, vol. 2659. Springer, Berlin, pp. 1005–1014.

Chakrabarti, D., Faloutsos, C., Zhan, Y., 2007. Min-cut graph for network mining. International Journal of Human-Computer Studies, to be published.

Krepki, R., Miller, K.R., Curio, G., Balnkertz, B., 2007. Brain-computer interface—an HCI-channel for discovery. International Journal of Human-Computer Studies, to be published.

Mueller, E.T., 1990. Daydreaming in Humans and Machines: A Computer Model of the Stream of Thought. Ablex, Norwood, NJ.

Mueller, E.T., 2000. A calendar with common sense. In: Proceedings of the 2000 International Conference on Intelligent User Interfaces. Association for Computing Machinery, New York, pp. 198–201.

Mueller, E.T., 2003. Story understanding through multi-representation model construction. In: Hirst, G., Nirenburg, S. (Eds.), Text Meaning: Proceedings of the HLT-NAACL 2003 Workshop. Association for Computational Linguistics, East Stroudsburg, PA, pp. 46–53.

Norman, D., 2003. The Invisible Computer. The MIT Press, Cambridge, MA.

Panton, K., Matuszek, C., Lenat, D., Schneider, D., Witbrock, M., Siegel, N., Shepard, B., 2006. From Cyc to intelligent assistant. In: Cai, Y., Abascal, J. (Eds.), Ambient Intelligence for Everyday Life, vol. 3864. Springer, Berlin.

Pentland, A., 1996. Smart Rooms, Smart Clothes, Scientific American, pp. 68–76.

Robertsson, L., Iliev, B., Palm, R., Wide, P., 2007. Perception modeling for human-like artificial sensor systems. International Journal of Human-Computer Studies, to be published.

Roberts, R., 1989. Serendipity—Accidental Discoveries in Science. Wiley, New York.

Watts, D., 2003. Six Degrees. Norton.

Wong, P.C., 1999. Visual data mining. IEEE Visual Data Mining. IEEE Computer Graphics and Applications 19 (5).

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