Pervasing Advertising Technologies

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The internet is finally leaving the confines of the PC, the office and the living room and is conquering the world around us. The vision of computer scientists in the 80s was that humans would partly leave the real world and spend more and more time in artificial, computer-generated realities (virtual reality). What is happening now, however, is exactly the opposite. Humans stay in the real world, and instead computers and the internet are woven so deeply into everyday life that they are becoming indistinguishable from it. This vision is called pervasive or *ubiquitous computing*. The concept and term *pervasive computing* goes back to Marc Weiser's visionary paper in the early nineties in which he came to the conclusion that "...the most profound technologies are those that disappear. They weave themselves into the fabrics of everyday life until they are indistinguishable from it" (Weiser 1991). The set-up of the work space at Xerox PARC at that time served as a precursor to the impending future era of computing in which users are surrounded by a multitude of computers in everyday situations. Today, as myriads of small processors and sensors – integrated not only in household appliances, toys, tools, and clothes, but also in price labels, receipts, product packages, and shopper loyalty cards – spread throughout our environment, pervasive computing has become the subject of highly progressive research in applied computer science. (Schmidt 2008)

In the following paper, a brief historical overview is presented and followed by an illustration of technical advances concerning processing power, storage, networking, sensors, and actuators. The remainder of this chapter will address concepts of automation, interactivity and ubiquity – all made possible by the previously presented technologies. It closes with an examination of the opportunities and challenges for the implementation of pervasive technologies in advertising.

Technical Advances

Processing, Storage and Networking

For a number of years, advances in the implementation of computing hardware have led to exponential increases in processing power, storage, and network capabilities. These developmental trends are referred to as Moore's Law (processing power), the Storage Law (storage and memory), and the Fibre Law (network bandwidth)[01]. As a consequence of such developments, devices are rapidly getting smaller and more powerful and now surround people in their everyday lives, enabling access at any time and in any place.

Most importantly, the ability to pack an increasing number of transistors onto an integrated circuit has led to a massive boost in computational power that has doubled approximately every two years. This trend has continued for more than half a century and still holds true today. The capabilities of many electronic devices are strongly linked to Moore's Law, such as processing power, memory capacity, and even the number and size of pixels in digital cameras. This has dramatically increased the usefulness of digital electronics in nearly every segment of the world economy. It is apparent today that processing power, storage, and bandwidth may no longer be a barrier to what computers can achieve in the future. For the most part, the capacities of desktop computers are currently underused, even when writing numerous e-mails, surfing the web or editing images. Hence, increasing processor speed will most likely not increase productivity. Instead creativity, rather than technology, will be the main limitation for future system development.

As a consequence of the exponential development described above, the ability has emerged to integrate all components of a computer into a single chip (integrated circuit), often referred to as system-on-a-chip (SoC) or micro-controller. This chip may contain digital, analog, mixed-signal, and often radio-frequency functions. A typical application pertains to the area of embedded systems. Micro-controllers usually have very limited computational resources and run a single custom programme. Popular examples of experimental hardware implementations include Arduino[02] (micro-controller) or the Beagle Board[03] (SoC). Such systems allow different types of sensors and actuators to be hooked up easily, and therefore enable the building of interactive systems in a small form factor.

Sensors and Actuators

The increasing prevalence of smart environments requires the integration of more and more sensors for obtaining information on the environment. The information collected is then processed further and used to modify the environment through the use of different types of actuators. Sensors can either be integrated within the infrastructure (e.g. allowing for information to be gathered on weather conditions, traffic congestion, etc.) or personal devices. Mobile phones, for example, now come with many integrated sensors (GPS, cameras, microphones, digital compasses) that enable the user to collect individualised data while at the same time controlling access to this information. The following section provides a brief overview of sensor and actuator technologies.

A range of optical sensors (from motion detectors to cameras) are available, which makes it possible to collect very simple (motion-related) but also very complex (human-behavioural) information, e.g. a person's mood, age, or gender[04]. The (semi-) automatic analysis of camera images is called computer vision. Today, cameras are so inexpensive (they cost only fractions of a dollar to produce) that they can be integrated into virtually any device. With systems-on-a-chip, processing power and storage can be directly integrated in the camera. So integrated systems can be built, which, for example, only output the number of detected faces, thereby preserving user privacy. In order to analyse the three-dimensional composition of a scene, stereo cameras are traditionally used. In addition to the normal camera image, a depth map is calculated that provides the distance of all objects in the camera's visual field. Stereo-vision relies on good features (e.g. textures) detected in the image and verified in both camera images (similar to the

01. See (Brown 2001) for a more comprehensive overview.
02. http://www.arduino.cc
03. www.beagleboard.org
04. Fraunhofer Shore (Sophisticated High-Speed Object Recognition Engine): www.iis.fraunhofer.de/bf/bsy/produkte/shore

human visual system), and requires considerable processing power. Recently, so-called depth cameras have become available, which generate depth maps by illuminating the scene with special (infrared) light. Two general technologies prevail: (1) Time-of-flight cameras (e.g. SwissRanger 4000 by Mesa) use technologies such as modulated light sources in combination with phase detectors to measure how long it takes light to travel from the camera to the object and back to the camera; (2) Structured light cameras (e.g. Microsoft Xbox Kinect®) project a light pattern onto a scene. A vision system then calculates depth information from the distortion of this pattern relative to the objects in the scene. Using depth images, some operations such as background subtraction are much easier than with normal camera images. The recent fall in price of depth cameras has also spawned a significant number of applications, such as gesture control.

Similar to cameras, microphones can either provide low-level information requiring only minimal processing (e.g. noise level, base frequency, characterisation of sound source) or high-level information (e.g. speech recognition). Microphone arrays can be used to determine the location of sound sources.

Today, location sensors can be used to obtain information on position, collocation and proximity of users both outdoors (GPS, GSM, WiFi, etc.) as well as indoors (Ubisense[05], Optitrack[06] etc.). Approaches often vary highly in granularity. Indoors, location sensors are typically embedded in the environment, as with the Active Badge system (Want et al. 1992). In the context of advertising, location sensing can be used for tracking purposes, such as the path customers take through the aisles of a supermarket.

To obtain information on direction, orientation, inclination, motion, or acceleration of a device, many mobile phones now come with accelerometers and/or gyroscopes. Whereas accelerometers measure proper acceleration of a device (relative to free fall), gyroscopes measure orientation and rotation (using the principles of conservation of angular momentum) hence making it possible to accurately recognise movement within a three-dimensional space. Accordingly, different types of contexts can be ascertained such as the orientation or movement of the device, whether it is stationary on a table or moving in a car. Acceleration is of particular interest when it comes to analysing usage patterns.

With the advent of the iPhone there has also been a proliferation of devices using touch technologies. In addition to smart phones, more and more displays and tabletops are being equipped with (multi-) touch support. Different technologies are used to create touch surfaces. Resistive touch screens use two flexible sheets coated with resistive material, which can register the precise location of a touch as they are pressed together. For capacitive sensing, a conductive layer is used and a small voltage applied to it, hence creating an electrostatic field. When a conductor such as the human hand comes near or touches the surface, a capacitor is formed and the change in capacitance can be measured from the corners of the panel. Optical touch technologies (such as FTIR) use light sensors, cameras and computer vision to detect fingers and objects on and above surfaces. State-of-the-art technology also includes PixelSense (e.g. Microsoft Surface 2.0), a technology where IR sensors are integrated in the LCD display, hence making it possible to see what happens on top of a surface without using a camera. See (Schmidt and Van Laerhoven 2001) for further information on sensor technologies.

Actuators allow information to be output in the form of different representations, for example, via visual, auditory, haptic, or olfactory channels. In the following paragraph we introduce the technologies and properties of actuators that address the different channels.

Display technologies include, among others, LCD (liquid crystal displays), plasma displays, projectors, and bendable displays, such as OLED (organic light-emitting diode) displays and e-paper. With the fall in price of displays, we envision that in the future literally any surface could function as a display at minimal cost. Important properties of displays include size, resolution, readability in sunlight, update frequency, brightness, and flexibility.

Haptics describes the recognition of objects through touch, including tactile perception, proprioception, thermoception, and nociception. For haptics, actuators are used that apply forces to the skin for touch feedback. Such actuators include vibration motors, electroactive polymers, piezoelectric, and electrostatic surface actuation. Haptic actuators are popular in robotics where they serve as the muscles of a robot. Most popular actuators include electric motors, linear actuators, series elastic actuators, air muscles, muscle wires, electroactive polymers, and piezo motors.

Finally, olfactory actuators allow for interaction based on smell. So-called olfactory displays can disseminate odours, hence serving as an olfactory channel between man and computer.

Concepts

The previously mentioned technologies (processing, storage, networking, sensors, actuators) are crucial prerequisites to pervasive computing and make possible its core principles of automation, interactivity and ubiquity.

05. Ubisense: www.ubisense.net

06. Optitrack: www.naturalpoint.com/optitrack

Automation

With the industrial revolution many work processes were automated; this automation continues today. Ever more mechanical and electro-mechanical systems are now computer-controlled, going beyond what we know as mechanisation. This enables so-called scale effects, which lead to lower average manufacturing costs per unit relative to increases in output. As a result, prices for products entering the market decrease as higher quantities are produced. An example of this is the fingerprint reader, which was a very specialised device some years ago but which can now be integrated in laptops at little additional expense. Today automation is no longer restricted to manufacturing but has found its way into telecommunications (e.g. telephone switchboards), medicine (e.g. electrocardiography), finance (e.g. automated brokering, ATMs), and also advertising (e.g. Google AdSense).

From a computer science perspective, the ultimate automation would be to create artificial intelligence (AI). In the beginning the objective was to build a general-purpose AI that can emulate all human cognitive capabilities (strong AI). This was found to be much more difficult than expected and by now most researchers and engineers have limited their ambitions to use AI technology only to solve very specific problems (weak AI). Closely related to AI, computer vision is mainly concerned with extracting and interpreting information from an image that can later be used to solve a task. Exemplary problems in computer vision are recognition (e.g. recognition of an object, identification or simply detection) and motion analysis (e.g. for tracking purposes). Similar to AI, it is generally not possible to build a general-purpose computer vision system that can recognise arbitrary things. Instead, one needs to define in advance a specific problem to be solved (e.g. finding faces in an image) and can then use computer vision techniques to solve this task. In this way, computer vision can, for example, be used to find and track people in a video stream, for face detection, face recognition (comparing faces to a database of known faces), interaction (e.g. gesture recognition), or activity recognition (e.g. whether somebody is seated).

Interactivity

Human-computer interaction (HCI) is concerned with "the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them"[07]. Since its subjects are man and machine, knowledge derived from the fields of computer science, as well as psychology, communication science, graphic and industrial design disciplines, linguistics, social sciences, etc. are all relevant. The driving goal behind HCI is to improve interaction between users and computers given a certain use context, which usually has a strong impact on the usability of a user interface. Hence HCI draws on methodologies and processes for designing and implementing interfaces, techniques for evaluating and comparing interfaces, developing new interfaces and interaction techniques, and developing models and theories of interaction. When it comes to interaction, two different types prevail. Traditionally, human-computer interaction focuses mainly on explicit interaction where the user tells the computer at some level of abstraction what he expects the computer to do, for example, by directly manipulating an object using a mouse, touch screen or speech input. Yet, as HCI extends beyond the desktop, implicit interaction, that is interaction occurring without the explicit intention or awareness of the user, will become ever more important. Schmidt defines implicit interaction as "an action, performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input" (Schmidt 1999). For example, a display may recognise that the audience is smiling and consequently display funny content.

With the market penetration of the smart phone and other related devices, the notion of layering relevant information into our visual field (augmented reality, AR) became a hot topic in HCI. AR describes through this the live direct or indirect view of the physical world whose elements are augmented with computer-generated, sensory input. In general, AR requires computer vision and object recognition in order for the real world of the user to become interactive and digitally manipulable. Examples of AR applications include navigation systems that allow views of the road to be augmented with cues on direction, points-of-interest, and upcoming obstacles. Furthermore, social interaction may be augmented in the future by providing additional information about the people we're conversing with by projecting such data onto our glasses.

Ubiquity

The ubiquity of pervasive computing technologies is one of their most profound properties. Computers that integrate information processing into everyday objects and activities as well as new

07. Hewett TT, Baecker R, Card S, Carey T, Gasen J, Mantei M, Perlman G, Strong G and Verplank W: ACM SIGCHI Curricula for Human-Computer Interaction. http://old.sigchi.org/cdg/cdg2.html#2_1 [accessed 23/03/2011] generations of the internet allow people to get in touch with one another at any time and in any place. Accordingly, this makes information-rich technologies and applications possible and further adds to Mark Weiser's vision of ubiquitous computing.

Mobile and wireless computing devices now come with high-resolution cameras, integrated GPS and provide easy access to the internet. Similarly, TVs are also linked to the internet and are no longer restricted to a single location (the home). As location-independent digital media entertainment becomes available with devices such as smart phones or tablets, younger generations in particular are eager to adopt these technologies.

Beyond mobile devices, more and more processors and sensors are integrated into everyday objects, such as household appliances, tools, toys and clothes. When linked through wireless networks, they create the so-called Internet of Things. This allows users to easily connect to social networks and virtual worlds and makes possible novel forms of applications and services that augment the physical world through new forms of interaction and communication.

Pervasive Advertising

Pervasive Advertising, i.e. the use of pervasive computing technologies for advertising purposes (Müller 2011), presents huge opportunities and challenges for our future. Pervasive advertising will soon arrive. Its fundamental orientation is being determined right now, and the direction we choose will influence the appearance of our urban space for years to come. We are at a crossroad where a decision must be made that will leave us in a better or worse off position. One direction might create a world clogged with pervasive spam, people being spied upon or subconsciously manipulated to buy things they do not need. However, the choice remains to take the future in a beneficial direction. This is a world in which pervasive computing actually achieves its positive potential. Where any information we may need, contacts to people we know and inspiring experiences are provided everywhere and at anytime. We believe that pervasive advertising faces three major challenges that must be addressed; these concern the areas of calm and engaging advertising, privacy, and ethical persuasion.

Advertising Needs to Be Calm and Engaging

That technology should be calm and require minimal attention has been a core feature of pervasive computing from its very inception. In their seminal paper on calm computing, Weiser and Brown (Weiser and Brown 1998) propose that, when computers saturate the surrounding environment, calm computers will be most effective. Key to this is the effortless sliding of information between the centre and periphery of our field of attention. This idea has strongly influenced research for decades and initially the underlying paradigm was that systems should remain invisible, predict the requirements and wishes of users from data obtained with various sensors, and then magically perform some actions like suppressing phone calls or switching on lights. Over the years, it became clear that predicting what users want through observation alone is very difficult or perhaps even impossible. In response to her observation of these facts, Rogers proposed the seemingly oppositional paradigm of engaging computing: computers should provide great experiences and engage users more in how they currently behave.

It is our belief that pervasive advertising should also be both calm and engaging. Although this might seem like a contradiction, it is not. Calm advertising means that advertisements should not be obtrusive but easy to ignore. Engaging advertising means that ads should provide engaging experiences when one is actively engaging with them. This can be achieved simultaneously. A pervasive ad could appear as calm, mildly flowing water when nobody engages with it, and then convert to an engaging mini-game once somebody pays attention.

Privacy Has to Be Guaranteed

Like calm computing, privacy has been an important topic for pervasive and context-aware computing from the outset. Most systems centre on the fair information principles of notice/awareness, choice/consent, access/participation, integrity/security, and enforcement/redress. A variety of systems (like pawS) have been proposed to implement these principles in technical systems (Langheinrich 2002).

In pervasive advertising there is a huge incentive for advertisers to collect as much user data as possible. Thus, it is crucial that user privacy also be protected. This can happen either through industry self-regulation, lawmaking or both. The degree to which privacy is protected and guaranteed will determine whether users trust advertisers. Winning such trust requires effort and can also be easily lost; guaranteeing user privacy is one of the foremost challenges facing pervasive advertising.

Persuasion Needs to Be Ethical

With regard to ethics, Fogg (Fogg 2002) mentions six significant ways in which persuasive technology can be abused. For example: the novelty of the technology may mask the persuasive intent; the positive reputation of computers may be exploited; computers can be proactively persistent; computers control the interactive possibilities; they can affect emotions but are not affected by emotions; and, finally, computers cannot shoulder responsibility.

It is said that intentions as well as methods and outcomes of persuasion can be ethical or unethical. Deception and coercion are always unethical, while operant conditioning and surveillance raise a red flag. Furthermore, it is unethical to persuade vulnerable groups like children. The method proposed to analyse ethics is known as stakeholder analysis, where all stakeholders are listed as well as what they have to lose. It is then evaluated which stakeholder has the most to gain or lose, and the ethics are determined by examining gains and losses in terms of values. Finally, the values and assumptions that are brought to the analysis should be acknowledged.

Persuasion is an integral part of advertising, and ethical use of persuasion is an important challenge facing pervasive advertising. With regard to advertising, it is our belief that any intention to persuade audiences against their own interests is unethical. Similarly, persuasion of vulnerable groups is unethical, as well as all methods that are deceptive, use coercion, operant conditioning or surveillance.

Conclusion

The great effectiveness and efficiency of pervasive advertising will be the key to its future success. The six most important opportunities of pervasive advertising are: it shifts more power to audiences and consumers, leading to symmetric communication between them and advertisers; it makes even tiny advertising campaigns viable, leading to niche applications (long tail) for small advertisers; it provides engaging experiences; it enables ads to adapt to the audience and the context; it enables detailed audience measurement; and finally, it enables advertisements to employ automated strategies for persuading audiences.

We believe that pervasive advertising is coming and will soon permeate public spaces. It is our responsibility to shape this development in a meaningful way. We see three important challenges: firstly, we should strive for calm advertising – ads that do not disturb audiences when they are not interested hence avoiding sensory overload especially in urban environments – while still providing engaging experiences for those who are. Cameras and other sensors allow interactive (multiplayer) games to be deployed that are fun and create a positive experience for the interested passer-by (Müller 2012). Secondly, we need to respect the privacy of audiences and build privacy-preserving architectures into the foundation of any pervasive advertising system. This becomes even more important in public spaces as the audience will be exposed to a multitude of sensors and cannot easily opt out. Thirdly, while advertisements may try to persuade customers, the method of persuasion must always be overt, and may never employ unethical means to achieve its goals.

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