Ambient Intelligence in HomeLab
As we are driven to enhance people’s lives, we want to know and fully understand how people interact with technology. We want to learn from them so we can make sure our innovations work for them. The HomeLab is a proof point for our dedication to this in the context of our Ambient Intelligence vision. The tremendous advances in wireless connectivity, speech technology and design enable us to bring advanced intelligent technologies into people’s homes while being fully integrated in their personal environment. Ambient Intelligence is the vision that Philips uses to denote this new paradigm in consumer electronics, which completely changes the way we communicate and live. We view ourselves as one of the industry shapers that will turn this vision into reality. Philips has a long tradition in ambient intelligence. At the 1958 World Fair, we presented the very first multimedia presentation ever: *Le Poème Electronique*, created by the world-famous architect Le Corbusier, futurist Iannis Xenakis and composer Edgar Varèse. They envisioned a world striving for ‘newness and harmony’ using multimedia – at the time a brand new way for creative artists to express themselves. The three artists took it even a step further by integrating all the electronics into the pavilion’s walls, making the experience ‘ambient’ and revolutionary for its day and triggering a whole new way of communicating ideas. I am sure that HomeLab will become the seminal research facility to help us understand better ‘the moments people touch technology’. At the same time, it will act as native soil for many technological innovations that will lead to the ultimate invisible experience enhancing and enriching the lives of people.

HomeLab will serve a great purpose in the integration and deployment of Ambient Intelligence-related technologies in novel applications and at the same time will be used to better understand human interaction with this entire new world we try to create. It is a unique facility, well equipped and well positioned to exhibit our commitment to further technologies that enhance people’s lives. The realization of the Ambient Intelligence vision can only be achieved by combining a broad range of technologies with innovative product and service design. In a true Ambient Intelligence environment, all electronic features and functions are integrated into people’s backgrounds. This requires full control over a wide spectrum of enabling technologies, ranging from micro-sized radio devices with autonomous power support, via all kinds of portable, wirelessly interconnected devices for personal communication, vast amounts of distributed storage functions, up to large wall-sized displays that support virtual and multimodal interaction. In the ultimate Ambient Intelligence environment, these components and systems are seamlessly integrated in such a way that they can be combined with extreme and opposite performance characteristics, so as to provide very large bandwidths using wireless connections or extremely high processing speeds at ultra-low power. These challenges very much fit the breadth and depth of our technology basis. This provides Philips with an almost unique opportunity to assume leadership in this new domain of applications and to building a strong position in the many new markets that will be opened up by the developments in Ambient Intelligence.
Maximum enjoyment
Ambient Intelligence aims at enhancing our leisure experiences and enriching the quality of our lives. From choosing to record the TV programme that it knows we like to watch, to monitoring the efficiency of an exercise workout in order to improve our athletic performance, Ambient Intelligence systems will operate quietly in the background to make the experience more enjoyable. Unlike the paradigm of the desktop computer, recognizing what sort of mood we are in will be vitally important. The system must know when to keep quiet and when to speak up, what to say and what not to say, and it must recognize those times when we need to be left alone with our thoughts.

From vision to reality
Although turning this vision of Ambient Intelligence into reality involves some formidable challenges, Philips is in an ideal posi-
A new modernity

The intelligent technologies emerging today are ‘light’. Miniaturized and almost intangible, they can merge seamlessly into our environment: homes, offices, cars, streets, clothing – even ourselves. This means, for instance, that the home of tomorrow will look more like the home of yesterday than the home of today. The bulky boxes containing today’s ageing technologies will disappear. Instead, the functions we need will be hidden in timeless objects, those that have been and always will be present: surfaces to sit on or put things on, containers, ornaments, and the walls, floors and roof that protect us from the elements.

Our environment will come ‘alive’ with intelligence. Objects that were formerly inanimate, passive spectators will become animate ‘subjects’, interacting with us and other objects in intimate and highly personalized relationships. The task of design is to ensure that these relationships are as enriching and as fulfilling as possible for the people served by these ‘objects-become-subjects’.

A social system

Naturalizing the human interface poses even greater challenges. Not only must the technologies of speech, gesture and handwriting recognition be refined far beyond their current status, they must also be integrated into multi-modal models that combine information on gesture, voice intonation and facial expression to determine the semantics of conversational dialogues. Even the way we react to and use Ambient Intelligence, together with its social implications, will require considerable research. To investigate the practical, psychological and social implications of Ambient Intelligence, Philips Research will use its HomeLab, which is located at the Philips High Tech Campus in Eindhoven, The Netherlands. Comprising a fully equipped home, complete with living, sleeping and kitchen facilities, HomeLab will be equipped with a distributed embedded infrastructure in which Ambient Intelligence can be developed and investigated. As a window on how the home of the future might look, one thing is certain: it is sure to be an exciting place to live and work over the coming years.

Protocols need to be established for peer-to-peer communication between computing nodes in self-configuring networks, algorithms need to be developed for resource location and management, and ‘intelligent agent’ technology needs to be developed so that applications can move around freely to locate resources and follow the user from one location to another.
New system concepts
HomeLab has been designed to allow studies of novel system concepts, which today may still require a lot of equipment to realize, but which can be expected to become compact enough to disappear in the background in the near future. It allows studies of distributed home networking systems which require connecting different rooms and floors as found in a real-home environment. By prototyping such systems in HomeLab, researchers can discover and solve the issues that emerge in such actual use environments.

Situational awareness
Ambient Intelligence systems are envisioned to be supportive, because they are aware of the users, and can adapt to their habits and wishes. Therefore, such systems need to include methods to discover the identity and location of users, devices and objects. Research projects are ongoing to develop optimal technologies, e.g. by investigating the behaviour of radio waves and ultrasound waves in an actual home environment, where furniture and moving people cause a much more complex reflection and transmission behaviour than in an outdoor environment.

Natural interaction
Speech is often considered one of the most natural modalities for interaction between users and ambient systems. Thus far, however, improvement of recognition rates in natural language dialogues, and even in the more limited command and control
Optimal systems will likely consist of a combination of such technologies, most of which operate in the same frequency band. HomeLab offers a realistic environment to test effects like mutual interference and the influence of walls and ceilings, and to study, for example, security mechanisms and bridging of networks in home.

Ubiquitous sound and vision
The key output modalities needed are sound (music, speech) and vision (images). Whereas today the latter is typically concentrated in one TV screen in the living room, future homes will have display solutions in any space where that is appropriate (kitchen, bedroom, etc.). They will range from small displays for messages to full-wall-sized displays for movies. Entirely new technologies will be required to realize such visions in actual home situations, e.g. where people do not have the room required for existing back-projection solutions, or the money for current large-flat-display technologies.

Again, HomeLab offers Philips the opportunity to already create the experiences today that such future technologies will bring tomorrow.

Separating functions from boxes
Once the information is fully digital, and ubiquitous connectivity has been realized, it becomes possible to separate the functions actually desired by users (images, sounds) from the boxes that are needed to produce them, thus providing users with a much greater freedom. Users can, for example, choose to place the TV tuners or PCs out of the field of view, and eventually to let them disappear in the background. Many issues emerge when trying to realize such solutions in real-life circumstances, and HomeLab is a rather unique environment for learning how to solve them: in its ‘user spaces’ it provides all the actual elements found in a real house (e.g., walls blocking the infrared remote control), whereas through its ‘research spaces’ ambient solutions that require further miniaturization before they can be made ambient, can already be realized today.

Feasibility research
In the months up to the opening, HomeLab has already proven to be a valuable tool to study and demonstrate the feasibility of the novel system concepts developed in several Research projects, and to collect the feedback of visitors and users. Many more projects will populate HomeLab in the coming years.

Mobile assistants
Mastering speech and gesture recognition allows studies into exciting further user interaction concepts, such as mobile, robotic personal assistants. These studies are also conducted in HomeLab. HomeLab provides the actual conditions that such mobile assistants have to be able to cope with, like staircases, multiple rooms and families with children.

Connectivity
The Ambient Intelligence systems aim at providing users with the freedom to choose what kind of information or entertainment they want when and where, e.g. on portable screens they can take with them as they move through the house. This means that such systems typically rely on ad-hoc wireless networking of devices. Depending on the type of device (mobile phone, PDA, portable PC, webtable) and content (photos, films, messages), an appropriate wireless connection is applied, e.g. WLAN (802.11b or 802.11a) for large bandwidth, and Bluetooth or Zigbee for ultra-low power.
Multi-disciplinary approaches
Advanced technology is readily advertised to enhance the quality of future home life. For example, the introduction of network technology in the home is said to reduce the functional redundancy found in current homes and increase efficiency and ease of use to save time do the things one really wants to do (quality time). But, how are future electronic products going to use these networks to achieve the anticipated user benefits, and what user-system interaction knowledge is required to realize a true paradigm shift from ‘operating devices’ to enhanced and new ‘interactive experiences’? To find answers to these questions we need to study the physical, social and cultural context in which technology will be used and its implications on daily life. HomeLab offers a unique environment that is optimized to conduct research in these areas. Multi-disciplinary teams of researchers together with potential end-users explore the advantages and disadvantages of prototypes of future electronic systems in a realistic home setting.

User-centred research
Nowadays, the technological possibilities to enhance home life are vast; to quote the prototypical engineer, “tell us what you want and we can make it”. But, what do people really want? Once we better understand the needs and desires of people, the output of a structured idea generation process is expected to yield product or system concepts that show an increased potential to truly enhance living and being at home. Of course, such claims should be validated by evaluating the anticipated user benefits before a selection is made to bring certain concepts into a second research and design cycle. In a next iteration cycle, more detailed user requirements need to be uncovered and fed into the generation and implementation of concrete design solutions. Next, the utility and usability of the proposed solutions can be checked by conducting carefully planned user tests. This iterative process which is carried out by multi-disciplinary teams and in which user involvement plays a crucial role is called user-centred research. HomeLab is designed to become the place where researchers and designers can team up with end-users to realize a shared and tangible vision of the future of in-home electronic systems.

User involvement
Although HomeLab provides a fully-functioning home environment where people could live for a longer period of time, it is expected that people, initially, only participate in interactive HomeLab sessions that typically only last a couple of hours. During these sessions, researchers can directly interact with the participants and the systems under investigation, or people can explore the Ambient Intelligence environment on their own while unobtrusively being observed by researchers that make use of the HomeLab observation facilities.

HomeLab is well equipped to support both types of user behaviour research. The interior decoration and the possibilities to flexibly re-arrange or move furniture around the house makes it easy to adapt the house to match the particular lifestyle of intended target groups, making the ‘inhabitants’ of HomeLab feel safe, happy, at ease, and stimulated. HomeLab has two observation rooms which in combination with 34 cameras, distributed over the house and controlled by the HomeLab control system, provide the right infrastructure for doing observational user studies. The type of user studies that can be facilitated ranges from observations of user (and system) behaviour to ‘traditional’ usability tests. Below some imaginary examples are described.

Wizard-of-Oz
Bob and Linda have been invited to HomeLab to experience how a future living room might support the planning of their yearly summer holiday. After a tour around HomeLab, which surprisingly well matched the claims should be validated by evaluating the anticipated user benefits before a selection is made to bring certain concepts into a second research and design cycle. In a next iteration cycle, more detailed user requirements need to be uncovered and fed into the generation and implementation of concrete design solutions. Next, the utility and usability of the proposed solutions can be checked by conducting carefully planned user tests. This iterative process which is carried out by multi-disciplinary teams and in which user involvement plays a crucial role is called user-centred research. HomeLab is designed to become the place where researchers and designers can team up with end-users to realize a shared and tangible vision of the future of in-home electronic systems.

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The Oxygen Partnership Alliance

Rodney Brooks, Director of the Artificial Intelligence Laboratory and Professor of Computer Science and Engineering of the Massachusetts Institute of Technology

The Oxygen project aims to create a system that brings abundant computation and communication, as pervasive as free air, naturally into people’s lives. Intelligent spaces, like the Artificial Intelligent Laboratory’s Intelligent Room, will serve its occupants as transparent points of interaction. In the Intelligent Room, robotics and vision technology are combined with speech-understanding systems and agent-based architectures to provide ready at hand computation and information services for people engaged in day-to-day activities, both on their own and in conjunction with others.

Rodney Brooks: “Only through living with our technologies can we discover which ones really improve our lives and which ones only sound good as proposals.”

Members of the Oxygen Partnership Alliance include Acer Group, Delta Electronics, Hewlett-Packard, Nokia, NTT and Philips.
Studying human behaviour
The possibility to observe participants during their stay in HomeLab is one of its primary functions. A tailor-made HomeLab control system has been developed in-house to collect and analyse observational data. The system controls the cameras and the routing of the video and audio signals. Human activities, postures, facial expressions, social interactions and user-system interactions can be recorded and digitally stored to study patterns, trends and relationships. Results will be used to improve products, to eliminate imperfections and to explore new applications. The main observation room offers a place for an observation leader and four observers. The observation leader is responsible for the data collection and will be the director of the HomeLab interactive session. The observation leader modifies camera set-ups, routes video and audio signals, and monitors the capture stations. The main task for an observer is to concentrate on monitoring the behaviour of the participants. This can be done by looking directly into the home through a one-way mirror, or by viewing a video monitor that can be connected to any of the 34 cameras in the house. The behaviour of a participant is 'scored' in terms of events that characterize the observed scene. The scored events are time-stamped and appended to the video data. In this way, the HomeLab control system both implements an accurate and efficient support tool for doing observations and facilitates a flexible system for exploration and analysis of the acquired data.

Technical infrastructure
HomeLab has more to offer. Broadband Internet facilities enable various ways to connect parts of the HomeLab infrastructure to the Philips High Tech Campus network or even to the outside world. A wireless Local-Area Network (LAN) offers the
possibility to connect people in HomeLab without running cables. However, if cables are required, double floors provide nice hiding places. Corridors, adjacent to the rooms in HomeLab, accommodate the equipment that researchers and developers need to realize and control their systems and to process and render audio and video signals for the large flat screens in HomeLab. A power control system features remote controllable light settings and power switches.

But it still leaves the possibility for participants to simply turn on and off the lights by using ‘ordinary’ switches. Future intelligent systems that aim to enhance people’s emotions and experiences by means of lighting will be able to interface with the HomeLab power control system.

ERKKI LIIKANEN: ‘HomeLab is an excellent example of a natural surrounding where normal “man and woman on the street” can join members of the research community, from industry and academia, to pull together their effort and build coherent approaches to realize the Ambient Intelligence vision.’
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Georgia Tech Aware Home

Gregory Abowd, Director of the Aware Home Research Initiative and Associate Professor in Georgia Tech’s College of Computing

The Aware Home of Georgia Institute of Technology serves as a living laboratory for research in ubiquitous computing for everyday activities. The goal is to develop the requisite technologies to create a home environment that can both perceive and assist its occupants. The scope of the projects carried out at the Aware Home ranges from fundamental technical development to cognitive and ethnological studies that assess the most appropriate and compelling technological strategies.

Gregory Abowd: “Building a living laboratory to investigate the impact of ubiquitous technologies in the home is critical for the understanding of how technology impacts our domestic life. It not only allows us to investigate feasibility but also provides insights into the desirability of the augmented home life. And for an advancing population, the investigation of technologies for successful ageing are paramount.”

Aware Home is sponsored by Intel Research, Motorola Labs, Hewlett-Packard and Visteon Corporation.

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MIT House

Kent Larson, Director of the Changing Places Lab: a Joint MIT Media Laboratory and Department of Architecture Consortium

House is a multi-disciplinary consortium of researchers and companies that have come together to reconsider the home: how it is designed, how it is built, and how new systems, services and technologies can prepare our places of living to better meet the challenges and opportunities of the future.

A single-family prototype house has been designed for an MIT-owned lot in Cambridge, Massachusetts. The facility will be used to evaluate design and digital/physical infrastructure concepts and to accommodate ongoing research as a ‘Living Lab’. The Living Lab is designed to allow long-term, scientific studies of occupants and their relationships to their environment and the technology of the home. Kent Larson: “Responsive technologies may profoundly alter the places that people inhabit, but we have not yet found answers to the central question: How can complex and ever-changing systems be made accessible and useful in the context of the highly varied and continuously evolving activities that take place in the home? My hope is that the Philips HomeLab and the MIT Changing Places Lab will become key components of an international community of research facilities to develop and test new technologies in the context of life.”

House Consortium members include International Paper (Building Materials Group), Owens Corning, Salt River Project, State Farm Insurance, Procter and Gamble, Bentley Systems Inc., and Invensys.
The Philips Pavilion
At the World Fair in Brussels in 1958, Philips demonstrated its technology and vision in a special Philips Pavilion. Nearly two million visitors experienced a media show, totally different from a typical display of consumer products. What they saw, was a dazzling demonstration of cutting-edge technology in the service of the arts. Philips presented a fully automated, 480-second programme of colour, voice, sound and images that was broadcast within a space of warped concrete shells. The building was initiated by Philips’ artistic director L.C. Kalff and designed by Le Corbusier and Yannis Xenakis to set an exceptional stage for the first immersive media experience: *Le Poème Electronique*. In the scenario of *Le Poème Electronique*, Le Corbusier brought together the music composed by Edgar Varèse with a series of images illustrating evolution from the dawn of humanity to the atomic age, not without some critical remarks, and a plenty of visual and sound effects fitted into the extraordinary architecture.

The Philips Pavilion aimed to make a statement about the harmony between human values and technology, a central theme of Le Corbusier. The structure consisted of a mathematical figure combined with a human form: a shell structure of hyperbolic paraboloids rose above a floor plan in the shape of a human stomach.

An experience was created with stochastic music and sound effects (*musique concrète*) that would not have been recognized as

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**IN GOOD COMPANY - Microsoft Concept Home**

*Craig Mundie, Senior Vice-President of Consumer Strategy, Microsoft*

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**LE POÈME ELECTRONIQUE - the first immersive media experience**

*André Meyer*
music at the time. Projected images were modified and enhanced with coloured light that supported the flow through the building, an early example of liquid architecture. *Le Poème Electronique* reminded visitors of a musée imaginaire with its collection of references to all sorts of global cultures.

*A seminal experience*

Marc Treib, professor at the Department of Architecture (University of California), studied the Philips Pavilion and brought it back to life in his visually compelling book called ‘Space Calculated in Seconds: The Philips Pavilion, Le Corbusier, Edgard Varèse’ (1996, Princeton University Press). In his opinion, the Philips Pavilion should be seen as a landmark multimedia production: “… the Philips project […] can be viewed as a pioneering quest into the production of modern art, or even as a prototype of virtual reality.” Although the pavilion was dismantled after the World Fair, the memory of this fascinating project, this important achievement in the history of Philips and this pioneering attempt to harmonize innovative technology with people’s values is kept alive.
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