findings do not rule out a role for mTORC2 in aging. What Lamming *et al*. do achieve is a clear dissociation of impaired glucose homeostasis and enhanced longevity. Indeed, *mtor*$^{+/-}$ *mlst8*$^{+/-}$ mice have normal glucose homeostasis, indicating that delayed aging derives from some other consequence(s) of mTORC1 inhibition.

Considerable effort is being directed to identify new and better mTOR inhibitors. The results from Lamming *et al*. lead to some early predictions about the ability of such compounds to modulate longevity. For instance, high-specificity inhibitors that target the active site of mTOR, such as PP242 and Torin, have recently been developed (*14*). Although blocking both mTORC1 and mTORC2 function may be ideal for oncology and other conditions, these inhibitors may be less effective than rapamycin for increasing longevity and preventing age-associated diseases. The study by Lamming *et al*. may point the way toward such therapeutic approaches.

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COMPUTER SCIENCE

How Smart Is Your Home?

Technical advances are bringing intelligent homes that respond to residents' needs and wishes within reach.

Diane J. Cook

Individuals spend most of their time in their home or workplace; for many, these places are their sanctuaries. Over the course of the 20th century, technological advances have helped to enhance the comfort and shelter provided by our homes. Insights gained from capturing and modeling behavior in these places may be useful in making our environments more intelligent and responsive to our needs. Recent advances are bringing such "ambient intelligence" in the home closer to reality.

Since the miniaturization of microprocessors, computing power has been embedded in familiar objects such as home appliances and mobile devices; it is gradually pervading almost every level of society. Ambient intelligence extends the notion of computing to provide customized, automated support that is so gracefully integrated with our lives that it "disappears" (*1*). In the home, the idea is that computer software playing the role of an intelligent agent perceives the state of the physical environment and residents using sensors, reasons about this state using artificial intelligence techniques, and then takes actions to achieve specified goals, such as maximizing comfort of the residents, minimizing the consumption of resources, and maintaining the health and safety of the home and residents.

During perception, sensors embedded in the home generate readings while residents perform their daily routines (see the figure). The sensor readings are collected by a computer network and stored in a database that the intelligent agent uses to generate useful knowledge such as patterns, predictions, and trends. On the basis of this information, the intelligent agent selects an action and stores this selection in the database. The action is transmitted through the network to the physical components that execute the command. The action changes the state of the environment, triggering a new perception/action cycle.

Filling a home with sensors and controlling devices by a computer is not only possible, but it is simple and commonly found in homes today. Sensors are available off-the-shelf that localize movement in the home, provide readings for ambient light and temperature levels, and monitor usage of doors, phones, water, and appliances. Tiny, inexpensive sensors can be attached to objects to not only register their presence but also record histories of recent interactions. Such smart objects can harvest their own energy, and recent standards facilitate vendor-independent plug-and-play sensor design and modeling (*2*).

Proliferation of sensors in the home results in large amounts of raw data that must be analyzed to extract relevant information. Most smart-home data from environmental sensors such as infrared motion sensors and magnetic door sensors can be processed with a small computer. Once data are gathered from wearable sensors and smart phones (largely accelerometers and gyroscopes; sometimes adding camera, microphone, and physiological data), the amount of data may get too large to handle on a single computer, and cloud computing is appropriate. Cloud computing is also useful if data are collected for an entire community of smart homes to analyze community-wide trends and behaviors.

Currently, most users write rules by hand to interpret sensor data and to control devices. For example, home owners installing home automation equipment must write their own rules for when their lights turn on and off. Artificial intelligence (AI) plays a pivotal role in automating this process. AI and data-mining technologies seek useful information on resident behavior and the state of the home. Computer algorithms have been designed to predict and identify activities performed in the home and to recognize emotions, body mannerisms, and gestures (*3*, *4*). These capabilities, as well as the abilities to recognize activities, identify trends, make assessments, and take action, are becoming more available and robust, but are not commonly found in actual homes.

The goal of much current research in ambient intelligence is to enable devices to interact with their peers and the networking infrastructure without explicit human control. The intelligent home must also be imbued with an awareness of the resident context (location, preferences, activities), physical context (lighting, temperature, house design), and time context (hour of day, day of week, season, year). Providing this type of context-aware reasoning makes it possible to design environments that provide, for example, customized lighting and temperature settings based on learned resident preferences; information retrieval and

Washington State University, Pullman, WA 99164–2752, USA. E-mail: cook@eecs.wsu.edu

displays that follow residents from computer screen to wall to tabletop; and automated reminders to residents of important tasks they need to perform (*5*). As AI research progresses, these services will increasingly be provided on the basis of detected behavioral patterns, rather than rules provided by the user, as is currently the case.

Because ambient intelligence seeks to be both unobtrusive and ubiquitous, it can affect almost every aspect of human life without drawing attention to itself. Three applications of ambient intelligence in the home have received particular attention: health monitoring, energy efficiency, and social computing.

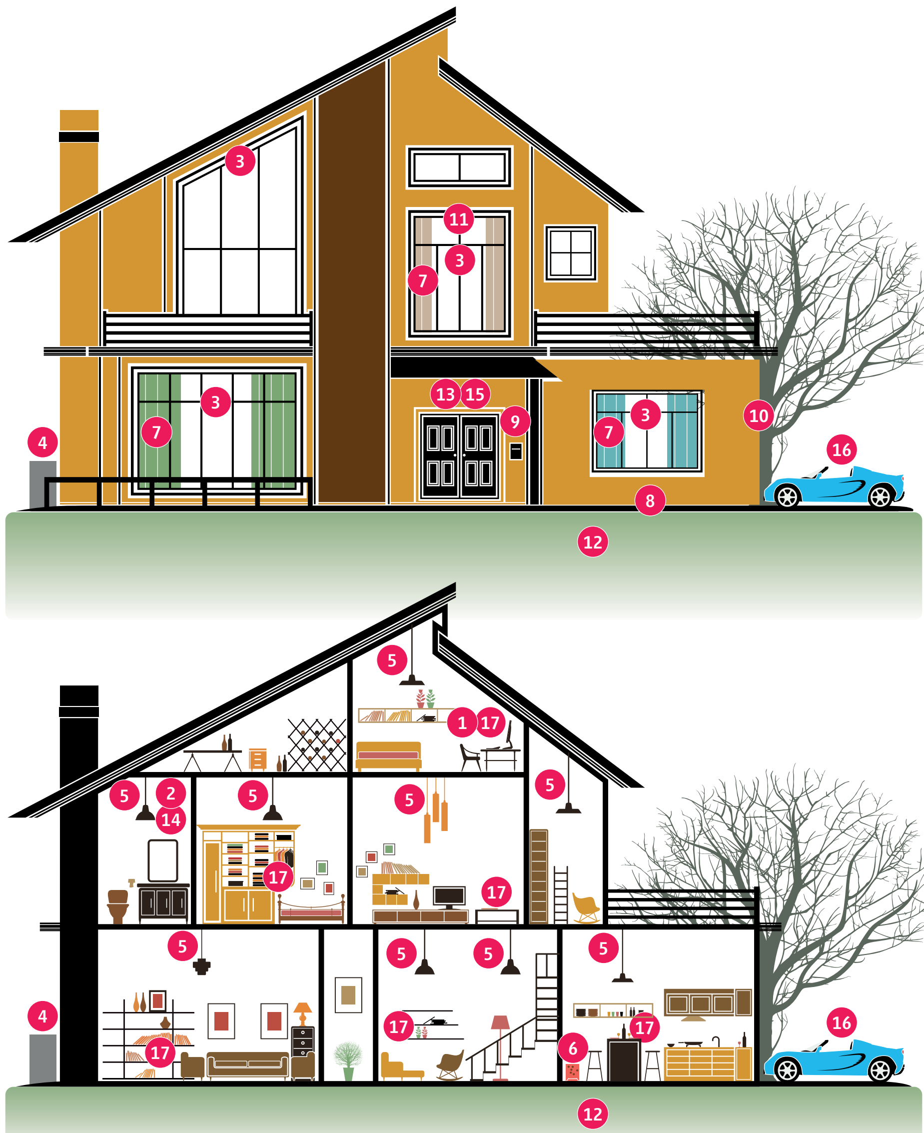
Ambient intelligent homes offer technologies for automated health monitoring, assessment, and intervention. For example, researchers have used capabilities found in ambient intelligent homes to find a link between changes in mobility patterns and the onset of symptoms of dementia (*6*). Motion sensors were placed throughout the home, and total space covered throughout the day as well as walking speed were estimated for individuals over multiple years. Changes in these parameters correlated with early symptoms of dementia. Other researchers have used ambient intelligence technologies to perform early-childhood screening for autism (*7*). Building upon context awareness, smart homes provide well-timed prompts to remind individuals to perform familiar routines and to initiate new health behaviors (*8*).

Monitoring energy consumption in the home is also increasingly important, because energy consumption is rising at a higher rate than population growth, and households are responsible for over 40% of total energy use in most countries. Ambient intelligent homes facilitate smart energy management through nonintrusive load identification and estimation, as well as minimally intrusive load shedding and automation for energy efficiency (*9*).

Another aspect of daily life is social interaction. Social signals have long been recognized as important for establishing relationships, but only with the introduction of sensed environments have researchers become able to monitor and measure these signals (*10*). Building upon ambient intelligence technologies, we can look at socialization within the home (such as entertaining guests, interacting with residents, or making phone calls) and examine the correlation between socialization parameters and productivity, behavioral patterns, and health. These results will help researchers not just to understand social interactions but also to design products and behavioral interventions that promote interaction, or to leverage existing social relationships in ways that influence interventions and purchasing choices.

The dream of ambient intelligent homes is, however, hampered by some formidable challenges. A primary concern is the need to consider possible implications for privacy and security. Many individuals are reluctant to introduce sensing technologies into their home, wary of leaving digital trails that others can monitor and use to their advantage, such as to break in when the house is empty. To allay such concerns, researchers are investigating ways to define and provide guarantees for levels of privacy and for the safety of the technologies. Similarly, smart homes need to ensure that the resident retains the ultimate authority to reset the system and to impose constraints that prevent the home from taking undesired or harmful actions.

Another critical challenge for home-based ambient intelligence is to provide



1 AmI control
2 Light sensor
3 Windows and door control
4 Hvac control
5 Lighting control
6 Automatic pet feeder
7 Motorized drapes
8 Automatic watering
9 Mailbox sensor
10 Driveway sensor
11 Security system
12 Lawn moisture sensor
13 Face recognition sensor
14 Motion sensors
15 Door sensors
16 AmI interface with car
17 AmI interface with smart phone

Coming soon to your home? In an ambient intelligent home, sensors collect information about the environment and the residents. An "intelligent agent" uses this information to decide whether actions need to be taken to adjust e.g., temperature or lighting.

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intelligent support seamlessly both inside and outside the home. With the introduction of wearable sensors and smart phones, ambient intelligence is not limited to the home environment (*11*). Our ambient intelligent agent needs to seamlessly merge support inside the home with that available in a mobile setting. Smart homes currently offer useful monitoring and automation with guidance from the resident. As the field matures, we anticipate that these services will be provided in a more independent manner.

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COMPUTER SCIENCE

How Smart is Your City?

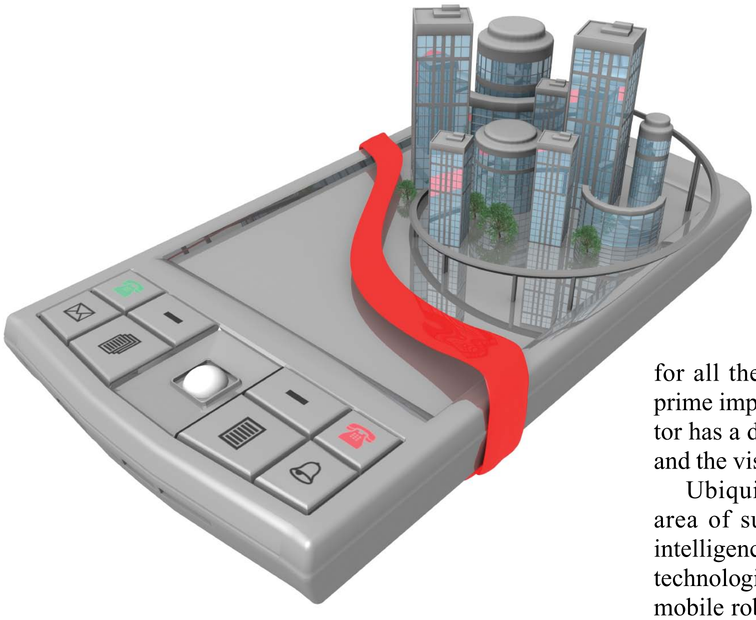
Michael O'Grady and Gregory O'Hare

From art galleries to our cities' streets, ambient intelligence can help to make the human environment more responsive to the needs of individuals.

The idea of ambient intelligence implies an intrinsic link between individuals and their environment, enabling individuals to access and interact with computing artifacts in ways that are intuitive and do not disrupt everyday activities. Given the many different environments encountered as part of everyday life—within the home (*1*) as well as beyond it—enabling such interaction is a formidable technological challenge. The reward may be an environment that is safer, uses less energy, and responds to the needs of all individuals (see the figure). Recent advances in embedded systems, robotics, and sensor technology suggest that ambient intelligence may indeed be realized, particularly if crucial privacy and security concerns are addressed.

Three examples illustrate the potential of ambient intelligence across different domains. First, information filtering and personalization in a museum context offer a practical and eminently achievable vision of ambient intelligence. Second, autonomous mobile robotic services are a development that challenges perception, trust, and acceptance of ambient intelligence. Third, a simple ambient intelligence smart-phone service shows how the quality of life of those afflicted with dementia can be improved.

University College Dublin, Belfield, Dublin 4, Ireland. E-mail: michael.j.ogrady@ucd.ie



A changing world. Through smartphones and related devices, users have the world at their fingertips. But what if the city environment could respond automatically to individuals' needs and wishes?

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Museums and art galleries comprise many exhibits, yet tend to offer broad generalized information, usually in the form of visitor or audio guides. Ambient intelligence challenges this "one-size-fits-all" approach, envisaging a digital information space that enables the personalization of information to meet diverse user needs (*2*). This may include generating recommendations for visiting other exhibits, based on, perhaps, what the visitor has already seen and what their cultural interests are. Typically, a conventional smart phone is sufficient to enable this kind of interaction, acting as a lens into the information space. In sharing positional and personal information, multimedia content may be personalized and presented via the visitor's smart phone, resulting in a more satisfactory experience. However, a prerequisite is the deployment of a suitable ambient intelligence technological infrastructure—using radio-frequency identification (RFID), for example—and the construction of an information space for all the exhibits. This latter issue is of prime importance, demanding that the curator has a deep understanding of the exhibits and the visitors they hope to attract.

Ubiquitous robotics (*3*) represents an area of substantial potential for ambient intelligence in the longer term. Many of the technologies to successfully deploy suites of mobile robots exist. For example, the DustBot project (*4*) has demonstrated robots collecting waste in an urban environment without direct human oversight, demanding obstacle (stationary and mobile) avoidance on the part of the robot, as well as interaction with householders. Computational intelligence, embedded both on the robot and in the environment, is essential for enabling this behavior. However, at present the cost remains excessive. Until this is addressed, robots cannot be deployed in a widespread fashion, and the key issues of human-robot interaction and social acceptance cannot be researched thoroughly.

Ultimately, ambient intelligence is about people and improving their quality of life. Consider the case of people with dementia, an issue that will have increasing implications for society in the coming years. Wandering is characteristic of many with dementia and is a major factor contributing to institutionaliza-