Tech Talk – Move over AI, here comes AmI - By Ernest Worthman

Ambient Intelligence (AmI) – one of those terms that, unless you are close to the topic, sounds like something out of the 1960s. But today, because of the micro-scale of available technology, it is poised to become a fundamental platform for the Internet of Anything/Everything (IoX) and smart "x."

The vision of an AmI future sees us surrounded by intelligent electronic environments, responsive and sensitive, and to our desires, requirements, and needs. Ubiquitous sensors will be embedded in every nook and cranny of our world. Predictions abound that AmI will be heavily populated by gadgets and systems that are capable of powerful capabilities nano-bioinformation and communication technology (NBIC).

AmI was born in 1998 from a vision by Royal Philips, of The Netherlands. It was the brainchild of a consortium of individuals, including Eli Zelkha and Brian Epstein of Palo Alto Ventures who, with Simon Birrell, coined the name 'Ambient Intelligence'. It is defined as "envisioning a world where homes will have a distributed intelligent network of devices that provide us with information, communication, and entertainment."

While the smart home was the original vision of AmI, today, AmI has "left the house" for a much more ubiquitous positioning, thanks to Internet dust (see a post I wrote a few years ago: https://semiengineering.com/when-the-iot-turns-to-dust/).

AmI has evolved into a vision of how people interact with technology - everywhere. A seamless environment of computing, advanced networking technology such as Internet dust and intelligent interfaces. It is aware of the specific characteristics of human presence and personalities. It takes care of needs and is capable of intelligently responding to spoken or gestured indications of desire, and even can engage in intelligent dialogue (although this will take a while to develop to a level that is realistic).

INTERNET DUST

Because sensor, and circuit technology has come such a long way, interface devices for the IoX have become tiny – around one square mm, some even smaller. And power for them can be supplied by a number of platforms, batteries, solar, direct connect, even energy harvesting. That means that they can be fitted to virtually any product, and for any application.

It is reasonable to expect that, soon, everything that can be created; wearables, currency, appliances, vehicles, the paint on our walls and the carpets on our floors, and even some things that cannot (air, water?), will have some measure of embedded intelligence. Expect that networks of tiny sensors and actuators, which some have termed "smart dust," will be prolific.

However, as usual, how this will play out is still in the visionary stage for some of them. There are issues in all of the key technologies just discussed, that will need to be addressed before a ubiquitous state of AmI exists across all segments.

THE AMI DIFFERENCE

What makes AmI stand out is that it will provide personalized services, largely via big data, on a scale that will dwarf anything we have seen so far. AmI will surround us with intelligent objects that will understand us, to some degree. Because the dust and other objects will continually, and on a real-time basis, feed information to the "cloud" for analysis and tweaking to our particular environment and circumstances. It will also be able to preemptively assess what we are wanting to do, thereby providing a smooth progression of actions that we want to take.

Certainly, there are great visions for AmI. Some may be a bit of a stretch for now, but others can certainly be envisioned. For example, the computing and communications we now have will be interfaced to the sensors and devices on the IoX. The next level of this will be capable of is both recognizing, and responding to the presence of different individuals and entities in a seamless, inconspicuous, and transparent way. This will be accomplished via a continuous loop of actions (see Figure 1) that begins and ends with sensing.

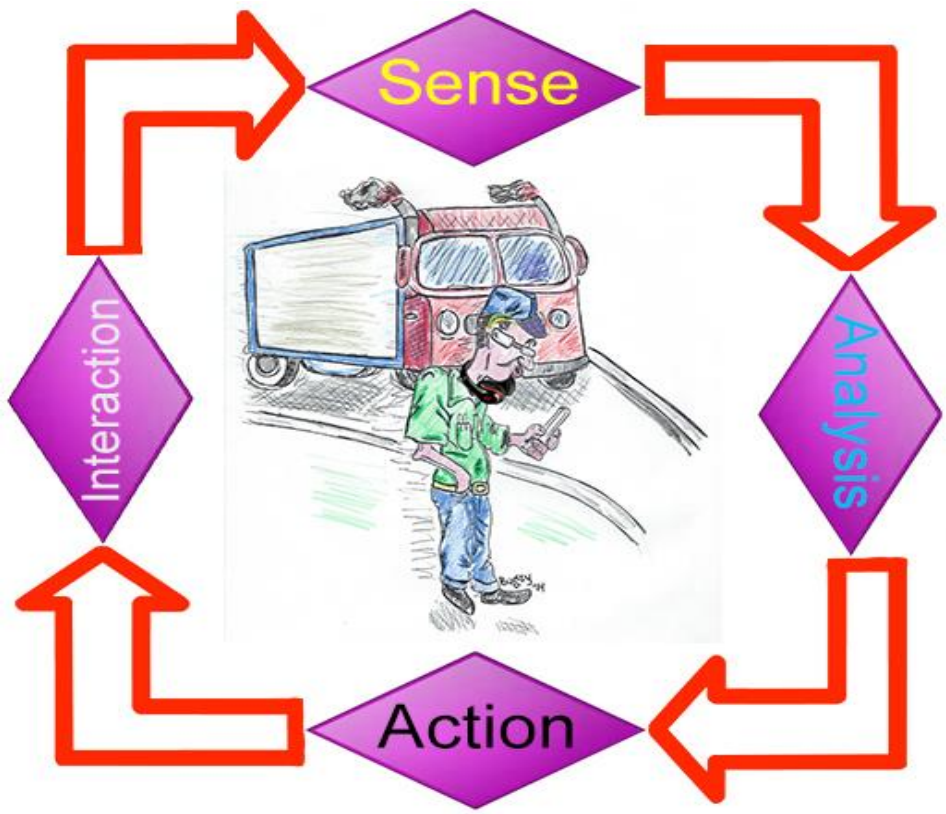

Figure 1. The flow of data from input to result
Artwork by Stephen M. Siegal.

The number of objects that sensors can attach to is limitless. As well, sensors can be mobile – free-floating or detachable. Examples of sensors

- Ambient and wireless
  - Motion (cabinets and drawers, people, animals, bath fixtures, proximity)
  - Atmosphere (fire/smoke, carbon monoxide, light)
  - Appliances and plumbing
  - Locks, temperature, sound detection)

- Wearables
  - Health
  - Exercise
  - Clothing
  - Location
  - Virtual

These are only two of the pervasive list of categories and sub-categories that can have sensors attached to devices and targets.

THE ELEMENTS

Sensing – The first element that needs to be in place is the sensor. And not just any sensor. With AmI, the network must be able to respond to real-world stimuli. Components must integrate agile agents that perceive and respond intelligently, not simply pick from a database full of scenarios by algorithms (which would not be realistic for dust, or micro-type sensors with limited resources, anyway).

Once the data is captured, intelligent analytics are applied. This is done at a centralized system of one sort or another if the sensor itself is only used to capture, store, and forward data. If the system is distributed, the sensors will have some type of onboard processing power that will preprocess, to whatever degree is designed into the system.

The type of network depends largely on the application. Mobile dust networks, such as those that may be used to monitor a forest fire, will likely just report to the central station. Fixed networks, such as weather sensors, likely will have some local processing power integrated.

In any network that is somewhat ubiquitous, the data set will generally consist of multiple volumes of multi-dimensional temporal or spatial information. Because systems cannot be made 100 percent reliable, the system must be able to discern, intelligently, between non-essential data, erroneous data from a noisy sensor, or inference of some sort. Or there can be missing data from a defective sensor. For example, a sensor fails its data set redundancy check or some segment of it may be incomplete.

This is where big data analysis techniques would be useful. Large volumes of sensor data are collected from disparate sources, and part of it may be erroneous or missing. Synthesizing it to produce accurate and rational results requires new methodologies and models that are now being developed under the big data umbrella. However, today, most sensor data fusion is done with Kalman filters or probabilistic approaches.

One early example of this is the In the MavHome smart home project [1]. Collected motion and lighting information alone results in an average of 10,310 events each day. In this project, a data mining pre-processor identifies common sequential patterns in this data, then uses the patterns to build a hierarchical model of resident behavior.

However it is approached, assessment algorithms must be real-time responsive, adaptive, and have the ability to apply a variety of reasoning types, including recognition, user modeling, activity analysis, decision making, and spatial-temporal reasoning.

Modeling – One of the features that AmI integrates is the ability to differentiate between general computing algorithms and specific ones that can adapt to or learn about the user. Such "learning" systems do exist and are fairly adept at this.

Even so, the problem with these systems is that to do it, with any amount of efficiency, requires a deep well of hardware and software resources. That works in many cases and will work in AmI cases with sufficient resources.

However, agile systems envisioned in AmI will need to be able to do this, efficiently and accurately, in a small form factor, with the ability to refine and adapt itself on the fly.

The volume of data generated by sensors can challenge modeling algorithms. Adding audio and visual data into the model increases the data quantity by, at least, an order of magnitude. It also adds another dimension of sensed data. For example, video data can be used to find intertransaction (sequential) data in observed behavior or actions, which is useful in identifying and predicting errant conditions in an intelligent environment.

One of the most promising applications in AmI is identifying social interactions, especially with the proliferation of social networking technologies. This has broad implications, all the way from predictive crowd behavior to corporate meeting environments. It can also be a tool in determining the state of such data (supported, hearsay, false, or manufactured) for social media platforms, as has been the case recently.

Prediction and Recognition – Prediction and recognition are, perhaps, the two most key elements of reasoning In AmI environments. Prediction is accomplished by attestation, from which comes intelligence. Intelligence begets recognition, which is used in prediction. Theoretically, sufficient reiterations of this cycle will increase the intelligence within the networks to near-human capability.

For example, in theoretical AmI models, such as the Neural Network House, the networks use prediction and recognition to control home environments. This is accomplished, on the fly, by predicting the location, routes, and activities of the residents, based on previous recognition as well as prediction by machine learning.

A number of prediction algorithms have been developed that can predict activities for single, as well as some multiple resident cases. These algorithms are relatively adept at predicting resident locations, even some resident actions. The AmI network can, with a reasonable degree of accuracy, anticipate the resident's needs and even assist, or automate performing the action.

This has huge implications in the medical space. AmI can, literally, be a watchdog for patients with dementia or physical impairment. Similarly, for injury and surgery cases as well as other situations.

Decision Making – Part of the AmI platform is AI and deep learning. Neural networks are a key element in the decision-making process. Temporal reasoning can be implemented in conjunction with rule-based algorithms to perform any number of functions; from identifying safety concerns to analyzing medical data and adjusting medications, to diet planning based upon wearable sensor data, to environmental comfort settings.

Temporal and Spatial Components; The Support Elements –
Spatial and temporal reasoning are also crucial elements of AmI. There is a wide collection of algorithms that have been developed and honed to deal with the various segments of spatial, temporal, and spatio-temporal reasoning. Such algorithms are another element of the network that allows AmI to understand the activities in an AmI application.

Any intelligent system relies on either explicit or implicit reference points of where and when the events of interest occur. For any network to be able to decide on actions, preemptively, or in real-time, an awareness of what the targets are is essential.

This is where space and time come into the equation. For example, assume a situation is developing where someone left a stove burner on and the temperature around the stove rises. In this scenario, time and temperature have to have a correlation to assess the situation, relative to rate and rise of heat vs. time, location, and perhaps even air quality. The network has to understand that this condition is different than, say, the heat coming on, which may produce a similar condition if there is a heating duct near the stove.

MISSIVE
There are, of course, many more elements to AmI, but space and time limit what can be discussed in a paper of this type.

One of the issues that have prevented large-scale development in fields such as neural networks, AI, and AmI, is the tremendous processing power required to develop such "intelligence."

However, the evolving state of technology is about to change all of that. Semiconductor technology is finally crossing the thresholds of capacity, performance, size, and integration. The new technologies in chip configuration and systems, particularly quantum computing, will see tremendous achievements in technology to support AI, AmI, the Internet, and Smart everything as well as peripheral and parallel segments, industries, and vectors that go with it.

It is, indeed, an exciting time to stand at these thresholds.

1. Wikipedia, et al.