SENSORS AND SENSIBILITY

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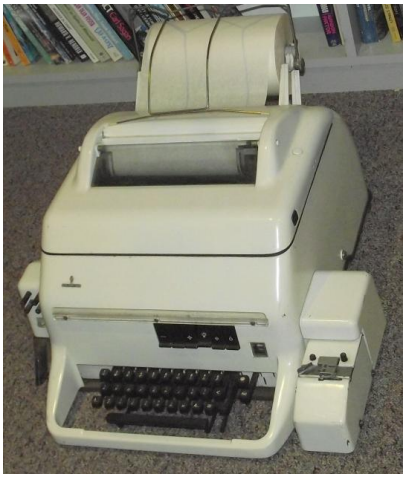
I can always tell if it is going to be a nice day by getting up and looking into my toilet. This is not like some sort of clairvoyant gross tea-leaf reading thing, it's a scientific observation. You see, we have a septic tank system which is partially sealed through a network of vapour locks and automatic vents. A sudden rise in air pressure that heralds a sunny day also turns our toilet system into a giant barometer and the water level in the toilet will drop several centimetres.

It occurred to me that here is a topic worthy of expansion. Today our homes, our cars and our workplaces are crammed with sensor devices that did not exist outside of a lab only a single generation ago.
Generally speaking, there are two basic categories of sensor device. There are sensors which simply collect information for humans to observe and there are sensors which use the information to make decisions automatically. A thermometer on the wall showing outside temperature may be a passive device which could prompt an observer to put on an extra jacket before venturing outside. An active thermometer sensor can tell your kettle when to stop boiling, shut down your car engine or activate a fire sprinkler system.

These decision making sensors have crept into every facet of our lives. Go back a scant 50 years and examine how industrial machinery was manufactured. It looks quite big and chunky. Go back further and it gets heavier and chunkier. Machines were made to perform a task and they had to survive the worst case of stressful situations and unexpected events. To achieve this they used sheer mass to make them 'tough'. By adding more and more sensors to machines it allows machines to protect themselves better and therefore reduce their mass. The machines become smaller, lighter and cheaper to build.

Old machines were heavy & tough



The Siemens 100 miracle of Mechanical engineering

Consider the difference between a teleprinter and an inkjet printer. The teleprinter had more than a thousand carefully crafted metal parts and weighed maybe 50 kg. The inkjet may have 150 parts, mostly plastic, weighs about 4 kg. Inkjet printers have sensors to measure ink dosage, track the position of the print head, count the amount of paper left in the tray and much more. In terms of printed output, they perform a similar function, but the inkjet printer can do a lot more.
It is cheap sensor devices that have delivered these products in our homes. Indeed they make our lives safer by monitoring for contingencies we can not see for ourselves. The household smoke alarm is a fine example of this technology. The simple 2-bar radiator now has a sensor switch in its base to kill the power if it falls over. Earth Leakage circuit breakers in all of our homes monitor both Active and Neutral currents at the same time. If they differ by as little as 30 milliamps, they assume someone is being electrocuted with-respect-to Earth and instantly disconnect the supply. (giving thousands of breakfast eaters warm, fuzzy self-assurance as they merrily pry their toaster with a butter knife to liberate a recalcitrant crumpet.)

We rely upon our sensors to work unfailingly every day. We get to turn our back on automatic garage door closers, safe in the knowledge that sensors will stop the cat from getting squashed.

But what happens when things go wrong. By being surrounded by hundreds of sensors do we not expose ourselves to more risk when they stop working? Many people find the presence of sensor devices as an intrusion. (Is sensorship a new word?) It may be argued that the more we rely upon sensors devices, the more risk we assume without being aware of it. Pushing the brake pedal really hard on a modern car is the right thing to do because the ABS sensors will keep your wheels turning, but put the same driver in another car *without* ABS lurking in the background and pushing really hard is one of the worst things to do. The driver of a vehicle therefore needs to know how much technology is lurking in the background. If they anticipate the presence of a feature that is not there, then they can come unstuck very quickly.

Unfortunately, there is not a lot of redundancy in our systems. A wastewater or sewage tank may have a pump that starts when one level is reached and stop when a different level is reached. But a cheap float switch sensor may get stuck or fail at any time. One of two things will always happen. The tank may overflow with unmentionable substances spreading far and wide, or the pump may run-on, go dry and have an expensive melt-down a short time later. Good sensor technology should have a fall-back position. A second sensor is often needed to tell us when the first one has stuffed up. Doubling up on sensors in a given situation doesn't necessarily double the risk of failure, but it does give the monitoring systems more information for its decision making process.

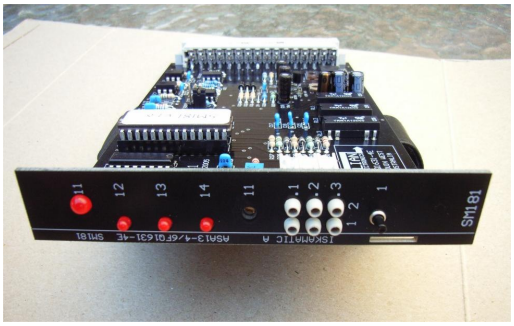
Some of you may remember a classic movie from 1966 with Peter O'Tool and Audrey Hepburn called *How to steal a Million*. In this movie they needed to steal a statue from a Paris museum that was full of the latest sensor technology. It was impossible to get near the target without breaking beams etc and setting off alarms. So they hid in a cupboard at night and set off the alarms with a toy boomerang before hiding once more. Three times in the night they frustrated security staff and police with what they thought were false alarms, until they decided to turn the alarm system off. Later, our burglars simply walked across the room and stole the statue while the alarms were deactivated. For me, the moral of this story is in how do we know when we can trust what a sensor is telling us? With modern cars, almost half of all reported faults are not actual problems, but faulty sensors that are reporting problems. There are many real-life instances where people did not believe their own safety systems when sensors report faults, only to have calamitous failures causing terrible loss of life. Chernobyl's meltdown is just one example of this.
(Jack Lemon tried to warn us….)

The weak point in security was in convincing human guards to loose faith in their sensor devices.

Recently I did some work with low-cost gas sensors that look for LPG and Carbon Monoxide build-up in caravans and motor homes. I was surprised to see how much variation there was between the gas sensor devices, sourced from the same manufacturer at the same time. The baseline for 'no gas present' could be anywhere within 30% of the working sensor range. Unless each sensor was to be individually calibrated with a trimpot, there was no reliable threshold where dangerous gas levels could be detected. I didn't like that idea, because after 5 years these sensors need to be changed and there is no guarantee that the replacement gets adjusted properly. In the end a software solution was used whereby the sensor would run for a minute and self-calibrate whenever it was briefly unplugged and reconnected. With the result stored in memory the alarm threshold is automatically set at 10% higher than the variable baseline.

All too often Sensors won't tell you everything you want to know, but they will still work within a useful range. The trick is in knowing how to interpret the results that are returned. A good starting point is to see how the monitoring system deals with a sensor that has been either unplugged or shorted out. A good system will recognise an out-of-range reading and respond

with a meaningful error. A bad system, such as an open-circuit temperature sensor may tell you that it is 255º outside, meaning you need a new probe or a really good sunscreen.


A voting monitor for temperature sensors

About 10 years ago I was approached to re-engineer a module for interpreting temperature measurements in a power station. (You can relax…I think it was for somewhere in Egypt) Power stations don't like to damp the fires and shut down because a single thermistor falls off the side of a furnace. This module would monitor three separate temperature sensors. If all three agree, then everything is fine. If one sensor did not agree with the other two, then that sensor was ignored, the plant continued and an alarm was triggered for a technician to examine the suspect device. The original version had a bucket of transistors and 24V logic circuits. The new version had software to perform the same tasks within a small microprocessor. The new unit was also cheaper to build and checked for a wider range of aberrant sensor behaviour than the original one designed in the 1970's. (Siemens distributors had been actively purchasing the spare parts of older power stations and crushing them as an added incentive for new multi-million dollar controls to be fitted where the old controls are no longer supported…but that's another story)

Fundamentally we don't want a sensor to fail right when it is needed the most. How many times have aircraft circled to use up fuel because they could not be sure if the landing gear was locked?. More sensors means more information and more intelligent outcomes. At our home we use infrared beams across the driveway to tell us when deliveries are arriving. One beam alone would drive us nuts with false alarms from birds, bugs and cars on their way out. By adding a second beam and some interpretive software we don't hear chimes unless both beams are broken in the right order. This gives us direction of travel, so the household chime only sounds when visitors arrive, not when they leave. If we were keen, it would be simple to also calculate the speed of the moving incursion, compare it with the duration of the beam break, then decide if it was a person walking, a single car, or a truck that had just arrived. More sensors means more information and better decision making.


Is it really hot out here, or is that just my thermostat telling me it is…

Once I was told of a classic case where the air conditioning thermostats on two floors of an office building had their wires swapped by mistake. The problem took months to find. Someone in the upper floor would feel a bit hot and crank up the temperature on the wall. This just made the floor below hotter, so they would turn the thermostat further down, making upstairs even colder. Before the day was out the upstairs room had snow flurries while downstairs began to feel like Tatooine

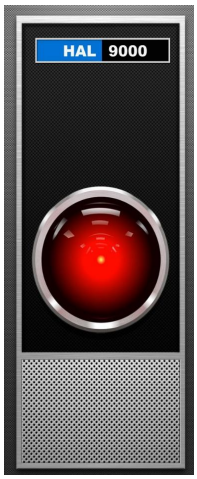
There is a natural marriage between sensor technology and interpretive software. Making hot water is a good example. In its basic form, a thermostat heating up a hot water system is pretty dumb. If water is below one temperature it heats. If it is above another temperature, it doesn't. If the sensor is faulty, it can happily boil the water or let it go cold. If software is monitoring the system, perhaps checking other sensors or the time of day, it can figure out that it has been heating longer than usual, or not heating at all. Software can build up a profile of what is normal behaviour, then call for intervention when something doesn't seem right. Good software can find problems you don't realise existed.

A couple of years ago our solar hot water system seemed to be working well, but our power bills went up significantly. Certainly, we had plenty of hot water, but I had a vibe that something wasn't right. I set up a current probe on the booster heating element and connected it to a data

logger for a few days. I found out that the Night/Day timer had a welded relay contact enabling the booster heater to operate whenever it liked. Each morning, after a few people had showers, the booster would kick in and re-heat the water to full temperature at the maximum power tariff before the solar panels had a chance to do it for us for free.
Without applying sensors and correctly interpreting the results, this could have gone on unnoticed for years.

Just because they are in the sun, it does not mean that they are working as they should be

In the movie 2001 the HAL9000 computer sensors thought that an AE35 unit was going to fail when actually, there was nothing wrong with it. The computer had made a decent attempt at diagnosing problems using its sensors and recommended repairs *before* it failed. It always thought it was doing the right thing "*I am putting myself to the fullest possible use, which is all I think that any conscious entity can ever hope to do*" But then of course, it tried to cover up its mistakes by killing people and generally things went downhill from there…



Sensors get really interesting when they are used in exotic ways to extrapolate information from obscure sources. Like measuring sewage flow rates during ad breaks to work out TV ratings, or a mobile phone camera measuring microscopic changes in facial skin colour from a few metres away to measure your pulse. Satellites can use microphones on their heat shields to triangulate the location and magnitude of strikes by meteorites and space junk particles. Similar technology is now being used by microphones on the tops of buildings to locate where guns have been fired in a city.
A few years ago I speculated on the design of a flow sensor that could be placed in series with the regular water meter. It was going to look for water flow that didn't change for say 30 minutes. If it detected this it could trip a servo motor on a gate valve and turn the water off, just like a circuit breaker. (The unit could be powered by the water flow itself) In a normal home an extended, unchanging water flow would be abnormal and could mean that there was a burst pipe causing a lot of water damage while the residents are out for the day. A burst laundry hose could give the owner a $1500 water bill on top of the damage to the home. In country areas, prematurely draining the household water tanks through a forgotten tap or a burst pipe would be a huge inconvenience to overcome in a long summer. Maybe one day….

Occasionally it is possible to measure something by omission, which is to say if you cannot measure the effect that you want, then measure as many other things as you can, then extrapolate details of the missing aspect from the hole in the available data. The presence of planets in other star systems can be proven, not by looking for the planet itself, but by looking at the wobble in the orbits of the nearby sun

If you were to plot the pervasive trend of sensor technology you will find that it continues to build up around us. Often helpful, sometimes intrusive. But they're not going away. We need to be aware that while sensors are a window into another world, someone must look through that window to make sense of what has been seen. The intelligence that evaluates the sensor technology is more important than the volumes of data it is possible to collect. Someone or something must establish the value and priority of the information. Like Jane Austen once said nearly 200 years ago… "*Which of all my important nothings shall I tell you first*"