The 15 Year Cycle of Robotics.

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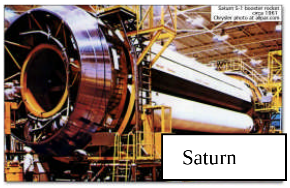
“Every single thing we buy or use is inferior to something else that has been invented or developed and never made it to the marketplace.” This philosophical lament leads to several conclusions. For one thing, it means that better or best technology does not automatically determine commercial success, nor does it lead to technological progress. The former is important for the simple fact of the economics of technology, it takes money, and without it (seed capital, venture capital, mortgages), technology development slows. The latter suggests that society does not always progress as rapidly as it could, or worse that it does not progress in the best direction.

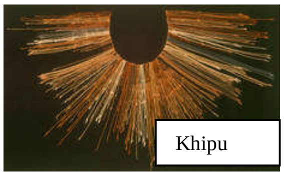
More importantly, there is another conclusion, it means that there is something other than the inventiveness and genius behind technology development that determines its efficacy and influence. Any successful entrepreneur knows this. In the real world, finance, personalities, market demands, networks and the such, really do play a big role in the way our society progresses, or fails to progress.

Technology is an interesting thing in another way. I once read that there are sufficient parts still around to complete three Saturn rockets. All the bits and pieces of those rockets that took mankind to the moon.



Saturn

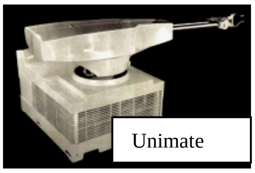
But there is no possibility of ever launching them, if that were ever to be desired, because the knowledge to do so has gone. It resided in the brains of individuals, the user manuals and procedure manuals notwithstanding, and those people have retired, or moved to different jobs, or passed away. This means that technology is really in the brains of people. Not in the artifacts and devices themselves. When they die out, like in the case of the Incas for example, the technology fades. So we can no longer understand the Inca khipu writings, even though they are their own specification manuals. (Interestingly, at the time of this re-write there is research suggesting that Inca khipu, the knotted strings traditionally believed to be bookkeeping, may to be a binary form of non numerical text.)



Khipu

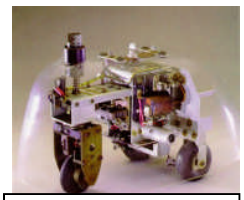
This leads me to my experience with mobile robotics and the recent comment by Rodney Brooks (2004) that in another 15 years robots will be everywhere.

At a conference in Boston about a decade ago, I heard my friend Joe Engelberger, the “Father of Robotics”, in his keynote address, admonishing the audience, mostly academics, that they had contributed little to the progress of robotics. I cringed and the room went quiet. Joe was close to retiring from a field he co-pioneered in around 1956 when he commercialized the industrial robot or “robotic arm” with George Devol, inventor of the Unimate, and it seemed to me that he was venting a lifetime of frustration. He too, even back then, was decrying the lack of fecundity with robotics in the world. While I was embarrassed at the time, today I understand completely how he felt. Let me explain by starting with my own experience.

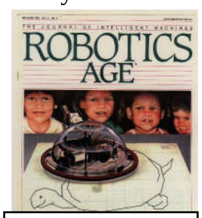


Unimate

In 1979 I invented and released a mobile robot product called the Tasman Turtle. It was a significant technical achievement for the time, and was an instant commercial success. Until then there had been perhaps only four true robots (whatever that means) in the whole world, each a pioneering research robot.



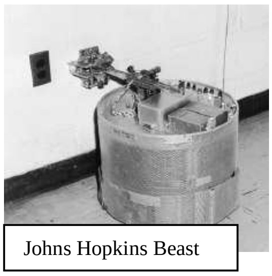
Grey Walter Tortoise



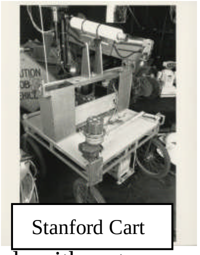
Tasman Turtle

The first was Grey Walter’s set of cybernetic mice or tortoises (he used both terms) in England in the early 1950’s, little self-contained thermionic-tube driven vehicles that demonstrated tropisms like attraction to, or avoidance of, light. They retired to a small safe hutch as their response when lights were turned on or off in their environments. These historical devices have now retired to Queensland Australia.

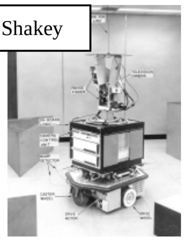
15 years later, with the benefit of transistors, appeared the Johns Hopkins Beast, the Stanford Cart and Shakey. All were larger, more sophisticated, with better sensors examining the world, and used pioneering Artificial Intelligence software to perform more than simple reflexes.


Johns Hopkins Beast

The Beast traveled up and down corridors to look for power outlets so it could recharge when its batteries got low. That was its life.


Stanford Cart

The Cart at Stanford University used clever stereo vision to identify objects it needed to negotiate in order to reach a destination, at times taking a half day to travel 20 yards, stopping for an hour or so at yard intervals to move its single camera to the opposite stereo position then to process the huge amounts of visual data with its tiny computer, (by today's standards).


Shakey

SRI's Shakey implemented the world's first task oriented algorithms to move objects around in ways it worked out for itself, in order to achieve an outcome such as stacking blocks on top of each other using a ramp, also stopping sometimes for a day or so while new software was loaded for the next phase of the activity.

These robot projects and the scientist behind them were, and are, critical to the development of robotics, but the endeavors were never meant to be commercial ones.

Another 15 years later was when I released the Tasman Turtle, named after its place of birth in Tasmania. Just ahead of the Tasman came the Terrapin and the General turtles, one too simple and one too complex, and therefore neither successful for their applications. Soon after the Tasman came the Valiant, another Brit which is still around, but Tasman was the first commercially successful mobile robot and there are some lessons in that.

The Tasman was used in education to teach students mathematics, algebra, geometry, computer programming, computer science and problem solving skills in general. It used a special computer language called Logo, developed by Seymour Papert at the Media Lab at MIT, which was actually a complex and complete language, structural in style like Pascal, with recursion and procedures, and with the precursors of objects, but presented in a way that even very young students could relate to and use. The power of programming on a computer and seeing the results in the actions of a robot, even though it was tethered to the computer, gave instant motivation and learning feedback to the user, and indeed to the observing teacher. Children would not leave school because they wanted to play with the Tasman, and as long as they played, they learned. Not like a similar phenomenon today where kids play for hours with violent video games that have little educational value.

The Tasman had speech recognition (one could command it by talking to it), speech synthesis (it would talk back to you), a digital compass for orientation (comparing a compass to the front direction for example allowed concepts of global and local reference frames to be explored), touch sensors around its perimeter for interaction with its world, a pen in its belly so that it could trace a path of where it travelled, and it could be programmed to draw a square say, or a triangle, or a circle (learning about right angles, the internal angle rule for triangles and integrals respectively). But it could map out the environment in a simplistic way from touching the walls, it could wander with purpose from this map, and amazingly it could learn. One demonstration program had the Tasman illustrate Pavlovian or classical conditioning by learning to avoid

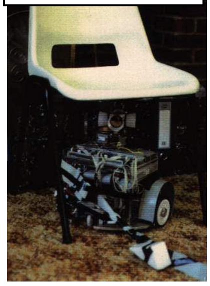
Omnibot


Chester


Elami

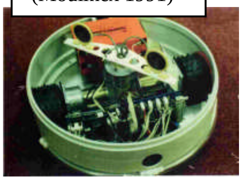

T-Bot

bumping into objects from warnings given to it when tapped on the back (the rear touch sensor). So it could do roughly the same as the earlier robots, in real time and for a few hundred dollars. It had to be for a few hundred dollars because the market it was designed for, the education market, is extremely cost sensitive. Numerous hobby robots from the 1980s like Elami, Chester and Omnibot derive directly from the Tasman.


D'Entrecasteaux Moulinex 1991-93

About 15 years later I completed a production prototype of a very different type of robot, a smart autonomous household vacuum cleaner. It was called D'Entrecasteaux and developed in France for Moulinex between 1991 and 1993, at the time an important international appliance manufacturer. This machine was controlled by one switch, "on/off". When set down on the floor of a house, it immediately mapped the room around it from an intelligent rotating sonar sensor, keeping the map current about 10 times a second. People and pets moving around were tracked, and furniture being moved was recognized and registered. Stairs were detected and avoided. Then D'Entrecasteaux planned the best way to systematically traverse the room in parallel paths much like a human would, in order to clean all of the exposed surface. This path was also determined dynamically; recalculated every second or so. If an item of furniture was moved after it had cleaned around it, the robot would go back and do that area. If it encountered a person standing in the way, it dealt intelligently with that, if an area was particularly dirty it would progress slower or even double back to do it again, and if its batteries got low it would go back to the starting position to recharge its batteries, then come back to the exact spot to continue. This was a smart machine, and in the early 1990's it could be manufactured in mass for an added technology cost of under $100.

The new technology for D'Entrecasteaux was developed from 1984 to 1987 under an Australian Federal Government research grant of around $100,000 also in Hobart, Tasmania, based on earlier work by Jim Crowley at Carnegie Mellon University (CMU) in Pittsburgh at the time, under an industrial alliance contract to Commodore Business Machines in Dallas Texas where I was CTO. A preliminary prototype called Florbot was prepared for General Electric Plastics in Pittsfield, MA in 1989, then released at the 1990 Domotechnica trade show in Cologne, Germany. For GE it was a marketing exercise only, and Moulinex unbeknownst to us never had the financial capacity to release it and wound up shortly afterwards. There were no Darpa grants or defense contracts. It was the history of building sophisticated functionality for cost sensitive markets in education and toys, combined with the need to be commercially successful to survive, that created our ability to do the same in industrial and service robotics.


Demobot (Moulinex 1991)


Karcher


Roomba


Electrolux


Florbot GE 1989

Video and details of the technology and a simplistic concentric perimeter following robot called Demobot that we developed only as a "proof of capability" for Moulinex, were presented to Philip McKerrow at Wollongong University, Hoover in Illinois, Electrolux in Sweden, iRobot in Boston, Karcher in Germany, and Helpmate in Connecticut, but the product went no further. Shortly afterwards though, roughly 15 years from the early development, iRobot released its Roomba floor cleaning robot. Simultaneously Karcher and Electrolux released their versions of a similar product.

Now back to my point. The foregoing appears to identify (approximately) an intriguing 15 year rule for robotics: 1950 (Grey Walter), 1965 (Shakey and co.), 1979 (Tasman Turtle), 1991 (D'Entrecasteaux), 2004 (iRobot's Roomba and Rodney Brooks's comment). And every 15 years or so, it is predicted that robots will be everywhere in another 15 years. Yet it has never happened. The question is why, and the answer has two parts.

The first part of the answer stems back to my introduction and includes the factors that apply to any technology, not just robotics. They are the resources, motivation, and all of the other human, social, commercial and product aspects of technology development. That is why it is more than genius that determines the successful take-up and proliferation of a technology. Technology is in the brains of people and people are unpredictable. Recent analyses of the "Global Financial Crisis" has re-emphasized a la Keynes that people constituting the market are not always rational. Someone with greater motivation can overcome a lack of resources for example. Great technology with no attention to the demand specifications of a market can produce laboratory toys that no one buys, people in positions of power and prestige often direct developments off-track towards their own agendas, and elegant solutions are usually superior to brute-force approaches that produce over-engineered and therefore costly products which amaze only the developers. There are examples of all of these in the history of robotics, some identified already.

What is far more interesting is the other set of reasons why the robots are not here yet, and these are specific to robotics. They are two.

Firstly robotics is extraordinarily difficult. A robot is essentially an artificial person. Any robotic application requires autonomous mobility, which requires smart sensors, mobility mechanisms, processing power, actuators, navigation and guidance, path planning, object detection and avoidance, object recognition and an understanding of their real world properties, self protection, energy maintenance, and so on. Then to be useful a task or application needs to be inserted on top of all that and integrated in such a way that the mobility functions are integrated to the task. In the case of multiple agents, the coordinating procedures also have to be included. These are greater specifications than for perhaps any other technical challenge.

Secondly, and more importantly, unlike almost any other technology, robotics has an established and entrenched competitor. Imagine a new biotech technology, say a cure for cancer that really works. The asking price can be anything because there are no alternatives. Imagine a new communication technology that presents a thousand-fold increase in bandwidth for a thousandth of the price. Again check books with unlimited upper limits would be ready to acquire it. Imagine a robot that can clean the floor, cook the meals, wash the car and mow the lawn. Unlike the previous examples, each of which have no competition, the competitor to this great robot is human labor. And human labor has a well established cost structure. If the new robot costs more than for a human to carry out the same tasks, our nature is to "buy" the human rather than the robot. That has been borne out time and again in the history of robotics.

And not only is there an established price point for a robot because of the human competitor, there is an established performance standard.

These are worth repeating: a robot must cost no more to operate than a human doing the same task, and perform as well, perhaps even better since it is starting from behind the ballgame.

There are exceptions of course. Hazardous environments because there are few humans willing to do that work, hence the competition is not severe; toy robots which are often extraordinarily innovative, and research robots, the only robots not required to have a function.

Back to the floor cleaning robots. Despite the presentations of a completed robot vacuum cleaner prototype, costing little and functionally sophisticated, to Karcher and Electrolux, they eventually released random wandering household vacuum cleaners costing up to $3,000 dollars, and sales were minuscule.

Roomba is a robotic vacuum cleaner that meets a realistic price point of around $300, and while its sales have been better than the more expensive ones, it reaches nothing like the multibillion dollar opportunity that market research predicts. Part of the reason is that it uses a simplistic path planner that instead of cleaning efficiently and completely like a human does, spirals and doubles up on paths inefficiently. So it meets half of the criteria only.

Most of my efforts in smart mobile robotics were successful, in a technical and commercial sense. The Tasman by serendipity, the others by hard work and hard-won experience. My discovery was that the rules of commercializing robotics are rigid. In addition to Asimov's Laws of Robotics (there are really 4, because he added a "zeroth" rule), perhaps should be added the above commercial rules.

0. A robot may not injure a humanity or, through inaction, allow humanity to come to harm.
1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.
4. A robot must cost no more to buy and operate than the price of human labor.
5. A robot must perform its functions as competently as a human.

(A quick aside: seeing the Robot Laws as special circumstances of the "Laws of Good Tool Design" was developed in the mid 1980's in presentations to the Tasmanian Development Authority and first published by the author in the mid 1990's in an IEEE paper, and not, as is circulating the Internet, due to "Asimov 2001", particularly as Asimov died in 1992.)

Even now I see the same problems in the robotics business and I wonder. Robotics truly has the potential to revolutionize our lives, for instance where it applies to things like medical health, which affects all of us, or where robots could be cleaning up antipersonnel mines cheaply and efficiently. But until all of the factors mentioned in this article are met, the 15 year cycle will prevail.

"In 15 years time, I predict that the then spokesperson for mobile robotics will predict that robots will be everywhere in another 15 years time."

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