Figure 1 Robotics physicist Mark W. Tilden with some of his most popular commercial robots from the past 14 years, all inspired by his minimalist "Biomorphic" and "BEAM" research. (SOURCE: Mark W. Tilden)

Pransky: If I was to come up with one word that I considered to be the 'Mark Tilden way' I would say 'analog'. Is this fair?

Dr Tilden: 'Analog' sort of covers my method, but there's also 'minimal', 'reductionist', 'non-linear', 'angular'. Someone once accused me of 'elegance' which was nice. Dated her for years.

My method is really anything that optimizes performance-to-silicon ratio in real-world mechanisms. As I've always preferred to program with a soldering iron (which involves fewer compiler headaches), it was surprising to see I'd evolved a recognizable style -- crystalline angles in nickel and aluminium, with lots of blinking lights and coloured heat shrink (coined as BEAM-Punk by some).

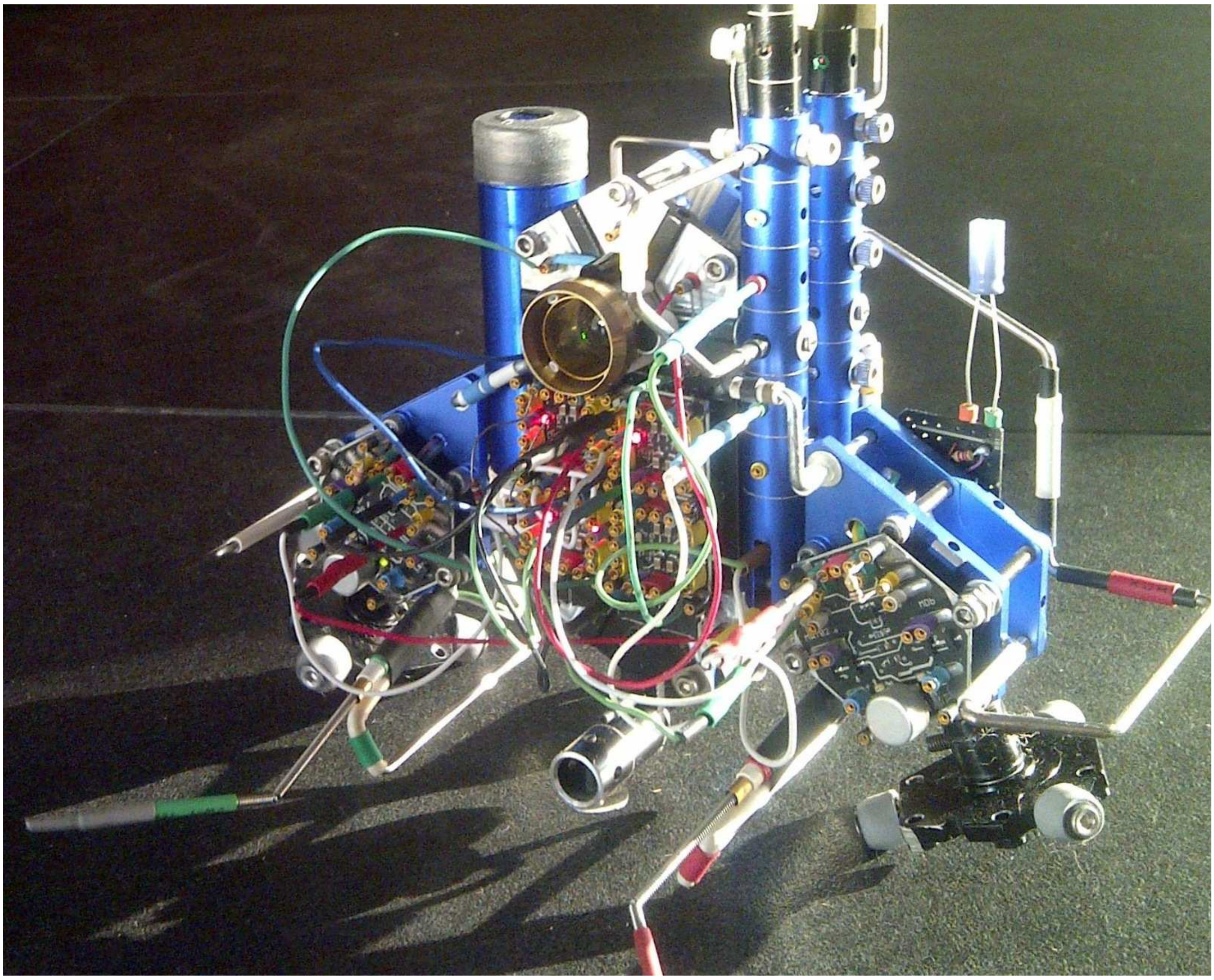

Figure 2 A recent example of Tilden's 'BEAM-Punk' style -- "Huey 1.2" is a self-mobile 'Nervous Network' breadboard with 32 analog neurons, touch, load, vision sensors, and an eight hour walking battery life for long-term wandering. (SOURCE: Mark W. Tilden)

Pity, as I was honestly trying for reducto-ad-absurdum: trying to find maximum competence from the smallest number of components. Instead I keep on reinventing archimedian tensegrity structures in both controllers and structure. Oh well, at least uniform parts are easy to work with.

Figure 3 Tilden poses with his five-foot-high spider robot "Roswell", and the inch long solar-powered "Bitbot", both held together with more springs than bolts. (SOURCE: Mark W. Tilden)

As a robotics physicist, I've always been interested in the paradox of why it's so hard to build artificially what nature seems to do so easily. For autonomous robots, I've found an answer in fractal scaffolding architectures where competence functionally scales from simplicity up through complexity. Nature seems to do this mostly through growing juvenile forms (fractal L-Systems), but we don't have this option in machines. However, when you can customize the controller to match the mechanism, your designs tend towards minimal, efficient, systems anyway.

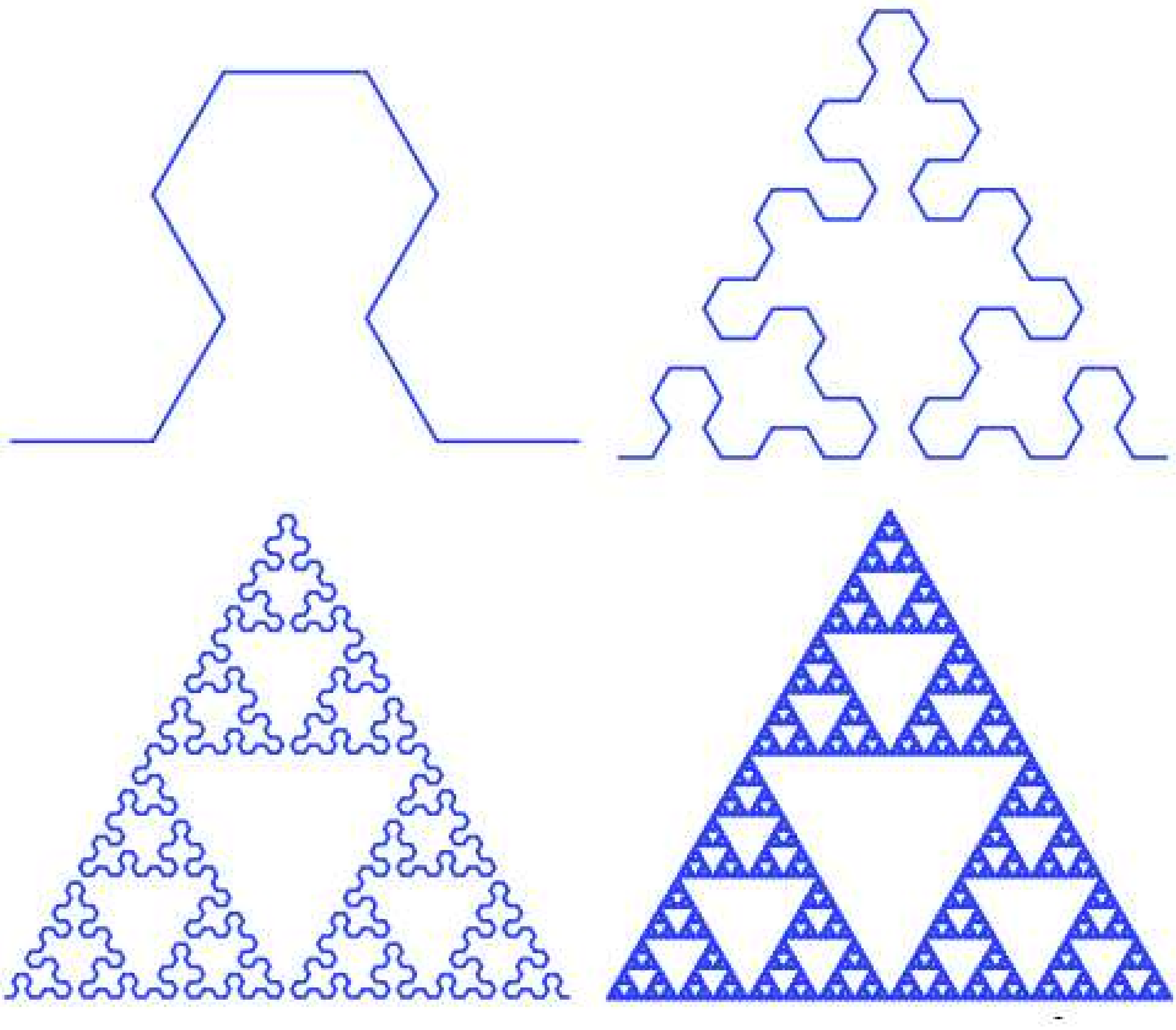

Figure 4 An example of a progressive structure L-system. Tilden uses such structures to form robust distributed oscillator brains and even mechanical structures for his research robots. (SOURCE: Wikipedia)

A form follows function approach -- reliable, fast, cheap, and mass manufacturable. If that's a 'way', then I claim copyright.

Pransky: In nature, simple life forms are pre-programmed and are more-or-less fully functional from the moment they are born, whereas higher life forms such as humans have minimal pre-programming and are pretty useless at birth but learn as they go along. We expect robots to work right out of the box, but do you think your robots also have the capacity to learn? And can your analog/mechanical mechanisms learn or will this learning come from the digital

controller?

Dr Tilden: I do have a variety of nervous-network architectures that can "learn". The distributed analog systems I like to work with quickly find their optimal motive solution(s) while you watch -- I call this 'annealing' rather than 'learning'. However for proper competence-from-experience 'learning', analog machines have to go through the pains of interactive responsibility like the rest of us. Their networks are small, they learn quickly, so I don't feel too bad when I mess with their heads looking for alternate behavior architectures.

Interesting, but not practical, which is where my systems really benefit from digital controllers with coded responses. The problem is that "learning" digital is typically very expensive and subject to local minima difficulties that make it difficult to test for commercial products. Frustrating for users as they want predictability out of the box, not variations in mood or personality. Consequently, we have to keep any learning functions very transparent. Usually learning abilities wind up "on the cutting room floor" so to speak, and we just load up the robots with preprogrammed "bodycon" responses.

It's an interesting contradiction that the randomness we consider desirable from other social animals (humans, dogs, goldfish, etc.) is the last thing the general population wants from their machines. I mean, would you want your cell-phone to change its settings all the time trying to second guess you? There's enough hatred just from auto-correct.

Learning abilities will be necessary for future commercial systems, but no-one that I've seen has really cracked the interface to make humanoid learning truly transparent to human needs in work or play. Learning in the animal sense is an interesting feature but one that'll need a lot more work.

Pransky: The rest of the world started to go digital about 60 years ago partly because ones and zeroes are much simpler to deal with than the integral and differential equations associated with simple devices like capacitors and inductors. While the rest of the world was getting into digital because it couldn't do analog, did you get into analog because

you couldn't do digital?

Dr Tilden: No, I do digital quite well; it's the machines that 'want' analog as minimal solutions to a complex continuous-value world. Digital is fine for precision repetition but is usually a bit-flip away from disaster, whereas many of my Biomech nervous systems can have half their brains ripped out and still converge a solution. Biomorphic (or Biomech) circuits cost pennies a board, are static resistant and self-converging, so devices can be made operational while the client waits (which has saved me in several vital presentations).

But primarily, analog is just more fun than the tedium of keypunch (anyone that's ever had to enter motion-dynamic linked-list matrices by hand might sympathize). And if your circuits and mechanics follow a classic symmetry, you can usually pull things together without a circuit diagram, quickly. Best of all, analog allows for accidental discoveries you generally don't find except through computationally intensive digital methods. As an experimental physicist, that's always exciting for me.

Robotics can be fast and fun -- it's not just a Hollywood myth -- but getting the analog monster together has to be done in the most reliable way before you slam the digital brains in. That's when it starts to get really interesting.

I'm sure the future of real-world robotics has to involve a cost-appropriate hybrid of analog and digital -- extremes in either without the other, are just cost prohibitive. If what the world needs now is a good $2,000 life-size humanoid that can bring you coffee, I'm convinced this'll be the best way to do it.

Pransky: Your robots clearly demonstrate the benefits of an analog approach when applied to toys. Do you think they can be scaled up or do you expect that larger and more sophisticated robots would have to be more digital?

Dr Tilden: Well I have built massive and miniature machines with analog, simple and complex, but I'm hardly a digital luddite -- just a firm believer in the horse-and-rider approach. That is, if you've got a good analog horse, your digital rider doesn't have to be so complicated (and a blue-screen of death won't destroy your hardware).

Analog just allows me to quickly build reliable competent cradles into which digital brains fit, enhance, or function-replicate with little difficulty. An analog "horse" with a digital "rider" uses both to their strengths, so you don't have to push zero-moment calculations on the analog and you don't have to sweat motor dynamics on the digital.

For example, my method for product design always follows a familiar path: I make a working efficient Biomech analog prototype, my engineers record all values into dead-cheap digital audio sequencers, and the toys link these recorded analog actions into a range of functions (with sounds and lights added for effect). Not all the adaptive features of the original nervous-network are preserved in the digital recreation, but enough do. My 36cm-high Robosapien humanoid, for instance, has a walking battery life of over 20 hours from regular alkalines. Pretty sure that's a lot longer than any Asimo-architecture servo robot of similar size.

But a deeper answer to your question is just how complex might you get recognizable, positive-motive, analog behavior from autonomous robot recursive analog architectures? The answer is more mathematical than physical, as it involves flipping Lorenz orbits on analog oscillator controllers under interactive stress, using the motors-as-the-measure for subsequent 'decisions'. I love playing with such bots, but the results, though interesting, are hardly repeatable for mass manufacturing: far too much 'tuning' required. That's why I always have to go digital on my commercial units.

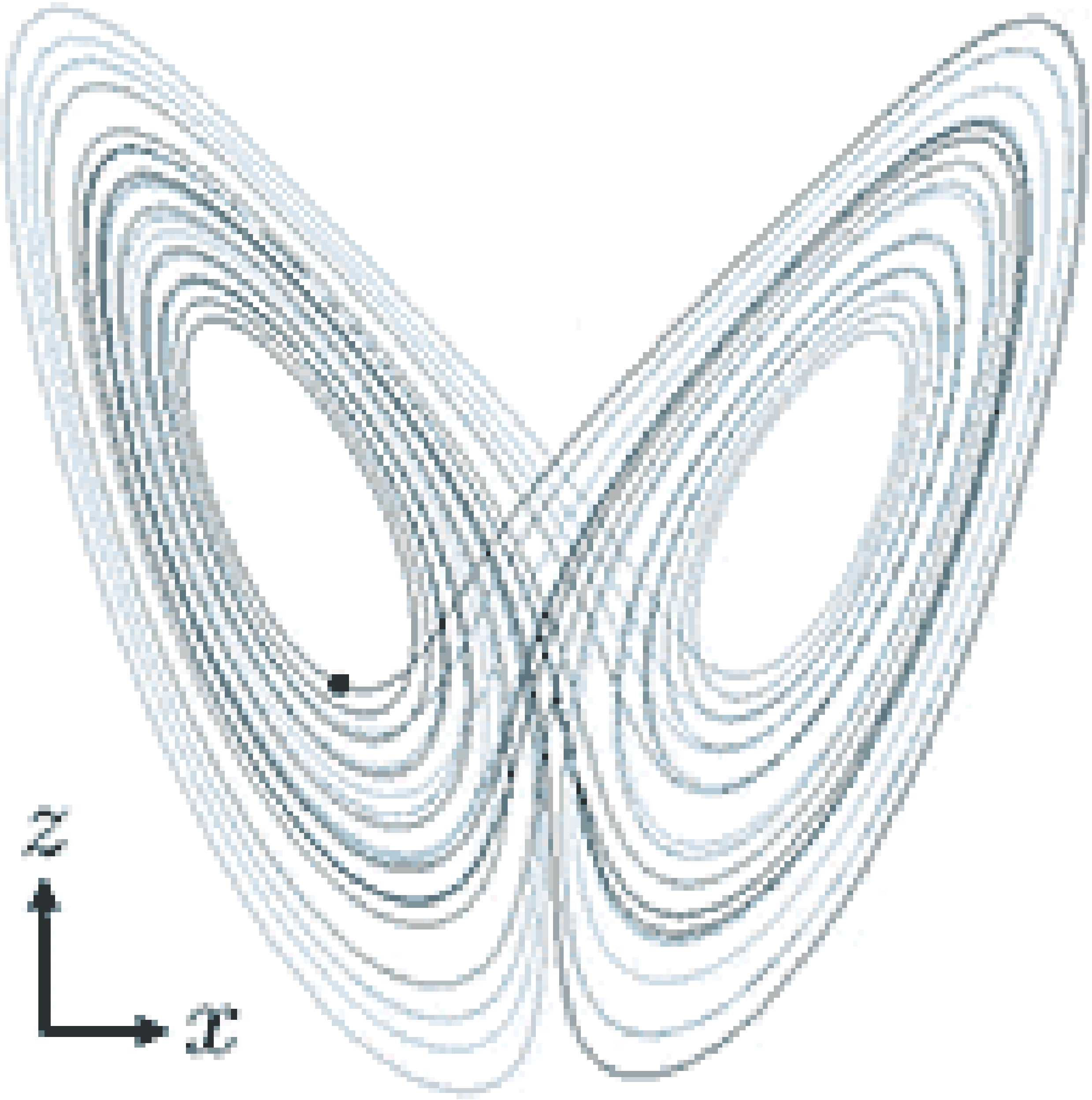

Figure 5 A Lorenz attractor orbit Biomech "brain" can be made from two oscillators pulling at each other while stomping through a real world -- random but bounded, (SOURCE: Wikipedia)

The short answer to your question is balanced analog-digital hybrids will allow for the benefits of both in affordable, understandable products, but the competence limits of pure analog 'brains' are still to be discovered.

They're fascinating though.

Pransky: Do your robots tend to have one central digital brain? And do you think that the future for your approach might lie in having a large number of simple brains each controlling a small sub-mechanism?

Dr Tilden: My analog research robots are (usually) distributed networks of oscillators and Integrate-and-Fire (IF) neurons, often scattered around the structure near whichever sensors, ears, eyes, motors they're responsible for.

My commercial robots do tend to one custom digital RISC brain, though the larger ones also have discrete DSPs for vision, LCD processing, and other dedicated functions. Coordinating multiple digital control centers is always a headache though, but the future will be in connection minimality and function transparency like they're doing for cars now.

Robot nervous system architectures can be simple or complex, but making them affordable, reliable, and efficient is the common thread I always try to push for.

Pransky: The natural world is more analog than digital and is still far more powerful and energy efficient than any artificial digital machines. Artificial intelligence such as that under development by OpenCOG could be regarded as using digital computers to make analog decisions – do you agree with this and do you think that using powerful computers to make analog type decisions is the way we should be going or would it be better to stay analog from the outset?

Dr Tilden: My vote is bust-proof analog bodies for digital brains, otherwise wonderful digital consciousnesses like OpenCOG could be trapped in their virtual worlds forever. While that might be good news for the gaming industry, it's not going to bring you breakfast. Finding inexpensive, pliable ways to get machine brains to interact with the world sounds like a standard dystopian sci-fi trope, but from long experience there's nothing to fear: they're idiots.

What we might learn from analog research, and the neuromorphic biological exemplars which serve as frustrating existence proofs, is the scaffolding structure that we might hang our digital thoughts on. That's more topology than algorithms though, but who would fund an institute of "Alternative Mind Design" (besides myself) to find out?

Again, the marketable (though not unique) solution is hybridization, and I'm hoping my association with Dr. Ben Goertzel and others at the OpenCOG lab will yield some better results than a few nice dinners.

People forget that robotics is not one discipline, it's all of them. We have to proctor bots from lesser to greater, but right now it's such a rich man's sport. We've got to change that somehow.

Pransky: How did you make the jump from being an engineer tinkering with parts from Radio Shack to getting your ideas into commercially successful toys? Did you approach WowWee or did they find you?

Dr Tilden: When I was the entire robotics department at Los Alamos National Laboratory (New Mexico) for a decade, I wound up on not-a-few TV documentaries. WowWee (and other clients) saw me on late-night discovery and science channels and invited me for a talk. I still catch myself occasionally on in-flight shows (obviously when they've nothing better to show).

I live still in syndication, and the internet never forgets. An important lesson for budding roboticists: your face is as important as your devices. Learn to talk to a camera.

Pransky: Most robot designers start by creating sophisticated simulations to test out their ideas. Do you ever do this or do you dive straight in to the hardware and get your hands dirty?

Dr Tilden: Sometimes I do simple proof-of-concept simulations or sketches, but mostly I just start breadboarding from instinct and designing internally. Been doing it for decades now, so it's natural. For example, before I sat down to build the first Robosapien in a solid ten day build, I thought about every design aspect for a month until it was clear in my head. The prototype worked from the first power-on (with prominent witnesses). I find sims slow the fun, but if it's clear in your head, it's great just to sit with purpose (and a bottle of Perrier for your soldering iron sponge).

Thinking and hacking are much more plastic techniques than conventional simulation, at least for me. Your mileage may vary.

Pransky: Why do you live in Hong Kong? Is it because you need to be close to the manufacturers of your bots or do you find the Chinese more receptive of your ideas than perhaps they would be in the USA?

Dr Tilden: That and I like fine Sushi.

It's a very different model here from the usual academic chase -- business heads in Hong Kong don't care how it works, only that it does, at a good cost, and with marketable repeatability. Nothing moves faster in this town than an inexpensive working prototype from mass-manufactured components. It's an honest reality that makes for fast negotiations, quick turnaround, and on-time shipping.

Plus... Sushi, and a taxi any time you need it.

I had great fun as a professor and researcher in North America and I do miss the culture and interactivity, but it's generally too slow to start the great robot revolution.

And as we say in the business, "Santa don't wait".

Pransky: What is the biggest mistake/greatest lesson you learned?

Dr Tilden: Well, there have been lots of lessons and mistakes, but my biggest regret was in helping shut down the robotics division at Sony.

In 2005, Sony Robotics was moving on from the Aibo robot dog to QRIO, a sophisticated $50,000 programmable humanoid that you can still see on

YouTube. It was beautiful and my bosses asked if I might cobble together something similar for the toy market. The result was the Robosapien Version 2 (RS2) which hit the market in Christmas of that year. Could see, hear, dance, walk, talk, get up, get down (wah!), and generally had more functions than Darth Vader's underwear. It was also the same rough size as the QRIO, and sold millions at $250 each.

Figure 6 The Robosapien Version 2 (RS2) was a 13 motor, 2 foot high fully controllable humanoid robot with full-sized hands and multi-function remote. Now a collectors' item, it was designed to be fully hackable with

a Phillips screwdriver. (SOURCE: Mark W. Tilden)

Years later, I found out that a lot of my Japanese colleagues and friends had lost their dream jobs working on the QRIO when the lab shut down, and Sony had cited my RS2 as a prominent (though not the only) reason why. Ouch. Many of those engineers just got moved to other divisions so it wasn't a complete disaster, but I always feel bad because these sort of cool projects, due to the nature of our business, are rare.

Only 200 times cheaper. Who'd a thunk it.

Pransky: Have you made a lot of money out of robotics – and is this important to you?

Dr Tilden: Personal question, but my profits go into further development of new Biomech devices, components, supporting businesses and technologies. Basically, old generation sales support research for the new generations, and some of my bots have been continuously selling for over a decade now.

Primarily, it's a relief to not have to go hunting academic funding anymore. Guess that's important as there's still so much to do.

The evolution continues.

Pransky: Speaking of evolution, you recently formed, along with three other Dream-Team members, the GENI lab in an effort to build the world's smartest, life-sized humanoid robot. What is your vision of this humanoid?

Dr Tilden: Well, my vision of this humanoid is in a plastic bag beside my bookshelf, waiting to be taken to the sculptors for a rework. My vision is very clear, but can't go into details else it'll spoil the market impact.

It was great finding a synergy between the GENI lab antagonists (sic) right here in Hong Kong though. Ben Goertzel's got one of the most cohesive working models-of-mind I've seen anywhere; Dave Hanson's expertise with expressive faces and emotional interaction is legendary; I'm the leg man. Seemed natural to see if we could pull all our skills together for a horse and rider product that might actually do something about the house or office for a reasonable price.

Details pending.

Pransky: What do you think PhD and Masters of Engineering students should be doing while in school to prepare them best for the commercial side of robotics?

Dr Tilden: Learning to draw. Seriously. It's either that or start learning a dozen languages.

The future's coming. What skills do you have that are too hard to automate?

About the author
Joanne Pransky has been an Associate Editor for Industrial Robot Journal since 1996. Joanne was also the Director of Marketing and one of the principals of the world's first medical robotics journal, The International Journal of Medical Robotics and Computer Assisted Surgery. Joanne served as the senior sales and marketing executive for Sankyo Robotics, a world-leading manufacturer of industrial robot systems, for more than a decade. Joanne has also consulted for some of the industry's top robotic and entertainment organizations including: Robotic Industries Association, Motoman, Staubli, KUKA Robotics, STRobotics, DreamWorks, Warner Bros., as well as for Summit Entertainment's film "Ender's Game" in which she brought never-seen-before medical robots to the big screen. In the summer of 2013, Joanne was hired as a Robotics Consultant for SciFutures, an innovative futures agency that uses science fiction prototyping to help the world's leading brands create and implement disruptive futures. Joanne Pransky can be contacted at: drjoanne@robot.md