Velodyne

'The Year of the Robot' – A Conversation with Wolfgang Juchmann, Ph.D.

In early January, the late New York Times media columnist David Carr recounted his experience at CES: "As I walked past the booth staffed by robots selling robots, the plants that water themselves, and the prototype Mercedes with no driver at the International CES trade show last week, it occurred to me that the future of human existence might not require many humans."

Is he right? In the near term, what do you see as the most compelling playing field for robotics?

Juchmann: In my view, unmanned aerial vehicles (UAVs) for automated flying will be a very promising application for robotics, especially in agricultural areas. Now that the Federal Aviation Administration has issued regulations addressing commercial UAV flights, we know what's required, legally, to survey and overfly agricultural areas using pre-planned UAV routes. UAVs are capable of seeing how plants are growing, areas where sprinklers aren't working, why everything is brown, etc.

The goal isn't to have someone control the UAV as it flies over the field – it's a robot, after all. The goal is to use pre-programmed GPS data of the field, and then let the UAV just do it. You send it out and half an hour later, it comes back with the information you need. It tells you where the irrigation system isn't hitting, where growth is exceptionally good or isn't happening, where you need more fertilizer, and so on.

The same approach would apply in the mining industry. UAVs can use preprogrammed routes to fly over, and actually measure, extraction of coal or any other resource taken out of the earth. Today, that's a cumbersome task that requires a plane and is cost-prohibitive to do on a frequent basis. Ditto for the construction industry, where regular 3D measurements can compare the current status of building projects with plans and timelines proposed by the builder.

Or consider the automotive industry, where we have focused much of our work. While the long term goal might be robots (that is, computers) that can "drive" vehicles with complete autonomy, robots/computers have already taken some control, if not the wheel itself. Electronic stability control (ESC) systems, automated braking systems (ABS), adaptive cruise control -- all of these systems effectively replace the driver with a computer that can make better/faster decisions for limited, well-defined tasks. In mining, trucks already drive themselves autonomously, but the framework is limited to the mine, with its pre-programmed paths and highly specific tasks.

The level of sophistication of robotic tasks increases every year. Indeed, Uber's recent announcement that it eventually intends to replace drivers with self-driving cars suggests that this vision has legs.

In the UAV world, are FAA regulations apt to reshape the market?

Juchmann: Hard to say. Any time a UAV flies for a commercial purpose, strong limitations apply. A hobby pilot can fly anywhere at any time, but as soon as you make money with it, it's considered commercial and remains prohibited.

The FAA definitely needed to come up with a set of rules governing commercial flights. Some exceptions to the ban were made prior to the regulations -- Hollywood is one. Instead of renting a helicopter, some studios and directors are using UAVs to film. Apart from that, I'm aware of one company that is allowed to fly in Alaska.

Commercial or otherwise, it's necessary to have a UAV pilot's license and to understand the rules. You're not allowed to fly over airports or interfere with normal commercial air traffic, among other requirements.

Just about any business can own a UAV these days. Costs have come down and the technology is pretty basic. It's becoming feasible to take a daily snapshot of what's happening in real life outside.

At this stage, the point seems to be avoiding populated areas, which is why agriculture and mining are so appropriate. Can UAVs be made smart enough to avoid wires and other obstructions?

Juchmann: In the agricultural example, GPS coordinates programmed in determine exactly where the unit is flying, so the flight path specifically avoids wires. If those powerlines or phone lines are 30 feet high, the UAV flies at 60 feet.

We've seen interest from some organizations that want to be able to detect wires and other objects in the environment. They want to fly autonomously, where the UAV can make decisions. These tend to be military applications, with UAVs operating much like self-driving cars. In a "self-flying" UAV, LiDAR sensors can be deployed to detect obstacles and landing sites, and analyze data to make decisions.

If the UAV is not preprogrammed and is confronting an unknown situation, it needs fast detection of its surroundings. That's obviously not the case with the farmer, who knows the field and programs the UAV for that acreage. Most people don't want to pay for the additional equipment needed to make the UAV nimble enough to avoid hazards.

What does a typical UAV cost these days?

Juchmann: Around $10,000. Some of the low-end models are actually below $1,000, But if you want to include a more sophisticated camera and automated flight planning, you're getting into the $10,000-$20,000 range.

For that farmer, the investment could pay for itself in avoiding crop losses or maximizing yield, is that correct?

Juchmann: Yes. You save on personnel costs as well, and you can mine the data.

Let's return to the matter of unforeseen hazards. In early 2009, when the pilot landed his plane in the Hudson after those bird strikes, we all became aware of that kind of hazard. Could a LiDAR-equipped UAV avoid bird strikes, in theory?

Juchmann: Yes, but it's all a matter of how fast the birds and the UAV are flying. The UAV might recognize the birds and maneuver to avoid them, but the birds may do the same

maneuver and they collide. It is of course easier if another object is programmed with a projected trajectory -- how it has been flying, and in the last second you have to detect it.

If it's bird, it can change erratically, so that is especially difficult to predict. But other objects -- wires, even trees -- can be detected and avoided. If the object is larger than tennis ball, it's not something you want to fly into as a UAV.

The FAA governs U.S. airspace. How are regulations outside the U.S. affecting UAV deployments? And are those differences affecting the development of new markets for UAVs?

Juchmann: I've heard about some activity in Italy, but I'm not 100 percent sure.

Every nation has an aviation authority…

Juchmann: If you operate a large mine or a farm, you can certainly allow a UAV over your own property, no matter where you live. Your only risk is if someone is underneath. In developing countries, suppose someone owns a huge mine or several square hectares of land -- who's going to care if a UAV flies over uninhabited land? It's the same issue, which is to say, a non-issue.

Even though the FAA has finally weighed in, it's possible that other countries may also establish model regulations for UAVs. Indeed, I predict that that's going to happen – there's almost no way to prevent it. It is far better to define a network of rules that works than to say no, overflights are not allowed.

From where you sit, what's the most exciting or useful robotics application that will come online in 2015?

Juchmann: It's actually an announcement made late last year, dealing with robots in stores to greet shoppers. For example, you can tell the robot that you bought such and such a light bulb. The robot recognizes the bulb and brings you to the aisle to find that product immediately. It's still quite early, so not that many have been deployed. But I suspect that more retailers will want this capability.

This is pure speculation, but I can imagine that in the Apple Store of the not-too-distant future, instead of a geek in a Polo shirt, you'll be greeted by a computer. It'll ask if you have an appointment, then escort you to the Genius Bar or some other section of the store. This could, of course, apply to any retailer, not just Apple.

So Wal-Mart greeters will no longer have to wear silly costumes …

Juchmann: High-tech companies might do this earlier because it's consistent with their image. Wal-Mart isn't high-tech, but Apple or Best Buy, certainly.

On its own, might this capability attract new customers?

Juchmann: Yes, probably so.

What looms as the biggest challenge for the robotics market? What has to happen to make robots members of the family or members of the business – part of a working team?

Juchmann: There are several obstacles. There have to be certain economies of scale. Robots need to be programmed to do certain things. And if the programming isn't

intended for a large number of units or for repetitive tasks, that process is going to take longer and, of course, cost more. Programming the robot has to be worthwhile from a dollars and cents perspective.

Robotic equipment also figures in to this -- accessories, robot sensors, gripping arms, etc. Prices really need to come down to make it worthwhile, or the number of units produced needs to be quite large.

At this juncture, could troubleshooting be a deterrent to widespread acceptance? User-friendliness would seem to be essential. How do you provide tech support for a robot?

Juchmann: One way is to make it easier to program, or reprogram, the robot. To change a task, you need to change the programming. Line-by-line programming, digging into the code, isn't feasible for most users. Robots don't typically learn intuitively; they are controlled with a joystick, slowly, in a certain motion.

In learning mode, a robot can be instructed in much the same way you can create an Excel spreadsheet macro – it will remember the positions, and it learns by doing. You don't have to write the various positions down. When you say, "do it again," it will – mistakes and all, so you can then re-program, if need be. This is ideal when repetitive motion is involved, as it usually is.

Sensors like LiDAR can provide real-time detection and enable the robot to react to something unforeseen. In our mining application, say there's a self-driving dump truck, and large boulder falls into the road, or another dump truck is stuck and a rear-end collision is imminent. We're talking about a different kind of programming task.

If you need a robot to pick something up, it's necessary that the object is always in the same orientation and is right side up. (that is, "correct" side up). The robot can then be programmed to handle that specific object in a predictable fashion. If there's any randomness in the environment at all, make the robot more intelligent ; include a camera or a 3D sensor that detects distinguishing characteristics about the object, so the robot knows how to grab it.

Eventually, might that capability become part of every robot? Today, it may be overkill. But will there be a time when that kind of intelligence – dare we say "judgment" -- is standard equipment? And if, so, how long from now?

Juchmann: Actually, I don't think so. Robotic activity depends completely on the task at hand. Robots are supposed to help with certain jobs. We have the idea there will be humanoid robots running around looking like people. That truly would be overkill. We want robots to move something from point A to point B, or to perform some mechanical operation. If it's a repetitive motion and nothing changes, we can control it. But we don't want to spend extra money on a robot that has additional cameras and sensors for undefined tasks.

For the foreseeable future, we'll want to keep the robot as affordable as possible, but still able to do the task. Outside of the bounds of that task, you clearly do need extra sensors, much as in the UAV example. Consider that farm; you know your field. So there's almost no reason to do collision avoidance because it's flying there.

Now, say you're in Afghanistan. You don't know where you're flying, who's shooting at you, or where the trees and the powerlines are. You'll want those additional sensors

because now you need to make these decisions, but the economics of that kind of robot are entirely different from, say, robotic applications in agricultural or mining environments.

In 'The Imitation Game,' the Alan Turing character builds a massive computer. Now, we've all got technology thousands of times more powerful, and the device – the smartphone – fits neatly in a purse or pocket. If somebody had said in the '50s or '60s that a terabyte could be housed in something about the size of a wallet, people would have regarded that statement as preposterous.

Juchmann: Clearly, more and more sensors will be added to automated equipment to do more automated tasks.

How are robotic applications developed and validated in industrial, military or scientific environments likely to migrate to the consumer world?

Juchmann: Institutions like NASA's Jet Propulsion Lab or MIT's Robotics Lab are focused heavily on obtaining government funding. They're engaged in challenges, with prizes, to develop humanoid robots. It's quite an undertaking. Human beings, of course, are very, very complex. Try to replicate locomotion in a robot is a major challenge (please see http://youtu.be/M8YjvHYbZ9w). From these projects, these projects will come up with compelling solutions. And from these will come spinoffs and commercial applications– even as "basic" as a tactile way of grabbing objects of different shapes without reprogramming. After all, Teflon coatings came out of NASA's development of heat shields for the space program.

Are institutions focusing enough on robotics, or will the market drive robotics development? Are we waiting for a killer app, much as it took Elon Musk's Tesla to make the electric car exciting?

Juchmann: The robotics market is quite diverse. There are, at the low end, very simple robots, plastic boxes really, to regulate AC and heat. They use relatively simple logic and are priced in the $20-$50 range. There's a former Apple designer who made the home thermostat quite aesthetic, and put some intelligence behind it. It learns without programming – it essentially watches you. For that, people are willing to pay something like $300. It's not the same as the electric car, but it is a breakthrough, of sorts.

Google has been buying a number of robotics companies, though it's not clear exactly what the company is up to. Perhaps the Elon Musk effect will happen in robotics.

Or the Larry Page effect?

Juchmann: Yes -- it happened with cars. Google rolled out the first self-driving cars in 2010, and the car industry had to jump on the bandwagon. The question is, how can a software company make it happen and car companies in Detroit can't?

So perhaps the disruption in the robotics market will come from a new player. Is there an industry in particular that you see as most ripe for a robot invasion?

Juchmann: Warehousing. Robots are most useful dealing with quantities and numbers. Look at Amazon, which will ship orders the next day. That requires complex logistics -- parts stocked, packaged and sent to you, and sometimes combined with other things.

Amazon already has huge logistics centers and they're already highly automated. But even more can happen. Merchandise needs to move around in these centers. Real-time sensors become important because you don't want to run the person -- or the robot -- over. It's a question of efficient traffic management.

Industrial applications in robotics would seem to have the potential to be catalysts for other kinds of changes, involving transportation, employment, even housing. Is that a fair assessment?

Juchmann: I think so. Again, we already have models and businesses that could accommodate robots fairly easily. The postal system has done a lot of automation, as have airport baggage handling systems.

How much of the robotics market is driven by economics and pricing? What's driving demand for robots today?

Juchmann: The market is driven mostly by business right now, so the economics are everything. People want to produce something and make money. The less a product costs to produce, the easier it will for the emerging generation of robots to be involved. Robots have been in the logistics of manufacturing for quite some time, but industry is finding new ways to drive costs down and out, to be smart about building products.

At Velodyne, we make products in hundreds and thousands. Now we want to sell in the 10,000s. We're in the robotics market as both a supplier and a consumer. Automated testing and robots enable us to lower our prices as well.

People tend to think about humanoid robots, but mostly, that's science fiction. Today's robots reside in your smart refrigerator, as part of the Internet of Things, which tells you whether the milk is beyond its sell-by date. That's far more realistic than a humanoid robot fetching you coffee.

Look ahead to 2025. Where might this go? What do you foresee in a decade?

Juchmann: It sounds basic, but consider what's involved to load and unload ships. Traditionally, you needed somebody in a crane high above the ship -- four loading bays, four cranes and four operators. Now, with the help of sensors, robotics is streamlining the process, where one operator remotely monitors four cranes, almost working autonomously.

By 2025, robotics will still answer that most basic question: what is it that people don't like to do? What tasks are the most mundane and the most prone to human error? For consumers, those tasks might include vacuuming the house, mowing the lawn, refilling the refrigerator, etc.

Of course, shopping to buy the things that go into the fridge is another story. Not because it's technically challenging to do, but because many of us consider shopping enjoyable. Activities that involve social interaction aren't ever likely to be candidates for robotic applications. Robots are designed to handle tasks people hate doing – tasks that can be automated.

So robots are going to get better at being our servants, but won't be our replacements?

In my view, robots will never supplant humans. Robots can be adept at some routine tasks, but they have a long way to go before they can truly mimic human intelligence. For the foreseeable future, robots will be optimized for certain tasks and within that framework, they can replace humans, but as soon as something out of the ordinary happens, people need to step in and make decisions.

Robots excel at performing repetitive work and following pre-programmed decision trees, and they aren't likely to get distracted or have emotional or philosophical issues with a given job. On the other hand, aren't emotions what makes life interesting?

So no robots on Match.com, in other words.

Juchmann: Right. The closest we'll get to companionship is apt to be an iPhone or iPad app that speaks to people, probably through social media, through the medium of a robot.

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For more on the robot revolution, please see http://www.msichicago.org/about-the-museum/press/robot-revolution/.