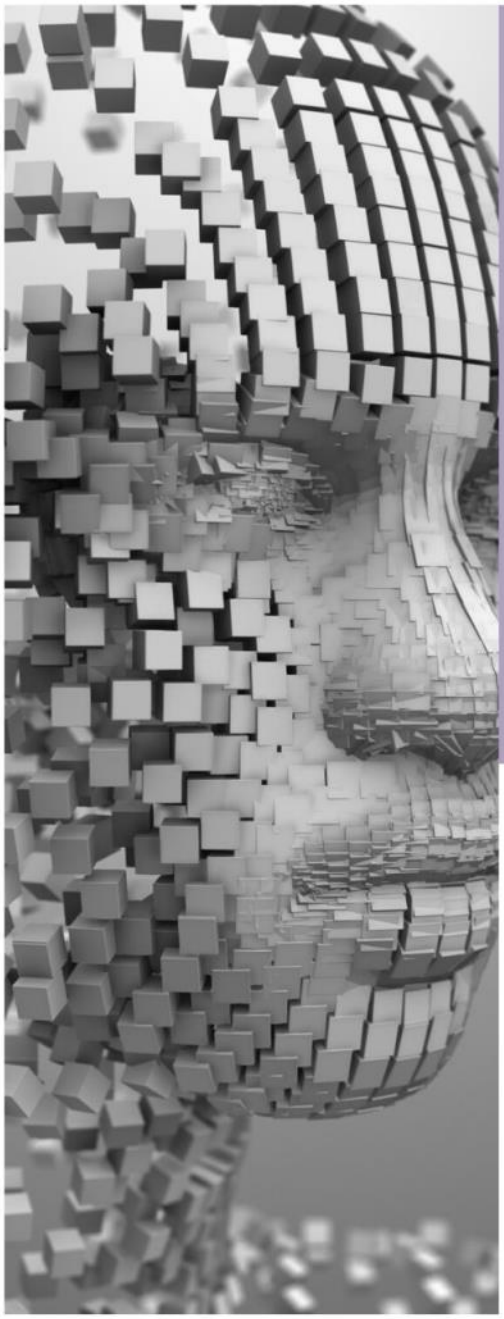
Northwestern | Retail Analytics Council

RETAIL ROBOT ROUNDTABLE

Robot Adoption Trends in a New Retail World

JUNE 2020



The Retail Analytics Council

The Retail Analytics Council (RAC) is the leading university-based applied retail analytics and AI research institute focused on the study of consumer shopping behavior across retail platforms to provide an understanding of how these impact retailers, particularly as new technologies are introduced. The RAC unites industry, faculty, students, and its Advisory Board members for the study and exchange of ideas and research. To learn more about the Retail Analytics Council, please visit: rac.medill.northwestern.edu.

RAC Retail Robotics Initiative Sponsors

AVATARMIND

badger technologies

CloudMinds

simbe

Northwestern | Retail Analytics Council

There has been growing interest in robotic automation in retail and supply chain for some time. COVID-19 will accelerate adoption. The Retail Analytics Council recently hosted a roundtable discussion regarding the state of robot adoption trends in this new retail world during the pandemic. Eight panelists were asked to respond to a series of questions. Generally, the questions probed the participants' thoughts on the opportunities and challenges of robot adoption. Roundtable participants included:

Christopher Blum
Mechanical Engineer, Kroger Technology

Blum graduated from Tuft's University's Mechanical Engineering program in 2015 before starting work related to electro-mechanical systems. After working with Siemens on Motor Control Center manufacturing, he has been working on developing sensors for Kroger's stores.

Chris Daniels
Technology Engineer, Kroger Technology

Daniels has spent years working and collaborating with Kroger Research and Development, as well as the Digital organization. His most notable projects include ClickList, Temperature Monitoring, and IoT Strategy. He is a founding member of Kroger's internal research enterprise enablement team. He was responsible for the original design of Kroger's university labs program, including heavy involvement in the design and build out of their first two labs.

Dr. Don High
Former Chief Scientist, Walmart

High is an inventor and data scientist with an exceptional track record as Chief Scientist at Walmart's technology groups. He inspires innovators globally to produce amazing results in robotics and aeronautics. Associated research and development initiatives put 680 inventions into the patent queue with more than 250 published and more than 140 granted. His success stems from helping others to be successful.

Gerry Hough
Senior Expert, Store Innovation, McKinsey & Company

Gerry has spent nine years at McKinsey working on operational and innovation topics across several retail formats. She works at the intersection of technology and operations to help retailers and tech providers unlock more value from stores, supply chain, and omnichannel offerings.

Roundtable participants continued:

Dr. Todd Murphey
Professor of Mechanical Engineering, McCormick School of Engineering and of Physical Therapy and Human Movement Sciences, Feinberg School of Medicine, Northwestern University

Murphey received his Ph.D. in Control and Dynamical Systems from the California Institute of Technology. His laboratory is part of the Center for Robotics and Biosystems, and his research interests include robotics, control, computational methods, rehabilitative robotics, and computational neuroscience. He received the National Science Foundation CAREER award in 2006, was a prior member of the Defense Science Study Group and is a member of the Air Force Scientific Advisory Board.

Wesley Rhodes
Vice President, R&D and Technology Transformation, Kroger

Rhodes holds academic appointments in Cyber Security, Health Informatics, Supercomputing Applications, and advanced R&D research. Rhodes has an advanced degrees in business and technology from the University of Houston, University of Western Carolina, University of Texas at Austin and from the University of Maryland, University College.

Dr. Adam Rigby
Senior R&D Scientist, Kroger Technology

Adam earned his MSC in Physics as well as Data Science from Cardiff University and Ph.D. at the University of Manchester. Most recently Adam was brought into Kroger R&D to help work on new technologies and now works closely with the university outreach programs as the subject matter expert for sensors, devices and robotics.

Dan Whitacre
Senior Director, R&D and Technology Transformation, Kroger

Whitacre focuses on innovation and transforming Kroger's enterprise approaches to data and analytics architecture, technology strategies and practices as well as its disruption roadmap. He served as the CTO and Vice President of Business Development for a technology services organization and spent six years consulting at IBM on Information and Analytics strategy and architecture.

Steven Keith Platt
Research Director, RAC and Adjunct Professor, Northwestern University and moderator of this roundtable discussion.

Platt is Research Director, Retail Analytics Council and Adjunct Professor, Northwestern University. He received his BSBA in Finance and Marketing, JD, and LL.M. in Taxation from Boston University. At BU, he served as Articles Editor for the University's Journal of Tax Law. He has published numerous studies about retail analytics and digital communication networks.

Platt:

Good morning and thank you for participating in today's retail robot roundtable. These are extremely interesting times, as we all know, in terms of what is happening in retail, particularly in the grocery segment. With that, let us start with our panelists introducing themselves.

Daniels:

Good morning. Chris Daniels from Kroger Technology. I started as a software engineer - a full-stack developer for Kroger, originally as an intern. I have worked my way through a lot of different applications, such as Kroger Pickup, temperature monitoring, etc. From there, I became engaged in internet of things applications. A lot of sensor work. I have also been representing Kroger with the ZigBee Alliance. We have done a lot with them and contribute to their standards, as well as adopting a lot of their best practices. I have been heavily involved with the university programs that we are doing, setting up our first innovation labs at the University of Cincinnati and Northern Kentucky University. I have had a strong passion for interacting with universities and figuring out how we can better partner with them to deliver cool opportunities.

Blum:

Hi. I am a mechanical engineer out of Tufts University. I have been with Kroger R&D over the past four years and have been working on developing the sensors, cameras, and other devices for use inside the stores and some of our other facilities, distribution centers, etc. I am not directly working on AI video or computer vision, but I am enabling the people who do that programming.

Rigby:

My background is mostly in physics software and also in some device fabrication. I completed a master's in physics focusing on semiconductor physics and statistical mechanics, which is a great way to start a conversation.

I then moved on and completed a master's in data science and then a Ph.D. in liquid crystal structures. Looking at self-assembly structures, how things with different shapes and charges can orientate and build into different structures. With that, I worked a lot on nanotech design. I did some device fabrication on the nanoscale using chemical vapor deposition, some wet etching, spin coating, played around a little bit with AFMs and STEMs. Being able to look at a lot of really small atoms and structures and move them around a little bit.

I then relocated to the U.S. from the U.K. I worked initially at the University of Kentucky in the Center for Applied Energy Research, doing, again, different self-assembly structures and modeling. And now I am very happy working at Kroger R&D as a subject matter expert and a senior R&D scientist. I do a lot of work on sensors and develop a lot of the applications that we are working on with the university outreach program.

High:

I was the Chief Scientist at Walmart. While I was there, I worked on more than 600 inventions that are going through the patent process right now. So far, 147 or so have been granted. I wrote Walmart's 130th invention, and then I built a team and took the team to push Walmart to over 4,000 patent filings. I worked on the Walmart Intelligent Store Ecosystem, which was the IoT connection of all the disparate systems. I then moved on to Ashley Furniture so they could do the same thing within their manufacturing process. I recently left them, and I am now working for Strategy Innovators, where we are working with companies to help them with their innovation.

Murphey:

I am a faculty member in mechanical engineering and I also have a secondary appointment in the medical school and physical therapy. My team does a pretty broad range of work in robotics, but the thing that ties it all together is that we are interested in how robots learn on the fly, so real-time learning when they can't learn

from prior data. There is a lot of talk right now in the world about big data and using existing data sets, but for an awful lot of what robots need to do there does not exist data that supports their needs. And, because we work with the medical school, we do a lot of work where robots interact with people. People are certainly a great example of the vast unknowns that cannot necessarily be determined by prior datasets.

Hough:

I am a senior expert at McKinsey in our retail operations practice. I lead all of our store technology and innovation efforts at the firm going on ten years now. I lead some of the internal innovation labs that we use for testing retail technologies and partnerships with clients. I also help our teams broadly structure a lot of their work, which is, of course, becoming more and more tech-enabled and robotics enabled; thinking through everything from what is the infrastructure needed to how to integrate external solutions and marring this with core operations.

I also help the firm structure a lot of our external partnerships and collaborations with leading solution providers and have lately been involved with our grocery focused COVID-19 response efforts. I have been deeply involved in trying to get ahead of the trends and understanding where the industry is heading.

Platt:

Did you do the Mall of America Project as well Gerry?

Hough:

Yes, I stood up that store. It is not operating during COVID-19, but it was an actual functioning store that we stood up in the Mall of America in partnership with them to provide a popup space and a test lab for retailers to test various solutions in a live customer setting and get real data and insights. We put a data science team over the top of it, built the infrastructure behind it, and it was a place where people could rotate through and get some real insights on what technology works, does it deliver an ROI, etc.

Rhodes:

I am the VP of R&D and Technology Transformation at Kroger. I have been with Kroger for a little over two years. I spent eighteen years with IBM before that. My background with IBM was in consulting and the R&D area of IBM, and also in the U.S. Federal and the NATO space. I worked in a variety of different areas, including AI space and drones, and other areas that required massive amounts of data to get actionable insights, as well as to inform devices that would act on their behalf. So how intelligent can we make those devices so they can work independently.

Whitacre:

I am the Senior Director of Technology Transformation and R&D at Kroger. I am charged with university labs, third-party partnerships, and extracting value from chaos.

Platt:

Thank you. I am the Research Director at the Retail Analytics Council, as well as an adjunct professor at Northwestern University. The RAC has two major activities. We have our AI Lab, where we run AI experiments with retailers. We also have our Retail Robotics Initiative, which is focused on research on moving computation off the robot payload, interfacing with IoT devices, and creating retail data schemas, among other things.

Now that we have all been introduced, let us get to some questions. Don, let me start with you. How are you seeing robots currently being deployed in retail?

High:

So, it all depends on how you define a robot. We have everything from cash recyclers to towers, to the robot that is scanning shelves, to robots that are washing the floors. So how would you, or how does this team, want to define what a robot is?

Platt:

I would generally define a robot, for our purposes, as an autonomous or semi-autonomous, physical embedded automated device. So generally, a robot that is capable of functioning in a store and performing functions such as shelf-audit, floor cleaning, spill detection, and the Walmart Fast Unloaders, although that one may be a bit of a stretch.

High:

Yes, and if I may, I would also like to add a bit of intelligence to that definition. I think that is part of the autonomy piece that you are mentioning. Steven, regarding the Fast Unloader you mentioned. I would pose the question: what is robotic about it? It is a machine in the back room that as boxes come off a truck, it sorts them and sends them to different departments for stocking on shelves. It is reading a label. You could say it is pretty much automation and not necessarily robotic, but if you want to have a loose definition of robotic devices, that would be one. Just like the cash recycler is another, where you give it a cash drawer, like a cartridge, and it goes through and looks at all the bills that are in there. It takes out all the $10 bills and puts them in a bag to be taken out. And the recycler is considered a bank. And so, if it finds money that is not good quality, that needs to be taken out of the system, it will separate those. It will separate the checks and the coupons and all those kinds of things, and then add up the drawer. And then there is some artificial intelligence that is applied to that data afterward that helps us determine which cashiers need to be audited more frequently or assisted and to help them do a better job.

Those are just some of the things that they do. Most of you already know about the robot that's going around called Auto-S, which is the one that is scanning the shelves and telling us what where there are stock-outs, where there are splits, where is our plugs, where there are price discrepancies, and things like that. Of course, the price discrepancy thing will probably go away as you move more and more towards electronic shelf labels.

So, when I was at Walmart, we incorporated a lot of robotics in that way. We also flew drones autonomously, and we worked with the FAA to do that. We were doing package delivery in a town called Port Mansfield, Texas. We would load up a drone at the airport and fly it autonomously to people's homes and deliver groceries. We set up a website where they could order products and select drone delivery for that. We did lots of fun things with robots if you want to call a drone a robot as well.

Platt:

What can you tell us about the Alphabot, Don?

High:

That is in the storage area of a store, and there are small autonomous vehicles that travel along on a track and grab boxes off the shelf and put them back. It is an ASRS system: automatic storage and retrieval system. It is different than the cranes because if one of those breaks down, it is easy to take it out of the way and put another one in. If a crane breaks down, on the other hand, then you have got a whole area that is shut down. So, having those things a little bit more where they can be free, seems to be a good system. Now there are even autonomous forklifts that can do that work, and we were working with several different companies when I was with both Walmart and Ashley Furniture.

Platt:

Great. Thank you. So, Gerry, what are you seeing in terms of retail robot applications?

Hough:

Recently there has been a lot of interest around cleaning robots and out of stock detection, whether it is autonomous robotics or drone-based detection, all of which are especially applicable during COVID-19.

And then there is a lot of excitement, of course, around upstream picking automation, as well as in the store itself. A lot of these types of tech player's phones are ringing off the hook with interest, which is making even more sense as ecommerce is on the rise and probably going to continue. It is starting to make sense to either set up a mini-fulfillment center or at least automate and set-up a much more efficient picking operation in the store. So, there is a lot more interest there.

Platt:

Thank you. So, we all have seen shelf-audit robots, autonomous floor scrubbers, spill detection, among other applications being deployed. We are also starting to see, as Gerry mentioned, automation in terms of online fulfillment, particularly in grocery. For example, in May Ahold Delhaize raised its U.S. online sales growth forecast from 30 percent to 50 percent in 2020. With that, Wes, where do you see robots being deployed in retail in the next 12 to 24 months?

Rhodes:

Well, I think because of COVID-19, we are seeing a major shift in consumer behavior. Certainly, because of it, there was a change, but we have been in this mode for so long, there is going to be a persistent behavioral shift. That is a drive to digital that is going to continue. Of course, when we do not have such physical distancing and related protocols, it is going to snap back for some of the behavior, but we are going to be having a greater digital intensity than we have had before. That will drive more pickups at the store and more delivery. The objective is going to be to get those groceries picked much more quickly and to have greater accuracy in the shelf labeling. We can always improve our speed issues and accuracy. We strive to get much more productivity out of the stores that we have, to create the volume that we need.

We do all kinds of experimentation. Anything that is going to help our customers out is something that we would be looking at. You can get them to consider delivery and so forth, but there's also faster ways, and that is why we are looking at more intelligent drones to do that. As we look at pick up, how do we take a store that does X and then make it do 4X, 5X, 6X in the same period within the same format? Well, procedures get you just so far. There has to be some level of automation that helps you get that additional productivity, that additional efficiency out of the queuing, and so forth.

So where do I see it heading? I see that digital is going to increase dramatically. Customers want the convenience of delivery. As well, they are going to want the convenience of driving up and within minutes, having their groceries put into their trunk. And they are going to be very impatient about waiting around. Additionally, regarding customer behavior within the stores, they are going to become more and more impatient standing in line, because they are going to be saying—wait a minute, I am bunching up at the front end of the store. And so, there is going to be some additional automation that is going to be necessary to reduce the wait time to check out.

Automation is going to be within the store to enable a person to be able to check out much more quickly. But that friction occurs all within the store. The technology has to be embedded throughout the store to get that capability. So not the big walking around robot, but small devices throughout the store to accelerate the customer through the store and out the door.

Blum:

If I may expand on that a little. One thing that Kroger has looked at a lot is robotics and the definition of that, and I think that is a pretty good definition. I am not going to necessarily debate that, but the idea is one robotic system. We have invested in sensing capability and the separation of the processing, the sensor, and the actuator, all of which are important parts of a robot, which is still a very useful form of automation and can behave in ways very similar to a robot without necessarily having that singular physical presence that is going to be more of a direct interaction with humans.

Platt:

Following up on Wes's point, grocery retailers are taking various approaches. You see Walmart adding 20,000 square feet to the back of their stores for their Alphabot fulfillment. You see other firms setting up areas of their stores just dedicated to automation applied to pick. You see people running around Walmart stores manually filling orders as well. And then you have Kroger and Ocado. If I am Kroger, with more than 2,700 stores, it is pretty hard to just overnight cancel some of those leases and say, you know what? We realize we do not need as many stores. We need more warehouses. So how do you figure out the balance, Adam, between the Ocado warehouse fulfillment system versus the in-store fulfillment system, bots in the store, people in the store? How do you get some logic out of that, Adam?

Rigby:

That is a good question. It is difficult because we want to build these systems to fit the demands, and the demands are going to change based on where certain events are happening. So, for example, in higher population areas we may want to look at a more robotic backroom system or a system that can get food out much, much faster for delivery. If we are out in the middle of nowhere, we might want to look more at stores that can stretch further and deliver at a much greater distance.

At the moment, I would not be able to give you a straightforward answer to that because it is as not so simple as it sounds. There is a lot that goes into understanding all the different variables. I do think that as we move forward, it is worth trying to look at all the different ways in which we can optimize the processes. And like Chris was saying, our focus now is on the robotic systems, in general, so things that we can adapt to all the different stores, no matter what the scenario is for them.

Platt:

Thank you. Todd, I know you are not necessarily a retail expert, but you are certainly a robotics expert. As you hear a little bit about the challenges and one of the things you mentioned about your area of study, to-wit: robots adapting to environments, how does your research potentially help deployments, in these kinds of environments with these kinds of challenges?

Murphey:

First, I would be hesitant to assert that my particular research is going to change how robots go into retail. And I think that this is where thinking about how we understand what constitutes a robot does help a little bit. If we think of hedging a bit and talking about the spectrum from automation to robotics, instead of talking about one versus the other, the things that we are most willing to adopt tend to be at the gray area between the two. And there is a good reason for that, because anything that you would think of as an advanced robot, it typically does not work very well. It is not reliable enough to say that you are going to be able to integrate it into a pipeline in manufacturing or a pipeline in healthcare. And that is because it does not have the characteristics of automation, which are roughly that it works well, it produces the same result whenever it is supposed to, and that we understand why it works. And so generally, the things that we're willing to incorporate into some sort of a pipeline will be things where we know that there's some machine learning, but we also know that really what that machine learning is doing is detecting vision features that we get to engineer to a large extent. And that's part of how we can ensure that it is reliable. Open-world problems, where you have a

robot out delivering in a completely untethered environment interacting with people, that is a much harder problem. And there are things like how is the robot going to know that it is delivering medicine to the right person if all the robot knows is which address to go to? Because there are privacy concerns surrounding medicine that do not necessarily show up when you are talking about groceries.

And so now suddenly the robot is in the business of not just showing up at the right place, it is in the business of confirming people's IDs. And that is suddenly the type of thing where we do not have a very good model of how people do that. We certainly do not have a very good model of how robots should do that unless we re-engineer the context in which they are operating. So if we decide that everyone who's going to accept their medicine by drone is also going to give the drone their credit card, something that we generally think is going to be specific to that person, that sort of re-engineering of the interaction is going to make it much easier for the drone or the robot to do its job.

And so this idea that the robots have to manage their information landscape, but we have to give them a manageable landscape so that the closed-loop system becomes something where there are solutions, that makes it sound a whole lot more like automation and a whole lot less like whatever our sort of movie picture of a robot might be. I am not sure if that quite answered the question that you wanted to ask, but I think that that is maybe closer to what I imagine being a realistic path forward.

High:

Todd, I appreciate what you are saying because this is the next level of intelligence that we have to accomplish. And that is the interaction between these different systems. How do we get them in a trustless environment to be able to work together and to enable them to be sure that they have the right person with the right medicine at the right place and especially when the drone or the UAV may be owned by a third party even. It may not even be owned by a store. It may not be owned by the person. These vehicles may have shared ownership. There may be multiple people who own it, and they all own a certain piece of it, almost like timesharing.

And then they have to be able to interact, and they have to know that they are going to the right drone mailbox, so to speak, that is up and away from the children and the dogs and such, and it could land in and deposit its order, and then the people can get it. There are all sorts of things that have to be worked out. Everybody is building their own systems right now. And no one is thinking of it more like the Internet, where it's everybody network together, working together to make these systems able to communicate, share, to be able to interact financially, to be able to share services, share information, share even recharging and all those types of things. And so how do you make it so that these things can do that? And that is the real challenge. And I think you are right. I think that is the next level of artificial intelligence that we have to get to.

Daniels:

To Don's point, I think that the data and the interactions of these different systems are going to be what is critical to move things forward. We have a huge focus on data at Kroger with our data science team. We use a lot of that information from various sensors and systems to help drive the best possible experience for our customers. So, I think that narrative is what is really going to push things forward for us and a lot of other retailers as well.

Whitacre:

It is a very interesting problem that robots will have to work with robots, where one robot might be delivering, and one robot might be receiving. And so, what is the communication protocol to do that?

High:

I am writing a white paper on it, and Steven and I have already talked about this a little bit and anybody that wants to join in, let me know, but kind of using tokens and smart contracts.

Hough:

I did not want to throw out the word blockchain, because I just hate doing that. But I am curious Don. Have you thought about where does that live? Who owns that? And is it a decentralized ledger?

High:

So, it would be decentralized, and multiple people would own it. Whoever is on the node would own their part of that, probably do it in Ethereum so that it can be a public and open type system. These are the kinds of things that I am working on right now. If you are interested in working on something like that, let me know. But that is the next level of intelligence that we have got to get to for the interaction of the vehicles. It can be even trustless autonomy, all those types of things.

Hough:

It is interesting because I have been involved with similar projects from a supply chain and RFID perspective and to see the application of hyper ledger - the supply chain aspect of validation and fraud. So, this is just kind of another extension of something similar to that.

High:

Exactly, and hyper ledger is perfect for that because it is more of a private closed type system. So, if you are doing a supply chain, there is only a select few that you are going to want to be involved in. You want to have anonymity between the robots, where they can interact, share services, share information, and even share recharging. One of the things I was working on just before I left Walmart was wireless recharging. Because we did not want to have separate docking stations for the floor scrubber, for the shelf scanner, etc. At that point we were predicting by 2025, we were going to have ten different types of robots within the store running around, all from different vendors, all that cannot interact with each other, they are all disparate systems. And how are we going to solve all that?

Platt:

If I may, at the RAC, we have been partnering with the Association for Advancing Automation to create industry-wide standards to address several of these issues. Don mentioned ten different recharging ports, for example, as one illustration of the problem. And then you start to look at the data integration component. We have challenges right now just disseminating and leveraging that data internally. In other words, the RFID data that produces inventory-accuracy information, how does that tie into the whole supply chain?

Murphey:

So as you start to connect these robots, and you start to connect them to the rest of the service systems that are available and connect them to people, how do you even specify what it is that you want from the sort of ensemble automation system? And part of the reason this matters is, and I don't know if you guys remember the Tay AI system that Microsoft had that was on Twitter and within 24 hours, it had become racist and misogynist and all sorts of unintended outcomes. Those unintended outcomes happened largely because there was an attack surface that Microsoft had not anticipated. And the reason Microsoft had not anticipated it is, at least partially, because they had not yet thought the dynamics of Twitter as an ensemble behavior that is going to affect their robot.

When we are talking about retail robots, retail robots are more constrained, in terms of what we are asking them to do. People have fewer chances to interact with them, but there are also way more interactions to scrutinize. And if someone wants to disrupt the system, they are going to succeed at least initially. Because people are going to discover vulnerabilities that are either there, that they specifically discover, or there are going to be vulnerabilities that sort of emerge as a consequence of how we fit together the puzzle pieces of our systems based on what we want, but not based on the entire universe of things that we do not want. I think about it from a systems engineering perspective. The more times we generate an interconnection be-

tween two robots or between a robot and a person, the more we should be expecting unintended, unanticipated outcomes that we are going to have to respond to quickly.

From my perspective, this is not really about designing a system and then deploying it. It is about designing a draft of a system and deploying it with an entire enterprise behind it that is ready to respond to unanticipated outcomes. Suddenly that means that your system is in the business of diagnostics. When something goes wrong, all of those robots should be immediately collecting data surrounding the incident, and you should not have to tell them to do that. It should be obvious to the entire system that this is a priority because of the failure. And that is now a system-wide sort of information-theoretic requirement because it is not just individual automation or individual autonomy. They are a part of this big overarching umbrella system that must function reliably.

High:

And once people start realizing these are IoT devices, they are connected to the internet, they are subject to cyber-attacks and holding companies' hostage. Because some of the things that we were concerned about when we were testing these vehicles were we wanted to make sure that their paint had some kind of fire retardant because we did not want a walking torch running around the building setting it on fire. There is also personal privacy because these robots have cameras on them. So, there are certain areas that we would not allow them to go into that we made logical blocks for, which would be like the restrooms and things like that. Todd, you are right. There is a whole bunch of problems that come about every time we put in a solution that people don't think about, even something as simple as an open port, where somebody can stick in some kind of virus.

We wanted to ensure that everything was covered so that people could not plug in a USB and hack into the thing. So, there was a whole series of tests that we had to go through. And then we had to think about the same thing when I was at Ashley Furniture. When I was at Ashley, we had machines that were running old operating systems, and they were doing just fine. But once they got connected up to the Internet people could hack into them and use them for mining Bitcoin. That is real. And you do not see it as a cyber-attack because they are not doing anything harmful other than just slowing down your system.

Murphey:

On the subject of cyber-attacks, I think these IoT systems will be subject to a broad spectrum of attacks. Some of those attacks might have to do with understanding the physical environment of your warehouses and understanding the physical environment that the robots are being deployed in. You could potentially have something like a cyber-attack that does not ever directly attack the computer itself. Where if you managed to, in a distributed way, have the entire country appear to be ordering carrots all at the same time, right, that synchronicity is something that most design and most simulators are going to assume does not happen. So that means that when you execute it, unanticipated outcomes could happen. People are going to do that just for fun. Like a smart 13-year-old kid will do that.

Blum:

The previous comments also bring up, for me, the thought of what is the most effective way to try do machine learning? The thought of what is the most effective way to try and do machine learning, or even earlier, you mentioned how we have to balance between being able to understand why our devices do what they do versus getting reliable results. Regarding the Microsoft example, it was able to do and was almost required to do, machine learning as it was working, which is what allowed that to happen at the same time. If you can allow real-world machine learning on real-world instances, rather than highly controlled data that you're feeding it, it allows us, it potentially allows it to be more flexible, but you also know even less about why it's doing what it does then if you were to give it only very specific inputs.

Hough:

I haven't seen retailers do this, and it's a more 'out there' idea, but you could take a page from what you see in the digital finance markets, where you have bug bounty programs. I don't know that I necessarily see retailers doing this, but the notion of offering a bounty for smart folks to find the faults in these new systems is interesting because there is only just so much you can anticipate that a random 13-year-old is going to do or find just for the fun of it, to your point. So you got to incentivize those 13-year-olds (or other smart people) to help you out.

Daniels:

As the system needs to evolve and we see more interactions between these different systems, we are going to continue to see a lot of more unexpected consequences. I think standardization can help a lot in that department. In our fifteen or so years with the ZigBee Alliance to align on one wireless protocols and how to make all of that happen, we are seeing a lot of acceleration and streamlining to help narrow down what those interactions look like, and what's possible coming out of that as well as multiple organizations working together to help nail down those security aspects, making sure that we lock down those processes to get more expected outcomes rather than unexpected.

Platt:

I would like to change direction here a little bit. We are all technology enthusiasts, which is fun stuff, but at some point, an ROI has to show itself. Adam, as you explore all these different technologies, how do you view ROI and economic justification, which must enter the equation.

Rigby:

That is a good question. And one of the biggest issues for a lot of the robotics stuff is replacement parts. If something breaks, as often it will. A lot of the work that I am looking at the moment is around modularization and "soft robotic." That to me seems to be the way forward, especially in retail, because if there is an interaction in any way between a human and a robot, the robot itself is more forgiving. After all, it is soft. Its very nature allows for a much more, let us call it, a pleasant interaction.

If you work, for example, in the automotive production industry and you get hit by one of those automated arms, you feel it. In retail, when we have interactions with people, we want to try and minimize any sort of damage that the person could experience, and obviously for legal reasons as well. I am also interested in the modular soft robotics because they are easier to replace parts for. We are looking as well at things like 3D printing components, having the actuators that are pneumatic and hydraulic allows us to quickly switch things over. As soon as one-part breaks, we do not have to hire somebody to come out and take everything apart. We can just swap one or two of the pieces.

I think that if we want to be looking further forward, it is plastics sort of materials that are the cheap, soft materials that do not interact too heavily, and that we can quickly replace. And then by making them modular, we can expand what they do to other things without actually having to redesign everything in a big way. We just add a few more hinges, a few more elbows to it. And instead of an arm that just goes up and down, we are getting some nice twists and grips.

Whitacre:

If there is somebody in your market now doing multifunction robots, that certainly would help your ROI. Everything seems to be a single purpose. Therefore, for ten functions, I need ten robots.

Platt:

Multimodality is important to the equation. Robots that do shelf-audit by day and disinfect with UV at night.

Whitacre:

I think more like the robot is a janitor part of the time and a security officer the other.

High:

I would highly recommend that you not look at robots for labor savings, but rather look at robots for customer experience, safety, security. Steven, as you were saying, all those aspects are far and away from where you are going to get the ROI. When I was working with Ashley Furniture, the robots that they were putting in, they originally started trying to look at it purely from an ROI perspective and it never would pay for itself. You know, you would have a $2 million line of robotic devices that would take ten years before they would pay for themselves if considering only the labor savings. I encouraged them to think about throughput analysis instead of labor savings. How much throughput are we getting? And the things that you mentioned, Steven, I think are spot on. That is what you have to do to look at for ROI. I do not like to see a robot replace one person. That is just so wrong.

Blum:

I would like to continue on that a little bit and then briefly expand on what Adam just said. Kroger looks at three things. Cost is one of those, whether that's labor, but it can also be reducing shrink, spoilage or theft, different things like that. But then safety and speed are two of the other major things we are looking at. You already talked safety, but the speed in the sense of what Wes mentioned in the context of COVID-19, the speed at the front end is very important for safety. In that sense, our two priorities are intermixing, but even outside of that safety aspect, we expect that our customers will see value if they can get through the checkout lane in sixty seconds versus having to wait eight, ten, fifteen minutes for this massive line to work its way through.

So definitely different aspects of that ROI more than just simple labor savings. But then going back to the modularity point that Adam raised and being able to replace components in the same way as multiple components are going to increase that modularity. If you need to upgrade a sensor, you are not replacing the entire system. If you need a little bit more processing, you throw in a new server. If you need to update the actuators, you can still rely on the rest of your system that already exists. And so that allows for innovation and improvement without scrapping the entire investment that would potentially ruin your ROI.

High:

We were discussing multiple functions instead of single-function vehicles. Many of these vehicles have mapping techniques. Many of them have the computer vision, they have the LIDAR, they have all these capabilities. In addition to having multiple purposes, there are also multiple uses. So, if you can bring that map, that point cloud, along with the camera pictures and all that, and you bring that in, and you can ingest that. You can serve that up to your customers, where they can find things faster within the store, be able to lay it down with augmented reality, with the blue dot, showing them exactly where to go and those types of things.

The device can look at human behavior and see if someone's shoplifting within the area. The other thing, back to Todd's point, about the whole system of systems. Another thing that you have got is you have got cameras within your building that can also be part of your eyes for your vehicles. You have got other things, other sensors within the building that can be part of what helps these things interact. So once again, we go back to the sharing of information and different systems being able to use it and process it.

Murphey:

When we talk about the systems, one of the things that helps a lot, and it's sort of to this ROI point, is when you develop a robot, I think often times a robot that's developed to be at scale, it's going to be developed for a specific purpose. And you have a choice. You can either make a robot that is built for a specific purpose where you have made that robot as cheap as possible for that one purpose. And that probably means that

when it interacts with a person, that person is never going to be able to exploit its broader capabilities to do something beyond its original intended use. But if you develop a robot for one purpose that generally uses off the shelf capabilities, like point clouds for instance, then people will be able to use the robot in a more flexible way that might lead to unintended ROI.

So, for example, the autonomous floor-cleaning robots that interact with the staff whenever they get stuck. Over time staff gets a text message from the robot whenever it gets into a situation that it cannot get itself out of. But then, as a result, the staff starts relying more and more on what the robot can do. And then they start allocating their effort more and more towards things the robot cannot do. And so, the initial ROI was very different than the eventual ROI. And that is because it was a capable system. If all the robot was able to do was sort of zigzag across nice open areas, and it never even tried to get into corners, then its actual long-term use is going to be severely limited. And instead, the well thought out engineering of how the robot and the person worked together allowed the system to evolve into something better than what it started as.

So, I guess I am hesitant to think that the introduction of robotics and AI type technologies is going to be a factor of two types of effect. The reason I'm pushing back is that if you cut the robot capability, if you cut the cost of the robot in half, I'm not sure that that changes the long time horizon impact on whether a company should invest in it or not.

I think it is the combinatoric effect. Like it's when you have these systems that can interact with each other, and that you're either going to realize the good that comes out of that, or you're going to realize the risk that comes out of that. And so, managing those systems of systems issue, I think is a much more fundamental problem than figuring out how to cut the cost of an individual robot in half. Now that's easy for me to say; that's just my instinct that both the potential benefits and the potential risks grow combinatorically as they start to interact with each other, and cutting individual assets by a factor of two seems like a much smaller long-term issue.

And it will happen as soon as you start connecting them together. You are going to start building things more at scale as we have already seen that with things like LIDAR. Not that long ago, LIDAR was insanely expensive as a sensor, and now it is a commodity sensor. And so, to me, market effects do not do everything, but certainly in this space market effects do a lot.

Hough:

That's interesting because when you think about some of the autonomous stock detection robots, you start with essentially a base layer of the out-of-stock impact, but even more power starts to come out once you start adding on top. For example, pricing and promo impact in a world where you're not using ESL, better perpetual inventory, and then eventually you can start harnessing that data and giving it back to your vendors and suppliers or start using it for customer experience and wayfinding. It starts to become more of the network effect versus can I cut this robot cost in half and hope that just the out of stock value in and of itself is going to foot.

High:

Steven mentioned earlier his research using 5G to move the compute off the payload to lower the cost. You are correct about that because that is where the majority of the cost set was in the computing. The more and more that you can offload the intelligence and use these things where, like you were saying Steven, where it's a robot, its purpose is to move around and it can take on different attachments. Those kinds of things can help. We were talking about making things more modular. And you know, that was one of the other efforts that we were working on at one time was how can we say this is a service, and think of this from a modular perspective and then being able to attach it with whatever it needs to have attached to it, to accomplish some kind of thing. And I think that helps bring the ROI rather than building this single disparate system that can do everything rather than one single purpose.

Platt:

Wes, any thoughts on how one might think about ROI on these technologies?

Rhodes:

Well, for a retailer cost is everything. You cannot have single-use expensive things. So for us, we think of multi-use on everything. An approach that we would use, for example, would be using a camera as a multi-use sensor, and then ask ourselves the question, what can I do to have less camera density? They are more expensive. Can I get more certainty using other sensors? That way I can use data and a few choice observations to then get a high degree of certainty on a prediction that we are going to make or understanding that a real-world action, we would use digital twins to understand prediction. Well, the same goes for robots. The system of systems conversation Todd raised is right on the money. It is the effect that all these systems come together to fill in the mosaic that you are trying to understand.

The more they fill in, the more of a contextual picture you get, and the better you understand. What I am a proponent of is having the robots not have a lot of computation sitting on them. I want them to be able to be extensions of eyes and ears and smells and so forth so that they can gather the information. And then I can make a high-quality decision on smaller actions. A cooling unit's getting too high, maintenance is needed here. I am actuating a door. So, I need to shut it. There are tons of actions that we can take that are small and they save a lot of money. I can observe that food is in a zone that it is not meant to be, and for how long it is there. And then for reducing spoilage, I can count how long it has been out of the zone. Then, monitor how long it has been put back in that zone to recharge, its original coolness that it needs to have, and then reset. And it can be out of that zone again, if for a certain length of time, versus having to assume the worst-case and throw it away. For us, the amount of shrink that we can reduce is critical. So the same sensors that are used for increasing the customer experience we use for cost reduction and optimization and labor prediction and looking at the customer to understand if they're confused and need help on a predictive basis so that we can then send a message over to a customer.

With a contextual view, we can direct labor as needed. We can intervene with the customer. We can better determine assortment for endless isles and to know what assortment to put into the stores by looking at what has been done before. It is that fusion of data, the right pieces of data and sensors, the right observations in the store, and actions from robots or the right intervention that we have humans make. So I look at the human and the robots and the sensors and drones and all those things from picking to free the humans to deal with customers, freeing us up from manual or menial activities that can be done so much cheaper and faster with purpose-built robots and devices as part of that system of systems. It is a classification of tasks and engineering of all sensors to do much more than the one thing that they were designed for.

Platt:

As we are approaching the end of our session, I have two additional questions I would like to ask. One is COVID-19-related. In China they are introducing bots that can take customers' temperature in mass, I believe 200 or so per minute. They can detect if people are wearing face masks. It can call out people that have a temperature or are not wearing face masks. It can track how many people are in the environment for safe distancing. I have been approached by a few firms in China to take a look at their introduction into the States, and my biggest hesitancy is privacy. Dan, would Kroger ever put a robot in the front of its stores and scan everybody walking in?

Whitacre:

I do not think so.

Hough:

That has been the answer from every retailer I have talked to - be it apparel, grocery, etc. The response from every retailer I have talked to is "no."

Whitacre:

There are too many problems associated with that.

Platt:

Is it a privacy issue, Gerry?

Hough:

Privacy, operationalizing it with the volume that you have got, and then a whole different animal of clients. The issue is the operational lens first and foremost. Forgot about the reliability of some of these infrareds, temperature checkers, and I think there are some questions there, but then there's just the question of, "Okay, well, what do I do with that?" Especially in a high-volume environment.

Whitacre:

Do you stop them? What do you do? We must consider the actions that could be taken and the impact of those actions.

High:

Well, there also is a HIPAA question?

Rhodes:

I just think of it as a brand issue. And I think like Gerry said, "What do I do with it?" Do you deny them entry? Do you take some kind of action like that? Is that what your brand is willing to do? What about false negatives? What if you are screening, thinking for X and they do have a temperature, but they have Y? How do you make sure that you have not differentiated in a bad way? There is much to consider.

Blum:

There is also the problem that may be fifty percent of people that have it are either asymptomatic or pre-symptomatic. So, if I am only going to catch half the people coming in the store anyway, I have got possible false positives, is the system worth implementing at all? And then, especially with IR cameras, that is something that has been brought up. Well, if everyone wanted to get IR cameras, who expects they would be able to get enough?

Rhodes:

You must also consider the message you are sending. Am I, by doing that, giving a false sense of security? And I say, "Oh, I'm catching everybody." No, I am not. So, do I put a sign up? I may be flipping a coin - fifty percent may be caught, fifty percent maybe not. What message are you sending?

High:

And Wes because you have the information, do you take on the liability?

Wesley Rhodes:

I am concerned about liability. I am also concerned about what I just told the customer. I just do not see how to win there.

Murphey:

I think that the only way that I can see retailers wanting to participate in this is if it becomes part of the tracing technology. So that all they are doing is providing a different, physical layer of insight beyond what Apple and Google are doing for keeping track of where the hotspots may or may not be. That could be positive PR. It is adding to the national response, but it is not saying that the individual retailers are going to use that data as

part of their daily operation, which I think sounds like nothing but a risk to me. But I do think that this idea of sensitizing the public environment to try to better understand the pandemic does not seem crazy to me. And the idea that retailers might be one of the most natural places to do that. But the idea that retailers would then integrate it into their daily operation, that seems just unworkable in multiple ways.

Platt:

The RAC just published a Research Article titled "Emerging Trends in Retail Robotics." In it, we discuss the recent shift to online grocery purchasing, which as we all know has been significant. Recent estimates of online grocery purchases are around 6.3 percent versus 11.4 percent for retail generally. If grocery were to reach that 11.4 percent threshold, you are talking about a $45 billion shift to online. That is a big opportunity, going from approximately $50 billion currently to something approaching $100 billion. Wes, is this going to be a trend that you think will stick with consumers post-pandemic?

Rhodes:

Yes, and let us think about it in these terms. What prevents someone from using online grocery? It is typically the fear and the experience of trying it once. Now you have this COVID-19 experience that required you or highly incentivized you, to learn it, to get over that fear, to try it, to get comfortable with it. So, the question is once you get comfortable with it, it is incumbent upon us, as a provider, to fine-tune the service to enable a good experience for you. Will you keep that behavior now that you have found that you like it? And most of the people that have tried it, really liked it because it is faster. It is quicker. It is easy and less hassle.

Will you keep doing it? I think that a good portion of customers have now tried it. So, the fear, the barrier to entry has been greatly lowered because now they are comfortable with the technology. They have used it. They have enjoyed it. So yes, I think that a lot of this behavior is going to stick. Some will go back to their old way of shopping. But then again, it may be another kind of incident to make them want to go right back to online. Or they may just get really busy and want to use it again as a time-saving mechanism.

Hough:

Our research supports that as well. Obviously, not at the height of COVID-19 levels, but for sure much higher than before. Ecommerce activity and every sentiment survey that we have undertaken has shown that. If you look over in Asia, the trends continue there in terms of continued use of online channels. I think it's creating interesting shifts in terms of customer behaviors of which stores they are going to, banners they're choosing--not across the board, but there is a good chunk of customers that are switching because of the quality and the service level of the retailer's ecommerce offering. It is creating a shift in behavior. Who knows if that will stick and whether customers will revert to their previous patterns or banners they shopped with, but what an opportunity for grocery stores to capture that customer in an ecosystem and provide a service and a value that creates stickiness.

Rigby:

The only thing that may inhibit this is the ability to add innovations and optimizations quickly enough for the consumers to stay happy. Because of COVID-19, we are doing a lot better, and, as Wes said, we have had a lot more people experience our online ordering services and they enjoy it. So, it is sort of more on us now to optimize the processes. It might even be a case that we want to start looking towards stores that do not have people in them. We just entirely try to operate on delivering the products outside of the store. So immediately when they come and pick them up, which again would be an excellent purpose for robotics.

Platt:

Don, what do you think? Is this online shift to grocery going to continue to stick following all this?

High:

I think Wes is correct. I think now that people have been forced to try it, they are going to see that it is con-

venient. Some of the issues that people have with it are around produce and fresh meat selection. I think there are a couple of things that people like to pick and some of the other issues that I have seen is with substitutions. So, if you order something online thinking that it is at the store and the store thinks it is at the store, but it is not at the store. And so, they have to substitute it.

And using robots to carry the groceries out to the car is a good use case because there's a lot of pickup occurring and people don't necessarily have to feel uncomfortable about somebody sneezing or coughing in their face. Now you have got a robot that is bringing their things out while before COVID-19 happened, people would not have wanted that maybe, but now they may prefer it. So now you are seeing that robots in retail are going to probably have a better chance of taking off and doing great things than they did before COVID-19.

Blum:

So as far as dedicated pickup centers, I am not sure how many of those are going to stick around in the future, but as far as pickup at normal stores, that is going to increase. Just think about it as habit-forming behavior. As long as we ensure that there is a positive experience, that they do not have to wait that long. If someone shows up to the store and they must wait thirty minutes to get their groceries, they might not continue doing so after the COVID-19 precautions are no longer being followed. But if you have that positive experience and it takes me less time to get my groceries by ordering online, and that becomes the defacto easy thing to do, then the people who built that habit are going to continue that regardless of what else happens.

High:

And Chris, I have been to some stores recently and seeing the pickers there and there is a major fight between the customers and the pickers because the pickers are trying to get that job done. The other thing that I have seen besides that is I cannot get a window on some of these service websites for me to get something. It is like full up every day.

Blum:

That is a really big challenge. I mean, we are working on that and we are in our stores trying to expand that capability. To pick faster, pick more, be able to offer more windows. And the one big advantages of the pickup center is you do not have customers and associates utilizing the store simultaneously. I should be able to track all my incoming orders. I know ahead of time what is going out. So, it should be less likely that we need to substitute, but this becomes a question of scaling up existing capacities, which is not necessarily linear. What works for a small number, does not work for a large number. And there is a lot of work going into making it work.

Whitacre:

We are going to have to train our associates differently, so they can pick the product well and find the products. A picker may not know what yeast is or where to find it in the store. Customers may not get products on a list that we know are in the store. To be successful it requires training.

High:

And you are losing impulse buying. It used to be you went to the store to pick up five items and came home with fifty. You may have missed some of the five items that you were supposed to pick up and so you have to go back.

Whitacre:

Where is the end cap now? What is on the end cap. What does it matter?

High:

Exactly, the end cap features all those types of things. The other thing that you will miss out on is the thing that happens to me all the time. I go to the store to buy something and I let my wife know, "Hey, I'm in the store," and then I'm on my way home and she says, "Hey, can you also get this?" And so, I have to go back to the store. So, customer satisfaction is highest with impulse items because they did not stop to think about it. They just went to get it. So, if you are missing those types of things, if you're online and looking stuff up, you're going to be comparing prices, comparing services, comparing things while if you're at the store, it's a little different.

Blum:

That brings up a really good point of trying to make the digital experience closer to the physical experience. VR is something that is becoming more prevalent. I would not exactly say it is widespread in your typical household, but VR experiences at a store could reproduce the possibility of impulse purchases or potentially make the shopping experience like a video game. You open it on your browser, and I am not saying that either of those is going to necessarily bear fruit, but it is something that the industry is going to need to think about.

Platt:

Todd, thank you for joining us today. Any parting thoughts?

Murphey:

First, it was great to meet everyone, and I hope we get to talk again. I think that when we discuss training staff, particularly when we are talking about groceries, the staff that you have to train to do something new when people order a set of things that are not always going to be available. There may or may not be impulse buying associated with it, but you have staff members who have a really good model of human behavior. One thing that we are going to do well is modeling data. And suddenly, you might be in the business of asking people, "Oh, it looks like you are ordering chicken, avocado, tomato, and tortillas. Are you making fajitas?" Because that knowledge about what they are trying to do is going to mean something to the person that is picking. And it is going to mean something to the entire fulfillment pipeline that I do not think we can expect the machines to make those inferences for us.

Of all of the things that we have been talking about, I guess my parting point would be figuring out how to use your employees so that you are doing something better than you were doing it before, rather than trying to replace prior capabilities that the employees were creating. As far as I can tell in the robotics industry, that is the thing that has led to payoff. It has led to a better product. It has led to better capability and a more robust system.

Platt:

Thank you all for your participation today. Great session. Note that the RAC continues to address standards and we are the right institution to do that. We welcome your involvement as we continue our journey toward more automation in our stores.