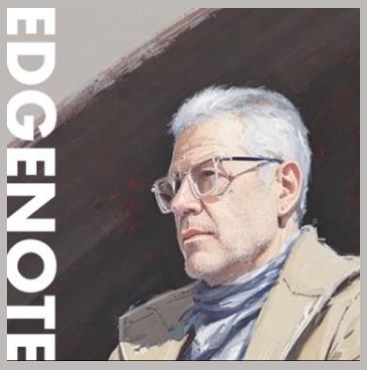


The Robots Are Coming

Pete Bernard – EDGECELSIOR

KEY THEME – ROBOTICS IS BECOMING THE PHYSICAL INSTANTIATION OF AI AND A SOPHISTICATED EDGE COMPUTING PLATFORM THAT WILL TRANSFORM SOCIETY

We have imagined "robots" for thousands of years, dating back to 3000 B.C. when Egyptian water clocks used human figurines to strike hour bells. They have infused our cultural future with movies like Metropolis in 1927 through C3PO and R2D2 in Star Wars and more. They intrigue us perhaps more than any other technology since they're often anthropomorphized to be so much like our imagined selves.

Practically speaking, today's deployed robots are much less glamorous. They have been developed over the past decades to handle dangerous and repetitive tasks and resemble nothing like humans. They roll through warehouses, mines, and deposit fertilizer on our farms. They also extend our perceptual reach through aerial and ground-based inspection systems, using visual and other sensor input.

"The robots are coming right out of the lake, their slipping and stumbling, they're barely awake. They just need some coffee poured into intake - perkity, clankity, glurp."[1]

[1] © 2000, Andy Rash

But things are changing and this EDGENOTE will not focus on a broad definition of robotics[2] – of which there are many great resources on the web – but on ***what is changing with robotics, and why now?***

Robotics is where AI meets physics. They require sophisticated physical capabilities to move grasp, extend sense and perform a wide range of tasks, but they are also software platforms that require training and decision making, making them prime candidates for more sophisticated AI capabilities as semiconductors get more powerful, networks get faster and software development and orchestration becomes more capable.

Let's level set with a taxonomy of robots and a definition of terms. There are many ways to describe the taxonomy of robots - they can be sliced by environment (warehouse) or by function (payload) or even by mobility (un-manned aerial vehicles). Here is a sample of some types of robots in deployment today:

- **Pre-programmed robots**
  - These can be Heavy Industrial robots, used in very controlled environments for repetitive and precise manufacturing tasks. These robots are typically fixed behind protective barriers, costs hundreds of thousands of dollars.

- **Tele-operated robots**
  - These are used as "range extenders" for humans to perform inspections, observations, or repairs in challenging human environments – including drones or underwater robots for welding and repair. Perhaps the best-known tele-operated robots were the robots sent to Mars by NASA in the last few decades. There has also been a fish robot named SoFi designed to mimic propulsion via its tail and twin fins, swimming in the Pacific Ocean at depths of up to 18 meters. [3]

- **Autonomous robots**
  - You probably have one of these in your house in the form a vacuum cleaner robot navigating without supervision and relying on its sensors for navigation. Recently we have seen a number of "lawnmower" robots introduced to take on this laborious task. In Agriculture, robots are already inspecting and even harvesting

[2] Robotics is the practice of studying and developing robots
[3] https://www.csail.mit.edu/research/sofi-soft-robotic-fish

crops in an industry with chronic labor shortages[4]. There is also a thriving industry for autonomous warehouse robots - including in Amazon warehouses. [5]

- **Augmenting robots**
  - These are designed to aid or enhance human capabilities such as prosthetic limbs or exoskeletons. You probably first were exposed to this category of robots when you watched The Six Million Dollar Man" on TV –but on a more serious note, they are providing incredible capabilities for amputees and enabling safer work environments for physical labor.[6]

- **Humanoid robots**
  - Here's where it gets interesting. We have developed a bi-pedal world – why not develop robots that work in that world as it's been designed? Humanoid robots represent humans – as bi-pedal (or quad pedal in the case of Boston Dynamics), can communicate in natural language and facial expressions and perform a broad range of tasks using their limbs, hands and human-like appendages. The number of quad-pedal robot have only been deployed in the low thousands worldwide and we are still in the very early stages of development, deployment, and reasonable cost. Companies like Enchanted Tools[7] are demonstrating humanoid robots that can move amongst humans for carry lighter loads, deliver items, and communicate in natural language. Although humanoid robots will catch the bulk of the attention of the media in coming years, and face the most "cultural impact," the other robot categories will also benefit greatly from generative AI and drive significantly greater efficiencies across industries.

Enchanted Tools Robot, operating at NVIDIA GTC Conference - March 2024

[4] https://builtin.com/robotics/farming-agricultural-robots
[5] https://www.aboutamazon.com/news/operations/amazon-introduces-new-robotics-solutions
[6] https://www.automate.org/robotics/service-robots/service-robots-exoskeleton
[7] https://enchanted.tools/

"The Robots like coffee with sugar and cream. They make their milk frothy with nozzles marked "steam." They bake some biscotti with microwave beams. Beepity dunkity slurp."

Impact of Generative AI

It's hard to overstate the impact that Generative AI will have on the field of robotics. Beyond the ability for much more natural communication and understanding, Generative AI model architectures like Transformers will be combined with other model architectures like CNNs, Isolated Forests and others to being image recognition, anomaly detection and observational learning to these platforms.

Let's take a look at the differences between traditional AI used in robotics and what Generative AI can bring:

Traditional AI	Generative AI
Rule-Based Approach: Traditional AI relies on strict rules set by programmers – like an actor following a precise script. These rules dictate how the AI system behaves, processes data, and makes decisions.	**Learning from Data Examples:** Generative AI learns from data examples – essentially "tokenized movement." It adapts and evolves based on the patterns it recognizes in the training data – like a drummer that watches their teacher and keeps improving. This can be done in the physical world or in a simulated world for safer and more extensive "observational training."
Limited Adaptability: Traditional AI is weak in adaptability. It operates based on predefined instructions. However, it can run on very resource constrained environments at very low power and cost.	**Creating New Data:** Unlike traditional AI, generative AI can create new data based on experience and can adapt to new surroundings or conditions. However, this requires significant more TOPS/W and RAM, which can drive cost and battery powered applicability.
Data Analysis and Prediction: Traditional AI excels at data analysis, pattern recognition, and making predictions. However, there is no creation new data; it merely processes existing information.	**Applications in Robotics:** Generative AI can drive new designs and implementations in robotics that leverages their ability to generate new data, whether it's new communication/conversational techniques (in multiple languages), new movement scenarios or other creative problem solving.

In summary, while traditional AI is excellent for analyzing existing data and making predictions, generative AI has the ability to create new data and adapt dynamically based on experience. ***The application of Generative AI to robotics will unlock observational learning, rich communication, and a much broader application of robots across our industries and our lives.***

"The robots are perking more mugs than required. We'll have to start jerking their heads off with pliers. The caffeine is working they're totally wired. Jittery zappity burp."

Safe and Ethical Robotics

Whenever robots are mentioned, the comparison to "evil robots' from our culture are not far behind. The Terminator, Ultron or Gunslinger from Westworld. And at the same time, we have enjoyed anthropomorphized robots like C3PO and R2D2, or Wall-E. And then there are ones in -between, like from the movie The Creator.

As attention has been paid to the scope Generative AI moving to AGI, what guardrails, best practices and outright legislation exists to keep robotic efforts – pared with Generative AI – in the category of good or neutral?

Isaac Asimov famously penned his three laws of robotics back as part of his short story "Runaround" in 1942:[8]

- A robot shall not harm a human, or by inaction allow a human to come to harm
- A robot shall obey any instruction given to it by a human
- A robot shall avoid actions or situations that could cause it to come to harm itself

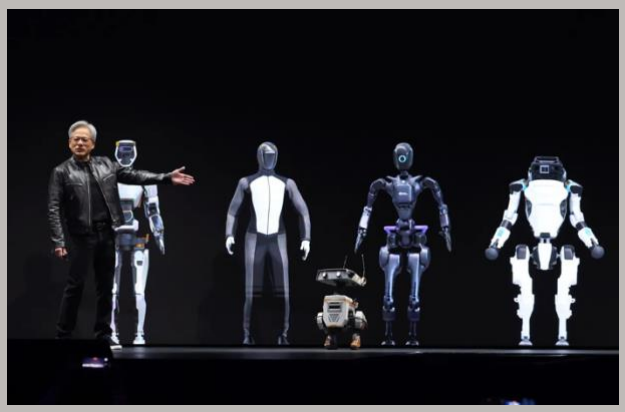
In 2021, Dr. Kate Darling - a research specialist in human-robot interaction, robot ethics and intellectual property theory and policy at the Massachusetts Institute of Technology (MIT) Media Lab – wrote an article in The Guardian proposing that we think about robots more like animals than a rival to humans. Once we make that shift, we can better discuss who are responsible for robot actions and who is responsible for the societal impacts that robots bring, such as transformations in the labor market.[9]

The European Union published "Civil law rules on robotics" back in 2017 that addressed the definition of a robot, where liability lies, the role of insurance and other key items. In 2023 a law

[8] https://www.goodreads.com/en/book/show/48928553
[9] https://tdwi.org/articles/2021/06/16/adv-all-building-ethical-guardrails-into-ai-driven-robotic-assistants.aspx

was introduced in Massachusetts in the US that would 1) ban the sale and use of weapons-mounted robotic devices, 2) ban the use of robotic devices to threaten or harass, and 3) bann the usage of robotic devices to physically restrain an individual. It's unclear how or when similar legislation will make it to the federal level.

Observational Learning Is a Game Changer



Observational learning (sometimes referred to as behavior cloning) in AI allows robots to learn new skills simply by watching humans – in reality or in a simulated physical environment. Instead of being programmed step-by-step, robots can make connections in their neural networks based on observing human behavior and actions. This kind of unstructured training will enable robots to better understand the nuances of a given task and make their interaction with humans much more natural.

There have been a number of key advanced in AI models for observational learning, starting with CNN model types and recently leveraging diffusion model types such as the one presented in the Microsoft Research paper in 2023 - *Imitating Human Behaviour with Diffusion Models*.[10]

In March of 2024, NVIDIA introduced Gr00t[11], their own foundational model designed for observational learning of their ISAAC/JETSON robotics platforms. It was demonstrated at the NVIDIA GTC keynote by Jensen Huang and also leverages their Omniverse "digital twin" environment to develop virtualized physical environments that can train robots via observational learning in a safe and flexible virtualized environment.

Deepu Talla, who runs NVIDIA Robotics and Edge Group, described robotics as a "three computer problem" – there is a AI model training in the cloud using generative AI and LLMs, there is model execution and ROS running on a robotics platform itself, and a simulation/digital twin environment to safely and efficiently develop and train.

"Everything That Moves Will Be Robotic" – Jensen Huang

The confluence of Generative AI and Robotics is swinging the robotic pendulum back into the spotlight. Although Boston Dynamics has only deployed over 1500 Spot robots worldwide so far, expect many more, and in many more configurations, throughout our warehouses, our farms, or

[10] https://www.microsoft.com/en-us/research/publication/imitating-human-behaviour-with-diffusion-models/
[11] https://nvidianews.nvidia.com/news/foundation-model-isaac-robotics-platform

manufacturing floor, as well as our yards and houses. Expect many more humanoid experiments and expect a hype wave washing over us with plenty of media coverage of every failure.

Running Generative AI on these platforms will require significant TOPS horsepower as well as RAM. Currently, NVIDIA Jetson Orin, or the top end of the Qualcomm Snapdragon one, or the new Intel Core Ultra, are candidates. Interestingly, the AI PC should actually advance the availability of SoCs that can combine optimized LLMs with "lower power" silicon to support these battery powered robotics platforms. The scale of the AI PC business should help rationalize making parts available as reasonable costs and deployment designs.

However, in addition to requiring top end semiconductors and plenty of RAM, robotic platforms – especially humanoid ones – will require very sophisticated sensors, actuators, and electro-mechanical equipment – costing tens of thousands of dollars for the foreseeable future.

To keep things in perspective, Goldman Sachs[12] forecasted a 2035 Humanoid Robot TAM of US$38bn with shipments reaching 1.4mn units. That's not a tremendous unit volume for humanoid robots (Pcs ship around 250m units per year, smartphones north of a billion) – we can expect orders of magnitude more "functional form factor robots" in warehouse, vacuuming homes and doing other focused tasks.

We cannot underestimate the impact that new humanoid robotics platforms will have on our culture, our labor force, and our existential mindset. We're at a turning point as generative AI is combining with edge platforms like robotics and developers, designers and scientists are pushing the envelope and closing the gap between our imaginations and reality. Like with cloud-based AI, there are important guardrails, best practices and legislation that need to be considered to keep us not only safe but make this newfound expansion of robotics capabilities accretive to our society.

When humanoid robots become commonplace in 10 years – what will the world look like and what will be our role in it?

[12] https://www.goldmansachs.com/intelligence/pages/gs-research/global-automation-humanoid-robot-the-ai-accelerant/report.pdf