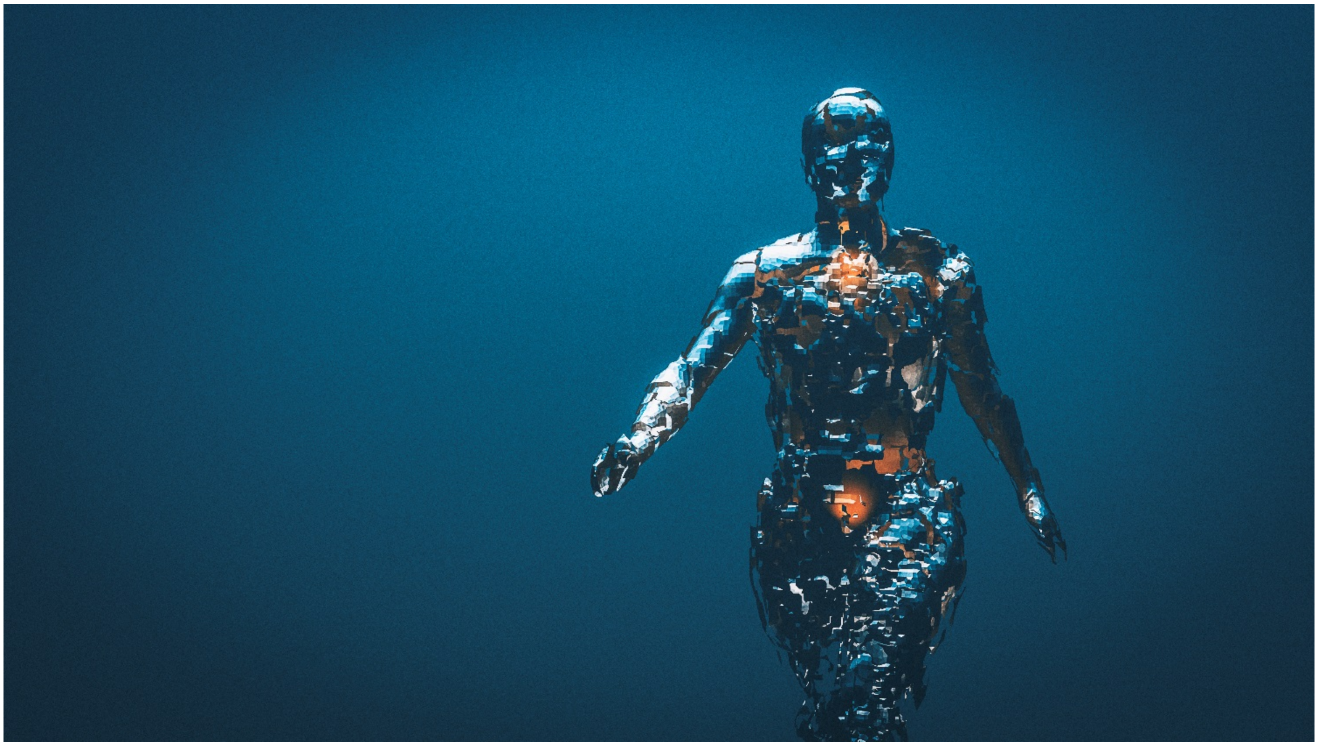
Robotics and Automation: A Retrospective and the Reality of Bot Nation



Implications for IT Programs in Washington State Community and Technical Colleges

Center of Excellence for Information & Computing Technology
Hosted at Bellevue College, Washington State

Authors:
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Introduction:

Robotics: "The Fourth Industrial Revolution"

Initially it appears there was never going to be a connection between artificial intelligence (AI), machine learning, nanotechnology, 3D printing, biotechnology and deep machine learning. Looking ahead these fields and technological advances will experience rapid evolutions paving the way for interconnectedness and close relationships to each other. "Concurrent to this technological revolution are a set of broader socio-economic, geopolitical and demographic developments, each interacting in multiple directions and intensifying each another."

It is projected between 2018 and 2020 the following will happen:

- Robots will be able to see, smell, feel, move like enhanced humans, and be able to pass a Turing test.
- It will make more sense from the perspectives of industry, government, consumers to have robots execute tasks and jobs that humans have historically performed.
- Robotics and automation will impact jobs across all industries, but most critically in the manufacturing and service industries.
- Cars, trucks, trains, planes, and automobiles will become partially or fully autonomous by 2020.
- Because of robotic advances, a majority of our global workforce in administrative and professional services will find themselves replaced.
- STEM jobs will continue to grow.

Manufacturing and production jobs will continue to experience loss. These type of industry job losses may stabilize by 2020. The people who will lose their jobs due to automation or robotic replacements will still have a relatively good potential for learning new technical knowledge and skills to use as work productivity will be swifter and nimbler due to technology advancements.

Source: The Future of Jobs, Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution

This report has been researched and defined to enable IT program faculty across the state to consider the changes robotics and automation will bring to the workforce, as well as consider what kinds of program or curricular changes they might make to their current IT programs.

Maureen A. Majury, M.Ed.
Director for the Center of Excellence for Information and Computing Technology
Hosted at Bellevue College, Washington State

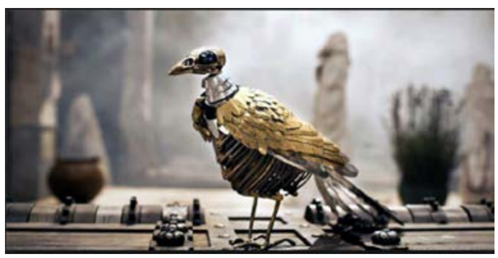
Source: All definitions and graphics are taken directly from Wikipedia.org, unless noted otherwise.

Section 1:

Robotics and Automation: Historical Highlights

The history of robotics and automation is fascinating from the perspective of creativity, perseverance, and risk. Imagination and dreams fuel innovation. Consider how historically it began with wanting to create artificial animals, in that instance a bird, over 2,300 years ago, to today as we witness comfort robot pets. Below are the highlights of the beginning and continuing effort to design, program, and build functional robots.

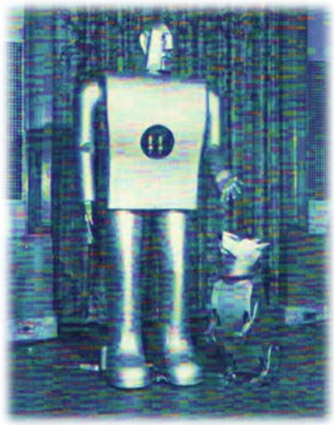
- Automation [automaton] has a long history dating back to the Greeks and possibly earlier. Archytas of Tarentum may be the grandfather of robotics. Sometime around 350 B.C., Archytas is said to have designed and built an air or steam-powered wooden dove that was capable of flapping its wings and flying through the air —such a device would represent one of history's earliest automatons.



Leonardo da Vinci's Columbina from "Da Vinci's Demons"
(Image: Da Vinci's Demons)

- 1495: Leonardo da Vinci sketches plans for a humaniod robot. Leonardo Da Vinci wrote extensively about automatons, and his personal notebooks are littered with ideas for mechanical creations ranging from a hydraulic water clock to a robotic lion.
    - Perhaps most extraordinary of all is his plan for an artificial man in the form of an armored Germanic knight. According to Da Vinci's sketches of the key components, the knight was to be powered by an external mechanical crank and use cables and pulleys to sit, stand, turn its head, cross its arms and even lift up its metal visor.
    - In 2002, NASA roboticist Mark Rosheim used Da Vinci's scattered notes and sketches to see if he could create his own version of the 15th century automaton. The Rosheim knight proved fully functional, suggesting that Da Vinci may very well have been a robotics pioneer.

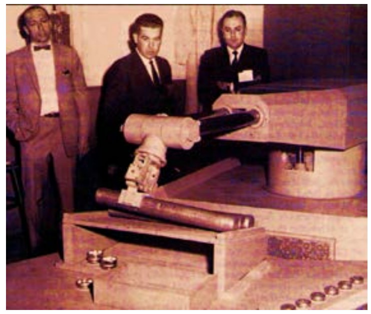
- 1921: The term 'robot' was first used to denote fictional automata in a science fiction play *R.U.R.* by the Czech writer, Karel Čapek [from Czech robotnik "slave," from robota" forced labor, compulsory service, drudgery"]
- 1930's / 40's: Japan produces "Lilliput" the first robot toy. The square, yellow robot was always thought to date from the 1930's, but experts now believe he was actually first made in post-War occupied Japan around the mid-1940's.



Elektro, the humanoid robot, presented at the 1939 New York World's Fair

- 1939: The humanoid robot known as Elektro was debuted at the New York World's Fair. Seven feet tall and weighing 265 pounds, it could walk by voice command, speak about 700 words, smoke cigarettes, blow up balloons, and move its head and arms.

- 1942: Isaac Asimov formulates the Three Laws of Robotics: A robot may not injure a human being or, through inaction, allow a human being to come to harm; A robot must obey the orders given it by human beings except where such orders would conflict with the First Law; A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.
- 1948: The first electronic autonomous robots with complex behavior were created by William Grey Walter of the Burden Neurological Institute at Bristol, England. The three-wheeled tortoise-shaped robots could find their way to a recharging station when they ran low on battery power.



George Devol [Spectrum.IEEE.Org]

- 1954: The first digitally operated and programmable robot was invented by George Devol which became the first industrial robot installed in a General Motors plant in 1961. Devol's patent for the first digitally operated programmable robotic arm represents the foundation of the modern robotics industry.

Sources:

History of Robotics: Timeline (RobotShop Inc.)

A Brief History of Robots (Industry Tap into News)

7 Early Robots and Automatons (History Lists TM)

Section 2: Recent Evolution of Robotics

Over the past seven decades, the advancement of robotics has developed dramatically. Initially used for repetitive applications on the factory floor, increasingly flexible and capable robots have found their place in military, nautical, aerial, medical, and even consumer applications.

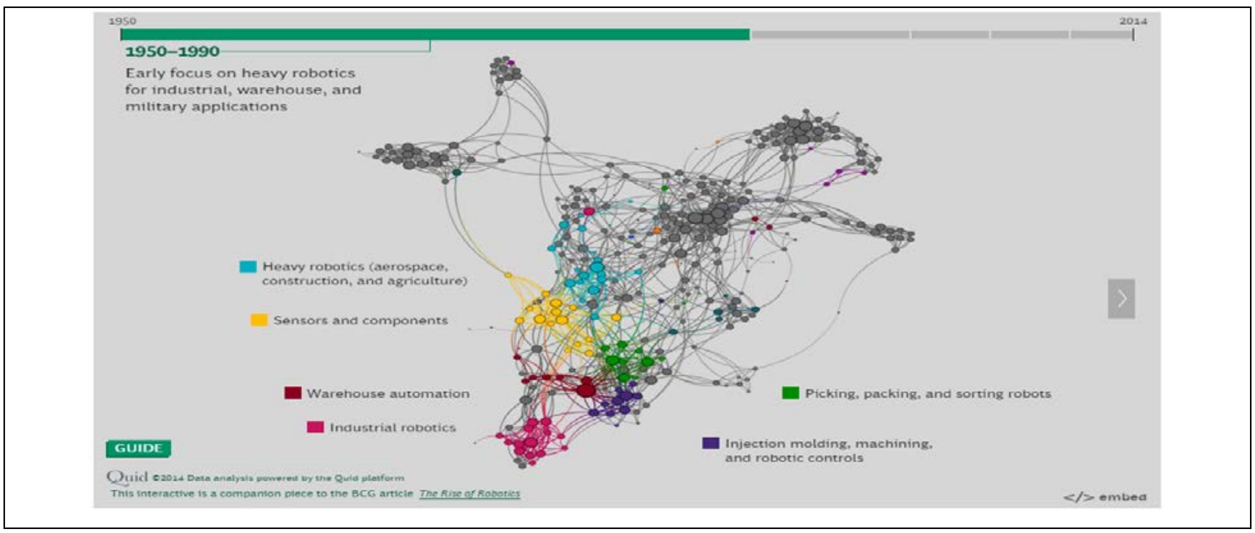
1950-1990 -- Early focus on heavy robotics for industrial, warehouse, and military applications

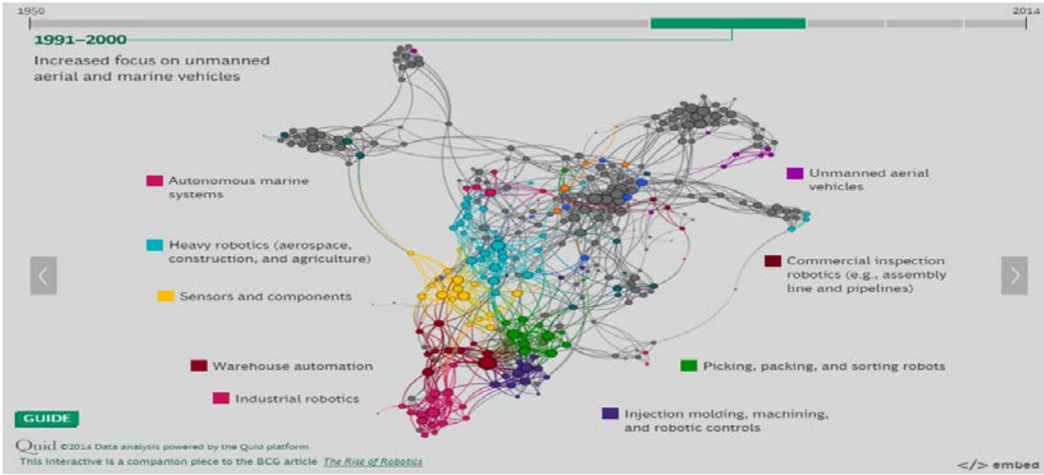
1991-2000 -- Increased focus on unmanned aerial and marine vehicles

2001-2005 -- Growth in medical and anthropomorphic applications

2006-2010 -- Rapid growth in anthropomorphic robots and toys, robotic surgery and lab automation, and unmanned ground vehicles

2011-2014 -- Growth in unmanned aerial vehicles for agriculture, therapeutic bionics, and consumer applications




1950
2014
1991–2000
Increased focus on unmanned aerial and marine vehicles
Autonomous marine systems
Heavy robotics (aerospace, construction, and agriculture)
Sensors and components
Warehouse automation
Industrial robotics
Unmanned aerial vehicles
Commercial inspection robotics (e.g., assembly line and pipelines)
Picking, packing, and sorting robots
Injection molding, machining, and robotic controls
GUIDE
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This interactive is a companion piece to the BCG article The Rise of Robotics
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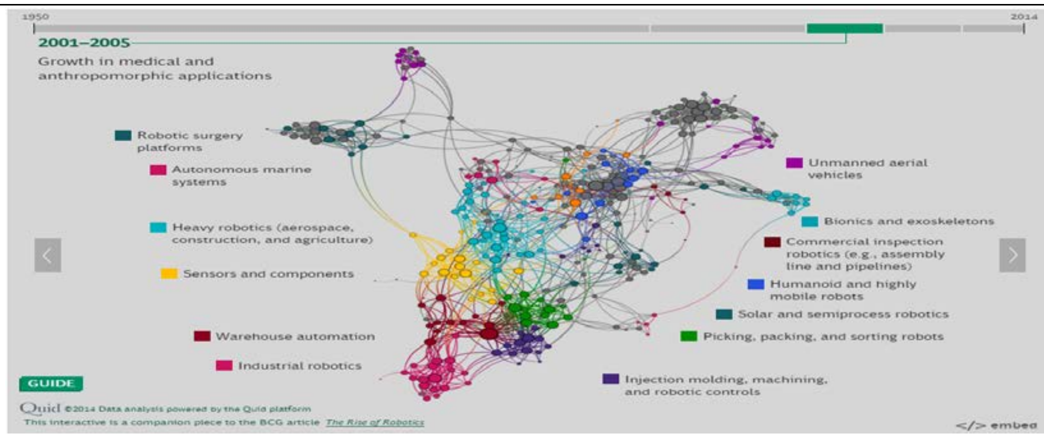
1950
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Growth in medical and anthropomorphic applications
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Warehouse automation
Industrial robotics
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Commercial inspection robotics (e.g., assembly line and pipelines)
Humanoid and highly mobile robots
Solar and semiprocess robotics
Picking, packing, and sorting robots
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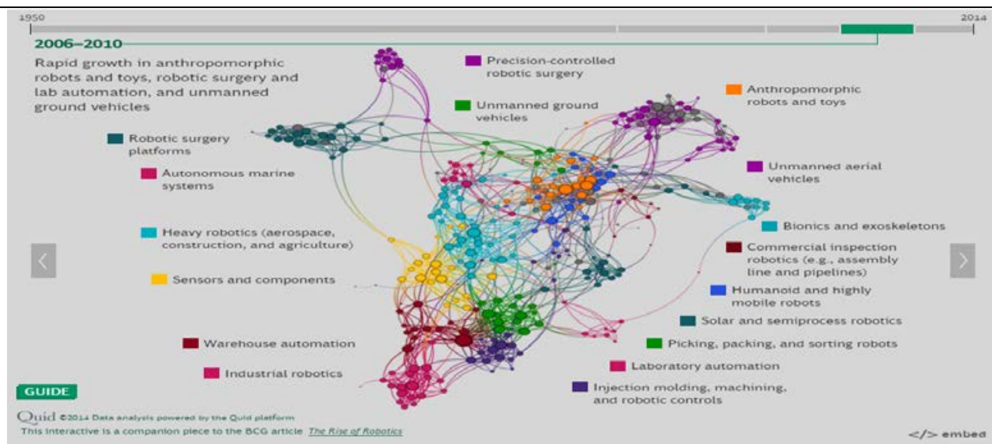
1950
2014
2006–2010
Rapid growth in anthropomorphic robots and toys, robotic surgery and lab automation, and unmanned ground vehicles
Precision-controlled robotic surgery
Unmanned ground vehicles
Anthropomorphic robots and toys
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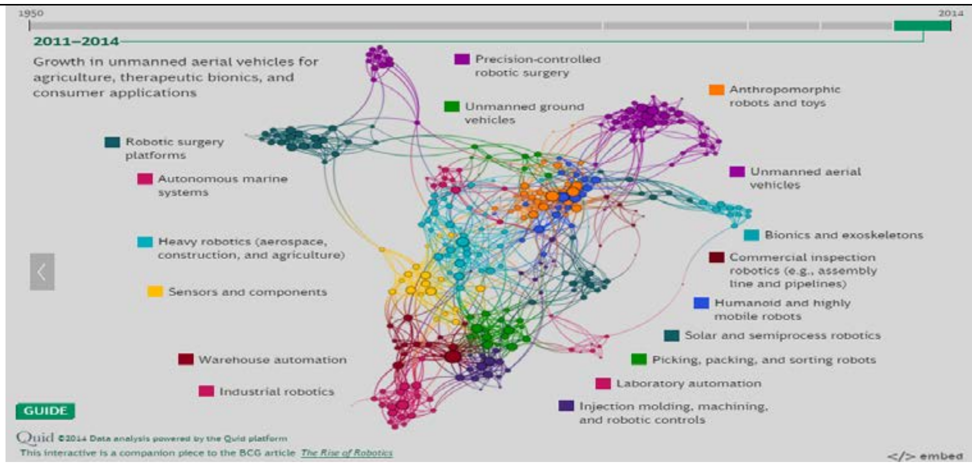

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Growth in unmanned aerial vehicles for agriculture, therapeutic bionics, and consumer applications
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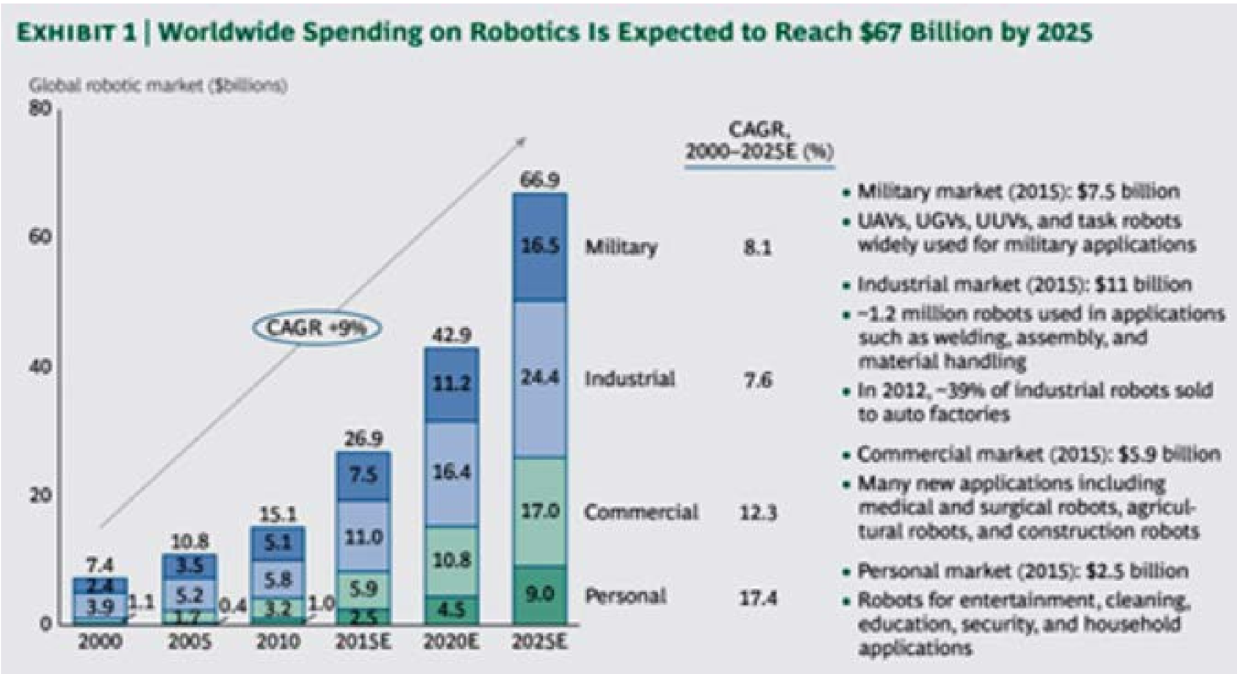
The scope of financial investment to develop and produce robots is staggering: spending on robots worldwide is expected to jump from just over $15 billion in 2010 to about $67 billion by 2025. Driving this growth is a convergence of falling prices and performance improvements. The cost of high-quality robots and components is dropping rapidly, with central processing units (CPUs) becoming faster and application programming increasingly stronger, quicker, and smaller. As robots become cheaper, and in some cases tinier and more energy efficient, they gain flexibility and finesse, increasing the reach of potential applications.



Sources:

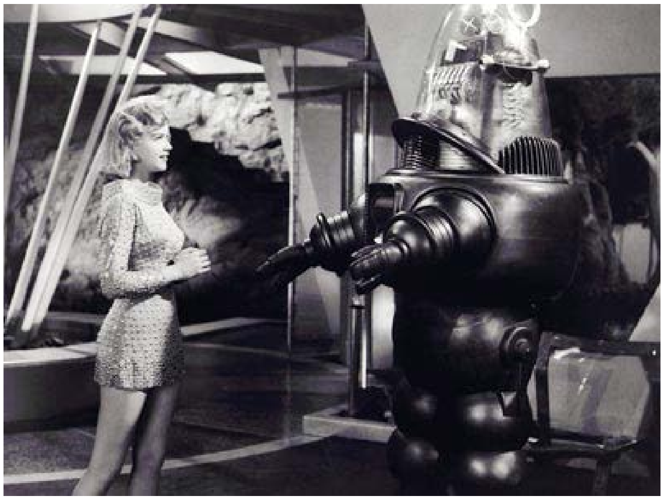
[The Evolution of Robotics (bcg.perspectives)]

[The Rise of Robotics (bcg.perspectives)]

Section 3: Famous Robots, Artificial Intelligence, and Automatons (Automated Thinking Machines) in Movies

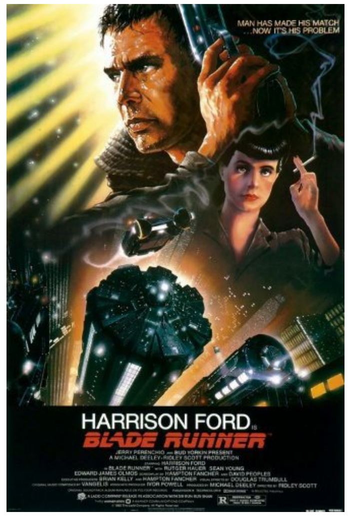
Films often create a world that doesn't exist or mirrors what is presently occurring or will eventually happen. Thinking about films and how they envisioned robotics, artificial intelligence (AI), and automation is important as a source of what might be possible. Or, is already in process.

- 1908: An animated doll is stolen by a young boy, Pickles, and given to his sister in the silent film, *An Animated Doll*
- 1927: Maria/Futura in the silent science fiction film, *Metropolis*
- 1951: Gort, the robot in the film, *The Day the Earth Stood Still*



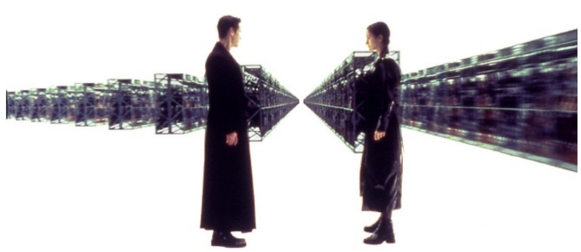
***Forbidden Planet*, MGM, 1956**

- 1956: Robby (Robby the Robot) in *Forbidden Planet*
- 1971: The all-robot police force in *THX 1138*
- 1975: *The Stepford Wives*
- 1977: C-3PO, R2-D2 IG-88, 4LOM and others in the Star Wars films
- 1979-92: Ash and Bishop in the *Alien* films



***Blade Runner*, Warner Brothers, 1982**

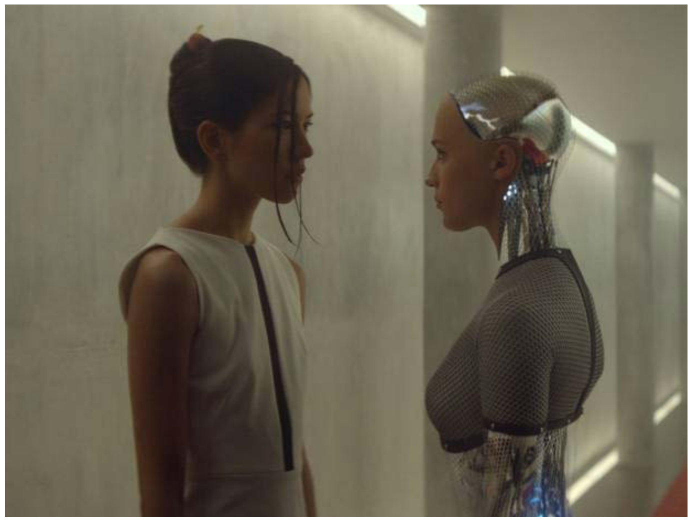
- 1982: The replicants in *Blade Runner*
- 1984-2015: The *Terminator f*ilms
- 1985: *D.A.R.Y.L.* (Data Analyzing Robot Youth Lifeform)
- 1986: H.A.L. in *2001: A Space Odyssey*
- 1986-88: Johnny 5 and the other S-A-I-N-T (Strategic-Artificially-Intelligent-Nuclear-Transport) military robots in *Short Circuit* (1 & 2)
- 1986+: Optimus Prime and many others in *The Transformers* movies
- 1987: ED-209 in *RoboCop*



***The Matrix*, Warner Brothers, 1999**

- 1999: The Sentinels from *The Matrix*
- 2002: Spyder robots in *Minority Report*
- 2004: Sonny (Type NS-5) and many others in *I, Robot*

- 2005: Marvin, the Paranoid Android, in *The Hitchhiker's Guide to the Galaxy*
- 2008: *WALL-E*
- 2014: Baymax in *Big Hero 6* (2014)
- 2014: TARS and CASE, adaptable rectangle robots in *Interstellar*



***Ex Machina*, Universal Pictures International, 2015**

- 2015: Ava, the android in *Ex Machina*

Section 4: Modern Robots

Within the last three decades the advancements within the robotics industry have been tremendous. The rapidity of what today's robots are being tasked with performing in place of humans is astounding. Highlights and a timeline demonstrate that the evolution of robots is quickening and creating increasingly complex and high functioning robots.

- 1979: Carnegie Mellon establishes the Robotics Institute.
- 1981: Shigeo Hirose developed Titan II. It is a quadruped which could climb stairs.
- 1985: Created by the General Robotics Corporation, the RB5X was a programmable robot equipped with infrared sensors, remote audio/video transmission, bump sensors, and a voice synthesizer. It had software that could enable it to learn about its environment.

Hitachi Robots in the past and present

- 1985: Waseda Hitachi Leg-11 (WHL-11) was a biped robot developed by Hitachi Ltd. It was capable of static walking on a flat surface. It was able to turn and could take a step every 13 seconds.
- 1988: The first HelpMate service robot went to work at Danbury Hospital in Connecticut.
- 1989: Aquarobot, a walking robot for undersea use, was created at the Robotics Laboratory at the Ministry of Transport in Japan.
- 1989: Developed by Kato Corporation, the WL12RIII was the first biped walking robot which was able to walk on a terrain stabilized by trunk motion. It could walk up and down stairs and could take a single step every 0.64 seconds.
- 1990: iRobot Corporation was founded by Rodney Brooks, Colin Angle and Helen Greiner and produced domestic and military robots.

- 1992: The Inaugural FIRST Robotics Competition is held in a high school gymnasium in New Hampshire.
- 1996: Honda created the P2, which was the first major step in creating their ASIMO. The P2 was the first self-regulating, bipedal humanoid robot.
- 1997: Honda created the P3, the second major step in creating their ASIMO. The P3 was Honda's first completely autonomous humanoid robot.

[Kasparov vs Deep Blue - Real time Commentary by GM Yasser Seirawan (1997)]

- 1997: IBM's Deep Blue supercomputer beat the champion Gary Kasparov at a chess match. This represented the first time a machine beat a grand champion chess player.
- 1997: NASA's PathFinder landed on Mars. The wheeled robotic rover sent images and data about Mars back to Earth.
- 1998: Campbell Aird was fitted with the first bionic arm called the Edinburg Modular Arm System (EMAS).
- 1998: Dr. Cynthia created Kismet, a robotic creature that interacted emotionally with people.
- 1999: Personal Robots released the Cye robot. It performed a variety of household chores, such as delivering mail, carrying dishes, and vacuuming. It was created by Probotics Inc.
- 1999: Sony released the first Aibo robotic dog.
- 2000: Honda debuts ASIMO, a groundbreaking humanoid robot.

The 20-inch-tall, 10 pound SDR-3X, or Sony *dream robot*

- 2000: Sony unveiled the Sony Dream Robots (SDR) at Robodex. SDR was able to recognize 10 different faces, expresses emotion through speech and body language, and can walk on flat as well as irregular surfaces.
- 2000: The FDA grants approval to Intuitive Surgical's da Vinci Surgical System
- 2001: iRobot Packbots searched through the rubble of the world Trade Center. Subsequent versions of the Packbot robots are used in Afghanistan and Iraq.
- 2001: MD Robotics of Canada built the Space Station Remote Manipulator System (SSRMS). It was successfully launched and worked to assemble the International Space Station.
- 2002: Honda created the Advanced Step in Innovative Mobility (ASIMO). It is intended to be a personal assistant. It recognizes its owner's face, voice, and name. It also can read email and is capable of streaming video from its camera to a PC.
- 2002: iRobot released the first generation of Roomba robotic vacuum cleaners.
- 2003: As part of their mission to explore Mars, NASA launched twin robotic rovers on June 10 and July 7, 2003 called Spirit and Sojourner.
- 2003: Kiva's Mobile-Robot Fulfillment Robot System automates the warehouse environment.
- 2003: RobotShop Distribution Inc. was founded to provide today's society with domestic and professional robot technology that can help increase the pleasure, knowledge, liberty, and security of individuals.
- 2005 Cornell University created self-replicating robots.
- 2005: Self-balancing MURATA BOY goes for a bike ride.
- 2005: The Korean Institute of Science and Technology (KIST), created HUBO, and claims it is the smartest mobile robot in the world. This robot is linked to a computer via a high-speed wireless connection; the computer does all of the thinking for the robot.
- 2007: iRobot Packbots begin disarming bombs for the US Army

- 2012: Nevada becomes the first state to issue a driver's license to an autonomous car
- 2013: Four Giant Industrial Robots are used to film the blockbuster "Gravity"
- 2013: Google buys eight promising robot startups while SCHAFT wins DARPA Robotics Challenge.

Lee Se-dol, a professional Go player from South Korea, was smiling amid other players despite losing four of five games against a Google computer program called AlphaGo. Lee Jin-Man/Associated Press

- 2016: Google's Deep Mind's artificial intelligence program, AlphaGo, beats Lee Sedol, a Go World Champion, four games to one.

Source:

History of Robotics: Timeline, RobotShop, INC.

Section 5: Examples of Robot Applications in Various Industries

There is a wide and increasing variety of robots. Depending on the type of applications, they can be completely or semi-autonomous, and humanoid or not.

An area of robotics that is seeing a lot of attention is in the applications of human augmentation. Exosuits are designed to augment human power, senses, and stamina to accomplish new tasks or decrease fatigue of repetitive and challenging activities. Early on, robotic-assistance was used primarily for military applications. Increasingly it is used in the medical field helping physically challenged patients to recover their independence. This same technology is starting to appear in construction and industrial applications.

"Technology market tracker ABI Research estimates that by 2020, the annual US revenue of exoskeleton technology will reach about$292 million. In Japan, where the technology is already developed, the prospective figures are much higher: the Ministry of Economy, Trade, and Industry projects a tenfold market growth, to nearly $1 billion per year."

Source: **How exoskeletons are shaping the future of health care** (Forum for the Future, August 24, 2015)

Examples of robotic applications

Prospero. A small, six-legged bot that works in pair with its "brothers." Together, these bots make "swarms of farming robots" that can plant vast portions of land with perfect precision. The Prospero robot type is quite simple. It does not require GPS or computer vision software. Prospero sees what is beneath.

Agriculture

- Animal husbandry
- Cultivating, planting and harvesting crops

Industrial

- Manufacturing
- Assembly

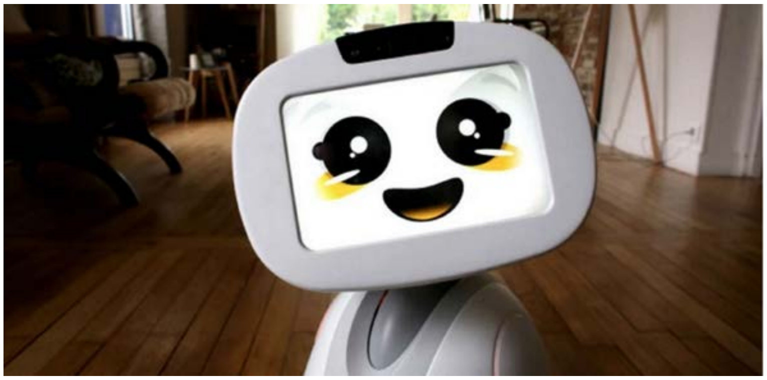
- Packaging
- Inspection
- Co-robots designed to team up with human operators/ decision makers
- Warehousing, material movement

Construction

- Welding, building and assembly
- Finishing and painting
- Inspection
- Power-enhancing exosuits

Service and Hospitality

- Support to aging and handicapped population; providing assistance in physical tasks, these types of robots are increasingly designed to monitor feeling and mood to form a personal relationship with human users.
- House cleaning



Meet Buddy, the companion robot.

- Companions
- Home monitoring
- Assisted and autonomous vehicles
- Room service

Entertainment and education

- Toys
- Children learning

- Companions

Military/ Law Enforcement

- Surveillance
- Patrol
- Demining
- Assault
- Power-enhancing exosuits

Hazardous Environment

- Excavation
- Exploration – space, undersea, hazardous environments
- Hazardous material handling

Healthcare

- Medical surgery/procedure robots
- Patient care
- Exosuits

Section 6: State of the Robotics Industry

How the robotics industry will transform other industries is a dawning awareness not just for industry watchers and forecasters, but for everyone. Even a cursory search for robotics, or a scanning of a news article or update, demonstrates the age of robots is transforming our lives in ways we either have imagined or never believed would happen. The moment is finally upon us.

Looking at this list of highlights should signal to everyone, specifically workforce experts and college IT program developers, that preparing students and graduates for pathways into the robotics industry (from AI to mechatronics to networking to the processing of big data) is something that is action-worthy right now.

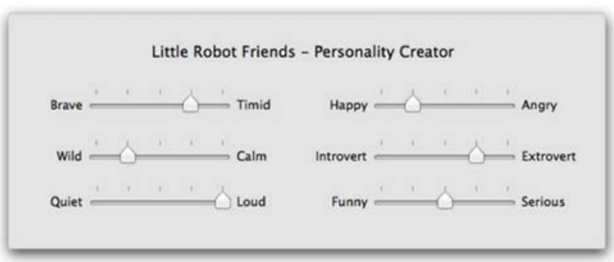
- Boston Consulting Group predicts that the robotics industry will balloon from $15 billion in 2010 to $67 billion by 2025.
- Most of the robots will be in the military and industrial markets, but personal robots that help out with cleaning, security, and entertainment will still make up a sizable portion of the industry. *[Boston Consulting Group , Aug 2014]*
- The personal segment—robots used for entertainment, cleaning, education, security, and household applications—is projected to grow the fastest at 15.8%/yr. to $9.0 billion.
- The commercial segment—robots used for medical and surgical purposes, agriculture, and construction, among other applications—is expected to grow at 11.8%/yr. to $17.0 billion.
- The industrial segment—robots used in applications such as welding, assembly, painting, and material handling—will continue to be the largest, growing at 10.1%/yr. to $24.4 billion.
- The military segment—for unmanned aerial, ground, and underwater vehicles, among other applications—is projected to grow at 8.1%/yr. and will be second largest at $16.5 billion.
- By 2020 many farming tasks will be performed with autonomous robotic devices. [EE Times, Jan 2015]

Some notable investments by industry leaders

Follow the money, always. If venture capitalists are financing robotic, AI, and automation start-ups in Washington State, they will be looking for employees. If Google, Apple, Amazon, Microsoft are investing, then it's happening right now. And, they will be looking for employees.

And, when you see McDonalds replacing 90% plus of its workforce at your local fast food restaurant, consider all those laid-off employees will be looking for work. The state's community and technical (CTC) colleges need to start thinking about how they will retrain these workers and why IT will always be a good academic and career pathway for them.

- In 2013, Google bought Boston Dynamics that developed the Cheetah (military robot) and has been acquiring other companies that produce similar products. They later up this acquisition up for sale in March 2016. The tech industry is wondering why.
- [Google] is teaming up with Johnson & Johnson's Ethicon subsidiary to build the "ultimate" platform for robotic surgery. Google says its goal is to use algorithms to analyze 3-D endoscope images and display critical information. [Wired, March 2015]



[Little Robot Friends](#) from Toronto-based [Aesthetec Studio](#) are a series of tiny robots that can listen, sense light, detect touch, and communicate using infrared light. Each robot is mounted on a CNC milled wood base and is embedded with a "brain" consisting of an 8-bit 32K microcontroller that provides space for coding behaviours or storing memories.

- Google secures patent for robots with customizable personalities [rt.com, Apr 2015]
- Google received US patent for technology that would enable it to use the cloud to control an army of robots [ComputerWorld, April 2015]
- Boeing's future is in robots, and Kuka Aerospace, the automation company Boeing has been working with, is opening a state-of-the-art facility in Everett, WA. The robots will be part of an automated system that will drill and install 50,000 fasteners on the fuselage of each new Boeing 777 — and even more on the upcoming 777-9X. Today those fasteners are installed by hand.
- Ford's Research and Innovation Center in Palo Alto, is accelerating the company's innovation in connectivity, mobility, autonomous vehicles, customer experience and big

data. For autonomous vehicles, Ford is providing Stanford with vehicles equipped with aDRIVE (Autonomous Driving Refined in Virtual Environments) to test algorithms such as traffic sign recognition in dynamic driving situations and preparation for on-road testing.

- Amazon bought Kiva Systems, an automated material handling order Fulfillment Company, to help move packages in their warehouses through robotic technology. The company has 10 of these tech'ed-up fulfillment centers across the U.S., housing more than 15,000 Kiva bots. [techcrunch.com, Dec 2014] The company is already working on its ninth generation facilities — one is being built in Kent right now. The next generation will be even more automated. [Puget Sound Business Journal, Feb 2015]
- Hospitals in the San Francisco Bay Area are using robots to take over many of the everyday tasks involved in tending to patients – deliver food and drugs, pick up waste and laundry. [CNBC, Feb 2015]

IBM Watson-powered Pepper

Click to watch 58 second video

IBM Watson and Pepper announced a partnership at CES 2016. Watson's cognitive computing technology will allow Pepper to continuously gain knowledge and "understand the world the way humans do - through senses, learning and experience."

The Watson-powered Pepper robot will also be equipped with Watson software development kit (SDK) that allows developers and clients to tailor the interaction experience.

A SoftBank spokesman says the company hasn't set a date when the Watson-powered Pepper will go on sale, however, IBM says the first Watson-powered Peppers will be tested in hospitality and consumer retail stores. IBM says these Peppers will replace some of the mundane kiosks and not sales assistants.

From the Best Robots of CES 2016

Section 7: Exploration into the Future of Robotics

As demonstrated by the highlights below everyone has a different approach on how to define the robotic industry's future direction. What the robot looks like, what they actually do, how they function, and how they'll be integrated into existing with humans are all areas being researched, defined, and created.

- **Soft robotics or bio-inspired robots** "Taking ideas from biological systems, soft robots are made of deformable structures that can deal with uncertain and dynamic tasks, offering benefits over the rigid, linear and constraining motions and abilities of traditional robots. They are brought to life thanks to recent developments in materials science, sensor technology and biologically-inspired actuators. Controlling them are innovative systems and algorithms that make these soft robots aware of and responsive to their environment." **Soft Robots: Merging Nature and Future**

Darwin's Robots

- **Swarm robots** – collectively programmed multi-robot system. Swarm robotics is a new approach to the coordination of multirobot systems which consist of large numbers of mostly simple physical robots. It is supposed that a desired collective behavior emerges from the interactions between the robots and interactions of robots with the environment. **Swarm Robots**
- **Nano robots** (nanobots or nanoids) are typically devices ranging in size from 0.1-10 micrometres and constructed of nanoscale or molecular components. Robots which

allow precision interactions with nanoscale objects, or can manipulate with nanoscale resolution. **Nano Robots**

Trends in Robotics Sources:

Robotic Trends

A Brief History of Robotics (Industry Tap into news)

AI & Robotics (FutureTimeline.Net)

Section 8: Job Demand, Trends, and Technical Knowledge and Skills Needed

Job Demand

In searching O*Net Online (from the U.S. Bureau of Labor Statistics (BLS)), the outlook for Robotic Technicians is bright.

This occupation is defined as follows:

- Troubleshoot robotic systems, using knowledge of microprocessors, programmable controllers, electronics, circuit analysis, mechanics, sensor or feedback systems, hydraulics, or pneumatics. See more occupations related to this task.
- Disassemble and reassemble robots or peripheral equipment to make repairs such as replacement of defective circuit boards, sensors, controllers, encoders, and servomotors. See more occupations related to this task.
- Perform preventive or corrective maintenance on robotic systems or components. See more occupations related to this task.
- Maintain service records of robotic equipment or automated production systems. See more occupations related to this task.
- Install, program, or repair programmable controllers, robot controllers, end-of-arm tools, or conveyors.

Tools used in this occupation:

- Flowmeters — Flow meters
- Microcontrollers — Programmable automation controllers PAC; Programmable logic controllers PLC See more occupations related to this tool.
- Scanners — Laser scanners
- Signal generators — Function generators

Technology used in this occupation:

- Analytical or scientific software — Analytical software; Logic Design RoboLogix; Simulation software See more occupations related to this technology.
- Computer aided design CAD software Hot technology — Autodesk AutoCAD software; Dassault Systemes SolidWorks software

- Development environment software — ABB RobotStudio; Ada; C (Hot technology)
- Industrial control software — FANUC Robotics ArcTool; FANUC Robotics iRVision; FANUC Robotics Through Arc Seam Tracking TAST; FANUC Robotics Torchmate 3
- Operating system software — Linux (Hot technology) ; Microsoft Windows

(Hot Technology)=a technology requirement frequently included in employer job postings.

State and National Trends

United States	Employment		Percent Change	Projected Annual Job Openings [1]
	2014	2024		
Electro-Mechanical Technicians	14,700	14,800	+1%	370
Washington	**Employment**		**Percent Change**	**Projected Annual Job Openings [1]**
	2012	**2022**		
Electro-Mechanical Technicians	190	220	+14%	10

The demand for Robotics Engineers (who "Research, design, develop, or test robotic applications") is also growing and is higher than the national tend (below).

State and National Trends

United States	Employment		Percent Change	Projected Annual Job Openings [1]
	2014	2024		
Engineers, All Other	136,900	142,300	+4%	3,300
Washington	**Employment**		**Percent Change**	**Projected Annual Job Openings [1]**
	2012	**2022**		
Engineers, All Other	3,780	4,210	+11%	120

Bolstering the evidence of demand (as the BLS is always at least a year behind accurately forecasting real-time demand), one can do a quick search on Indeed.com for the word "robot" appearing somewhere in the job description or title. 46 jobs appeared. When the word "machine learning" was entered, and again had to appear at least once in the job title or description, 1,455 jobs appeared. The search used the location of Bellevue, WA and the radius for the job search was 100 miles. Eastern Washington currently does not have the demand that Western Washington has, but that will change.

Looking at what experts are thinking around job demand in robotics, Ms. Tanya M. Anandan wrote a comprehensive and fascinating article on this topic (see directly below).

Directly Taken from Source: Closing the Skills Gap in Automation: A Call for Action
By Tanya M. Anandan, Contributing Editor
Robotic Industries Association
POSTED 04/30/2015

> Manufacturers are adopting more automation than ever before. For many, it's no longer a question of whether to automate, only when and to what extent. With wages offshore rising, robot prices down and performance up, robot sales are at an all all-time high.
>
> Meanwhile, an aging workforce moves closer to retirement. Misconceptions of manufacturing as crude and demoralizing persist. Women and other minorities are still underrepresented. The skills gap is growing. Demand for automation talent outweighs supply.
>
> The result over the next decade according to a skills gap report by Deloitte: 3.4 million jobs, but only 1. 4 million qualified workers. It doesn't take a mathematician to see the huge disparity here.
> This is a call for action. A panel of automation professionals has weighed in, sharing ways to bridge the skills gap, recruit talent, and prepare our future workforce.

> As one industry expert put it so aptly, “If a robot can take your job, you need to up your game.” As an industry, we need to up our game. We need to provide access to the hands-on training, educational tools, and early childhood STEM building blocks integral to shaping our technical talent.

Why Community Colleges Might Be the Answer

The Center posited that two-year degrees might initially be an acceptable academic credential in place of a Bachelor’s degree. Washington State IT employers typically want to hire a graduate with a four-year degree.

However, as the demand is so high right now and will continue to grow that particular IT employer mindset might change. And, while strides will be made to update and advance robotic degrees at the four-year level, the skills gap might narrow because a two-year degree is obviously a shorter academic pathway than a four-years.

It might be between three and seven years before higher education catches up and creates industry-approved four-year degrees on a larger scale than what is currently being offered. Currently, most robotics programs are geared towards students seeking post-graduate degrees (Masters and Doctoral).

The article below sets up the logic around how this short-term solution could be provided by community and technical colleges.

From the article, **Closing the Skills Gap in Automation: A Call for Action**, the case is being made for “Rethinking Community Colleges.”

Rethink Community Colleges

"But if I look at the general discussion about jobs and education, the big economic growth is not going to come out of the universities," says Christensen, who is also Founder of the Robotics Virtual Organization and key contributor to the U.S. Robotics Roadmap. "It's going to come out of the community colleges. I see the general shift going from unskilled labor to operators on the line that must have some minimum degree of education, but they don't need a four-year college education. So the big numbers are going to be in those community college educations where you get a two-year degree."

"We need this for all the big factory lines, and I'm seeing lots of factories," says Christensen. "The best example we have in the Southeast is Airbus, which is building a factory in Alabama. Mercedes is building a new factory. Kia built a factory a few years ago. Porsche just moved its North American headquarters to Atlanta. We're seeing tremendous growth in automotive, electronics, aerospace and in general industries. That's where I see the big economic lift. But we have to make sure we have enough people with a certain degree of education that can be machine operators."

"They need to be able to operate robots and do some basic programming," he adds. "If they can do this, they can be very valuable contributors."
"We're trying to build relationships with a number of community colleges in the Southeast, and would like to see a partnership between companies and the community colleges to get this education out there," says Christensen. "We can then help the community colleges design curriculum that's targeted."

Section 9: Technical Knowledge and Skills Needed for Robotics, AI, Automation, and More…

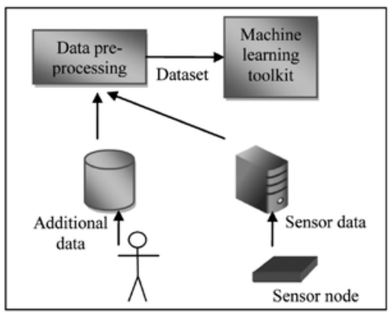
The following technical knowledge and skills were all taken from robotics, AI, deep machine learning, data analytics (as it relates to the field of robotics), and security jobs posted to Indeed.com during the month of June 2016. The following five technical knowledge and skills areas focus on the fundamentals when considering an overview integration of robotics into an IT program.

1. Deep Machine Learning: Deep learning (also known as **deep structured learning**, **hierarchical learning** or **deep machine learning**) is a branch of machine learning based on a set of algorithms that attempt to model high-level abstractions in data by using a deep graph with multiple processing layers, composed of multiple non-linear transformations.

- Natural Language Processing (NLP): Natural language understanding, enabling computers to derive meaning from human or natural language input; and others involve natural language generation.
- NLP research is gradually shifting from lexical semantics to compositional semantics and, further on, narrative understanding. Human-level natural language processing, however, is an AI-complete problem.
- That is, it is equivalent to solving the central artificial intelligence problem—making computers as intelligent as people, or strong AI. NLP's future is therefore tied closely to the development of AI in general.
- The following **natural language processing toolkits** are popular collections of natural language processing software. They are suites of libraries, frameworks, and applications for symbolic, statistical natural language and speech processing.

Name	Language	License	Creators
Apertium	C++, Java	GPL	(various)
Deeplearning4j	Java, Scala	Apache 2.0	Adam Gibson, Skymind
DELPH-IN	LISP, C++	LGPL, MIT, ...	Deep Linguistic Processing with HPSG Initiative
Distinguo	C++	Commercial	Ultralingua Inc.
General Architecture for Text Engineering (GATE)	Java	LGPL	GATE open source community
Gensim	Python	LGPL	Radim Řehůřek
LinguaStream	Java	Free for research	University of Caen, France
Mallet	Java	Common Public License	University of Massachusetts Amherst
Modular Audio Recognition Framework	Java	BSD	The MARF Research and Development Group, Concordia University
MontyLingua	Python, Java	Free for research	MIT
Natural Language Toolkit (NLTK)	Python	Apache 2.0	
Apache OpenNLP	Java	Apache License 2.0	Online community
UIMA	Java / C++	Apache 2.0	Apache

Courses to review and adapt: Natural Language Processing Natural Language Processing (Coursera)



Vertical system integration

2. On-Sensor Machine Learning: The application of machine learning (ML) algorithms on automatically gathered sensor data combined with manually collected data in order to predict different events.

Source: ***Using Machine Learning on Sensor Data Authors***: Alexandra Moraru, Marko Pesko, Maria Porcius, Carolina Fortuna, and Dunja Mladenic

Courses to review and adapt: Intelligent Sensors

3. R Programming Language: R is a programming language and software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing. The R language is widely used among statisticians and data miners for developing statistical software and data analysis. Polls, surveys of data miners, and studies of scholarly literature databases show that R's popularity has increased substantially in recent years.

- R is project. The source code for the R software environment is written primarily in C, Fortran, and R. R is freely available under the GNU General Public License, and pre-compiled binary versions are provided for various operating systems. While R has a command line interface, there are several graphical front-ends available.

Courses to review and adapt: R Programming – Introduction 1, Statistical Analysis with R Programming

4. Malware Analysis: It is the study or process of determining the functionality of given malware samples such as virus, trojan horses, rootkits, and backdoors. Malware or malicious software is a computer software intended to harm the host operating system or to steal sensitive data from users, organizations or companies. Malware may include viruses, worms, trojan horses and spyware that gathers user information without permission.

There are two types of malware analysis that an internet security professionals can perform:

1. **Static Malware Analysis**: Static or Code Analysis is usually done by dissecting the different resources of the binary file and studying each component. The binary file can also be disassembled (reverse engineered) using a disassembler such as IDA. The machine code can be translated into Assembly code which can be read and understood by humans. A malware analyst can then make sense of the Assembly instructions and have an image of what the program is supposed to perform. Analyst can also learn ways to defeat and as a result sanitize the system from the infection of the disassembled malware.
2. **Dynamic Malware Analysis**: Dynamic or Behavioral analysis is done by watching and logging the behavior of the malware while running on the host. Virtual machines and Sandboxes are extensively used for this type of analysis. The malware is debugged while running using a debugger such as GDB or WinDbg to watch the behavior of the malware step by step while its instructions are being processed by the processor and their live effects on RAM.

Courses and Content to review and adapt: Reverse-Engineering Malware: Malware Analysis Tools and Techniques, Malware (GitHub, lectures, labs, and project files)

5. Mathematica: Mathematica is a symbolic mathematical computation program, sometimes called a computer algebra program, used in many scientific, engineering, mathematical, and computing fields. It was conceived by Stephen Wolfram and is developed by Wolfram Research of Champaign, Illinois. The Wolfram Language is the programming language used in Mathematica.

Features of Mathematica include:

- Elementary and Special mathematical function libraries
- Support for complex number, arbitrary precision, interval arithmetic and symbolic computation
- Matrix and data manipulation tools including support for sparse arrays
- 2D and 3D data, function and geo visualization and animation tools
- Solvers for systems of equations, diophantine equations, ODEs, PDEs, DAEs, DDEs, SDEs and recurrence relations
- Numeric and symbolic tools for discrete and continuous calculus including continuous and discrete integral transforms
- Constrained and unconstrained local and global optimization
- Multivariate statistics libraries including fitting, hypothesis testing, and probability and expectation calculations on over 140 distributions.
- Support for censored data, temporal data, time-series and unit based data
- Calculations and simulations on random processes and queues
- Supervised and unsupervised machine learning tools for data, images and sounds
- Tools for text mining including regular expressions and semantic analysis
- Data mining tools such as cluster analysis, sequence alignment and pattern matching
- Computational geometry in 2D, 3D and higher dimensions
- Finite element analysis including 2D and 3D adaptive mesh generation
- Libraries for signal processing including wavelet analysis on sounds, images and data
- Linear and non-linear Control systems libraries
- Tools for 2D and 3D image processing and morphological image processing including image recognition
- Tools for visualizing and analyzing directed and undirected graphs
- Tools for combinatoric problems

- Number theory function library
- Tools for financial calculations including bonds, annuities, derivatives, options etc.
- Group theory and symbolic tensor functions
- Import and export filters for data, images, video, sound, CAD, GIS, document and biomedical formats
- Database collection for mathematical, scientific, and socio-economic information and access to WolframAlpha data and computations
- Technical word processing including formula editing and automated report generating
- Programming language supporting procedural, functional and object oriented constructs
- Toolkit for adding user interfaces to calculations and applications
- Tools for connecting to DLL, SQL, Java, .NET, C++, Fortran, CUDA, OpenCL, and http based systems
- Tools for parallel programming
- Using both "free-form linguistic input" (a natural language user interface) and Wolfram Language in notebook when connected to the Internet

Course and Content to review and adapt: Integrating Wolfram/Alpha into College Courses (video, 9:05 minutes), Mathematica, Hands-on Start to Mathematica and How To's Documentation Center (video, 6:59 minutes)

When looking for undergraduate programs that offer robotics degrees or curriculum, MIT, UC Berkeley and Columbia University are worth looking at for best practices and robotics program models.

Conclusions

While “conclusions” imply “the end or finish of an event or process,” it is clear the robotics industry is exploding in ways that may have been envisioned, but not yet realized. The reality facing the Washington State, the United States, and the global economy is that robotics and automation will produce jobs for those in IT and mechatronics. It will also replace many jobs currently filled by humans and then the question must be asked, what will those people do to earn a sustainable wage? There are no definitive answers to that particular question.

It’s too soon to panic, but it’s not too soon to think about how the IT programs across the Washington State CTC system can look at their IT programs and consider how they might adapt and adopt robotics curriculum. This retrospective and preview of the future provides an opportunity for colleges to prepare IT graduates for high demand jobs in a rapidly developing industry.

While robotics can clearly be seen as a disruptive technology, and the word “disruptive” certainly to some has negative connotations, disruption simply means the way we have done things will change. The traditional way we operate across all industries will evolve to create both simplicity and complexity. The unexpected shouldn’t be feared or avoided; it should be carefully measured and studied.

This is an exciting journey for IT education and its students.