

The Challenges of Building and Testing Increasingly Autonomous Systems

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Once, computers were humans doing computing functions



More recently, humans built computers they operated



Now, computers operate themselves



Some autonomous systems may be expert software systems



Finance



Medicine



Real-time Process Control

... while others are very real,
such as robots and UAS



These smart machines are more than *automated* systems



. . . and more than *virtual reality* devices



Telepresence

Autonomous systems in use today are the result of decades of R&D



R&D areas include

- Digitization of sensors
- Adaptive algorithms
- Natural user interfaces
- Machine learning
- Machine vision



... and improved software practices

Virtual integration (integrate-then-build)

Replaces traditional build-then-test

Relies on architectural
model repository

Reduces risk, cost, and
development time



... As well as the convergence of software capabilities



“This car is the holy grail of autonomous driving because it can do it all—from changing lanes on highways, driving in congested suburban traffic, and navigating traffic lights.”

Prof. Raj Rajkumar, co-director, CMU-General Motors Autonomous Driving Collaborative Research Lab



Autonomous systems improve productivity



1954
first robotic
arm



2012
Baxter
deep-learning
robot

1950s 1960s 1970s 1980s 1990s 2000s 2010s

1979
Articulated
robot arm



They can operate continuously



1957
Sputnik

1984
Landsat 5

Set record in 2013
as the longest-
operating Earth
observation satellite



1950s 1960s 1970s 1980s 1990s 2000s 2010s



1998
International
Space Station

They increase information sharing



1972
Aquila drone

- Originally a battlefield target designator
- Now used to bring Internet access where none exists

2010
Disaster relief in Haiti

Global Hawk mapped damage to help target relief efforts



1950s 1960s 1970s 1980s 1990s 2000s 2010s

Distributed Sensor Network program

Explore challenges of distributed/wireless sensor networks, in partnership with MIT/LL, CMU and others

Advancements in sensing technologies

Ushering in the Internet of Things



They can process tremendous volumes of data



2011-today
Watson

1990s

2000s

2010s

1997

Deep Blue

Autonomous chess-playing computer; defeated world champion Garry Kasparov



They will work where we cannot safely go



1994
Dante II
Robotic
exploration
of extreme
terrains



2011
Fukushima

1990s

2000s

2010s



2000s
Explosive Ordnance
Disposal Robots

- World Trade Center
- Iraq
- Afghanistan



We use them to explore the universe



1977- today
Deep
space
probes



1950s 1960s 1970s

1980s

1990s

2000s

2010s



1997
Pathfinder

The **relationships** between
machines and people are
moving from the
cooperative to the
co-dependent to the
competitive.

Gartner analysis



Our systems are increasingly autonomous

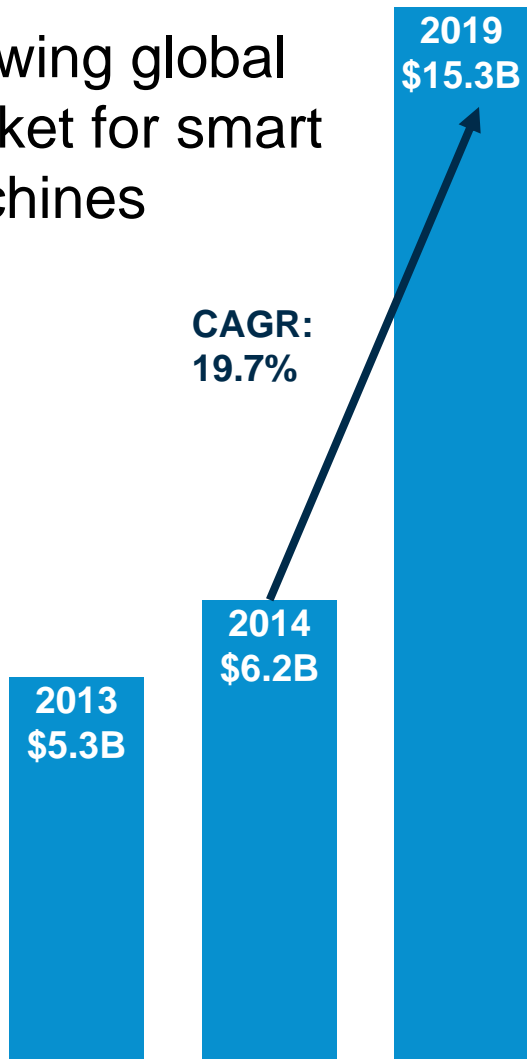
2020

- Algorithmically driven agents, outside of human control, will participate in 5% of all economic transactions
- 20% of all business content will be authored by machines
- 6 billion connected things will be requesting support
- 50% of the fastest growing companies will have fewer employees than instances of smart machines
- More than 3 million workers globally will be supervised by “robobosses”



Autonomy is also becoming big business

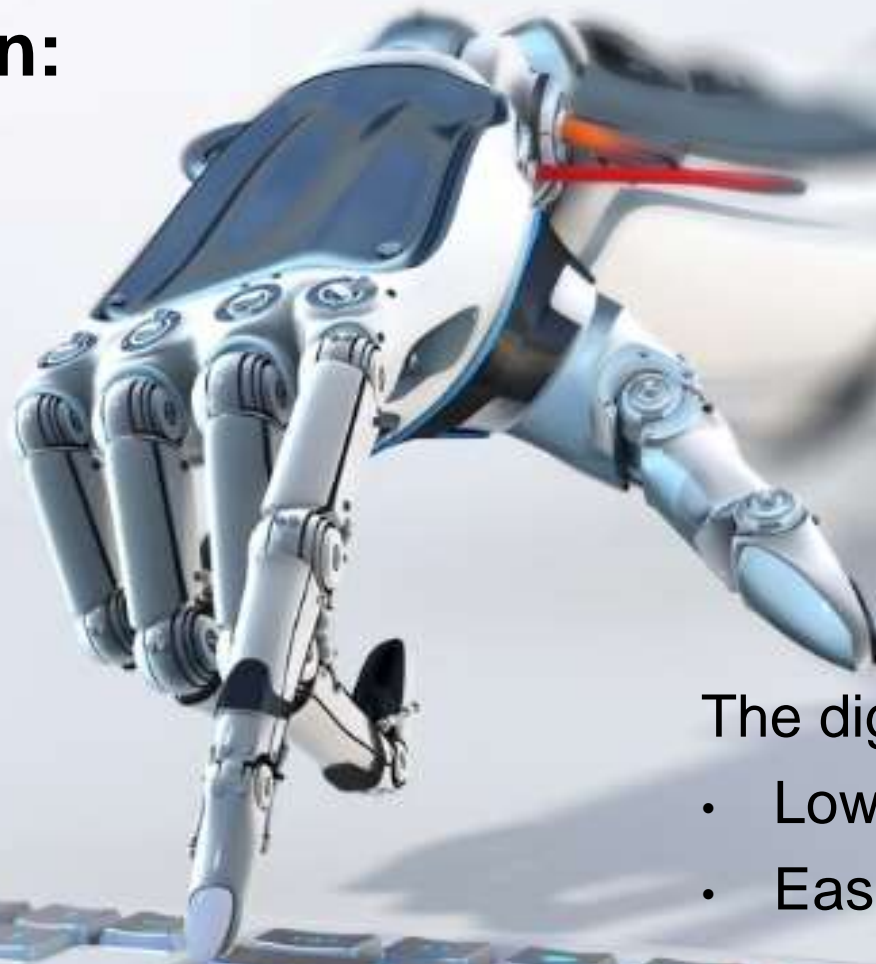
Growing global market for smart machines



By 2021, 1 million Internet of Things devices will be purchased and installed per hour



One concern: economic disruption



The digital workforce

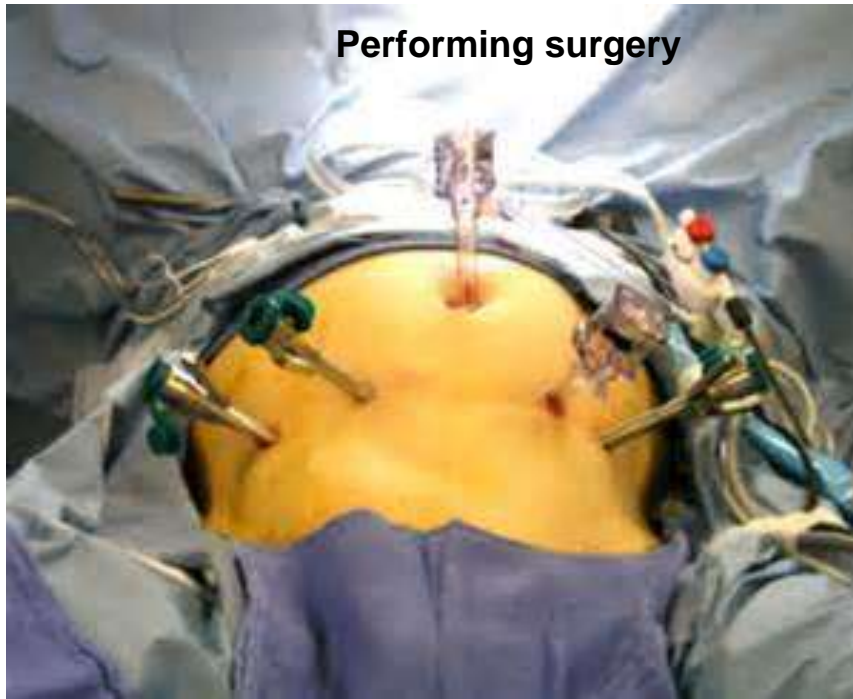
- Lower cost
- Easier to train



Autonomous systems do tedious, time-consuming tasks better



They can also perform specialized jobs



One view: the digital workforce will eliminate human jobs

“Gartner predicts **one in three** jobs will be converted to software, robots, and smart machines **by 2025.**”

New digital businesses require less labor; machines will make sense of data faster than humans can.”

—Peter Sondergaard, Gartner's research director

Some jobs humans may lose to autonomous systems

- Pharmacist
- Lawyer
- Paralegal
- Driver
- Astronaut
- Store Clerk
- Soldier
- Babysitter
- Rescuer
- Sportswriter
- Reporter



Alternate view: the digital workforce will create human jobs



47% of devices (such as vending machines, washing machines, and aircraft) will be able to request support from human-operated businesses

They work faster and produce more, winning more orders.

Their higher productivity brings jobs back from lower wage competitors.

They provide an efficient test platform for innovation.

They save on costs because they perform dangerous tasks safely.

Source: Inc. Magazine

Another concern: ethics of autonomy

Britain has a CCTV camera for every 11 people



Can we give autonomous systems an ethical framework and context?

What are the limits to autonomy—in conflict, in law enforcement?

How do autonomous systems impact privacy and civil rights?

Artist's rendering of attack by drone swarm



Can an autonomous system choose the greater good?



Suppose an autonomous vehicle . . .



senses a ball rolling into the street in its lane . . .



. . . and semi-truck coming toward it in the other lane?

The next generation of algorithmically driven financial agents will be fully autonomous

```
53     $("#fin").select();
54 });
55 function array_from_string(a) {
56     a = a.replace(/(\r\n|\n|\r)/gm, " ");
57     a = replaceAll(" ", " ", a);
58     a = a.replace(/ +(?= )/g, "");
59     return a.split(" ");
60 }
61     $("#unique").click(function() {
62     var a = array_from_string($("#fin").val()), b = $("#limit_val").val();
63     if (c < 2 * b - 1) {
64     return function("check" + c), this.trigger("click");
65     }
66     for (b = 0; b < a.length; b++) {
67     "" != a[b] && "" != a[b] || a.splice(b, 1);
68     }
69     b = $("#User_logged").val();
70     c = array_from_string(b);
71     for (b = 0; b < c.length; b++) {
72     "" != c[b] && (c[b] = "");
73     }
74     }
75     });
```

- Accumulate and spend money
- Set up and participate in contracts
- Adapt, replicate, and create new autonomous systems
- Compete with bank accounts and other products offered by financial institutions

A new concern: personal drone ownership



GPS-guided flying robot available for as little as \$300 USD

May be 1M drones owned by end of 2015

Most common use: Photo/videography

Issues

- Privacy
- Arming
- Interference with commercial aircraft

Another drone crashes near White House. Can FAA keep up with drones?

Christian Science Monitor, October 9, 2015



Some predict that autonomy will pose an existential threat

“Computers are going to take over from humans, no question. If we build these devices to take care of everything for us, eventually they'll think faster than us and they'll get rid of the slow humans to run companies more efficiently.”

(Steve Wozniak)

“Hope we're not just the biological boot loader for digital superintelligence. Unfortunately, that is increasingly probable.” (Elon Musk)

“The development of full artificial intelligence could spell the end of the human race.” (Stephen Hawking)

Others say autonomy will enhance, extend human life



Ray Kurzweil

- By 2029, computers will be able to do all the things that humans do.
- “We're going to use those tools to make ourselves more expressive and more intelligent.”
- “. . . by the 2030s we'll be putting millions of nanobots inside our bodies to augment our immune system, to basically wipe out disease.”



Neil Harbisson, human cyborg



Born color-blind, human cyborg Neil Harbisson has an antenna implanted in his skull that allows him to perceive colors as sounds on the musical scale.

“When I started to dream in color, I felt the software and my brain had united.”



How do we build trust?





Closing



Autonomous functionality is increasing and accelerating

- Trust, in many manifestations, is a central concern
- How can the ER community contribute to
 - building trust
 - understanding the limits to trust
 - making human-machine teams more effective

