

**CMSC 409:**  
***Artificial Intelligence***

<http://>

**Virginia Commonwealth University,**  
**Fall 2023,**  
**Dr. Milos Manic**  
**([mmanic@vcu.edu](mailto:mmanic@vcu.edu))**

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**CMSC 409:**  
***Artificial Intelligence***

**Session # 02**

**Topics for today**

- Announcements
- Previous session review
- AI today and its future...
- Some difficult questions of AI...
- Learning, Intelligent Agents
- Electrical Properties of Nerves
  - *Nerves – a biological aspect*
  - *All-or-nothing nature of nerve signals*
  - *More on neurons*

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## **CMSC 409: Artificial Intelligence**

### **Announcements   Session # 02**

- Canvas
  - Slides, class paper instructions and template uploaded
  - All enrolled should have access – please check
  - Couple of announcements posted
- Class roster
  - All of you should be on the Canvas class email list – contact Instructor in case you are not receiving these emails
- Prereqs
  - Must have the pre-reqs CMSC 401, MATH 310 (except when approved prior).
- Subject line and signature
  - Please use [CMSC 409] Last\_Name Question

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### A few slides on

- "zeroth" assignment
- forming groups
- Canvas
- Zoom info

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## Your “zeroth” assignment (deadline Aug.31)

- A:**
1. Form a team (team lead + up to 2 members)
  2. Provide information in [google document](#)
  3. Inform Instructor ([mmanic@vcu.edu](mailto:mmanic@vcu.edu)) & TAs

Sandun Bandara ([mavikumbureh@vcu.edu](mailto:mavikumbureh@vcu.edu)),

Victor Cobilean <[cobileanv@vcu.edu](mailto:cobileanv@vcu.edu)>

Note: Team lead should always keep team members in cc

- B:**
1. Send an email to Instructor & TA:
  2. Use subject line [CMSC 409] Your Name, Background
  3. Describe your professional/academic background (briefly)
  4. Describe your interests in AI and course expectations

*I receive a large number of emails on daily basis. Please use this subject line so your email ends up in right place in my Inbox. If any urgent matter arises, please append your subject line with “ – URGENT”.*

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1. Form a team (team lead + up to 2 members)

2. Provide information in

<https://docs.google.com/spreadsheets/d/1YMP0tcAzOeB4sH9OU4OvvX9h3afKOOGn/edit#gid=697412957>

3. Inform Instructor ([mmanic@vcu.edu](mailto:mmanic@vcu.edu)) & TAs

Sandun Bandara ([mavikumbureh@vcu.edu](mailto:mavikumbureh@vcu.edu)), Victor Cobilean <[cobileanv@vcu.edu](mailto:cobileanv@vcu.edu)>

Note: Team lead should always keep team members in cc

*<- Populate this document by Aug.31*

Important: If you are looking for additional team members, please contact below:

Group Name	# team members	First Name	Last Name	Canvas Group Status
LastNames1_LN2_LN3	3	FirstName1	LastName1	Not Created
		FirstName2	LastName2	Not Created
		FirstName3	LastName3	Not Created
	3			Not Created
	3			Not Created
	3			Not Created
	2			Not Created
	3			Not Created
	3			Not Created
	3			Not Created
	3			Not Created
	2			Not Created
	1			Not Created
	2			Not Created
	2			Not Created
	3			Not Created
	2			Not Created
	1			Not Created
	2			Not Created

Name 1, Name 2,... Looking for a team, please contact me if you are looking for another team member (contact email):

Created

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**Canvas:**

**Zoom (office hours)**

- Login to <https://vcu.zoom.us/> - that activates your zoom account in case you do not have it already
- This is the licensed account

**This option is activated =>**  Only authenticated users can join: Sign in to Zoom

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- Zoom Chat (contact me any time)
  - Login to zoom app
  - Start Chat
  - If there is a green dot next to my name, I am not in Zoom call
  - You can “chat me” here during and outside office hours

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• **Discussions**

- Welcome thread created
- Feel free to use it, create new ones...

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## ***CMSC 409: Artificial Intelligence***

### **Reminder:**

- Office hours - Zoom (please make appointment)
  - <https://vcu.zoom.us/j/81934704959>, pass: Y9aC9DLL1y
  - <https://vcu.zoom.us/j/81934704959?pwd=SEdkaFlyd2NoblN2dVJCWTFYnZxUT09>
- Zoom
  - Login to <https://vcu.zoom.us/> - that activates your zoom account
  - All students should have licensed account (contact IT)
  - **Authentication option activated (you must be signed in)**

**Require authentication to join: Sign in to Zoom**

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# Back to...What *IS* Artificial Intelligence?

...and difficult questions it comes with...

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**Engineers pre-train AI computers to make them even more powerful**

Date: September 22, 2020  
Source: Swiss Center for Electronics and Microtechnology - CSEM  
Summary: Engineers have developed a new machine-learning method that paves the way for artificial intelligence to be used in applications that until now have been deemed too sensitive. The method, which has been tested by running simulations on a climate-control system for a 100-room building, is poised to deliver energy savings of around 20%. Read more:

Share: [f](#) [t](#) [p](#) [in](#) [e](#)

**What If AI Pilots Became Good Enough to Fight Other Warplanes?**

September 18, 2020 | Tom Jowdy | Digital America | Big Data | Heiselet | Tech | War Technology, Weapons, War, Artificial Intelligence

**Moore's Law Is Dead. Long Live Huang's Law.**

September 18, 2020 | Tom Jowdy | Digital America | Big Data | Heiselet | Tech | War Technology, Weapons, War, Artificial Intelligence

I call it Huang's Law, after Nvidia Corp. chief executive and co-founder Jensen Huang....Between November 2012 and this May, **performance of Nvidia's chips increased 37 times for an important class of AI calculations**, says Bill Dally, chief scientist and senior vice president of research at Nvidia. On average, in other words, the performance of these chips more than doubled every year, a rate of progress that makes Moore's Law pale in comparison.

**DITCH THOSE CLOTH MASKS FOR THIS TRANSPARENT N95 FACE MASK WITH AN AI-POWERED VENTILATION SYSTEM**

**Just within one month (Sep. 2020)**



**Why CyberSecurity And AI Are Top Governance Risks For Board Directors And CEOs?**

Cindy Gordon Contributor  AI CEO, Innovation Leader Passionate about Modernizing via AI



CyberSecurity and Artificial Intelligence harmonized with reduce hacker risks... 0 comments

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# What IS AI...?

**Artificial** = Made by humans; Created, produced - rather than natural.

Defining Intelligence – much harder!

- The capacity to **acquire** and **apply** knowledge.
- The **ability to learn** or understand things or to deal with new or trying situations: the skilled use of reason.
- Terminology..
  - AI, ML, CI, Deep learning

**AI our attempt to build models of ourselves?**

**AI today...**

“data driven”

takes many forms 

**Why NOT use AI today?**

## The difficult questions...

- How do you...
  - ...replicate something we do not understand.
  - Sentence...emotion, love, dream, conciseness, fear, anger, memory (ours is subjective, fallible)
  - Trust and trustworthiness; how to quantify?
  - Regulate? Public and gov policies
  - Autonomous vehicles and intelligence - ethical, moral questions



“AI would be the biggest event in human history.  
Unfortunately, it might also be the last” Elon Musk (Tesla)

“If a super-intelligent machine decided to get rid of us, I think it would do so pretty efficiently” Shane Legg, DeepMind co-founder

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## Intelligence

- a. The capacity to **acquire** and **apply** knowledge.
- b. The faculty of thought and reason.
- c. Superior powers of mind.
- d. The **ability to learn** or understand things or to deal with new or trying situations: the skilled use of reason.
- e. The ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria.
- f. Christian Science: the basic eternal quality of divine Mind.

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However, whatever the definition of intelligence may be there are things beyond it, or some will argue within it, which can also be formulated by **rephrasing** A. C. Clarke (who uses information instead the intelligence) as follows:

### Arthur C. Clarke, 1917-2008

#### 2001: Space Odyssey (1968)

- The "Big Three" of science fiction: Robert A. Heinlein, Isaac Asimov, and Arthur Clarke.



[https://en.wikiquote.org/wiki/Arthur\\_C.\\_Clarke](https://en.wikiquote.org/wiki/Arthur_C._Clarke)



*"Before you become too entranced with gorgeous gadgets and mesmerizing video displays, let me remind you that information is not knowledge, knowledge is not wisdom, and wisdom is not foresight. Each grows out of the other, and we need them all."*

<https://www.goodreads.com/quotes/110914-before-you-become-too-entranced-with-gorgeous-gadgets-and-mesmerizing>

We can adopt a simple working definition of AI suitable for this course:

**Artificial Intelligence is a (super)set of everything which makes computers do what the human brain is able to do,  
or,  
AI is just our attempt to build models of ourselves.**

Terminology:

- Artificial Intelligence
- Machine Learning
- Computational Intelligence (Fuzzy/Neural/Genetic)
- Deep learning
- .....

## AI in (not so) distant future...

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## AI in (not so) distant future?

- It's (only) a movie...
  - The Humans, 2015
    - *"In a parallel present, the latest must-have gadget is a Synth: a highly-developed robotic servant. In an attempt to keep his family together, Joe Hawkins purchases a Synth, only to discover that sharing life with a machine has far-reaching and chilling consequences..."*



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## AI...difficult questions...

- How do you...
  - ...replicate something we do not understand
  - What is human emotion?
  - Sentience...emotion, love, dream, conciseness
  - Fear, anger, violence?
  - Memory - ours is subjective, fallible
  - How do you teach a computer to forget...or to dream? It is something our minds need to do...
  - .....



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## AI...difficult questions...

- *How to replicate something we do not understand?*
- *human emotions, love, dream, conciseness, fear; anger, violence, memory...*



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{ classical music playing,

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**Elon Musk (Tesla)**

*"AI would be the biggest event in human history. Unfortunately, it might also be the last"*

**Stephen Hawking, English physicist**

*"The development of full Artificial Intelligence could spell the end of the human race"*

**Larry Page (Google co-founder)**

*"Google will fulfill its mission only when its search engine is AI-Complete"*

**Bill Gates, Microsoft**

*"I don't understand why some people are not concerned"*

**Shane Legg, DeepMind co-founder**

*"If a super-intelligent machine decided to get rid of us, I think it would do so pretty efficiently"*

**Shane Legg, DeepMind co-founder**

*"Are search engines a map of what people are thinking, or actually a map HOW people are thinking?"*

**...From Ex-Machina**

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## AI...now already?

*(what happens when we “dress” computers?)*

**CNN**  
Cuddly Therapy: A Robot Seal That Heals

**PARO**

Stuffed animal or \$6K medical device?  
<http://www.parorobots.com/>

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The screenshot shows the homepage of the IBM Watson AI XPRIZE website. At the top, there's a navigation bar with links for 'ABOUT', 'NEWS', and 'TEAMS'. Below the header, a large banner features a woman in a lab coat working with a pipette. The banner text includes 'August, 2016', 'http://ai.xprize.org/REGISTRATION NOW OPEN', and 'Show the world how artificial intelligence can help solve humanity's greatest challenges.' A 'REGISTER TODAY >' button is visible. To the right of the banner is a grid of icons representing various fields of study or technology. Below the banner, the main title 'INCENTIVIZING INNOVATIVE AI APPROACHES & COLLABORATION' is displayed. A detailed description of the competition follows, mentioning it's a \$5 million competition over four years with annual milestones. At the bottom of the page are links for '© M.' and 'READ ABOUT THE COMPETITION >'. The page has a clean, modern design with a blue and white color scheme.

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This screenshot shows a news section with a large image of a smiling scientist in a lab. The heading 'PUSHING THE BOUNDARIES OF AI' is overlaid on the image. To the left, a box contains the statistic '90% OF THE DATA IN THE WORLD HAS BEEN CREATED IN THE LAST TWO YEARS ALONE.'. To the right, another box contains '2.5 QUINTILLION BYTES (QUINTILLION = ONE BILLION BILLION) OF DATA IS PRODUCED EVERY DAY, FROM SENSORS, MOBILE DEVICES, ONLINE TRANSACTIONS, AND SOCIAL NETWORKS.'. Further to the right, a third box poses the question 'WHAT IF HUMANS CAN COLLABORATE WITH POWERFUL AI TECHNOLOGIES TO GATHER, ANALYZE AND TACKLE THE WORLD'S GRAND CHALLENGES?'. Above the main image, there's a 'LATEST UPDATES' section and a 'MORE NEWS >' link. The overall layout is clean and professional, using a mix of blue, white, and black text on a white background.

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**XPRIZE launches AI 2020 competition with IBM Watson**

Posted Aug 10, 2016 by John Mannes (@JohnMannes)

<https://techcrunch.com/2016/08/10/xprize-launches-ai-2020-competition-with-ibm-watson/?ncid=rss>

Alex Garland's 2015 science-fiction drama *Ex Machina*

Close your eyes. What do you see when you think about artificial intelligence? *Hal 9000* defying human orders? *Ava* savagely murdering her maker? What about *AI:IA* taking over the country from deep inside the Pentagon?

With a new competition, **XPRIZE and IBM Watson challenge us** to think slightly more pragmatically (or at least less apocalyptically dystopian) about the implications of artificial intelligence research on the future of humanity.

To date, more than 1,000 people have registered to form teams with plans to tackle such issues as health, climate, transportation, space travel, robots, city planning, surgery, education and even civil rights. Because the competition is an open challenge, teams are expected to come up with criteria on which they will ultimately be judged in 2020.

Some teams may be backed by corporations or angels; while others may go it alone as a team. Labs, startups, a group in a corporation or even a spinoff can constitute a team.

"We think this prize specifically might drive a lot of financing activity," said Amir Banafsheh, XPRIZE lead for the competition.

The interdisciplinary nature of the competition is what makes it so exciting. Teams may be comprised of some folks adept at traditional skills, like machine learning, and others with knowledge of cognitive science, mathematics, linguistics and even design.

The AI competition officially starts in March 2017 and offers a number of check-ins and milestone awards. The final presentation will be at TED 2020. Because the challenge will occur over multiple years, final projects will include technologies and utilize skill sets that don't exist today.

XPRIZE was founded 20 years ago to catalyze radical breakthroughs that could benefit humanity. The nonprofit gained recognition for coordinating the Ansari XPRIZE for suborbital spaceflight, which resulted in the flight of SpaceShipOne in 2004.

The winner of the AI prize will receive \$3 million courtesy of IBM, with the runner-up getting \$1 million and the third-place recipient getting \$500,000.

If you think you have what it takes to change the world with AI, [register here](#).

**CrunchBase**

**IBM Watson**

**DESCRIPTION**  
IBM Watson, a cognitive system that uses natural language processing to understand and engage with people that enhance and scale human intelligence.

**WEBSITE**  
[http://www.ibm.com/smarterplanet/](http://www.ibm.com/smarterplanet/us/en/ibmwatson/)

**X PRIZE Foundation**

**TC NEWSLETTER**

**Questioning Cinema: *Ex Machina***

**Ex Machina**  
2014 / Release 2015 - 108 min.

**Cast**  
Caleb Smith  
Domhnall Gleeson  
Nathan Bateman  
Alicia Vikander  
Kyoko

**Crew**  
Director and screenplay writer: Alex Garland

**Synopsis**  
"Caleb (Domhnall Gleeson), a programmer at an internet-search giant, wins a competition to spend a week at the private estate of the company's brilliant and reclusive CEO, Nathan (Oscar Isaac). Upon his arrival, Caleb learns that Nathan has chosen him to be the human component in a Turing test - evaluating the capabilities, and the consciousness, of Nathan's latest experiment in artificial intelligence."

**Plot**  
That experiment is Ava (Alicia Vikander), a breathtaking A.I. whose emotional intelligence proves more sophisticated - and more deceptive - than the two men could have imagined."

**Distribution Leaders**

- Dr. John C. Powers, VCU History and STS
- Dr. Miles Manic, VCU Computer Science and Modern Heuristics Research Group
- Alessandro Martelli, VCU Social Psychology
- Dr. Jennifer S. Rhee, VCU English and MATX

**THE FOLLOWING PREVIEW HAS BEEN APPROVED FOR APPROPRIATE AUDIENCES BY THE MOTION PICTURE ASSOCIATION OF AMERICA, INC.**

**FILM RATINGS**

**R**  
PARENTAL ADVISORY: GRAPHIC NUDITY, LANGUAGE, DRUG USE, AND SOME VIOLENCE.  
DOL 17 RECOMMENDED FOR 17 AND OLDER.

[www.filmratings.com](http://www.filmratings.com) [www.mpaa.org](http://www.mpaa.org)

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## What's the Difference Between Artificial Intelligence, Machine Learning, and Deep Learning?

<https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/>

Artificial intelligence is the future. Artificial intelligence is science fiction. Artificial intelligence is already part of our everyday lives. All those statements are true, it just depends on what flavor of AI you are referring to.

For example, when Google DeepMind's AlphaGo program defeated South Korean Master Lee Se-dol in the board game Go earlier this year, the terms AI, machine learning, and deep learning were used in the media to describe how DeepMind won. And all three are part of the reason why AlphaGo trounced Lee Se-Dol. But they are not the same things.

The easiest way to think of their relationship is to visualize them as concentric circles with AI — the idea that came first — the largest, then machine learning — which blossomed later, and finally deep learning — which is driving today's AI explosion — fitting inside both.

ARTIFICIAL INTELLIGENCE  
Early artificial intelligence stirs excitement.

MACHINE LEARNING  
Machine learning begins to flourish.

DEEP LEARNING  
Deep learning breakthroughs drive AI boom.

Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence — first machine learning, then deep learning, a subset of machine learning — have created ever larger disruptions.

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## What's the Difference Between Artificial Intelligence, Machine Learning, and Deep Learning?

Artificial Intelligence (AI)...

- Future, science fiction, already part of our lives?
- AI (ML (DL) )
- AI recently exploding (GPUs, parallel processing)
- Mid 50s (C-3PO, The Terminator)...reason, sense like we do...in movies...
- What **can** be done..."narrow AI" (image classification, face recognition)
- ML (algorithmic approaches)
  - Decision trees, clustering, reinforcement learning, Bayesian, CI, DL...
- Today...general intelligence? drivereless cars?



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## What's the Difference Between Artificial Intelligence, Machine Learning, and Deep Learning?

Artificial Intelligence (AI)...

- Today...general intelligence? drivereless cars?

Driverless Cars to Carry Uber Passengers in Pittsburgh



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# Where is AI going?

- A few illustrations ...

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## AI in Automation & Manufacturing

### New Automation Era AI, ML, Robotics

Automation potential varies across sectors and specific work activities.

McKinsey&Company  
**Human + machine: A new era of automation in manufacturing**  
90+ years business consulting  
14K consultants worldwide  
120+ cities with McKinsey offices

<https://www.mckinsey.com/business-functions/operations/our-insights/human-plus-machine-a-new-era-of-automation-in-manufacturing>

Where and how much to automate?

- Study of 46 countries on 80% global workforce (2015)
  - 64% manufacturing working hrs (478B of 749B) automatable with **current technology**
  - 236M of 372M FTE (\$2.7T of \$5.1T) could be eliminated/repurposed
- Machines
  - Matching or outperforming human (even work requiring cognitive capabilities)
- Manufacturing
  - While one of the highly automated industries -> **Still significant automation potential!**

**Why NOT use AI today?**

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# The Factory of the Future?

## Improvements in plants

### Structure, Digitization, Processes

**EXHIBIT 3 | Key Elements Along the Automotive Value Chain in the Factory of the Future**

Category	Element	2016 (%)		2030 (%)		2030+ (%)	
		2016 (%)	2030 (%)	2016 (%)	2030 (%)	2016 (%)	2030 (%)
Plant Structure	Modular line setup	92	85	92	85	92	80
	Energy efficiency	85	85	85	85	85	85
	Flexible equipment*	81	81	81	81	81	81
Plant Digitization	Smart robots	85	85	85	85	85	85
	Predictive maintenance	83	83	83	83	83	83
	Decentralized production steering	80	80	80	80	80	80
Plant Processes	Digital plant logistics	79	79	79	79	79	79
	Additive manufacturing	72	72	72	72	72	72
	Lean management	67	67	67	67	67	67

Source: BCG and the Laboratory for Machine Tools and Production Engineering at RWTH Aachen University, 2016 Factory of the Future Study.  
\*Flexible equipment includes flexible presses for highly functional and rare parts as well as 3D printing for parts with complex structures.  
Lean management is expected to be relevant throughout the value chain.

**Digitization** - smart, collaborative robots (Changan Ford), Additive Manufacturing (Rolls-Royce Phantom, BMW 3D printing), AR/VR (Volkswagen, logistics), Immersive Training (Mercedes-Benz, virtual assembly lines), Decentralized Production Steering (Bosch, tool location detection), Big Data & Analytics (Mercedes-Benz, predictive analytics)

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# AI as part of Factories of the Future

## AI → up to 70% cost reduction

### Opportunities, yet skepticism...

**EXHIBIT 3 | Around the World, a Large Gap Exists Between AI Ambition and Reality**

Country	Share of companies planning to implement AI within the next three years (%)	Share of companies that have fully implemented more than one AI use case (early adopters) (%)
US	28%	11%
Canada	28%	10%
Mexico	15%	10%
UK	38%	10%
FRANCE	38%	10%
GERMANY	37%	10%
AUSTRIA	37%	10%
Poland	33%	10%
China	28%	10%
Japan	28%	10%
India	28%	10%
Singapore	55%	10%
Average	28%	10%

Source: BCG Global AI Survey, February–March 2018.  
Note: The survey asked respondents whether their company is planning to implement AI and whether the company has already implemented AI use cases in its production processes. For each country, the size of the icon corresponds to the level of ambition.

**Early industry adopters:** Transportation and Logistics (21%), Automotive (20%) highest, while engineered products (15%) and process industries (13%) lag behind

Global survey 1,000 executives (2018)

- Forefront: Transportation, logistics, automotive
- Process industries lag behind
- Germany – automotive most advanced, process ways to go

**Trend**

- Lowest adopters
  - Japan (11%), Singapore (10%), France (10%)
- Early adopters vs. highest ambitions
  - US (25%), China (23%), and India (19%),
  - Singapore (97%), India (96%), China (94%)
- China has overtaken the US in AI

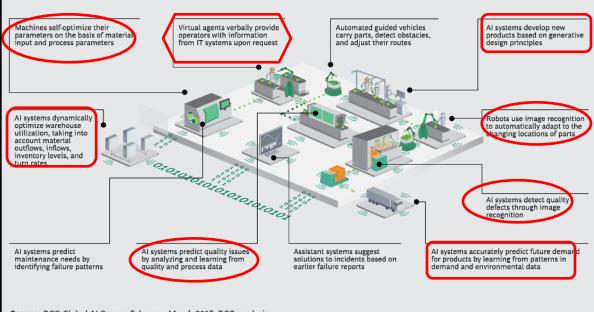
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# AI in the Factory of the Future

## AI everywhere...

EXHIBIT 2 | AI Will Be Ubiquitous in the Factory of the Future



Source: BCG Global AI Survey, February–March 2018; BCG analysis.

### • Inside the Factory (cont.)

- Quality—ML vision for defect identification; Logistics – in-plant and warehousing, autonomous movement and efficient supply of material w/ obstacle detection (UAG), warehouse self-optimization (moving high-demand parts to closer for faster access, and low-demand parts to more remote locations).

Global survey 1,000 executives (2018)

### AI application areas

#### • Outside the Factory

- Engineering - R&D, simplifying production, generative product design (AI suggesting unconventional solutions like bionic structures)
- Supply Chain Management – demand forecasting (big data analytics, customers, media, weather, enterprise resource planning with customer insights)

#### • Inside the Factory

- Production—continuous and discrete (chemicals and assembly tasks); self-optimization, material composition, image recognition for unsorted parts in undefined locations (bin, conveyor belt)
- Maintenance – reduce equipment breakdowns, increase asset utilization (predictive maintenance, data analytics)

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# AI, ML, Data Analytics



ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, AND DATA ANALYTICS NATIONAL LABORATORY PROGRAM ANNOUNCEMENT NUMBER: LAB 19-2119  
DOE/NATIONAL LABORATORY PROGRAM ANNOUNCEMENT NUMBER: LAB 19-2119

*Data streams faster than humans...  
...who have (only) partial knowledge...*

### Needed:

- Real-time data reduction
- AI/ML acquisition/automation
- Validating AI/ML predictions

SCIENTIFIC MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE: UNCERTAINTY QUANTIFICATION  
DOE/NATIONAL LABORATORY PROGRAM ANNOUNCEMENT NUMBER: LAB 19-2122

AFOSR:  
Topic 19: Machine Learning and Physics-Based Modeling and Simulation

*Incoming...Machine vs. Machine!*

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# NSF Future Manufacturing (NSF 20552)

**Why Future Manufacturing?**

- Worldwide competition in manufacturing has emphasized maturation, commoditization, and automation
- Next generation of manufacturing will require new materials, devices, systems, processes, machines, design methods, social structures, and business practices

**Future Manufacturing areas of interest**

- Three targeted thrust areas in FY 2020:

Health University, Richmond, VA

**STRATEGY FOR AMERICAN LEADERSHIP IN ADVANCED MANUFACTURING**  
A Report by the SUBCOMMITTEE ON ADVANCED-MANUFACTURING COMMITTEE ON TECHNOLOGY of the NATIONAL SCIENCE & TECHNOLOGY COUNCIL October 2018

**CYMANII** The Cybersecurity Manufacturing Innovation Institute

National Science Foundation WHERE DISCOVERIES BEGIN

LED By The University of Texas San Antonio (UTSA), CyManII is an inclusive national institute with over 40 member organizations from across the country. CyManII's mission is to develop and demonstrate technologies leading the nation in advanced manufacturing, robotics, cybersecurity, and industrial control systems and physical infrastructure. CyManII's partners include Battelle, Sandia National Laboratory, Los Alamos National Laboratory, and the University of Texas at Austin. CyManII's research focus is on the development of technologies for the digital transformation that will continue to propel U.S. innovation in manufacturing for decades.

VCU part of \$111M cybersecurity manufacturing partnership

"VCU and its Cybersecurity Center will play a strategic role in cybersecurity and securing automation within the CyManII initiative," Marin said. "This unique set of our center's talents enable us to continue demonstrating leadership in the field in the nation."

VCU Cybersecurity Center will provide advanced expertise in securing automation as part of a new Department of Defense manufacturing public-private partnership through the 10-year Department of Energy GridWise Project.

VCU President, Dr. Michael Rao, a member of CyManII, announced in the VCU College of Engineering, he is transitioning to a new position.

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## Current trends...(keeping operator in the loop) AI Augmentation for Trustworthy AI

- **Hardware:**
  - Universal Robots CB-Series **UR5 robot** with standard controller
  - Die **grinder** as end effector
  - 6-axis **force sensor** mounted to the wrist
  - Two stereo GigE cameras for **stereoscopic** visualization; Three Intel RealSense D435i cameras for **point-cloud** acquisition;
  - Microphone
- **Augmented AI:** AI technologies working alongside humans
  - + Improve productivity, efficiency, quality of human activities, and enhance human-machine cognition
  - + Build trust

**D. L. Marino et al., "AI Augmentation for Trustworthy AI: Augmented Robot Teleoperation," 2020 13th International Conference on Human System Interaction (HSI), Tokyo, Japan, 2020, doi: 10.1109/HSI49210.2020.9142659.**

**Fly by AI**

Fig. 5. Testbed

**From rule driven to AI driven**

Fig. 6. Input Device

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## Surgeries

Surgeries require:

- Surgeon experience
- Muscle memory
- High precision
- Critical tool maneuvers

Bottom line...training of surgeons is **crucial**

- Typically:
  - Apprenticeship (slow)
  - Cadavers (expensive, anatomical distortion)

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## Physics Enhanced Data-Driven Models with Variational Gaussian Processes

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**ABSTRACT**  
 Centuries of development in natural sciences and mathematical modeling provide valuable domain expert knowledge that has yet to be explored for the development of machine learning models. When modeling complex physical systems, both domain knowledge and data provide necessary information about the system. In this paper, we present a data-driven model that takes advantage of partial domain knowledge in order to improve generalization and interpretability. The presented approach, which we call EVGP (Explicit Variational Gaussian Process), has the following advantages: 1) using available domain knowledge to improve the assumptions (inductive bias) of the model, 2) scalability to large datasets, 3) improved interpretability. We show how the EVGP model can be used to learn system dynamics using basic Newtonian mechanics as prior knowledge. We demonstrate how the addition of prior domain-knowledge to data-driven models outperforms purely data-driven models.

**INDEX TERMS** Bayesian Neural Networks, Domain Knowledge, Gaussian Process, Uncertainty, Variational Inference.

*D. L. Marino, M. Manic, "Physics Enhanced Data-Driven Models with Variational Gaussian Processes", IEEE Open Journal of the Industrial Electronics Society, DOI: 10.1109/OJIES.2021.3064820, <https://arxiv.org/abs/1906.02160>*

FIGURE 3: Diagrams of physical systems considered

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# ResNet Autoencoders for Unsupervised Feature Learning from High-Dimensional Data: Deep Models Resistant to Performance Degradation

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**ABSTRACT** Efficient modeling of high-dimensional data requires extracting only relevant dimensions through feature learning. Unsupervised feature learning has gained tremendous attention due to its unbiased approach, no need for prior knowledge or expensive manual processing, and ability to handle exponential data growth. Deep Autoencoder (AE) is a state-of-the-art deep neural network for unsupervised feature learning, which learns embedded-representations using a series of stacked layers. However, as the AE network gets deeper, these learned embedded-representations can deteriorate due to vanishing gradient, leading to performance degradation. This paper presents ResNet Autoencoder (RAE) and its convolutional version (C-RAE) for unsupervised feature learning. The advantage of RAE and C-RAE is that it enables the user to add residual connections for increased network capacity without incurring the cost of degradation for unsupervised feature learning compared to standard AEs. While RAE and C-RAE inherit all the advantages of AEs, such as automated non-linear feature extraction and unsupervised learning, they also allow users to design larger networks without adverse effects on feature learning performance. We performed classification on learned embedded-representation to evaluate RAE and C-RAE. RAE and C-RAE were compared against AEs on MNIST, Fashion MNIST, and CIFAR10 datasets. When increasing the number of layers, C-RAE outperformed AE by showing significantly lower performance degradation of classification accuracy (less than 3%) compared to AE (33% to 65%). Further, C-RAE exhibited higher mean accuracy and lower variance of accuracy than standard AE. When comparing RAE and C-RAE with widely used feature learning methods (Convolutional AE, PCA, ICA, LLE, Factor Analysis, and SVD), C-RAE showed the highest accuracy.

*Chathurika Wickramasinghe, Daniel Marino, Milos Manic, "ResNet Autoencoders for Unsupervised Feature Learning from High-Dimensional Data: Deep Models Resistant to Performance Degradation", IEEE Access, March 2021. DOI: 10.1109/ACCESS.2021.3064819*

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# Modeling and Planning Under Uncertainty Using Deep Neural Networks

Daniel L. Marino  and Milos Manic , Senior Member, IEEE

- Control of underactuated systems: modeling and open-loop planning.**
  - Fully actuated – controls which matured on rigid robotic arms in structured factory environments; Underactuated robotics focuses on control systems which use the natural dynamics of the machines in an attempt to achieve extraordinary performance (speed, efficiency, robustness); Open loop – non-feedback controller
  - Deep Bayesian neural networks (DBNN) for accurate long-term estimations
  - The accuracy of the learned stochastic model allowed us to plan completely offline and execute the trajectory in open loop.
  - Approach allows to move all computationally expensive optimizations offline and make the presented approach applicable in real-world scenarios.

*Daniel Marino, Milos Manic, "Modeling and Planning under Uncertainty using Deep Neural Networks" in IEEE Transactions on Industrial Informatics, May 2019, DOI: doi: 10.1109/TII.2019.2917520*

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## Good bias vs. Bad bias

**Problem:** Control and manage unaccounted for and unwanted bias in AI

- Inherent AI bias negatively affects AI decision making process
- Bias may lead to
  - Unfairness (loan, credit card applications, autonomous cars, advertising)
  - Damaging interaction between humans and machines
  - Distrust in AI
  - Extensive damage to people and property

**Good, bad, or biased: AI is learning our actual selves.**

*The Engine*, June 2020



**Robotic Judges likely to arrive by 2070**  
Passionate In Analytics, Oct.2020

## Learning of Agents...

## Learning of Agents

### An agent is learning...

- *after making observations about the world*
- *world (data, examples, scenarios)*
- *if it improves its performance*

*• How to measure performance improvement?*

### Forms (types) of learning

- Major factors of learning:
  1. *Which component is to be improved*
  2. *What prior knowledge the agent already has*
  3. *What representation used for data and component*
  4. *What feedback is available to learn from*

## Learning of Agents

### Forms (types) of learning (cont.)

#### 1. Components to be learned

- *Direct mapping from current state conditions to actions*
- *Means to infer relevant properties of the world*
- *Information about the way the world evolves and results of actions*
- *Utility information indicating the desirability of world states*
- *Action-value information indicating the desirability of actions*
- *Goals that describe classes of states which maximize agent's utility*

*(An example of learning to drive)*

## Learning of Agents

Forms (types) of learning (cont.)

**2. Prior knowledge** and representation

- *Propositional and first order logical sentences;*
- *Bayesian networks*
- *Inductive learning*
- *Analytical or deductive learning*

**3. Feedback** to learn from

- *Unsupervised (such as clustering)*
- *Reinforcement learning*
- *Supervised learning*
- *Semi-supervised learning*
- *(how does the same example of learning to drive relate?)*

## Electrical Properties of Nerves

- Nerves – a biological aspect
- All-or-nothing nature of nerve signals
- More on neurons

## Electrical Properties of Nerves

### Nerves – a biological aspect

- 19<sup>th</sup> century – electrical nature of nerve actions

How does brain communicate with muscles?

- Neural signals in body electrical in nature!

• The nerves can be:

- **efferent nerves**, or motor nerves
  - from spinal cord or brain (nervous centers) to muscles
- **afferent nerves**, or sensory, receptor nerves
  - from muscles (and glands) to nervous centers
  - indicate muscle stretch, touch, pain, warmth, sound, smell, sight, pressure, chemical composition, and other “senses”

## Electrical Properties of Nerves

### All-or-nothing nature of nerve signals

- stretch the muscle!
- when reaches a lower limit (threshold), attached nerve sends a signal
- amount of elongation signaled by the current (flow of electricity)!

### Signal

- series of pulses
- sudden jump, then gradually to zero
- all this in 1/1000 of a second

### Extent of stretching?

- manifested only by the higher frequency of pulses
- **the duration and the amplitude stays the same!**

## Electrical Properties of Nerves

### All-or-nothing nature of nerve signals

Again, the extent of stretching?

- manifested only by the higher frequency of pulses
- the duration and the amplitude stays the same!

Properties of these signals:

- **saturation**
  - upper limit of frequency of pulses
  - above certain point, no further change in the signal propagated
- **threshold**
  - they do not respond until the strength of the stimulus exceeds certain minimum value

*Like an on-off switch!*

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## Electrical Properties of Nerves

### More on neurons

**Body**

- 2-3 feet long, 1/100 of an inch in diameter

**Brain**

- 1/1000 of an inch in diameter maximum dimension

**Interneurons (internuncial)**

- connecting receptor and effector neurons

**Number of neurons:**

- **total number:**  $10 \times 10^9$  (ten billion)
- **interneurons:**  $9 \times 10^9$  (nine billion)

Typically, several neurons excite “receiving” neuron

*The body of receiving neuron acts as a “summing amplifier”*

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## Things to remember...

- Form teams asap
  - *populate in [google document](#)*
- Exam dates
  - “*save the date*” in your calendars now!
- Consider writing the class paper
  - *Great experience and can be used of topics!*
- Intelligence?
  - *The ability to learn!*
  - *Powerful (but with great power comes great responsibility)*
- Three “types” of learning
  - *unsupervised, supervised, and semi-supervised*
- Some “hot” topics in AI
  - *Physics enhanced data driven techniques*
  - *Uncertainty modeling and propagation*
  - *Trust in AI, explainable AI (XAI), ethics, biased AI*
  - *Enhancing unsupervised techniques with lessons learned from supervised*

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## Things to remember (cont.)...

- Types of nerves
  - *three types: sensory, motor, and interneurons (connecting)*
  - *9 out of 10 are interneurons*
- Nature of nerve signals
  - *electrical (well, chemical as well)*
  - *like an on-off switch (all-or-nothing nature)*
  - *series of pulses – intensity manifested by their frequency*
- Lower and upper “limit”
  - *saturation (cannot transmit value higher than that)*
  - *lower limit (threshold) – nothing gets transmitted below it*

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