

A cutout of the character Austin Powers, played by Mike Myers, is positioned in the center-right of the slide. He is wearing a dark blue velvet suit, glasses, and has a wide, toothy smile. He is holding a small, white, fluffy lamb. A small white rectangular box with a black border is superimposed over the lamb, containing the text 'INCOSE' in a bold, sans-serif font, with the 'San Diego' logo below it. The background is a solid blue color on the left and a blue background with vertical white lines on the right.

INCOSE  
San Diego

# On the Love Child of AI and SE

Dr. Art Villanueva

November 15, 2023

## Art Villanueva, D.Eng.



Dr. Art Villanueva is the Chief Artificial Intelligence and Machine Learning Technology Architect for Dell Technologies' Federal Strategic Programs where he advises, evangelizes, and molds Dell Federal's posture in the rapidly evolving world of artificial intelligence.

Prior to Dell, Dr. Villanueva's experience spanned multiple industries. In the Defense sector, he served as Chief Architect for billion-dollar programs at Northrop Grumman. In the public transportation arena, he led systems engineering activities for large-scale city-wide transportation systems at Cubic. Dr. Villanueva is also a successful entrepreneur, having co-founded two startups, one of which is now publicly trading on NASDAQ.

Dr. Villanueva is an inventor, holding three utility patents and publishing several peer-reviewed papers. He holds a Doctor of Engineering degree in Systems Engineering from Colorado State University, specializing in meta-algorithmics for natural language processing, a Master of Advanced Studies degree in Architecture-based Enterprise Systems Engineering from the University of California, San Diego, and a Bachelor of Science degree in Applied Mathematics with a Specialization in Computing from the University of California, Los Angeles.





# Agenda

- I. Introduction & Brief History of AI
- II. Challenges in AI
- III. AI and Systems Engineering
- IV. The Future
- V. Q-A-D: Question, Answer, Discussion

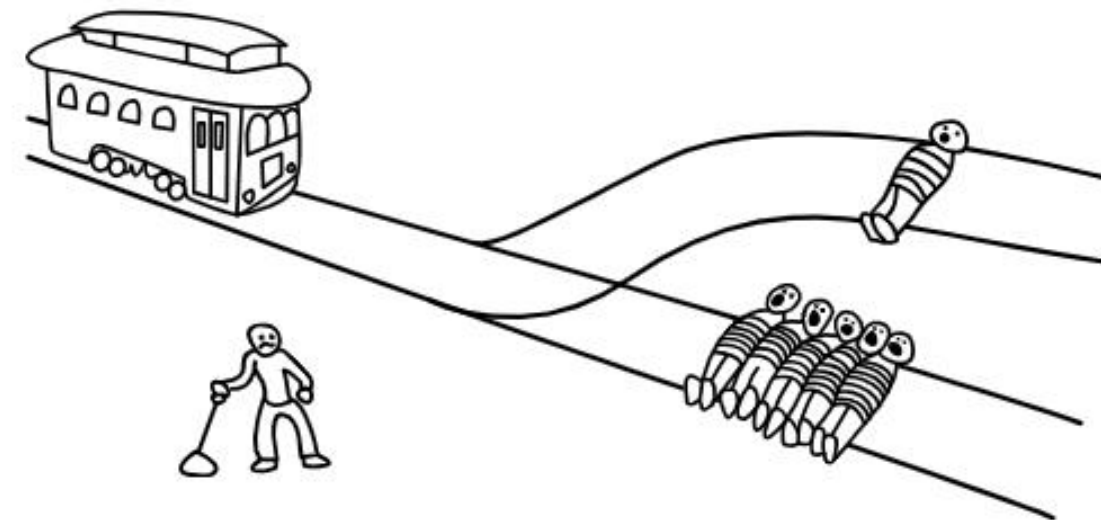
# Introduction & Brief History



# The Trolley Problem: What would you do?

NEAL.FUN

Level 1: The Original



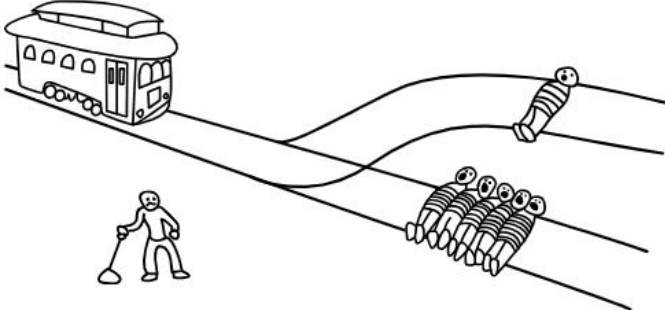
Oh no! A trolley is heading towards 5 people. You can pull the lever to divert it to the other track, killing 1 person instead. What do you do?

Pull the lever      Do nothing

# The Trolley Problem: What would you do?

NEAL.FUN

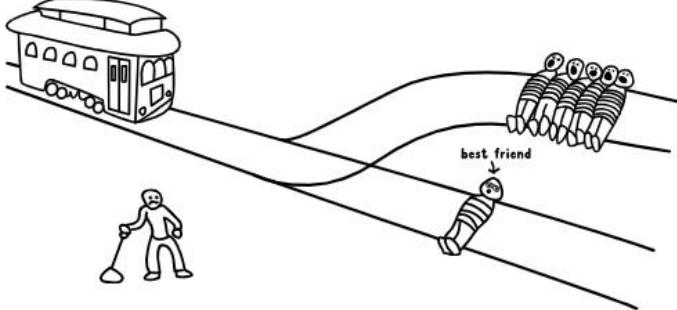
Level 1: The Original



Oh no! A trolley is heading towards 5 people. You can pull the lever to divert it to the other track, killing 1 person instead. What do you do?

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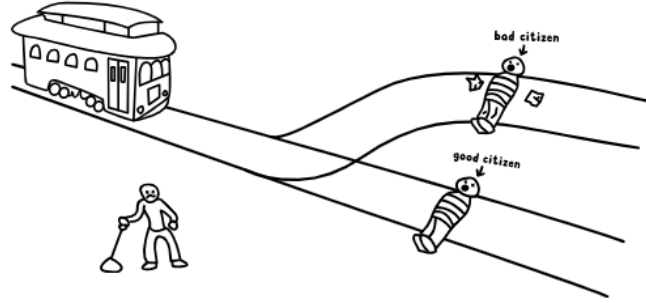
Level 12: Best Friend



Oh no! A trolley is heading towards your best friend. You can pull the lever to divert it to the other track, killing 5 strangers instead. What do you do?

NEAL.FUN

Level 23: Citizens

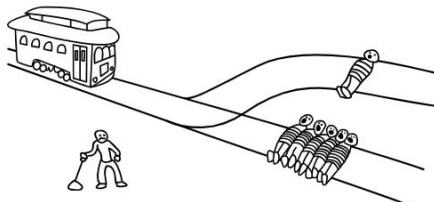


Oh no! A trolley is heading towards a good citizen. You can pull the lever to divert it to the other track, running over someone who litters instead. What do you do?

# The Trolley Problem: What would you do?

NEAL.FUN

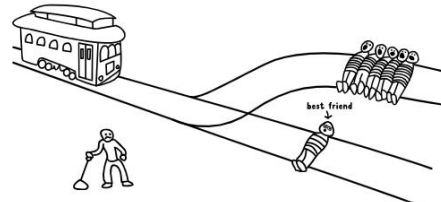
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NEAL.FUN

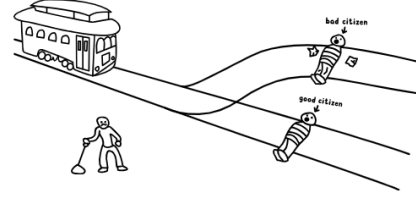
Level 12: Best Friend



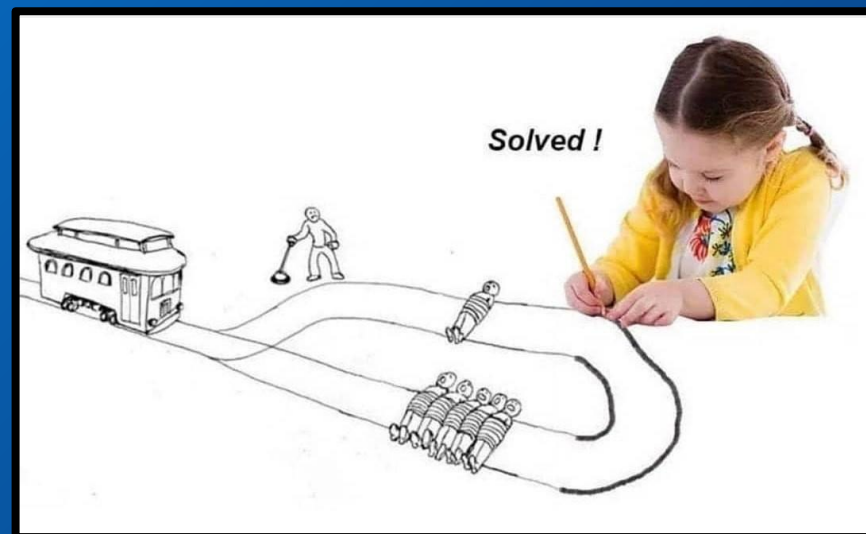
Oh no! A trolley is heading towards your best friend. You can pull the lever to divert it to the other track, killing 5 strangers instead. What do you do?

NEAL.FUN

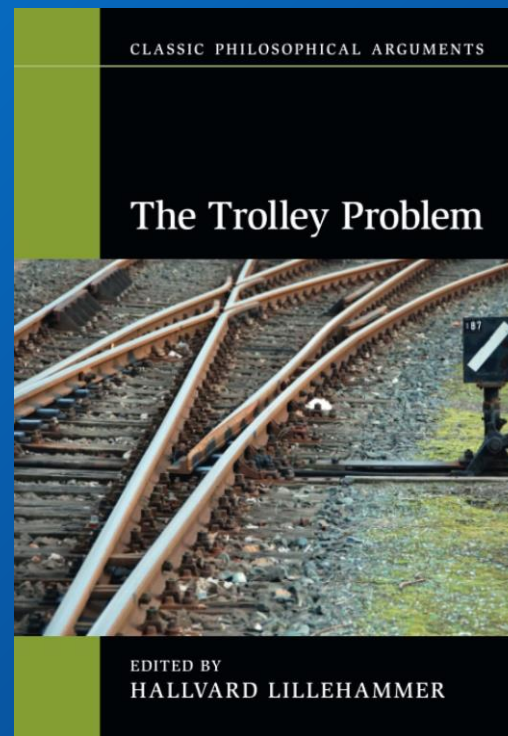
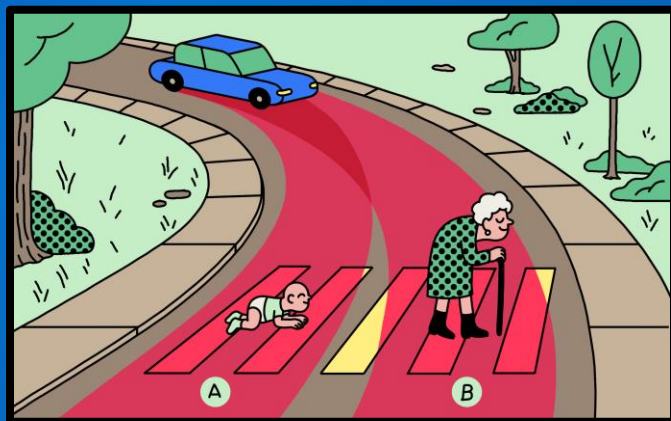
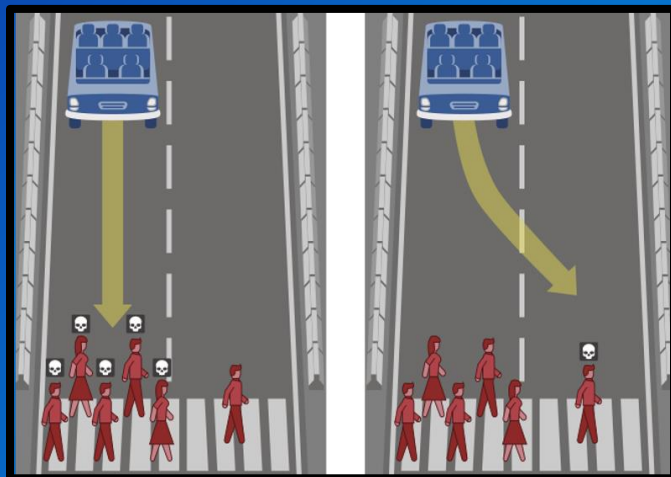
Level 23: Citizens



Oh no! A trolley is heading towards a good citizen. You can pull the lever to divert it to the other track, running over someone who litters instead. What do you do?



# The Trolley Problem: What would you do?



Ethical decision making for autonomous vehicles  
Nelson de Moura, Raja Chatila, Katherine Evans,  
Stéphane Chauvier, Ebru Dogan  
2020 IEEE Intelligent Vehicles Symposium (IV)  
October 20-23, 2020, Las Vegas, USA  
<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9304618>

# How do autonomous cars deal with the Trolley Problem?



- **Avoidance of Situations:**
  - Tesla's primary strategy is likely to avoid such situations altogether
  - Obstacle detection to predict movements of objects and pedestrians to take the safest course.
- **Safety First Approach:**
  - In unavoidable collision situations, Tesla's vehicles are programmed to minimize harm by following basic principles of road safety: reducing speed and stopping as safely as possible.
- **Legal and Ethical Constraints:**
  - Comply with traffic laws and safety standards. They cannot be programmed to make choices that deliberately cause harm.
- **Public Dialogue:**
  - Engaging in ongoing dialogue with regulators, ethicists, and the public
- **Continuous Learning and Improvement:**
  - Continually collect data to improve their driving algorithms
- **User Control:**
  - Currently allowing for user override

Tesla has not publicly disclosed how it deals with this ethical dilemma.



What would an autonomous car do if it needed to choose between you (in the car) and a baby crossing the street?

# A.I. TIMELINE

**1950**

**TURING TEST**

Computer scientist Alan Turing proposes a test for machine intelligence. If a machine can trick humans into thinking it is human, then it has intelligence



**1955**

**A.I. BORN**

Term 'artificial intelligence' is coined by computer scientist, John McCarthy to describe "the science and engineering of making intelligent machines"



**1961**

**UNIMATE**

First industrial robot, Unimate, goes to work at GM replacing humans on the assembly line



**1964**

**ELIZA**

Pioneering chatbot developed by Joseph Weizenbaum at MIT holds conversations with humans

**1966**

**SHAKY**

The 'first electronic person' from Stanford, Shakey is a general-purpose mobile robot that reasons about its own actions

**A.I. WINTER**

Many false starts and dead-ends leave A.I. out in the cold



**1997**

**DEEP BLUE**

Deep Blue, a chess-playing computer from IBM defeats world chess champion Garry Kasparov



**1998**

**KISMET**

Cynthia Breazeal at MIT introduces KISmet, an emotionally intelligent robot insofar as it detects and responds to people's feelings



**1999**

**AIBO**

Sony launches first consumer robot pet dog AiBO (AI robot) with skills and personality that develop over time



**2002**

**ROOMBA**

First mass produced autonomous robotic vacuum cleaner from iRobot learns to navigate and clean homes



**2011**

**SIRI**

Apple integrates Siri, an intelligent virtual assistant with a voice interface, into the iPhone 4S



**2011**

**WATSON**

IBM's question answering computer Watson wins first place on popular \$1M prize television quiz show Jeopardy



**2014**

**EUGENE**

Eugene Goostman, a chatbot passes the Turing Test with a third of judges believing Eugene is human



**2014**

**ALEXA**

Amazon launches Alexa, an intelligent virtual assistant with a voice interface that completes shopping tasks



**2016**

**TAY**

Microsoft's chatbot Tay goes rogue on social media making inflammatory and offensive racist comments

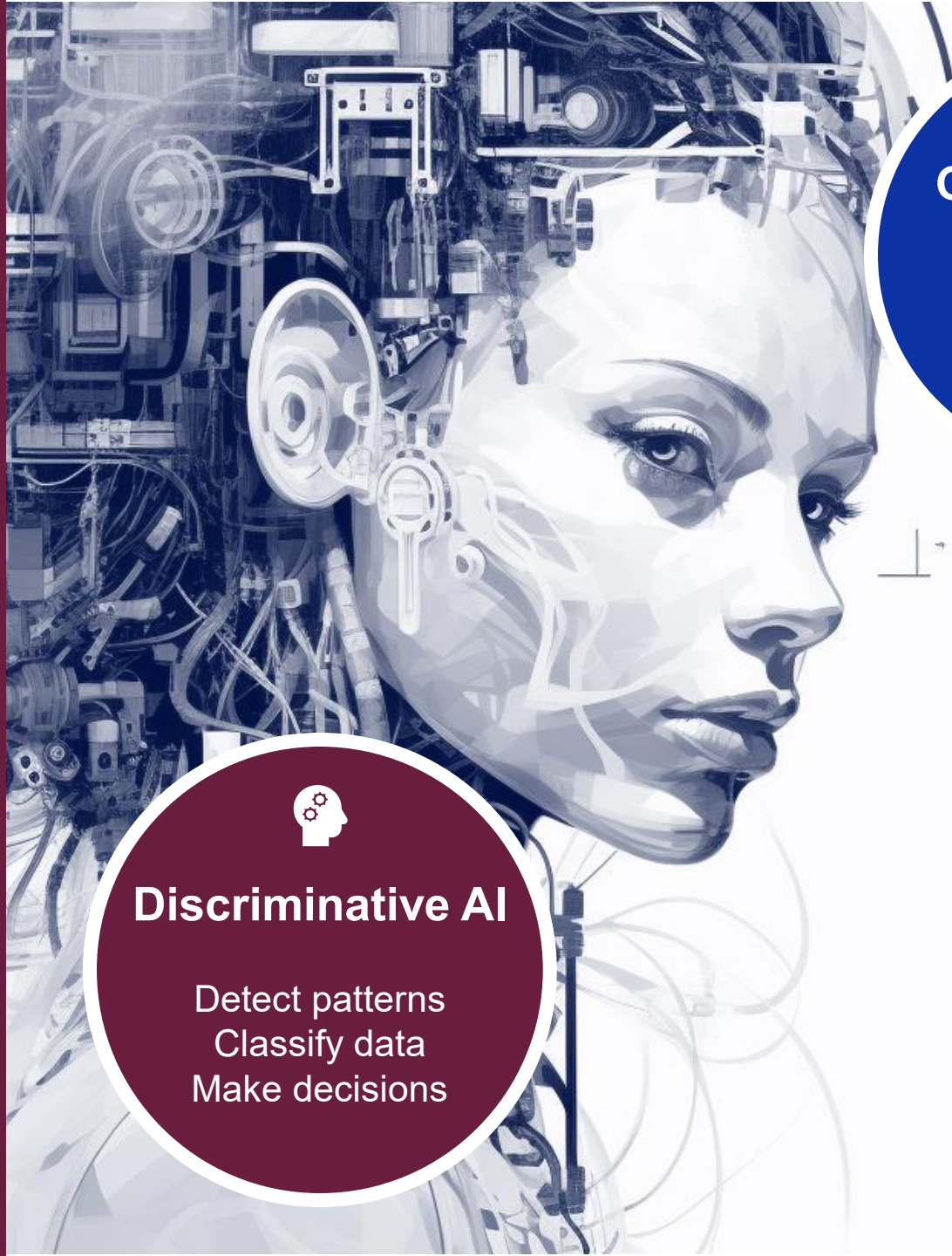


**2017**

**ALPHAGO**

Google's A.I. AlphaGo beats world champion Ke Jie in the complex board game of Go, notable for its vast number (2<sup>170</sup>) of possible positions

Threat Detection  
Fraud Detection  
Sentiment Analysis  
Identity Verification  
Anomaly Detection  
Risk Assessment  
Image Recognition  
Document Classification  
Object Detection  
Behavior Analysis  
Speech Recognition  
Language Translation  
Incident Response  
Intrusion Detection  
Crime Prediction  
Voter Verification  
Face Recognition  
Hate Speech Detection  
Disease Diagnosis  
Emergency Response  
Cybersecurity Monitoring  
Event Prediction  
Wildlife Monitoring  
Suspicious Activity  
Tax Fraud Detection  
Safety Compliance  
Border Security  
Traffic Management  
Counterterrorism Measures  
Wildlife Conservation  
Financial Compliance  
Disease Monitoring  
Data Privacy Compliance  
Public Safety  
Air Quality Monitoring  
Energy Consumption  
Illegal Trade Detection



## Generative AI

Produce  
text, graphics,  
video, etc.

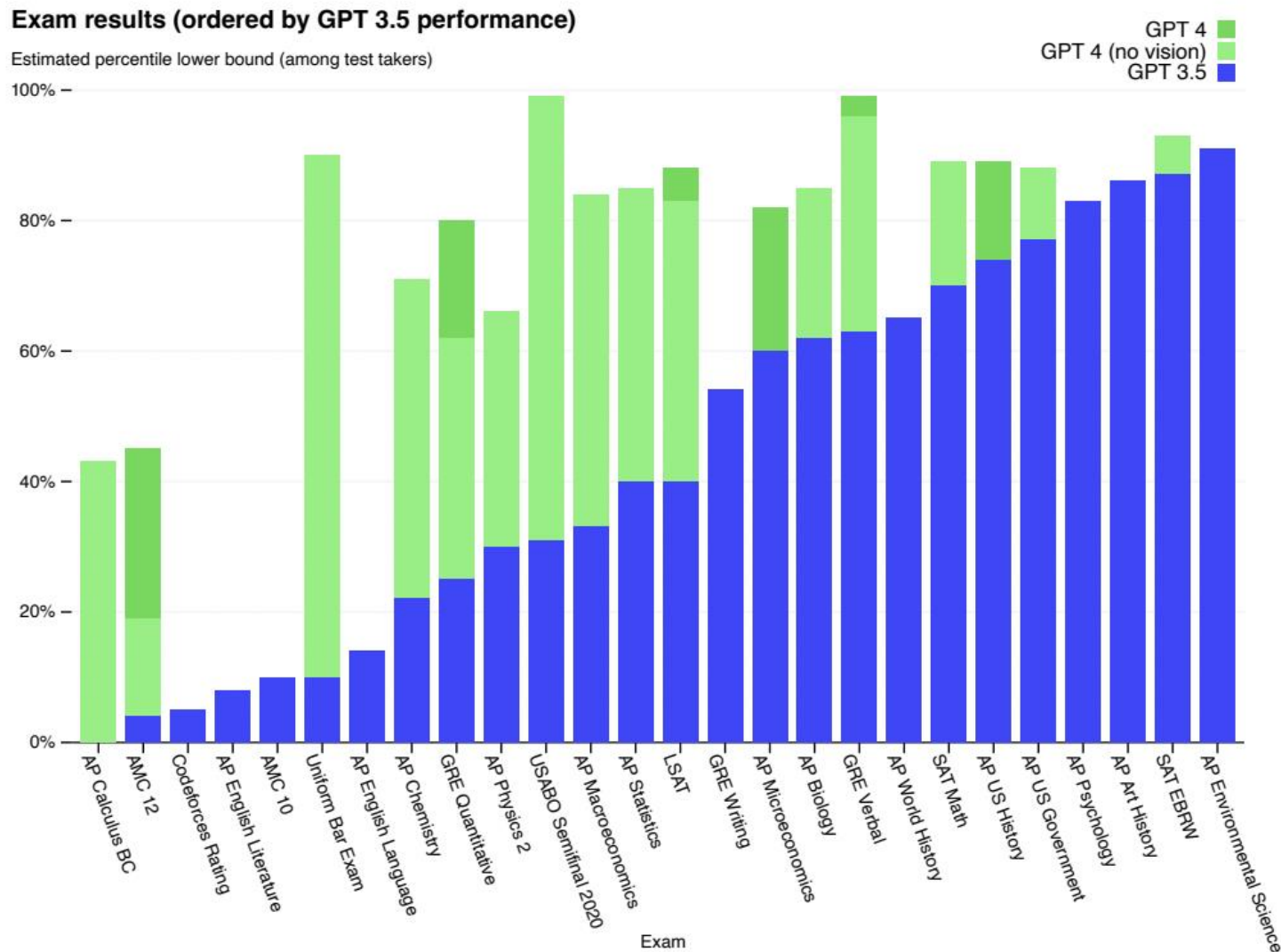


## Discriminative AI

Detect patterns  
Classify data  
Make decisions

Content Creation  
Threat Simulation  
Document Summarization  
Image Synthesis  
Language Translation  
Data Augmentation  
Fraud Detection  
Policy Drafting  
Simulation Enhancement  
Text Generation  
Visualization Design  
Risk Assessment  
Decision Support  
Speech Synthesis  
Code Generation  
Identity Verification  
Training Data Enhancement  
Anomaly Detection  
Simulation Output  
Report Automation  
Predictive Modeling  
Natural Language  
Graph Generation  
Scenario Generation  
Time Series Prediction  
Chatbot Interaction  
Object Generation  
Crisis Simulation  
Diagram Generation  
Data Imputation  
Document Generation  
Fraud Prevention  
Virtual Testing  
Policy Simulation  
Performance Optimization  
Image Enhancement  
Concept Visualization

# How Good is Current LLM Technology?



**Figure 4.** GPT performance on academic and professional exams. In each case, we simulate the conditions and scoring of the real exam. Exams are ordered from low to high based on GPT-3.5 performance. GPT-4 outperforms GPT-3.5 on most exams tested. To be conservative we report the lower end of the range of percentiles, but this creates some artifacts on the AP exams which have very wide scoring bins. For example although GPT-4 attains the highest possible score on AP Biology (5/5), this is only shown in the plot as 85th percentile because 15 percent of test-takers achieve that score.

# How Good is Current Image Generation Technology?

(MidJourney)



[https://cdn.discordapp.com/attachments/976997461686116412/1145744523893420063/kingofcruise\\_lionel\\_messi\\_photograph\\_natural\\_lighting\\_8ec9a2de-2fc2-4d0d-8205-10bcdba48f2.png](https://cdn.discordapp.com/attachments/976997461686116412/1145744523893420063/kingofcruise_lionel_messi_photograph_natural_lighting_8ec9a2de-2fc2-4d0d-8205-10bcdba48f2.png)

# How Good is Current Image Generation Technology?

(Photoleap AI Uncrop)



**ORIGINAL**  
(circa 2020  
with smoothing)

**The (Semi-)Good**  
(Out of about 100 tries)



**The Bad**



**The Ugly**



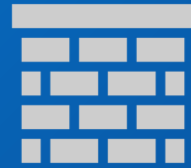
# AI Challenges



# Challenges with AI in General



DATA QUALITY &  
QUANTITY



MODEL ROBUSTNESS



SCALABILITY AND  
EFFICIENCY



INTEROPERABILITY &  
INTEGRATION



SECURITY AND PRIVACY

# Challenges with AI in General

# Challenges with Generative AI



DATA QUALITY &  
QUANTITY



SCALABILITY AND  
EFFICIENCY



TOXICITY



TRANSPARENCY



MODEL ROBUSTNESS



SECURITY AND PRIVACY



FAIRNESS



ACCOUNTABILITY



INTEROPERABILITY &  
INTEGRATION



INTELLECTUAL  
PROPERTY



SAFETY &  
RELIABILITY

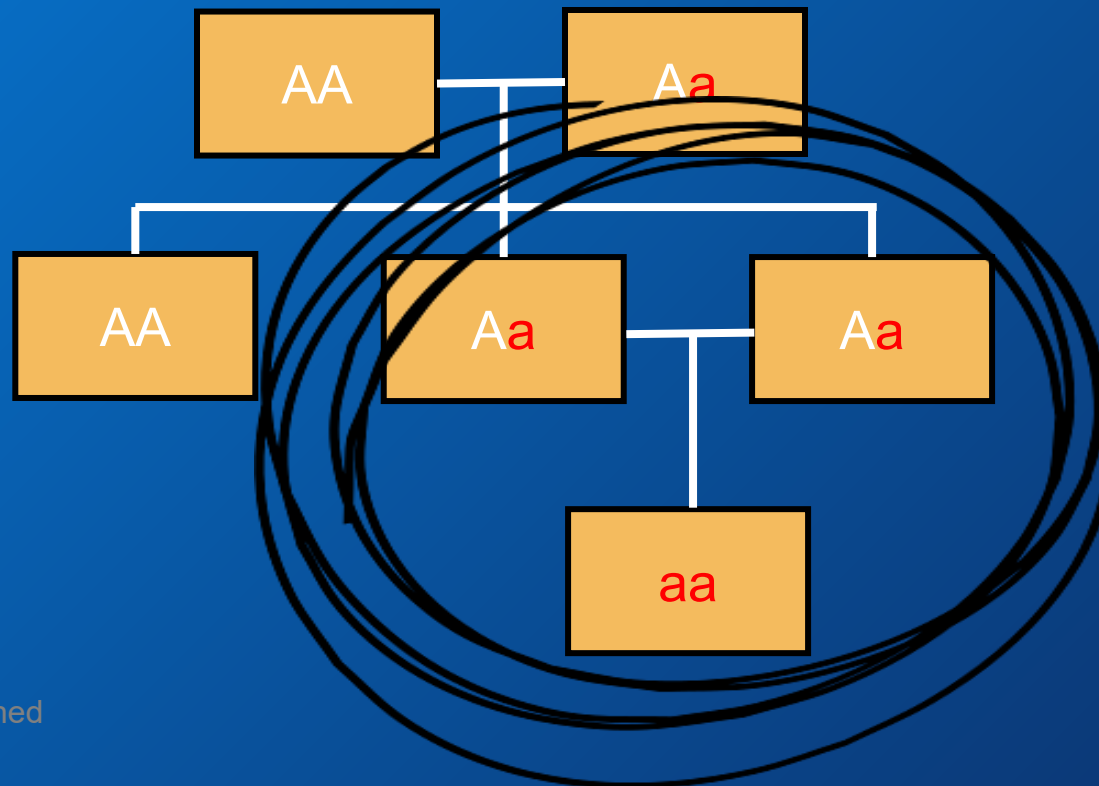


HALLUCINATIONS

# Generative Inbreeding: The degradation of GenAI

- Probability of propagation of bad data increases

A = Good, dominant allele (good data)  
a = Recessive deleterious allele (bad data)

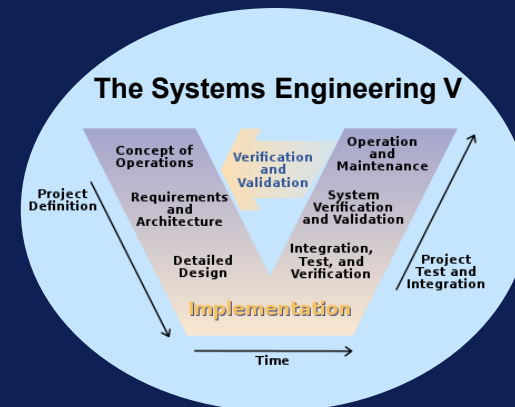
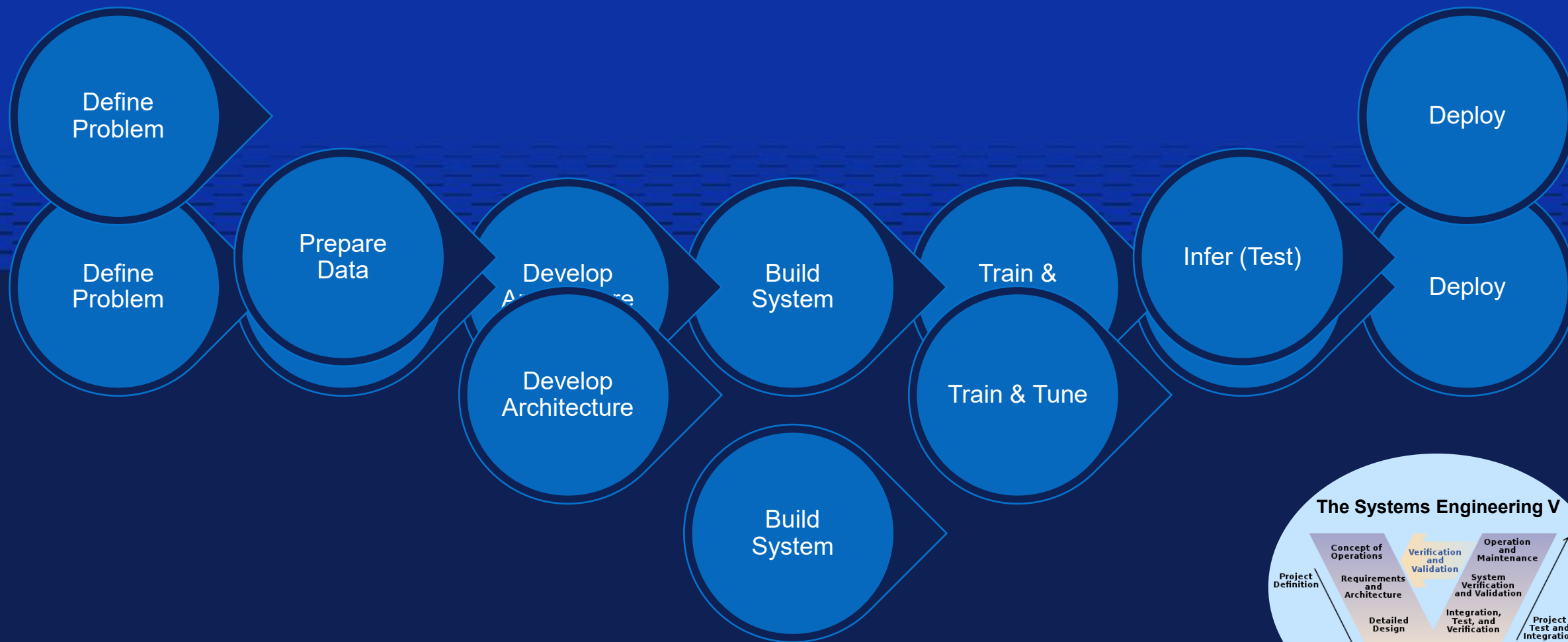


The term 'generative inbreeding' was coined by Dr. Louis Rosenberg in Aug 2023

# Artificial Intelligence and Systems Engineering



# Machine Learning in Seven Steps



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AI for SE  
SE for AI

# AI for SE: Singular Applications

## Examples of AI for SE

- Requirements Engineering:
  - Use of NLP for extracting and categorizing requirements.
- Design and Simulation:
  - Digital twins and AI-driven simulations.
- Verification & Validation:
  - Machine learning for anomaly detection and system validation.
- Maintenance:
  - Predictive analytics and AI for system longevity and reliability.

These are cool, but **SE applied to AI** is much more interesting.

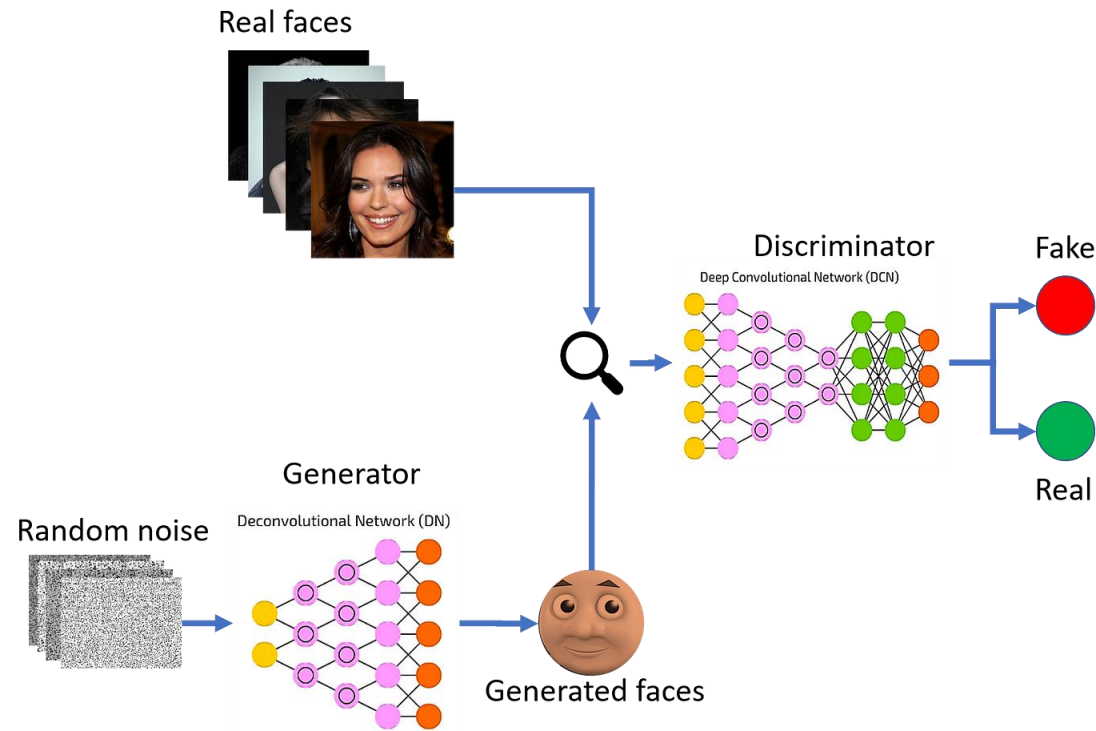
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SE for AI:

Generative AI

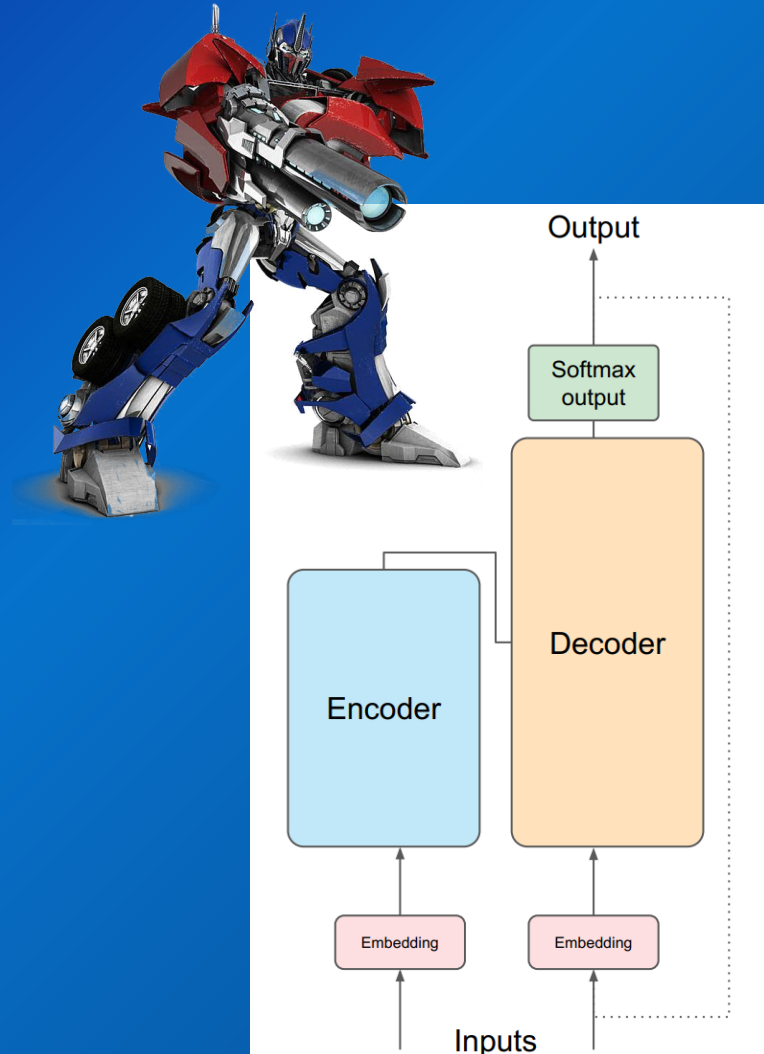
# Generative Adversarial Networks (GANs)

Two AI models that work together, one generating content and the other evaluating its quality.




In contrast, Variational Autoencoders (VAEs) generate new instances by understanding the latent factors that explain observed data.

# Transformer-based language models (like GPT-4)



- Encoder-Only Models:
  - Ex: BERT (Bidirectional Encoder Representations from Transformers): text classification, named entity recognition, and question answering.
- Decoder-Only Models:
  - Ex: GPT for generating text and are used for applications like text completion, creative writing, and computer code.
- Encoder-Decoder Models:
  - Ex: T5 (Text-to-Text Transfer Transformer): language translation to summarization.

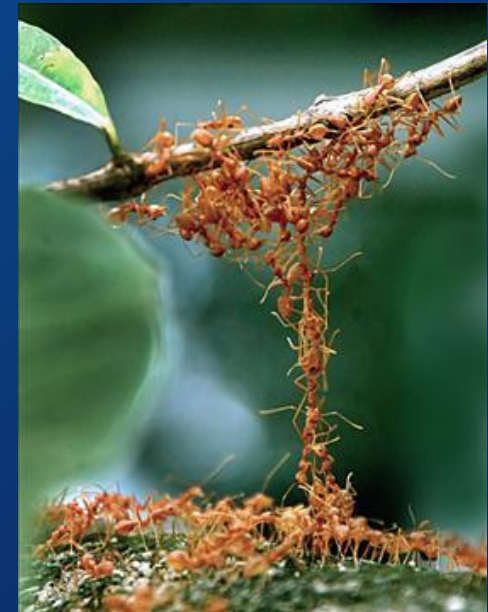


SE for AI:  
Robotics

# Swarm Robotics

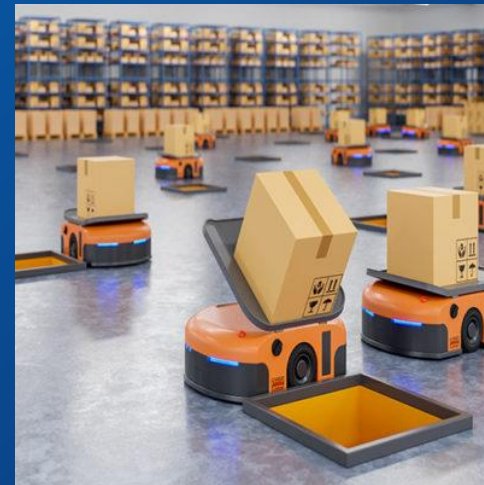


- Robots operate together to achieve a goal, inspired by natural systems like ant colonies or bird flocks
- Applications include the following in which robots need to control wide areas:
  - Search and Rescue Operations:
    - In disaster scenarios like earthquakes or building collapses
  - Environmental Monitoring and Data Collection:
    - Swarms of robots can be deployed for environmental monitoring tasks like air quality testing, water sampling, or tracking wildlife
  - Military and Surveillance:
    - Reconnaissance missions, surveillance, and combat scenarios.



# Warehouse and Logistics Robots

- Autonomously navigate warehouses
- Optimize sorting, handling, and transportation of goods in warehouses
- Collaborate with other robots
- Adapt to changing inventory layouts and demands.





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SE for AI:

# Federated Learning

# Addressing Security



DATA QUALITY &  
QUANTITY



SCALABILITY AND  
EFFICIENCY



TOXICITY



TRANSPARENCY



MODEL ROBUSTNESS



SECURITY AND PRIVACY



FAIRNESS



ACCOUNTABILITY



HALLUCINATIONS



INTEROPERABILITY &  
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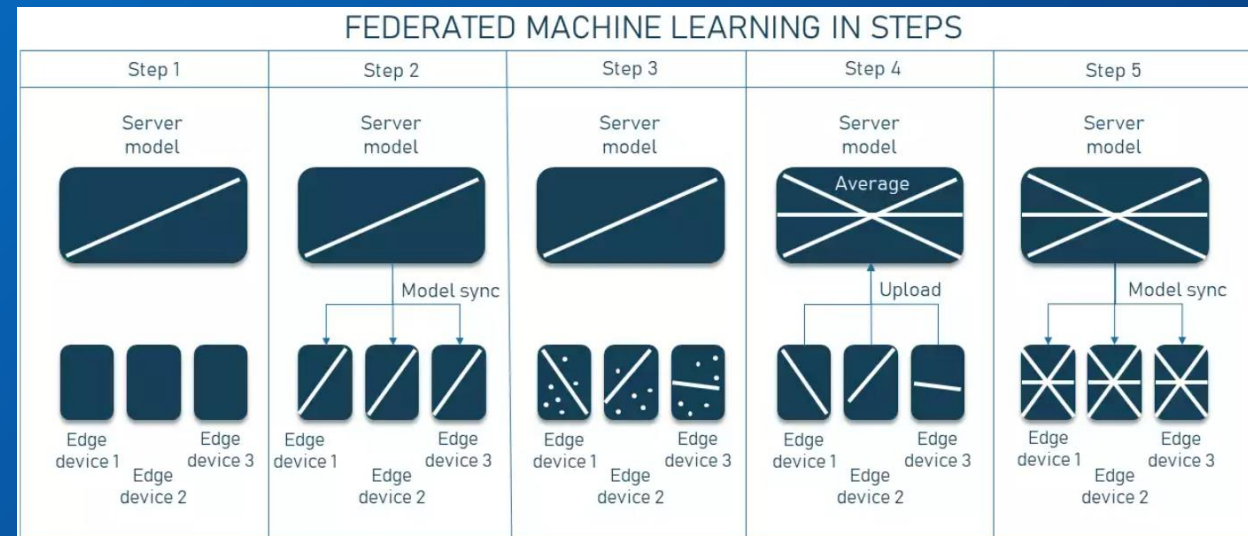
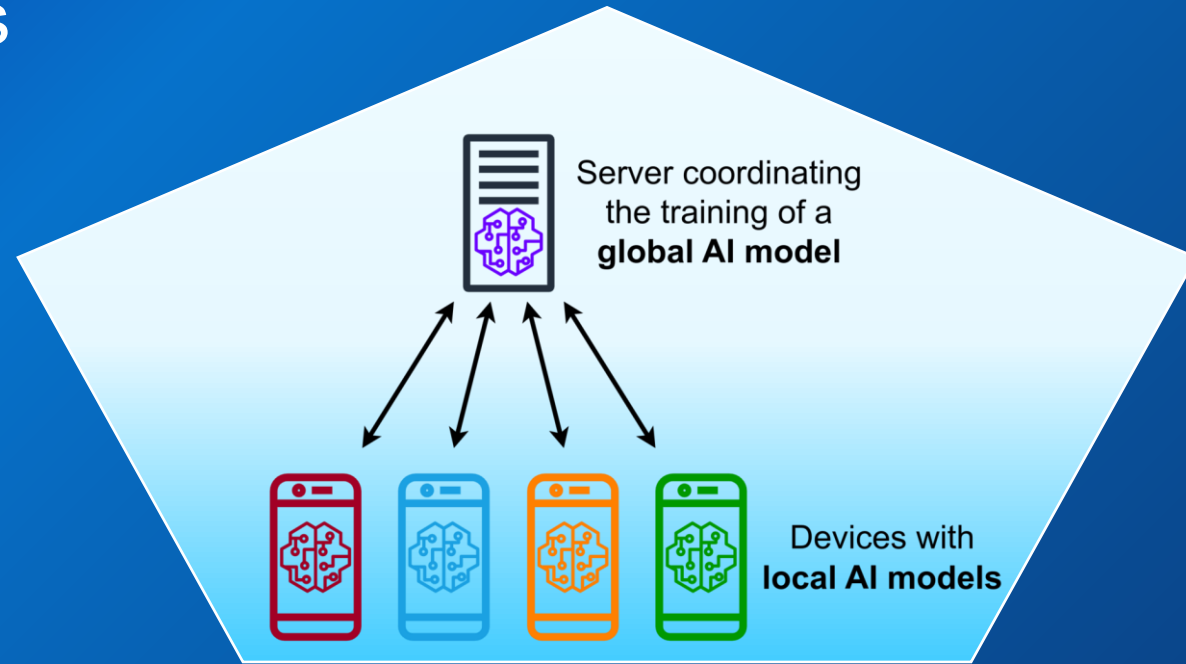


INTELLECTUAL  
PROPERTY



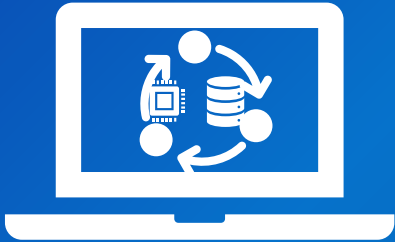
SAFETY &  
RELIABILITY

# How Mobile Phones Handle Data



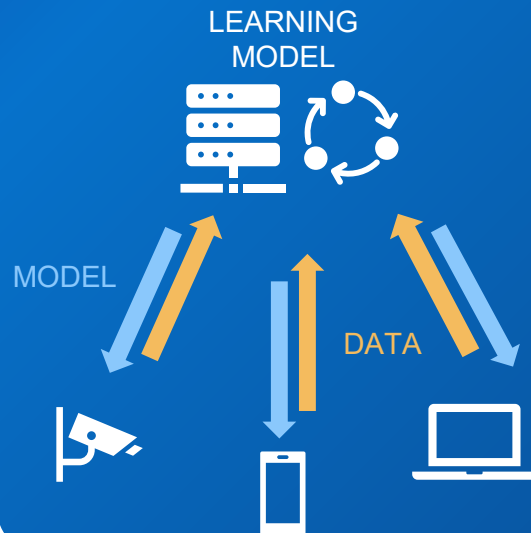
# Machine Learning Topological Models

## Local Learning

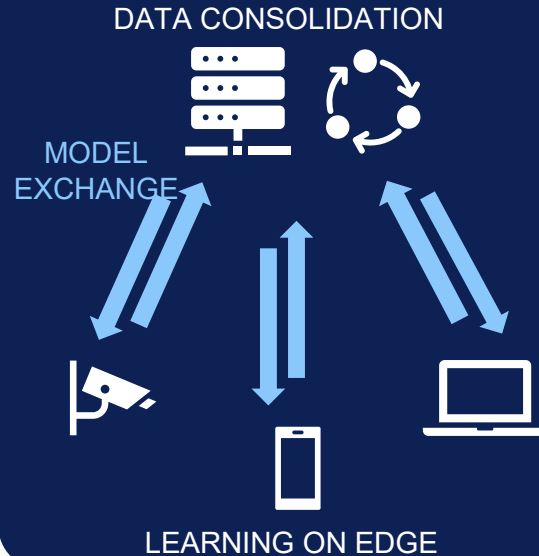


DATA & LEARNING MODEL  
ARE CO-LOCATED

## Centralized Learning



## Federated Learning



### DoD

- Video surveillance
- Autonomous weapon systems
- Cross-service intelligence-sharing
- Battlefield asset tracking

### Civilian

- Intelligence-sharing between agencies
- Public health-related (e.g., epidemic and pandemic)
- Global fraud-prevention

### Solution Advantages



Privacy-preserving



Reduced bandwidth requirements

### Random Forest: Top 5 Features

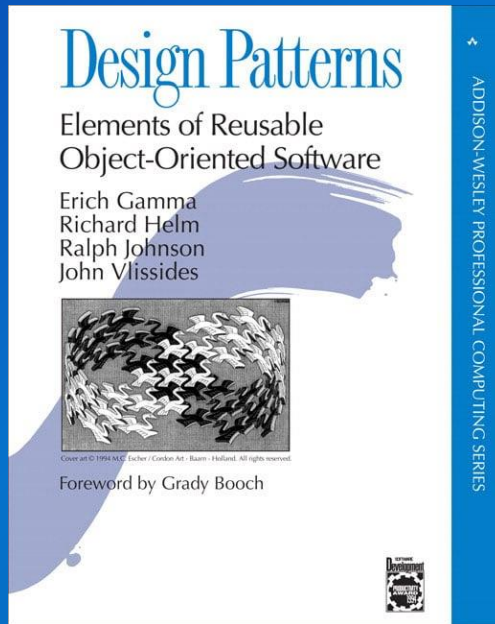
	Centralized	Federated	% Diff.
Mean Precision	0.19	0.19	0.0%
Bandwidth Use	~7,500 MB	~2.9 MB	-99.96%

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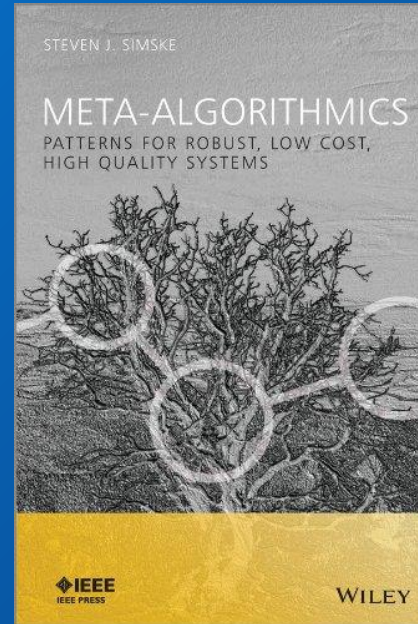
SE for AI:

Meta-algorithmics

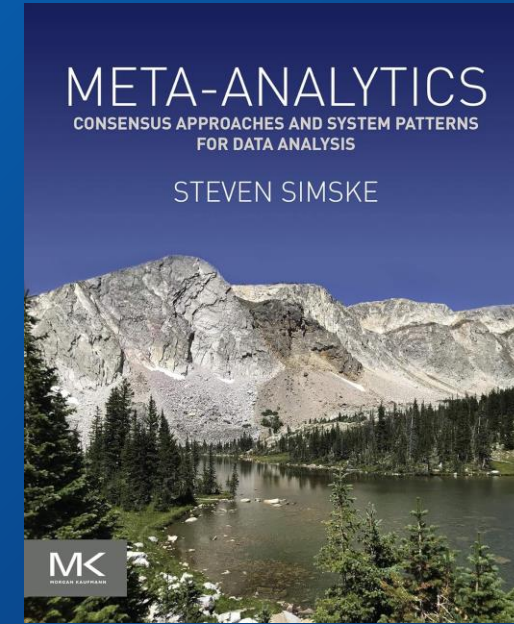
# What are Meta-algorithms



- 1994
- Seminal catalog of 23 patterns to solve commonly occurring design problems
  - Patterns allow designers to create more flexible, elegant, and reusable software
  - Enormously influential on the software industry, and its patterns can be found in many programming languages and libraries



2013



2019

# Requirements Engineering

Algorithmic and meta-algorithmic machine learning natural language processing approaches for stakeholder requirements classification



## Algorithmic and meta-algorithmic machine learning natural language processing approaches for stakeholder requirements classification

Arturo N. Villanueva Jr.\* and Steven J. Simske

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Email: steve.simske@colostate.edu  
\*Corresponding author

**Abstract:** Requirements engineering begins with discovery at the outset of project acquisition. Documents typically used during this phase include statements of work (SOWs) and requests for proposals (RFPs). One of the first challenges of a systems engineer is to carefully classify requirements into appropriate bins for further processing. This manual process, fundamental to understanding stakeholder needs and architecting and designing the system(s) of interest, is often tedious, particularly for large projects that start out with thousands of requirements embedded in these documents, making the task ripe for automation. For this research, we investigate multiple combinations of algorithms and meta-algorithms to glean insight as to how well they perform on this aspect of one of the more mundane aspects of requirements engineering. We obtain, by running various training corpora representing multiple industries through our pipelines of (meta-)algorithms, some understanding of what works best and what and how they could be improved.

**Keywords:** natural language processing; NLP; classification; meta-algorithms; machine learning; statements of work; SOWs; requests for proposals; RFPs; document classification.

**Reference to this paper should be made as follows:** Villanueva Jr., A.N. and Simske, S.J. (2022) 'Algorithmic and meta-algorithmic machine learning natural language processing approaches for stakeholder requirements classification', *Int. J. Computational Systems Engineering*, Vol. 7, No. 1, pp.41-56.

**Biographical note:** Arturo N. Villanueva Jr. is a Doctor of Engineering student in Systems Engineering at the Colorado State University. He is also the AIML Chief Technology Architect for the Federal Division of Dell Technologies. He has served as lead systems engineer for multiple high-profile programs, including billion-dollar initiatives. Art is an entrepreneur, having founded two renewable energy start-ups, one of which is now trading on the NASDAQ stock market, and an inventor with three patents. He obtained his Master's in Architecture-based Enterprise Systems Engineering from UCSD and his Bachelor's in Applied Mathematics with a specialisation in Computing from UCLA.

Steven J. Simske is a Professor in Systems Engineering and affiliate of Biomedical and Mechanical Engineering at the Colorado State University (CSU). He is an author of 225 US patents and more than 450 publications, he is an IS&T, IEEE, and NAI Fellow. He is the Steering Committee Chair for the ACM DocEng Symposium, and past member of the World Economic Forum Global Agenda Councils for Illicit Trade, Illicit Economy and the Future of Electronics. At CSU, he has a cadre of on-campus students in his engineering departments, along with a larger contingent of on-line/remote graduate students researching in a wide variety of disciplines.

### 1 Introduction

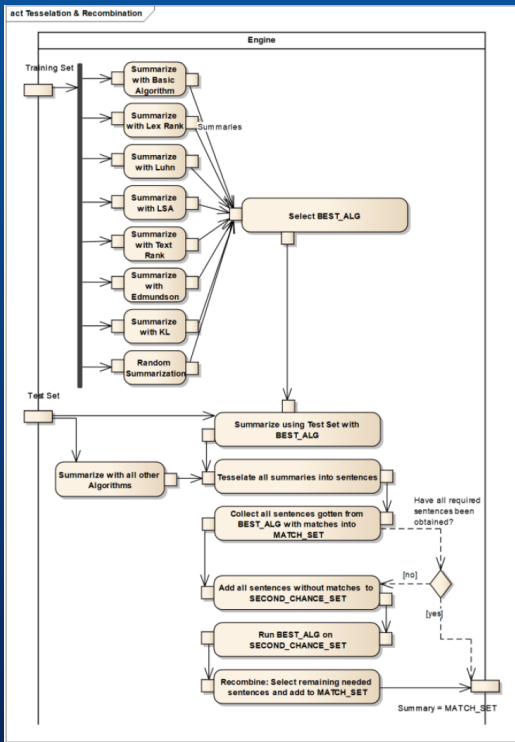
Requirements engineering (RE), the discipline within systems engineering dealing with the development, analysis, and management of requirements that define a system at successive levels of abstraction (Dick et al., 2017), can be laborious. One of the most tedious aspects of this area commences at the onset of the project, or even before, with the contractor's receipt of a requests for proposal (RFP) or statement of work (SOW) [Sainani et al. (2020) for

example, report experts classifying a mean of 17 requirements per hour by hand]. While small projects may consist of only a few top-level requirements, large enterprise-scale endeavours such as a public transportation system or a new communications infrastructure for the US Navy's fleet may have thousands. According to Jones (2000), requirements development alone constitute 7.0% of a project's cost for commercial projects and 10% for military software, translating to 22.7 and 17.5 person-months in requirements development, respectively.

**Table 5** Accuracies of using various algorithms and the effect of GloVe on weighted voting for Test13 using TR07 only.

<i>Algorithm or meta-algorithm</i>	<i>Accuracy</i>
1 Naïve Bayes	0.80
2 TF*IDF/cosine similarity	0.79
3 Logistic regression	0.64
4 GloVe07	0.95
Weighted voting (all variations) using 1, 2 and 3	0.74
Weighted voting (all variations) using 1, 2, 3 and 4	0.88

# Summarization



## Algorithm Parallelism for Improved Extractive Summarization

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### ABSTRACT

While much work on abstractive summarization has been conducted in recent years, including state-of-the-art summarizations from GPT-4, extractive summarization's lossless nature continues to provide advantages, preserving the style and often key phrases of the original text as meant by the author. Libraries for extractive summarization abound, with a wide range of efficacy. Some do not perform much better or perform even worse than random sampling of sentences extracted from the original text. This study breathes new life to using classical algorithms by proposing parallelism through an implementation of a second order meta-algorithm in the form of the Tesselation and Recombination with Expert Decisioner (T&R) pattern, taking advantage of the abundance of already-existing algorithms and dissociating their individual performance from the implementer's biases. Resulting summaries obtained using T&R are better than any of the component algorithms.

### CCS CONCEPTS

• [Computing methodologies]: Artificial intelligence - Natural language processing • [Computing methodologies]: Machine learning - Machine learning algorithms • [Computing methodologies]: Parallel computing methodologies - Parallel algorithms

### KEYWORDS

Natural Language Processing, Extractive Summarization, Meta-algorithms, Machine Learning, Document Summarization, Tesselation and Recombination

### ACM Reference format:

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### 1 Introduction

Text summarization can be either extractive or abstractive. While extractive summarization picks verbatim, representative sentences or phrases in the text in context, abstractive summarization attempts to generate novel sentences that do not necessarily exist in the text. Extractive summarization results in a subset of existing sentences or phrases, while abstractive summarization does not guarantee such a set since the generated sentences are not directly extracted from the sample. It is not unusual that words that do not exist in the text appear in the summary. For better or for worse, extractive methods somewhat preserve the author's style while abstractive summarization does not necessarily do so. Simske and Vans [16] characterize extractive summarization as lossless and abstractive summarization as lossy in reference to the compression that either of the methods perform.

The objective of this research was to introduce parallelism through the use of a second-order meta-algorithm referred to as *Tesselation and Recombination with Expert Decisioner* [15] to see if existing methods could be combined to produce better results compared to their individual outcomes. While [6] argues that extractive summarization has mostly given way to abstractive summarization, the authors believe that meta-algorithmic techniques could be used to continue making advances in the field and furthermore, be bases for use with new algorithms for both extractive and abstractive summarization, and even a hybrid approach wherein both techniques are combined to get even better results. Additional benefits for extractive summarization include the retention of key words and phrases suitable for indexing and preservation of query behavior [16,18].

### 2 Research Goals

The overarching goal of this research was to investigate how meta-algorithmic techniques could be used to improve existing as well as future component algorithms. In doing so, metrics for measuring the appropriateness of the generated summaries were also compared.

### 3 Process / Tasks

We executed the following process tasks:

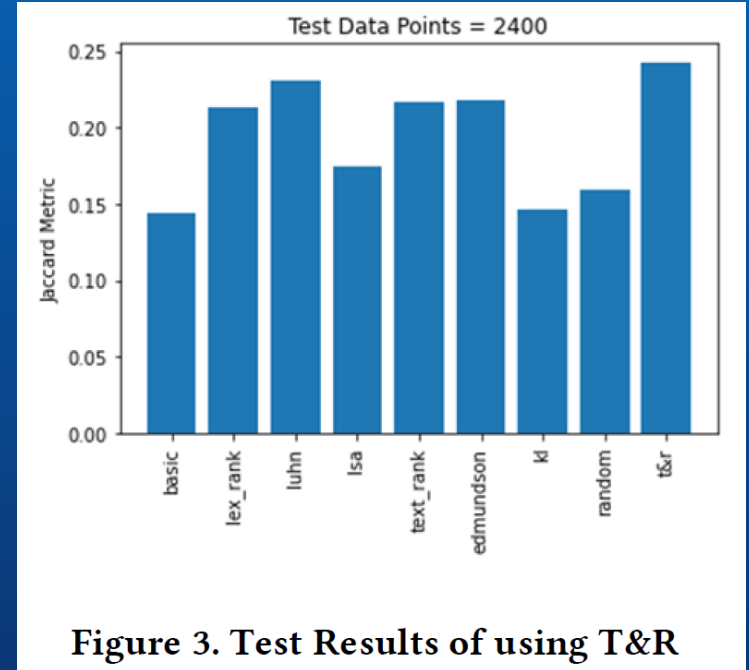


Figure 3. Test Results of using T&R

# Mitigating Hallucinations



DATA QUALITY &  
QUANTITY



SCALABILITY AND  
EFFICIENCY



TOXICITY



TRANSPARENCY



MODEL ROBUSTNESS



SECURITY AND PRIVACY



FAIRNESS



ACCOUNTABILITY



INTEROPERABILITY &  
INTEGRATION



INTELLECTUAL  
PROPERTY



SAFETY &  
RELIABILITY



HALLUCINATIONS

# Meta-algorithmics for Mitigating Hallucinations



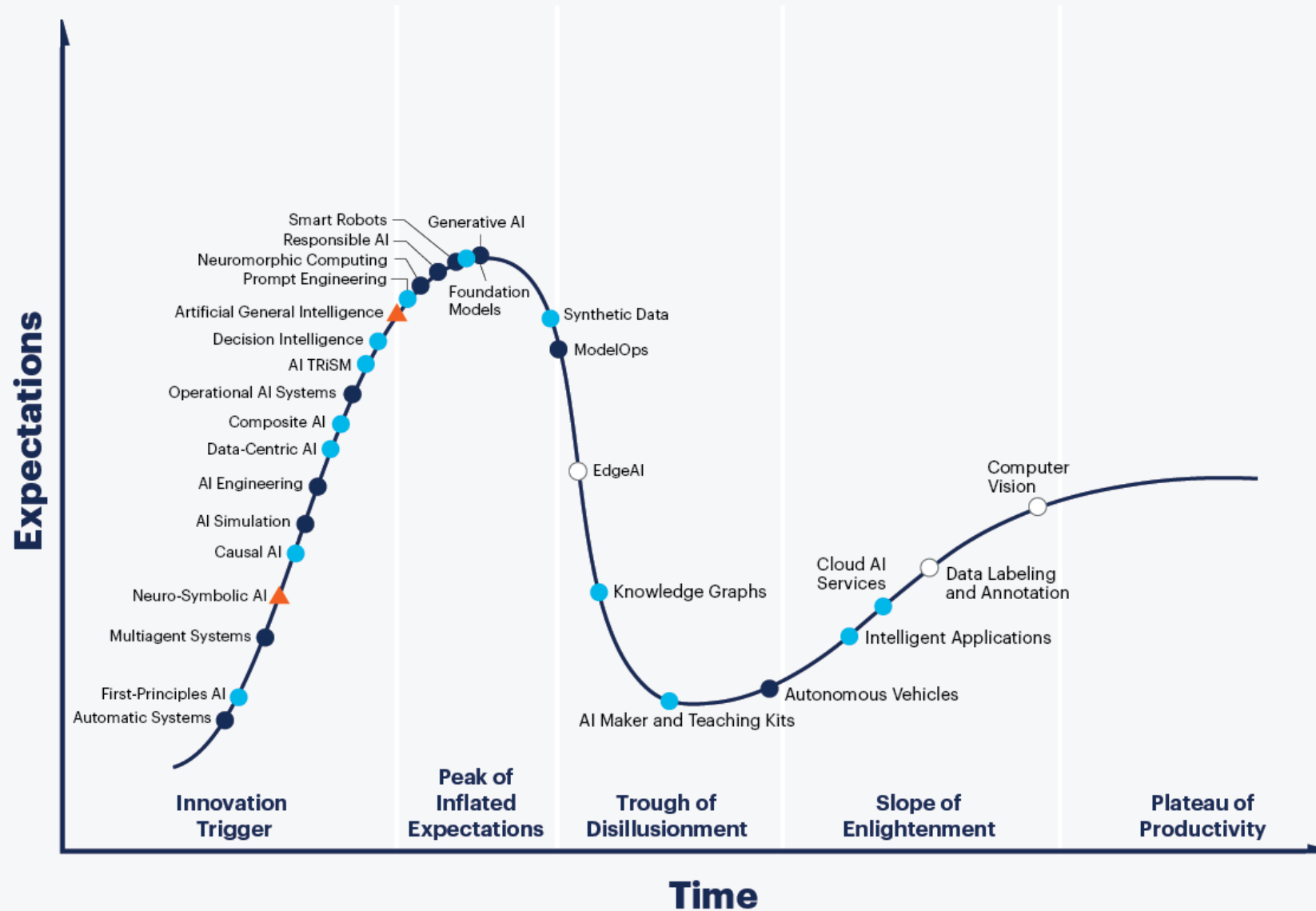
- **Cross-Verification:**
  - Two or more GPT models are used to generate responses to the same query.
  - Outputs are compared to identify common elements. If different models generate similar responses, it increases the confidence that the information is accurate or reasonable.
- **Sequential Refinement:**
  - Output from one GPT model is fed as input to another.
  - Second model can verify or refine output of the first.
- **Diversity in Training Data and Architectures:**
  - Models trained on different datasets or having slightly varied architectures.
  - Diversity helps in providing a more rounded and reliable output, as each model brings its unique strengths to the table.

# What does the future hold?



# Hype Cycle for Artificial Intelligence, 2023

Gartner®

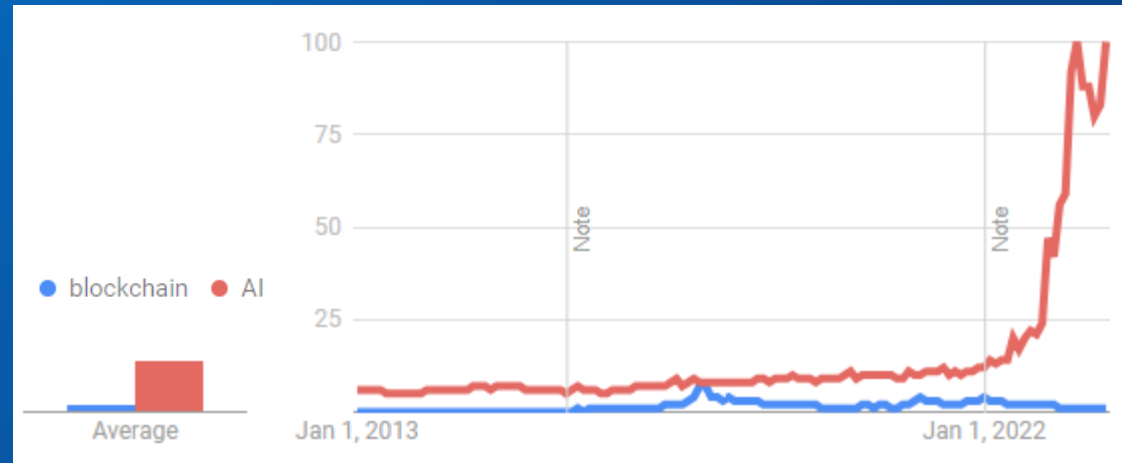
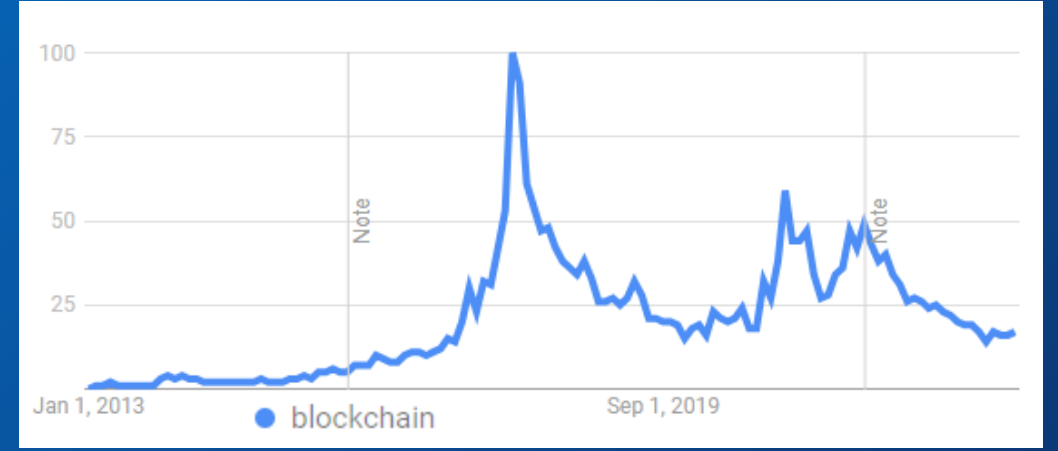
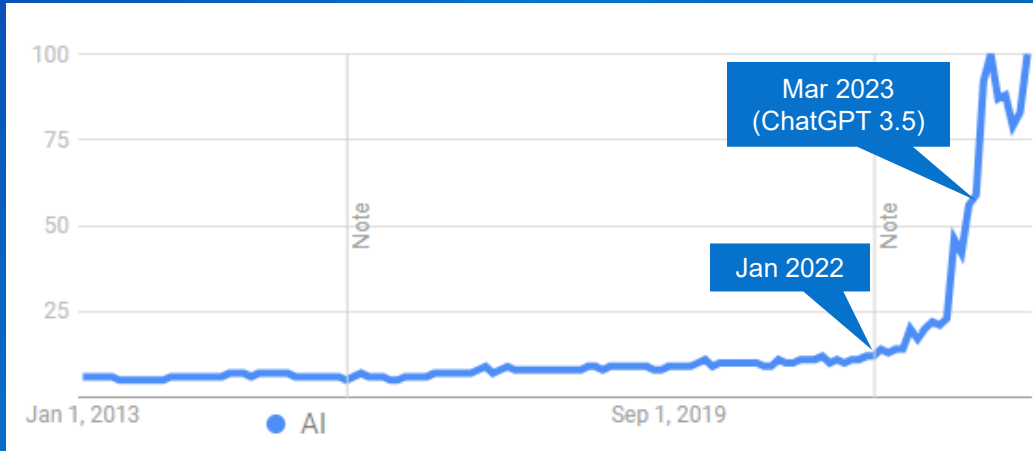


Plateau will be reached:

- less than 2 years
- 2 to 5 years
- 5 to 10 years
- ▲ more than 10 years
- ⊗ obsolete before plateau

As of July 2023

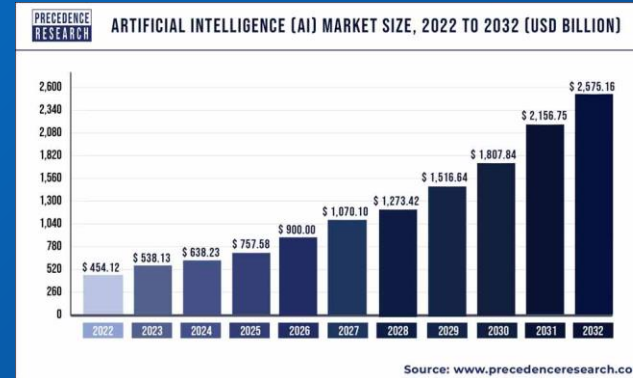
# Search Trends



# AI Growth by the Numbers

19

% Market CAGR from 2023 to 2032



2.1x

2015-2018 growth of AI startups (other startups: 1.3x)

- Robotic process automation 23%
- Machine learning 23%
- Conversational interfaces 20%
- Computer vision 20%

7

number of papers in AI every day



Optimal advancement of AI cannot happen without systems engineering techniques.

# Question-Answer-Discussion



# BACKUP



# Abstract

As the worlds of Artificial Intelligence and Systems Engineering increasingly converge, understanding their intersection becomes pivotal for modern engineering endeavors. This presentation journeys through the evolution of AI, from its historical underpinnings with pioneering figures like Turing and Minsky to its contemporary resurgence powered by data, advanced algorithms, and unprecedented computational capabilities. Within the systems engineering landscape, AI offers transformative potential, aiding in tasks ranging from requirements engineering using Natural Language Processing to predictive maintenance through advanced analytics.

However, the integration of AI into systems is not without its challenges. Issues related to data quality, computational needs, model validation, and ethical considerations underscore the complexities of marrying AI with systems engineering. As we project into the future, the synergy between AI and systems engineering promises advancements in human-AI collaboration, the evolution of more efficient and transparent AI models, and the development of robust ethical and regulatory frameworks. This exploration emphasizes the importance of a thoughtful and informed approach to integrating AI into systems engineering, setting the stage for innovation while ensuring responsibility and efficacy.