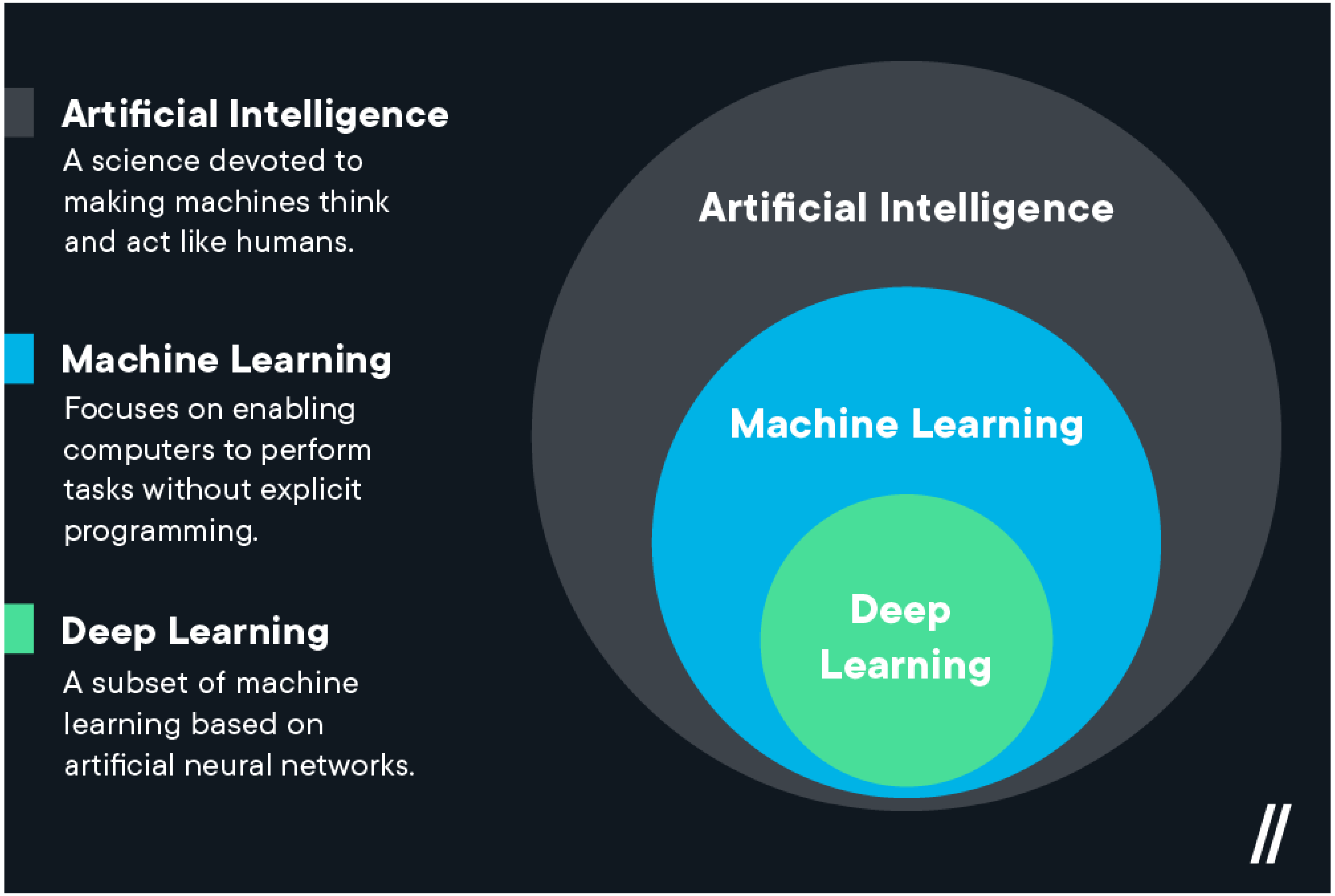
MTRN 3060: ROBOTICS and AUTOMATIONS
Week 9

Generative AI in Robotics and Automation

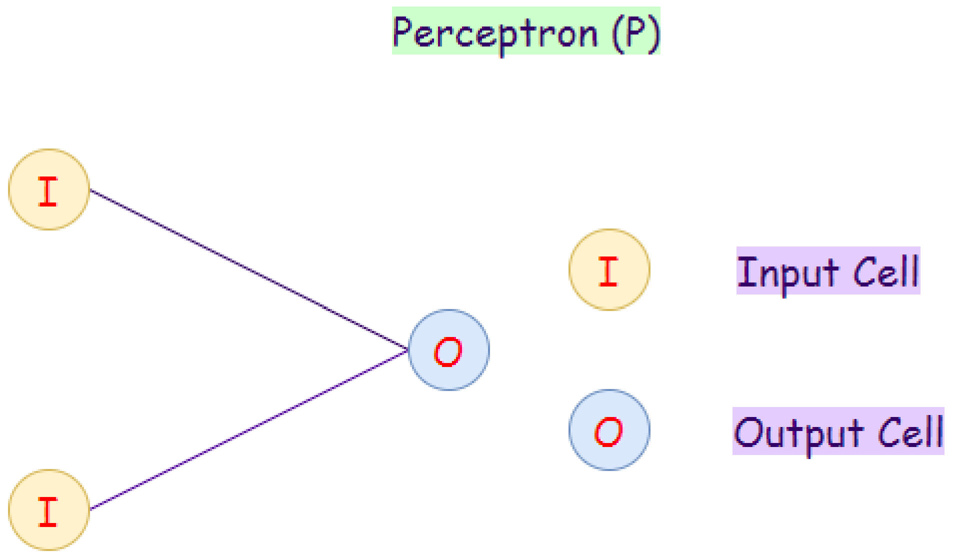
Introduction to Generative AI

https://www.youtube.com/watch?v=ad79nYk2keg&ab_channel=Simplilearn

AI (Machine vs Deep Learning)



Neural Network Topologies

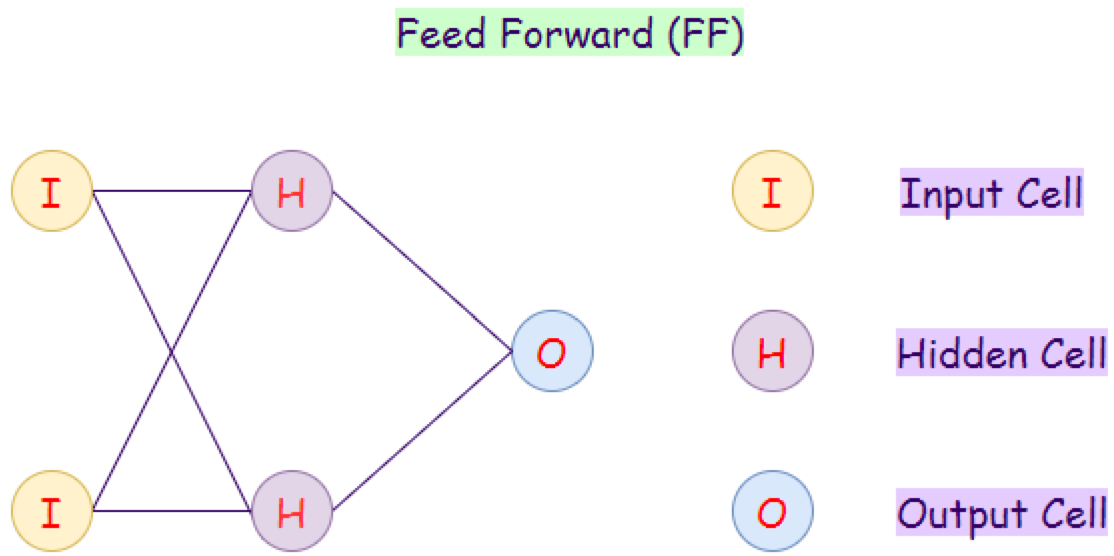


Also known as a single-layer neural network

Example application:

- Classification

Neural Network Topologies



- An Artificial Neural Network in which the nodes do not ever form a cycle.
- All the perceptrons are arranged in layers where the input layer takes in input, and the output layer generates output.
- The hidden layers have no connection with the outer world

Example application:

- Data compression
- Pattern recognition
- Computer Vision
- Sonar target recognition
- Speech recognition
- Handwritten characters recognition

Importance of AI

Automation and Efficiency:
AI enables automation of repetitive and time-consuming tasks, increasing efficiency and productivity in various industries.

Data-driven Decision Making:
AI analyzes vast datasets quickly and accurately, helping organizations make data-driven decisions for better outcomes and insights.

Innovation and Problem Solving:
AI fosters innovation by solving complex problems and enabling the development of new technologies, products, and services.

Personalization and User Experience:
AI-driven personalization enhances user experiences in applications such as e-commerce, entertainment, and healthcare, tailoring services to individual preferences.

Addressing Global Challenges:
AI contributes to solving global challenges like climate change, healthcare access, and cybersecurity by providing tools for predictive modeling, disease diagnosis, and risk assessment.

Generative AI

- Generative AI refers to a subset of artificial intelligence (AI) that focuses on creating or generating new data, typically in the form of images, text, or other content, that is similar to or indistinguishable from data that could have been created by humans.

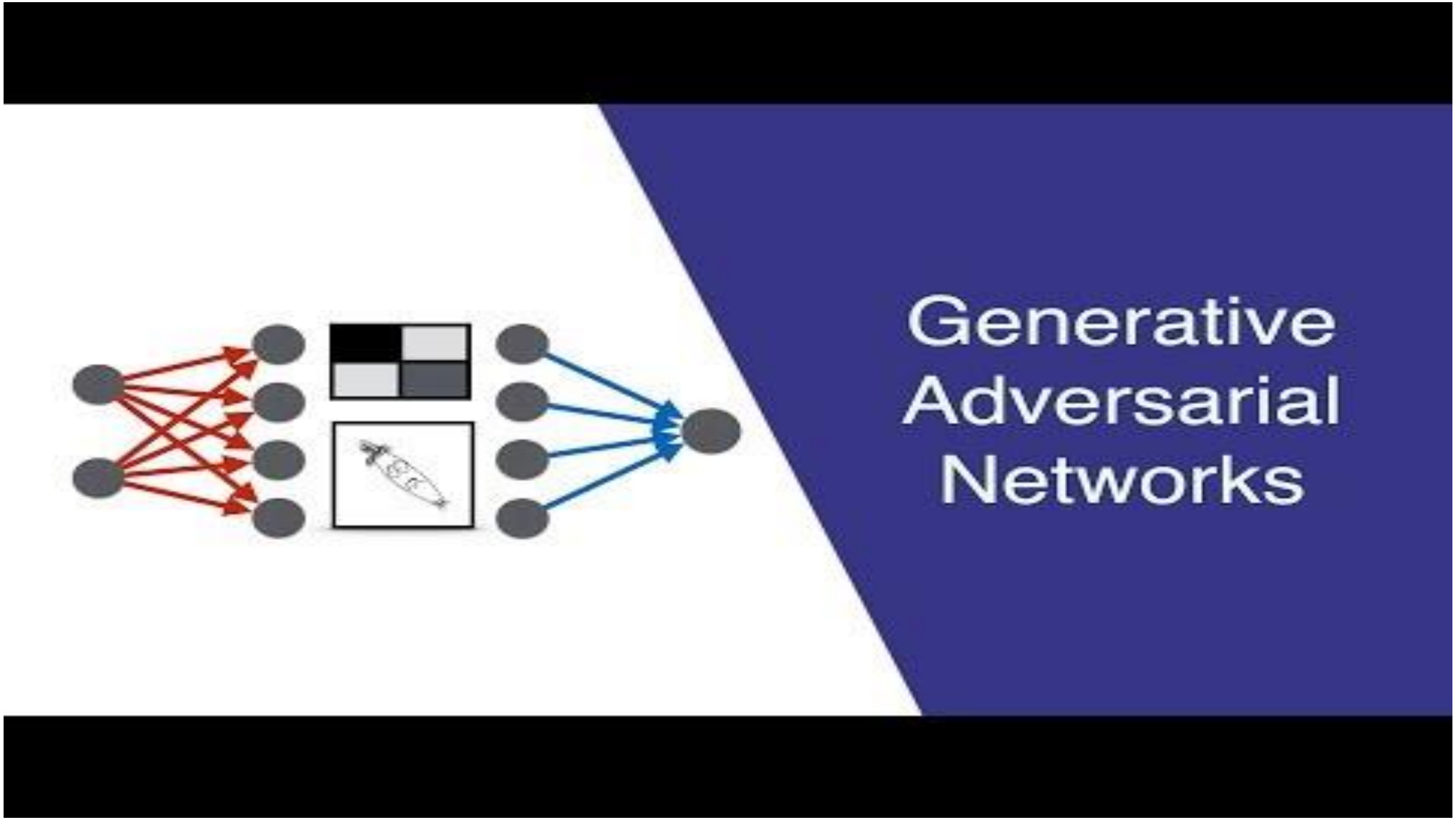
- Generative AI models are designed to understand patterns in existing data and use that understanding to generate new, novel content.

Generative models

1) Generative Adversarial Networks (GANs):

A generative adversarial network (GAN) is a machine learning (ML) model in which two neural networks compete with each other by using deep learning methods to become more accurate in their predictions. GANs typically run unsupervised and use a cooperative zero-sum game framework to learn, where one person's gain equals another person's loss.

Generative models



https://www.youtube.com/watch?v=8L11aMN5KY8&t=141s&ab_channel=Serrano.Academy

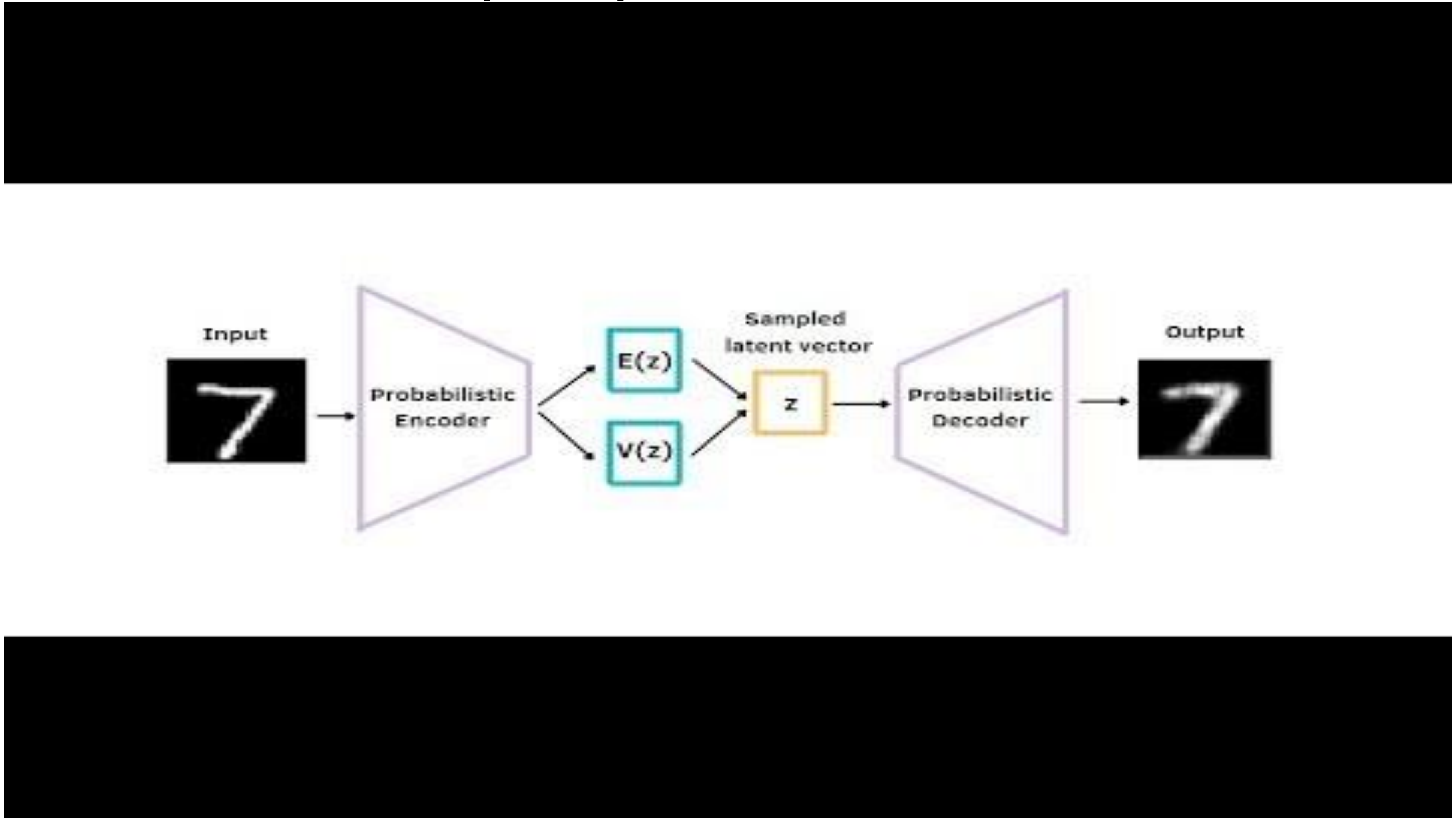
Generative models

2. Variational Autoencoders (VAEs)

Variational Autoencoders (VAEs) are a type of generative model used in the field of machine learning and deep learning. They are a variation of autoencoders, a class of neural networks primarily used for data compression and feature learning. VAEs, however, have the added ability to generate new data points that are similar to the training data, making them particularly useful for generative tasks.

Generative models

2. Variational Autoencoders (VAEs)



https://www.youtube.com/watch?v=fjvsxShBGn0&ab_channel=TechGuyGreg%E2%80%9CTG2%E2%80%9D

Reinforcement Learning

https://www.youtube.com/watch?v=C2zw2H1c5Fk&ab_channel=Synopsys

Generative models

3. Reinforcement Learning for Generative Models

- Reinforcement learning (RL) is a subfield of machine learning where an agent learns to make a sequence of decisions by interacting with an environment to maximize a cumulative reward signal. It is inspired by the behavioral psychology concept of learning through trial and error.

- Leverage generative models, which are skilled at producing data samples that resemble real-world data, and reinforcement learning, which helps us train these models to generate data that meets specific criteria or behaviors.

- Think of it as teaching a model to not just create data but to create data with a purpose.

Generative AI in Robotics:

1. Simulated Environments for Training

Provide a virtual, computer-generated replication of real-world scenarios, allowing robots and automated systems to be trained, tested, and fine-tuned before deploying them in actual physical environments. They offer

- Safety
- Cost Effective
- Rapid Prototyping
- Scalability
- Repeatable Experiments:
- Data Generation
- Complex Scenarios
- 24/7 Availability

https://www.youtube.com/watch?v=PgkyaJ4N1kA&ab_channel=KENS5%3AYourSanAntonioNewsSource

Generative AI in Robotics:

2. Data Augmentation with Generative Models

Data augmentation with generative models can be a valuable technique in robotics for improving the quality, quantity, and diversity of training data used in machine learning algorithms by:

1) Enhancing Training Data Quantity:

Generative models can create synthetic data samples that resemble real-world scenarios. In robotics, this can involve generating additional training data for various robot configurations, environments, or objects. Simulated data can complement limited real-world data, allowing models to learn from a more extensive and diverse dataset.

2) Improving Data Quality

Noise Reduction: Generative models can be used to denoise sensor data collected from robots. By training a generative model on clean data and using it to filter noisy data, you can improve the quality of input data for machine learning models.

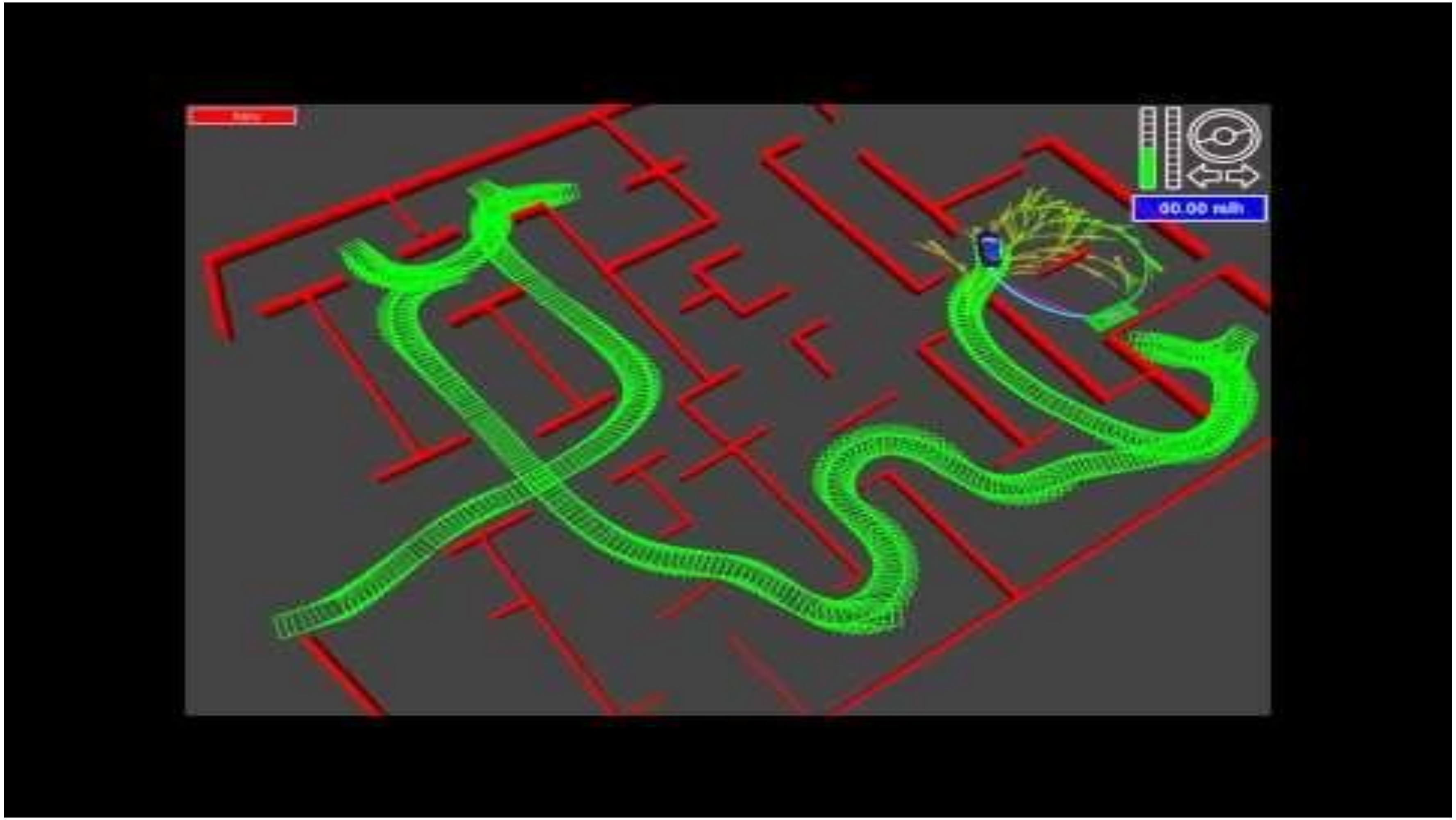
Anomaly Detection: Generative models can also be used to detect anomalies or outliers in sensor data, which is crucial for identifying and addressing unexpected robot behavior.

3) Continuous Learning

Generative models can enhance the realism of simulated environments used for training robots. By generating realistic data in simulations, the gap between simulation and reality is reduced

Generative AI in Robotics:

3. Case Studies: Robot Path Planning



https://www.youtube.com/watch?v=qXZt-B7iUyw&ab_channel=Udacity

Generative AI in Automation:

1. Enhancing Industrial Process Efficiency

Automation of Repetitive Tasks: AI-powered robots can take over repetitive and mundane tasks that were previously performed by humans. This frees up human workers to focus on more creative and complex tasks, increasing overall productivity.

Precision and Accuracy: AI algorithms enable robots to perform tasks with high precision and accuracy. This is critical in industries like manufacturing, where even small errors can lead to defects and quality issues. Consistent and precise operations result in higher-quality products.

Optimized Resource Allocation: AI can optimize the allocation of resources such as materials, energy, and labor. For example, in supply chain management, AI-driven robots can help optimize inventory levels and distribution routes, reducing wastage and transportation costs.

Predictive Maintenance: AI-driven sensors and analytics can predict when equipment is likely to fail. This allows for proactive maintenance, reducing costly downtime and ensuring that machines operate at their optimal performance levels.

Quality Control: AI-powered vision systems and sensors can inspect products in real-time, identifying defects or variations that might be missed by human inspectors. This ensures that only high-quality products reach the market.

Generative AI in Automation:

2. Generative Design in Product Development

Design Goals: Generative design begins with defining specific design goals and constraints. These can include factors like material properties, manufacturing methods, weight, cost, and performance requirements.

Generation of Design Variations: The generative design process generates numerous design variations, often with unconventional shapes and structures, that meet the specified criteria.

Continuous Refinement: Engineers and designers can iterate on these generated designs, refining and selecting the most promising options based on their expertise and the project's objectives.

Performance Optimization: Generative design seeks to optimize product performance and efficiency. It can find solutions that are lighter, stronger, more aerodynamic, or better suited to their intended purpose than traditional designs.

3D Printing Compatibility: Generative designs are often well-suited for 3D printing, as they can include intricate and complex features that traditional manufacturing methods might struggle to produce.

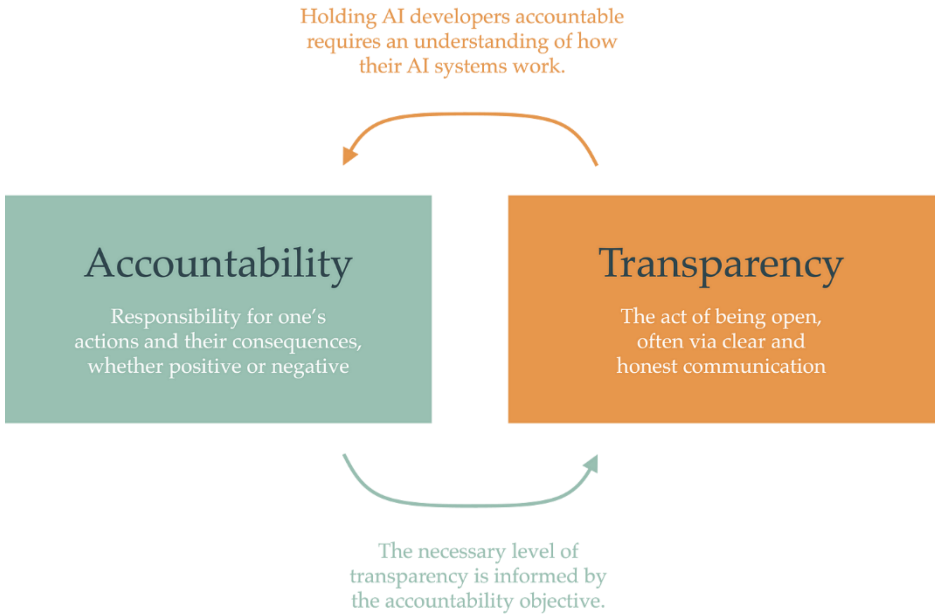
Challenges and Limitations of Using AI in Robotics and Automation

Ethical Considerations

The use of AI in automation brings about various ethical considerations that need to be carefully addressed. Here are some of the key ethical concerns:

Job Displacement

Transparency and Accountability



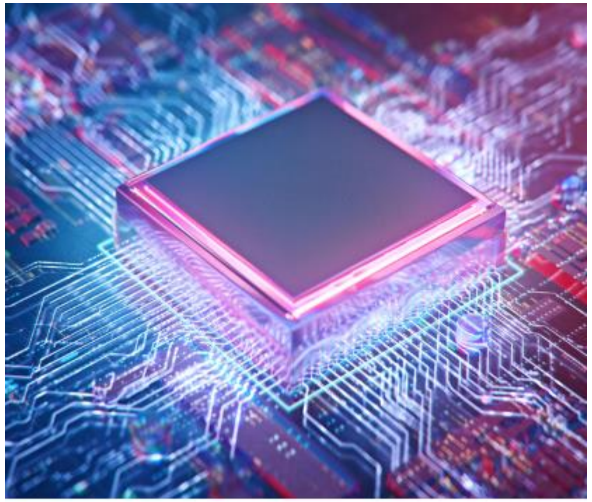
Privacy Concerns

Challenges and Limitations of Using AI in Robotics and Automation

Computational Resources

Computational resources play a pivotal role in the challenges and limitations of using AI in robotics and automation.

Processing Power



Energy Consumption

Memory and Storage

Real-time Processing

Implementing Generative AI in Real-World Projects

TECHWIRE ASIA

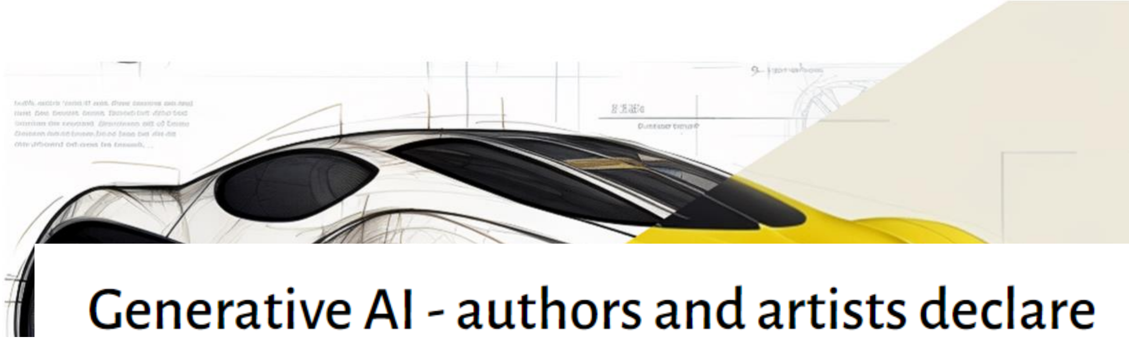
Insights Latest Popular Jobs Topics

Google Cloud and Continental to equip generative AI in cars

Generative AI Revs Up New Age in Auto Industry, From Design and Engineering to Production and Sales

Advances in AI revolutionize the vehicle lifecycle, boosting productivity and sparking innovation.

August 9, 2023 by DANNY SHAPIRO



Google is training robots the way it trains AI chatbots

Google robot choosing a ball. Image: Google

/ Google's new robots don't need complex instructions now that they can access large language models.

By Emilia David, a reporter who covers AI. Prior to joining The Verge, she covered the intersection between technology, finance, and the economy.

Jul 29, 2023, 2:47 AM GMT+10 | 6 Comments / 6 New

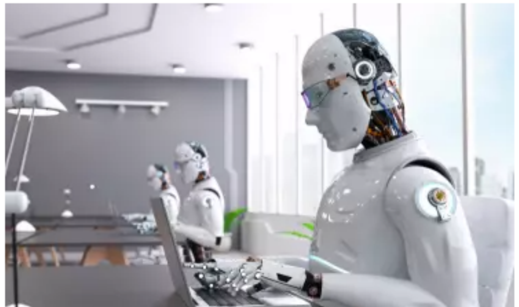
Generative AI - authors and artists declare …n AI vendors worldwide

…ris Middleton September 27, 2023 Audio mode Dyslexia mode

The fightback against ChatGPT and others starts here as online rebellions, US class actions, and an alliance of nearly a million professionals take the fight to AI's creators – companies who have been careless at best.

The Creator opens this week, depicting …e future between humans, robots, and …orn concept that dates back to the …e word 'robot' in the 1920 play, *R.U.R.*

…e signs that the battle is beginning for …US law courts; in strikes; in Europe – …y a million professionals are rebelling; in



ilearn submission assignment

In this 10-minute group discussion, you will analyse a case study highlighting the application of generative AI in robotics and automation. The objective is to briefly discuss key aspects of the case study and summarize your group discussion findings in a concise 200-word report and submit in ilearn.

Start the discussion by explaining the importance of generative AI in shaping the future of robotics and automation.

You should read and discuss the case study, focusing on the following points:

1. How generative AI is applied in the case study.
2. The specific problem or task it addresses.
3. Benefits and potential challenges of its implementation.
4. Any ethical considerations mentioned.

Singularity

Singularity

"Singularity" refers to a specific configuration or position in which the robot arm loses one or more degrees of freedom, making it unable to move or control its end effector (the tool or device attached to the end of the arm) effectively. Singularities are significant points of concern in robotic arm design and control.

- **Momentary singularity:** is a term used in robotics to describe a brief and temporary situation where a robot arm or manipulator passes through a singular configuration during its motion but does not remain stuck in that configuration.

- **Permanent singularity:** refers to a situation where a robot arm or manipulator becomes mechanically locked or reaches a configuration where it cannot continue its motion without external intervention.

Singularity

Singularity happen when the Jacobian is not invertible

$$\mathcal{V} = J\dot{\theta}$$

Cartesian velocities

Jacobian

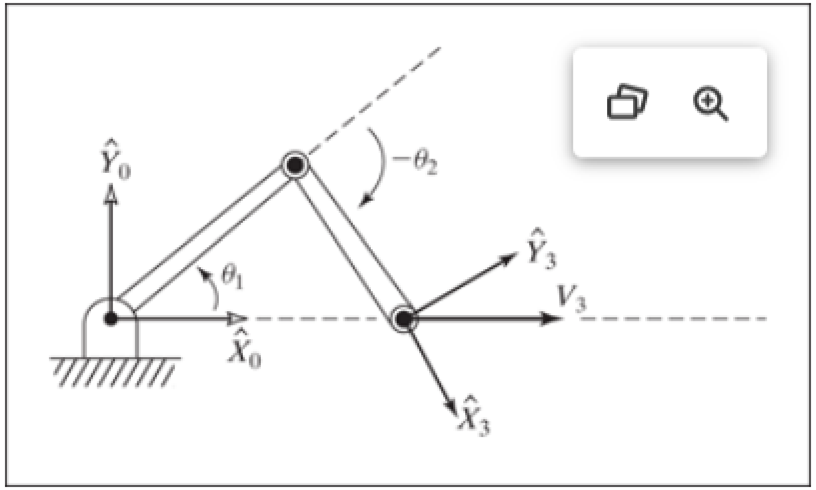
Joint velocities

$\dot{\theta} = J^{-1} \cdot \mathcal{V}$ → Given $\mathcal{V}$, we can find $\dot{\theta}$

If $\mathrm{Det}(J) \neq 0$ → J is invertible

if $\mathrm{Det}(J) \approx 0$ → J is invertible, but dangerous joint velocitis will occur

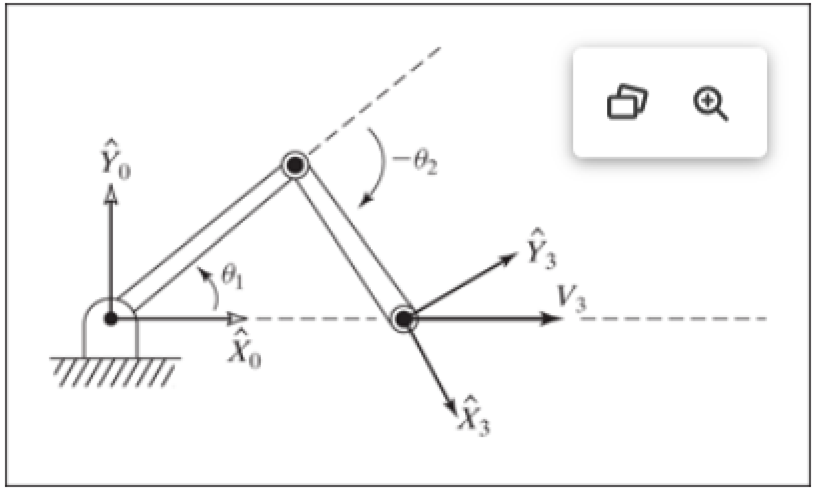
Example 1



$$DET[J(\Theta)] = \begin{bmatrix} l_1 s_2 & 0 \\ l_1 c_2 + l_2 & l_2 \end{bmatrix} = l_1 l_2 s_2 = 0.$$

Clearly, a singularity of the mechanism exists when θ_2 is 0 or 180 degrees. Physically, when $\theta_2 = 0$, the arm is stretched straight out. In this configuration, motion of the end-effector is possible along only one Cartesian direction (the one perpendicular to the arm). Therefore, the mechanism has lost one degree of freedom. Likewise, when $\theta_2 = 180^\circ$, the arm is folded completely back on itself, and motion of the hand again is possible only in one Cartesian direction instead of two. We will class these singularities as workspace-boundary singularities, because they exist at the edge of the manipulator's workspace. Note that the Jacobian written with respect to frame {0}, or any other frame, would have yielded the same result.

Example 1



$$DET[J(\Theta)] = \begin{bmatrix} l_1 s_2 & 0 \\ l_1 c_2 + l_2 & l_2 \end{bmatrix} = l_1 l_2 s_2 = 0.$$

The inverse of the jacobian is

$$^3J^{-1} = \frac{1}{L_1 L_2 S_2} \begin{bmatrix} L_2 & 0 \\ -L_1 c_2 - L_2 & L_1 S_2 \end{bmatrix}$$

Since: $\dot{\theta} = {}^3J^{-1} \cdot {}^3v \Rightarrow \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} = \frac{1}{L_1 L_2 S_2} \begin{bmatrix} L_2 & 0 \\ -L_1 C_2 - L_2 & L_1 S_2 \end{bmatrix} \cdot {}^3\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix}_3$

Then: $\dot{\theta}_1 = \frac{\dot{x}}{L_1 S_2}$

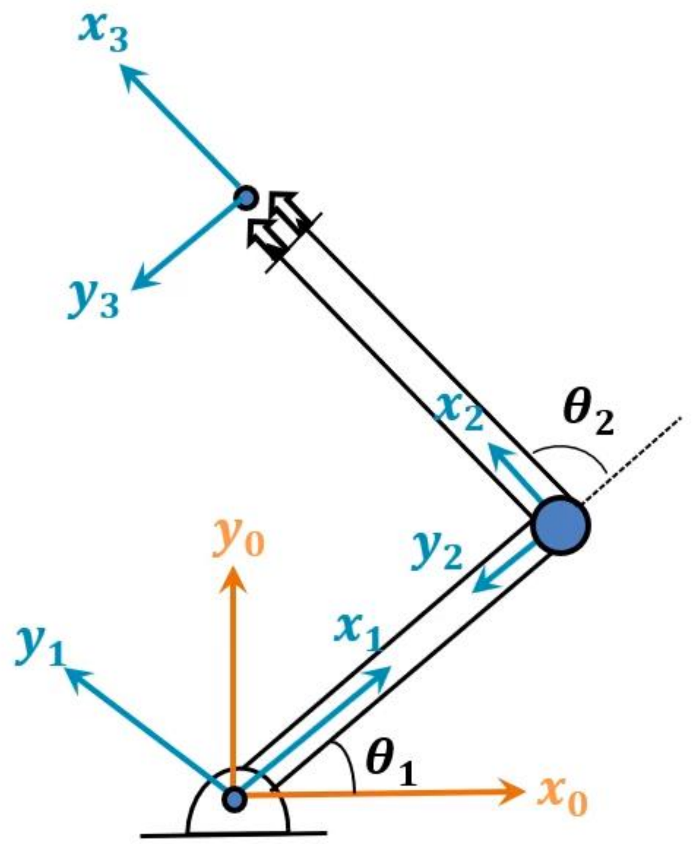
$$\dot{\theta}_2 = \frac{-(L_1 c_2 + L_2)\dot{x}}{L_1 L_2 S_2} + \frac{\dot{y}}{L_2}$$

$$\begin{bmatrix}\dot{\theta}_1\\ \dot{\theta}_2\end{bmatrix} = \frac{1}{L_1 L_2 s_2}\begin{bmatrix} L_2 & 0 \\ -(L_1 c_2 + L_2) & L_1 s_2 \end{bmatrix} {}^3\begin{bmatrix}\dot{x}_3\\ \dot{y}_3\end{bmatrix}$$

When $\theta_2 = 0^o$ (stretched completely out), or when $\theta_2 = 180^o$ (folded back), the Jacobian will be a singular matrix and thus has no inverse.

This means that a solution for the above equation would not exist.

It would require the joint rates to reach extremely large magnitudes going up to infinity, in order to acquire certain E. F. linear velocities.

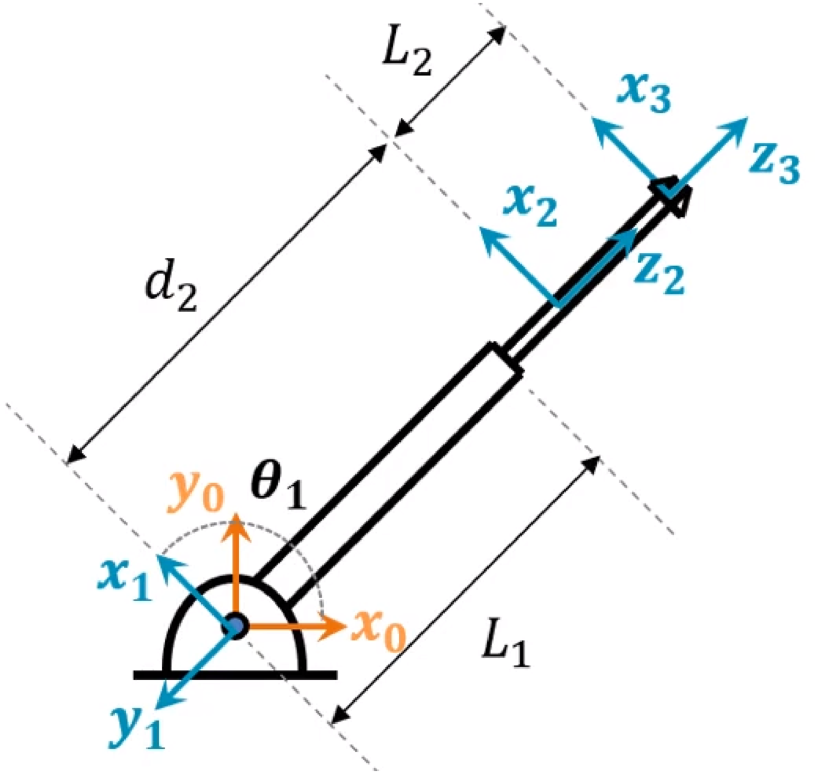


Example 2

For a planar 2 DOF RP robotic arm

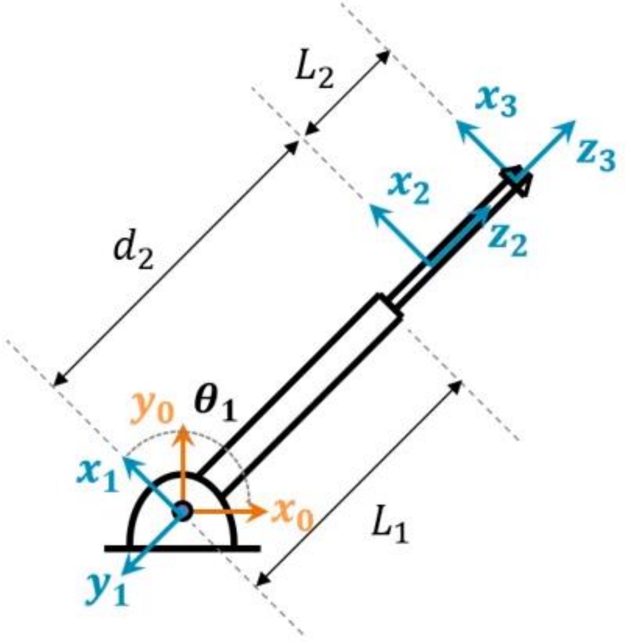
$$
{}^{0}\begin{bmatrix}\dot{x}_3\\ \dot{y}_3\end{bmatrix} = \begin{bmatrix} c_1(d_2+L_2) & s_1 \\ s_1(d_2+L_2) & -c_1\end{bmatrix}\begin{bmatrix}\dot{\theta}_1\\ \dot{d}_2\end{bmatrix}
$$

Under which condition, would there be a singularity for this manipulator?



Example 2

$$
{}^{0}\begin{bmatrix} \dot{x}_3 \\ \dot{y}_3 \end{bmatrix} = \begin{bmatrix} c_1(d_2 + L_2) & s_1 \\ s_1(d_2 + L_2) & -c_1 \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \\ \dot{d}_2 \end{bmatrix}
$$



$$
{}^{0}[\mathrm{J}_v]_{2\times 2} = \begin{bmatrix} c_1(d_2 + L_2) & s_1 \\ s_1(d_2 + L_2) & -c_1 \end{bmatrix}
$$

$$
|\mathrm{J}_v| = c_1(d_2 + L_2)(-c_1) - s_1 s_1(d_2 + L_2)
$$

$$
|\mathrm{J}_v| = -(d_2 + L_2)(c_1)^2 - (s_1)^2(d_2 + L_2)
$$

Set $|\mathrm{J}_v| = 0$

$$
(d_2 + L_2)\left((c_1)^2 + (s_1)^2\right) = 0
$$

$$
d_2 = -L_2
$$