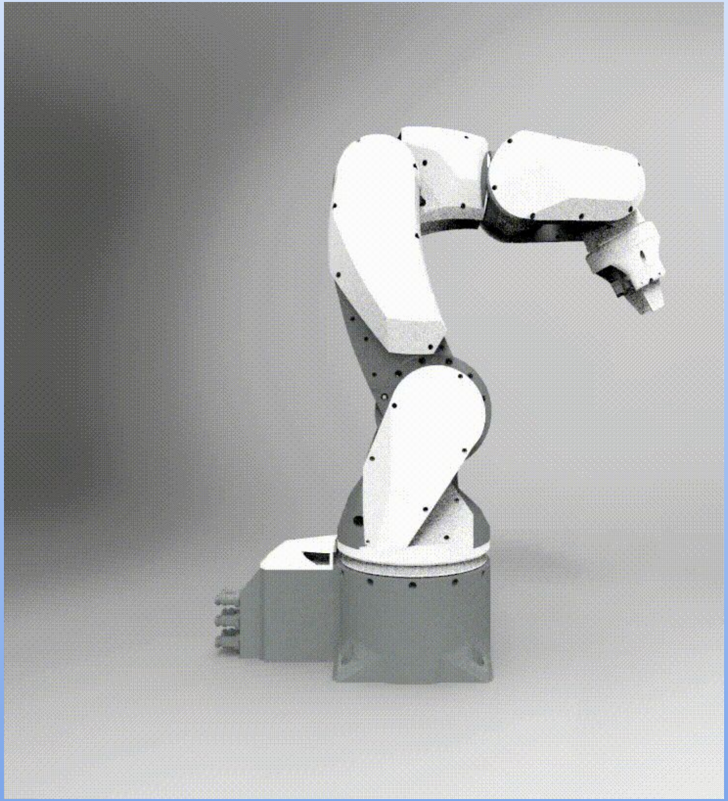
Robotic Arm : A Brief Survey



Subject : Modern Control System
Project : Robotic Arm : A Brief Survey
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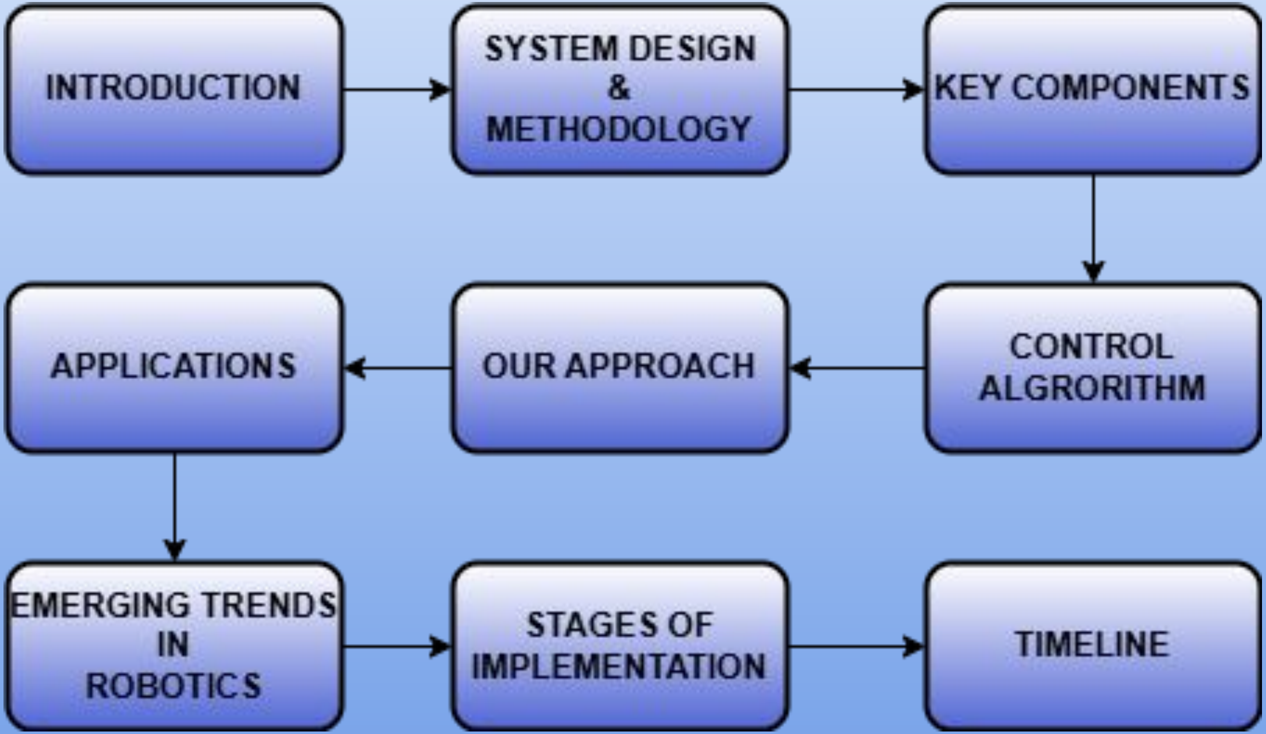
AGENDA


INTRODUCTION
SYSTEM DESIGN & METHODOLOGY
KEY COMPONENTS
CONTROL ALGRORITHM
OUR APPROACH
APPLICATIONS
EMERGING TRENDS IN ROBOTICS
STAGES OF IMPLEMENTATION
TIMELINE

INTRODUCTION

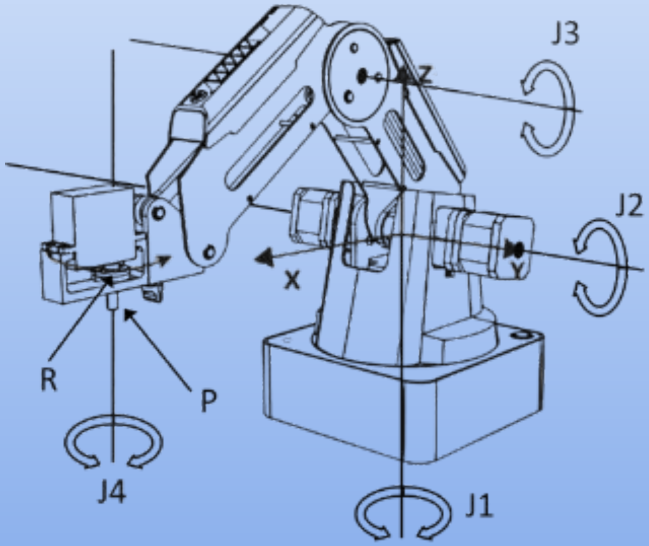
Revolutionized sectors: Automation impacts manufacturing, agriculture, robotics.

Robotic systems: Focus on imitating human hand movements for tasks like object manipulation and assembly.

Robotic arms: Designed for precision tasks such as picking, placing, and manipulating objects.

Challenges in automation: Affordability, adaptability, and handling complex tasks in dynamic environments.

Proposed solution: Use of **Machine Learning (ML)** with **TensorFlow** for object identification, detection, and traversal.



IMPLEMENTATION METHODOLOGY

System Design

Focuses on the mechanical structure and versatility of the robotic arm.

Machine Learning

Involves object detection and classification using deep learning.

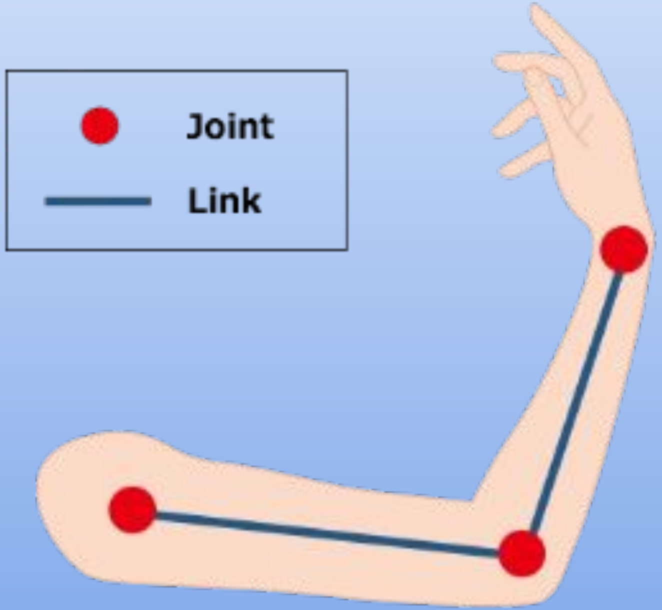
Control Algorithm

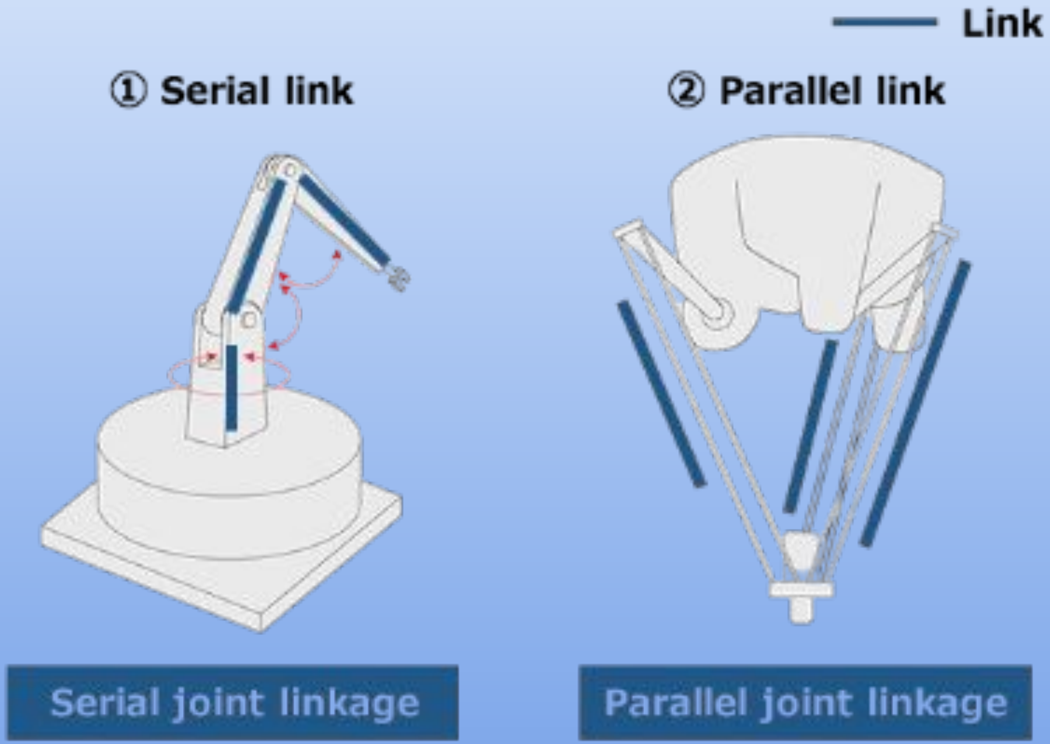
Integrates sensor feedback for precise movement and manipulation.

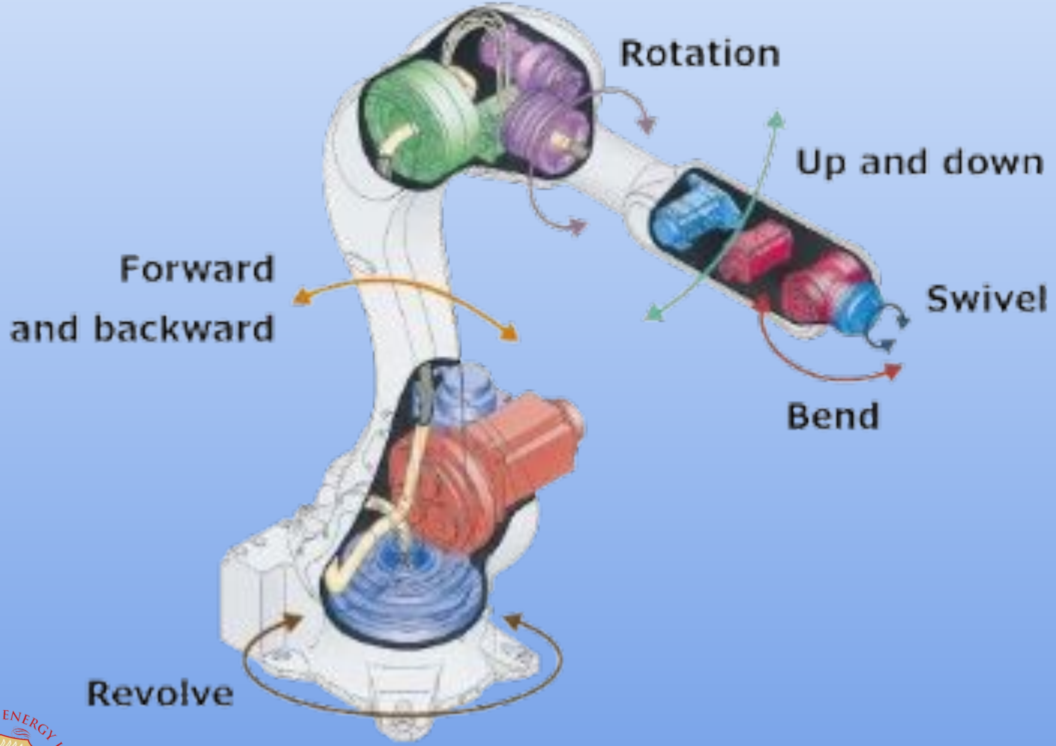
Gripper Design

Mimics human hand versatility for diverse object handling.

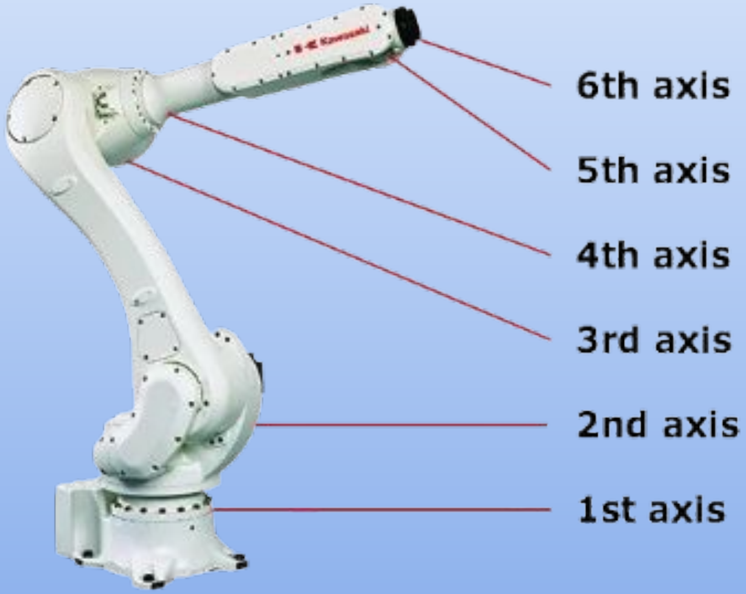
DIFFERENT COMPONENTS IN ROBOTIC ARM

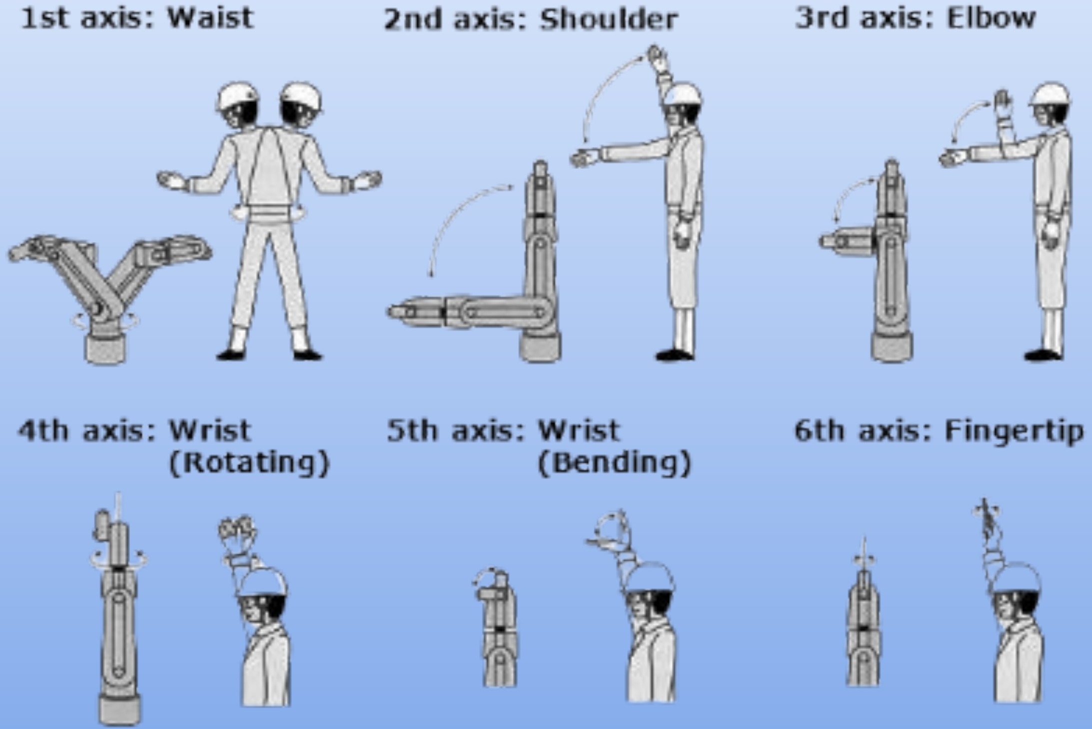





Rotation
Up and down
Forward
and backward
Swivel
Bend
Revolve


Kawasaki


6th axis
5th axis
4th axis
3rd axis
2nd axis
1st axis


1st axis: Waist
2nd axis: Shoulder
3rd axis: Elbow
4th axis: Wrist
(Rotating)
5th axis: Wrist
(Bending)
6th axis: Fingertip

DIFFERENT DESIGN OF END-EFFECTOR IN ROBOTIC ARM

CONTROL ALGORITHM

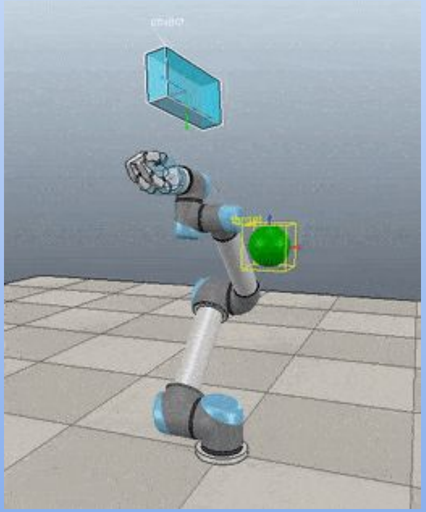
Core functionality: Integrates sensor feedback (position data, object detection, environmental inputs).

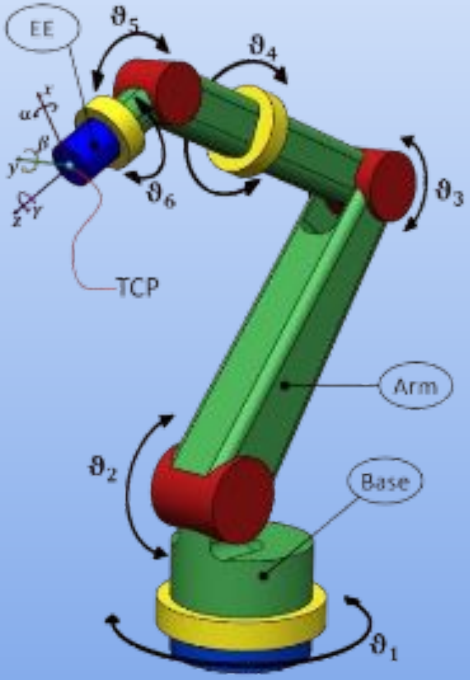
Real-time adjustments: Modifies arm movements and actions based on feedback.

Advanced control techniques: Ensures arm handles varying loads, object shapes, and complex environments.

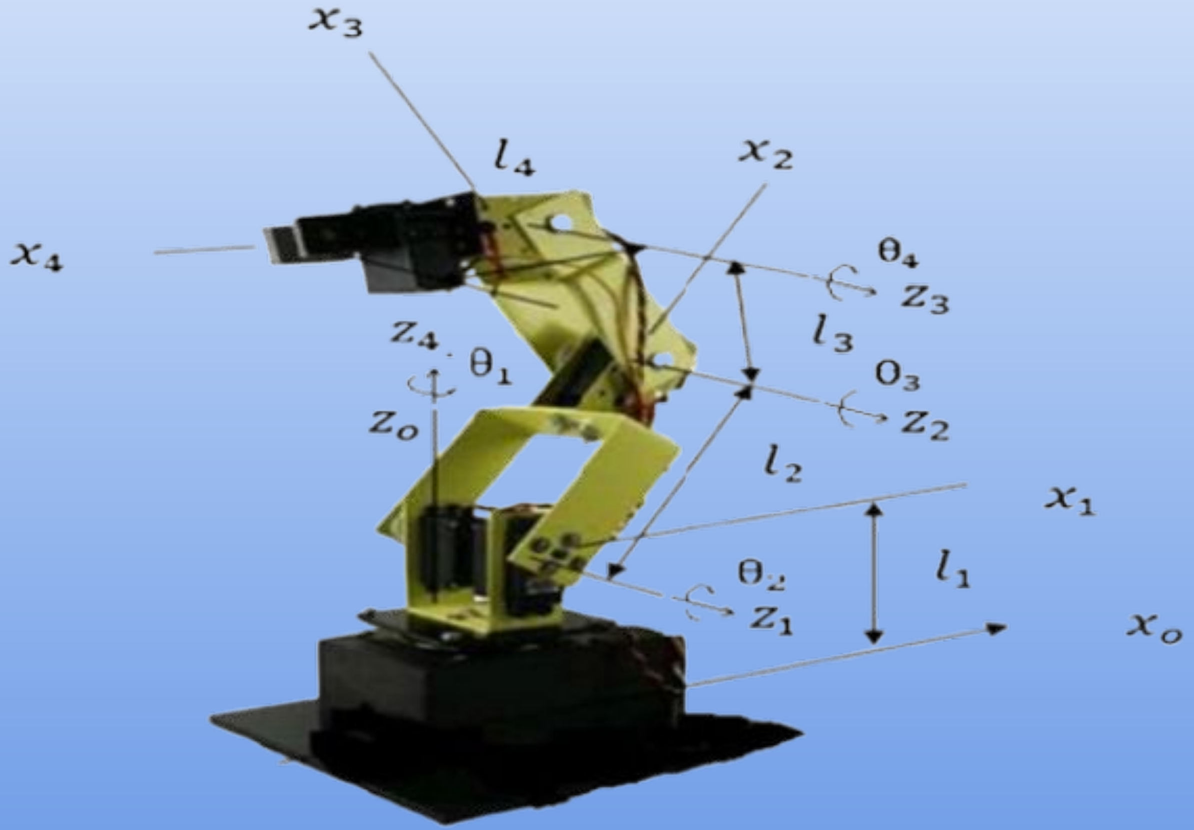
Kinematic and dynamic models: Continuously updates arm positions and movements.

Adaptive approach: Responds to environmental changes for precise pick-and-place tasks.





Control Algorithms For a Four Link Robotic Arm



Euler - Lagrange equation

$$\frac{\mathrm{d}}{\mathrm{d}t}\frac{\partial L}{\partial \dot{q}} - \frac{\partial L}{\partial q} = Q$$

Where:

- L = Lagrangian, defined as $L = K - V$ (kinetic energy minus potential energy).
- q = Generalized coordinate (joint angles).
- $\dot{q}$ = Generalized velocity (rate of change of joint angles).
- Q = Generalized force or torque applied to the system.

Total Kinetic Energy

$$K(\theta, \dot{\theta}) \sum_{i=1}^{n} K_i(\theta, \dot{\theta}) = \frac{1}{2}\dot{\theta}^{\mathrm{T}} D(\theta)\dot{\theta}$$

Where:

- K = Total kinetic energy of the manipulator.
- $\dot{\theta}$ = Joint velocity vector.
- $D(\theta)$ = Inertia matrix representing the mass distribution of links.

Manipulator Inertia Matrix

$$D(\theta) = \sum_{i=1}^{n} J_i^T M_i J_i$$

Where:

- $D(\theta)$ = Inertia matrix of the robotic arm.
- J_i = Jacobian matrix of the ith link.
- M_i = Generalized mass matrix of the ith link.

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Potential Energy

$$V_i(\theta) = m_i g h_i(\theta).$$

Where:

- V_i = Potential energy of the ith link.
- m_i = Mass of the ith link.
- g = Acceleration due to gravity.
- $h_i(\theta)$ = Height of the mass center of the ith link.

Euler–Lagrangian dynamic model

$$D(\theta)\ddot{\theta} + C(\theta, \dot{\theta})\dot{\theta} + g(\theta) = \tau$$

Where:

- $D(\theta)$ = Inertia matrix representing mass properties of links.
- $\ddot{\theta}$ = Joint accelerations.
- $C(\theta, \dot{\theta})$ = Coriolis and centrifugal forces acting due to motion.
- $g(\theta)$ = Gravity forces acting on joints.
- τ = Control torques applied to the joints.

Coriolis Term For The Manipulator

$$C(\theta \quad \dot{\theta}) = \mathit{\Gamma}_{ijk}\dot{\theta}_k = \frac{1}{2}\left(\frac{\partial D_{ij}}{\partial \theta_k} + \frac{\partial D_{ik}}{\partial \theta_j} - \frac{\partial D_{kj}}{\partial \theta_i}\right)\dot{\theta}_k.$$

Where:

- $C(\theta, \dot{\theta})$ = Coriolis and centrifugal matrix.
- Γ_{ijk} = Christoffel symbols (terms describing velocity interactions).
- D_{ij} = Elements of the inertia matrix.
- $\dot{\theta}_k$ = Velocity of joint k.

Gravity Forces On The Robotic Manipulator

$$g(\theta) = \frac{\partial V}{\partial \theta_i}$$

$$g(\theta) = g \begin{bmatrix} \frac{\partial(m_1h_1+m_2h_2+m_3h_3+m_4h_4)}{\partial \theta_1} \\ \frac{\partial(m_1h_1+m_2h_2+m_3h_3+m_4h_4)}{\partial \theta_2} \\ \frac{\partial(m_1h_1+m_2h_2+m_3h_3+m_4h_4)}{\partial \theta_3} \\ \frac{\partial(m_1h_1+m_2h_2+m_3h_3+m_4h_4)}{\partial \theta_4} \end{bmatrix}$$

Where:

- $g(\theta)$ = Vector of gravitational forces.
- $V(\theta)$ = Total potential energy.
- θ_i = Joint angles.
- $m_i, h_i(\theta)$ = Mass and height of each link.

PID Control Law

$$\tau = K_P\tilde{\theta} + K_I \int \tilde{\theta}\mathrm{d}t + K_D\dot{\tilde{\theta}}$$

Where:

- τ = Control torque applied to the joints.
- K_P = Proportional gain (corrects based on current error).
- K_I = Integral gain (eliminates steady-state error by considering past errors).
- K_D = Derivative gain (predicts and counteracts future errors).
- $\tilde{\theta}$ = Deviation from the desired position.

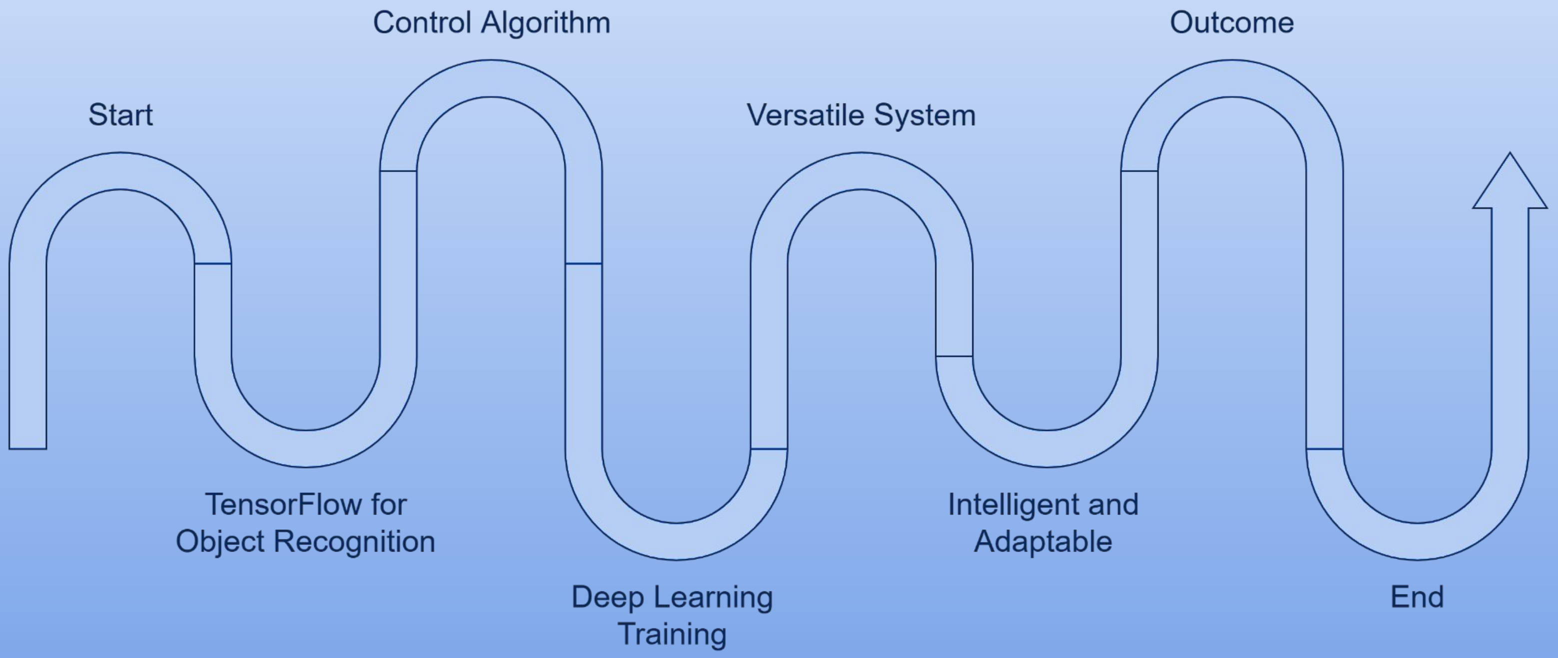
Feedback Linearization

$$\ddot{\tilde{\theta}} + 2\lambda\dot{\tilde{\theta}} + \lambda^2\tilde{\theta} = 0.$$

Where:

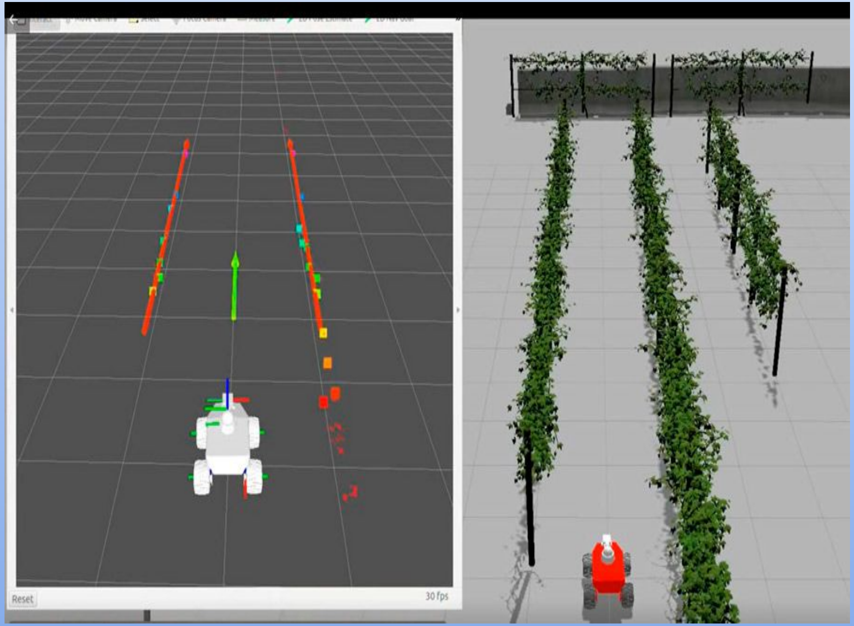
- u = Transformed control input.
- $\ddot{\theta}_d$ = Desired acceleration of the joint.
- λ = Control gain determining response speed.
- $\tilde{\theta}$ = Error between desired and actual position.

OUR APPROACH



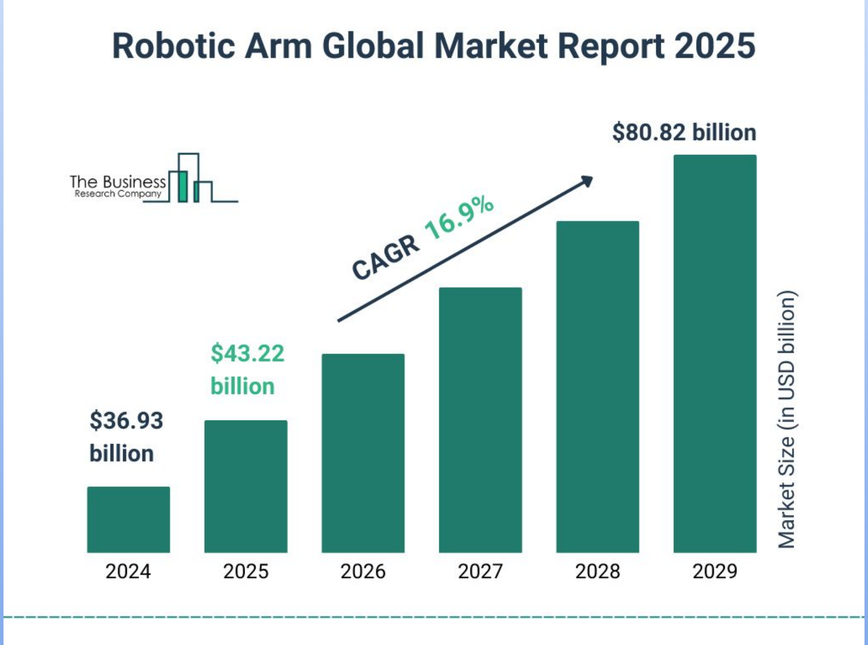
APPLICATIONS

- **Industrial Automation**: Ideal for **assembly lines**, performing tasks like **picking**, **placing**, and **assembling components** with high precision and speed.
- **Agriculture**: Used in **smart agricultural systems** for tasks such as **harvesting crops**, **spraying pesticides**, and **inspecting plants**, boosting productivity and ensuring sustainable farming practices.
- **Healthcare**: Robotic arms with **advanced gripper designs** are employed in **medical procedures**, including **surgeries** and handling **precision medical equipment**.
- **Gesture-Controlled Systems**: Enables users to interact with robots through **gesture control**, offering a more **intuitive** and **natural** form of **human-robot interaction** in diverse applications.



TRENDS

The future of robotic arms lies in their ability to seamlessly integrate with artificial intelligence and machine learning technologies. There is a growing trend towards robots being able to adapt and learn from their environments, allowing them to handle a wider range of tasks and interact with humans more effectively. Gripper design is also evolving, with more research focused on creating hands that can mimic human dexterity while being energy-efficient and cost-effective. Furthermore, advancements in wireless communication and control algorithms are enabling more intuitive interaction with robotic systems, including gesture-controlled robots.



STAGES IN IMPLEMENTATION

Research and Design

Initial stage involves studying technologies and designing the arm

Prototyping

Prototype built with gripper design, sensors, and trained models

Testing and Optimization

Prototype tested in conditions, algorithms refined for performance

Deployment and Scaling

System deployed in real-world applications, improvements made

TIMELINE

Month	Stage	Description	Key Tasks
Month 1	Stage 1: Research and Design	Weeks 1-2	- Conduct in-depth research on robotic arm technologies. - Finalize the robotic arm structure design (actuators, sensors). - Select machine learning algorithms (TensorFlow, CNN).
	Stage 2: Component Selection and Prototyping	Weeks 3-4	- Select components (grippers, servos, sensors, controllers). - Build the initial prototype and integrate basic sensors.
Month 2	Stage 3: Machine Learning Integration	Weeks 5-6	- Integrate TensorFlow for object recognition and classification. - Start training neural networks with datasets. - Test object detection and image processing.
	Stage 4: Control Algorithm Development and Testing	Weeks 7-8	- Develop control algorithm for coordinating arm movements. - Test the feedback loop and real-time adjustments. - Optimize algorithm for precision in object manipulation.
Month 3	Stage 5: Testing, Optimization, and Deployment	Weeks 9-12	- Comprehensive testing to validate performance in real-world scenarios. - Refine control algorithm based on test feedback. - Deploy robotic arm in a controlled environment and scalability testing. - Final adjustments and system preparation for demonstration.

CONCLUSION

The integration of machine learning with robotic arm systems represents a significant leap forward in automation and artificial intelligence. By incorporating a sophisticated control algorithm and advanced gripper design, our system provides a flexible, efficient, and cost-effective solution for various industries. Whether in manufacturing, agriculture, or healthcare, the robotic arm's ability to perform complex tasks with precision and adaptability makes it an invaluable tool for improving productivity and sustainability. The continued development of these technologies promises a future where robots are increasingly capable of seamlessly working alongside humans to tackle complex tasks across diverse domains.

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3. K. R. N S, N. J. Avinash, H. Rama Moorthy, K. Karthik, S. Rao and S. Santosh, "An Automated Robotic Arm: A Machine Learning Approach," *2021 IEEE International Conference on Mobile Networks and Wireless Communications (ICMNWC)*, Tumkur, Karnataka, India, 2021, pp. 1-6, doi: 10.1109/ICMNWC52512.2021.9688512.

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