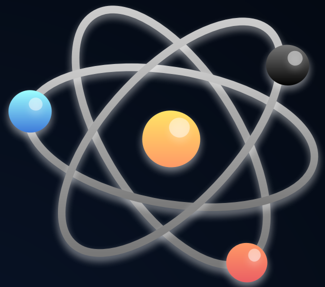
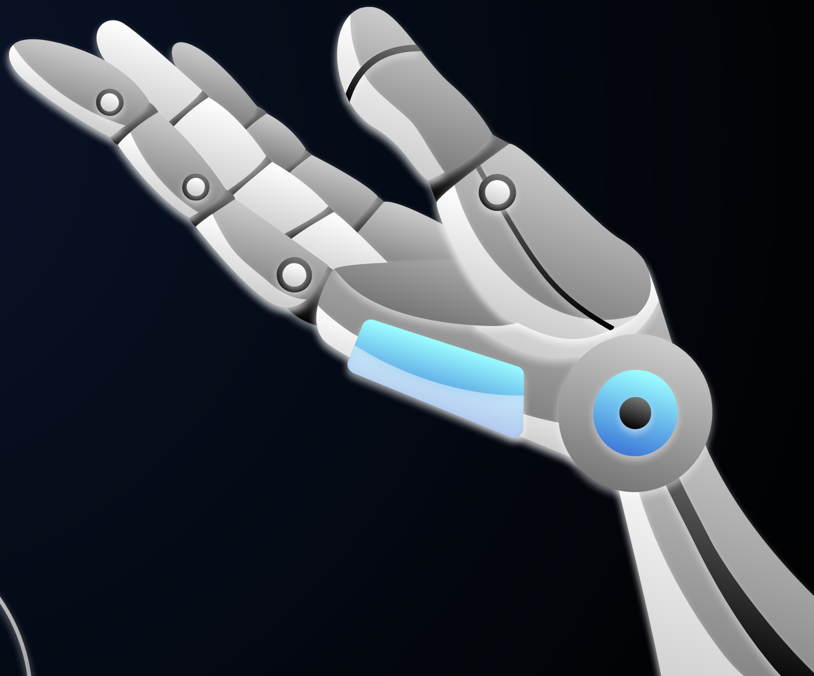
HUMANOID ROBOT





Muhammad Hafizuddin bin Omran
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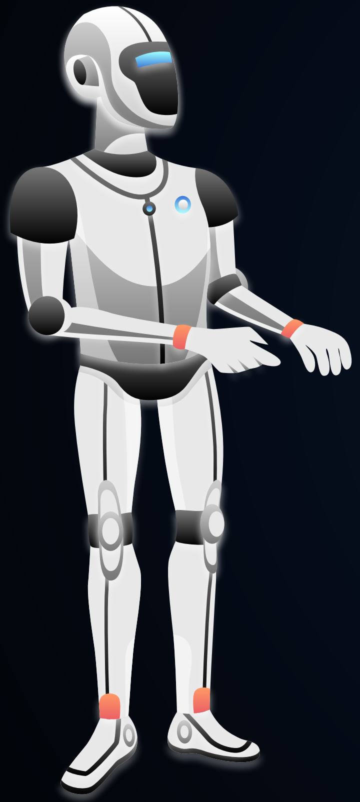


INTRODUCTION

What is Humanoid Robot? And its Application?

HUMANOID ROBOT

A humanoid robot is a type of robot designed to resemble or imitate human physical characteristics and movements. It is typically equipped with a body structure similar to that of a human, including a head, torso, arms, and legs

HUMANOID ROBOT

- Humanoid robots are designed to have a human-like appearance, with features such as a face, eyes, and sometimes even hair. This resemblance to humans helps create a sense of familiarity and enables more natural interaction between the robot and humans.

- Humanoid robots are built with joints and actuators that allow them to move in a manner similar to humans. They can walk, run, climb stairs, and perform various complex movements, enabling them to navigate and interact in human environments.

Application of Humanoid Robot

1. Human Interaction: One of the main goals of humanoid robots is to interact with humans effectively. They can recognize and interpret human speech, gestures, and facial expressions, enabling communication through natural language processing and computer vision techniques. This makes them suitable for tasks such as customer service, companionship, or assisting individuals in various settings.

2. Research and Development: Humanoid robots are used in research and development to study human locomotion, cognition, and social interaction. By creating robots that mimic human capabilities, researchers can gain insights into human behavior and explore new technologies and algorithms.

3. Education and Entertainment: Humanoid robots have applications in education and entertainment. They can serve as interactive tutors, teaching subjects like language, math, or programming. In entertainment, humanoid robots can perform in shows, exhibitions, or theme parks, entertaining and engaging audiences.

4. Healthcare and Assistance: Humanoid robots are increasingly being used in healthcare settings. They can assist with tasks like patient monitoring, medication reminders, and rehabilitation exercises. Additionally, humanoid robots can provide companionship and emotional support to individuals who may feel lonely or isolated.

5. Hazardous Environments: Humanoid robots are well-suited for tasks in hazardous environments where it may be unsafe or impossible for humans to operate. They can be used in disaster response situations, nuclear facilities, or space exploration missions to perform tasks such as inspection, maintenance, or rescue operations.

6. Social Robotics: Humanoid robots are being developed to enhance social interactions and improve the quality of life for individuals. They can provide companionship for the elderly, people with disabilities, or those in need of social support. Humanoid robots can engage in conversations, play games, and assist with daily tasks.

7. Industrial Applications: Humanoid robots find applications in industries such as manufacturing and assembly. Their human-like dexterity and ability to handle objects make them suitable for tasks that require precision and flexibility. They can work alongside humans in factories or perform repetitive tasks, increasing efficiency and productivity.

8. Art and Creativity: Humanoid robots have also been used as artistic creations or platforms for artistic expression. Artists and performers have used humanoid robots to explore the boundaries between technology and creativity, combining robotics with music, dance, or visual arts.

02

HISTORY OF HUMANOID ROBOT

Where does humanoid robot come from?

History Timeline

PHASE 1

1970

WABOT-1, developed by researchers at Waseda University in Japan, becomes one of the earliest fully functional humanoid robots. It had arms, legs, and vision capabilities.

PHASE 2

1986

Honda introduces the "E0" humanoid robot, which laid the foundation for their later models. It stood at 6.6 feet tall and had basic walking capabilities.

PHASE 3

1993

Honda unveils the P1 humanoid robot, improving on the E0 model. P1 could walk, climb stairs, and even maintain balance on uneven surfaces.

PHASE 4

1997

NASA develops the Robonaut, a humanoid robot designed to assist astronauts in space missions. It could perform tasks alongside humans in zero gravity environments.

History Timeline

PHASE 5

2002

Honda introduces ASIMO (Advanced Step in Innovative Mobility), one of the most well-known humanoid robots. ASIMO demonstrated improved mobility, dexterity, and human-like movements.

PHASE 6

2011

NASA's Robonaut 2 (R2) becomes the first humanoid robot to be sent to the International Space Station (ISS) to assist with maintenance and repair tasks.

PHASE 7

2016

SoftBank Robotics releases Pepper, a humanoid robot designed for human interaction and companionship. Pepper has speech recognition, emotion detection, and the ability to engage in conversations.

PHASE 8

2018

Boston Dynamics introduces Atlas, a highly advanced humanoid robot capable of performing various dynamic movements, including walking, running, and even backflips

03

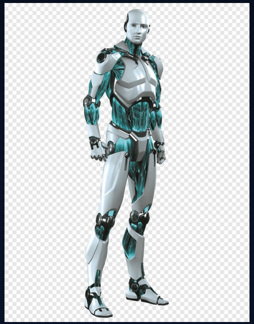
HARDWARE COMPONENTS OF HUMANOID ROBOT

What components used to build the Humanoid Robot

ROBOTIC DESIGN

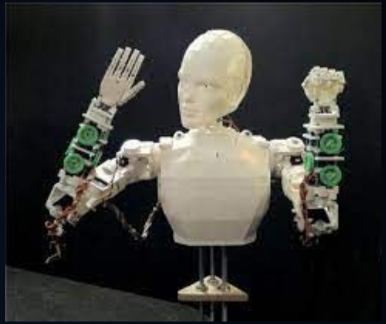
Bipedal Design

Bipedal humanoid robots are designed with two legs and a torso, enabling them to walk and maintain balance on two feet. This design closely resembles the human form and allows for more natural movement in human environments.



Android Design

Android humanoid robots aim to replicate not only human-like movements but also the external appearance of humans. They typically have a head with facial features, including eyes, nose, and mouth, which can display expressions. Android robots often strive to achieve a high level of realism in appearance.



Humanoid Torso

Some humanoid robots focus on mimicking the upper body or torso of humans. They have arms, a head, and a torso but may lack legs or have simplified leg structures. These robots are designed for tasks that primarily require upper body manipulation and interaction, such as assisting with household chores or working in a factory.

ROBOTIC DESIGN

Legged Design

While humanoid robots traditionally have two legs, legged humanoid robots can have more than two legs, resembling animals or creatures with multi-legged locomotion. These robots can navigate challenging terrains and perform tasks that require stability and mobility in non-human environments

Human-Exoskeleton Hybrid

Some humanoid robot designs are intended to augment or enhance human capabilities. These robots, known as exoskeletons, are worn by humans and provide additional strength, endurance, or assistance in movements. They can be used for rehabilitation, heavy lifting, or supporting individuals with mobility impairments.

LOCOMOTIVE SYSTEM

Wheeled Driven

Some humanoid robots incorporate wheeled propulsion systems for locomotion. These robots have wheels attached to their feet or base, allowing them to move on flat surfaces with relative ease. Wheeled systems are efficient for indoor environments but may face challenges on uneven or rough terrains.

Legged Driven

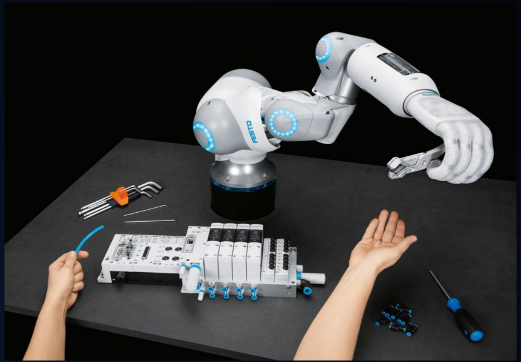
Legged propulsion systems are a popular choice for humanoid robots aiming to achieve bipedal or multi-legged locomotion. These systems use legs with joints and actuators to mimic human or animal-like walking, running, and climbing motions. Legged systems offer versatility and the ability to navigate complex environments, including stairs and uneven terrain.

Hybrid

Hybrid propulsion systems combine multiple methods of locomotion to optimize robot movement. For instance, a humanoid robot may have wheeled bases for efficient movement on flat surfaces but also include legs for tasks requiring more agility or navigating challenging terrains. Hybrid systems aim to combine the benefits of different propulsion methods.

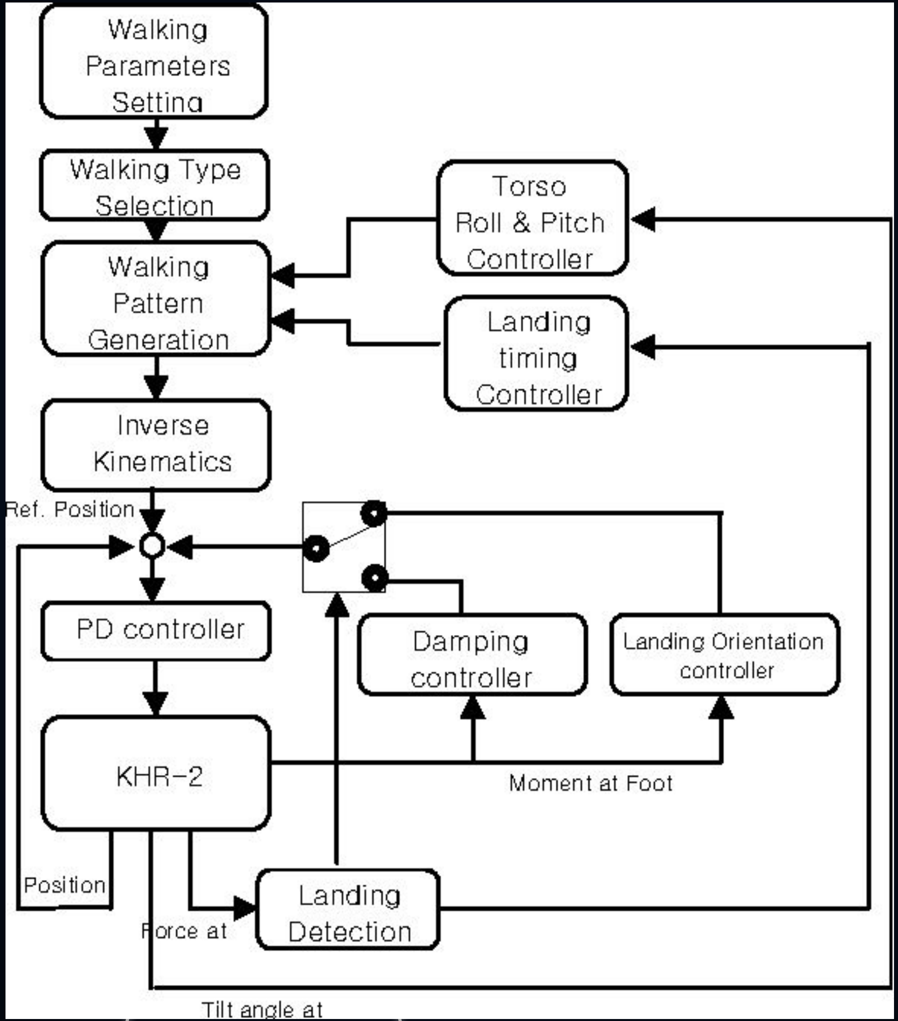
Exoskeleton

In some cases, humanoid robots can have an exoskeleton design that is worn by a human operator. These robots, known as exoskeletons, provide additional support, strength, or assistance to the wearer's movements. Exoskeletons typically use actuators and sensors to detect and enhance the operator's motions.



Pneumatic/Hydraulic

Pneumatic or hydraulic systems use compressed air or fluid to power the actuators and joints of humanoid robots. These systems can provide high force and precise control over movements. Pneumatic systems are often used in scenarios where strength and flexibility are required, such as lifting heavy objects.



Walking Parameters Setting
Walking Type Selection
Walking Pattern Generation
Torso Roll & Pitch Controller
Landing timing Controller
Inverse Kinematics
Ref. Position
PD controller
Damping controller
Landing Orientation controller
KHR-2
Moment at Foot
Position
Force at
Landing Detection
Tilt angle at

Navigation system

The navigation system of a humanoid robot refers to the set of components and algorithms that allow the robot to perceive and move through its environment. It involves sensing the surroundings, planning a path, and executing the necessary motions to reach a desired location. Here are the key components typically found in a humanoid robot's navigation system:

- Sensors: Humanoid robots use various sensors to gather information about their environment. These may include cameras, depth sensors (such as LiDAR or depth cameras), inertial measurement units (IMUs) for detecting orientation and acceleration, and contact sensors to detect physical interactions with objects.

- Perception: The robot's perception module processes sensor data to extract relevant information about the environment. This includes recognizing obstacles, identifying landmarks, mapping the surroundings, and estimating the robot's position and orientation (also known as localization).

- Mapping: The mapping component builds a representation of the environment based on the sensor data received. This representation, often referred to as a map, can be 2D or 3D and is used by the robot to understand the layout of the surroundings and plan its movements accordingly.

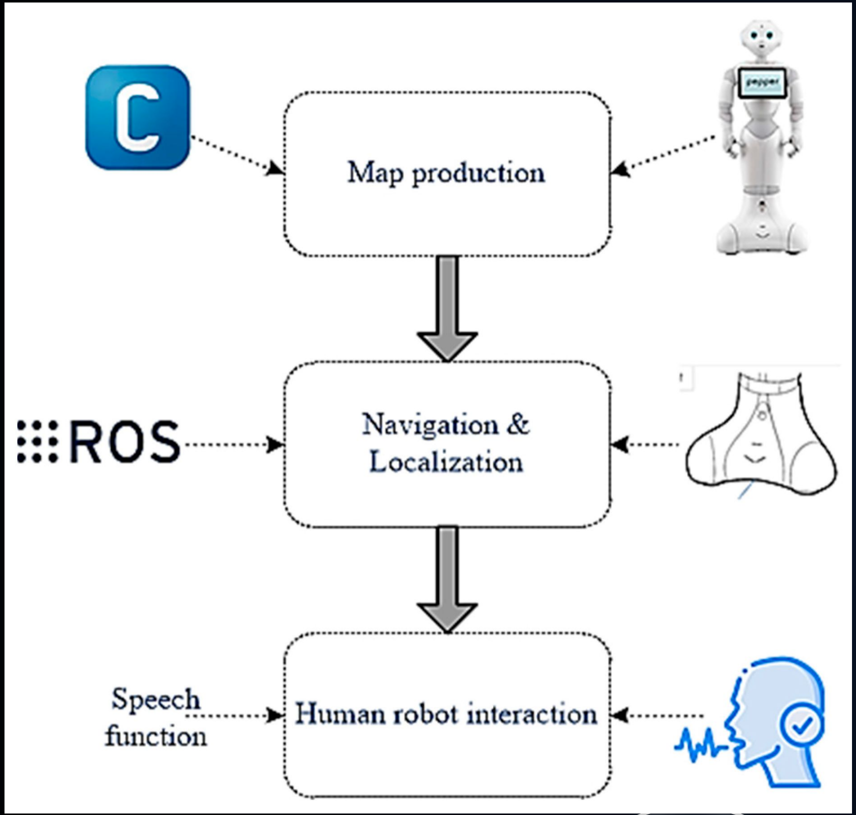
- Path Planning: Once the robot has knowledge of its surroundings and its own position, it can plan a path from its current location to a target location. Path planning algorithms, such as A* or Dijkstra's algorithm, take into account obstacles, the robot's physical limitations, and any constraints to find an optimal or feasible path.

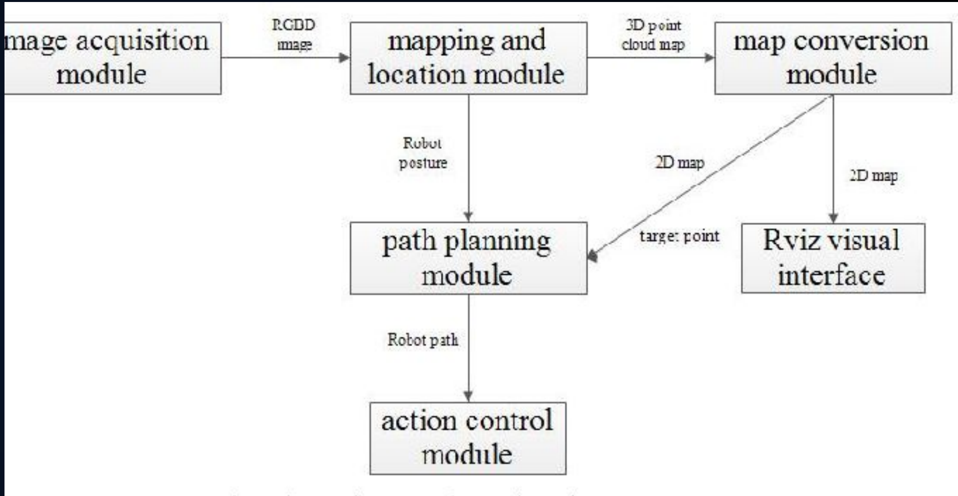
- Motion Control: The motion control component translates the planned path into specific motor commands for the robot's joints. It takes into consideration the robot's kinematics, dynamics, and balance to ensure safe and stable locomotion.

- Obstacle Avoidance: To navigate autonomously, humanoid robots need to avoid obstacles in their path. This is typically achieved by combining sensor data (IR sensor or proximity sensor) with the planned path and dynamically adjusting the robot's movements to steer clear of obstacles.

- Feedback and Adaptation: A navigation system often incorporates feedback mechanisms to ensure the robot can adapt to unexpected changes in the environment. This can involve continuously updating the map, relocalizing if the robot becomes lost, or adjusting the planned path in real-time.

By integrating these components, a humanoid robot can perceive its surroundings, plan a path, and execute the necessary movements to navigate autonomously or interact with its environment effectively.


Map production
ROS
Navigation &
Localization
Speech
function
Human robot interaction


mage acquisition
module
RGBD
image
mapping and
location module
3D point
cloud map
map conversion
module
Robot
posture
2D map
2D map
target point
path planning
module
Rviz visual
interface
Robot path
action control
module

Data Collection System

The data collection system of a humanoid robot typically involves various sensors and devices that enable the robot to perceive and understand its environment. These sensors gather information, which is then processed and utilized by the robot for decision-making and performing tasks. Here are some common components of a data collection system in a humanoid robot:

1. Vision Sensors: Humanoid robots often have cameras or vision sensors to capture visual information from their surroundings. These sensors enable the robot to recognize objects, detect movement, and navigate the environment.
2. Depth Sensors: To perceive depth and distances accurately, humanoid robots may employ depth sensors such as time-of-flight cameras or stereo cameras. These sensors provide 3D information, which aids in object recognition, obstacle avoidance, and spatial mapping.
3. Inertial Measurement Unit (IMU): An IMU typically consists of accelerometers, gyroscopes, and sometimes magnetometers. It helps the robot to measure its orientation, angular velocity, and acceleration. The data from an IMU is essential for balance control, motion planning, and stabilizing the robot's movements.

Data Collection System

4. Tactile Sensors: Humanoid robots may be equipped with tactile sensors on their limbs or hands to sense contact or pressure. These sensors allow the robot to interact with objects or humans in a more nuanced manner, enabling tasks that require delicate manipulation or force sensing.

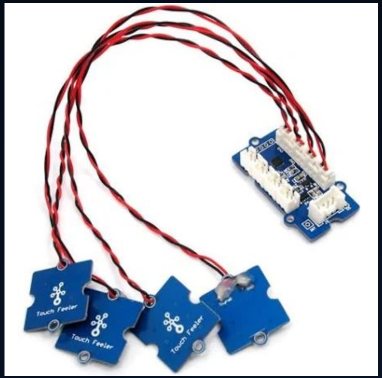
5. Force/Torque Sensors: Force sensors measure the forces or torques applied by the robot on objects or encountered during interactions. They help the robot in tasks that require precise force control, such as grasping, lifting, or pushing objects.

6. Microphones and Audio Sensors: Sound sensors, such as microphones or audio arrays, enable the robot to perceive and process auditory information. They can be used for speech recognition, sound localization, and even for social interactions by detecting human speech and responding accordingly.

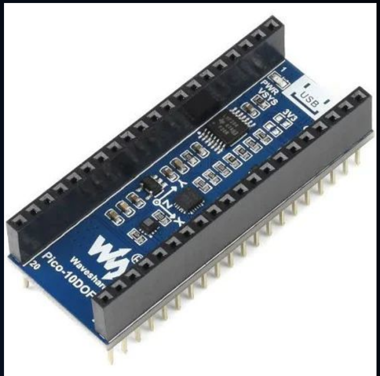
7. Environmental Sensors: Some humanoid robots may have additional sensors like temperature sensors, humidity sensors, or gas sensors to monitor the environment and gather relevant data for specific applications or safety purposes.

The data collected by these sensors is usually processed by the robot's onboard computer or central processing unit (CPU). It may involve complex algorithms for image recognition, object tracking, sensor fusion, or machine learning techniques to analyze and interpret the data. The processed information is then utilized for decision-making, control, and executing tasks based on the robot's programming or learning capabilities.

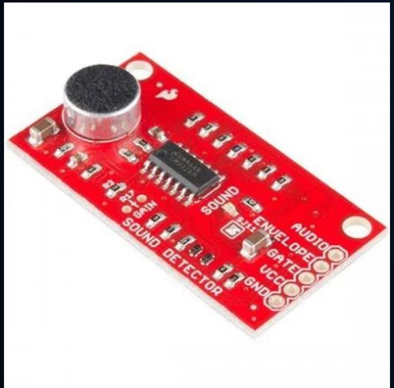
LIDAR



Tactile sensor



IMU sensor



Sound sensor

Stereo camera

Data Transmission

The data transmission system of a humanoid robot involves the transfer of data between the robot and external devices or systems. This communication enables the robot to exchange information, receive commands, and share its sensor data or processed results with other entities Here are the key components and processes involved in a humanoid robot's data transmission system:

1. Communication Interfaces: Humanoid robots are equipped with various communication interfaces to establish connections with external devices. These interfaces can include wired connections such as Ethernet or USB ports, as well as wireless connections like Wi-Fi, Bluetooth, or even cellular networks.
2. Data Encoding: Before data can be transmitted, it is often encoded into a specific format suitable for transmission. This encoding process converts the data into a digital representation that can be easily transmitted over the chosen communication medium. Common encoding schemes include binary formats, ASCII or Unicode for text-based data, and various image or audio compression algorithms.
3. Protocols: Communication protocols define the rules and procedures for data transmission between devices. Protocols ensure reliable and efficient communication by specifying how data packets are structured, transmitted, acknowledged, and error-checked. Examples of communication protocols commonly used in humanoid robots include TCP/IP (Transmission Control Protocol/Internet Protocol), HTTP (Hypertext Transfer Protocol), and MQTT (Message Queuing Telemetry Transport).

4. Real-Time Communication: In scenarios where real-time interaction is required, humanoid robots may utilize specialized protocols or technologies that offer low latency and guaranteed timing constraints. These real-time communication mechanisms ensure that time-critical data, such as sensor readings or control commands, can be transmitted and received within strict time limits.

5. Remote Control: Humanoid robots often feature remote control capabilities, allowing them to be operated or monitored from a remote location. Remote control interfaces enable users to send commands to the robot and receive real-time feedback, either through dedicated control software or custom-designed interfaces.

6. Sensor Data Streaming: Humanoid robots frequently transmit sensor data to external devices or systems for analysis or monitoring purposes. Sensor data streaming allows the robot to share its perception of the environment with other entities in real-time or near real-time. For instance, a humanoid robot equipped with a camera can stream live video to a remote workstation for visual monitoring.

7. Telemetry and Logging: Telemetry refers to the transmission of diagnostic or performance-related data from the robot to external systems for monitoring and analysis. This can include information about the robot's internal state, sensor readings, motor statuses, or battery levels. Logging mechanisms record this telemetry data for later analysis or troubleshooting.

Components Used in Data Transmission

1. Network Interfaces: Network interfaces are essential for establishing wired or wireless connections for data transmission. This can include Ethernet ports, Wi-Fi modules, Bluetooth modules, cellular communication modules (such as 3G or 4G/LTE), or other specialized communication interfaces.
2. Transceivers: Transceivers are components that enable bidirectional communication over a specific communication medium. They convert digital data into signals suitable for transmission and receive incoming signals for data reception. Examples include Ethernet transceivers or wireless transceivers for Wi-Fi or Bluetooth communication.
3. Antennas: Antennas are used for wireless communication to transmit and receive radio frequency signals. In humanoid robots with wireless capabilities, antennas are essential for establishing reliable connections and ensuring signal strength and coverage.
4. Cables and Connectors: Wired data transmission often requires cables and connectors to physically connect the robot to external devices or networks. Examples include Ethernet cables, USB cables, or specialized cables for specific communication protocols.
5. Protocol Converters: In situations where different devices or systems use different communication protocols, protocol converters or adapters may be used to bridge the gap. These converters allow data to be transmitted and received between devices using incompatible protocols.

6. Microcontrollers: Microcontrollers or embedded systems may be utilized to manage the data transmission process. They handle the low-level communication protocols, data encoding, decoding, and manage the data flow between different components involved in data transmission.

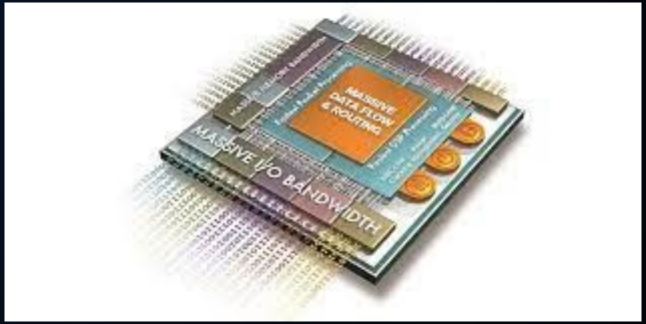
7. Data Encoders/Decoders: Data encoders and decoders convert data into specific formats suitable for transmission and reception. They encode the data before transmission and decode it upon reception, ensuring compatibility and reliable data transfer between the robot and external devices or systems.

8. Wireless Access Points/Routers: In cases where wireless communication is used, wireless access points or routers may be involved. These devices provide network connectivity and facilitate the communication between the robot and other devices connected to the same network.

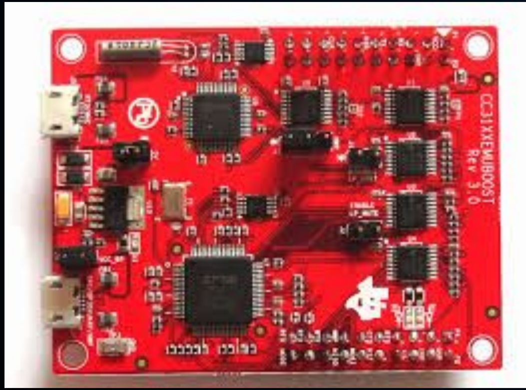
9. Data Storage Devices: If data is temporarily stored or buffered before transmission, data storage devices like memory buffers or cache may be used. These devices can hold the data until it is ready to be transmitted or until the transmission is complete.

10. Security Mechanisms: When transmitting data, security measures such as encryption algorithms and authentication mechanisms may be employed to ensure data privacy and prevent unauthorized access or tampering.

Microcontrollers



Wi-fi Module



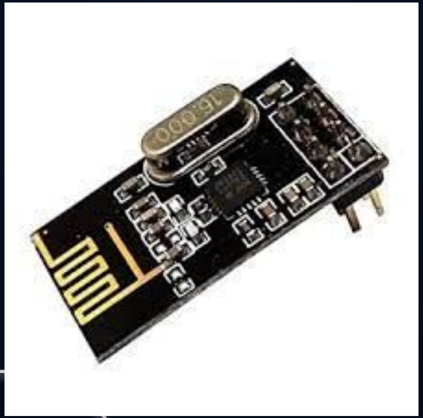
CC3100

WIZnet WiFi

Transceiver Module

SP1ML-868

CC2500



nRF24

Power Management

The power management system of a humanoid robot is responsible for managing the power supply, distribution, and control of electrical energy within the robot's system. It ensures that the robot's components receive the appropriate voltage, current, and power required for their operation. Here are some key aspects of the power management system in humanoid robots:

1. Power Source: Humanoid robots typically have one or more power sources, such as batteries, power banks, or direct power connections. The power source provides the initial electrical energy that will be distributed and utilized by the robot's components.
2. Power Conversion: The power management system may include components for converting the electrical energy from the power source into suitable forms for different components. This can involve voltage regulation, current control, and power conditioning to meet the specific requirements of various subsystems within the robot.
3. Power Distribution: Once the power is converted, it needs to be distributed to different components and subsystems in the robot. Power distribution modules, such as power distribution boards or power distribution units (PDUs), allocate the power to various sections of the robot's system based on their power demands.
4. Voltage Regulation: Different components in the humanoid robot may require different voltage levels for their operation. Voltage regulators, such as DC-DC converters or voltage regulators integrated into microcontroller boards, ensure that the voltage supplied to each component is within its specified operating range.

5. Current Management: The power management system monitors and manages the current flowing through the robot's components. Current sensing mechanisms, such as current sensors or shunt resistors, can be employed to measure the current consumption of individual components or subsystems. This information can be used for power optimization and protection against excessive current draw.

6. Power Monitoring and Control: Power management systems often include monitoring and control mechanisms to track the power consumption of different components and subsystems. This allows for efficient power allocation, power optimization, and the ability to detect anomalies or malfunctions related to power usage.

7. Power Protection: Humanoid robots may have protection mechanisms to safeguard against overvoltage, undervoltage, overcurrent, or short circuits. These can include fuses, circuit breakers, or electronic protection circuits that automatically cut off or limit power flow in case of an abnormal condition, preventing damage to the robot's components.

8. Power Efficiency and Optimization: Power management systems aim to optimize power usage to maximize the robot's operating time and minimize energy waste. Techniques such as power gating, dynamic voltage scaling, or power-saving modes can be implemented to reduce power consumption during idle or low-demand periods.

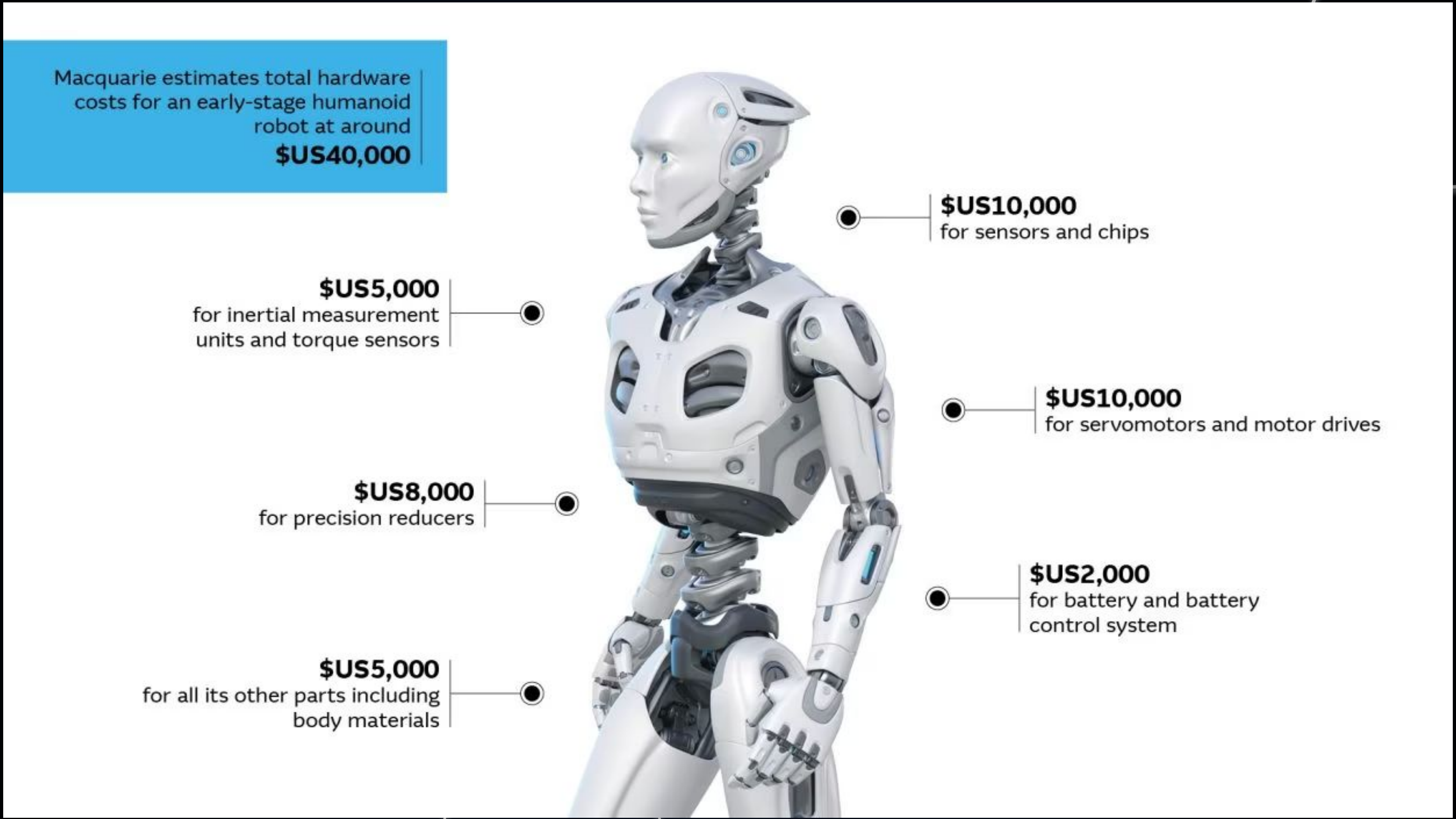
9. Charging and Battery Management: If the humanoid robot uses rechargeable batteries as its power source, the power management system may include battery management mechanisms. This involves charging circuits, battery monitoring, and protection circuits to ensure safe and efficient charging, as well as battery health monitoring.

Table 5. Comparison between lithium batteries, fuel cells, and solar cells characteristics.

Type	Efficiency	Power	Work Temperature/°C	Power Density	Cycle life	Specific Capacity/mAh/g
LiPO4 [101]	90%	N/A	−20–60	549 Wh/kg	>2000 times	150
LCO [101]	95%	N/A	−20–55	200–250 Wh/kg	500–1000 times	145
NCM [101]	95%	N/A	0–45	588 Wh/kg	>1000 times	110–120
AFC [100]	60%	10–100 kW	50–200			
PAFC [39]	40%	1–100 kW	160–220			
MCFC [39]	45–50%	100–400 kW	620–660	>500 Wh/kg	5000–20,000 h	N/A
SOFC [39]	60%	300 kW–3 MW	800–1000			
PEMFC [39]	35–60%	1 kW–2 MW	60–80			
Solar Battery [102]	10.1–25%	10 W–50 MW	Best at 25 °C	80 W/kg *(Solar Impulse 2)* [103]	20 Year	N/A

Table 2: Comparison of different batteries [93].

Characteristic	Ni-Cd	Ni-Mh	LiPo	Li-S
Specific energy (Wh/kg)	40	80	180	350
Energy density (Wh/l)	100	300	300	350
Specific power (W/kg)	300	900	2800	600

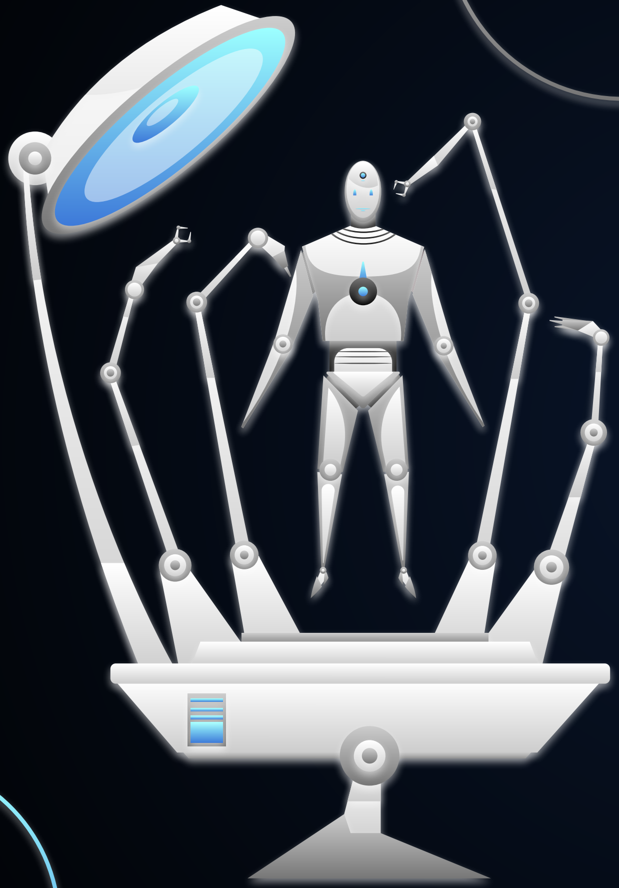

Macquarie estimates total hardware costs for an early-stage humanoid robot at around
$US40,000
$US10,000
for sensors and chips
$US5,000
for inertial measurement units and torque sensors
$US10,000
for servomotors and motor drives
$US8,000
for precision reducers
$US2,000
for battery and battery control system
$US5,000
for all its other parts including body materials

Conclusion

In conclusion, humanoid robots represent a fascinating and rapidly evolving field of robotics. These robots, designed to mimic human form and behavior, hold great potential in various domains, including healthcare, assistive technologies, entertainment, and research. Through advancements in mechanical design, artificial intelligence, and sensing technologies, humanoid robots are becoming more capable, versatile, and interactive.

Humanoid robots offer unique advantages such as human-like movement, dexterity, and the ability to navigate and interact in human-centric environments. They have the potential to assist in tasks that require human-level understanding, manipulation, and communication. Whether it's aiding in complex surgeries, supporting elderly care, or enhancing human-robot collaboration in industrial settings, humanoid robots are poised to revolutionize numerous industries and improve the quality of human life.

In conclusion, humanoid robots are no longer confined to the realms of science fiction. They are increasingly becoming a reality, and their impact on society is set to be transformative. With further advancements and collaborations between robotics experts, engineers, and researchers, we can unlock the full potential of humanoid robots and embrace a future where humans and robots coexist, collaborate, and thrive.



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