

ADVANCED MANUFACTURING FACILITY FOR HUMANOID ROBOTS

FIELD OF INVENTION

[0001] The present disclosure relates to manufacturing facilities for humanoid robots, and more particularly to a high-volume manufacturing facility designed for efficient production of humanoid robots using advanced automation, modular assembly, and integrated quality control systems.

BACKGROUND

[0002] The modern labor landscape is undergoing a profound transformation driven by an acute workforce shortage, with over 10 million jobs in the United States deemed unsafe, undesirable, or otherwise unappealing for human workers. These positions, prevalent across industries such as manufacturing, construction, agriculture, and logistics, often involve hazardous conditions, repetitive tasks, or physically strenuous duties that pose significant risks to human health and safety. The growing labor gap threatens productivity and operational continuity, necessitating innovative solutions to mitigate workforce challenges. In response, the development and deployment of advanced robotic systems, particularly general-purpose humanoid robots, have emerged as a viable means to address these issues by automating tasks traditionally performed by human workers.

[0003] General-purpose humanoid robots are designed with an anthropomorphic structure, typically featuring a bipedal locomotion system, dexterous manipulators, and an interface resembling a human face to facilitate interaction. This human-like form factor allows them to seamlessly navigate and operate within environments designed for people, such as warehouses, construction sites, and healthcare facilities, without requiring significant infrastructure modifications. By replicating human movements, these robots can execute a diverse range of functions, including material handling, assembly, inspection, and caregiving, thereby reducing the need for human intervention in labor-intensive or hazardous occupations. Additionally, advancements in artificial intelligence enable these robots to learn, adapt, and optimize task performance over time, further enhancing their versatility and integration into various industries. Their adoption not only improves workplace safety but also enhances productivity and addresses labor shortages by supplementing the existing workforce.

[0004] Despite this progress, several challenges remain in the widespread adoption of humanoid robots, including the high cost of development and production. The scalability of manufacturing humanoid robots is another critical challenge, as traditional production methods may not be optimized for the intricate integration of mechanical, electrical, and software components required for these systems. Also, the fragmentation in hardware and software ecosystems creates interoperability challenges, making it difficult for businesses to integrate robots from different manufacturers or scale their robotic workforce efficiently. Therefore, there is a need for an advanced manufacturing facility for humanoid robots.

SUMMARY

[0005] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0006] The present disclosure provides a manufacturing facility for humanoid robots, comprising: a production line configured to assemble humanoid robots; a plurality of subassembly stations feeding into the production line, wherein at least one subassembly station is configured to produce actuators; a warehouse area strategically positioned to efficiently deliver raw materials to the production line; a quality control system integrated throughout the production process; and a digital infrastructure for managing and optimizing manufacturing operations.

[0007] The present disclosure provides a method for manufacturing humanoid robots, comprising: assembling actuators at a dedicated subassembly station; integrating assembled actuators into larger functional units at subsequent subassembly stations; performing quality control tests on subassemblies using automated inspection systems; assembling a complete humanoid robot on a main production line using the tested subassemblies; and calibrating the assembled humanoid robot using a series of automated and manual tests.

[0008] The present disclosure provides a system for optimizing humanoid robot production, comprising: a manufacturing execution system (MES) for real-time monitoring and control of production processes; a supply chain management module integrated with the MES for coordinating component delivery; a quality control module utilizing machine learning algorithms

for defect detection; and a data analytics platform for identifying production inefficiencies and suggesting process improvements.

[0009] The present disclosure provides a method for integrating humanoid robots into a manufacturing process, comprising: assembling a humanoid robot on a production line; activating the assembled humanoid robot; directing the activated humanoid robot to join the production line; and utilizing the humanoid robot to perform assembly tasks in the production of subsequent humanoid robots.

[0010] The present disclosure provides a scalable manufacturing facility for humanoid robots, comprising: modular production lines capable of being replicated or expanded; a flexible layout design allowing for the addition of parallel production lines; standardized equipment and procedures for consistent production across multiple facilities; and an adaptable digital infrastructure supporting multi-site operations and centralized management.

[0011] The present disclosure provides a method for quality control in humanoid robot manufacturing, comprising: performing non-destructive testing on critical components using X-ray imaging or ultrasonic inspection; conducting environmental stress screening on assembled robots to evaluate reliability under various conditions; implementing statistical process control methods to monitor and control the manufacturing process; and maintaining a comprehensive traceability system for tracking individual components throughout the assembly process.

[0012] The present disclosure provides a system for automated humanoid robot assembly, comprising: a series of robotic arms configured to perform precise assembly tasks; a conveyor system for transporting robot components and subassemblies between stations; vision systems for component identification and alignment; and an artificial intelligence controller for coordinating the actions of the robotic arms and optimizing the assembly sequence.

[0013] The present disclosure provides a method for designing humanoid robots for mass production, comprising: analyzing the manufacturing process of a prototype robot to identify time-consuming steps; redesigning components to reduce part count and complexity; selecting manufacturing processes that optimize production speed and efficiency for high volumes; and implementing modular design principles to facilitate assembly and future upgrades.

[0014] The present disclosure also relates to a modular manufacturing system for humanoid robots, incorporating reconfigurable assembly stations that adapt to different robot models. The production line integrates automated systems, including grease dispensing mechanisms for

precise actuator lubrication, fastening systems for secure structural attachment, and computer vision-based inspection systems to verify actuator integration. Material transport between stations is facilitated by automated guided vehicles (AGVs), while a centralized control system dynamically optimizes production flow.

[0015] Additionally, the actuator assembly process involves fabricating custom gears using metal injection molding, integrating motors and sensors into actuator housings, and calibrating each actuator via an automated testing system. Integration of assembled actuators into functional units includes secure attachment using automated fastening systems, establishing electrical and data connections with control boards, and verifying assembly quality through computer vision-based inspection. Quality control measures include simulated load testing using robotic fixtures, machine learning-based defect detection, and automated segregation of defective components. Non-destructive testing is conducted using high-resolution X-ray imaging analyzed by AI algorithms to detect internal defects or misalignments. Environmental stress screening is performed through thermal cycling (-40°C to 85°C), multi-axis vibration testing, and high-humidity exposure (95% relative humidity), with continuous sensor monitoring to identify performance degradation.

[0016] Further, the manufacturing execution system (MES) enables real-time production scheduling, dynamically adjusting operations based on component availability and production targets. A digital twin of the production line facilitates process simulation and optimization, while an AGV control system coordinates material movement. Supply chain management is enhanced through predictive analytics for demand forecasting and inventory optimization, supplier performance tracking, and blockchain-based traceability to ensure component authenticity. Humanoid robots assist in assembly by accessing digital instructions, collaborating with human workers via gesture recognition and natural language processing, and automating the training of newly activated robots. Predictive maintenance systems analyze performance data to schedule preventive maintenance, and continuous software updates improve operational efficiency and adaptability.

[0017] Moreover, artificial intelligence optimizes manufacturing through neural network-based assembly sequencing, adaptive scheduling of robotic arms, and predictive maintenance analytics. Computer vision systems utilize high-resolution cameras, laser scanning for 3D model verification, and edge detection algorithms to ensure precise alignment of components. Design

optimizations focus on reducing part count and complexity by consolidating multiple components into single, structurally optimized parts. Advanced CAD tools and finite element analysis (FEA) simulations ensure manufacturability and mechanical performance.

Manufacturing processes prioritize efficiency by transitioning from CNC machining to injection molding, die casting, and metal injection molding for high-volume production. Automated assembly is enhanced through robotic arms, computer vision-guided placement, and additive manufacturing for rapid prototyping of complex, low-volume components.

[0018] Finally, a secure and intelligent digital infrastructure supports manufacturing operations, incorporating a cloud-based MES for real-time monitoring across multiple facilities, machine learning algorithms for predictive maintenance and process optimization, and secure data exchange protocols for seamless production site integration. Additional automation and security features include robotic process automation (RPA) for administrative tasks, augmented reality (AR) interfaces for assembly guidance, and cybersecurity modules implementing encryption and access controls to protect sensitive manufacturing data. These combined technologies create an adaptable, high-efficiency manufacturing ecosystem for humanoid robots, ensuring precision, reliability, and scalability in production.

[0019] The foregoing general description of the illustrative embodiments and the following detailed description thereof are merely exemplary aspects of the teachings of this disclosure and are not restrictive.

DETAILED DESCRIPTION

[0020] The following description sets forth exemplary aspects of the present disclosure. It should be recognized, however, that such description is not intended as a limitation on the scope of the present disclosure. Rather, the description also encompasses combinations and modifications to those exemplary aspects described herein.

A. Facility Overview

[0021] The BotQ facility is a high-volume manufacturing plant dedicated to the production of humanoid robots. Spanning approximately 60,000 square feet, the facility is designed with a vertically integrated manufacturing approach, enabling comprehensive control over the build process, quality assurance, and delivery of high-functioning robots to market. In its initial configuration, the facility is capable of manufacturing up to 12,000 humanoid robots per year. To

meet this volume, BotQ produces a robot every 20 minutes, but the real magic happens upstream at the feeder lines: A finger every 2 minutes and an actuator every 40 seconds. To achieve these goals we have broken down the complexity of robots into simple station-specific tasks and created dedicated jigs and fixtures to ensure speedy assembly. Every robot part has been painstakingly reviewed for assembly flow, tool access, and cycle time. We have eliminated scores of fasteners, sensors, and PCBAs by reimagining the system to reduce part count. Our team spans a background across automotive and consumer tech high rate manufacturing and our line will put that knowledge to work.

[0022] The facility's layout is optimized for material flow, beginning with strategically positioned warehouse access points that ensure efficient delivery of raw materials to the first assembly stations. Actuator production lines and subassembly lines converge into a final robot assembly and test main line. The actuator lines focus on producing motion components critical for robot movement, while subassembly lines create larger functional units, such as limbs and torsos, integrating actuators, sensors, and structural elements. These modular subassemblies undergo rigorous testing and calibration before final integration, ensuring that they meet predefined performance criteria.

[0023] Designed for scalability, the facility allows for expansion through additional production lines or reconfiguration of existing lines to accommodate growing demand. Dedicated areas for component manufacturing, subassembly, final assembly, testing, and quality control ensure streamlined material handling and process efficiency. Additionally, supporting functions such as engineering, quality assurance, and supply chain management are integrated within the production floor to facilitate cross-team collaboration and rapid problem resolution.

[0024] The BotQ facility incorporates advanced manufacturing technologies to enhance precision and efficiency. Automated assembly systems, robotics, and computer-controlled machinery are deployed across multiple production stages. Modular and reconfigurable elements in production lines enable quick adaptation to design changes or varying production requirements, minimizing downtime and retooling efforts. In-house development of critical components, such as actuators and control systems, ensures rapid iteration and continuous improvement based on production feedback and performance analytics.

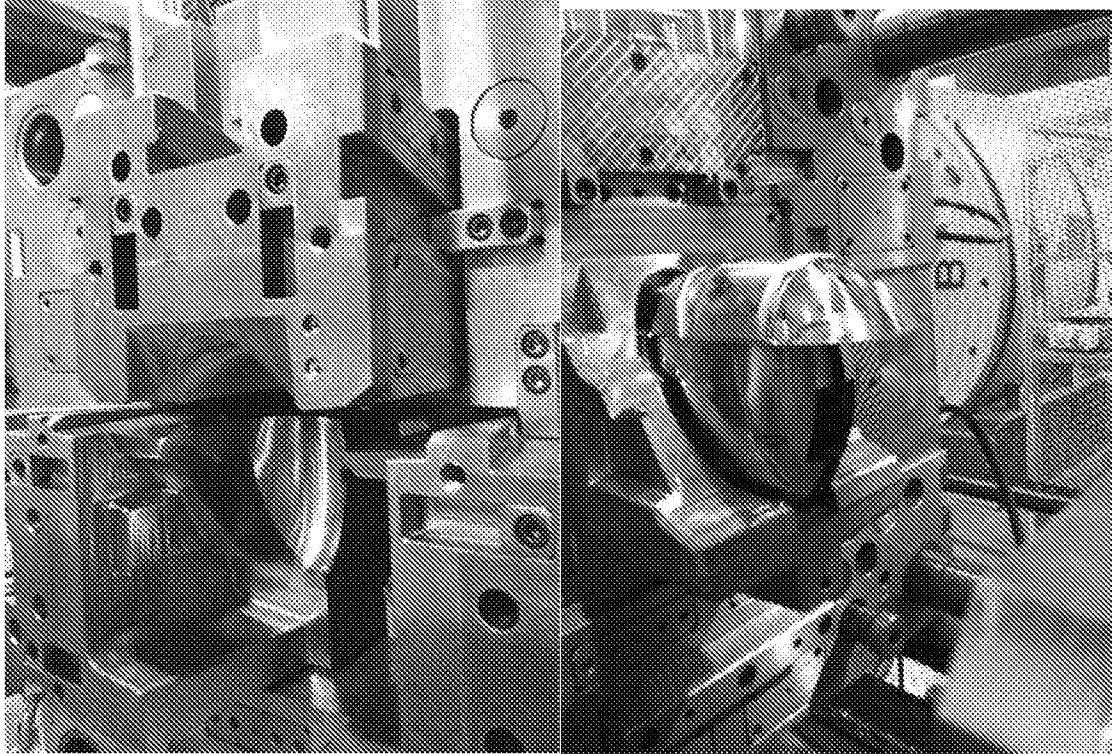
[0025] The facility's dedicated production zones incorporate specialized environmental controls where necessary, particularly for sensitive components such as electronics and optical

systems. Advanced testing and calibration equipment verify the functionality of each robot through gait analysis, motor skill assessments, and real-world scenario simulations. Quality control measures are implemented at every stage of production to identify and address defects early in the manufacturing process. A comprehensive digital infrastructure underpins the facility's operations, integrating real-time data analytics, augmented reality systems for maintenance and quality control, and collaborative platforms for inter-team coordination. This infrastructure fosters a culture of continuous improvement, allowing for dynamic enhancements in both manufacturing processes and robot designs.

B. Robot Architecture and Design Considerations

[0026] The optimization of humanoid robot architecture for mass production involves a comprehensive redesign process that integrates advanced manufacturing techniques, materials, and methodologies to enhance production efficiency, reduce costs, and improve overall performance. This process includes transitioning from computer numerical control (CNC) machining to tooled manufacturing processes such as injection molding, die casting, metal injection molding, and stamping. The transition offers significant advantages for high-volume production, including reducing manufacturing time from over a week with CNC machining to under 20 seconds using complex steel molds, significantly increasing production throughput and efficiency.

[0027] Injection molding is utilized for producing plastic components with high precision and consistency, allowing for complex geometries and intricate detailing that may not be feasible with traditional machining methods. Die casting is employed for metal components, enabling the creation of lightweight yet structurally robust parts with finely detailed surfaces. Metal injection molding (MIM) combines the benefits of plastic injection molding with the mechanical strength of metal materials, making it particularly suitable for small, complex metal components requiring precise tolerances. Stamping is used to produce flat or slightly formed metal parts in high volumes with exceptional speed and accuracy, further streamlining production efficiency.



[0028] A key aspect of the redesign is reducing the overall part count by integrating multiple components into single, more complex parts. This integration minimizes the number of assembly operations, reducing production complexity and the likelihood of errors while improving mechanical integrity. Components may be designed with self-aligning features, snap-fit connections, and standardized fasteners to facilitate automated assembly processes. The implementation of robotic assembly lines can further enhance efficiency by leveraging precision-guided robotic arms to handle intricate assembly tasks with minimal human intervention.

[0029] Although transitioning to tooled processes requires a significant upfront investment in molds and specialized equipment, the per-unit production cost is significantly reduced at high volumes, leading to long-term economic benefits. Material selection is another critical consideration in this optimization process. The use of advanced composite materials can provide an optimal strength-to-weight ratio, while specialized alloys may be developed to meet specific performance requirements while maintaining compatibility with high-volume manufacturing techniques. Engineers employ advanced computer-aided design (CAD) and simulation tools to refine part geometries, ensuring structural integrity while minimizing material waste. These tools enable virtual prototyping and iterative design refinements, identifying potential issues before physical prototypes are fabricated, thereby reducing costly trial-and-error cycles.

[0030] Beyond traditional tooled processes, additional manufacturing techniques may be incorporated into the production workflow. Additive manufacturing, or 3D printing, enables rapid prototyping and the creation of complex, low-volume parts that may be impractical to produce using conventional methods. Laser cutting provides high-precision shaping of sheet materials, allowing for intricate patterns and designs. Ultrasonic welding facilitates the joining of plastic components without requiring adhesives or mechanical fasteners, further simplifying assembly and reducing weight.

[0031] The redesign process extends beyond mechanical considerations to electronic and software component optimization. The integration of custom application-specific integrated circuits (ASICs) or system-on-chip (SoC) solutions consolidates multiple electronic functions into a single component, reducing board space, power consumption, and assembly complexity. Additionally, modular electronic components may be developed to facilitate easier repairs and upgrades, improving the robot's serviceability and lifespan. Consideration of the entire lifecycle of the robot, including maintenance and potential future upgrades, ensures that modular components can be quickly replaced or upgraded in the field, enhancing long-term usability and adaptability.

[0032] Further, the facility takes advantage of advanced automation systems. An example of automation for quality is the automated grease dispense station for our gearboxes. We can control the location and volume of the gearbox grease far more accurately with an automated dispensing tool than with a manual grease gun. An example of automation for speed is our cell test and load station: A robot is far faster than a human at picking up, scanning, and testing every battery cell before assembly into the battery pack.

[0033] To maintain high quality in mass production, specialized testing and quality control measures are implemented. Automated inspection systems leveraging machine vision and artificial intelligence (AI) can be integrated into the production line to detect defects or deviations from design specifications in real-time. RFID tags or similar tracking technologies may be embedded in critical components to facilitate real-time inventory tracking, ensuring precise control over material flow and production logistics. The optimization process also extends to the manufacturing facility layout and production line design. Advanced simulation tools enable engineers to model and optimize factory workflows, identifying bottlenecks and inefficiencies before they impact production. The implementation of innovative conveyor

systems, automated guided vehicles (AGVs) for material transport, and even humanoid robots for assembly tasks further enhances manufacturing efficiency.

[0034] By integrating these advanced manufacturing strategies, material optimizations, and automation techniques, the humanoid robot architecture can be comprehensively refined for mass production. This holistic approach ensures higher production efficiency, improved product quality, and reduced overall manufacturing costs while allowing for scalability and adaptability in a rapidly evolving robotics market. The combination of tooled manufacturing processes, optimized materials, electronic integration, and advanced quality control measures results in a highly efficient production ecosystem capable of supporting large-scale deployment of humanoid robots. These advancements will allow us to create Figure 03 robots 90% cheaper and 300x faster than Figure 02.

C. Supply Chain and Vertical Integration

[0035] The supply chain management and vertical integration approach for humanoid robot production is designed to optimize manufacturing efficiency, maintain stringent quality control, and enable scalability for high-volume production. This strategy balances in-house manufacturing of critical components with strategic external sourcing to ensure cost-effectiveness and flexibility in adapting to technological advancements and market demands.

[0036] Core technologies integral to humanoid robot performance, such as actuators, hands, batteries, and final assembly, may be manufactured in-house. This decision is based on factors including component criticality, quality control requirements, and the protection of proprietary technologies. Internal manufacturing allows for rigorous testing, enhanced process optimization, and integration of custom design specifications that contribute to superior product performance.

[0037] The selection of external suppliers for various robot components follows a rigorous evaluation process, which assesses technical capabilities, production capacity, quality control measures, and scalability. Suppliers may be chosen for their expertise in specialized manufacturing techniques or their ability to produce complex components requiring advanced equipment. To ensure compliance with design and performance standards, a collaborative approach may be adopted, where suppliers receive design specifications, performance benchmarks, and quality assurance guidelines. In some cases, specialized tooling or equipment may be provided to external partners to enable the production of custom components that meet precise engineering requirements.

[0038] The supply chain is structured to be highly scalable, supporting increased production volumes as demand for humanoid robots grows. This scalability is achieved through multiple strategic initiatives, including:

1. Dual-Sourcing of Critical Components: Reducing supply chain risks and enhancing production capacity by engaging multiple suppliers for key components.
2. Long-Term Supplier Partnerships: Establishing stable relationships with key suppliers to ensure consistent supply and collaborative innovation.
3. Just-in-Time Inventory Management: Minimizing storage costs and improving production efficiency by synchronizing component deliveries with assembly schedules.
4. Regional Supplier Networks: Reducing transportation costs and lead times by leveraging localized supply chains for different markets.

[0039] Advanced technologies such as artificial intelligence and machine learning may be integrated into the supply chain management system to optimize inventory levels, predict demand fluctuations, and preempt potential disruptions. AI-driven predictive analytics enhance production continuity by identifying vulnerabilities and mitigating risks before they impact manufacturing operations.

[0040] Beyond manufacturing, vertical integration extends to research and development, software engineering, and after-sales service. This holistic approach ensures complete control over the product lifecycle, from initial design and prototyping to deployment, maintenance, and continuous improvement. Modular component design may be implemented to standardize key elements across different humanoid robot models. This standardization reduces supply chain complexity, simplifies assembly, and facilitates cost-effective maintenance and upgrades.

[0041] A supplier development program may be established to enhance the technical capabilities of key partners through training, quality management assistance, and joint research and development initiatives. By investing in supplier growth, the overall resilience and innovation potential of the supply chain can be enhanced. To improve supply chain visibility, real-time tracking systems leveraging Internet of Things (IoT) sensors, blockchain technology for secure data sharing, and cloud-based platforms for seamless information exchange may be deployed. These technologies enhance transparency, enable proactive issue resolution, and streamline logistics operations.

[0042] Sustainability initiatives may be incorporated into the supply chain strategy by sourcing eco-friendly materials, implementing energy-efficient manufacturing processes, and developing recycling programs for end-of-life components. A circular economy approach may be adopted, facilitating the refurbishment and reuse of key robotic elements to minimize environmental impact. Risk management strategies, such as geographically diversified sourcing, stockpiling of critical components, and alternative manufacturing process development, may be employed to mitigate supply chain disruptions. Continuous improvement methodologies like Six Sigma and Lean Manufacturing may be applied to enhance productivity, reduce waste, and eliminate inefficiencies across the supply chain.

[0043] Vertical integration may also encompass the development of proprietary manufacturing equipment and processes tailored specifically for humanoid robot production. Custom production tools can enhance efficiency, reduce defects, and create additional competitive barriers for market entrants. Human resource development programs may be introduced to cultivate a skilled workforce proficient in complex supply chain operations and advanced manufacturing techniques. This could involve partnerships with academic institutions, specialized training programs, and the development of expertise in emerging robotics technologies.

[0044] Advanced predictive maintenance systems leveraging sensors and machine learning algorithms may be deployed across the manufacturing process and supply chain. These systems monitor equipment performance, predict failures, and schedule proactive maintenance, minimizing downtime and extending the lifespan of production assets. Digital twin technology may be used to create virtual simulations of the entire supply chain and manufacturing ecosystem. These digital models can optimize workflows, identify potential bottlenecks, and enhance decision-making through real-time data analysis.

[0045] Blockchain technology may further enhance supply chain security and transparency by facilitating automated procurement, payments, and quality assurance processes through smart contracts. This reduces administrative overhead and mitigates risks associated with fraud and errors. Automation technologies, including automated guided vehicles (AGVs) and robotic process automation (RPA), may be employed for inventory management, material handling, and order fulfillment, increasing efficiency and reducing labor costs. Collaborative robotics (cobots) may be integrated into manufacturing lines to assist human operators, improving safety,

productivity, and flexibility in assembly processes. 3D printing may be leveraged for rapid prototyping, on-demand component manufacturing, and customized part production. This additive manufacturing capability reduces lead times, lowers tooling costs, and enhances supply chain agility.

[0046] By incorporating these advanced strategies and technologies, the supply chain and vertical integration framework for humanoid robot production achieves a high level of efficiency, flexibility, and innovation. This comprehensive approach not only enhances manufacturing performance but also establishes a robust foundation for adapting to future advancements in robotics, ensuring sustained competitiveness in an evolving technological landscape.

D. Manufacturing Team, Infrastructure, and Systems

[0047] The manufacturing team also integrates advanced material handling systems, including automated guided vehicles (AGVs) and robotic arms, to optimize component movement and reduce manual handling errors. Augmented reality (AR) technology is employed for real-time assembly guidance and quality inspection, improving worker efficiency and reducing training time. Statistical process control (SPC) methodologies enable precise control over production parameters, improving consistency and defect reduction. Furthermore, an adaptive robotic assembly system can be employed to dynamically adjust assembly sequences based on real-time data, optimizing throughput and minimizing bottlenecks.

[0048] Sustainability and efficiency initiatives include the development of energy-efficient production processes, waste reduction programs, and integration of renewable energy sources. Green manufacturing practices not only reduce environmental impact but also contribute to cost savings and improved public perception. Additionally, the team explores novel materials such as advanced composites, shape-memory alloys, and self-healing polymers to enhance robot durability and functionality. The implementation of closed-loop recycling systems for manufacturing byproducts may further improve sustainability by reducing material waste and minimizing the ecological footprint of production operations.

[0049] To accommodate growing demand for customized humanoid robots, the manufacturing team implements modular production systems and flexible assembly processes that enable mass customization without sacrificing efficiency. Adaptive manufacturing systems utilizing machine learning algorithms dynamically adjust production parameters based on real-

time data, ensuring optimal process performance despite variations in material properties or environmental conditions. Furthermore, a demand-driven supply chain framework, integrated with predictive analytics, allows for just-in-time manufacturing, reducing inventory costs while ensuring timely component availability.

[0050] By integrating advanced technologies, digital infrastructure, and data-driven methodologies, the manufacturing team establishes a highly responsive and adaptable production system. This holistic approach not only enhances current manufacturing capabilities but also positions the company to swiftly adapt to future advancements and evolving market demands in humanoid robotics.

E. Robots Building Robots

[0051] The integration of humanoid robots into the manufacturing process represents a significant advancement in automation and production efficiency. In some cases, humanoid robots may be utilized to perform assembly tasks and material handling operations within the production line. This approach leverages the versatility and adaptability of humanoid robots to enhance manufacturing capabilities.

[0052] In some implementations, humanoid robots equipped with advanced artificial intelligence systems may be employed in the assembly process. These robots may be capable of performing complex assembly tasks that traditionally require human dexterity and decision-making. The AI system may enable the robot to adapt to variations in component positioning, identify and handle different parts, and execute precise assembly movements.

[0053] Material handling within the manufacturing facility may also be accomplished using humanoid robots. In some cases, these robots may transport components between different stations on the assembly line, reducing the need for fixed conveyor systems and increasing layout flexibility. The ability of humanoid robots to navigate human-centric environments may allow for seamless integration with human workers and existing infrastructure.

[0054] The concept of robots building robots may be implemented by incorporating humanoid robots into the production process of other humanoid robots. This approach may create a self-replicating manufacturing system where each generation of robots contributes to the production of subsequent generations. In some implementations, as soon as a humanoid robot is assembled and activated, it may be directed to join the production line and assist in building its counterparts. The integration of humanoid robots in the manufacturing process may also

facilitate rapid adaptation to design changes or new product variants. The flexibility inherent in humanoid robots may allow for quick reprogramming and retooling, potentially reducing downtime between production runs of different robot models.

[0055] In some implementations, a hybrid workforce combining human operators and humanoid robots may be employed. This approach may leverage the strengths of both human expertise and robotic precision, creating a highly adaptable and efficient production environment. Human operators may oversee complex decision-making processes while robots handle repetitive or physically demanding tasks. The use of humanoid robots in manufacturing may also contribute to improved workplace safety by reducing human exposure to hazardous environments or strenuous activities. In some cases, robots may be assigned to tasks involving heavy lifting, working with high-temperature components, or handling potentially dangerous materials.

F. Quality Control and Testing

[0056] The manufacturing process incorporates comprehensive quality control measures and testing procedures to ensure the production of high-quality humanoid robots. These measures are implemented at various stages of the manufacturing process, from component-level testing to final product validation.

[0057] In some cases, subassemblies may undergo testing on dynamometers to evaluate their performance characteristics. This testing may involve measuring parameters such as torque output, speed, and efficiency for actuators, or range of motion and grip strength for hand assemblies. The use of dynamometers allows for precise measurement and analysis of mechanical performance under controlled conditions.

[0058] Data logging and analytics may be employed throughout the assembly process to capture and analyze information at every step. In some implementations, this may involve the use of sensors, cameras, and other monitoring devices to collect data on assembly operations, component characteristics, and environmental conditions. The collected data may be processed using advanced analytics algorithms to identify trends, detect anomalies, and optimize the manufacturing process.

[0059] Final calibration and testing of assembled robots may be performed to ensure overall functionality and performance. This process may involve a series of automated and manual tests designed to evaluate the robot's range of motion, balance, sensory capabilities, and cognitive

functions. In some cases, the robots may be subjected to simulated real-world scenarios to assess their performance under various conditions.

[0060] The quality control system may utilize statistical process control (SPC) methods to monitor and control the manufacturing process. This approach may involve the use of control charts, sampling techniques, and other statistical tools to identify and address variations in the production process. By analyzing trends and patterns in the collected data, the quality control team may be able to proactively identify potential issues and implement corrective actions before they impact product quality.

[0061] In some implementations, non-destructive testing techniques such as X-ray imaging, ultrasonic inspection, or thermal imaging may be employed to evaluate the internal structure and integrity of critical components without causing damage. These methods may help identify hidden defects or inconsistencies that may not be visible through external inspection.

[0062] The quality control process may also incorporate automated visual inspection systems using machine vision technology. These systems may be capable of rapidly inspecting components and assemblies for defects, ensuring dimensional accuracy, and verifying proper assembly. In some cases, artificial intelligence algorithms may be employed to enhance the detection capabilities of these systems, allowing them to identify subtle defects or anomalies that may be difficult for human inspectors to detect.

[0063] Environmental stress screening may be performed on components and assembled robots to evaluate their reliability under various environmental conditions. This process may involve subjecting the robots to temperature cycling, vibration testing, and humidity exposure to identify potential weaknesses or failure modes that may not be apparent under normal operating conditions.

[0064] In some implementations, a traceability system may be integrated into the quality control process, allowing for the tracking of individual components and assemblies throughout the manufacturing process. This system may use technologies such as RFID tags or unique identifiers to maintain a comprehensive record of each robot's assembly history, test results, and component origins.

[0065] The data collected from various testing and quality control processes may be integrated into a centralized quality management system. This system may provide real-time visibility into production quality metrics, facilitate root cause analysis of defects, and support

continuous improvement initiatives. By analyzing historical data and identifying correlations between manufacturing parameters and product quality, the system may enable predictive quality control measures to be implemented.

[0066] In some cases, the quality control process may include accelerated life testing to evaluate the long-term reliability and durability of the robots. This may involve subjecting the robots to simulated usage patterns and environmental conditions that represent months or years of normal operation compressed into a shorter timeframe. The results of these tests may be used to identify potential wear points, estimate product lifespan, and inform design improvements for future iterations. The quality control and testing procedures may be continuously refined and updated based on feedback from field performance data, customer reports, and ongoing research and development efforts. This iterative approach may help ensure that the manufacturing process remains aligned with evolving product requirements and quality standards.

G. Scalability and Expansion

[0067] The BotQ facility is designed with scalability and future expansion as key considerations, allowing for increased production capacity and potential replication in other locations. The modular nature of the production lines and the facility's layout may enable efficient scaling of manufacturing operations to meet growing demand for humanoid robots.

[0068] In some cases, the initial production capacity of 12,000 humanoid robots per year may be increased through various methods. The facility's layout may allow for the addition of parallel production lines, effectively multiplying the output without significant redesign of the existing infrastructure. The modular design of assembly stations may facilitate rapid reconfiguration or expansion of production capabilities.

[0069] The manufacturing processes implemented in the BotQ facility may be optimized for replication in other locations. Standardized equipment, tooling, and procedures may enable consistent production quality across multiple facilities. In some implementations, the facility's digital infrastructure, including manufacturing execution systems (MES) and enterprise resource planning (ERP) systems, may be designed to support multi-site operations, allowing for centralized management and coordination of geographically distributed production facilities.



[0070] Scalability may also be achieved through advancements in automation and robotics within the production process. As the capabilities of humanoid robots used in manufacturing improve, these robots may take on increasingly complex tasks, potentially increasing production efficiency and output. The integration of artificial intelligence and machine learning algorithms in production planning and quality control processes may further enhance scalability by optimizing resource allocation and identifying opportunities for process improvements.

[0071] In some cases, the facility's supply chain management systems may be designed to accommodate increased production volumes. This may involve developing relationships with suppliers capable of scaling their output, implementing advanced inventory management

techniques, and establishing logistics networks that can support higher production volumes and broader geographic distribution.

[0072] The BotQ facility's scalability may extend beyond physical expansion to include adaptability to evolving technologies and market demands. The production lines may be designed with flexibility to accommodate future iterations of humanoid robot designs or the introduction of new product lines. This adaptability may be achieved through reconfigurable tooling, modular assembly stations, and software-defined manufacturing processes that can be updated or modified without extensive hardware changes.

[0073] In some implementations, the facility may incorporate advanced simulation and digital twin technologies to model and optimize expansion scenarios. These tools may allow for virtual testing of different production configurations, capacity increases, and process modifications before physical implementation, reducing the time and cost associated with scaling operations.

[0074] The scalability of the BotQ facility may also consider environmental sustainability and energy efficiency. As production capacity increases, the facility may implement advanced energy management systems, waste reduction technologies, and sustainable material sourcing strategies to minimize the environmental impact of expanded operations.

[0075] In some cases, the facility's workforce development programs may be designed to support scalability. This may involve implementing training systems that can rapidly onboard new employees, developing leadership pipelines to support expanded operations, and fostering a culture of continuous improvement and innovation that can drive ongoing efficiency gains.

[0076] The BotQ facility's approach to scalability and future expansion may position it to respond effectively to market demands, technological advancements, and global manufacturing trends in the humanoid robotics industry. By incorporating flexibility, modularity, and advanced technologies into its design and operations, the facility may be well-equipped to grow and evolve in alignment with the dynamic landscape of robotics manufacturing.

H. Industrial Application

[0077] While the disclosure shows illustrative embodiments of a robot (in particular, a humanoid robot), it should be understood that embodiments are designed to be examples of the principles of the disclosed assemblies, methods, and systems, and are not intended to limit the broad aspects of the disclosed concepts to the embodiments illustrated. As will be realized, the

disclosed robot, and its functionality and methods of operation, are capable of other and different configurations and several details are capable of being modified all without departing from the scope of the disclosed methods and systems. For example, one or more of the disclosed embodiments, in part or whole, may be combined with a disclosed assembly, method and system. As such, one or more steps from the diagrams or components in the Figures may be selectively omitted and/or combined consistent with the disclosed assemblies, methods, and systems. Additionally, one or more steps from the arrangement of components may be omitted or performed in a different order. Accordingly, the drawings, diagrams, and detailed description are to be regarded as illustrative in nature, not restrictive or limiting, of the said humanoid robot.

[0078] While the above-described robot is designed as a head for use with a general-purpose humanoid robot, it should be understood that its assemblies, components, learning capabilities, and/or kinematic capabilities may be used with other robots. Examples of other robots include: articulated robot (e.g., an arm having two, six, or ten degrees of freedom, etc.), a cartesian robot (e.g., rectilinear or gantry robots, robots having three prismatic joints, etc.), Selective Compliance Assembly Robot Arm (SCARA) robots (e.g., with a donut shaped work envelope, with two parallel joints that provide compliance in one selected plane, with rotary shafts positioned vertically, with an end effector attached to an arm, etc.), delta robots (e.g., parallel link robots with parallel joint linkages connected with a common base, having direct control of each joint over the end effector, which may be used for pick-and-place or product transfer applications, etc.), polar robots (e.g., with a twisting joint connecting the arm with the base and a combination of two rotary joints and one linear joint connecting the links, having a centrally pivoting shaft and an extendable rotating arm, spherical robots, etc.), cylindrical robots (e.g., with at least one rotary joint at the base and at least one prismatic joint connecting the links, with a pivoting shaft and extendable arm that moves vertically and by sliding, with a cylindrical configuration that offers vertical and horizontal linear movement along with rotary movement about the vertical axis, etc.), self-driving car, a kitchen appliance, construction equipment, or a variety of other types of robot systems. The robot system may include one or more sensors (e.g., cameras, temperature, pressure, force, inductive or capacitive touch), motors (e.g., servo motors and stepper motors), actuators, biasing members, encoders, housing, or any other component known in the art that is used in connection with robot systems. Likewise, the robot system may omit one or more sensors (e.g., cameras, temperature, pressure, force, inductive or capacitive

touch), motors (e.g., servo motors and stepper motors), actuators, biasing members, encoders, housing, or any other component known in the art that is used in connection with robot systems.

[0079] In other embodiments, other configurations and/or components may be utilized. As is known in the data processing and communications arts, a general-purpose computer typically comprises a central processor or other processing device, an internal communication bus, various types of memory or storage media (RAM, ROM, EEPROM, cache memory, disk drives etc.) for code and data storage, and one or more network interface cards or ports for communication purposes. The software functionalities involve programming, including executable code as well as associated stored data. The software code is executable by the general-purpose computer. In operation, the code is stored within the general-purpose computer platform. At other times, however, the software may be stored at other locations and/or transported for loading into the appropriate general-purpose computer system.

[0080] A server, for example, includes a data communication interface for packet data communication. The server also includes a central processing unit (CPU), in the form of one or more processors, for executing program instructions. The server platform typically includes an internal communication bus, program storage and data storage for various data files to be processed and/or communicated by the server, although the server often receives programming and data via network communications. The hardware elements, operating systems and programming languages of such servers are conventional in nature, and it is presumed that those skilled in the art are adequately familiar therewith. The server functions may be implemented in a distributed fashion on a number of similar platforms, to distribute the processing load.

[0081] Hence, aspects of the disclosed methods and systems outlined above may be embodied in programming. Program aspects of the technology may be thought of as “products” or “articles of manufacture” typically in the form of executable code and/or associated data that is carried on or embodied in a type of machine-readable medium. “Storage” type media includes any or all of the tangible memory of the computers, processors or the like, or associated modules thereof, such as various semiconductor memories, tape drives, disk drives and the like, which may provide non-transitory storage at any time for the software programming. All or portions of the software may at times be communicated through the Internet or various other telecommunication networks. Thus, another type of media that may bear the software elements includes optical, electrical, and electromagnetic waves, such as used across physical interfaces

between local devices, through wired and optical landline networks and over various air-links. The physical elements that carry such waves, such as wired or wireless links, optical links, or the like, also may be considered as media bearing the software. As used herein, unless restricted to non-transitory, tangible “storage” media, terms such as computer or machine “readable medium” refer to any medium that participates in providing instructions to a processor for execution.

[0082] A machine-readable medium may take many forms, including but not limited to, a tangible storage medium, a carrier wave medium or physical transmission medium. Non-volatile storage media include, for example, optical or magnetic disks, such as any of the storage devices in any computer(s) or the like, such as may be used to implement the disclosed methods and systems. Volatile storage media include dynamic memory, such as the main memory of such a computer platform. Tangible transmission media include coaxial cables, copper wire and fiber optics, including the wires that comprise a bus within a computer system. Carrier-wave transmission media can take the form of electric or electromagnetic signals, or acoustic or light waves such as those generated during radio frequency (RF) and infrared (IR) data communications. Common forms of computer-readable media therefore include for example: a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, DVD or DVD-ROM, any other optical medium, punch cards, paper tape, any other physical storage medium with patterns of holes, a RAM, a PROM and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave transporting data or instructions, cables or links transporting such a carrier wave, or any other medium from which a computer can read programming code and/or data. Many of these forms of computer readable media may be involved in carrying one or more sequences of one or more instructions to a processor for execution.

[0083] It is to be understood that the invention is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as obvious modifications and equivalents will be apparent to one skilled in the art. While the specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the spirit of the invention, and the scope of protection is only limited by the scope of the accompanying Claims. It should also be understood that substantially utilized herein means a deviation less than 15% and preferably less than 5%. It should also be understood that near and proximate utilized herein means within 10 cm. It should also be understood that

adjacent utilized herein means within 1 cm. It should also be understood that other configuration or arrangements of the above-described components is contemplated by this Application. Moreover, the description provided in the background section should not be assumed to be prior art merely because it is mentioned in or associated with the background section. The background section may include information that describes one or more aspects of the subject of the technology. Finally, the mere fact that something is described as conventional does not mean that the Applicant admits it is prior art.

[0084] In this Application, to the extent any U.S. patents, U.S. patent applications, or other materials (e.g., articles) have been incorporated by reference, the text of such materials is only incorporated by reference to the extent that they do not conflict with materials, statements and drawings set forth herein. In the event of such conflict, the text of the present document controls, and terms in this document should not be given a narrower reading in virtue of the way in which those terms are used in other materials incorporated by reference. It should also be understood that structures and/or features not directly associated with a robot cannot be adopted or implemented into the disclosed humanoid robot without careful analysis and verification of the complex realities of designing, testing, manufacturing, and certifying a robot for completion of usable work nearby and/or around humans. Theoretical designs that attempt to implement such modifications from non-robotic structures and/or features are insufficient (and in some instances, woefully insufficient) because they amount to mere design exercises that are not tethered to the complex realities of successfully designing, manufacturing and testing a robot.