Robotics in the Era of Industry 4.0

11.1 Introduction

1. Industrial robots handle tasks that are dangerous for humans and enhance production speed, accuracy, and cost-effectiveness.
2. Human limitations in physical capabilities lead to a shift from human labor to robots.
3. Collaborative human-robot work is crucial for efficient and robust manufacturing.
4. Traditional robots perform repetitive tasks in a dedicated workspace, limiting flexibility for new production lines.
5. Challenges include robot reconfiguration, lack of skilled operators, human morale, high costs, and safety concerns.
6. Industry 4.0 integrates smart factories with intelligent robots, IoT, cloud computing, and Big Data analytics.
7. Cyber-Physical Systems (CPS) combine virtual and physical worlds to enable autonomous robots with sensing, decision-making, and failure recovery.
8. Networking, predictive analytics, and sensor technology are vital for smart factories.

11.2 Recent Technological Components of Robots

11.2.1 Advanced Sensor Technologies

1. Sensor technology enhances data processing, sharing, and IoT-based networking.
2. Cameras and vision sensors enable robots to perceive and handle tasks like picking, obstacle detection, and safety.
3. Techniques include photogrammetry, stereo vision, structured light, and 3D vision using RGB-D sensors.
4. Sensors like Microsoft KinectTM and VelodyneTM detect objects and provide depth information.
5. Wearable devices and safety scanners, e.g., Epson Moverio BT-200TM, estimate human proximity to adapt robot behavior.
6. Force sensors provide tactile feedback for tasks like fitting and assembling parts safely.
7. Smart devices notify operators of errors for real-time corrective actions.

11.2.2 Artificial Intelligence

1. AI enables robots to monitor, optimize, and reconfigure production processes with self-awareness and self-maintenance capabilities.
2. Current robots lack full self-assessment and rational command evaluation.
3. Cloud computing and Big Data analytics enhance predictive manufacturing and CPS integration.
4. Vision sensing allows robots to manage uncertainties, calibration errors, and mechanical defects.
5. Autonomous robots assist humans, optimize energy consumption, and improve production flexibility.
6. Intelligent frameworks for human-robot collaboration and multi-agent systems improve efficiency.
7. Middleware platforms with Robot Operating System (ROS) and Artificial Neural Networks (ANN) enable learning-based robot control.
8. Key intelligent features include self-adaptiveness, self-organization, and reconfigurability.