NAC **Executive Insights**

Cobots

Key Points

- Collaborative robots, commonly known as cobots, are transforming the engineering and construction sector by enhancing productivity and efficiency, making them a crucial topic for industry professionals.
- Cobots are designed to work alongside human workers, promoting a collaborative environment that improves safety and operational effectiveness.
- Cobots are equipped with cutting-edge safety mechanisms, which allow them to operate safely in dynamic environments.
- Cobots can perform a wide range of tasks—from material handling to precision assembly—making them adaptable to various project needs and enhancing their utility on job sites.
- The implementation of cobots can lead to significant cost savings by optimizing labor, reducing downtime, and improving overall project efficiency, making them an attractive investment for businesses.

Introduction

This Executive Insight provides a comprehensive overview of collaborative robots, commonly known as cobots, which are revolutionizing the engineering and construction industries. Cobots are designed to work alongside human workers, unlike traditional industrial robots, enhancing productivity, safety, and efficiency. This Executive Insight also provides an in-depth look at the attributes, capabilities, and applications of cobots in engineering and construction projects, along with successful integration strategies, challenges, and real-world examples.

Key Attributes of Cobots

Key attributes of Cobots can be described in terms of:
- Safety
- Flexibility and adaptability
- Ease of use
- Cost effectiveness

Let us look at each of these attributes more closely.

Safety Features

Cobots are equipped with advanced safety features that facilitate them operating safely in conjunction with human workers. These features include built-in sensors, force feedback, and safety mechanisms that enable cobots to detect and respond to human presence, preventing accidents and injuries. The ability to work without physical barriers makes cobots ideal for collaborative tasks in dynamic environments such as what is experienced at a construction site.

Flexibility and Adaptability

One of the most significant advantages of cobots is their flexibility and adaptability. Cobots can be easily reprogrammed to perform various tasks, making them versatile tools in construction projects. Whether it is material handling, precision tasks, or repetitive activities, cobots can be quickly adapted to meet changing project requirements. Cobot operators and programmers represent an emerging industry training and skill need.

Ease of Use

Cobots are designed with user-friendly interfaces that require minimal training for operation. This ease of use ensures that workers can quickly learn to operate cobots, reducing downtime and increasing productivity. The intuitive programming interfaces allow for quick setup and deployment, making cobots accessible to a broad range of users.

Cost-Effectiveness

Cobots offer a cost-effective solution for automation in construction projects as compared with traditional industrial robots. Additionally, cobots can reduce labor costs by automating repetitive and physically demanding tasks, leading to increased efficiency and reduced operational expenses. The field application of cobots can be complemented with more traditional industrial robots in major module yard settings.

Capabilities of Cobots in Construction

The capabilities of cobots in construction can be described in terms of their performance on tasks such as:
- Material handling
- Precision tasks
- Automation of repetitive tasks
- Human/robot collaboration

Material Handling

Cobots excel in material handling tasks, such as transporting and positioning materials. They can assist in heavy lifting, reducing the physical strain on workers and improving overall safety. Cobots can also handle repetitive tasks with high precision, ensuring consistent quality and efficiency.

Precision Tasks

Cobots are capable of performing tasks that require high accuracy, such as welding, drilling, and cutting. Their precision enhances the quality of work and reduces errors, leading to better project outcomes. Cobots can also perform tasks like painting and coating with uniformity, improving the finish quality.

Automation of Repetitive Tasks

Cobots can automate repetitive tasks such as bricklaying, concrete pouring, and fastening devices such as screws. By taking over these monotonous activities, cobots increase productivity and consistency while freeing up human workers to focus on more complex and creative tasks.

Human-Robot Collaboration (HRC)

Cobots are designed for seamless human/robot collaboration, working alongside human workers to enhance productivity and safety. Cobots can assist in tasks that require human dexterity and decision-making, while also handling physically demanding or repetitive activities.

Applications in Engineering Projects

Cobots have a role to play in engineering and specialty supply chain tasks. Two examples include:
- **Site Inspection and Monitoring** - Cobots can be used for real-time site inspections and monitoring. Equipped with sensors and cameras, cobots can collect data on site conditions, identify potential issues, and provide valuable insights for project management. This capability enhances safety and efficiency in construction projects.
- **3D Printing and Additive Manufacturing** - Cobots are increasingly being used in 3D printing and additive manufacturing. They can print building components directly on-site, allowing for customization and rapid prototyping. This technology reduces material waste and enables innovative construction methods.

Cobot Challenges and Considerations

Two challenges faced by cobots include:
- **Integration with Existing Systems** - Integrating cobots with existing construction technologies can be challenging. Compatibility with current systems and workflows is essential for seamless operation. Training the workforce to adapt to new technologies is also crucial for successful integration.
- **Regulatory and Safety Standards** - Compliance with industry regulations and safety standards is vital when deploying cobots in construction projects. Ensuring that cobots meet these standards is necessary to guarantee safe and reliable operations.

Future Trends and Developments

The trajectory of cobots is very much being shaped by rapidly emerging technologies and feedback from real world applications. The integration of AI (Artificial Intelligence) and machine learning with cobots is driving significant advancements in their capabilities. AI-driven insights enable predictive maintenance,

autonomous decision-making, and enhanced performance. These technologies are expected to further improve the efficiency and effectiveness of cobots in construction projects.

As cobots continue to demonstrate their value in construction projects, their adoption is expected to increase. Successful case studies and real-world implementations will drive further interest and investment in cobot technology, leading to widespread adoption in the industry.

Classification of Cobots by Function

The range of potential use cases for construction cobots can best be categorized by functions, including:
- Material handling
- Precision tasks
- Inspection and monitoring
- Repetitive task automation
- Human/robot collaboration (HRC)
- 3D Printing and additive manufacturing
- Maintenance and repair
- Data collection and analysis

Reference is provided to specific cobots as illustrations. Other providers exist and new ones are emerging.

Material Handling Cobots perform tasks such as:
- **Transporting Materials**: Cobots like Fetch Robotics' AMRs (Autonomous Mobile Robots) are used for transporting heavy loads across construction sites.
- **Positioning and Assembly**: KUKA Robotics' cobots assist in the precise placement of materials and assembly tasks in automotive and construction projects.

Precision Task Cobots provide a range of capabilities often initially introduced in an industrial setting but finding their way into field applications. These include:
- **Welding and Soldering**: Universal Robots' UR10e cobot is used for high-precision welding tasks in manufacturing and has a broad range of applications in a warehouse setting.
- **Drilling and Cutting**: FANUC's CRX series cobots are employed in aerospace manufacturing for drilling and cutting operations and used in automated drilling for prefabricated building components.
- **Painting and Coating:** ABB Robotics' IRB 5500 is used in automotive painting applications for consistent and high-quality finishes and is adaptable to painting large surfaces or applying coatings.

Inspection and Monitoring Cobots offer a wide range of applications including:
- **Site Inspection**: Boston Dynamics' Spot robot is used for real-time inspections and monitoring in construction sites.
- **Quality Control**: Cognex's vision systems are integrated with cobots for quality control in manufacturing and other processes.

Repetitive Task Automation Cobots provide value on a range of common construction operations including:

- **Bricklaying:** Construction Robotics' SAM100 (Semi-Automated Mason) is used for bricklaying in various construction projects.
- **Concrete Pouring:** CyBe Construction's 3D concrete printing robots are used for automated concrete pouring and construction.
- **Screwing and Fastening**: Yaskawa Motoman's cobots are currently used in electronics manufacturing for automated screwing and fastening and can be applied to prefabricated structures.

Human/Robot Collaboration (HRC) Cobots are currently used in other industries for analogous functions and include:
- **Assisting Human Workers:** Rethink Robotics' Sawyer cobot is used in various industries to assist human workers in repetitive tasks such as material handling, especially in prefabricated construction components; real time inspection of structural components for defects; applying finishes to large surfaces; and various site logistics activities.
- **Safety Enhancement:** Omron's LD series mobile robots are used in healthcare facilities to enhance safety and efficiency and provide construction assistance in material transport and site logistics (moving tools and equipment as required).

3D Printing and Additive Manufacturing Cobots provide both onsite value as well as expediting offsite manufacturing of critical parts. Applications include:
- **On-Site 3D Printing:** Apis Cor's 3D printing robots are used for on-site construction of buildings and structures.
- **Additive Manufacturing:** Stratasys' cobots are used in aerospace and automotive industries for additive manufacturing of complex parts and in construction for creating complex architectural models, fabricating custom components, and on-site to print building components. They also support prototyping and testing of certain construction elements before full-scale production.

Maintenance and Repair Cobots perform:
- **Routine Maintenance:** Siemens' maintenance robots are used in industrial plants for routine maintenance tasks.
- **Repair Tasks:** Gecko Robotics' wall-climbing robots are used for inspecting and repairing industrial infrastructure.

Data Collection and Analysis Cobots facilitate:
- **Environmental Monitoring:** DJI's drones are used on construction sites for environmental monitoring and data collection.
- **Structural Health Monitoring:** Trimble's monitoring systems are used in construction projects for structural health monitoring.

Integration Strategies for Cobots from Different Vendors

Increasingly construction sites will employ multiple cobots from a range of potential vendors. The extent of this variability in vendors can be seen in the preceding section and many of the specific cobots identified have functionality in areas other than the one they were identified with. Integrating multiple cobots on a construction site safely and efficiently will be a growing challenge as adoption increases. Additionally, cobots will likely be shared across work crews and individuals, further raising the importance of integration.

Several integration strategies for cobots from different vendors exist, and include:

- **Define Project Requirements** - Clearly define the tasks each cobot will perform and ensure their capabilities align with project needs. This step is crucial for successful integration.
- **Standardize Communication Protocols** - Use standardized communication protocols like OPC UA (Open Platform Communications Unified Architecture) and ROS (Robot Operating System) to ensure different cobots can communicate effectively. These are discussed further in the next section. Middleware solutions can bridge communication between different systems.
- **Centralized Control System** - Develop or use a centralized control system to manage and monitor all cobots. Integration platforms like Siemens' MindSphere or ABB's Ability can facilitate centralized control and data management.
- **Data Integration and Management -** Ensure all cobots can collect and share data in a compatible format. Use data analytics tools to process and analyze data from different cobots for better decision-making.
- **Safety and Compliance -** Ensure all cobots comply with relevant safety standards and regulations and employ risk assessments to identify and mitigate potential hazards.
- **Training and Support -** Provide comprehensive training for operators to handle multiple cobots. Leverage support from vendors for troubleshooting and maintenance.
- **Testing and Validation -** Conduct pilot tests to ensure all cobots work together as expected. Gather feedback and make necessary adjustments to improve integration.
- **Scalability and Future-Proofing -** Design the system to be modular and scalable for future expansions. Stay updated with the latest advancements in cobot technology and integration methods.

Communication Protocols: OPC UA and ROS

In the last section we introduced the two predominant cobot communication protocols. These include:
- **OPC UA** (Open Platform Communications Unified Architecture) - OPC UA is a cross-platform, open-source standard for data exchange in industrial automation and communication. Developed by the OPC Foundation, it facilitates secure and reliable data transfer from sensors to cloud applications. Key features include interoperability, security, scalability, flexibility, and data modeling. OPC UA is widely used in industrial automation, process control, and IoT integration.

- **ROS** (Robot Operating System) – ROS is an open-source framework for writing robot software. It provides tools and libraries to help developers create complex and robust robot applications. Key features include modularity, communication, flexibility, and community support. ROS uses a publish-subscribe model for inter-process communication, primarily through TCPTOS (a transport layer for ROS messages) and DDS (a middleware protocol for data-centric communication between nodes) in ROS 2 (second generation of ROS). It is widely used in robotics, research and development, and industrial automation. The advantages that ROS provides is discussed on the next section

Advantages of Using ROS for Mobile Robot Development

The common use of ROS in cobots provides a number of advantages that include:
- **Modularity and Reusability -** ROS's modular architecture allows developers to create reusable components (nodes) that can be easily integrated into different projects. This modularity saves time and effort by enabling the reuse of developed nodes.
- **Interoperability and Flexibility -** ROS supports multiple programming languages and platforms, making it highly flexible for different applications. Its interoperability allows for integration with various hardware and software platforms.
- **Community and Ecosystem -** ROS has a large and active community that contributes to a vast repository of packages and tools. This extensive community includes numerous libraries, tools, and simulation environments which facilitate development and testing.
- **Simulation and Testing -** ROS offers powerful simulation tools which allow developers to test their robots in virtual environments before deploying them in the real world. Visualization tools help visualize sensor data and robot states, making debugging and development more efficient.
- **Scalability and Extensibility -** ROS can scale from small embedded systems to large, complex robotic systems, making it suitable for a wide range of applications. The modular nature of ROS allows for easy extension and customization to meet specific project requirements.
- **Real-Time Communication -** ROS uses a publish-subscribe communication model, which facilitates real-time data exchange between different nodes, ensuring efficient and reliable communication. It also provides mechanisms for synchronous and asynchronous communication, enabling complex interactions between nodes.
- **Cost-Effectiveness -** ROS is open-source, reducing the cost of development and allowing access to a wide range of free resources and tools.
- **Reduced Development Time:** The availability of pre-built packages and tools accelerates the development process, reducing time-to-market or application in the field.
- **Educational and Research Applications -** ROS is widely used in academic and research institutions for teaching and developing new robotic technologies. The open-source nature of ROS fosters collaboration and sharing of research findings, advancing the field of robotics in general and cobots in particular.

Challenges in Cobot Development

Cobot development and application in field construction settings is still at an early stage. Much more is possible and requires industry to address some key real-world issues and challenges. These include:
- **Environmental Complexity** - Real-world environments are often unstructured and unpredictable, posing difficulties for navigation and task execution.
- **Dynamic Obstacles** - Moving obstacles, such as people or vehicles, require advanced real-time planning and obstacle avoidance.
- **Sim-to-Real Gap** - Training robots in simulated environments may not fully capture the complexities of the real world, leading to performance gaps when deployed. A range of strategies have been developed to address this including domain randomization, physics-based simulation, sensor noise injection and others.
- **Transfer Learning** - Ensuring that policies and behaviors learned in simulation transfer effectively to real-world scenarios is a significant challenge.
- **Robustness and Reliability** – This must address both hardware durability as well as system reliability. Robots must be robust enough to withstand harsh conditions, such as extreme

temperatures, dust, and moisture. System reliability must ensure consistent performance over long periods without failure.

- **Real-Time Processing** - Real-time processing of sensor data and decision-making requires significant computational resources. Minimizing latency in communication and control systems is essential for responsive and accurate robot behavior especially when operating in conjunction with humans as a cobot.
- **Safety and Compliance** - Ensuring the safety of humans working alongside robots is paramount, requiring robust safety protocols and fail-safes. Regulatory compliance, adhering to industry regulations and standards, is necessary for legal deployment.
- **Autonomous Decision-Making** - Robots must make complex decisions autonomously, which involves advanced AI and machine learning algorithms. The ability to adapt to new and unforeseen situations is critical for effective operation in dynamic environments.
- **Battery Life and Power Management** - Ensuring sufficient battery life for extended operations is a common challenge. Optimizing power consumption to balance performance and longevity is essential.
- **Integration with Existing Systems** - Integrating robots with existing infrastructure and systems can be complex and requires careful planning. Ensuring seamless data exchange and integration with other systems for monitoring and control is paramount.

DARPA Subterranean Challenge

In the DARPA Subterranean Challenge, robots like Spot are used to explore and map underground environments. This project highlights several challenges, including navigating through narrow passages, dealing with low visibility, and maintaining communication in complex terrains.

Addressing these challenges requires continuous advancements in robotics technology, including improvements in AI, machine learning, sensor technology, and hardware design

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A Word on Exoskeletons

Exoskeletons and cobots (collaborative robots) are both advanced technologies used to enhance human capabilities, but they serve different purposes and have distinct characteristics.

Exoskeletons are wearable devices designed to augment human physical capabilities by providing support and enhancing strength and endurance. They are often used in industrial, medical, and military applications and include passive (unpowered) and active (powered) configurations. Exoskeletons help workers lift heavy objects, reduce physical strain, and prevent injuries.

Cobots are robots designed to work alongside human workers in a shared workspace. They are equipped with advanced sensors and safety features to ensure safe and efficient collaboration. Cobots have built-in safety mechanisms to detect and respond to human presence, preventing accidents. The range of applications has been discussed previously.

While both exoskeletons and cobots aim to enhance human capabilities, they do so in different ways:
- **Exoskeletons**: Focus on augmenting the physical abilities of individual workers by providing support and reducing strain.

- **Cobots:** Focus on automating tasks and collaborating with human workers to improve efficiency and safety in various applications.

In summary, **exoskeletons are not considered cobots**, but both technologies play crucial roles in enhancing human performance and productivity in different contexts.

Summary

In conclusion, collaborative robots, or cobots, represent a significant advancement in the engineering and construction industries, offering a multitude of benefits that enhance productivity, safety, and efficiency. As the demand for automation continues to grow, the integration of cobots into various workflows is becoming increasingly essential. Their ability to work alongside human workers not only improves operational capabilities but also fosters a collaborative environment that leverages the strengths of both humans and machines.

The key attributes of cobots—such as their advanced safety features, flexibility, ease of use, and cost-effectiveness—make them an attractive solution for a wide range of applications. From material handling and precision tasks to data collection and environmental monitoring, cobots are proving to be versatile tools that can adapt to the dynamic needs of construction projects. Their role in automating repetitive tasks allows human workers to focus on more complex and creative aspects of their jobs, ultimately leading to improved project outcomes.

However, the successful deployment of cobots is not without its challenges. Issues such as integration with existing systems, compliance with safety regulations, and the need for robust training programs must be addressed to ensure seamless operation. As the industry continues to evolve, it is crucial for stakeholders to stay informed about emerging technologies and best practices for cobot integration.

Looking ahead, the future of cobots in construction is promising. The ongoing advancements in artificial intelligence and machine learning are expected to further enhance the capabilities of cobots, enabling them to perform more complex tasks autonomously and adapt to unpredictable environments. As successful case studies emerge and the technology matures, we anticipate a broader adoption of cobots across the industry.

In summary, cobots are not just a trend; they are a transformative force that is reshaping the landscape of construction and engineering. By embracing this technology, companies can position themselves at the forefront of innovation, driving efficiency and safety in their operations. As we move forward, the collaboration between humans and cobots will undoubtedly pave the way for a more productive and sustainable future in construction.

About the Author

Bob Prieto was elected to the National Academy of Construction in 2011. He is a senior executive who is effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering, and construction industries.