

ECHO: Enhanced Collaboration for Human-Robot Operations

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Problem Overview

Robots are an essential integration in laboratories, hospitals, and creative studios, traditional safety systems are proving insufficient.

Current collaborative robots (cobots) face an obvious challenge – poor sensory precision for close human interaction leads to disruptive work stoppages and reduced efficiency.

ECHO transforms these limitations into seamless human-robot collaboration, enhancing both human creativity and robotic precision - driving safer, more intuitive automation across healthcare, manufacturing, and creative sectors.

Building on Success

- Phase 1 established virtual choreography of robotic movements
- Phase 2 introduced basic proximity detection with "go/no-go" zones
- Phase 3 demonstrates enhanced human detection and arm rerouting functionality

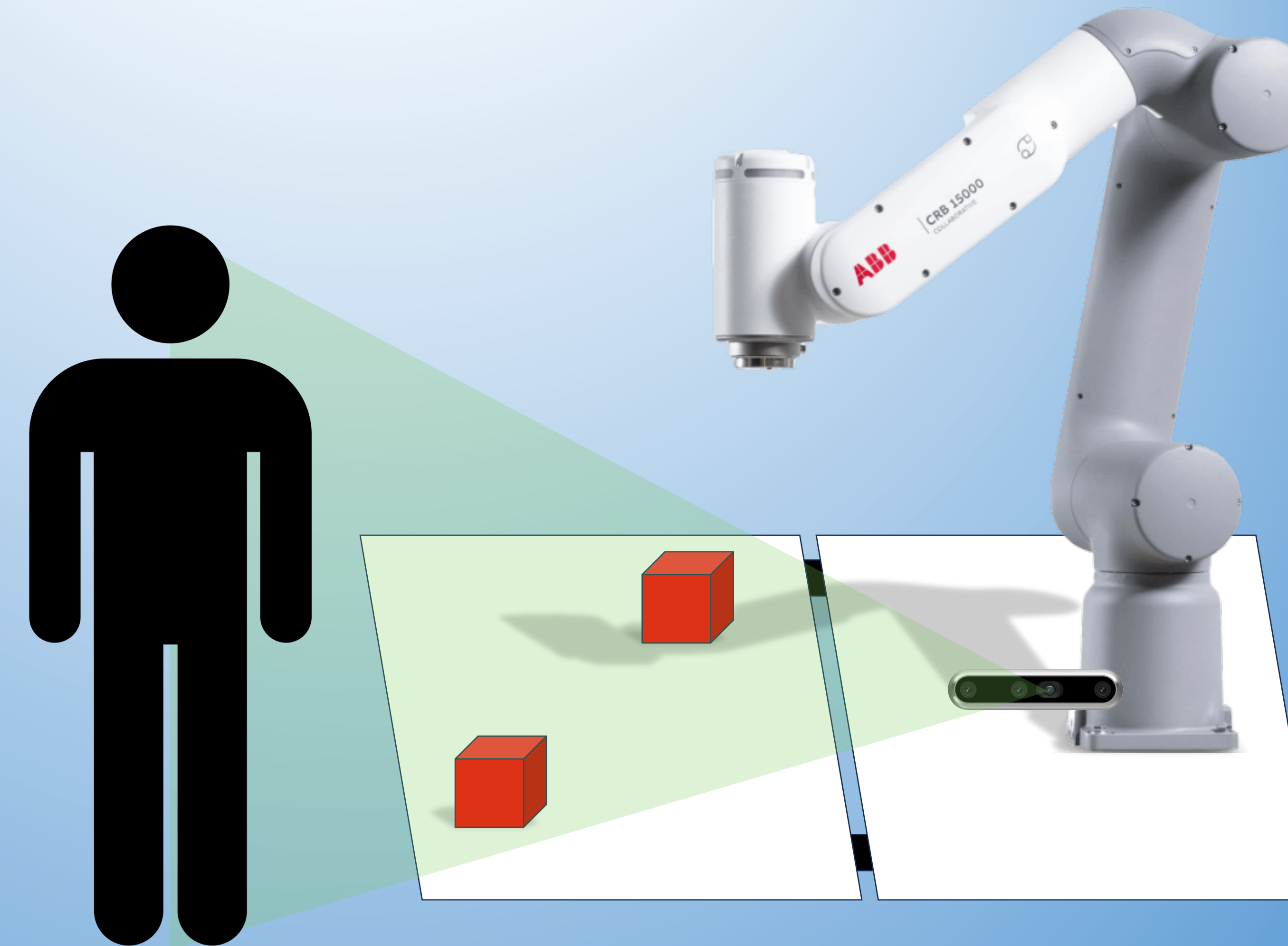
Use Cases

Collaborative Organizing Tasks

- The human and the robot arrange blocks to sort blocks by color, size, or shape into zones on the table.
- **Goal:** Efficiently organize while adapting to changes.

Dynamic Rerouting Capabilities

- Robot arm reroutes based on human proximity and position to avoid potential collisions *without* the need to halt.
- **Goal:** Avoid slowdowns due to excessive halting.



Data Flow

Data Collection and Processing

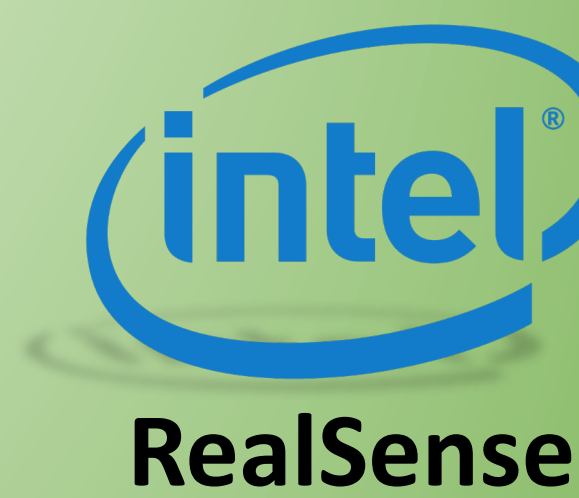
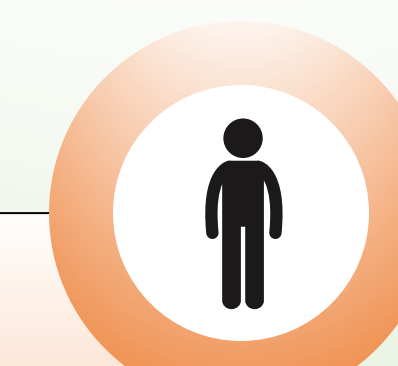
- RealSense D455 captures depth and RGB data
- NuiTrack processes spatial information in real-time
- Advanced human detection algorithms

Virtual Environment Construction

- Unity creates digital twin of the robot
- Real-time task planning and optimization
- Continuous safety monitoring and validation

Collaborative Task Execution

- Robot coordinates with human actions
- Dynamic workspace management
- Real-time task adaptation



Technical Specifications

Component	Specifications	Function
ABB Gofa	5kg payload, 950mm reach	Collaborative robot execution
Unity	Real-time simulation	Virtual environment & control logic
RealSense D455	1280×720 @ 90fps, 0.6-6m range	Spatial data acquisition
NuiTrack	30fps tracking rate	Human detection middleware

- **Communication Protocol:** Wireless UDP for real-time Unity-GoFa interaction with under 30ms latency
- **Digital Twin Synchronization:** Unity maintains virtual representation with position accuracy of $\pm 0.5\text{mm}$
- **Human Detection:** RealSense camera captures spatial data processed through NuiTrack with $< 2\%$ depth error at 4m
- **Safety Features:** Multiple proximity zones trigger adaptive robot behaviors with collision prevention

Potential Challenges and Limitations

When designing a potential solution for a safe human-robot collaboration setting, there are some challenges that appear:

- Latency in Response Time
- Human Behavior Prediction
- Balancing Safety and Efficiency
- Environmental Variability
- Maintenance and Sensor Degradation
- Dynamic Obstacle Recognition

Citations

- [1] Intel RealSense D455 Technical Documentation (2024)
[2] Previous VCU Capstone Projects (2022-2023) - Phases 1 & 2