

ETHOS AUTOMATION / WHITE PAPER

Intelligent Bin and Rack Picking in Manufacturing

Apera AI and Ethos Automation

How established manufacturers can reach the reliability of a purpose-built automated plant without replacing the bins and racks they already own.

AT A GLANCE

0.3 mm Placement accuracy achieved on a rack picking cell

Under 1° Rotational deviation at that accuracy

1.1 - 1.3 m Camera standoff window that made it possible

Millions Simulated examples behind each trained part model

2D stereo Monochrome pair reconstructing the 3D scene

Kept in service The bins and racks already on your floor

Executive Summary

Global manufacturing is entering a new phase of competition. Rising labor costs in major production regions have accelerated the rise of highly automated factories operating with minimal human intervention. These factories, nicknamed "ghost factories", set a new benchmark for throughput, consistency, and cost efficiency. Manufacturers unable to compete with this level of performance are at severe risk of losing market share.

The most evident gap between conventional factories and ghost factories lies in the transportation and introduction of parts to the assembly line. Ghost factories are new, and therefore start with fresh capital investment, which means variability can be accounted for from day one. Every bin and rack is engineered for precision, guaranteeing that parts arrive in the same position and orientation, every single time across thousands of cycles. Established facilities do not have that luxury. They operate with hundreds of existing bins and racks, tied to legacy line layouts and damaged over time. Replacing this

infrastructure to achieve repeatability would require massive expenditure with a negative return on investment in the near or mid-term.

The alternative is to preserve existing material-handling equipment at a usable standard and bridge the remaining variability with robotic vision. This middle path provides the adaptability of ghost factories without the prohibitive cost of rebuilding. This is the solution offered jointly by Ethos Automation and Apera AI. Apera AI supplies the vision intelligence while Ethos Automation delivers the mechanical design and robotic integration. Together, this approach closes the gap, enabling established manufacturers to remain competitive against new, fully automated plants.

Vision and Integration

Closing the gap with ghost factories using this method requires two things: the ability to find the part in all its real-world variation, and the ability to extract and place it consistently on the assembly line's datum.

Apera AI achieves the first through a stereo pair of 2D monochrome cameras that reconstruct a 3D model of the scene. This reconstruction combines classical feature-matching with AI-driven depth estimation, producing a more complete and accurate point cloud even in low-texture or noisy regions. Occlusions, shadows, and poor contrast that would normally cause missing depth are compensated for by the AI model. Once the 3D reconstruction is established, a second AI model identifies the target part within the point cloud. Because these models are trained from scratch for each part using millions of simulated examples, the setup effort is heavier at the front end. The payoff is a detector that generalizes reliably to real-world conditions: resilient to noise, variable lighting, geometric distortion, and partial occlusion.

Apera's AI models are computationally intensive, but Apera uses a staged software architecture that ensures this does not slow down production. Instead of running the heaviest model on an entire 3D reconstruction, the system first applies a fast, coarse detector to outline potential parts in the point cloud. A priority algorithm, chosen by Ethos and Apera case by case, then selects the candidates for further processing, and only those areas are passed to the full recognition model for confirmation. Once a part is confirmed, pose estimation runs, simulating multiple pickup approaches in virtual space to identify a collision-free grasp. The system then halts further processing as soon as a valid part is found that is capable of being picked up. This ensures that the resulting cycle time can support continuous production without sacrificing the added reliability and precision.

Detecting a part is only half the problem. The robot must still reach and extract it within the mechanical constraints of a real cell. Picking from bins or racks introduces tight clearances, variable orientations, and risks of collision with surrounding structures. This is where Ethos and Apera make the challenge a front-end problem rather than a painful surprise after fabrication. Ethos uses Siemens Process Simulate

to manually model the robot, the end-of-arm tool, and the entire motion path for picking and placement, confirming feasibility before the first piece of hardware is built. In parallel, Ethos leverages Apera Forge Labs to stress-test the end-of-arm tool across thousands of randomized bin and rack configurations, verifying that the design continues to meet customer requirements under real-world variability. Together, these tools allow us to foresee when a pedestal is required to reorient a part, or when a different end-of-arm tool design will be necessary, long before those issues become expensive changes on the shop floor.

Ethos brings together mechanical design, electrical engineering, and automation programming under one roof. In vision-based robotics, where countless part positions and behaviors must be managed, this integration is critical. Ethos has also developed a strong working rhythm with Apera, aligning workflows between teams. As the following examples show, this collaboration delivers systems that perform reliably under real-world manufacturing conditions.

Bin Picking: What the System Does

To illustrate the joint capabilities of Apera AI and Ethos Automation, we will start with bin picking, which represents Apera's bread and butter and demonstrates end-to-end strengths across the entire spectrum from pick to place.

- Software-defined obstacle constraints, such as bin walls, are incorporated into both pick-pose validation and retreat-path planning.
- A path-planning AI generates collision-free extraction trajectories while accounting for software-defined obstacles.
- The system supports multi-class part recognition, enabling automatic picking and sorting of different part types.
- Placement compensation is applied to correct for off-center grasps, ensuring accurate positioning even with symmetrical parts.

Bin Picking: In Practice

In all Apera bin picking projects, the bin picking cell is configured to recognize the physical boundaries of the bin itself, along with surrounding features such as fencing and camera mounts. These are defined as software constraints and included directly before the path-planning stage. Apera AI's pose estimation and path planning model then generates safe pick and retreat paths that respect these digital boundaries, allowing the robot to find alternative routes automatically. With front-end design, we can account for every situation, ensuring every scenario has a solution. Potential collisions or infeasible

moves are automatically discarded by the software as invalid options. The result is a multi-solution system where the robot does not fail, it only selects a different valid path.

Beyond obstacle avoidance, bin picking projects often require handling multiple part types within the same cell. Apera AI's part recognition model can be trained to recognize several distinct parts in a single bin, even when they are piled together or partially obscured. Ethos has configured a system where the parts are identified and sorted into the correct output locations. This approach allows a single robotic cell to replace multiple manual sorting stations, with the intelligence to adapt bin by bin without operator intervention.

Another strength lies in managing many potential grasp points, including for symmetric parts. In practice, this means the robot may grasp a part off-center or at an angle because of how the part is positioned in the bin. Ethos programs the robot to account for this during part placement. If a part is picked from the edge, placement motions are automatically adjusted to restore the correct final orientation. Each additional pickup configuration increases system resilience by ensuring fewer situations where the robot cannot continue. Over time, this library of configured pick poses becomes a safeguard against unpickable parts.

Rack Picking: A Harder Problem

Rack picking presents greater complexity than bin picking. Racks generally have more inter-rack variability, non-standard geometric constraints, and the racks themselves warp over time. Unlike bins, Apera's autopilot collision-avoidance cannot be applied directly, due to the complexity, which makes creative integration solutions essential.

- Eye-in-hand vision setups, with the camera mounted on the end-of-arm tool, demand precise positioning for the camera field of view.
- Custom AI models can be trained not just for parts, but also for rack features like hooks.
- Initialization sequences optimize camera-to-part distance for maximum accuracy.

Rack Picking: In Practice

In one project, the sheer size of the parts meant that the entire component could not fit within the camera's view at close range. To capture a usable image, the camera had to remain at least one meter away. Because this was an eye-in-hand application, we developed a strategy of incrementally moving the camera forward after the initial capture, keeping the part within a 1.1 to 1.3 meter range. This allowed the vision system to achieve the maximum resolution on the part, allowing it to reach the required 0.3 mm placement accuracy with less than one degree of rotational deviation.

The customer also requested an auto-set for camera depth so that the operator did not need to input the approximate depth when a new rack is loaded. The robot first performed a depth estimation pass, identifying the nearest part and establishing a baseline distance. From there, mathematical offsets were applied to position the camera at the optimal range for recognition and placement accuracy. This ensured that every subsequent pick began from the best possible vantage point, minimizing errors caused by noise, occlusion, or misalignment.

Another solution involved training an additional AI model specifically to detect the hooks holding the parts on the rack's front bar. Warpage in the racks meant that hook positions could vary from column to column, and rack to rack. By recognizing the hooks directly, the system adapted in real time, adjusting its extraction path up or down to avoid interference. This turned a potential source of error into a predictable part of the process.

Getting Started

Vision-guided robotics is best suited for tasks where parts must be introduced to an assembly line but arrive mixed or jumbled, with variation in position, orientation, or condition. Where traditional automation fails under variability, Apera AI and Ethos Automation provide a path to reliable performance without costly redesign.

The typical project begins with feasibility. Using CAD data or sample parts, Ethos runs simulations in Siemens Process Simulate and Apera Forge Lab to validate feasibility and highlight challenges early, modeling robot reach, end-of-arm tooling and motion paths at the same time. This combined study provides a clear view of technical fit, cycle times and ROI before committing to buying any hardware.

From there, a pilot cell is developed. Apera trains the AI model for the specific parts while Ethos designs and tests the tooling and robot program. This pilot proves the system's ability to pick and place under real conditions, giving confidence in both accuracy and throughput. Once validated, pushing to production is straightforward since most of the work is already done on the Ethos shop floor.

The final step is deployment. Ethos manages the installation and commissioning. Operators are trained, and the system transitions smoothly to production with minimal downtime. Whether for a simple bin picking station or a complex multi-rack cell, this phased process ensures predictable outcomes.

For manufacturers facing pressure from ghost factories and global competition, the next step is clear: explore how vision-guided picking can fit your operation. The Ethos and Apera teams are ready to demonstrate feasibility and guide you from concept to production.

About Ethos Automation

Ethos Automation is a Canadian automation integrator based in Brantford, Ontario. We design, build, program and commission robotic and automated systems for manufacturers in automotive, aerospace, nuclear and general industry, from single cells to complete lines.

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