

Calibration of Vision-guided Industrial Robots

Fast and Inexpensive Method to Reach High Accuracy of Vision-guided Robots

Industrial robots are standard in manufacturing. Robots equipped with cameras (2D cameras or 3D depth cameras) are particularly flexible. When the camera images are processed using specialized imaging processing systems, objects can be detected and their position in space can be determined, allowing them to be grasped or processed safely. However, industrial robots lose accuracy over time because mechanical wear parts cause the manufacturer's original calibration to become outdated. For applications requiring a high accuracy, regular robot calibration is essential. Calibration fully defines the robot's geometry and corrects the kinematic model using the parameters determined.

A new calibration method developed by KIT and MVTec Software GmbH utilizes the robot's existing camera for robot calibration. Calibration runs fully automatically, requires no expensive specialized hardware, and can be performed inline (i.e. without disassembling the robot).

Vision-guided Industrial Robots

In one of the robot designs, the camera is mounted at the end of the robot arm, the end effector, and supplies images of the surrounding work environment. Using image processing methods, objects can be

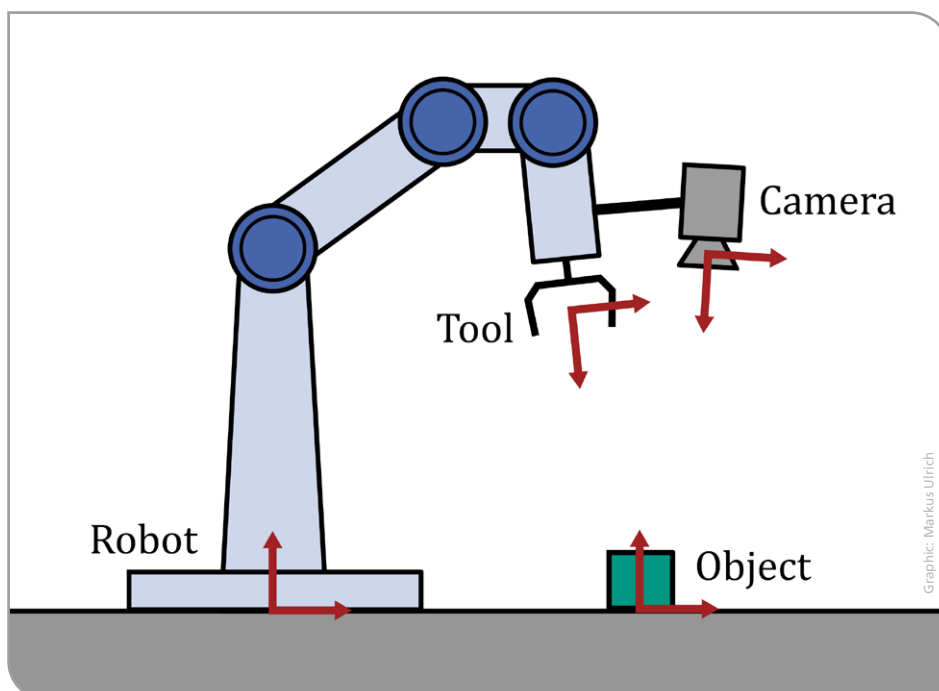
recognized in the camera images and their positions can be determined. If the camera's position relative to the robot tool (e.g. gripper) is known, the object's position relative to the robot can be calculated. This enables the robot to grasp or process the object reliably. Contrary to robots that "blindly" follow a given movement pattern based on fixed programming, vision-guided robots are far more flexible. They can react to changed object positions and new objects, which is a decisive advantage in Industry 4.0 applications.

Importance of Calibration

Whenever components need to be positioned, assembled, or inspected in the sub-millimeter range, exact knowledge of the robot geometry is of central importance. Robot geometry may change due to wear or changing environmental conditions. Robot calibration is used to define the robot's geometry (i.e. its kinematic parameters) and to correct the kinematic model accordingly. The accuracy with which a robot can perform a task therefore largely depends on the quality of its calibration. Regular, exact calibration is needed for vision-guided robots in particular, as these require not only precision (repeatability) but also accuracy (with the measured value being as close as possible to the specified value).

Limits of Presently Applied Methods

In industrial practice, robots are usually calibrated by manufacturing companies or external service providers. Many established robot calibration methods require expensive specialized hardware (e.g. laser trackers) and are time-consuming as they include numerous manual working steps. Often, the robot must be disassembled and calibrated offsite. This results in significant downtime and costs. Moreover, these methods are often proprietary and can hardly be transferred to other robots.



Principle of a vision-guided industrial robot.

Newly Developed Method: Image Processing Is Key

The new method replaces specialized hardware with the camera system already installed in all vision-guided robots. Using this camera system, the robot captures a defined calibration body (e.g. plate with a dot pattern) from several positions. The algorithms of the image processing system determine with high accuracy the underlying geometric parameters of the robot, such as the lengths of the arm segments and angular relations, from this image data. Calibration optimizes the kinematic parameters by minimizing the geometric distance between the features measured by the camera and the known features of the calibration body. As a result, the robot's accuracy is enhanced significantly.



Robot calibration: Imaging a calibration body

Benefits for Industrial Applications

Calibration is entirely software-based and requires neither expensive equipment nor specialized expertise. A calibration standard in the work area is sufficient. The process is completed within a few minutes, without the production flow being substantially affected. This allows for the early detection of wear or geometry changes, while accuracy remains stable over the long term.

Companies have the option of fully automated calibration repetition at regular intervals or as needed, without additional service orders being required. Moreover, simultaneous calibration of the entire system is possible: The position of the camera relative to the end effector (hand-eye calibration) and the camera parameters can be calibrated as well. This simple and fast calibration solution can be transferred to several robot models. Calibration also provides reliability metrics for the results, such that the success of calibration can be assessed.

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