FlexPlace

Watchmaker precision for robotic placement of automobile body parts

Staff Report

ABB's commitment to adding value for customers includes a constant quest for innovation and improvement – new ideas, new thinking, new solutions and stronger customer relationships. FlexPlace is an example of that new thinking. Developed at ABB's body-in-white facility in France, it is a software solution that will greatly improve efficiency and cost-effectiveness in auto body assembly. Robots with FlexPlace use sensors and pattern recognition to automatically assemble the larger parts of a car, like the roof and the doors, with sub-millimeter accuracy, and do away with the heavy and expensive tooling traditionally used.

In an auto body assembly line, parts such as the roof, doors and hatchback need to be accurately placed in position before assembly. These operations, which come after the framing station and re-spot stations, require robot path adjustment technology when the parts are positioned differently in each cycle. Five steps are involved in this process 1:

- *Auto body position measurement*, in which the measurement paths are determined at different locations on the auto body.
- *Profile analysis* to find particular points on the shape.
- *Sensor offset calculation*, based on a comparison of the measurements and the reference profile position acquired in a preliminary 'learning phase'.
- *Definition of a new robot position for assembly;* here the sensor offsets are sent to the correlation matrix software to find the correct robot path for the assembly operation.
- *Part placement*

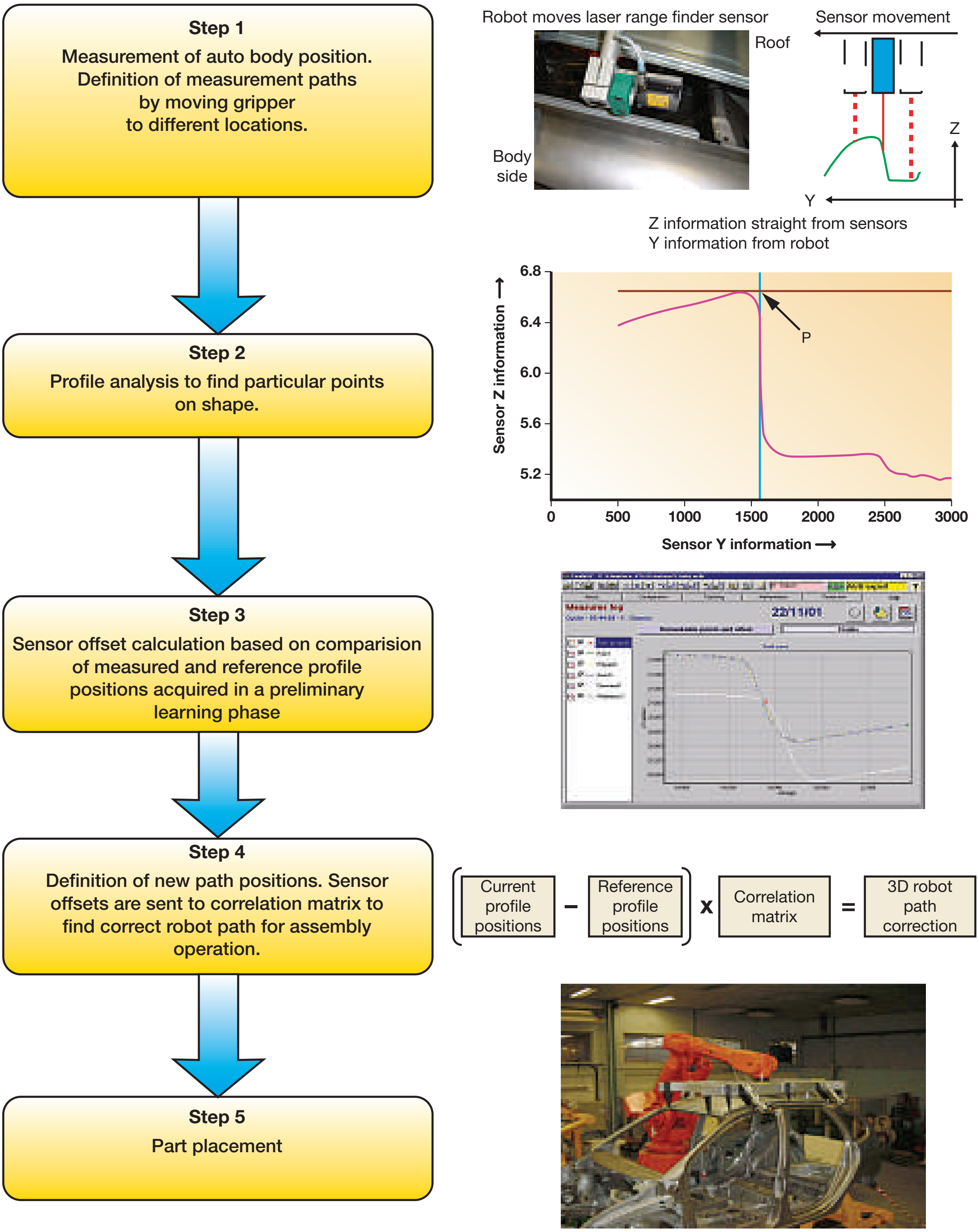
Simply put, robot path adjustment is a technology that ensures the accurate placement of components by a robot. With the help of FlexPlace, smart and efficient robots will replace the heavy machinery that has been used until now.

FlexPlace – A better solution for robot path adjustment

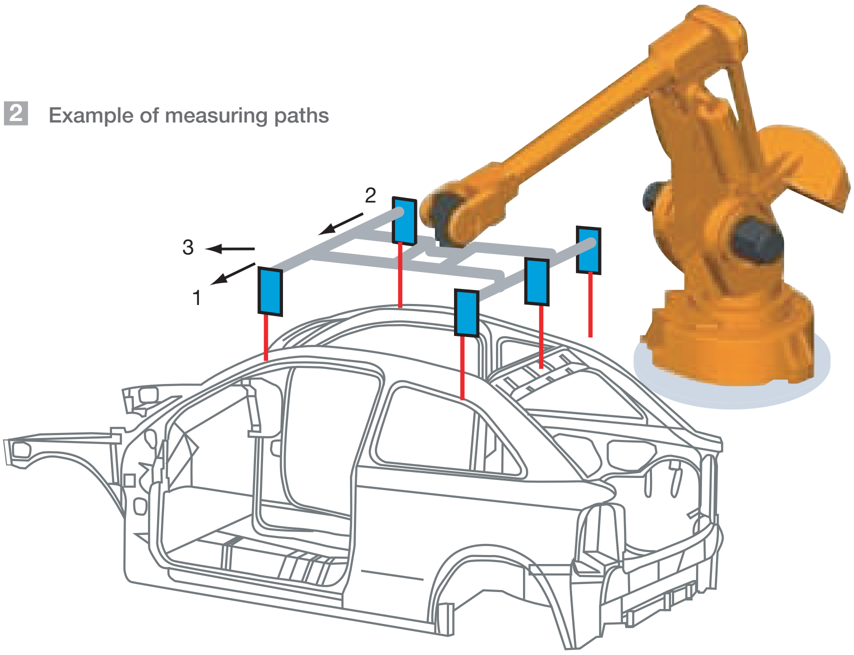
ABB developed FlexPlace to more accurately and more efficiently measure and place parts with a robot. The FlexPlace workstation consists of Windows NT/2000 software for data processing, a PC with an acquisition board, a set of sensors mounted on the robot gripper, a connection for sensor cabling, and a mastering tool.

The sensors are used to define the shape of the part (either by a robot or linear motion unit). The acquired shape and a previously stored reference shape are then compared to obtain a two-dimensional (2D) offset, which is used as input in a correlation matrix to compute the robot path adjustment. The matrix parameters are experimentally built up from successive robot positions. This is the so-called 'learning phase', and is automatically performed by FlexPlace.

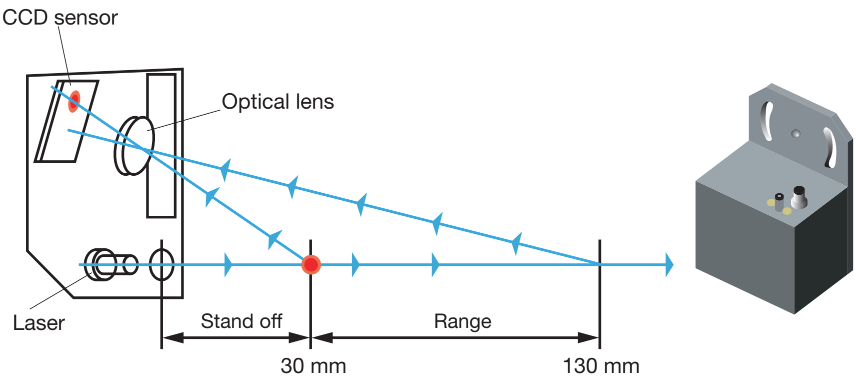
1 Robot path adjustment takes place in five steps.



2 Example of measuring paths



3 The sensor chosen for FlexPlace is basically a laser range finder. When it is moved, either by a robot or linear motion unit, it becomes a shape sensor.



How FlexPlace works

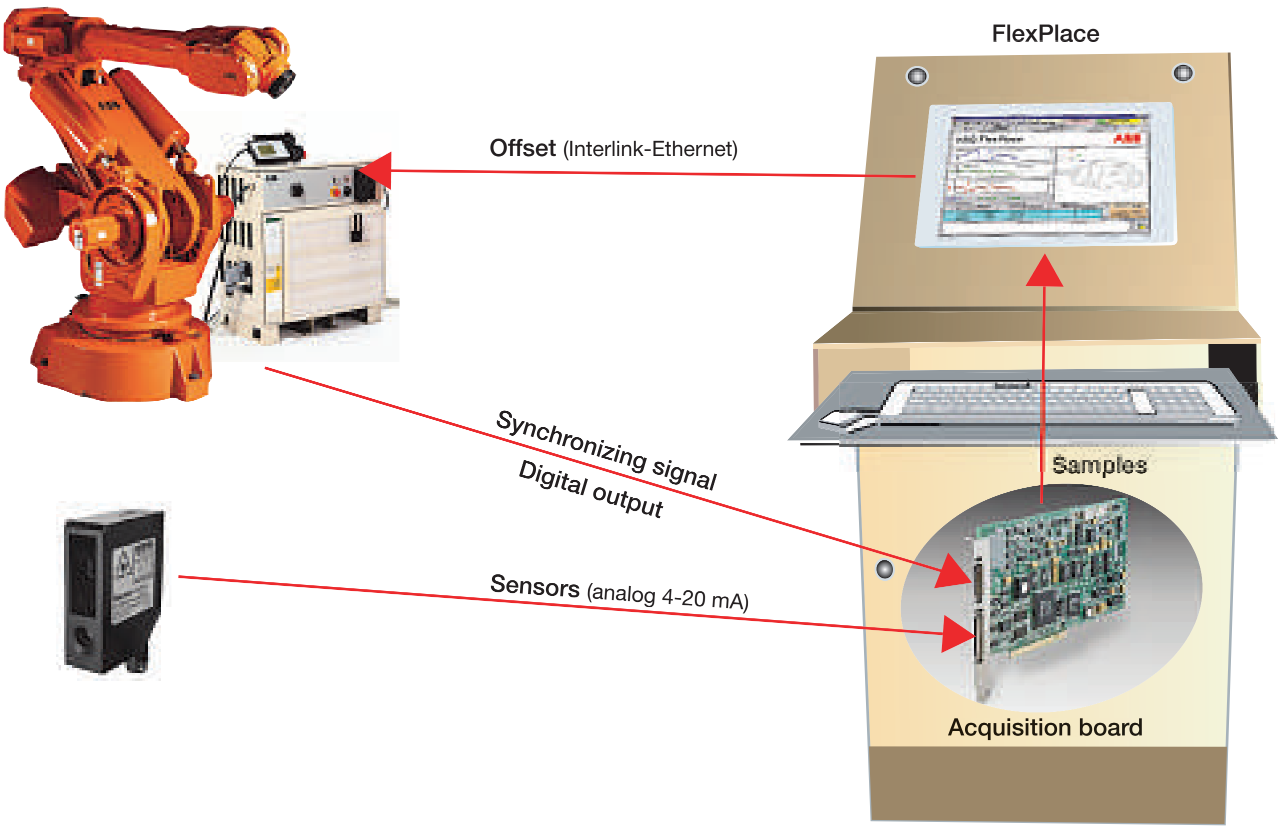
At the moment, FlexPlace is designed for body-in-white (BIW) operations, for example to place the roof, doors and hatchback or any other subassembly that needs placement relative to the position of the auto body. It goes without saying that FlexPlace can, of course, also be used for applications other than BIW. For example, it can be very useful for the placement of final assembly parts like seats, fenders, bumpers, front units and trim mounting, or to position the windshield on a vehicle 2. The same software can be used in each of these cases – in combination with a different type of sensor to allow customers to take measurements on a painted auto body.

"FlexPlace solves significant customer problems in automobile body production," says Francois Malatier, R&D manager at ABB's body-in-white facility in France. "By handling the robotic positioning of parts to be assembled on the auto body, it enables our customers to avoid the heavy tooling and machinery problems and costs associated with such assembly. FlexPlace is an outstanding technical solution and a significant achievement for ABB. It is an intelligent combination of sensor adaptation, pattern recognition software and matching software, packaged into one user-friendly product."

FlexPlace versus absolute path adjustment

Two different approaches to robot path adjustment are in evidence today: absolute and relative path adjustment (see Glossary). After benchmarking the different solutions and evaluating customers' feedback and needs, ABB chose the latter approach and one-dimensional optical laser (range finder) type sensors 3 for FlexPlace. The sensors are connected to the acquisition board via a 4–20 mA current loop signal, which is less sensitive to electromagnetic disturbances. A digital output from the robot controller

4 Example of measuring paths



synchronizes the measuring path and the acquisition board. The path adjustment values for the placing cycle is transmitted by an Ethernet link (ABB Interlink) 4. This link is also used to synchronize the robot movement with the PC program.

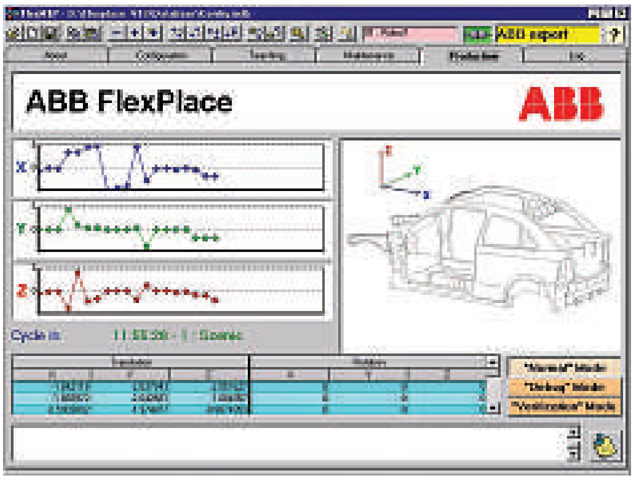
With FlexPlace, a vehicle roof can be measured and placed in its designated position in about 10 seconds with an accuracy greater than +/– 0.5 mm. The high reliability of the tool is mainly due to the type of sensor ABB has chosen, the small number of components and the reduced environmental sensitivity. The set-up and production phases are user-friendly. The graphic user interface is intuitive and provides direct access to the different application screens 5, 6.

Francois Malatier says FlexPlace is a solution that is primarily based on innovative software: “Our competitors solve this problem in different ways. Some use simple sensors and software, some use fixed cameras. The investment cost for such technology is very high – the system needs several sets of cameras if several auto models are assembled on the same line. Our solution is mainly a software product development. We explored the possibility of using partners, but decided on internal development. We had to develop very ‘near-vision’ software, but it didn’t prove too difficult, thanks to our methodical approach and the young, forward-looking engineers in the team.”

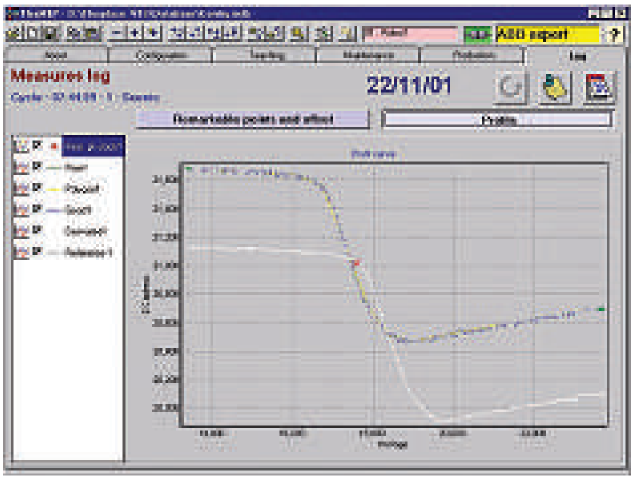
Functional and efficient

As already mentioned, the system’s high reliability is due in large part to the very accurate and proven one-dimensional (1D) laser sensors. To measure the auto body profile, the sensors are moved either by the robot (the sensors are mounted on the gripper) or by a small built-in shuttle unit. The product is anything

5 FlexPlace production screen



6 FlexPlace measurement log



but a 'black box', since the man-machine interface gives the user access to all the parameters. In addition, built-in process control functions make it easy for the customer to verify or diagnose any trouble or faults.

FlexPlace outperforms fixed sensors

Compared with absolute path adjustment, in which fixed sensors are used, FlexPlace offers a more efficient solution at almost every process stage and for every critical process factor. One innovation is the utilization of off-line calibration on a mastering fixture in the assembly station. And, the initial calibration phase takes account of robot arm geometry default. By comparison, absolute path adjustment requires the use of a 'gold model' and a coordinate measurement machine (CMM) in another station.

With FlexPlace there is no risk of the sensors disturbing each other because of their close proximity to the measured area. Neither are they as affected as cameras by flashing lights or similar interference in the workshop. FlexPlace's optical laser sensors do not make contact with the part, so users have considerable flexibility when choosing the auto body position to be measured for reference. By comparison, the fixed sensors in absolute path adjustment are further away from the measured area, so there is a high risk of interference. Fixed sensors are also more dependent on environmental conditions and make the simultaneous acquisition of measurements more difficult.

The new system makes a more flexible and adaptable layout possible. All that is needed to fit the sensors is some adaptation of the gripper. This is another advantage FlexPlace has over absolute path adjustment, which has inherent layout constraints. Most significantly, a steel structure must be designed and constructed to position and hold the sensors. The simpler sensors and intuitive software used with FlexPlace make the new solution less expensive. FlexPlace 'thinks for itself' and requires less costly infrastructure, preparation and maintenance. With the more complex fixed sensor method, an external supplier often has to be brought in for the calibration and highly qualified operators are needed to monitor the installation.

Of course, there is a higher risk of damage to the sensors used in FlexPlace because they are mounted on the gripper and exposed to shock and vibration. (In absolute path adjustment the sensors are mounted outside the working area of the moving equipment.) However, the modular FlexPlace sensors can be easily and quickly replaced using the mastering fixture in the station. (Replacement of absolute path adjustment sensors is complicated and time-consuming because the replacement sensors have to be calibrated with a CMM or laser measuring system.)

System checks and quality control are also easier with FlexPlace; placing the mastering fixture in the station allows the user to check the system whenever necessary. With absolute path adjustment, on the other hand, after the auto body has been measured the system has to wait until it has been in the check station before confirming the result.

With FlexPlace, any robot inaccuracy due to temperature change can be automatically compensated because the sensors are mounted directly on the robot. Absolute path adjustment requires an accurate robot model and a fixed reference in the station for this kind of compensation. Unlike absolute path adjustment, in which the location of each sensor must be accurately determined within the assembly station, the new solution considers all the defaults in the measurement chain.

Glossary

Absolute path adjustment
This is based on measurements of the auto body location with sensors mounted on a rigid structure in the station. The part and the robot positions are determined and the placing path is defined in the auto frame. Using these two absolute positions, the computer defines the relative offset to apply to the auto frame for assembly.

Relative path adjustment
Sensors are mounted on the robot gripper. The robot moves the sensors in front of the auto body, and the recorded profiles are processed to find the body position. For the 'learning phase', the reference vehicle is placed in the station and the known offset values are applied to the robot. The sensor values are registered for each position. At the end of this process, the system has learned the sensor responses to vehicle displacement, and this information is entered in the correlation matrix, which defines the correct robot positions.

Gold Model
An auto body manufactured especially to reduce geometrical variations. It is used to establish reference measurements in absolute path adjustment.

CMM (Coordinate Measurement Machine)
A machine designed for auto body or tooling measurements. It is used to measure the auto body Gold Model in absolute path adjustment.

Mastering Fixture
A tool mounted in the assembly station, used for initial calibration of the sensors and adjustments after a sensor replacement.

Body-in-white
The part of the auto manufacturing process that takes stamped parts and produces an assembled body shell complete with closures. At the end of this manufacturing step, the body is ready for surface treatment and painting, and the shining sheet metal looks almost white in color.

Correlation matrix
A mathematical template that changes the sensor offsets into robot position offsets. It contains coefficients that are determined from data collected during the learning phase, when the robot positions are changed and sensor offsets are recorded for each of the robot positions.