Low-cost Vision Guided Motion with Baumer’s VeriSens® Vision Sensor

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Introduction

Vision guided motion has seen steady growth over the past several years. Technology advances defined by Moore’s Law have resulted in vision systems that are smaller, less expensive and more powerful. In turn, this has enabled industrial robot manufacturers to deploy more vision systems in their processes. In their efforts to capture share of the dominant automotive market, many robot vendors and their vision collaborators have focused their efforts on high-cost, high-value applications. Vision-guided assembly, packing and that Holy Grail of vision-guided applications, random part bin picking, have focused development efforts in 2D, 2 1/2D and 3D vision guidance. Today, most major industrial robot manufacturers offer some sort of machine vision option, supported by a plethora of high-end vision systems integration companies.

Although high-end vision guidance applications have driven development efforts, there remains a substantial market for simple, 2D solutions. Applications such as load/unload, palletizing/de-palletizing and assembly can often benefit from vision guidance, especially in instances where part variables may render “blind” robots ineffective. These simple applications have been largely ignored by leading industrial robot providers. Most industrial robots either have proprietary, closed controller architecture or a dedicated vision platform. Support costs associated with these solutions confine the application base to higher-value solutions. Thus, an opportunity exists for a powerful, low-cost vision sensor capable of providing position and orientation to a robot controller. The challenge exists in finding open source robot and motion controllers capable of performing some data manipulation within the programming environment.

Fortunately, open source solutions exist. Vendors serving growth markets in Packaging, Food and Beverage and Life Sciences tend to favor off-the-shelf solutions based more on traditional IT platforms than on legacy industrial automation protocols. The trend of increased usage of PCs, tablets and wireless technology can be expected to accelerate as the manufacturing ecosystem follows the global technology growth curve. Thus, an opportunity exists for a low-cost, easy-to-use machine vision sensor capable of providing accurate guidance information to an open source motion controller, preferably with a non-proprietary protocol on a non-proprietary network. VeriSens® from Baumer Ltd. is such a platform. In this paper we'll examine how this low-cost sensor might be applied to simple motion guidance.

Vision Guided Motion Challenges

"Simple" does not imply "easy." In addition to the issues of lighting and optics that accompany every machine vision application, there are special methodology problems that must be overcome. First, the sensor must have software that enables it to robustly detect a part and its location in x, y, and rotation angle. Secondly, a precise relationship between pixel values and real world measurements must be established. Next, a correlation must be created between the world-space coordinates for the vision system and those of the motion controller. Finally, the vision sensor and the motion controller must be made to communicate effectively.

Finding the Part

In our simple example, we have provided a high-contrast image for illustration purposes. Not all applications have this luxury. That said, VeriSens®' part locate algorithms are contour-based and have been proven to be highly accurate over a variety of lighting conditions.

In order to locate a part, the vision sensor must first be taught what are acceptable parts. This involves selecting part features to be found in subsequent image captures. In addition to locating the part in x, y, and rotation angle, the inspection must provide a repeatable reference on the part for the motion controller. Figure 1 illustrates a typical taught part. The green rectangle indicates the area in question, in this case the part to be located. In this example it includes the entire part, although that is not always necessary. The orange outline indicates the features that the sensor will be looking for and the intersection of the two green arrows indicates the reference point.

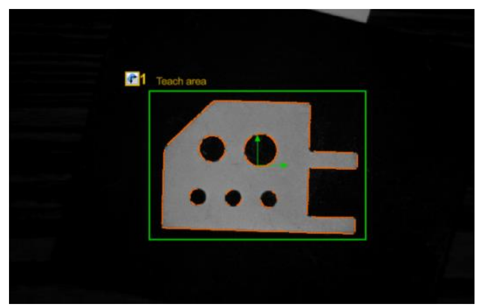

Figure 1

Figure 2 illustrates the part locating algorithm finding the part in a variety of locations and orientations. Note that the reference point (intersection of green arrows) does not change from image to image. This implies a high degree of repeatability on the part of the locate algorithm. This is important because the motion controller will use this as a reference point for any end effector used to pick up the part.

Figure 2

Pixel to World Space

Machine vision systems consist of a matrix of photosensitive elements called “pixels” (Figure 3). When this matrix is superimposed upon the “world,” spatial references can be calculated with proper calibration. The Field Of View (FOV) of the sensor is determined by the Working Distance (WD) and the lens. A vision sensor can acquire an image of an individual bacterium or an entire galaxy, depending upon how it is configured.

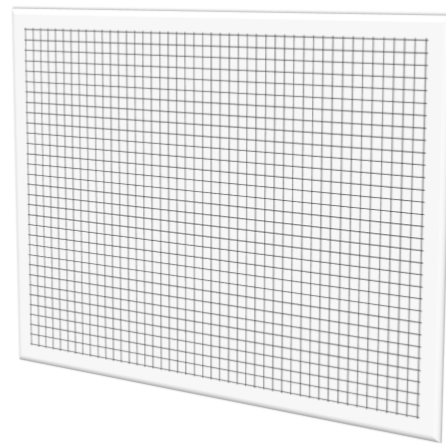

Figure 3

When calibrating a vision system to work in world coordinates, it is crucial to accurately know the spatial relationships of various points within the FOV. This is especially important in motion control applications because it is critical that parts be picked up at the same feature each time. The calibration process is a straightforward concept, simply determine the FOV in world units and mathematically convert the known number of pixels across that FOV to those units. For example, a vision sensor has a FOV of 400mm in the horizontal direction. A 2 Megapixel sensor has 1600 pixels in the horizontal direction. A simple calculation, 400mm/ 1600 pixels = 0.25 mm/ pixel.

Non-linearity

While the above method is valid as a general rule, accurate motion control requires more. Parallax and lens distortion introduce non-linearity into an image. This is not acceptable because motion control systems work in a linear Cartesian workspace. Therefore, it is important that a vision sensor that is to be applied for motion control have an accurate calibration method that compensates for parallax and lens distortion, as well as calculating the pixel-to-world space relationship.

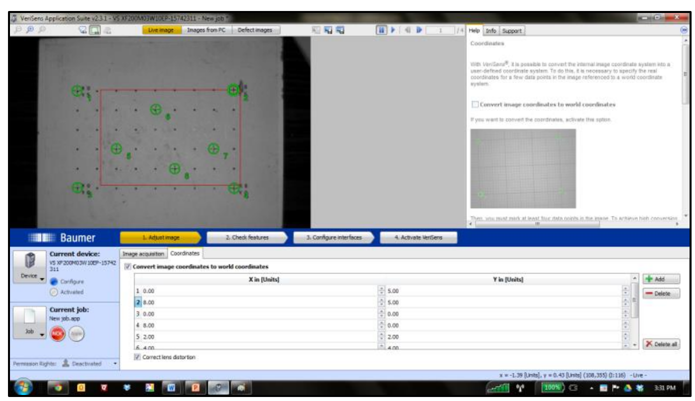

Figure 4

Figure 4 illustrates the easy-to-use grid calibration method within the configuration software of the Baumer VeriSens®. This simple calibration technique is able to compensate for non-linearity due to both parallax and lens distortion.

Talking to the Robot

When the data has been optimized at the vision sensor for position and rotation, calibrated for pixel-to-world space, and corrected for parallax and lens distortion, the x, y, and rotation angle values can be sent to the motion control device with assurance that positioning will be accurate. While there are a number of ways to transmit coordinate information to the motion controller, it is perhaps simplest to transmit a simple ASCII string via serial or Ethernet. The string contains the values x, y and rotation angle separated by a character. The motion controller reads these values and incorporates them into its program.

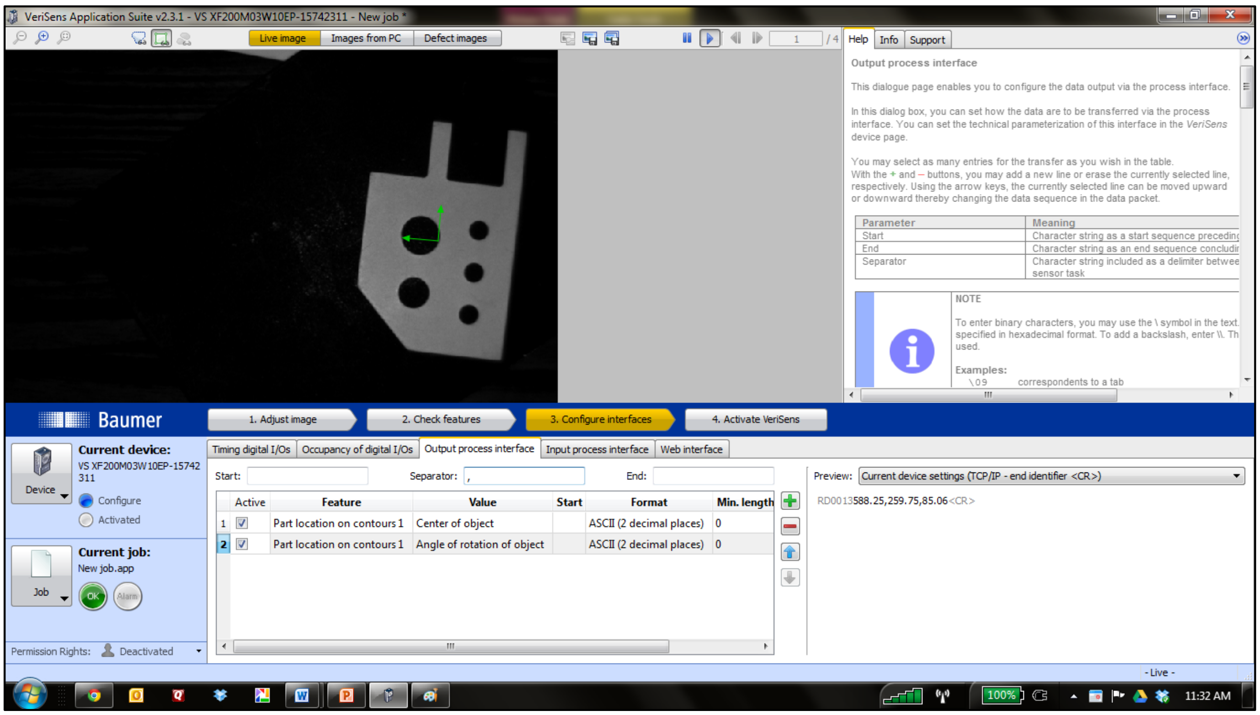

Figure 5

Figure 5 illustrates the configuration of the Baumer VeriSens® Part Locate tool to use the method described above. The “Center of Object” and “Angle of Rotation” are selected using the drop down menu as the variables to transmit. The string is displayed to the right of the tool configuration showing the x, y and rotation angle. This ASCII string is sent via TCP/IP to the motion controller.

Putting it All Together

The Baumer VeriSens® and *AppSuite* Software simplify the vision side of vision guided motion, but what about the robot side? What needs to be done there? The degree of "openness" of the motion controller determines the degree of difficulty. Two motion vendors that have the desired degree of openness are Intelligent Actuator and Staubli. IA works mainly with simple multi-axis Cartesian work spaces; Staubli has a complete line of multi-axis Cartesian, SCARA and articulated robots. As a simple illustration, we will discuss applying vision to a Cartesian workspace.

Vision Space to Robot Space

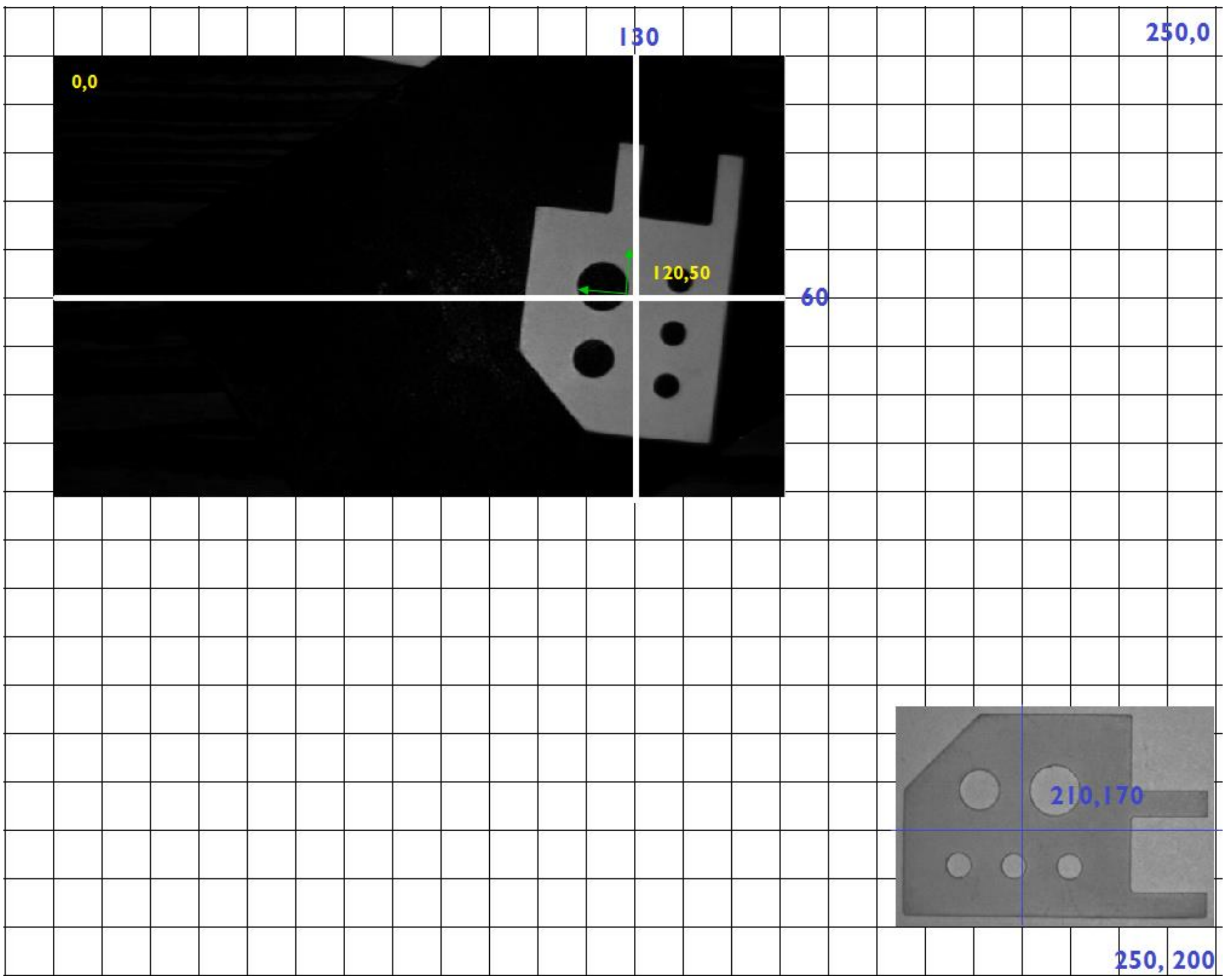

Figure 6

Please refer to Figure 6. Imagine that a part slides onto a tray (black background) in a random location and orientation. The part must be picked up from the tray and located onto a fixture (lower right, light background). The Cartesian work space is 250mm x 200mm. The "pick" point for the robot is a variable; the "place" point is a constant defined as x = 210, y = 170.

The vision system has been calibrated in millimeters and has located the part with a reference point at x = 120, y = 50. These coordinates are *vision space* coordinates. The vision space is offset from the robot Cartesian space by 10mm in x and 10mm in y. This offset must be compensated for in the motion program. Logically, the sequence would appear similar to the below:

1. Vision sensor obtain part in place digital input
2. Vision sensor acquire and process image and calculate x, y and rotation angle
3. Vision sensor trigger digital output to robot to move to “pick” location
4. Vision sensor transmit x, y and rotation via TCP/IP
5. Robot controller reads ASCII string, parses to x, y and rotation adding 10 to each of x and y
6. Robot controller compares rotation angle of “pick” point to that of the place point and calculates appropriate correction
7. Robot controller places appropriate values for x, y and theta into point table
8. Robot MOVE to Point 1; pick up part
9. Robot MOVE to Point 2; place part

Figure 7

What about “z”? Please refer to figure 7.

Conclusion

Following the principals described above, the Baumer VeriSens® can be a useful tool to provide a low-cost vision solution for motion guidance. With up to 2 Megapixels available, accuracy and repeatability can far exceed that available with the more common VGA cameras. The integrated software for pixel to world calibration, part finding and position transmittal and its ease-of-use make VeriSens® a logical consideration for open source robot controllers.