IMPORTANT FEATURES OF A VISION SYSTEM FOR SUCCESSFUL ROBOT GUIDANCE APPLICATIONS

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1. Introduction

Modern manufacturing processes need to be flexible because of frequent product design changes and shorter production runs arising from the increasing need for customized products. This has led to the extensive use of programmable robots. However robots alone are blind and parts need to be presented at a predefined location. Fixtures to accomplish this are often complex and require frequent attention for line changeovers. Adding vision guidance to a robot can allow parts to be presented unfixtured. This presentation describes performance, features and other considerations for adding vision capability to industrial robots. The following features will be covered:

- Vision system calibration
- Hand-eye calibration
- Robustness
- Accuracy
- Speed
- Integration with robot controller
- Multi-model capacity

2. Vision calibration

Calibrating the vision system means that it will return results in real world units (mm, inches…) not pixels. It also allows the system to compensate for problems like non-square pixels (which is the case for most cameras), perspective distortion (the camera is not perfectly perpendicular to the work surface) and lens distortion. Because of these corrections the system is much more robust, accurate and repeatable. The system will be able to give very accurate results independent from part orientation and camera placement. Furthermore, given that the vision system sees objects in their real size, models of objects are portable from one station to another even if the physical setup is not exactly the same. This greatly reduces the workload for deployment and maintenance of multi-station systems. In a good vision system, calibration is a very short and simple operation usually done by presenting a known target to the system.

3. Hand-Eye Calibration

This is an absolute requirement for vision-guided robots. The vision system and the robot work in two different reference frames. For vision results to have any meaning to the robot, we must find a transform that will enable us to translate vision results into the robot reference frame. This transform can be very simple or more complex depending on the setup and the accuracy needs (simplification can be made when we have coinciding axes and/or origins, which can be attained through proper choice of vision calibration parameters and target placement). It can range from simple X-Y offsets to a full 6 D.O.F transformation between the two frames. Hand-eye calibration usually takes more time and is more complex than vision calibration as it involves moving an object with the robot to many different positions in the field of view. Having a few point pairs in the vision and robot frames, it is then possible to compute a transform. Care must be taken to do this properly otherwise if hand-eye calibration is not accurate, accuracy of vision system is useless.

4. Robustness

One of the main goals of vision guidance is to reduce cost. If the vision system is not robust enough, all that is saved in fixtures will be spent in vision setup. The vision system must be able to work with ambient light and off the shelf cameras and lenses. It must also be able to tell when it cannot return a reliable result so that proper action can be taken at the application level. Robustness also means that the vision system won't be affected by changes in lighting, part orientation, defects or dirt on the part, part occlusion, a cluttered background or noise in the image signal. A very important element is also that the system must not detect parts that are not there and must detect all present parts. This may sound simple and is relatively easy in a lab environment but is very difficult to reach in real-world conditions.

5. Accuracy

Accuracy needs will vary depending on the application. Some very simple packaging applications need very high speed but do not require high accuracy. On the other hand precise assembly will require very high accuracy. If the vision system is not accurate enough for the task, the robot may pick up the part improperly and may have an improper grip and/or incorrect placement. For applications where the robot must work on the part (drilling holes, machining, …), features may be machined off tolerance leading to rejects or low quality. Since high accuracy is not always needed and is often reached at the cost of speed, a good system should have the flexibility to choose different levels of accuracy.

6. Speed

Speed requirements will also vary depending on the application. In some applications the operation the robot must perform or some other operation before or after is very long and so vision recognition time is not critical. But in many applications where robots are used, speed is critical and any time saved in recognition means higher throughput. This in turns of course means higher productivity and better ROI. It is important that speed be attained without impairing robustness. A system that is fast but returns wrong results is useless and can even lead to equipment damage. With modern computers, recognition times can be well below 100ms even for complex tasks and below 10ms for simpler tasks.

7. Integration with robot controller

This is a very important, often overlooked feature. If the robot controller and vision system are not made to work together, programming can be difficult and cumbersome and speed can decrease very significantly. Even if the vision system is very fast, if the time to communicate the result to the robot is long, total cycle time will greatly suffer. In poorly integrated system, this overhead can often be longer than the actual recognition time. A robot is often part of a workcell with other machines. Having a highly portable vision system means that it is possible to choose the best device to run it, whether it is the robot controller, a PC or embedded in another machine.

8. Multi-model

Multi-model capacity is not required in all applications but can be very useful when the part can have multiple stable poses or many parts need to be recognized (e.g. assembly of multiple parts or production of many products on the same line). It is usually (but not always) possible to handle multiple part type applications even with vision system that cannot handle more than one model at a time. However this leads to more complex programming, slower execution time and most importantly lower reliability. This becomes critical if you need to recognize very similar part. Having a knowledge of all possible parts, a multi-model system will be able to reliably disambiguate between the different possibilities and identify the correct part. If the system is not multi-model the burden is on the application programmer and the task is often impossible to accomplish. A one-model system will recognize both parts as the same with maybe a slight variation in the return result reliability (quality factor). A good multi-model system will be able to spot the subtle difference between the parts and give the correct result.

9. Conclusion

In this paper we have seen that using a good vision system to guide a robot can lead to cost savings and a better reaction time to changes. However to reach these goals, the vision system must have some important features. The ability of the vision system to responds to these needs will directly affect the success of your project.