Application Note

Industrial Inspection

Democratizing neural networks to inspect fuzzy, foamy, and fatty products

Keywords: smart sensor, machine vision, neural network, non-linear classifier, lifelong learning, industrial inspection, pass/fail assessment, product grading

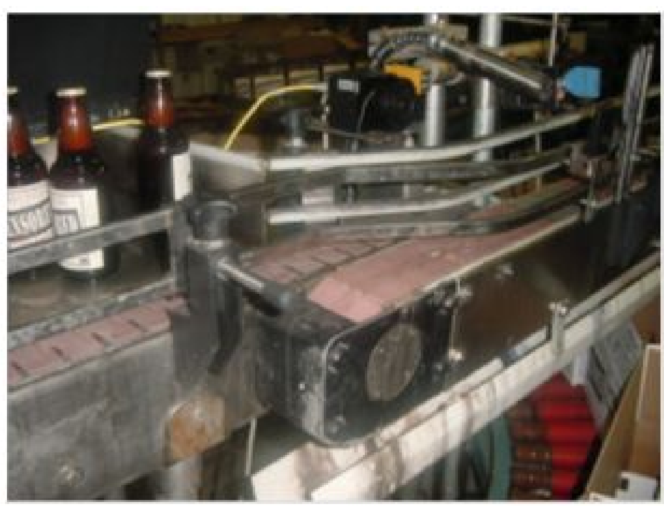
The challenge

Production and Quality Control managers are always interested in Machine Vision systems that can improve manufacturing processes, control the quality of products, and predict machinery maintenance before failure. They will have more faith in a system tested on their production line rather than in a laboratory setting. Still, their goodwill will shrink if the test must disrupt on-going manufacturing.

A General Vision smart camera powered by a NeuroMem neural network can be deployed in 3 easy non-intrusive steps and its training performed by the factory operators.

Setup mode	Backstage mode	Action mode
Easy installation Supervised training of the camera to build a primary knowledge	Always-on recognition without actuation Image recording with auto-annotations Data review and expansion of primary knowledge if corrections are needed	Enable actuation Selective image recording with auto-annotations for production analytics

In the picture to the right, the camera is mounted on a rail along the conveyor belt and connected temporarily to a touch-screen to adjust the sensor settings and teach relevant examples of bottles passing by. The recognition starts immediately but solely at first to monitor and record the classification of the bottles. The annotations generated by the network can be corrected and used as new examples to teach the neurons. Once the classification is satisfactory over a reasonable production batch, the camera's output lines can set enabled and actuate ejector, diverter, warning light, etc. The category recognized by the neurons becomes the action command.



Now that the non-disruption has been established, it is time to demonstrate to the complaisant manager that his operators can train the camera on their own and continuously fine-tune how the NeuroMem neural network must recognize or discriminate objects.

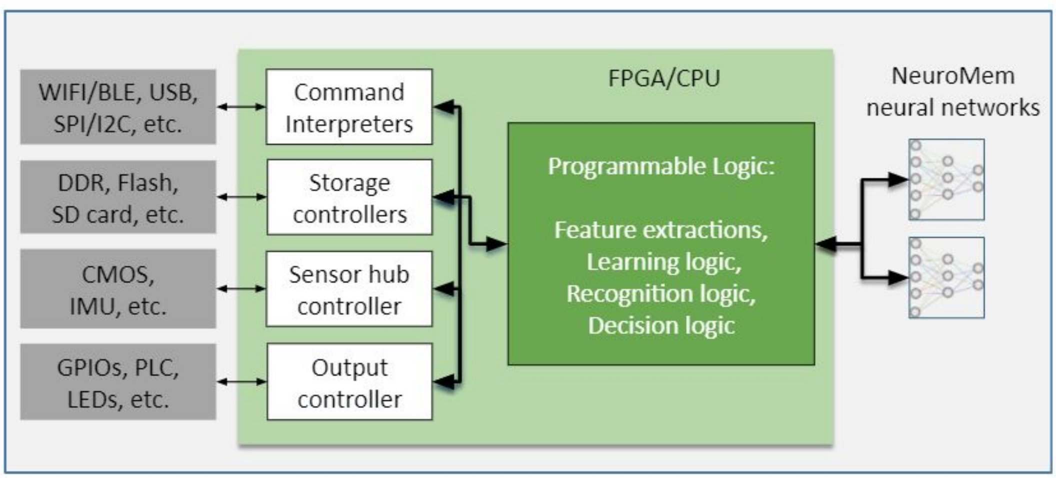
In the brewery, an operator with enough practice can predict if a bottle just filled with beer will end up with the proper amount of liquid once the foam has settled. Similarly, in a meat processing plant, a human inspector can grade the fat quality in the blink of an eye. The good news is that **this field expert can transfer his "visual" knowledge by simply annotating images** of products as they pass in front of the camera. There is no need to describe "why" an image is tagged with a certain category.

The Solution

Setup mode: hardware installation and supervised training

For industrial inspection, the architecture of a NeuroMem-Smart camera features at the minimum a CMOS sensor, an MPU and/or Field Programmable Gate Array to run the learning and recognition logic, a NeuroMem neural network, and GPIO lines for trigger inputs and optocoupler outputs. This baseline can be expanded to support sensor fusion, data storage, wireless communications, and battery-powered operations. A NeuroMem expansion connector can also enable the seamless increase of the neural network capacity as more training occurs. Due to the current NeuroMem chips' capacities, the network increment can be1024 and 576 neurons.

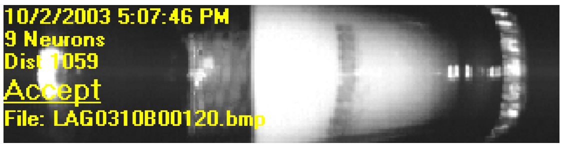
Camera architecture



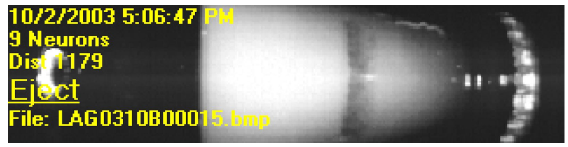
The installation of the camera on a production line is easy thanks to an industrial enclosure with ready-to-mount brackets. Using a temporary connection to a touch-screen tablet running General Vision's Knowledge Builder, an operator can verify the brightness and contrast of the sensor, test its triggering when an object enters the field of view, and verify the quality of the images. Teaching can then start.

A simple panel allows for editing the categories of objects to recognize and discriminate. The supervised training consists of clicking the category button corresponding to the highlighted region on screen. **As soon as you teach an example, the neurons learn it and it contributes to the next recognition**. You can see the impact immediately and do not have to show large amounts of examples, often redundant and unnecessary.

In the case of the brewery, the operator has the choice between an Accept or Reject button to transfer his knowledge of how the foam seen at the instant T will settle and produce, or not, an acceptable level of beer in the bottle. At the meat factory, he can have the choice to teach more than two grades of fat. Regardless of the type of inspection, **the field expert can transfer his “visual” knowledge with no need for mathematical nor empirical explanations.**



Example of Accept category



Example of Eject category

Naturally, if the teacher clicks the wrong category inadvertently, the neurons will integrate the error into their knowledge. To circumvent this problem, the Knowledge Builder application allows undoing the last N teaching instruction. This capability is unique to a NeuroMem neural network because its neurons are memories, neuromorphic memories to be precise. They can be read and restored to earlier configurations. If the Undo correction is not possible, more training can be done. The neurons holding contradictory prototypes will degenerate autonomously.

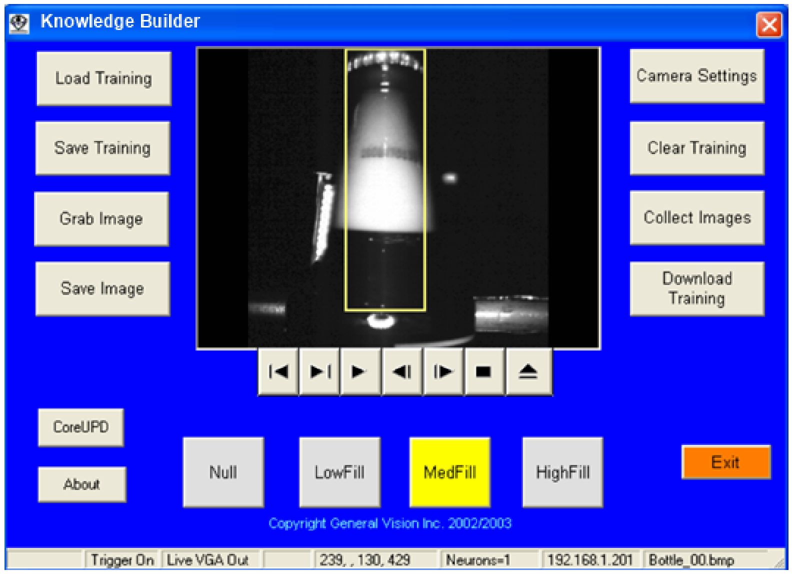
If you want to learn about the chain of actions between the sensor input and category output, you can refer to the NeuroMem Technology Reference Guide and CogniSight API. In short, a feature extraction logic calculates one or more signatures from one or more regions in a video frame. Each feature is associated with a context and broadcasted to the neurons for immediate learning or recognition. The simplest feature is a block subsampling, which aggregates information about color, shape, and texture. If its resolution is sufficient for the level of details required by an application, it offers the tremendous advantage of being calculated at frame rate. More complex features can be extracted and may require the use of alternate memory.

Once the neurons have built a primitive knowledge for the targeted inspection, they can be used to accelerate semi-supervised training.

Backstage mode: Accelerating training with semi-supervision

While the camera is running an always-on recognition, it can save or transmit images and their recognized category at a user-defined frequency and duration.

Under the Knowledge Builder application, the annotated images can be displayed per category for verification purposes. The operator can concentrate on detecting errors within one category at a time. If an image appears misclassified, he can overwrite its category, and the neurons immediately learn this new data set. At the end of this verification process, the neurons can resume inspection with a richer primitive knowledge.



Example of a simplified Knowledge Builder panel

Action mode: Launching autonomous decision

Once a knowledge delivers the expected accuracy, the camera's GPIO lines can be enabled and activate an ejection or other mechanism. Classification statistics can be calculated and stored in the camera's memory.

Building multiple knowledge files can accommodate changes in production and seasonal demands. For example, if a brewery uses different sizes of bottles and glass color, it can decide to build a knowledge per bottle model or a knowledge supporting several models of bottles. Common decision criteria are the learning curve and the neural network capacity.

A knowledge file is composed of a header describing the camera and feature extraction parameters, and a body describing the neurons' content (context, memory, and category). This information can be written to Flash memory so that the camera can resume inspection autonomously after a power shut-down.

Conclusion

A NeuroMem-Smart camera is an ideal solution for industrial inspections. Its installation and testing can be deployed without disrupting a running production, and it can cope with the learning and classification of complex and ill-defined objects with minimum supervision from a human operator. Tested applications include beer foam, fishes, glass surfaces, irrigation drips, printed labels, and more.

Knowledge Builder applications can be customized to offer the minimum controls to users and maximum flexibility to administrators. They can be designed to control multiple cameras distributed along a production line and diverting products as soon as they do not comply with quality requirements, thus reducing waste, increasing productivity, and improving the manufacturing process.