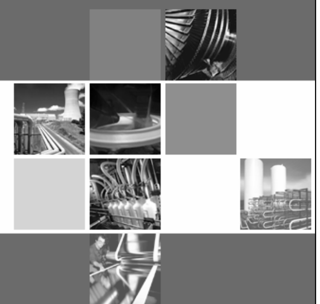
Automation Developers Forum

THE INDUSTRY EVENT FOR LEADING MEASUREMENT AND CONTROL TECHNOLOGIES



Incorporating Vision to Improve Quality and Control Production

NATIONAL INSTRUMENTS™

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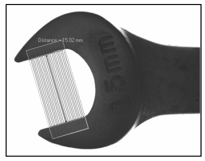
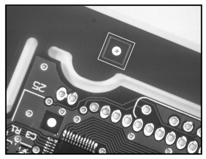
What Can Vision Do?

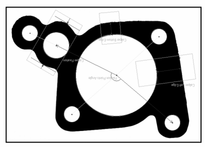
- **Enhance Image**
  - Calibrate images
  - Apply units
  - Filter images



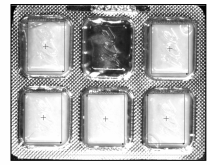
- **Locate Features**
  - Match patterns
  - Match geometric patterns
  - Detect Edges



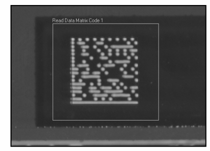
- **Measure Features**
  - Gauge
  - Geometry



- **Check for Presence**
  - Measure Intensity
  - Analyze Particles
  - Match Colors



- **Identify Parts**
  - Read characters (OCR)
  - Read 1D Barcodes
  - Read Data Matrix codes
  - Read PDF417 codes



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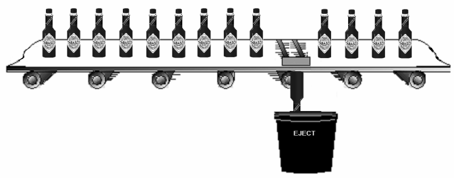
Although it is difficult to lump machine vision capabilities into categories, here are the five main areas where machine vision is found in production.

Each area is classified by its output, or the data that is returned to the user or controller.

- **Enhance** outputs an image. This relates to signal conditioning and calibration for robotics.
- **Check for Presence** outputs a Boolean (T/F). This is the simplest.
- **Locate Features** outputs a position (X, Y) and rotation angle.
- **Identify Parts** returns text, a name, or some kind of intelligent declaration
- **Measure Features** outputs calculated data.

Industrial Machine Vision System

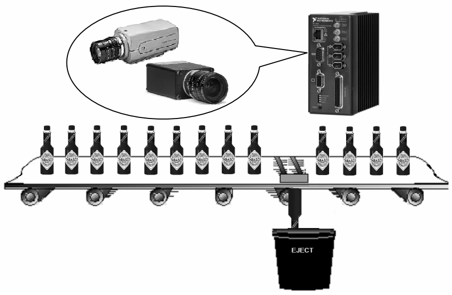


So with that in mind, we are going to start from scratch and build a typical machine vision application. In our example, let's travel to Avery Island, LA, the home of Tabasco Pepper Sauce. To inspect the Tabasco Sauce, there are three very high-level steps.

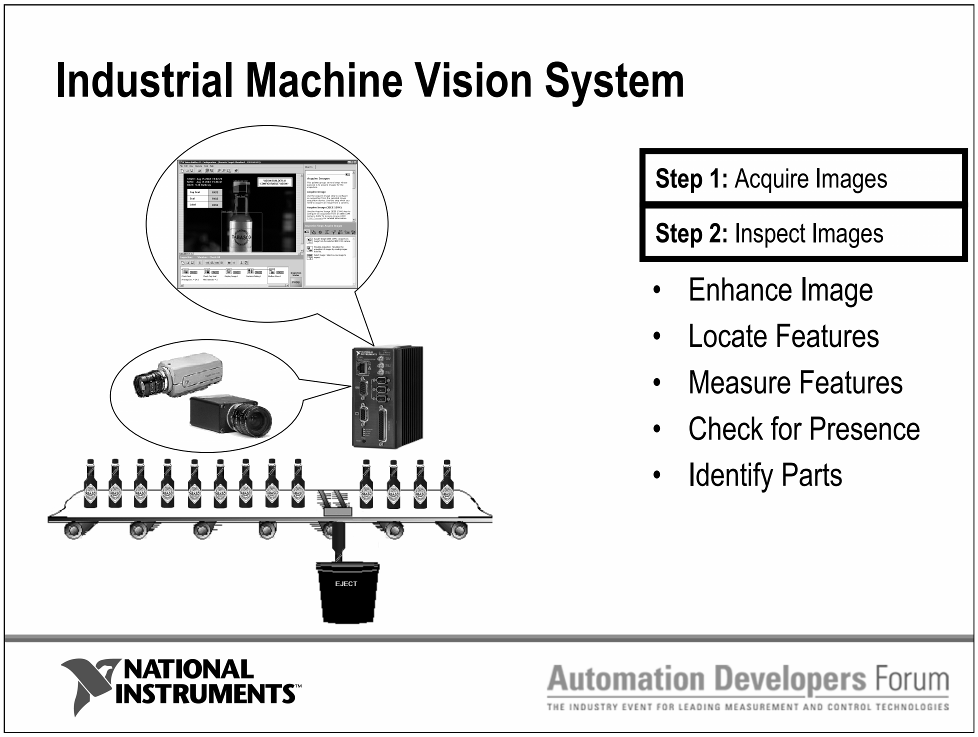
Industrial Machine Vision System

Step 1: Acquire Images

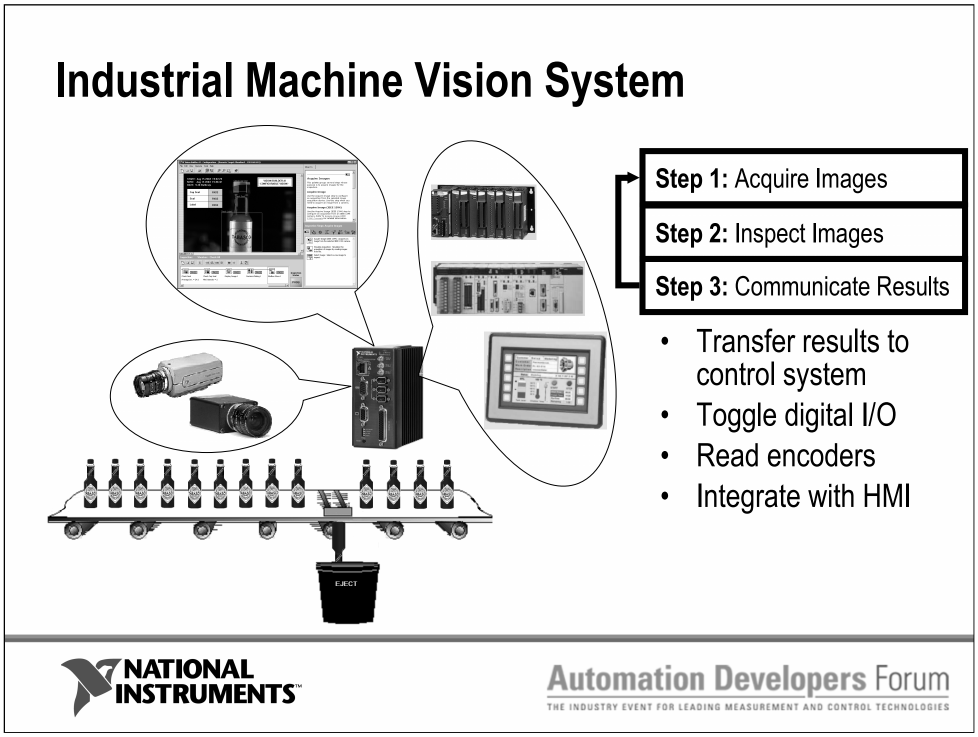
- Configure Triggers
- Setup Cameras
- Strobe Lighting
- Acquire Images



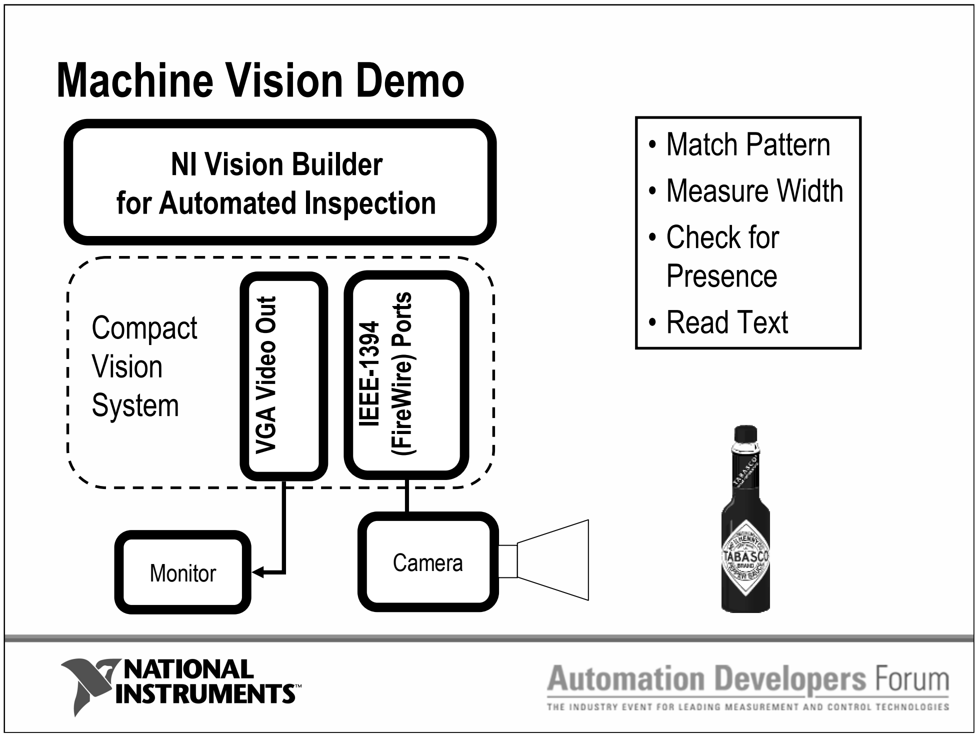
The first step is to acquire an image of the bottle. This is much easier said than done. Care should be taken to ensure that the image is well lit, in focus, and provides nice contrast. Having a clean image up front saves a lot of processing time and headaches down the road. Beyond acquiring a clean image, you might also want to trigger the camera to acquire an image only when the bottle passes in front of it.



The second step is to analyze the image. Here we will most likely use one of the five areas of inspection we talked about in the first slide. From this point, we will have acquired an image and made a meaningful measurement, whether it is the presence of the cap or the text on the bottle.



Finally, the last step is to communicate the results. This could mean we need to actuate a pneumatic device to shoot the product off the line, or communicate the data to another PAC or PLC running overall production. It could also mean that we need to save the image, the data, and the time it was analyzed to a server for later viewing.


Machine Vision Demo
NI Vision Builder for Automated Inspection
Compact Vision System
VGA Video Out
IEEE-1394 (FireWire) Ports
Monitor
Camera
• Match Pattern
• Measure Width
• Check for Presence
• Read Text
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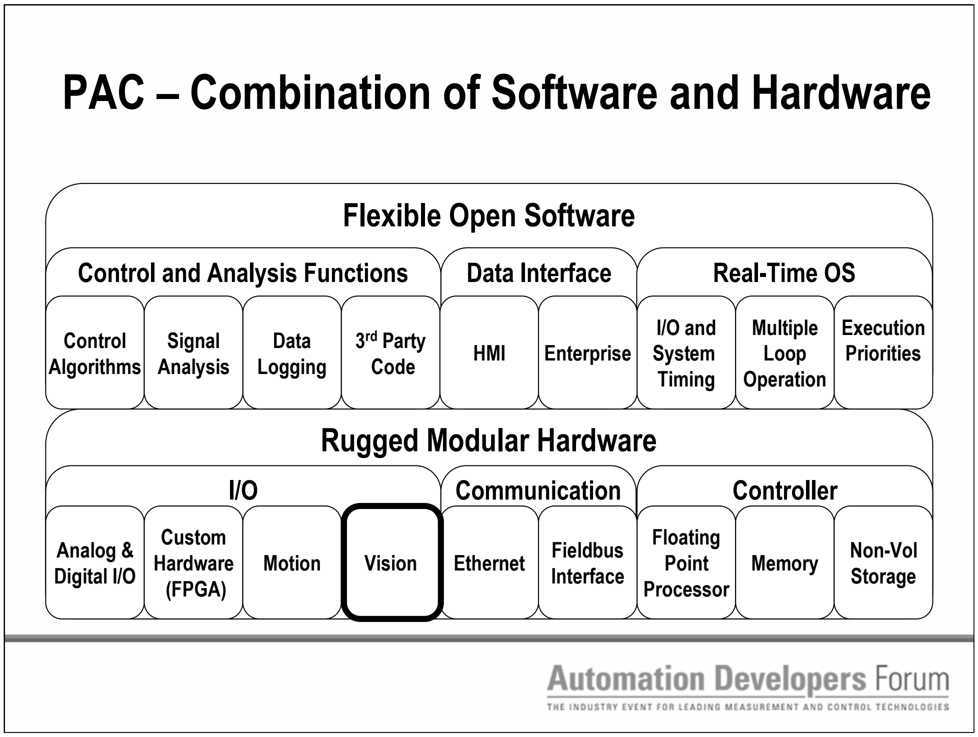

While we have just seen how, in the last several years the price, ease-of-use and performance of machine vision systems have all improved, it is important to note that not all machine vision applications use visible light. Over the last few years, infrared technology has seen a similar expansion as the cost of IR cameras has dropped.

To talk about how infrared technology can be used in an industrial automation setting to improve product quality we have FLIR Systems, the global leader in infrared camera technology.

Infrared – Taking Vision Beyond the Visual Spectrum for Machine Monitoring and Thermal Analysis

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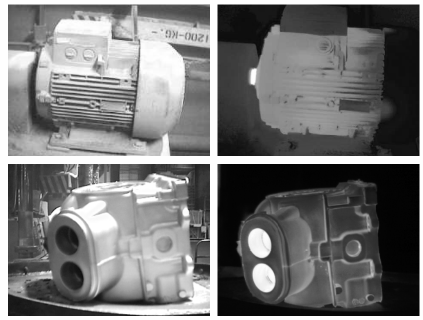
Agenda

- What is Infrared?
- Infrared Detector Technologies
- Different Types of Imaging
- Qualitative versus Quantitative
  - – Qualitative Applications
  - – Quantitative Applications



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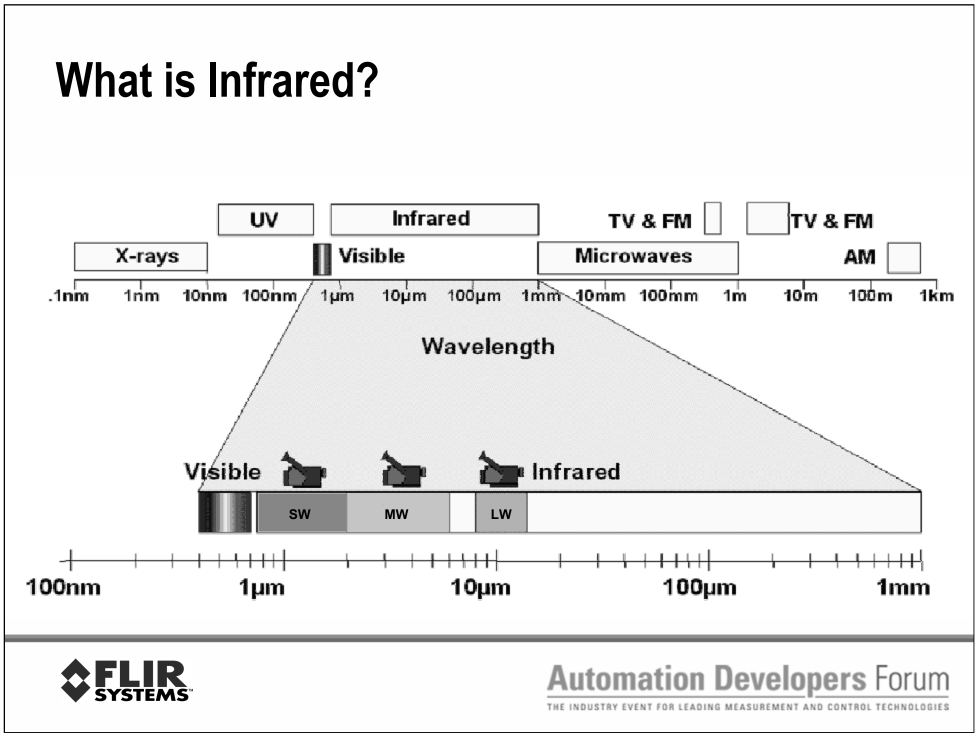
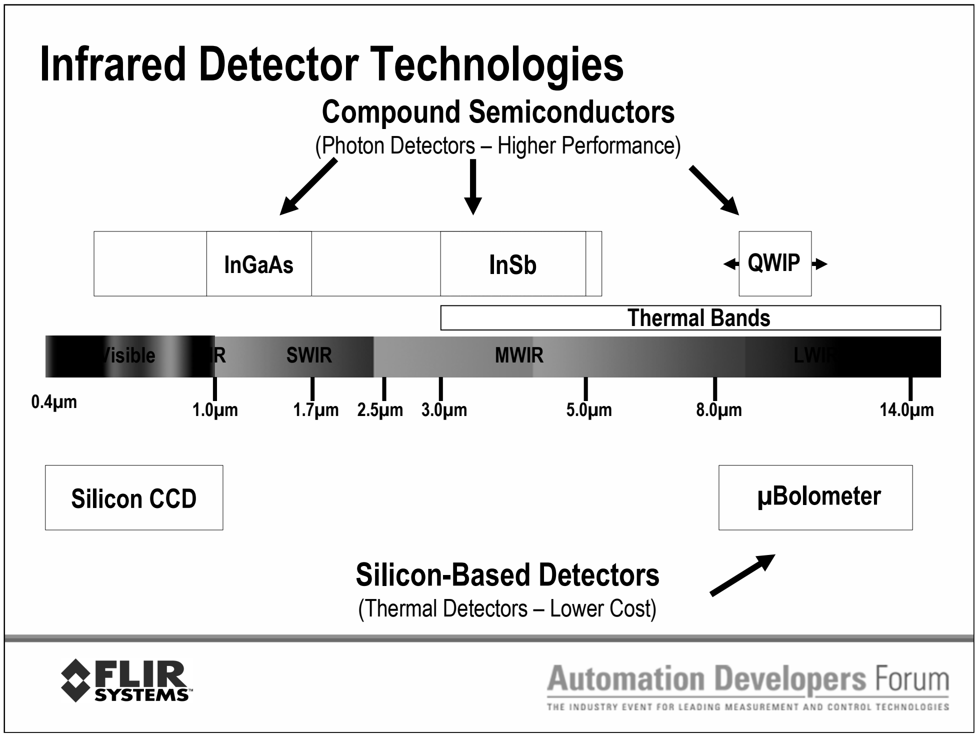
The purpose of this presentation is to highlight the use of IR technology for conventional machine vision applications. Today we will cover the basics of IR. We will discuss the different detectors that are used to sense IR energy, clarify the different types of imaging, define what a Smart Camera is, in regards to a thermal imager, and demonstrate some non-temperature applications in the recycling industry, pulp and paper industry, and automotive industry. We also will discuss the difference between qualitative and quantitative thermal imaging, which will lead us into temperature measurement applications.

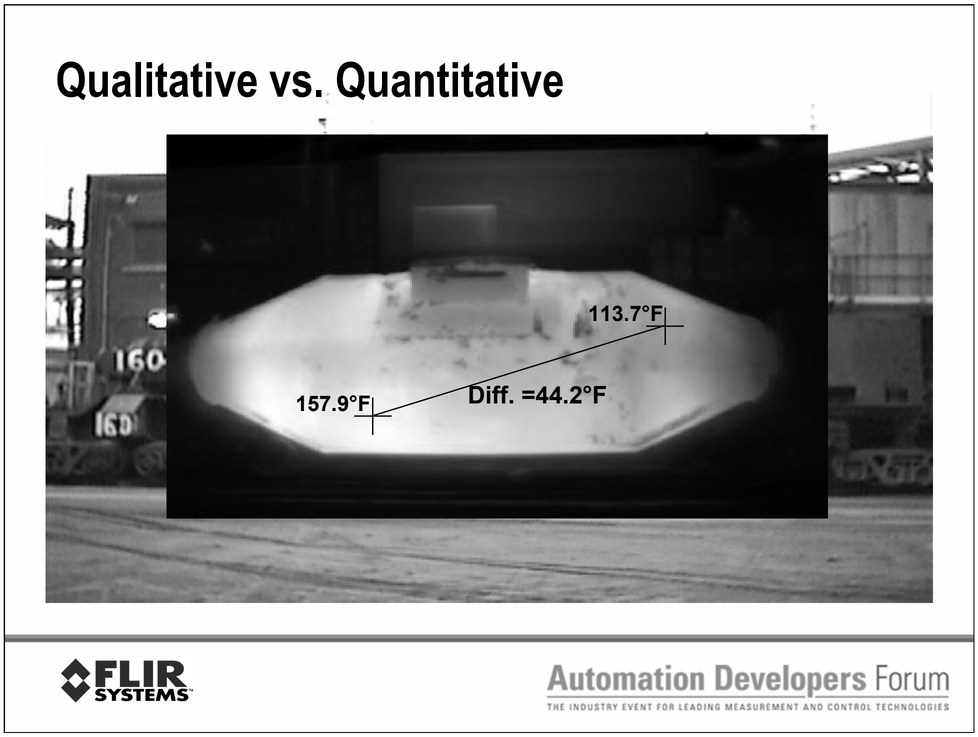


Infrared energy lies just past the visible spectrum of light that everyone is familiar with in our everyday lives. Within the IR spectrum, manufacturers like FLIR disseminate the "bands" into short-wave (SW), mid-wave (MW), and long-wave (LW) camera systems.

Infrared energy is part of the electromagnetic spectrum and behaves similarly to visible light. It travels through space at the speed of light and can be reflected, refracted, absorbed, and emitted. The wavelength of IR energy is about an order of magnitude longer than visible light, between 0.7 and 1,000 µm (millionths of a meter).



It is sometimes helpful to understand where various detector technologies fall within the electromagnetic spectrum. This will help in deciding what detector may be best suited for the application. It also will help to understand the terminology, like “ingas” (Indium gallium arsenide (GaAs) or “insbee” (indium antimonide - InSb).



It would help understand the two types of thermal imaging—qualitative and quantitative. At a higher level, you can think of qualitative thermal imaging as trying to see a target, like in the military. The military would use qualitative imaging to find bad guys hiding in the dark. They do not care how hot they are, they just want to know if someone or something is there.

This is a visible image of a torpedo transfer car that is used in the steel industry. This thermal image is taken with an uncooled longwave camera and as you can see, it displays varying thermal patterns. The colors are scaled from white, which is hot to black, which is cold. This is a qualitative image. We can "see" the information, but cannot determine the magnitude of the severity. For some machine vision applications, this is quite acceptable. True temperature measurement is not necessary. We can "see" different temperatures based on the colors (white is hottest, blues are cooler).

So, how can measurement help this company? As we now begin to add temperature measurements, operators can assess the variances with much more precise information and ultimately make better decisions about the product or process. This plays extremely well in the machine vision marketplace, when engineers want to understand the quality of a finished product. Operators can not only "see" the thermal patterns, but now measure the differences between various areas to determine the magnitude of the variances.

Qualitative Applications

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Now we will review a few examples of thermal qualitative imaging.

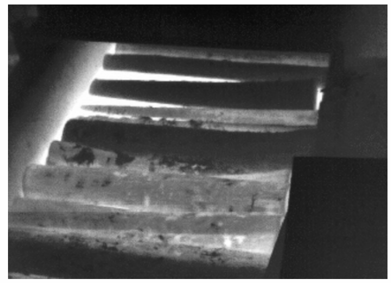
The “De-Barking” Process

The Problem

Operators can not “see” through the steam cloud caused by condensation in cooler air temperatures.

The Solution

IR offers another pair of eyes to “see” through the steam into the Log Vat for proper log alignment.



Steam

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In this application, logs are placed in a vat of boiling water to help loosen up the bark before they are sent through the de-barking machine. If the logs are not positioned properly, jams occur and ultimately shut down the process. Similar to the recycling application, in the colder months of the year, the differences in temperature between the water and the air, create a cloud that reduces the visibility. During normal conditions, the crane operators can simply see the logs that are creating the jam and reposition the logs. When steam is present, the operators have no idea where the jam is and ultimately shut down the process. IR helps the operators in the cranes “see” the troubled logs through the steam and helps them keep the operation functioning with little or no downtime.

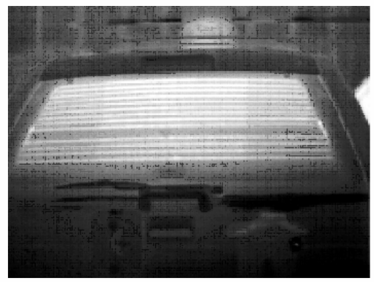
Automotive

The Problem

- Optional features in vehicles cannot be inspected without some type of contact.
- Slows production down.
- 100% inspection is expensive

The Solution

- IR can be permanently mounted to inspect these items.
- IR can be used in a "non-contact" method.



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There are many applications within the automotive industry because of the amount of parts associated with the assembly of a car. One such application is as simple as looking at the rear defroster. Currently the defroster is inspected using an electrical continuity test. If there is discontinuity, then the entire window may be scrapped. This, of course, is very expensive. By using an IR camera, the manufacturers and assembly plants can inspect the elements quickly and efficiently, so the finished product (vehicle) does not make it to the consumer damaged.

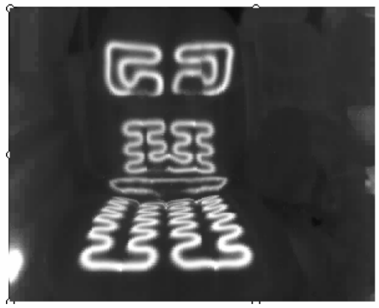
Automotive

The Problem

- Optional features in vehicles cannot be inspected without some type of contact.
- This slows production down.
- 100% inspection is tedious.

The Solution

- IR can be permanently mounted to inspect these items.
- IR can be used in a “non-contact” method.



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Similar to the previous application, this is generally a very easy application. Either the seat manufacturer or the assembly plant can perform a quick inspection to determine the quality of the parts. This is an inspection of a heated seat.

Quantitative Applications

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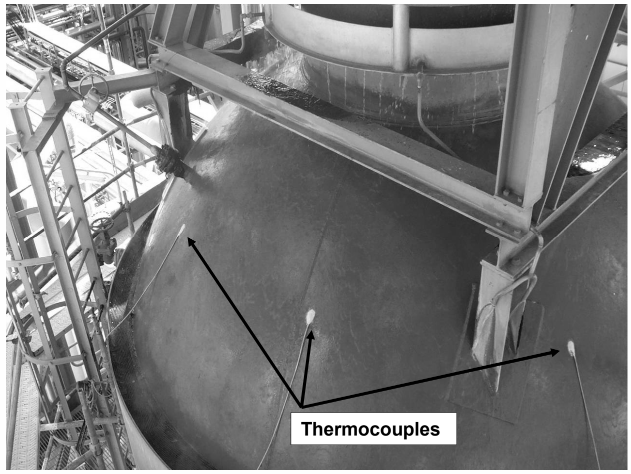
Now we will review a few thermal applications that require a quantitative approach.

Critical Vessel Monitoring (CVM)

The Problem

- High temperature / high pressure vessel monitored by 8 thermocouples
- Areas outside the single-point measurement points could potentially fail without warning and cause catastrophic damage



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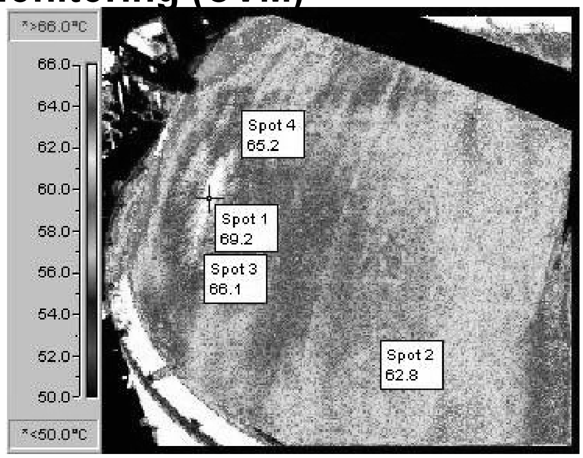
This particular application is very important to the well-being and safety of the plant workers. Under the current methods of this high temperature, high pressure vessel, the customer would use thermocouples that are strategically positioned around the ATR dome. However, as this picture depicts, the area that the thermocouple covers is quite small. Should there be a high temperature, say for instance, 3 feet to the bottom-left of the thermocouple, the dome may fail before the thermocouple has a chance to alarm.

Critical Vessel Monitoring (CVM)

The Solution

- IR cameras can thermally detect problem areas over an entire area, as opposed to a single spot.
- These images can then be sent to the control room for “alarms” and 24x7 monitoring.



This IR image shows the Hemispherical surface area of the vessel and illustrates the ability to depict all critical measurement points of interest.

Courtesy of Thermal Diagnostics Ltd.

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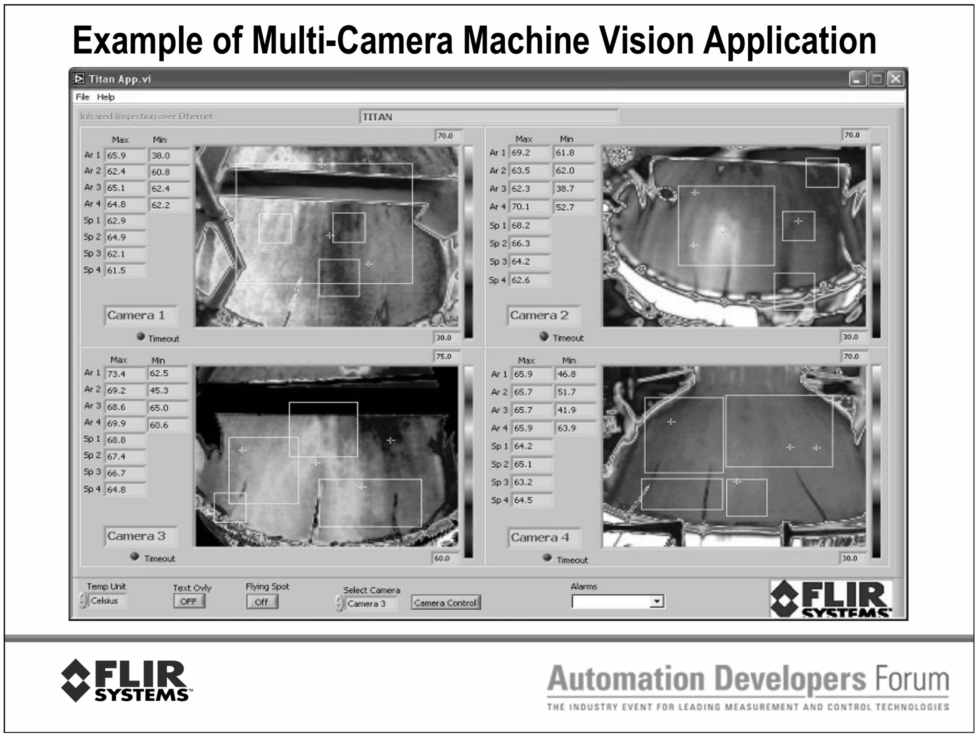
The IR image shows how we can not only see the thermal characteristics of the dome, but quantify the patterns. This gives the customer the ability to now assess the data and potentially predict the outcome. With the temperature data and trending models, this customer can now understand the process much more effectively and increase production. The benefit of the thermal image is that we can give the customer up to 76,800 (using 320×240 camera) “thermocouple” readings, as opposed to the original eight.



This slide shows a LabVIEW application showing the four perspectives of the drum. This is an example of a custom-built application that was generated using National Instruments, LabVIEW software. As you can see, we are able to view up to four cameras simultaneously. In addition, the software also uses the calibrated data from the FLIR camera and administers alarms that are set up by the end user. This application uses four areas (regions of interest) and four spotmeters.

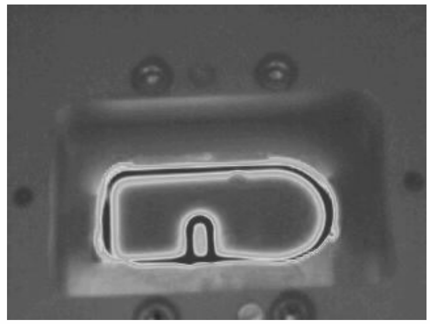
Automotive

The Problem

- Laser welding of plastic parts can not be screened with visible-light systems.
- Weld integrity must be monitored for 100% of the pieces per the customer requirements.
- Thermocouples do not accurately determine “hot” or “cool” spots.

The Solution

- IR can scan 100% of the production parts
- Entire areas can be viewed for quality assurance purposes.



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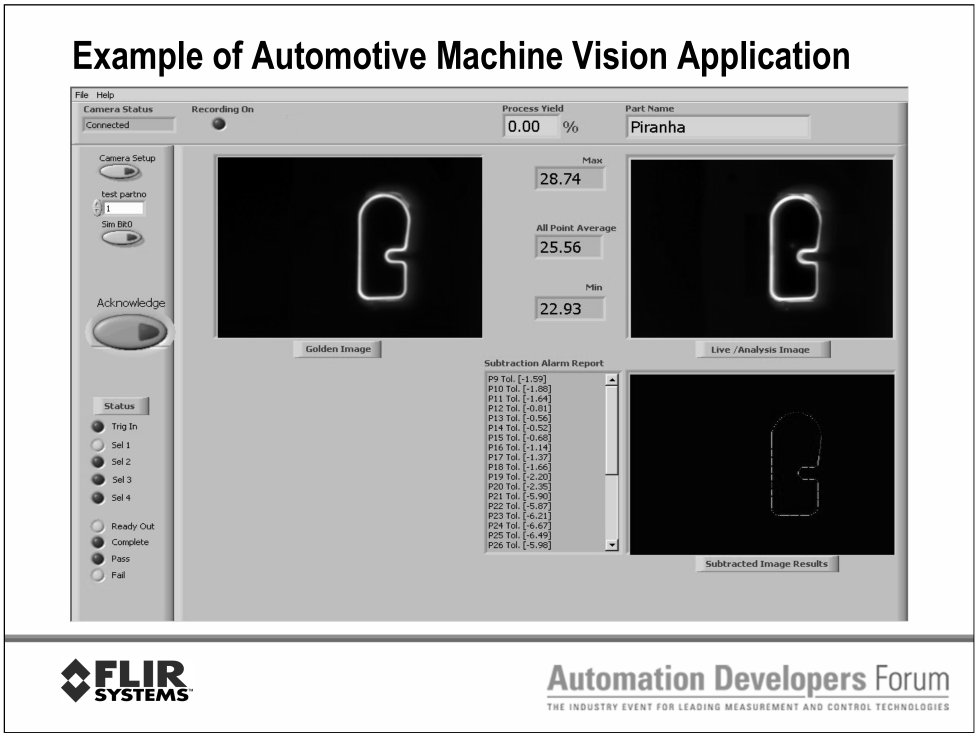
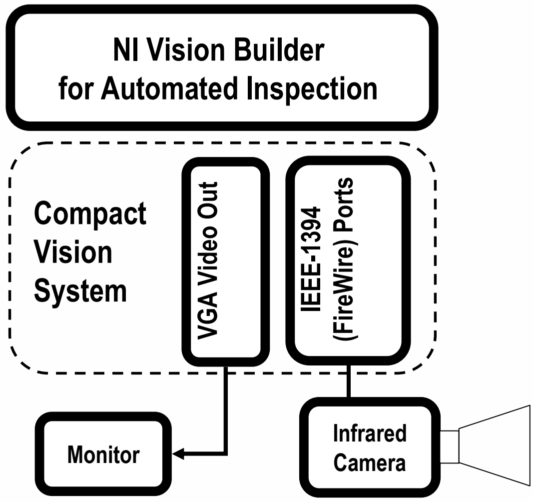
This application required precise temperature measurements along the weld area to determine the effectiveness of the weld. Non-Destructive Testing (NDT) was a major goal for this particular application and with the use of thermal imaging and quantitative measurements, this was achievable.



This is an example of a custom-built application that was generated using National Instruments, LabVIEW software. As you can see, we were able to view a "live" calibrated image while comparing it to a "golden" template. The resultant image then displays the affected areas that were compared to the users specifications.

Demo – Finding Hotspots with Vision



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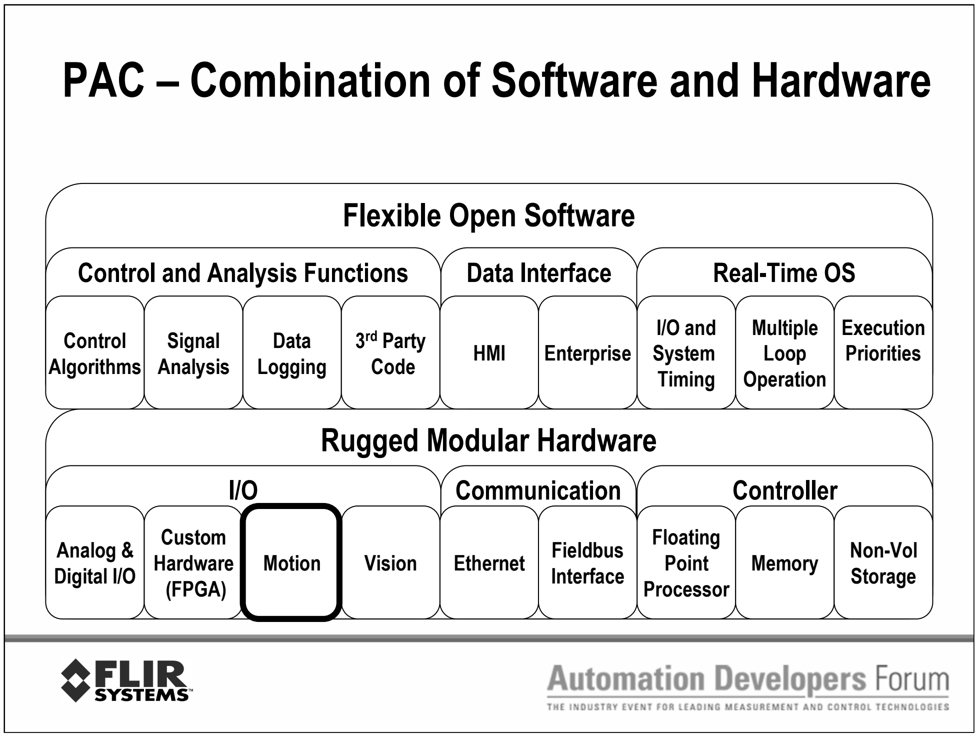

Now we are going to shift gears and focus on precision motion control. We are going to touch on every step of a precision motion system, from the motors all the way up to the controller software. To start things off, we have Parker Bayside to discuss actuators, transmissions, couplings, and bearings.

Precision Motion Control –
Actuators, Transmission, Coupling, Bearing

Parker BAYSIDE

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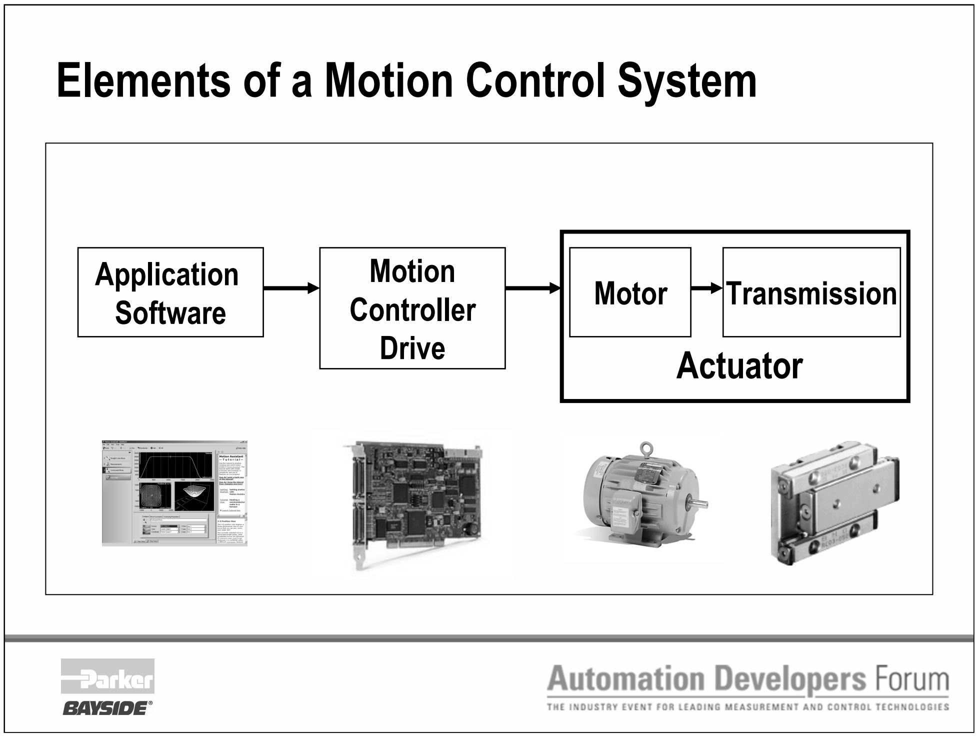
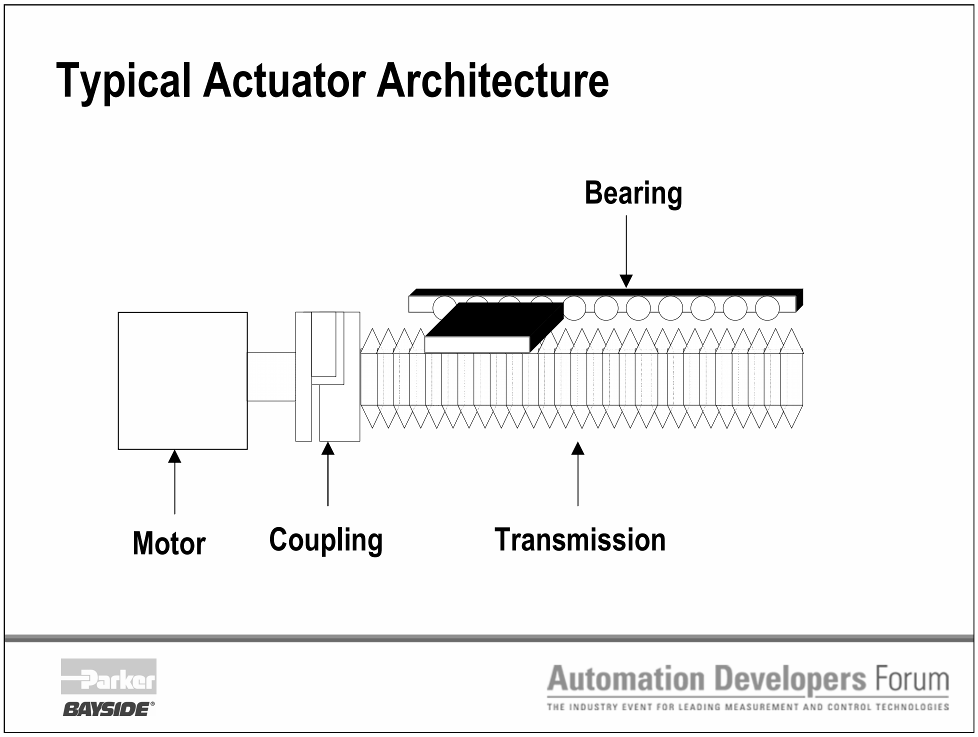
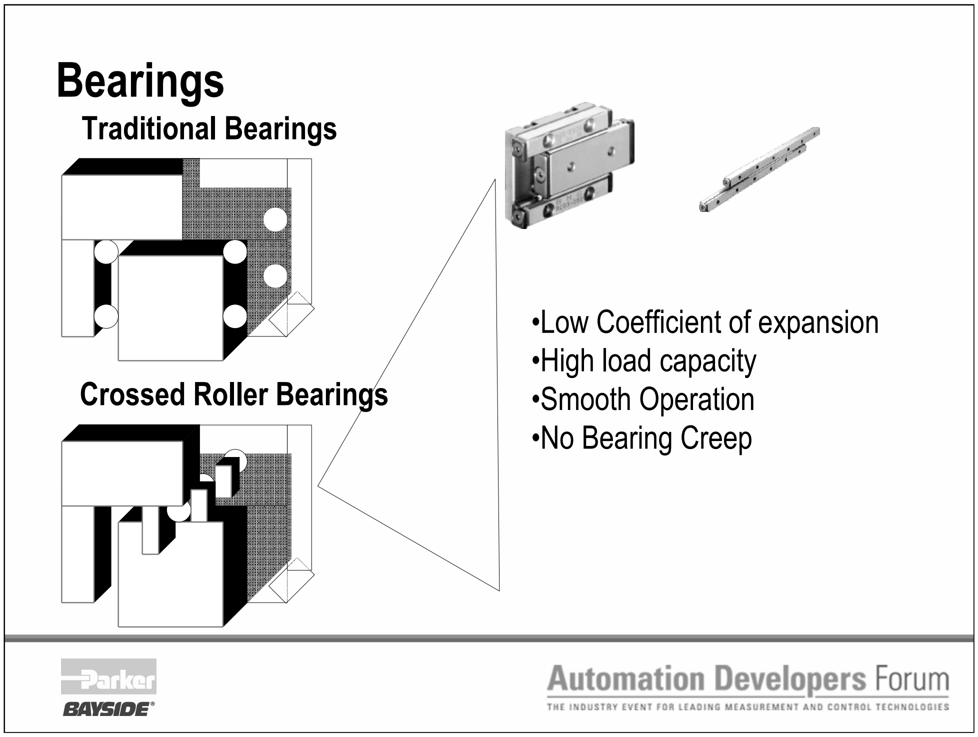


In this presentation we will focus on the precision motion actuators.



There are four main components of any actuator: motor, coupling, transmission, and bearing.



Let’s look at each component of an actuator. Let’s start with bearings. One of the latest technologies in bearings is the crossed roller bearing which offers a high load capability, smooth operation, and low misalignment.

Transmission Types

- Screw
- Linear Motor
- Piezo

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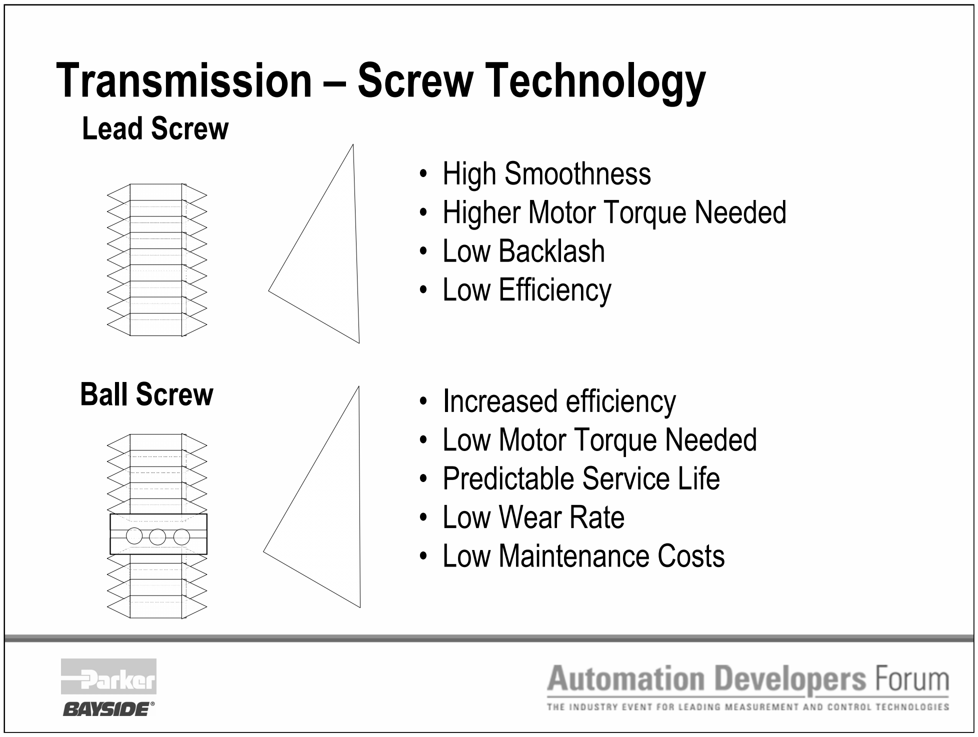
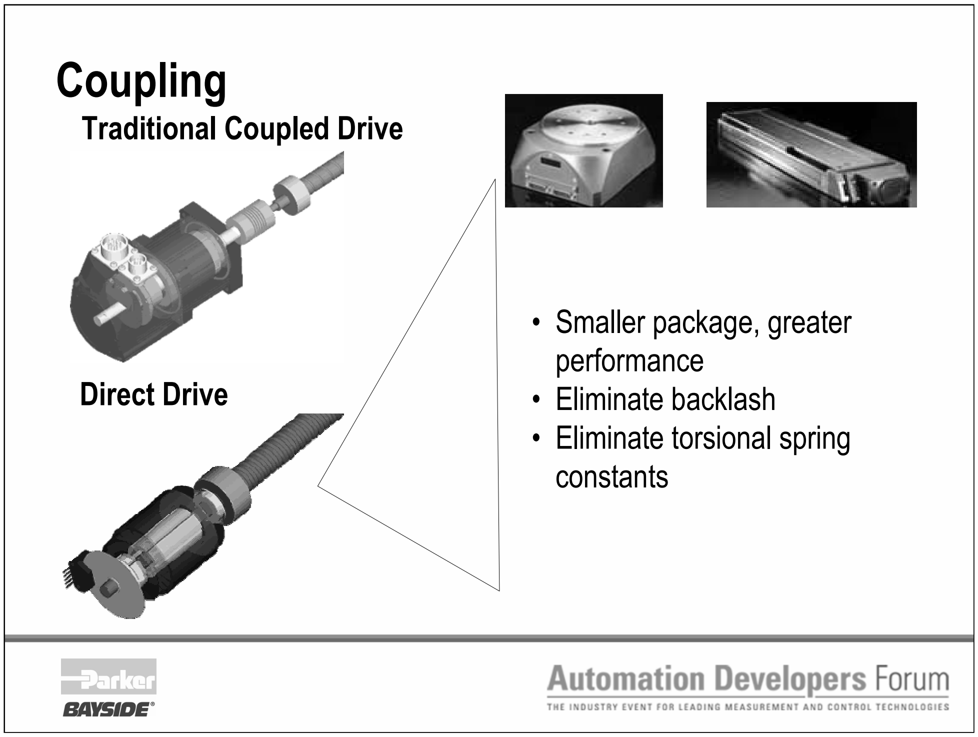
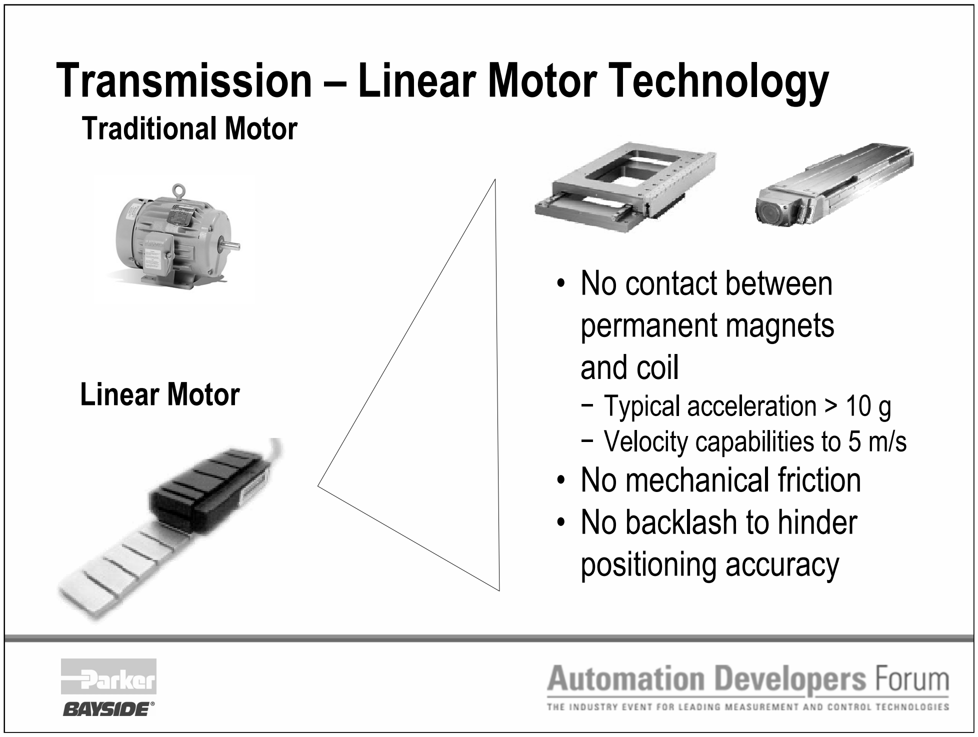
There are three kinds of main classes of transmissions used in precision motion control. The most common and basic is a screw. For higher performance applications there are also new products available using linear motors and piezo electric motors.



Ball screws are very similar to lead screws. There is, however, a ball bearing train between the screw and nut in a recirculating raceway. This raceway allows for predictable service life.



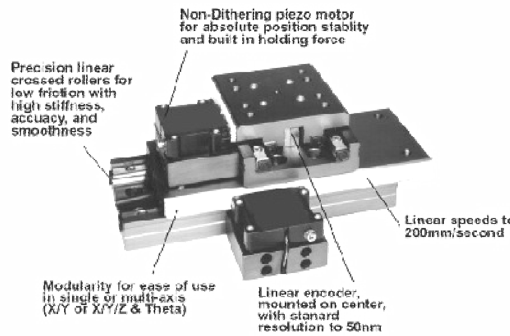
The motor needs to be coupled with the drive. Typically, a coupling can be fixed or flexible. Flexible couplings can be metallic or elastomeric. A direct drive eliminates the need for a separate coupling by combining the transmission with the motor.



Linear motor technology eliminates the need for contact between the permanent magnets and coils. You get a system with no mechanical friction and no backlash, hence higher accuracy.

Transmission – Piezoelectric Technology

- Piezoelectric effect converts electrical field to mechanical strain.
- This excitation creates a small elliptical trajectory of the ceramic tip.
- In essence the tips walk along the ceramic edge



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Piezoelectric materials generate a voltage when compressed. Conversely, you can cause a piezoelectric material to change shape by sending a voltage into it. Determining the relationship between the input voltage and the change in shape can help you predict the behavior of these materials and make them useful for high precision motion control. Because the change in shape is very small, you may not consider piezoelectric material useful for longer travel motion control. However, by using piezo elements to precisely generate a micro-ellipse and create continuous motion along the length of travel, you now can use piezo elements as motors for moving longer travel distances.

Comparing Actuator Technologies

Product Series	Feature	Width (mm)	Travel (mm)	Length (mm)	Max. Load (kg)	Actuation	Accuracy	Repeatability
Luge	Long Travel Precision	100 to 250 (3 sizes)	200 to 2,000	503 to 2,388	650	Linear Motor	+20µm to +3µm	+15µm to +2µm
Micro	Low Profile High Precision	50 to 150 (4 sizes)	25 to 200	164 to 538	652	Ball or Lead Screw	+23µm to +8µm	+10µm to +5µm
Nano	Nano Step Positioning	50 to 150	15 to 160	55 to 200	544	Piezo Ceramic	+20µm to +1µm	+10µm to +0.2µm

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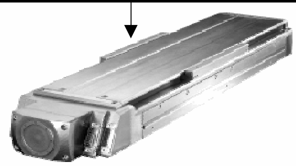
Let's compare the specifications on the three type of actuators—linear motor, ball/lead screw, and piezo.

Demo

Product Series	Feature	Width (mm)	Travel (mm)	Length (mm)	Max. Load (kg)	Actuation	Accuracy	Repeatability
Luge	Long Travel Precision	100 to 250 (3 sizes)	200 to 2,000	503 to 2,388	650	Linear Motor	+20µm to +3µm	+15µm to +2µm
Micro	Low Profile High Precision	50 to 150 (4 sizes)	25 to 200	164 to 538	652	Ball or Lead Screw	+23µm to +8µm	+10µm to +5µm
Nano	Nano Step Positioning	50 to 150	15 to 160	55 to 200	544	Piezo Ceramic	+20µm to +1µm	+10µm to +0.2µm



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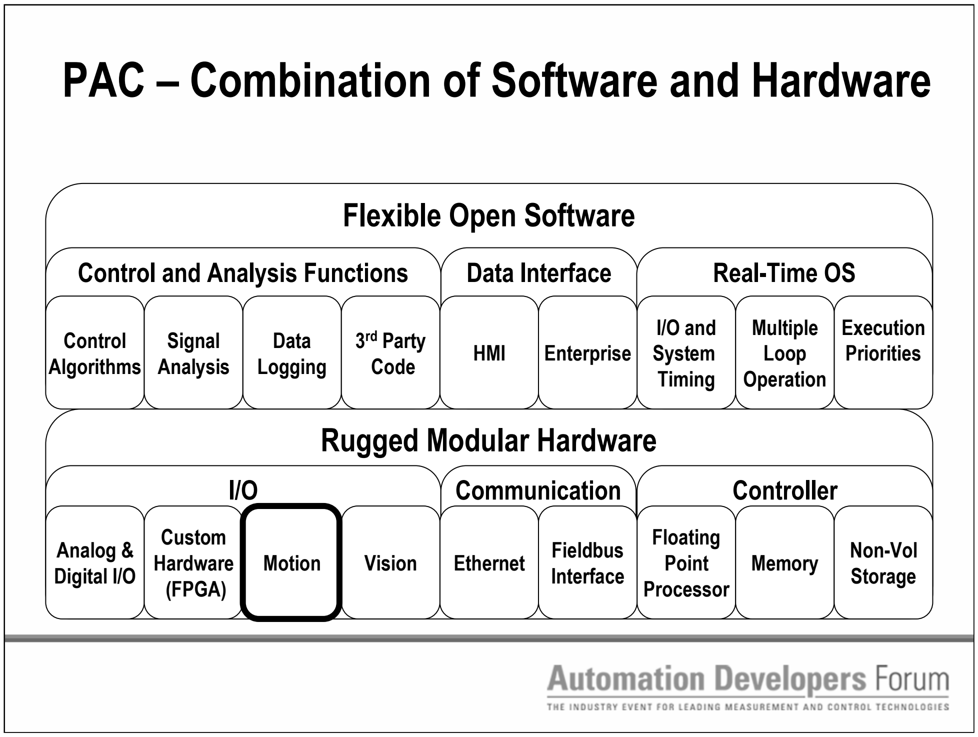
We are going to use the Luge product with linear motor technology for the demonstration.



Now we have discussed the front end components, the motors, transmission, and so on. Now it is time to move to the control hardware and software. National Instruments will now tell us how to precisely control these Parker Bayside motors and stages.

Precision Motion Control – Software and Controllers

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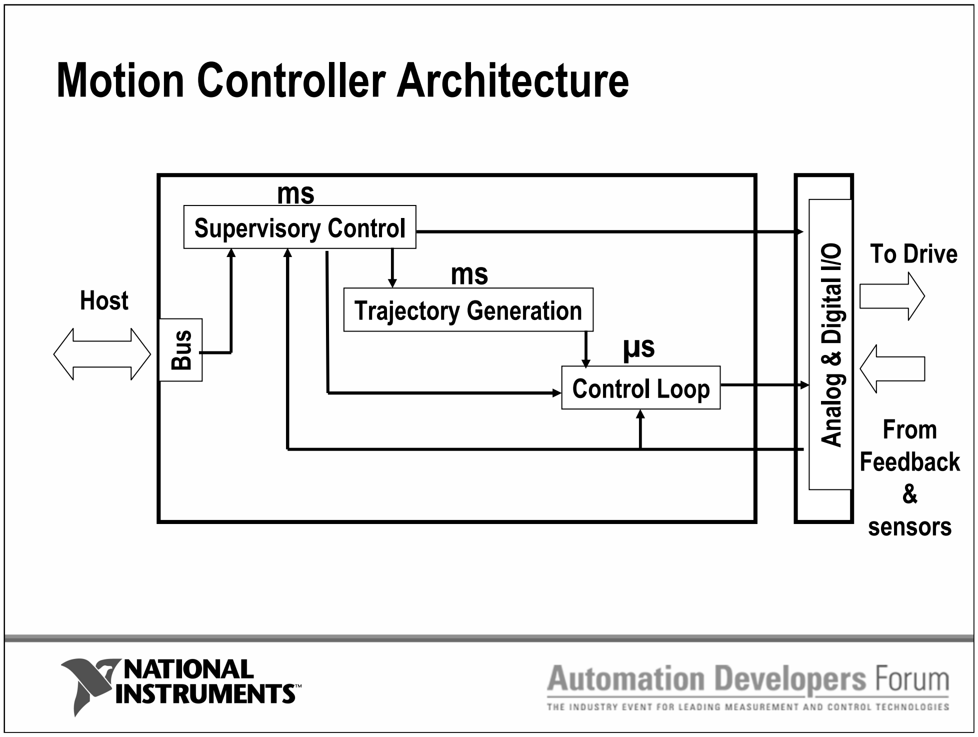
Elements of a Motion Control System

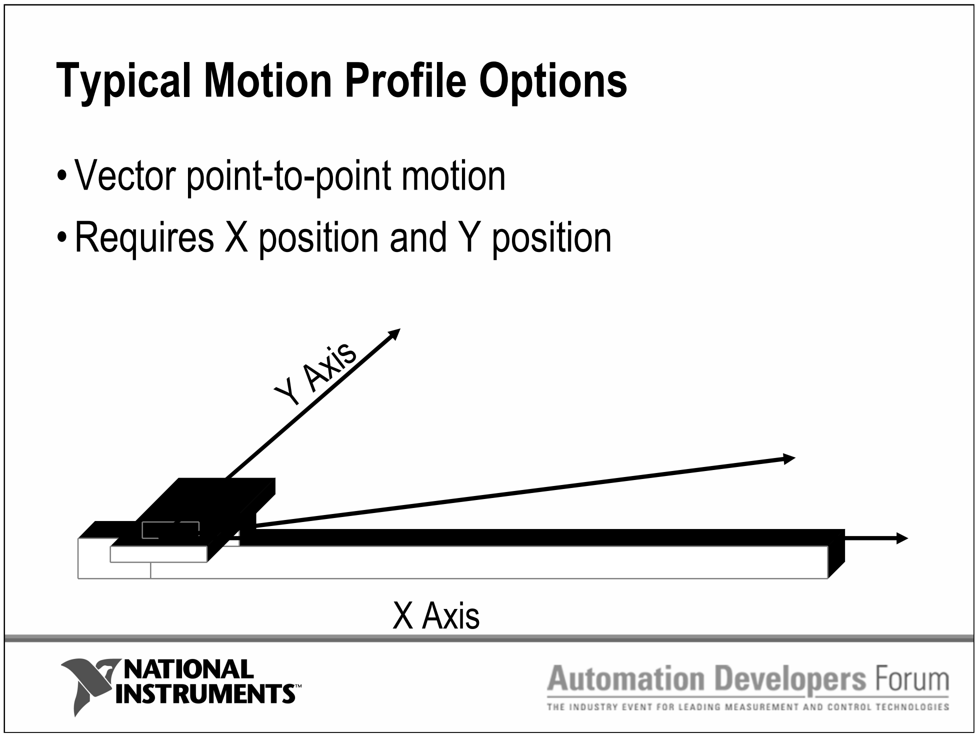
Application Software → Motion Controller Drive → Motor → Transmission



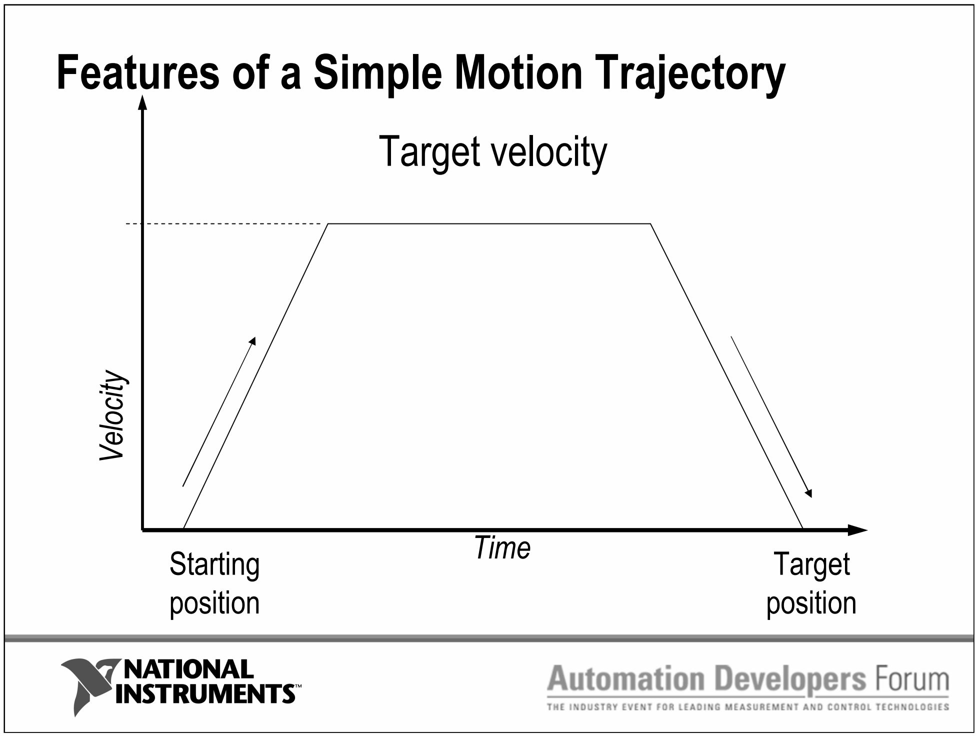
There are three main loops that are executed in a typical motion controller. The supervisory control is the interface that handles user defined requests and commands the trajectory generator to start calculating set points. The trajectory generator calculates a set point every trajectory loop iteration and writes it to the control loop. The control loop takes this set point and using a control algorithm ensures that the actuator follows this set point accurately.

The supervisory control loop needs to be executed in ms loop rates which is possible with a RTOS. Same for the trajectory generator. The control loop needs to execute in microseconds though. Hence it needs to be executed on a DSP or an FPGA.

Commands from the control loop are then sent to the motor through analog output or PWM signals and feedback is received from encoders using counters.



Let us consider the different moves you can achieve with a motion controller. A common type is the vector point-to-point move. This move involves multiple axes moving in coordination to get from one point to another in 2D or 3D space. The main requirement for a vector move is the final positions on the X, Y, or Z axis. Your motion controller will also require some type of vector velocity and acceleration as well. This type of motion profile is commonly found in XY type applications such as scanning or automated microscopy.

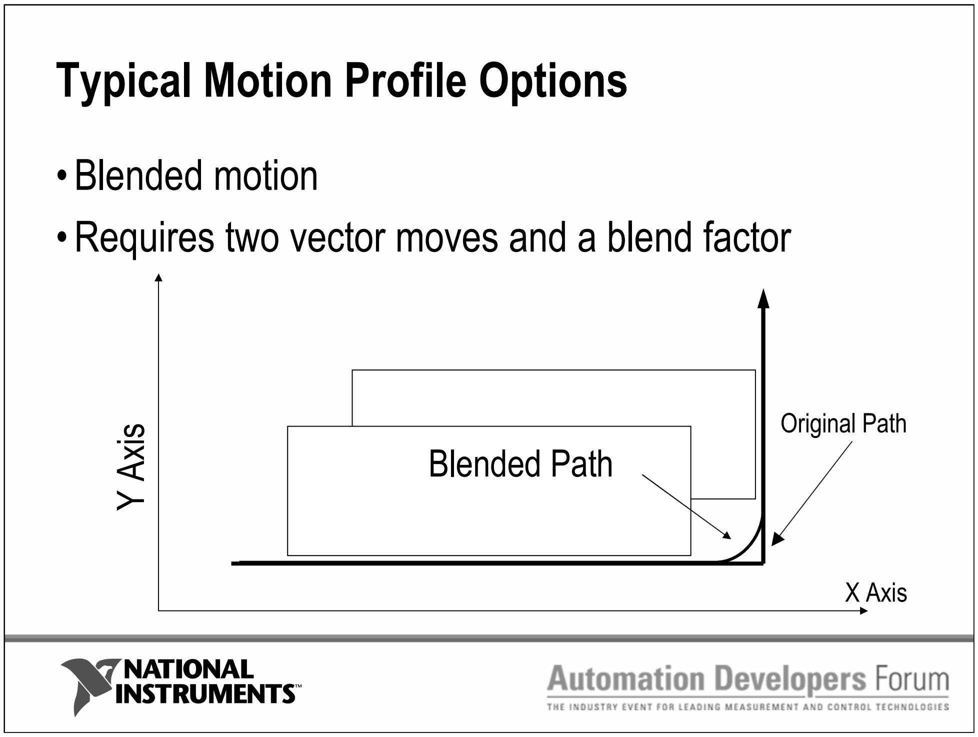


The motion trajectory describes the profile of the control or command signal output by the motion controller board to the driver/amplifier, resulting in a motor/motion action that follows the profile.

The intelligent motion controller calculates the segments of a motion profile trajectory based on the parameter values programmed you program.

The desired target position, maximum target velocity, and acceleration values are used by the trajectory algorithm to determine how much time is spent in the three primary segments of a move, acceleration, constant velocity and deceleration. In the acceleration segment, motion begins from a stopped position or from a previously in-process move, and follows a prescribed acceleration ramp until the speed reaches the target velocity for the move. Motion continues at the target velocity for a prescribed period until the controller determines that it is time to begin the deceleration segment to slow the motion to a stop exactly at the desired target position. If a move is short enough that the deceleration beginning point occurs before the acceleration has completed, then the profile will appear triangular instead of trapezoidal, and the actual velocity attained may fall short of the desired target velocity.

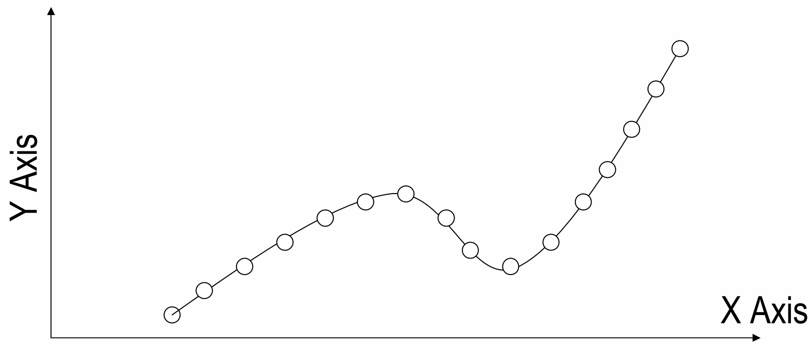
Enhancements to the basic trapezoidal trajectory include S-curve acceleration/deceleration, where the accel/decel ramp is modified into a non-linear, curved profile. This fine control over the shape of these ramps is very useful for tailoring the performance of a motion trajectory based upon the inertial, frictional forces, motor dynamics and other mechanical limitations in motion systems.



Another common profile option is blended motion. Blended motion involves two moves that are fused together by a blend as shown in the example here. The main requirement for a blended move is that you have two vector moves and a blend factor which specifies how large the blend will be. Blending is useful for applications where you need continuous motion between two different moves. One of the issues you will run into when using blended motion is that you will not pass through all of the points in your original trajectory. If the specific position along the path is important to you, another option to consider is contouring.

Typical Motion Profile Options

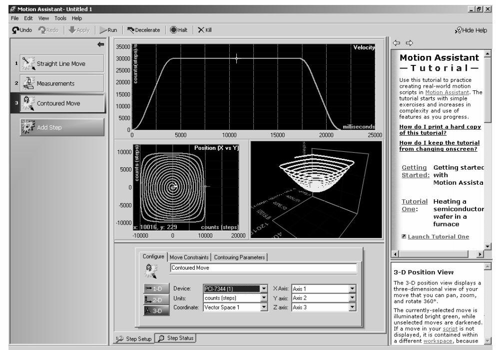
- Contouring – spline through a buffer of points
- Requires buffer of points



Contouring enables you to supply a buffer of those positions and then creates a smooth path or spline through those positions. The advantage of contouring is that you are guaranteed to pass through each position.

Motion Assistant Demo

- Input Profile – Points, Geometry, Teach Mode
- Straight Line, Blending, Contouring
- Generate Code



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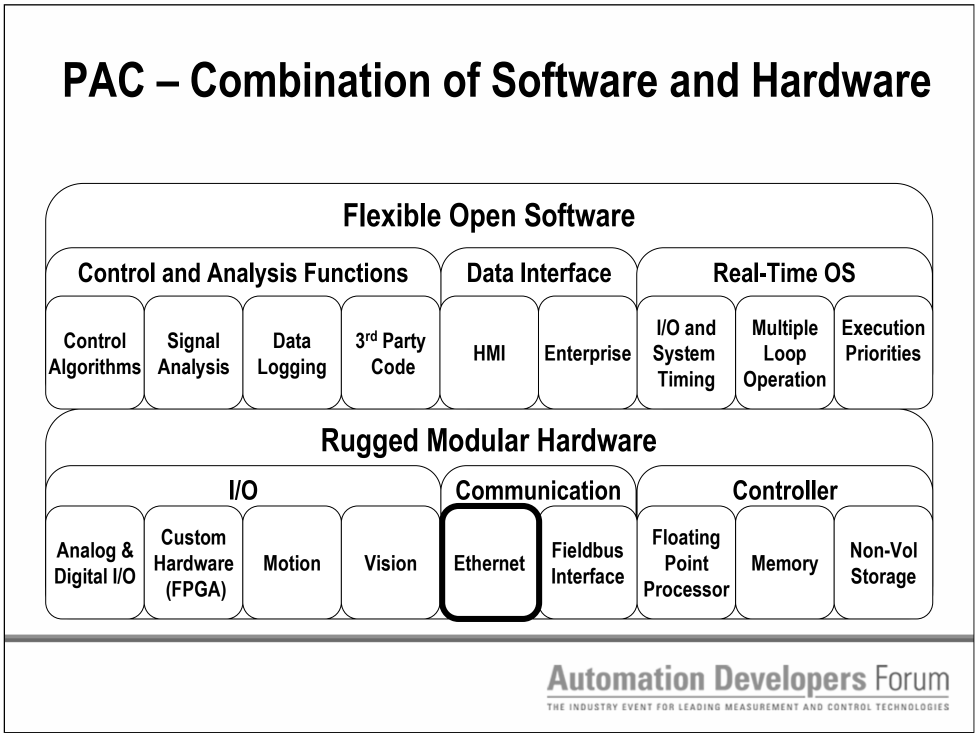
There is a wide range of software that you can use to program your motion control applications. When you get started, one of the first things you do is configure your system. For this, one example is the National Instruments Measurement & Automation Explorer (MAX), an interactive tool for configuring not only motion control but all other National Instruments hardware as well. For motion control, MAX offers interactive testing and tuning panels that help you verify your system's functionality before doing any programming.

When you have configured your system, you are now ready to start prototyping and developing your application. For prototyping, you can use an interactive prototyping tool called Motion Assistant. Motion Assistant enables you to configure moves using a point and click environment and then generate LabVIEW code based on the moves you configure.

After this prototyping phase, the next step is to develop the code. You can generate code for your PAC directly from Motion Assistant.



Ethernet has become the defacto standard used in the plant today. In this session we will review the details of Ethernet and explore the reasons why it has become the bus of choice for many industrial applications.