Automation Application in Quality Control and Inspection

L-8

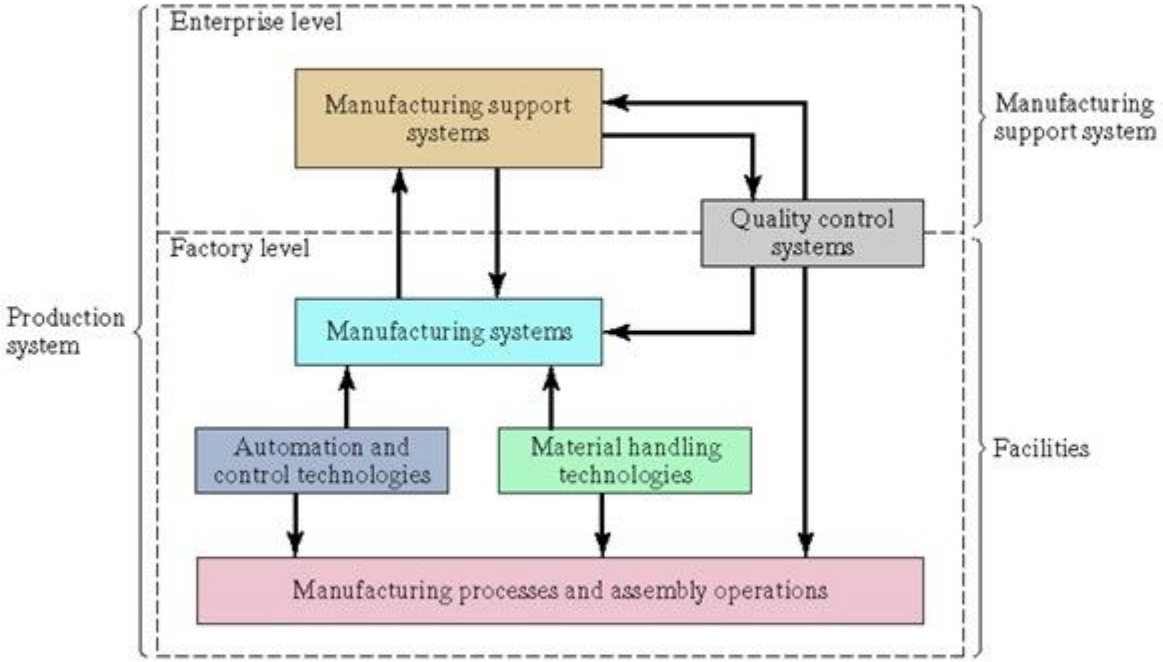
Automated quality control inspection

1) It uses automated systems to detect and classify defects in products or processes. This regulated process can be done using various technologies like sensors and artificial intelligence, machine vision system

Quality control in manufacturing systems

1) Quality programs for Manufacturing
2) Inspection Principles and Practices
3) Inspection Technologies

Quality control systems in Production System



Quality Programs for manufacturing

1) Quality in Design and Manufacturing
2) Traditional and Modern Quality Control
3) Process Variability and Process Capability
4) Statistical Process Control
5) Six Sigma
6) The Six Sigma DMAIC Procedure
7) Taguchi Methods in Quality Engineering
8) ISO 9000

Two Aspects of Quality in Design and Manufacturing

1) Product features
a) Characteristics that result from design
b) Functional and aesthetic features that appeal to the customer
c) Grade

2) Freedom from Deficiencies
a) Product does what it is supposed to do
b) Product is absent of defects and out-of-tolerance conditions

Aspect of Quality: Product Features

- Design configuration, size, weight
- Function and performance
- Distinguishing features of the model
- Aesthetic appeal
- Ease of use
- Availability of options
- Reliability and dependability
- Durability and long service life
- Serviceability
- Reputation of product and producer

Aspects of Quality: Freedom from Deficiencies

- Absence of defects
- Conformance to specifications
- Components within tolerance
- No missing parts
- No early failures

Quality Responsibilities

1) Product features are the aspect of quality for which the design department is responsible

- Product features determine to a large degree the price that a company can charge for its products

2) Freedom from deficiencies is the quality aspect for which the manufacturing departments are responsible

- The ability to minimize these deficiencies has an important influence on the cost of the product

3) These are generalities

- The responsibility for high quality extends well beyond the design and manufacturing departments.

Traditional Quality Control

1) Widespread use of statistical quality control (SQC), in which inferences are made about the quality of the population of manufactured parts and products based on a sample
2) Two principal sampling methods in SQC

- Control charts – Graphical technique used to track measured variable of interest over time

- Acceptance sampling – If the sample passes, the batch is accepted

Traditional Quality Control

Typical management principles and practices:

1) Customers are external to the organization

a) The sales and marketing department are responsible for customers

2) Company is organized by functional departments

3) Inspection department is responsible for quality

4) Inspection follows production

5) Knowledge of SQC techniques resides only in the minds of the QC experts in the organization

Modern View of Quality Control

High quality is achieved by a combination of:

1) Good management-three objectives of ‘’total quality management’’

a) Achieving customer satisfaction

b) Continous improvement

c) Encouraging involvement of entire work force

2) Good technology- traditional statistical tools combined with modern measurement and inspection technologies

Total Quality Management (TQM)

Typical management principles and practices:

1) Quality is focused on customer satisfaction

a) Internal customers and external customers

2) Quality goals are driven by top management

3) Quality control is pervasive in the organization

4) Quality must be built into the product, not inspected in afterward

a) Production workers must inspect their own work

5) Continous improvement

a) A never ending chase to design and produce better products

Process Variability

- Manufacturing process variations are of two types:

1) Random variations – result from intrinsic variability in the process

a) Process is operating normally

b) Human variations from cycle to cycle, minor variations in starting materials, machine vibration

2) Assignable variations – indicate an exception from normal operating conditions

a) Operator errors, defective raw materials, tool failures, equipment malfunctions

Process Capability

PC = $\mu \pm 3\sigma$

Where PC = process capability , μ = process mean set at nominal value of the parameter of interest (bilateral tolerances assumed), σ = standard deviation of the process

1) Assumptions:

a) Output is normally distributed

b) Steady state operation

c) Process is in statistical control

Process Capability and Tolerances

a) Natural tolerance limits – when tolerance is set = process capability

b) Process capability index

$$PCI = \frac{UTL - LTL}{6\sigma}$$

Where PCI = process capability index , UTL and LTL = upper and lower tolerances limits, and 6σ = range of natural tolerance limits

Statistical Process Control (SPC)

Use of various methods to measure and analyze a process, either in manufacturing or non-manufacturing situations

- Objectives of SPC:

a) Improve quality of process output
b) Reduce process variability and achieve process stability
c) Solve processing problems

Seven Tools of SPC

Sometimes referred to as the ‘’magnificent seven’’

1. Control charts
2. Histograms
3. Pareto charts
4. Check sheets
5. Defect concentration diagrams
6. Scatter diagrams
7. Cause and effect diagrams

Control Charts

A graphical technique in which statistics computed from measured values of a process characteristics are plotted over time to determine if the process remains in statistical control

a)Underlying principle is that the variations in a process divide into two categories:

(i) Random Variations

(ii) Assignable variations

Two Basic Types of Control Charts

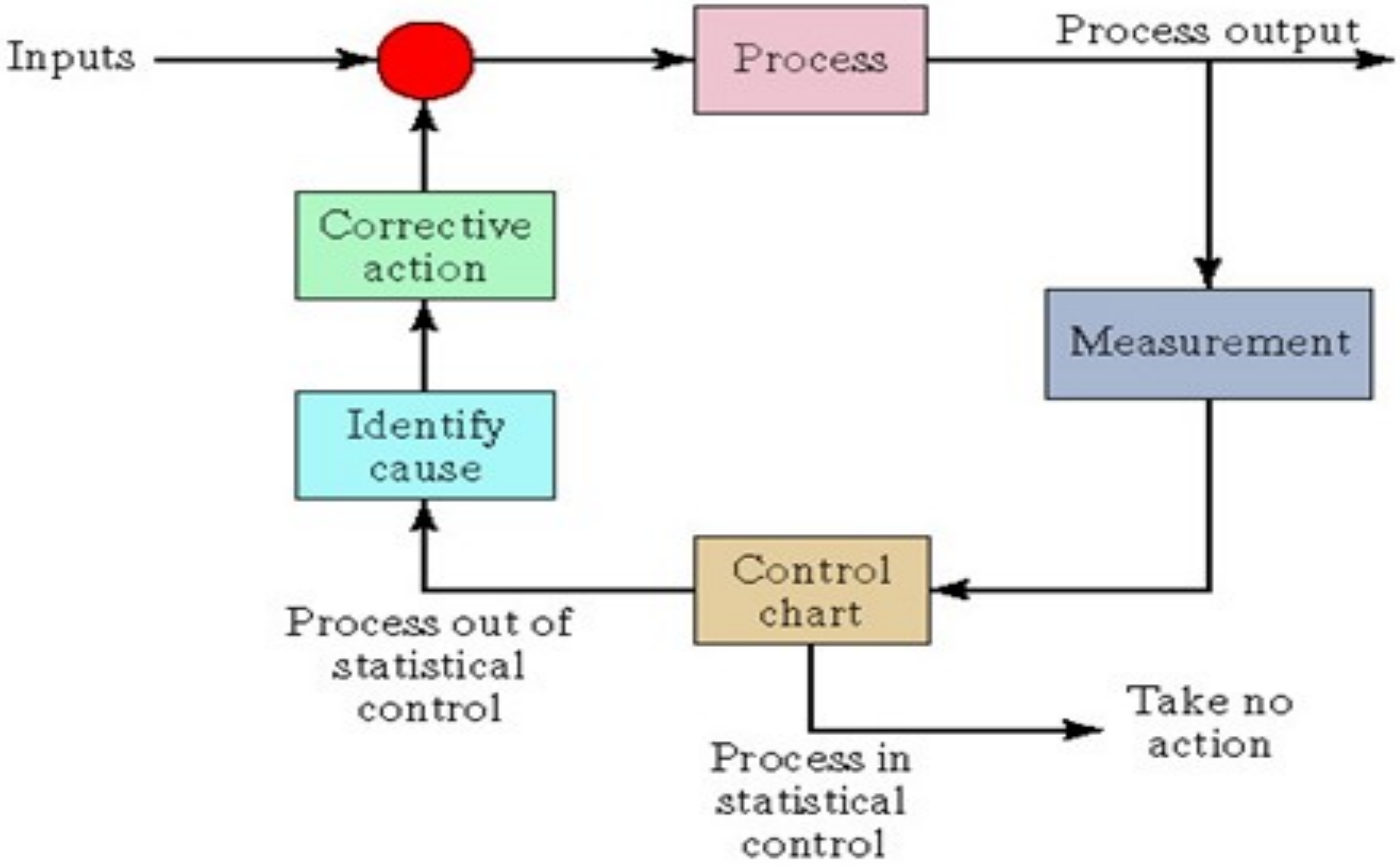
1) Control charts for variables
   a) Require a measurement of the quality characteristic of interest
   b) Two principle types: (1) X-bar chart and (2) R chart
2) Control charts for attributes
   a) Require a determination of either fraction of defects in the sample or number of defects in the sample
   b) Two principle types: (1) P chart and (2) C chart

Interpreting the Control Charts

1) Most obvious sign is when sample mean or range are outside UCL or LCL
2) Less obvious signs:

a) Trends or cyclical patterns in the data
b) Sudden changes in average values
c) Points consistently near UCL or LCL
d) Eight consecutive points that lie on one side of CL
e) Six consecutive points in which each point is higher (or lower) than its predecessor

Control Chart used as Feedback Loop in Statistical Process Control



Histogram

- Statistical graph consisting of bars representing different members of a population, in which the length of each bar indicates the frequency or relative frequency of each member
- A useful tool because the analyst can quickly visualize the features of the data, such as:

a) Shape of the distribution
b) Any central tendency in the distribution
c) Approximations of the mean and mode
d) Amount of scatter in the data

Pareto Chart

Special form of histogram in which data are arranged according to some criterion such as cost or value

1) Based on Pareto’s Law: ‘’the vital few and the trivial many’’
2) Often identified as the 80% -20% rule

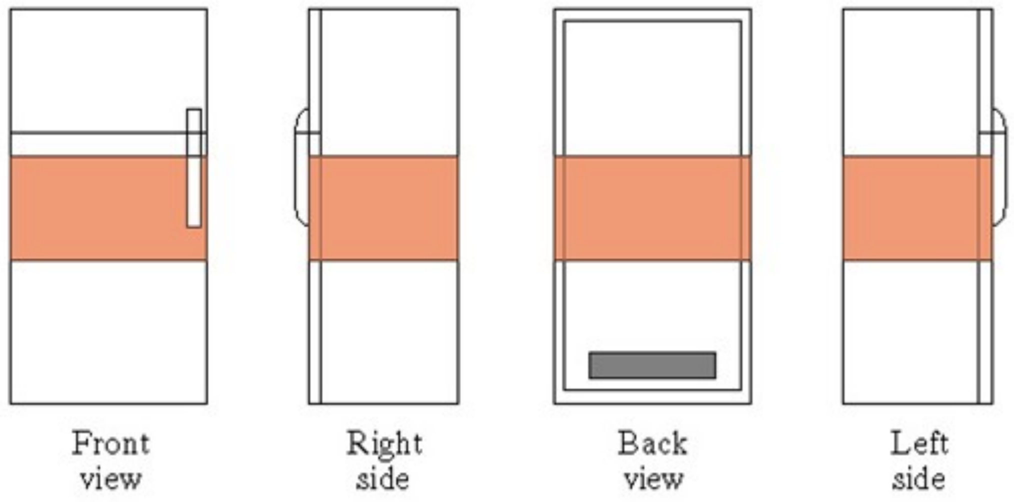
a) 80% of a nation’s wealth is owned by 20% of the population
b) 80% of sales are accounted for by 20% of the SKUs

Defect Concentration Diagram

A drawing of the product (all relevant views), onto which the locations and frequencies of various defects types are added

a) Useful for analyzing the causes of product or part defects

b) By analyzing the defect types and corresponding locations, the underlying causes of the defects can possibly be identified



Scatter Diagrams

An x-y plot of data collected on two variables, where a correlation between the variables is suspected

X_i

a) The data are plotted as pairs; for each Xi value, there is a corresponding Yi value

b) The shape of the collection of data points often reveals a pattern or relationship between the two variables

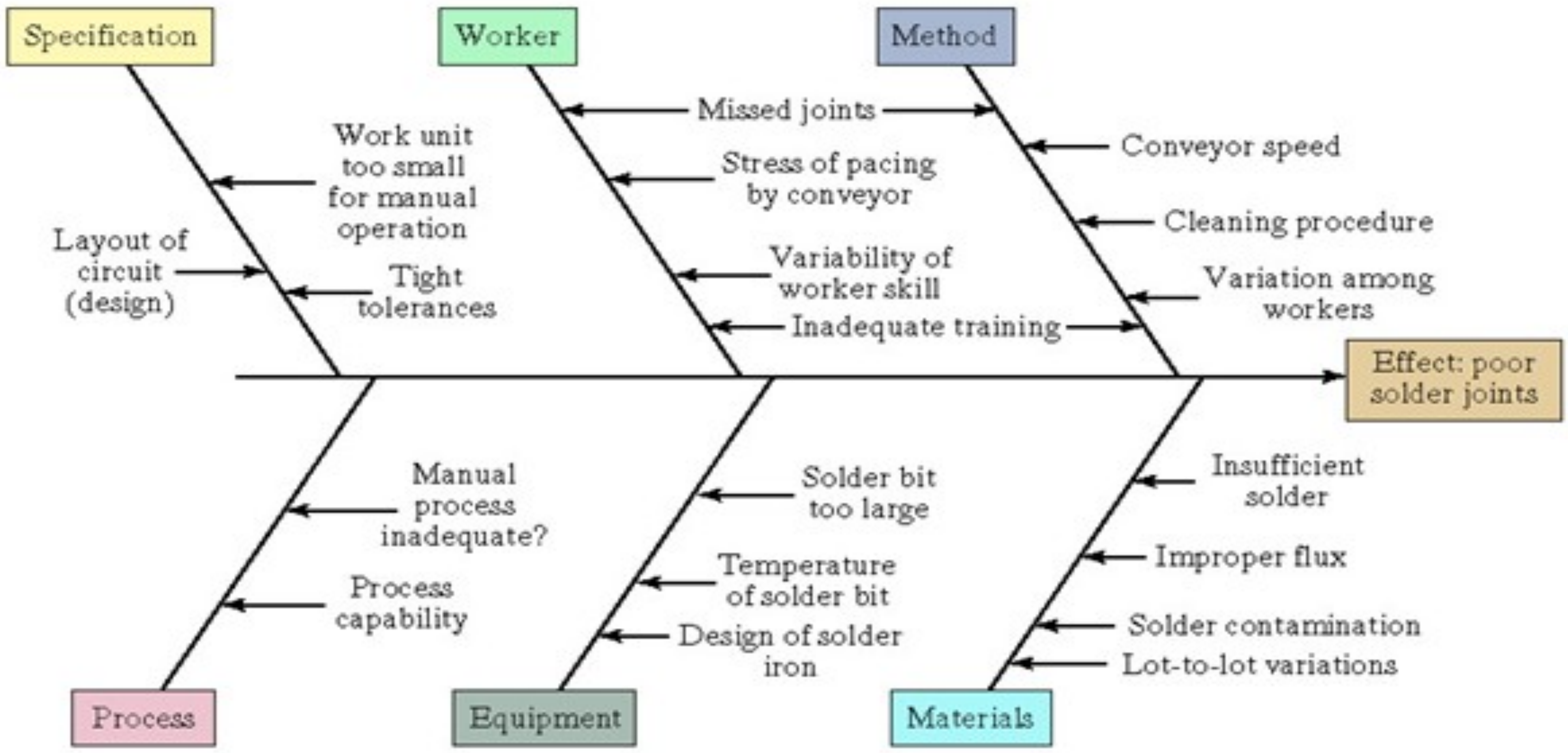
Cause and Effect Diagram

A graphical-tabular chart used to list and analyze the potential causes of a given problem

a) Also known as a ‘’fishbone diagram’’

b) Can be used to identify which causes are most consequential and how to take corrective action against them

Cause and Effect Diagram



Implementing SPC

Five elements usually present in a successful SPC program:

1) Management commitment and leadership

a) Management sets the example for others to follow

2) Team approach to problem solving

a) Team members contribute a broad pool of knowledge

3) SPC training for all employees

4) Emphasis on continuous improvement throughout the organization

5) A recognition and communication system to recognize successful SPC efforts

Six Sigma

A quality-focused program that utilizes worker teams to accomplish projects aimed at improving an organization's operational performance

- Started at Motorola Corp in 1980s
  - Started by Mikel Harry at Motorola in 1970s
  - Encouraged by CEO Robert Galvin
  - Motorola wins Malcolm Baldrige Award, 1988
- Subsequently adopted by other companies, including GE
  - GE claims savings in $billions

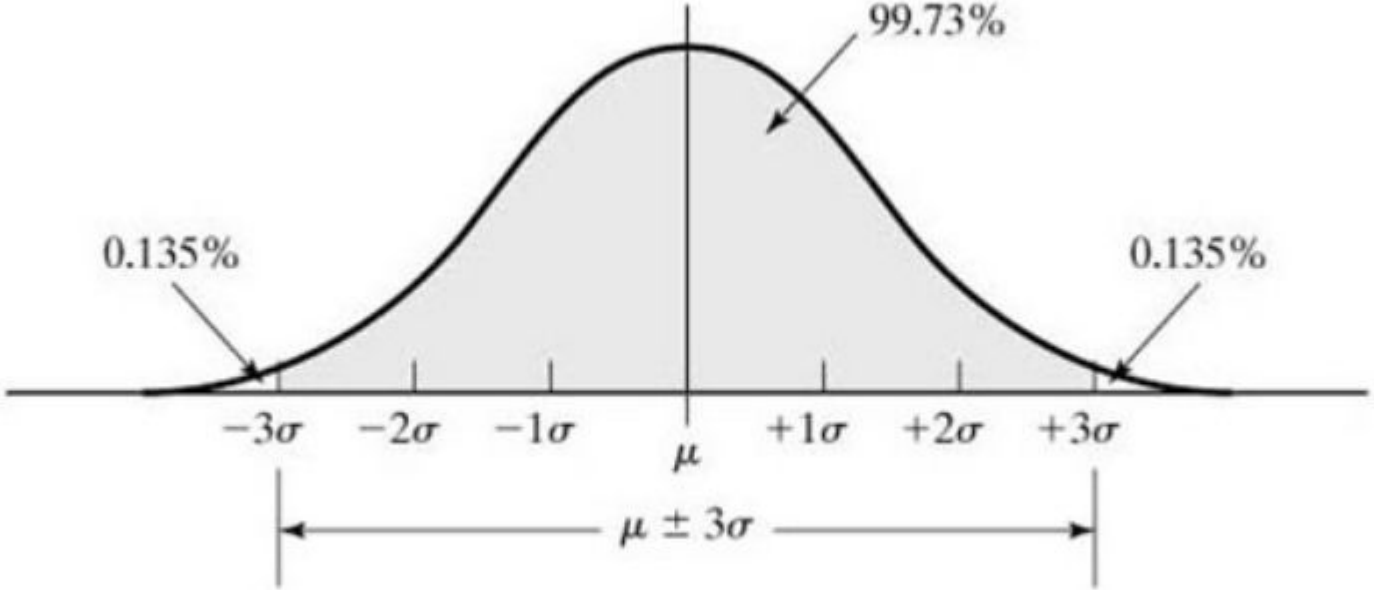
General Goals of Six Sigma

- Better customer satisfaction
- High quality products and services
- Reduced defects
- Improved process capability through reduction in process variations
- Continuous improvement
- Cost reduction through more effective and efficient processes

Quality based on Normal Distribution

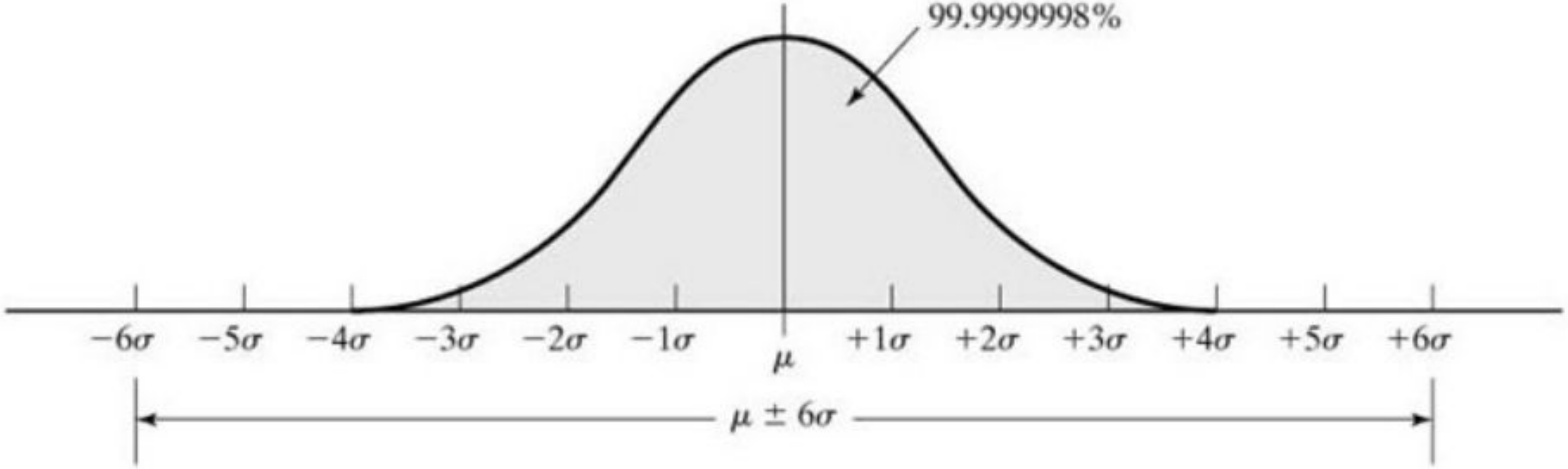
- Traditional metric for good process quality is $\pm 3\sigma$
  - Includes 99.73% of population
  - Defect rate = 2700 defects per million
- Six Sigma metric is $\pm 6\sigma$
  - In the Standard Normal tables:
    - Includes 99.9999998% of population
    - Defect rate = 0.002 defects per million

$\pm 3\sigma$ in the Normal Distribution



Normal distribution of process output variable, showing the $\pm 3\sigma$ limits

$\pm 6\sigma$ in the Normal Distribution



Sigma Value and Defect Rate in the Six Sigma Program

Process sigma	Defect rate	Yield
1σ	691,462 pm	30.9%
2σ	308,538 pm	69.1%
3σ	66,807 pm	93.3%
4σ	6,210 pm	99.4%
5σ	233 pm	99.98%
6σ	3.4 pm	99.99966%

Six Sigma DMAIC Procedure

1. Define the project goals and customer requirements
2. Measure the process to assess current performance
3. Analyze the process and determine root causes of variations and defects
4. Improve the process
5. Control – implement control over the new or improved process

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1. Define

Phases of the define step

1. Organize the project team
2. Provide it with a charter (the problem to solve)
3. Identify customers served by the process
4. Develop high-level process map

2. Measure

Phases of the measure step:

1. Create data collection plan
2. Implement the plan (collect the data)
3. Measure the current sigma level of the process

3. Analysis

Phases of the analysis step:

1. Basic data analysis
2. Process analysis
3. Root cause analysis

4. Improve

Phases in the improve step:

1. Generate alternative improvements
2. Analyze and prioritize alternative improvements
3. Implement improvements

5. Control

- Purpose is to maintain improved performance that was achieved through implementation of the proposed improvements
- Actions in the control step:
  1. Develop control plan
  2. Transfer responsibility back to original owner
  3. Disband Six Sigma team

Taguchi Methods in Quality Engineering

Quality engineering = broad range of engineering and operational activities whose aim is to ensure that a product's quality characteristics are at their nominal or target values

- Shares much with Total Quality Management
- Taguchi methods:
  1. Robust design
  2. Taguchi loss function

Robust Design Defined

A design in which the function and performance of the product or process are relatively insensitive to variations in any of the noise factors

- In product design, robustness means that the product performs consistently despite disturbances and variations in operating environment
- In process design, robustness means that the process continues to produce good product despite disturbances and variations in operating environment

Examples of Robust Product Design

- An airplane that flies in stormy weather as well as in clear weather
- A car that starts in Minneapolis in January as well as in Phoenix in July
- A tennis racket that returns a ball just as well when hit near the rim as when hit dead center
- A hospital operating room that maintains lighting and life support systems when electric power to hospital is interrupted

Taguchi Loss Function

- According to Taguchi, quality is “the loss a product costs society from the time the product is released for shipment”
- Loss includes:
  - Costs to operate
  - Failure to function, maintenance and repair costs
  - Customer dissatisfaction
  - Injuries caused by poor design, etc.
- Defective products (or their components) that are detected, repaired, reworked prior to shipment are manufacturing costs

Taguchi Loss Function - continued

- Loss occurs when a product's functional characteristics differ from their nominal or target values
- When the dimension of a component differs from its nominal value, the component's function is adversely affected
- As the deviation increases, the loss increases at an accelerating rate
- This viewpoint differs from the traditional QC approach which defines upper and lower tolerance limits, and anything between is acceptable

ISO 9000

- ISO = International Organization for Standardization
- U.S. representative to ISO 9000 is ANSI/ASQC
- ISO 9000 is a standard for the systems and procedures used by a facility that affect the quality of the products and services provided by the facility
  - It is not a standard for the products and services
- ISO 9000 is generic, not industry specific
  - It can be applied to any facility producing any product or providing any service

Two Ways to Apply ISO 9000

1. Implement the standards simply for the sake of improving a firm's quality systems
2. ISO 9000 Registration – formal certification that the facility satisfies the standard
   - Benefits:
     - Reduce frequency of quality audits by customer firms
     - Qualify for business partnerships with companies that require ISO 9000 registration (especially in Europe)

Automation in quality control inspection used where

1) In manufacturing production lines

a) Product inspection based on dimensional analysis

b) Product inspection based on surface analysis

2) Manufacturing

3) Food and beverage

4) Pharmaceuticals

5) Aerospace

6) Medical devices

Challenges in Automation of quality control inspection

1) Variation in materials, product designs and production speed
2) Creating machine learning algorithm to detect and classify defects reliably requires extensive training datasets and continuous refinement
3) Retrofitting automated inspection systems into these existing frameworks without disrupting operations or requiring extensive reconfiguration is a considerable challenge

Automation technologies used

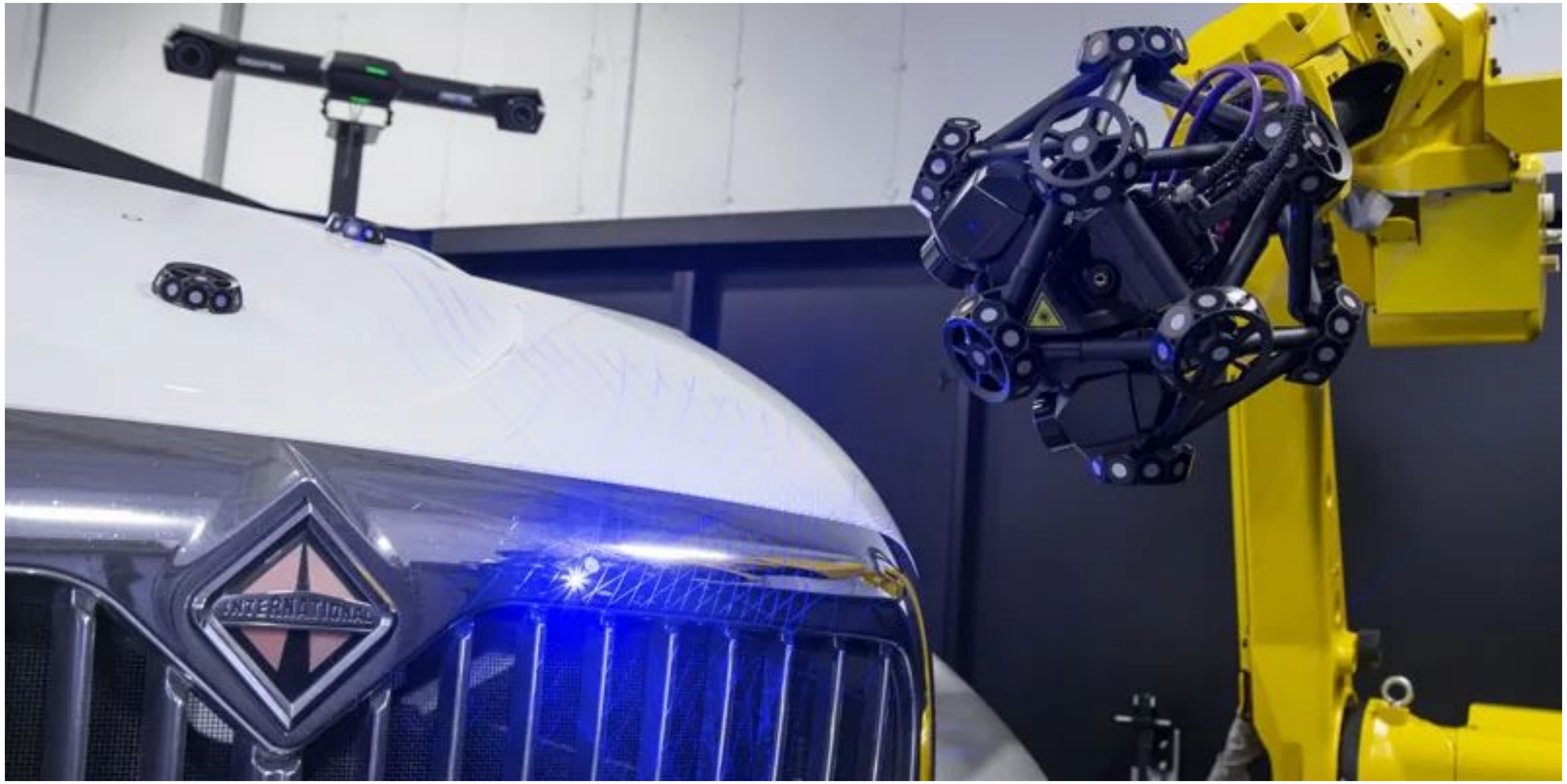
1) Customized robot- mounted optical CMM 3D scanner or turnkey 3D scanning coordinate measurement machine
2) Real time monitoring machine
3) Laser scanners
4) Temperature probes and pressure sensors

Analysis Type	Application Domain	Techniques Used for Digital Quality Control
Product Free-Form Analysis	Natural products and leather cutting examination	Polygonal curve deviation using Single-segment and Multiple-segment
	Inspection of micro-milling tools	Root mean square deviation (RMSD), Exponential transform, Infinite symmetric exponential filter
	Inspection and optimal parameter identification in alloys	Taguchi technique, Blob analysis
	Sorting and recycling of non-ferrous materials	PCA-SVM, Response surface methodology, Numerical simulation
	Agricultural produce deformities inspection	Linear regression, Oval Difference Degree, Grid Calculation, Hollow detection
	Tracking and processing livestock	Convolutional Neural Network (CNN), Rotation, scale, and translation augmentation techniques
	Identifying fatigue cracking in metallic compounds	Deeply Supervised Object Detector, YOLO algorithm, Single Shot MultiBox Detector, DenseNet algorithm
	Inspection of microscale e-jet printing	Blob analysis, Otsu thresholding algorithm, Morphological operations: erosion and dilation
	Automate produce harvesting	Fully Convolutional Network, Blob analysis, Stereo image analysis
	Examination of construction steel frames	Hough Transform, CED, Harris corner algorithm

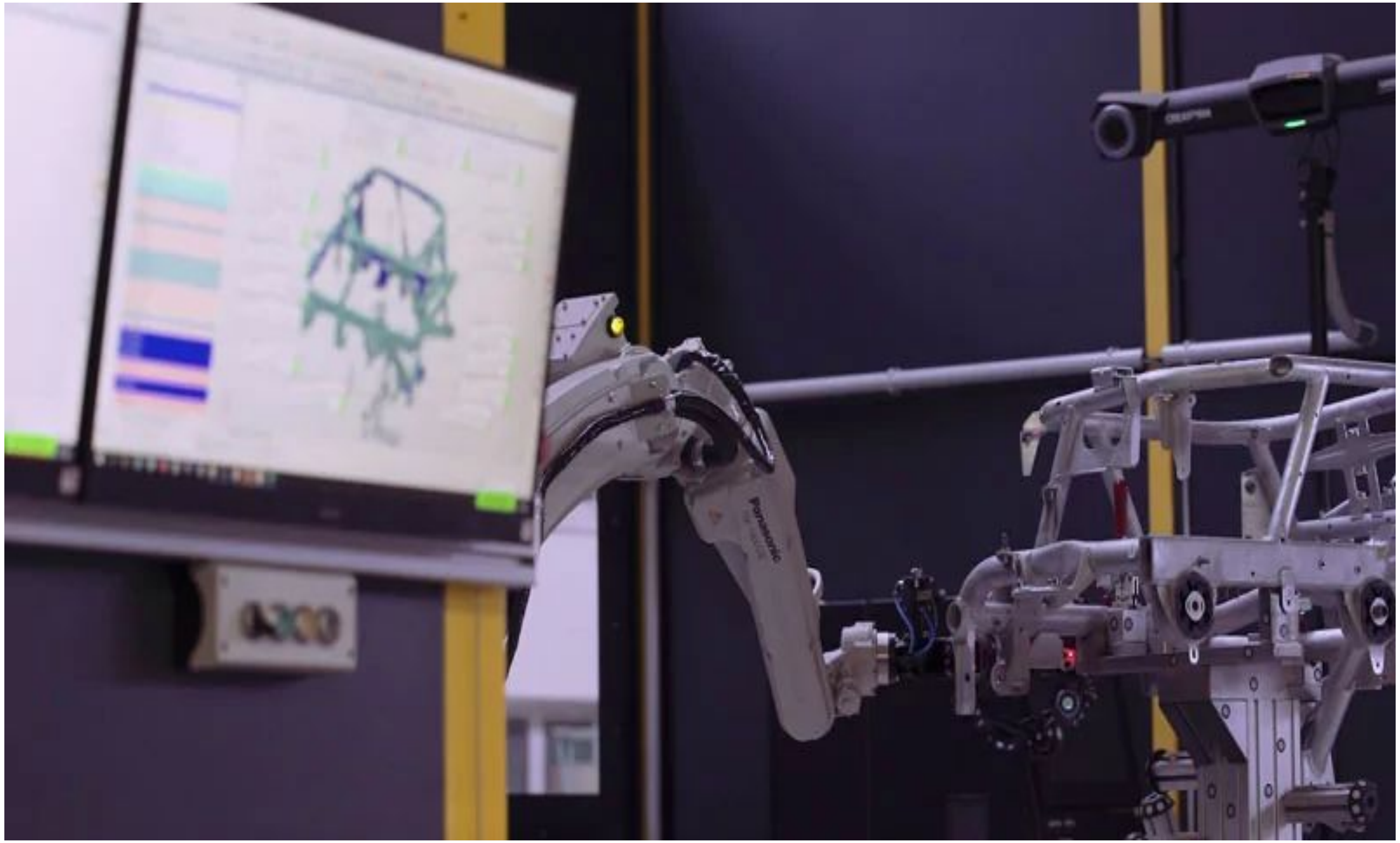
Product Dimensional Analysis	Determining precise measurements of industrial equipment	Subpixel edge detection, CED, Otsu thresholding, Taguchi method, Leastsquares regression
	Agricultural produce deformities inspection	CED, Sobel edge detection, Support Vector Machine (SVM), Median filter
	Inspection of alcoholic bottlequality	Fourier transform, Blob analysis, Least square circle fitting, Edge points double classifying
	Examination of additive manufacturing for construction	Otsu thresholding, Blob analysis
	Inspection of slate slabs	Texture analysis, Local binary pattern methods
Product Surface Analysis	Texture characterization forgrinded surfaces	Grey level co-occurrence matrix (GLCM), Principal component analysis(PCA), Multiple regression analysis
	Inspection of wine bottles	Hough transform, CNN, Depthwise convolution and pointwise convolution
	Examination of friction stir welding	Maximally stable extremal region algorithm, SVM
	Analysis of beef tendernessvia a mobile system	Rotation, scale, and translation augmentation techniques, GLCM, Feedforward Multi-layer Perceptron neural network, PCA
	Agricultural produce deformities and disease inspection	Top hat filter, Gabor wavelets, Multiclass SVM, Histogram of oriented gradients, Speed-up robustfeatures, GLCM, Neural Network
	Agricultural field and gardeninspection	SVM, CNN, Homomorphic filtering,Convex hull operation, Histogram intersectionkernel, GLCM

Coordinate measuring machine

Truck hood inspection using the CUBE-R automated quality control solution



Walter Automobiltechnick: Real-time 3D measurement data analyses of a motorcycle frame



CUBE-R shop floor operator working on scanning intelligence and robot path programming in VXscan-R software

Fully auto analyser integrated module

Components of fully automated analyser

- Bar code reader
- Sample tray
- Sample probe
- Reagent tray
- Reagent probe
- Vibrating rod/rotating paddle
- Reaction cuvettes
- Spectrophotometer
- ISE
- Microprocessors

Benefits of robots and sensors for automation in quality control and inspection

a) Increased efficiency and productivity
b) Improved data accuracy and consistencies
c) Enhanced safety
d) Reduction of human error (waste, scrap and rework)
e) A positive impact on the bottomline

Other benefits of quality control inspection