Machine Vision Questionnaire (MVQ)

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Why A Questionnaire is Needed

The *Machine Vision Questionnaire (MVQ)* is intended to assist in formalising the requirements and specification for a vision system that will perform a new inspection function, or one that has hitherto been performed by other means. The questionnaire raises a wide variety of issues that should be considered by a vision engineer, so that he/she can quickly decide whether Machine Vision is likely to satisfy the application requirements. Past experience has shown that, with careful initial analysis of the application requirements, a great deal of time and money can be saved; asking the right questions at an early stage can help to avoid frustration. The MVQ contains questions that help to establish technical feasibility and likely benefits of Machine Vision, as early as possible. The answers might also provide a basis for writing a detailed specification and contract for the design, construction and delivery of a vision system.

The MVQ outlined in this appendix concentrates on technical issues. In addition, a large number of managerial / contract details should be agreed between the equipment supplier and customer before work begins in earnest. These include maintenance, servicing, warranty, provision of spares, documentation, ownership of intellectual property, possible future upgrading of the system, safety, legal responsibility, ISO 9000/14000 certification, etc.

History

The *Machine Vision Application Requirements Check List* was originally devised by Nello Zuech, Vision Systems International, Yardley, PA 19067, USA. It was included in his book *"Understanding and Applying Machine Vision"*, CRC Press, Boca Raton, FL 33487, USA, ISBN-13 9780824789299, 1999. Nello Zuech's version of the *Machine Vision Application Requirements Check List* was published without restrictions on use.

An updated version of the *Machine Vision Application Requirements Check List* was subsequently made available and published via a web site created by Image Labs International, Inc., Bozeman, MT 59715, USA. URL http//www.vision1.com/vsi/mvaques.html, accessed 9th October 2008. The Image Lab version was published without restrictions on use.

The *MVQ* printed in this appendix was prepared by Bruce Batchelor and derives inspiration from the *Machine Vision Application Requirements Check List*. It is also published free of copyright; permission is granted to use the *Machine Vision Questionnaire* freely without restriction.

Machine Vision Questionnaire

Note: *Widget* is used to denote the *object to be inspected*.

$.1 Current Production & Inspection Processes

1   Name / & part number of the widget.
2   Latency (time between image aquisition and the final action (e.g. *accept / reject* widget)
3   What is the expected life of the widget?
4   What is the maximum acceptable pay-back period for capital expenditure on QA equipment?
5   How is inspection currently performed?
6   How the current inspection process is deficient.
7   Goal(s) for the proposed automated visual inspection / visual control system
    • avoid accidental damage to machines due to jamming on faulty products
    • improve process efficiency
    • improve process efficiency
    • improve process safety
    • improve product reliability
    • improve product safety
    • match production speed
    • reduce waste of materials
8   What is the current reject rate for bad widgets, according to your established factory-floor inspection methods?
9   What is your best estimate for the real rate of occurence of faulty widgets. (You could, perhaps, cite careful non-real time, laboratory analysis?)
10 Why do the answers to the two previous questions differ so much?
    • What is the false reject rate?
    • What is the false accept rate?
    • Is there any realistic chance of reducing these by improving the current inspection method?
    • Which is more problematical, *false reject* or *false accept*?
11 Production mode
    • Batch production
    • Continuous process
12 Change-over of manufacturing system to alternative product
    • Time required for change-over
    • Frequency of change-over
    • Skill levels involved needed for the change-over
13 Where widgets go after after inspection
    • Good widgets ("widget heaven")
    • Faulty widgets ("widget hell")
14 Are widget design or production process changes anticipated?
    • How do you envisage the present product range to change in the foreseeable future?
    • Anticipating future products, are there an any additional inspection functions that you would like the proposed Machine Vision system to perform?
15 Is every widget inspected?
    • Sampled inspection (specify the sampling rate)
    • 100% inspection
16 How inspection is performed
    • manually, as part of manufacturing process
    • manually, unaided, dedicated inspector
    • manually, with standard charts, pictures, swatches, etc.
    • manual application of instruments

- automatically (state how)
17 When a faulty widget escapes detection, what are the effects down-stream on the following?
- quality
- cost
- product safety
- process safety
- repair / rework
- loss of production
- serious damage to machine(s) down-stream
- jamming of machine(s) down-stream
- other
18 If inspection were effective, could any down-stream testing requirements be relaxed?
19 Cost (preferably expressed in quantitative terms)
- undetected faulty widget
- good widget that is falsely rejected
20 Previous experience / attitudes of staff towards Machine Vision / automation
- Factory-floor personnel
- Factory manager
- Project champion

$.2 Describing the Widget
This section should be completed for each type of widget.

21 What is the expected life of the widget?
22 Product volume (total number of widgets/day, all lines making this product)
- Is this expected to rise in the foreseeable future?
23 Production rate for each line
- average production rate (widgets/minute)
- peak production rate (widgets/minute)
- number of widgets arriving simultaneously at the inspection point
- Is this expected to rise in the foreseeabe future?
24 Manufacturing process(es) used when making the widget
- moulded
- cast
- forged
- stamped
- pressed
- rolled
- pressed
- turned
- extruded
- spun
- woven
- sintered
- cut from stock
- folded from sheet
- multi-stage machining
- other, specify
25 What is the last machining operation, just before the point of inspection?
26 No. of materials making up the widget
- single monolithic widget
- single multi-material widget
- assembly of monolithic widgets
- assembly of multi-material widgets
27 Materials used in manufacture (e.g. steel, brass, PTFE, glass, wood, etc)

28 Variation of appearance within a given batch
- fixed
- some variability within a batch
- very variable

29 Variation of appearance between batches
- fixed
- some variability
- very variable

30 Changes in appearance over time
- months
- days
- hours
- minutes
- unchanging

31 Coating (at least as important as the substrate material in determining appearance)
- none
- painted
- lacquered
- chemical coating
- powder coating
- plated
- other, specify

32 Colouring
- monochrome
- dichromic
- trichromic
- polychromic (multiple discrete colours)
- subtle colouring

33 Dimensions
- Absolute maximum, widget is allowed to be in any orientation
- Maximum when the widget is held so that important features are visible
- Orthogonal axis (90° to maximum visible axis)
- Along visual axis (include only visible features)

34 Fragility
- tough as old boots
- medium (comparable to glass bottle)
- fragile (comparable to egg shell)

35 Hazards
- radiation, specify type and level
- biohazard
- toxic
- sharp
- electrical
- physical (e.g. liable to explode/implode, presents finger trap, etc.)
- heavy
- insignificant

36 Internal detail
- not relevant, only external features are important for inspection
- important internal features can be observed
- optically
- UV
- IR
- x-rays

37 Light penetration
- opaque
- transparent

- transluscent
38 Overlay
    - none
    - printed
    - photography
    - lithography
    - other, specify
39 Patterned surface
    - regular
    - irregular
    - spotty
    - striped
    - chequered
    - blotchy
    - none
40 Photo-active
    - light sensitive
    - fluorescent
    - phosphorescent
    - photo-chromic
    - none
41 Physical form
    - spider-like
    - deep concavities
    - shallow concavities
    - convex
42 Stability of posture
    - neutral
    - effectively single stable state, guaranteed by mechanical handling system
    - single stable state, inherent in shape and mass distibution
    - several stable states
    - no stable state
43 Rigidity
    - rigid
    - flexible
    - articulated
    - serpentine
    - chain-like
44 Shape, as seen by inspector
    - spider-like
    - linear (e.g. screwdriver)
    - curved (e.g. banana)
    - serpentine
    - coiled
    - twisted
    - knotted
    - compact
    - round
    - flat
    - long & thin
    - cube
    - rectangular
    - other (specify)
45 Surface appearance
    - mirror-like
    - bright shiny

- dull-shiny (e.g. smooth rubber)
- matt
- egg-shell
- dull (e.g. soot)

46 Surface condition
- clean
- wet
- oily
- rusty
- oxidised
- stained
- dusty
- biological activity

47 Surface roughness
- mirror finish
- smooth
- rough
- very rough
- textured - regular
- texture - irregular

48 Dimensions
- Absolute maximum, widget can be in any orientation
- Maximum when the widget is held so that important features are visible
- Orthogonal axis (90° to maximum visible axis)
- Along visual axis (include only visible features)

49 Size, variability
- highly variable
- some variation
- nearly constant
- highly consistent

50 Temperature
- [<20°]
- [-20° - 0°]
- [0° - 50°]
- [50° - 100°]
- [>100°]

51 Unit value
- very low value ($\leq 1¢$)
- low (¢s)
- medium (€/$)
- high value (>10 €/$)

52 Weight
- [< 1g]
- [1g - 10Kg]
- [> 10Kg]

$.3 Faults in the Product

53 Biological damage
- micro-organisms
- rotting
- bird peck
- bite
- scratch

54 Colour
- missing imprint
- misplaced colour imprint
- low saturation
- high saturation
- wrong hue
- faded

55 Contamination, foreign bodies / material
- fingerprint
- oil
- water
- rust
- fungus, other micro-organisms
- dirt
- dust
- staining
- ink
- paint
- acid
- animal debris
  - bones
  - insects
  - rodents
  - excrement
  - urine
  - hair
  - nesting materials
- stones
- soil
- sand
- raw materials used in manufacture
- coolant
- lubricant
- other, specify

56 Dimensions
- too big
- too small
- too high
- too short
- spacing between features
- angle position of features
- radial position

57 Grading
- inferior grade
- superior grade
- wrong type

58 Incorrect assembly
- part missing
- part damaged
- part incorrectly fitted
- wrong part fitted

59 Light damage
- faded

60 Local defect
- cut
- tear

- crack
- split
- chip
- scratch
- pit
- blow hole
- debris
- sprue

61 Machining
- incomplete
- machining step missing
- machining error

62 Malformed
- bent
- broken
- twisted
- extra material
- mould seam marks
- sprue still attached
- machining fault

63 Misprinting
- colour imprint misregistration
- smudged
- ink spill
- oil

64 Number
- too few
- too many
- unable to count

65 Pose
- wrong orientation
- wrong position
- wrong posture
- inverted (up-side down)

66 Weave error
- weave
- broken thread
- pulled thread
-

$.4 Vision Task

67 How is inspection currently performed?
68 Explain how it is deficient in meeting the required performance? Why do you need to inspect the widgets or control their production process?
- improve process efficiency
- improve process safety
- improve product safety
- improve product reliability
- match production speed
- What is the current reject rate of bad widgets?

69 What is the accuracy of the current inspection system?
- false reject rate
- false accept rate

70 What benefits do you hope to achieve by installing a Machine Vision system?

71   Function(s) to be performed by the vision system
   - Detecting local faults
   - Detecting malformation
   - Grading
   - Sorting
   - Checking feature existence
   - Measurement
     - linear dimensions
     - angles
     - position (2 dimensions)
     - position (3 dimensions)
     - 3D shape
     - orientation
     - posture
   - Checking colour
   - Checking texture
   - Other, specify
72   Must every widget be inspected?
   - Sampled inspection is adequate (Specify the minimum sampling rate)
   - 100% inspection is desirable
   - 100% inspection is essential
73   Are widget design or production process changes anticipated?
   - How do you envisage the present product range to change in the foreseeable future?
   - Anticipating future products, are there an any additional inspection functions that you would like the proposed Machine Vision system to perform?
74   Operating mode of the proposed vision system
   - Will the vision system be retro-fitted to a new line or an existing line ?
   - Number of widgets to be examined at the same time
   - Number of different types of widget to be accommodated
   - How many lines/machines will vision system(s) be needed for?
   - Is inspection to be performed on-line or off-line?
   - Throughput rate (widgets per minute)
75   Check cleanliness
   - floor
   - material deposits around feed chute or hopper
   - stairs
   - tools
   - work space
   - Check feed-stock
76   Check transport system
   - discrete widgets, jumbled in a barrel / hopper
   - discrete widgets, loaded onto specialised carrier
   - granular material
   - linear object (strip / bar / pipe / tube / wire / cable / extrusion)
   - liquid level
   - motion
   - indexing
   - cleanliness
77   Checking safety
   - intruder surveillance
   - operator hands
   - stairs
   - gangways
   - flames
   - sprays
   - doors

- debris
- widgets transport
- materials transport
- chutes
- "waterfalls" of granular material

78 Classify
- identify
- identify piece widgets
- grading natural product species
- classifying natural product varieties or species

79 Machine/Robot Control
- Robot positioning has 1 / 2 / $2^1/_2$ / 3 / $3^1/_2$ / 4 / 5 / 6 degrees of freedom
- Function
  - assembly
  - cutting
  - drilling
  - grinding
  - marking
  - milling
  - packing
  - painting
  - palletising
  - polishing
  - sanding
  - soldering
  - sorting
  - spraying
  - stacking
  - turning
  - washing
  - welding
  - other, specify

80 Counting
- objects
- features on large objects

81 Detecting
- broken tool
- damaged widget
- error in materials feed
- incomplete widget
- malformed widget
- worn tool

82 Finding
- objects
- features on a complex object

83 Locating
- feature
- grasping point
- object

84 Measuring
- angle
- linear dimension
- area
- distance between features
- angles defined by widget features

85 Inspecting printing

- accuracy of colour rendering (hue & saturation)
- character recognition (printed text is not known beforehand)
- character verification (printed text is known beforehand)
- colour imprint alignment
- damaged paper
  - creased
  - torn
  - stained
  - dirty
- deficiency of ink
- print quality
  - character formation
  - sharpness
- smudging
- surplus ink

86 Recognise
- industrial widgets
- natural product, varieties

87 Web fault detection & classification

$.5 Viewing Background

88 Access
- possible
- limited
- impossible

89 Colour
- monochrome
- dichromic
- trichromic
- polychromic
- subtle colouring
- can be selected to suit vision system

90 Constancy
- constant
- constant with minor local changes
- major changes

91 Light level
- uncontrolled
- low
- medium
- bright

92 Reflectivity
- high
- medium
- low

93 Structure
- plain
- structured
- patterned
- textured
- factory floor
- equipment

$.6 Environment

94 Access, camera
- easy
- limited
- very difficult

95 Access, lamps
- easy
- limited
- very difficult

96 Acoustic noise
- none-to-moderate
- severe

97 Ambient light level
- total darkness
- very dark (e.g. moon-light)
- dark (e.g. in shadow in living room at night)
- bright (room lit by electric lamp)
- very bright (close to electric lamp)
- sunlight

98 Atmospheric pollution
- very little
- dust
- fumes
- smoke
- steam
- chemical mist (aerosol droplets)

99 Heat from lamps
- not important
- possible damage to product
- possible difficulties with process
- critical

100 Shrouding, screen around widget, camera and lights
- possible
- difficult
- impossible

101 Vibration
- little
- moderate
- severe

102 General working environment
- general factory
- laboratory
- clean room
- outdoor

103 Air quality
- dust
- smoke
- flying debris
- water droplets
- water mist
- steam
- oil mist
- oil droplets

104 Wash-down requirements
- water mist
- water jet
- steam
- chemicals, specify

105 Ambient light
- incandescent
- fluoresecent
- mercury lamp
- sodium lamp
- other artificial
- daylight (no direct sunlight)
- direct sunlight

106 Light pollution from nearby equipment
- little
- constant lights
- flashing lights

107 Temperature range (°C)

108 Humidity
- Relative humidity (%)
- Dew point (°C)

109 Radiation
- emi
- IR
- nuclear
- rfi
- UV
- x-rays

110 Vacuum, yes/no

111 Compressed air
- available / not available
  - content
- water
- dust
- oil
- other

112 Power
- AC
- voltage
- frequency
- single-phase
- 3-phase
- regulated
- action needed in event of general power failure
- DC
- voltage (V)
- voltage tolerance (±V)
- current limit (A)

$.7 Mechanical Handling

113 Widget delivery
- What is the last machining operation, just before the point of inspection?
- How will the widgets be transferred from there to the vision system?

- Rate of delivery (widgets / minute)

114 Is this production rate expected to rise in the foreseeabe future

115 Where widgets go after after inspection
- good widgets
- bad widgets (bad little widgets go to the widget hell!)

116 Repair / reworked of faulty widgets
- Is this technically possible?
- Is this economically viable
- Can Machine Vision assist in the diagnosis?

117 Type of handling system
- linear conveyor
- rotary conveyor
- robot
- chute
- free fall
- manual

118 Possible to damage widget during handling?

119 Special handling precautions (e.g. keep widget moist / cool)

120 Inspection station expected to perform other functions? (specify)

121 Production rate (widgets/minute)
- average throughput rate
- peak throughput rate
- is it possible to smooth the flow through inspection system by delaying widgets?
- latency (time between image aquisition and the final action (e.g. *accept / rejec*)

122 Indexed motion
- stationary time
- total in-dwell-out time
- settling time
- precision of placement
  - $\pm$ X (orthogonal to line of motion)
  - $\pm$ Y (along line of motion)
  - $\pm$ Z (vertical axis)
  - $\pm$ angle around X axis (degrees)
  - $\pm$ angle around Y axis (degrees)
  - $\pm$ angle around Z axis (degrees)

123 Widgets moving continuously
- Motion
  - linear
  - circular
- direction
- nominal speed
  - Variation in speed ($\pm$percent)
  - Speed, regulation possible?
- shudder during motion
- maximum variation of widget position across belt
- spacing between widgets along the belt
  - random
  - nominally fixed
- repeatability of spacing between widgets
- can the orientation be controlled (e.g. by guide rails)?

124 Widgets touching one another?

125 Widgets overlapping one another?

126 Space available for inspection station
- open
- restricted

127 Minimum distance from camera to computer

128 Distance from inspection system to interfaced equipment
129 Other physical constraints around installation site (specify)
130 Conveyor
- type
- structure (e.g. belt, chain, etc.)
- colour
- appearance (e.g bright metal)
- accumulation of dirt /debris?
- other factors affecting appearance
- by-pass mode required?

131 Is more than one camera likely needed to see all of the significant faults?
132 Will the vision system be fitted to a new line or an existing line (retrofit)?
133 Number of widgets to be examined at the same time
134 How many manufacturing lines must be fitted with a vision system?
135 Is inspection to be performed *on-line* or *off-line*?

$.8 Interfacing

136 Operator interface
- essential features
- desirable features

137 User
- educational level / experience
  - analogue electronics
  - computers
  - digital electrnics
  - digital photography
  - illumination enginering
  - manufacturing equipment
  - optics
  - video

138 Restricting personal access
- password protection
- face recognition
- voice recognition
- speaker recognition
- finger-print recognition

139 Display of results
  - summary staistics (specify reporting period)
  - tabulated data
  - graphs
  - "live" image from camera
  - images recorded from recent faulty parts (how many?)
  - images recorded from recent good parts (how many?)
- marking widget (e.g. spraying faulty widgets red)
- must reports be generated without interrupting inspection
  - hard copy required
  - electronic copy (format: CD, DVD, memory stick or remote computer)

140 Additional alarm
- audible
- flashing light
- alert remote computer

141 System failure
- action required

- power-failure action

142 Machines to be interfaced to the vision system
  - mechanically
  - electrically

143 Event that will trigger inspection
  - proximity detector
  - plc
  - computer
  - manufacturing machine (e.g. ejection of widget from moulding machine)
  - other (specify)

144 Machine-machine interface
  - interface standard (e.g. RS232, RS422, RS449, IEEE488, parallel, PLC, Ethernet, USB, IEEE1394)
  - opto-isolation

$.9 Other Issues

145 Accessibility. The following are helpful in the design process. Explain any problems.
  - collecting a large number of representative samples of good and bad widgets
  - engineering drawings of the widgets
  - protocols and *accept / reject* rules currently given to human inspectors
  - diagrams / pictures / swatches currently given to human inspectors
  - still protographs and/or video recording of the production process
  - virtual tour of the factory
  - direct observation of the production process in the factory

146 Calibration
  - procedure

147 equipment required (models, charts, swatches, etc)

148 Computer network, integration of vision sytem into company intranet

149 Cost
  - capital
  - operating costs

150 Documentation

151 Duty cycle (number of hours use per week)

152 Fixtures and cabling

153 Hardware, reliability of supply of spares from 3rd party

154 Intellectual property, ownership

155 Legal issues, specific to customer's type of business

156 License fees for installed software

157 Maintenance and cleaning
  - procedures
  - materials
  - frequency
  - duration

158 Operator safety

159 Paint colors

160 Post-sales support
  - help line

161 Power consumption

162 Response time for service

163 Responsibility
  - backup
  - installation
  - software changes
  - revisions

164 Safety of vision engineer

- protocol when vision engineer is visiting factory
- vision engineer handling dangerous widgets
- additional safety issues (e.g. standard enclosure required)

165 Shipping

166 Spare parts, stock requirments

167 Tests, installation site
- supply of good, faulty, and/or marginal widgets
- variations of parts (e.g. size /colour variations)
- sample size
- acceptability criteria
- widget position variations
- widget orientation variations
- lighting variations
- environmental conditions

168 Tests, vendor site
- supply of good, faulty, and/or marginal widgets
- variations of parts (e.g. size /colour variations)
- sample size
- acceptability criteria
- widget position variations
- widget orientation variations
- lighting variations
- environmental conditions

169 Training
- factory-floor personnel
- engineering staff

170 Verification procedure needed to system is performing correctly

171 Warranty
- duration
- terms and conditions