The Process Control in Manufacturing: Inspection of Ball Bearings

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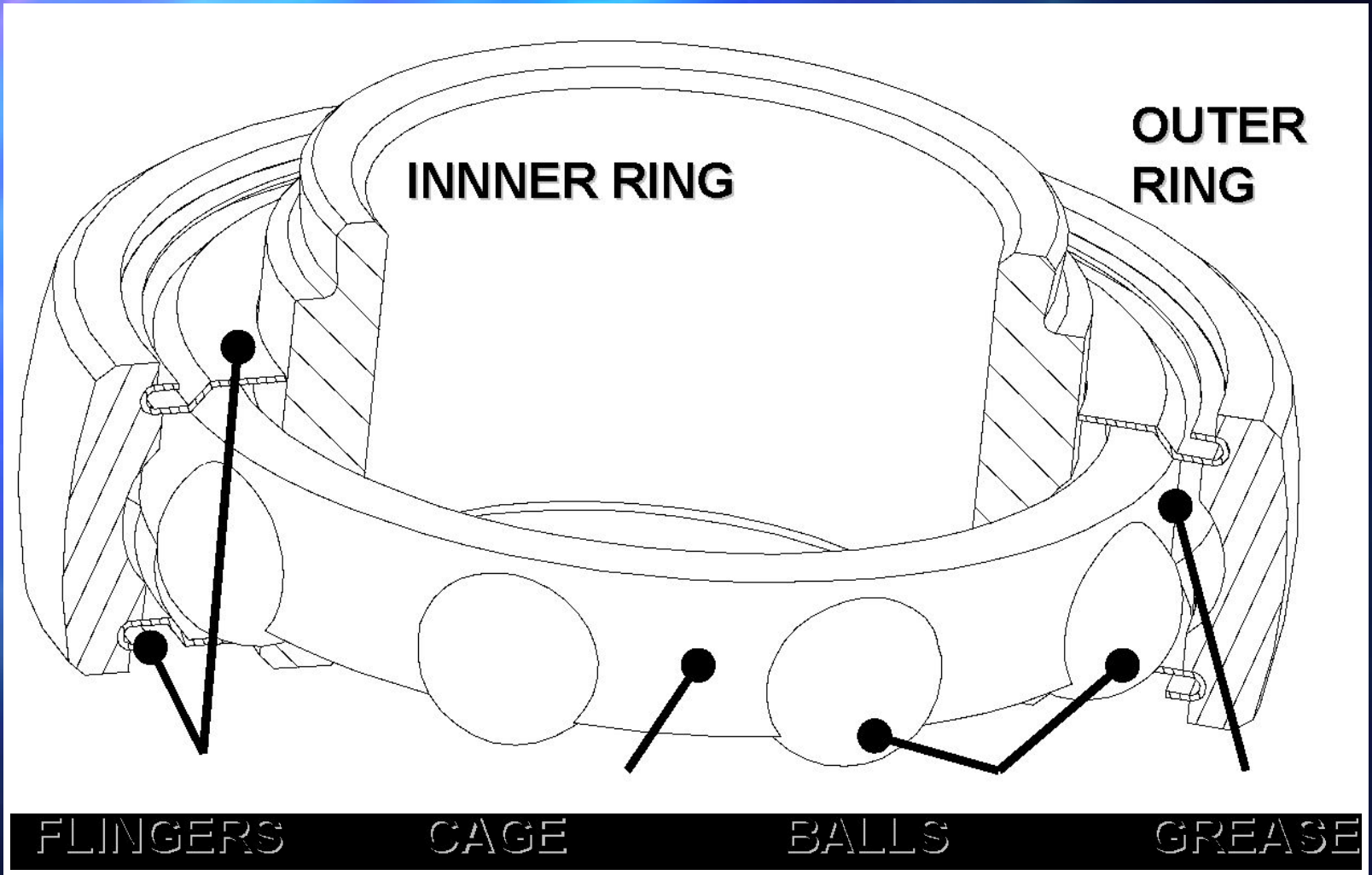
Introduction

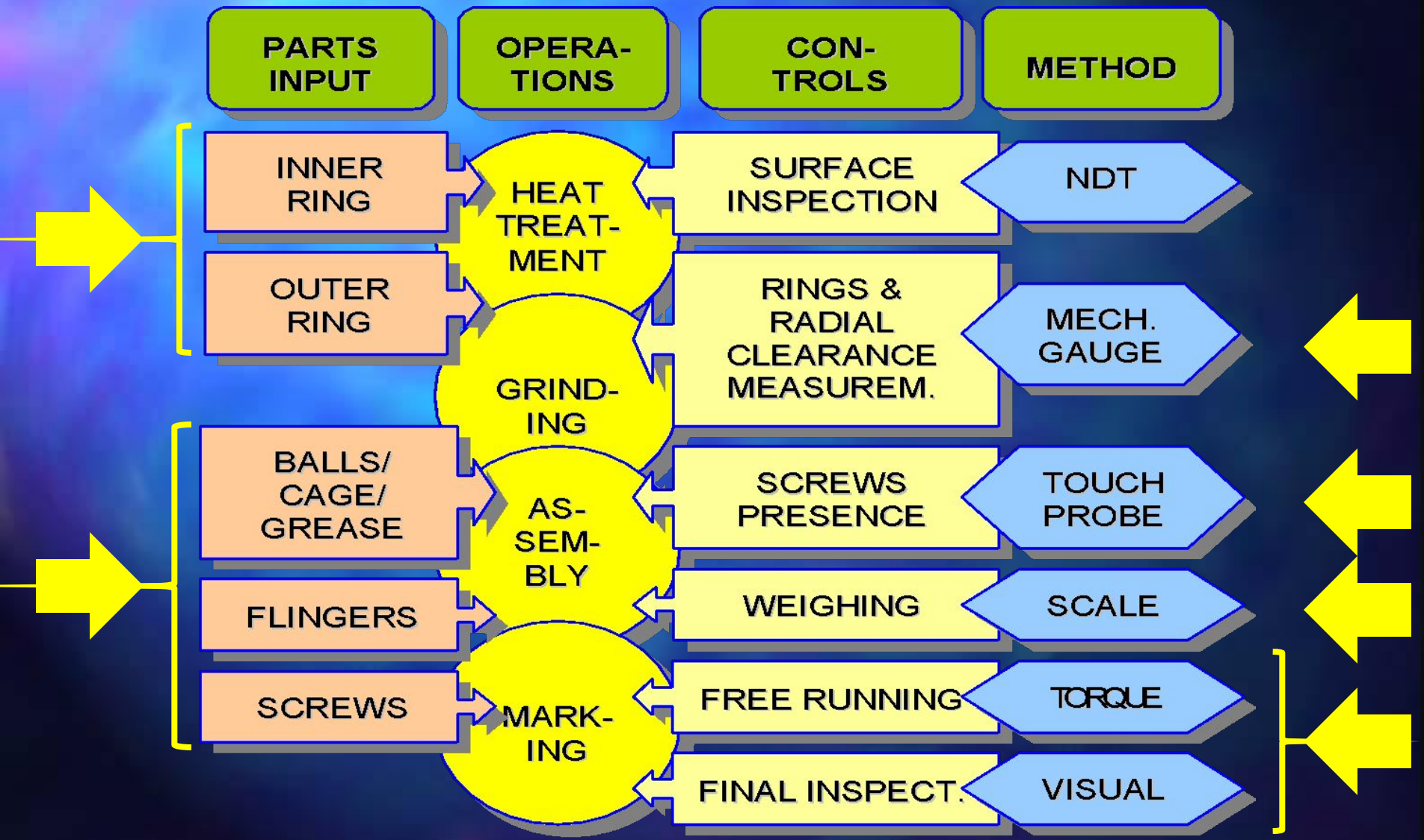
- Goal: improving the process in an existing manufacturing plant
- Finding possible solutions
- Feasibility study (artificial vision system)

The main functional parts

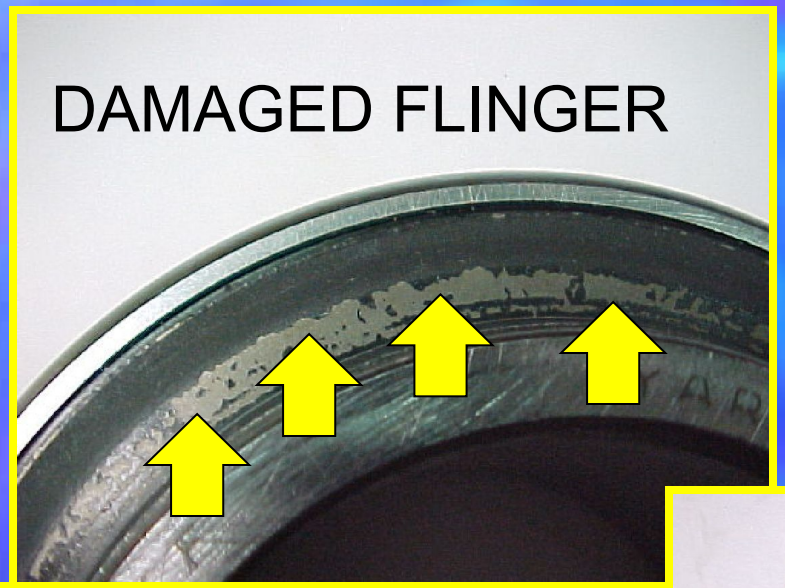


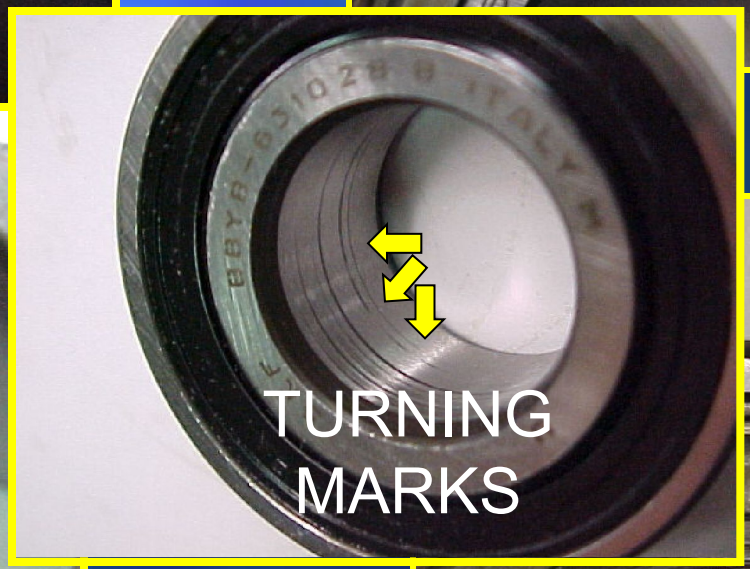
Ball bearing model SKF yet 208

The assembly process



Examples of defects





Turning or grinding marks

Classification of visible defects

Defect Name	Position and Example Reference	Relative Occurr.
TURNING MARKS	IS, OS, IPF, OPF	28%
GRINDING MARKS	IS, OS, IPF, OPF	11%
RUST TRACES	IS, OS, IPF, OPF	38%
HAMMERING	F	20%
BLOT	F	3%
UNREADABLE MARKING	IPF (ON 1 SIDE ONLY)	

The visual inspection station

Operator's tasks:

- **Checking the presence of all parts**
- **Detection of esthetical / surface defects**
- **R**

Specifications of the vision system

+

- **Functional test**
- **Handling**
- **Etc.**

Analisi dei difetti

Studio dei dati ricavati dalle azioni correttive relative a 9 mesi di produzione

Causa del mancato rilevamento dei difetti è imputabile a disattenzioni dell'operatore

Motivi del mancato rilevamento:

- **Soggettività della decisione di scarto.**
- **Operatore deve presidiare altre fasi del processo;**

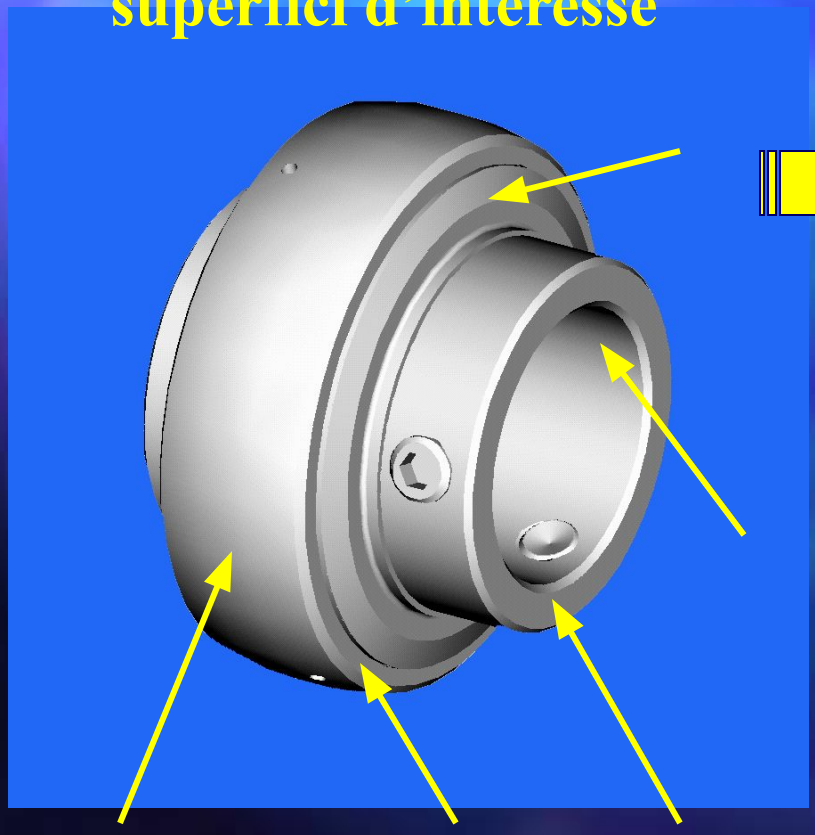
Possibili soluzioni:

- **Impiego di maggiori risorse umane;**
- **Utilizzo di un sistema di visione.**

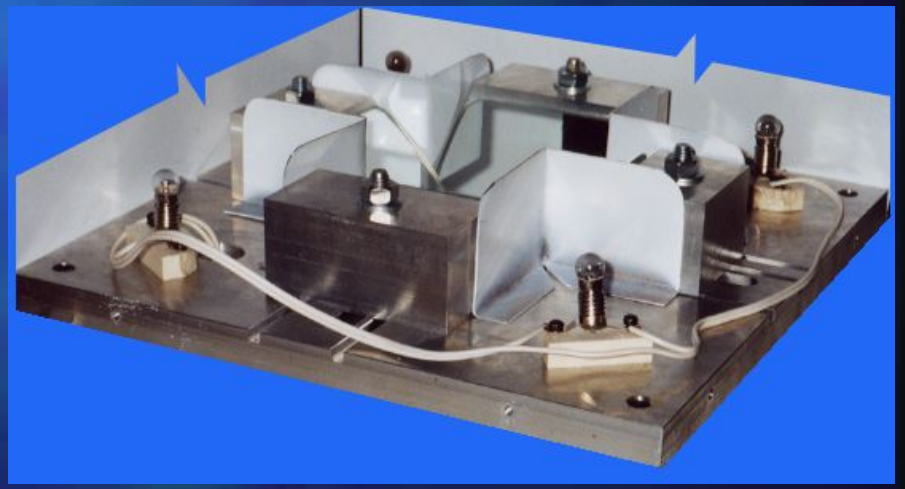
L'attrezzatura sperimentale

Analisi dei difetti

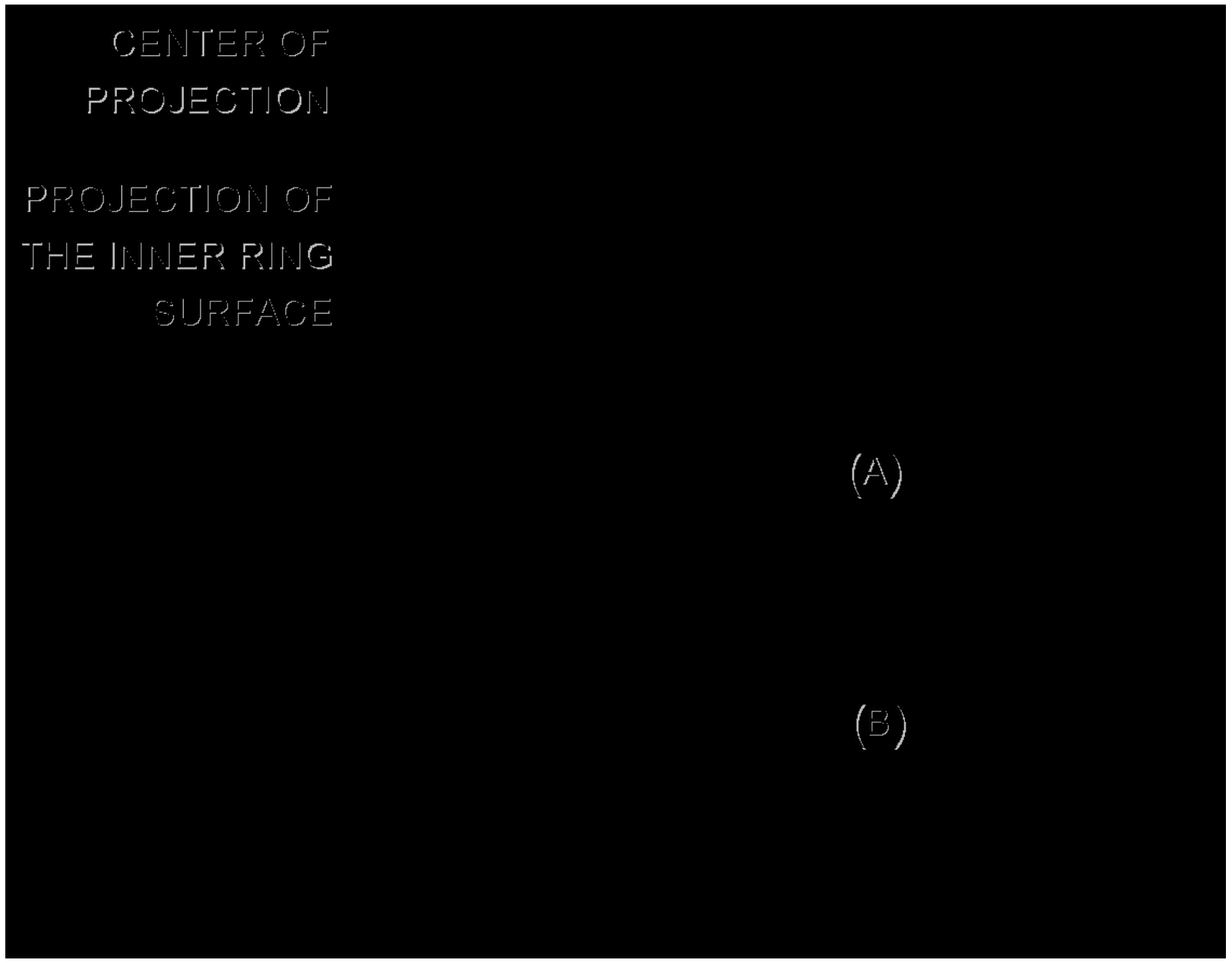
Individuazione delle superfici d'interesse



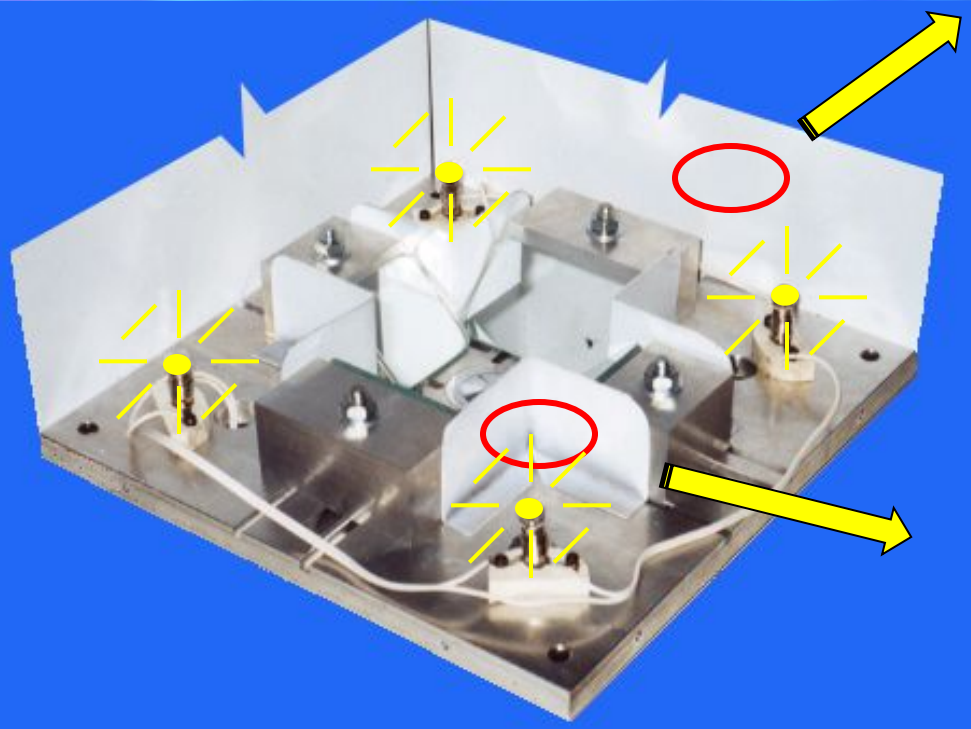
Progettazione e realizzazione dell'attrezzatura

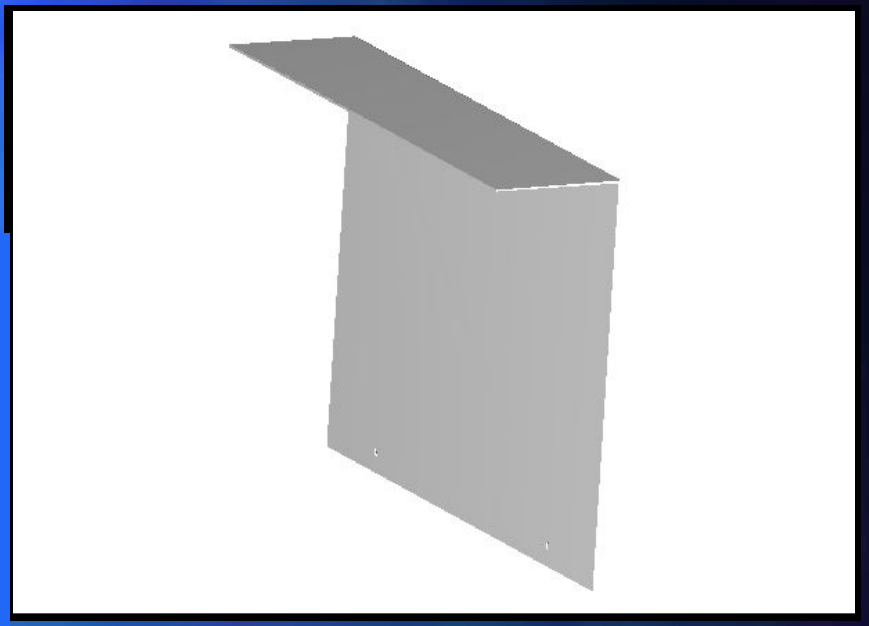


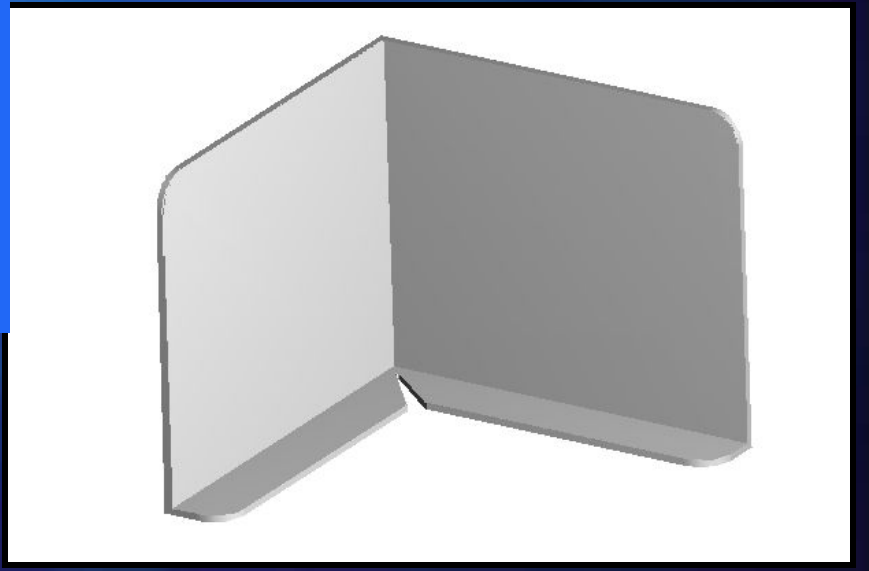
System configuration



Experimental setup

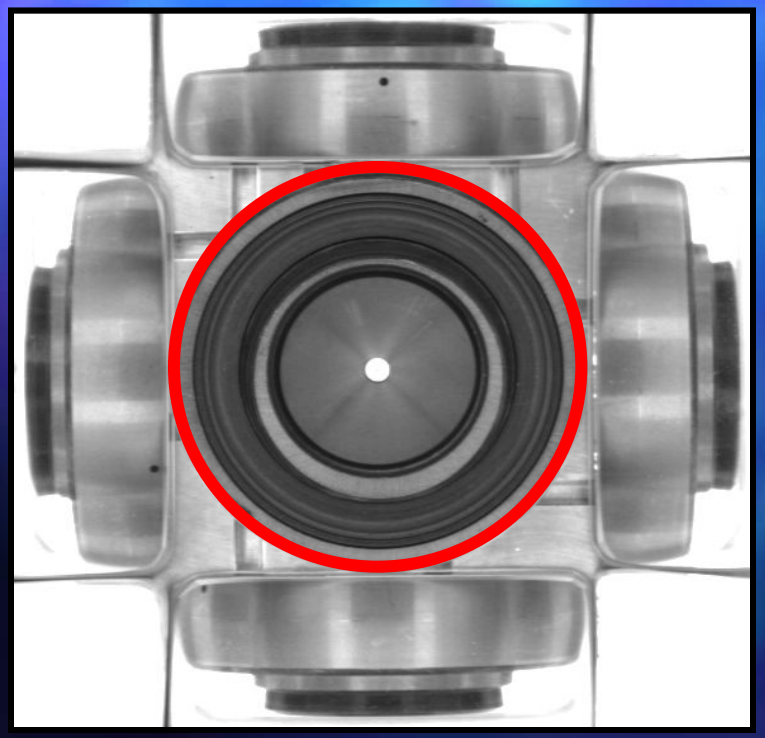






Description of the algorithms

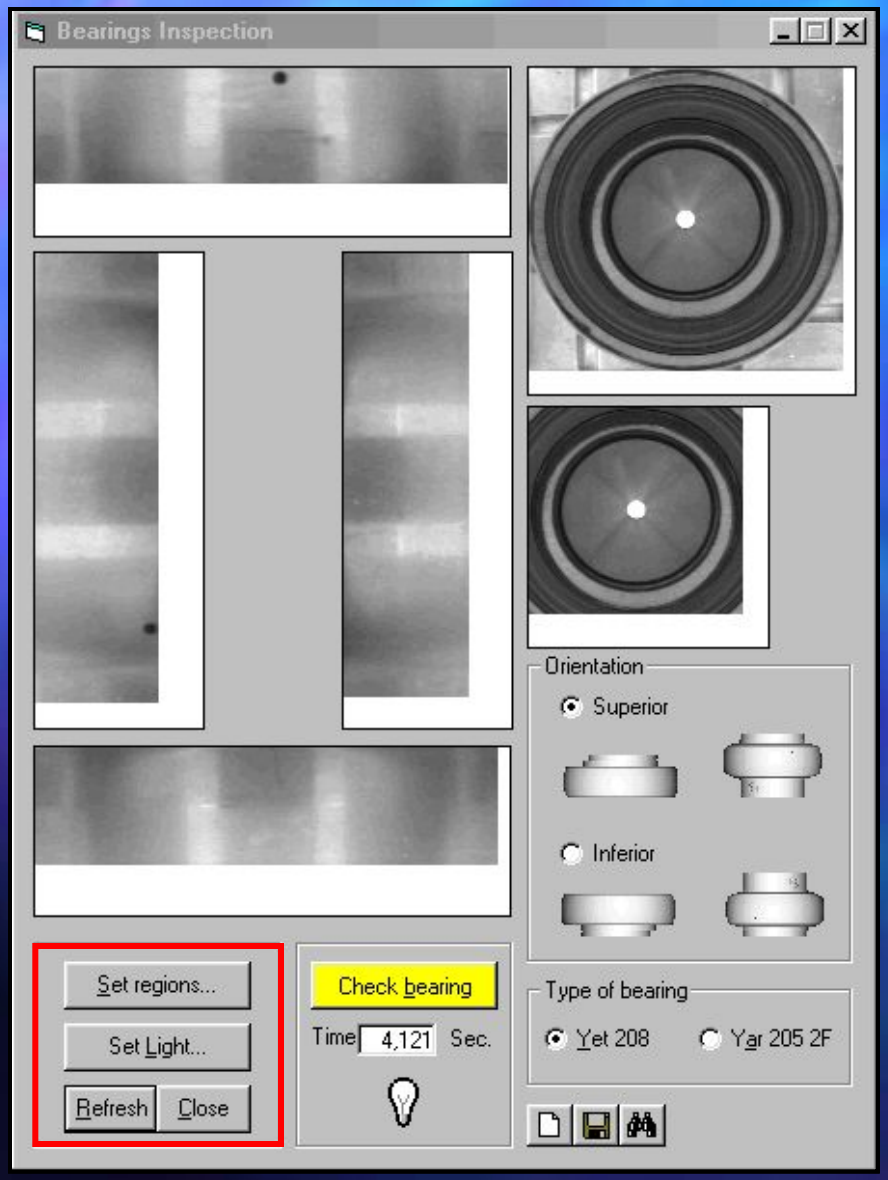
The grabbed image



1. **Only restricted areas contain useful information**
2. **Axial symmetry exploited by image rotation**

An interface has been developed to interactively select the region of interest

Main program



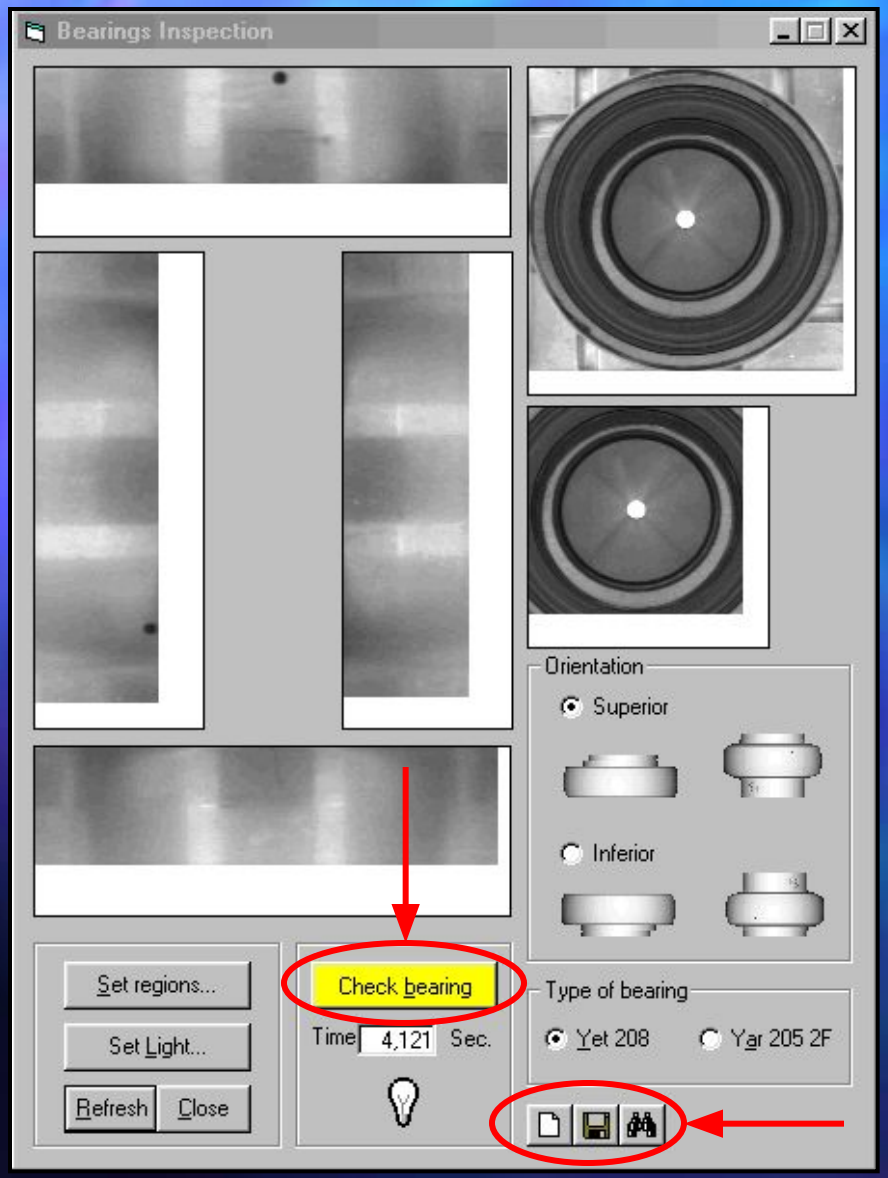
The main program interface with the selected image regions defined in the calibration phase

Selection of the ball bearing orientation

Selection of the ball bearing type

Buttons for the lighting system calibration

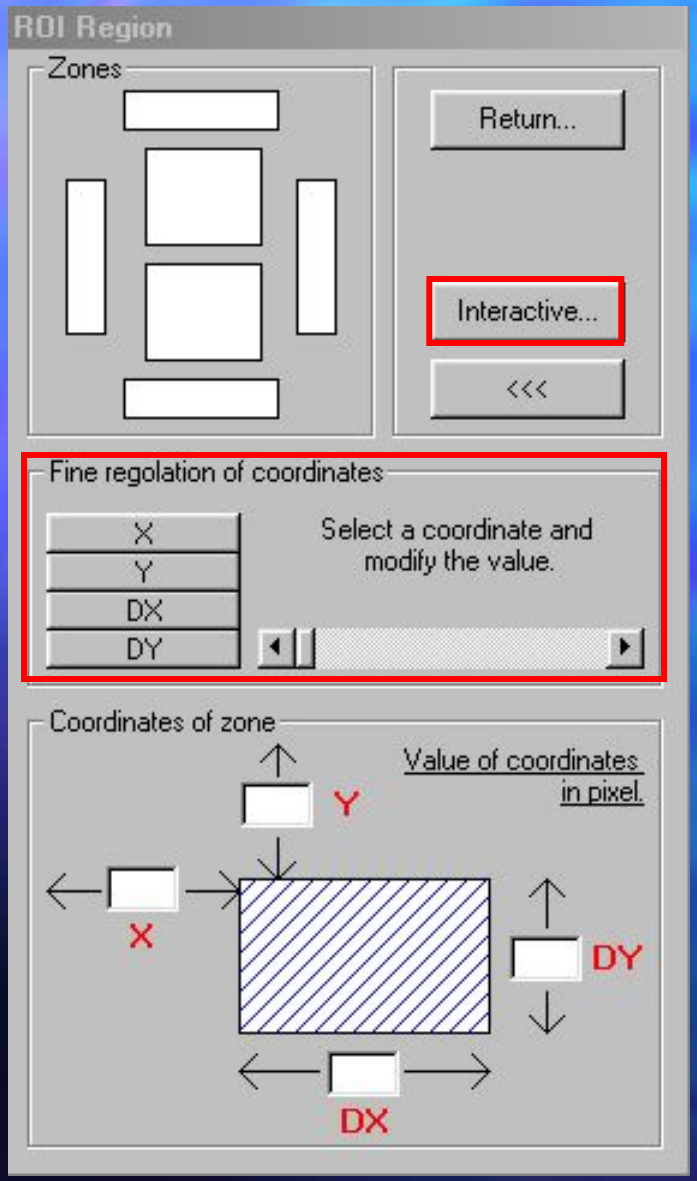
Main program



Start the inspection

Toolbar reporting activity

System calibration



Goal: Setting up the regions of interest

CALIBRATION PROCEDURE

To avoid positioning errors

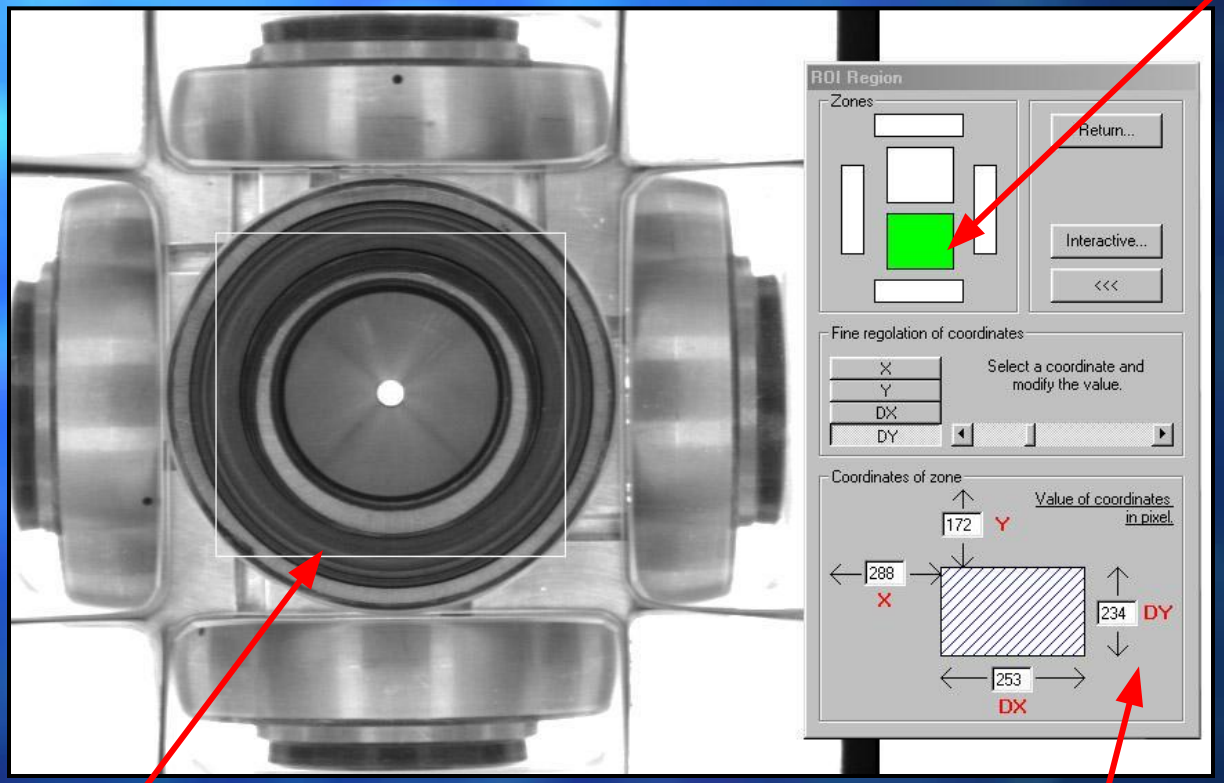
Selection of one of the regions to set

Interactive procedure

Fine tuning

Example of calibration

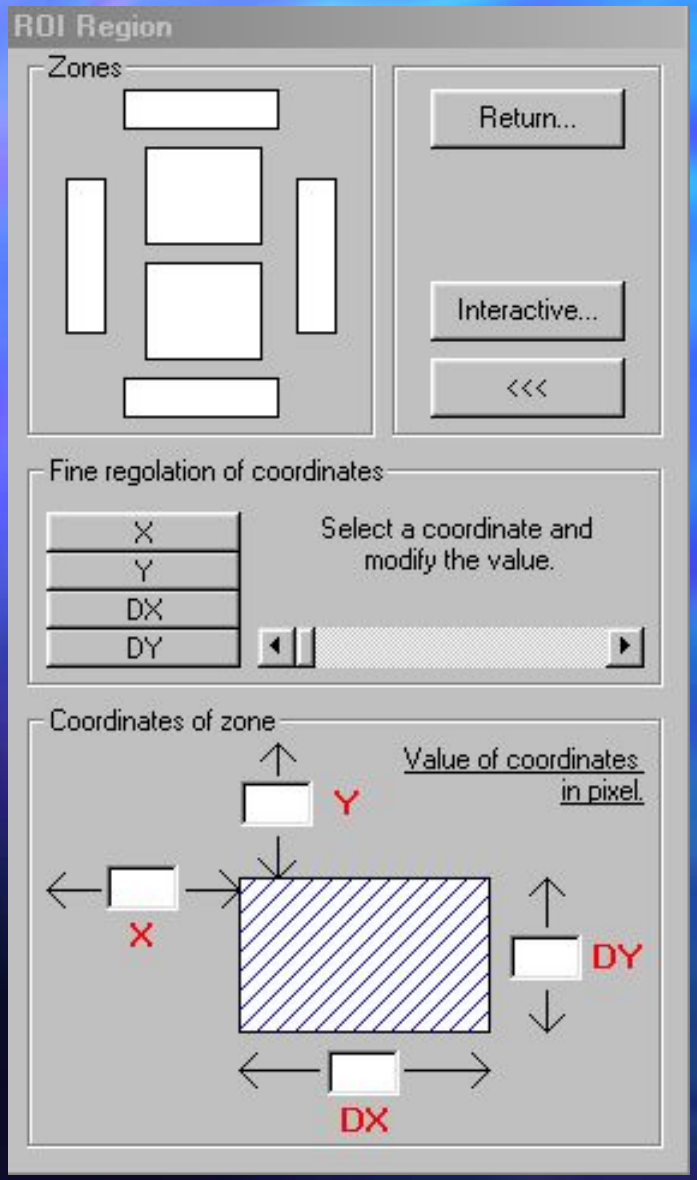
Selected display



Selection of region of interest

Coordinates of the region in pixels

Calibrazione



PROCEDURA DI CALIBRAZIONE:

Setup luminoso e report

Buona riuscita dei controlli dipende dalla luminosità dell'immagine

Schermatura dell'attrezzatura — **elimina interferenze ambientali**

Implementazione di un algoritmo che consenta la regolazione del diaframma dell'obiettivo

Tipo: Yet 208

Rilevato errore sullo schermo. -----> 23/06/00 -----> 16.58.31
Rilevato errore sulla superficie piana AE. -----> 23/06/00 -----> 16.58.32
Rilevato errore sulla superficie piana AE. -----> 23/06/00 -----> 16.59.01
Rilevato errore sulla superficie piana AE. -----> 23/06/00 -----> 16.59.19
Rilevato errore sullo schermo. -----> 23/06/00 -----> 16.59.35
Rilevato errore sulla superficie piana AE. -----> 23/06/00 -----> 17.00.30
Rilevato errore sullo schermo. -----> 23/06/00 -----> 17.00.43
Rilevato errore sulla superficie piana AI. -----> 23/06/00 -----> 17.01.01
Rilevato errore sullo schermo. -----> 23/06/00 -----> 17.01.28
Rilevato errore sullo schermo. -----> 23/06/00 -----> 17.08.35
Rilevato errore sullo schermo. -----> 23/06/00 -----> 17.09.44
Rilevato errore sulla superficie interna. -----> 23/06/00 -----> 17.10.24
Rilevato errore sulla superficie esterna. -----> 23/06/00 -----> 17.10.35
Rilevato errore sulla superficie interna. -----> 23/06/00 -----> 17.10.39

Posizione del difetto **Giorno** **Ora**

L'algoritmo di riconoscimento

Implementazioni classiche

- **Utilizzo di parametri statistici di facile individuazione (Moda, Media);**
- **Immagini ~~limite~~.**

$$I_{sup}(x,y) = I_m(x,y) + k \cdot \sigma(x,y)$$

$$I_{inf}(x,y) = I_m(x,y) - k \cdot \sigma(x,y)$$

Decisione scaturisce da un confronto con un modello di riferimento

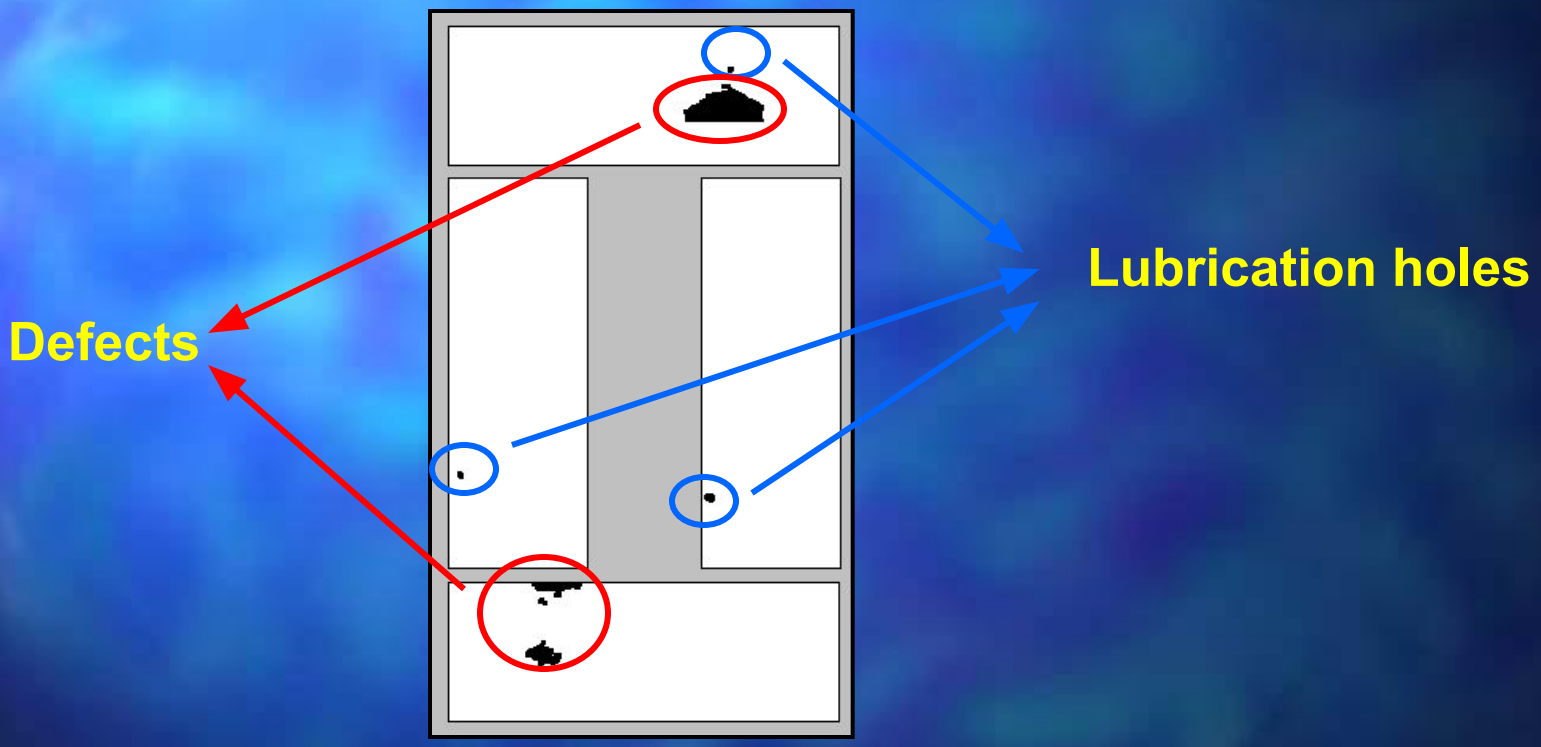
Studio attuale → **Variabilità naturale** > **Variabilità dovuta ai difetti**

$$I_{sup}(x,y) = I_m(x,y) + k \cdot \sigma(x,y)$$

$$I_{inf}(x,y) = I_m(x,y) - k \cdot \sigma(x,y)$$

→ **Sviluppo di nuove implementazioni**

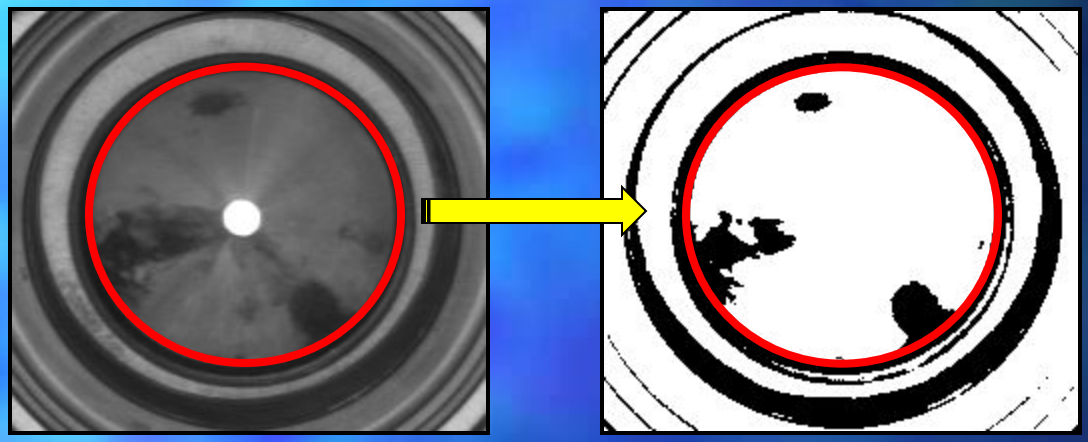
Inspection of the outer surface



Inspection of the inner surface

Model

Yet 208

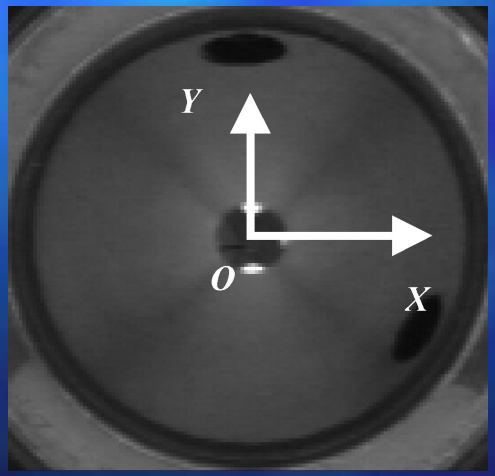


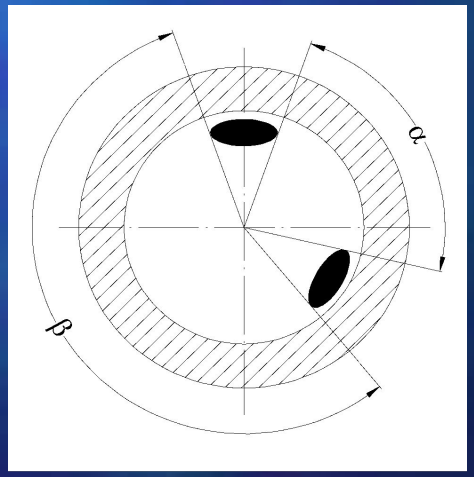
Original image

Binarized image

Model

Yar 205 2f





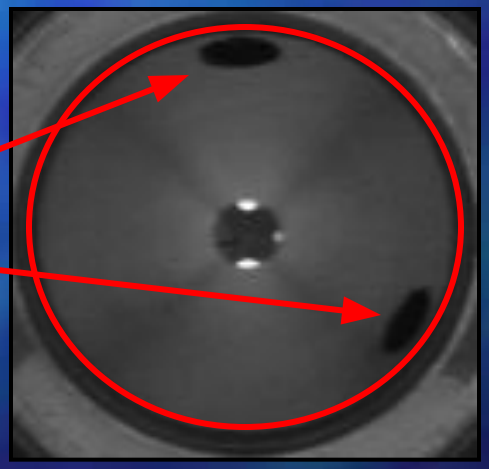
Hole-free area

L'algoritmo di riconoscimento

Verifica superficie anello interno (Yar 205 2f)

Si definisce un'ellisse di grandezza pari al cono centrale e si indaga sulla presenza di macchie al suo interno, scartando quelle causate dalle 2 brugole di fissaggio.

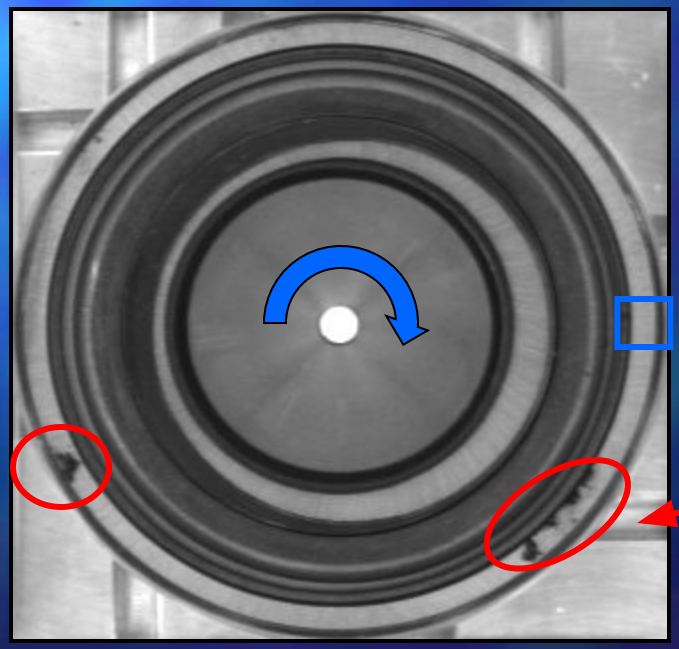
Brugole



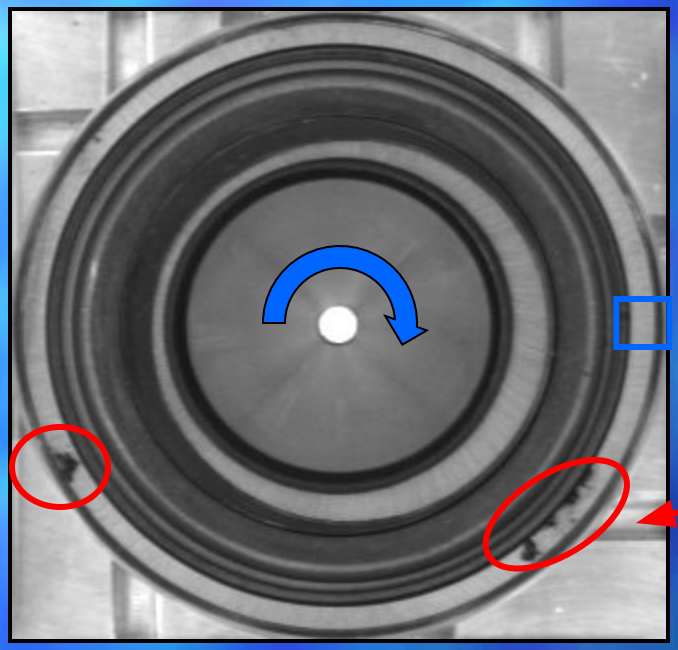
L'algoritmo di riconoscimento

Verifica superfici piane

Si individua un rettangolo di controllo all'interno del quale si ricerca una consecutività di pixel. La rotazione dell'immagine permette l'analisi dell'intera superficie piana.



Inspection of the plane faces...



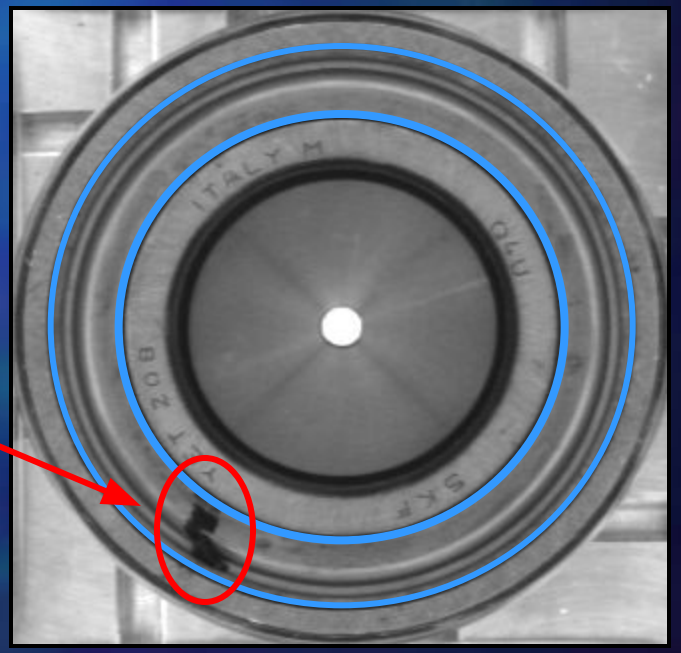
Inner and outer ring

Defect

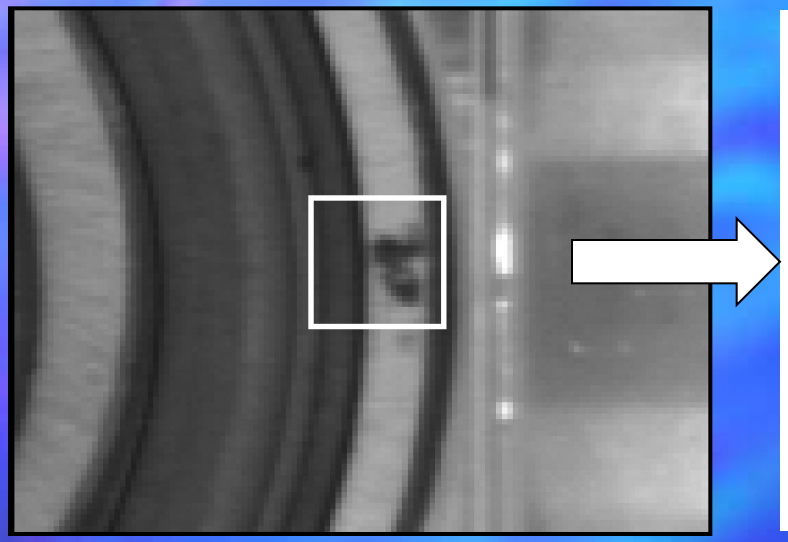
Defect

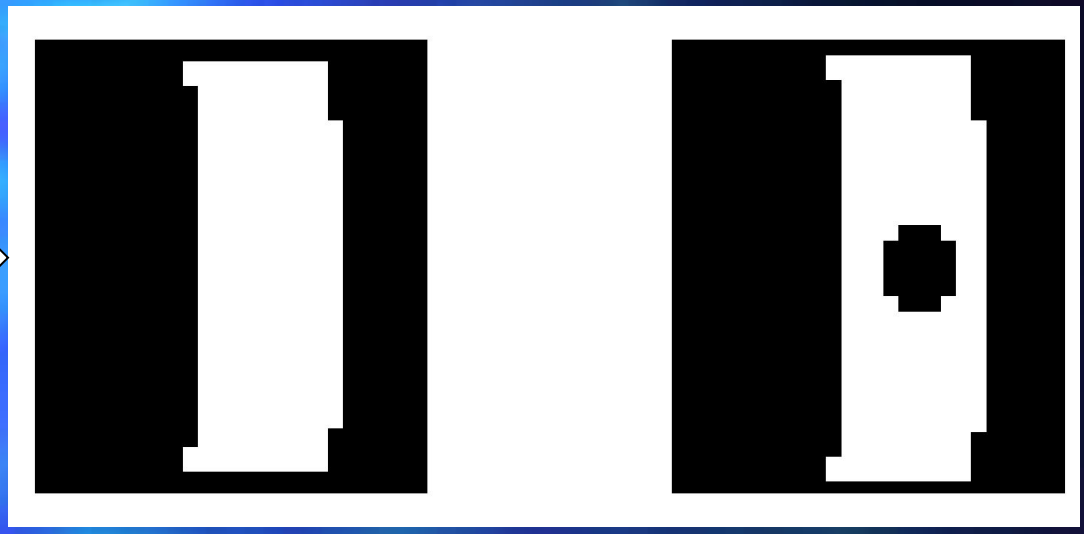
Flinger

Defect



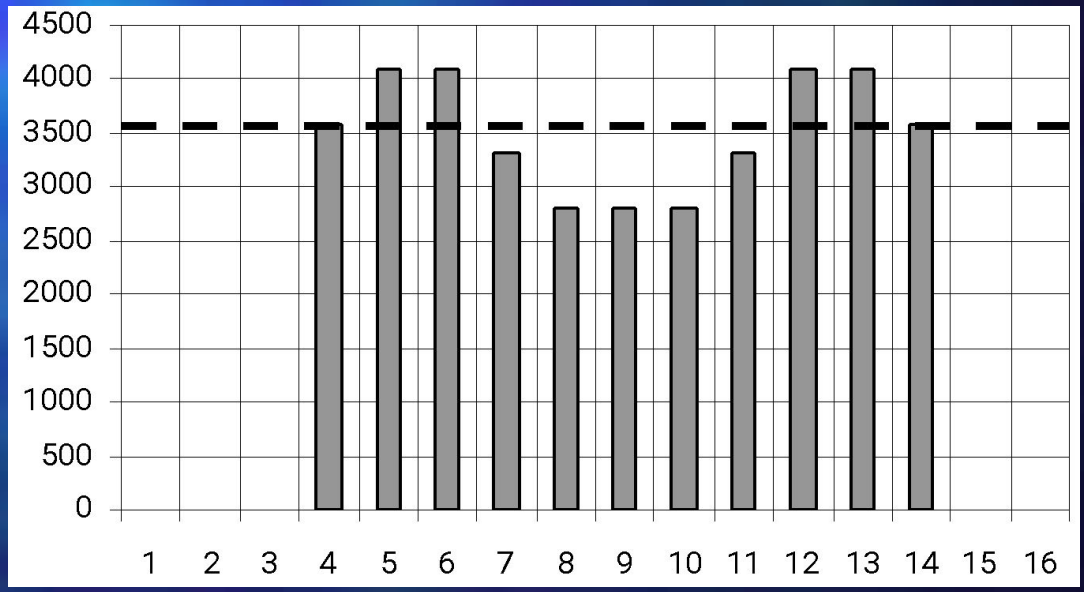
...Inspection of the plane faces





THRESHOLD

LIGHT INTENSITY PROFILE IN A COLUMN [PIXELS]



RADIAL COORDINATE [PIXELS]

Prove e risultati sperimentali

Prove in condizioni ottimali

- **Riconosciuti i cuscinetti buoni;**
- **Rilevati tutti i difetti tranne le seguenti tipologie:**

Macchie di ruggine

Piccole colpiture sugli schermi

Experimental results

Not detected	Reason	Possible solution
Small hammerings on flingers	Small light changes	Structured light Mechanical probe
Rust traces	Color information lost in grayscale	Corrective action with suppliers (housing and transportation)

Summary and future work

- Specific hardware developed
- User-friendly software developed
- Main defects detected
- Inspection time < 6 s

System engineering

- interface to the line
- use of a line camera

Conclusions

- ☑ Goal: improving the process in an existing manufacturing plant
  - System generalization
- ☑ Finding possible solutions
  - Corrective action taken with suppliers
- ☑ Feasibility study (artificial vision system)
  - HW and SW developed

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Conclusioni

- **Corrective action taken with suppliers**

<u>Vantaggi</u> del sistema sviluppato:
Dimostrata la fattibilità di un controllo di qualità sui cuscinetti con un sistema di visione.

1. ~~Costo contenuto del sistema di visione;~~

2. **Durata elevata dell'attrezzatura;**

3. **Ingombro e peso ridotti;**

4. **Adattabilità ai diversi modelli di cuscinetto;**

5. **Utilizzo di una sola immagine per la rilevazione di tutte le informazioni.**

Conclusioni

Sviluppi futuri :

1. **Interfacciamento con il ciclo produttivo;**
2. **Caricamento pezzi in automatico (braccio robotico);**
3. **Unità di smistamento per la separazione dei cuscinetti difettosi;**