# ON-LINE COMPUTER AIDED AUTOMATIC INSPECTION UTILIZING FORECASTING

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ABSTRACT

A microcomputer-based digital image processing system for bullets inspection has been designed and used for on-line automating inspection of the requested product dimensions. In bullets manufacturing, very strict inspection and close tolerances are needed. The developed system is aimed to replace a dedicated mechanical inspection system based on (go/no go) limit gauges. Tests showed a superior performance of the CAIS as compared with the old fashioned mechanical system, both in accuracy and economics. The CAIS showed remarkable suitability for shop floor environment. The statistical forecasting package used with the CAIS enhanced its performance. Supplemental developments in the system based on forecasted machine condition feed back loop are scheduled.

## 1. INTRODUCTION

There are many situations in industry where it is necessary to perform a 100% visual inspection on the product. Manual visual inspection normally is a costly labor intensive. The current trend in manufacturing industries is to substitute this costly inspection process by Computer Aided Inspection System (CAIS). CAIS is cheaper, faster and free of human errors. The relatively low-cost CAIS permits 100% inspection and offers an efficient inspection information capturing, data processing and statistical analysis mechanism.

With the advent of improved sensors and data processing power in personal computers, it is possible to built a reliable, efficient, cheap and extremely fast 100% inspection and data logging system. Over the last 15 years there has been enormous research effort in the general area of information processing and computer vision [1 to 5]. Recently, the term "Optical Computing" has been applied to parts of this flourishing field. "Optical Computing" implies the use of optical systems to perform numerical computations on data to form images. An important and growing are in this discipline is directed towards automating visual inspection and control procedures in manufacturing operations.

A wide variety of optical computing systems were introduced. The work presented by Hodgson and Rashed [6] and Wolfgang [7] are excellent examples for these systems. They used different light sources and scanning devices. In addition to the hardware development, a substantial and prospering knowledge of image processing and pattern recognition exists. The research published by Groen and Ekkers [8], Jeon and Kim [9] and Verbeek et al [10] show some of the essence of this interesting field. In these research The common theme, besides picture processing, is a reliance on modeling simulation and testing to verify that the chosen technique work on the specific problem under consideration. No attempt has been made to outline the various picture processing methods used in these papers.

The suggested CAIS has been designed and used for on-line inspection of the requested bullet case basic dimensional parameters sketched in Figure (1).

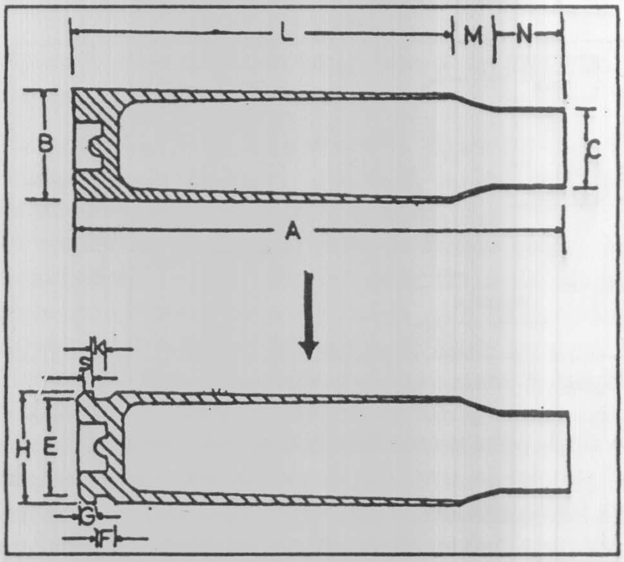


Figure 1. Final manufacturing stage showing the end product inspection parameters.

This product is a typical example for a multi dimensional product. The suggested CAIS is a general purpose setup which can be used to inspect complex multi dimensional products. In this assignment the developed on line system is aimed to replace off-line manual inspection system based on [go/no go] limit gauges.

Statistical forecasting and smoothing techniques, which are well established in business applications, are included in the software data processing package. The use of forecasting techniques [11, 12 and 13] is thought to offer a better quality control performance than the traditional trend analysis commonly used in the X and R quality control charts. Though the results achieved are very promising, further investigations, analysis and assessments are needed for improving the use of these freshly suggested techniques in quality control. With this supplemental development in the CAIS a feed back control loop is scheduled to adjust machining parameters viz. feed and depth of cut.

## 2. SCANNING TECHNIQUES:

Vision systems are becoming an integral part of many automated manufacturing and inspection processes. In this work the designed system is using Laser as a sensing element source. The sensing technique is based on projecting the Laser beam from a Helium-Neon tube onto the object and imaging the resulting illumination pattern into a photo detector. For triangulation a narrow Laser beam (0.5 mm diameter) projected from the Laser source on the product surface, as shown in Figure (2).

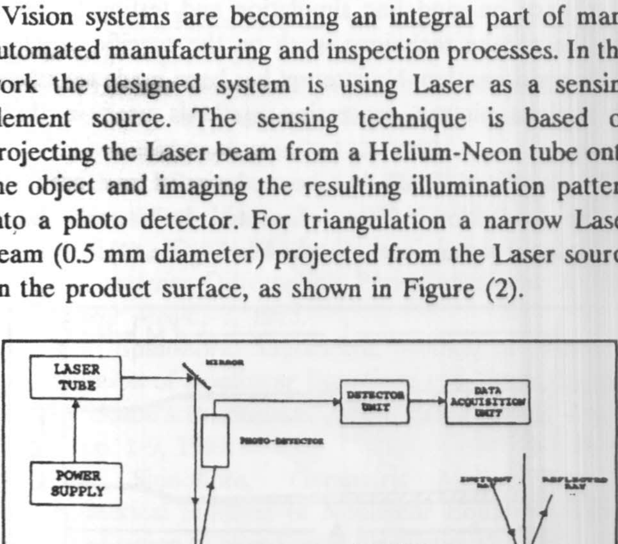


**Figure 2.** Measuring arrangement.

A single point is measured per sampling interval (n). For "m" samples "n x m" sample time is required to acquire data for an element image.

Alternate measuring arrangements were tried and the most significant image has been achieved when the Laser beam was perpendicular to the product axes. To compensate for position errors differential measuring usi splitter to split the source beam as shown in Figure (3) advisable.

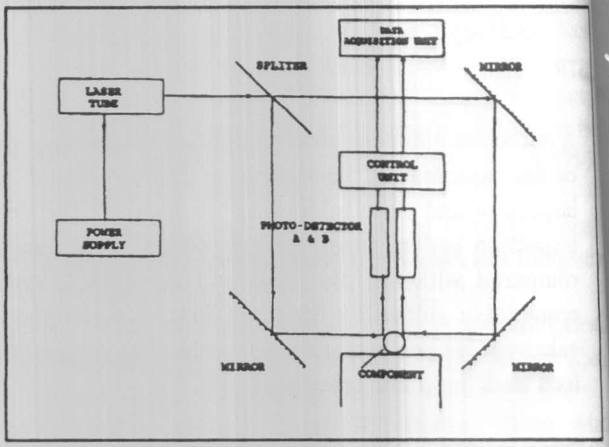


**Figure 3.** Differential measuring arrangement.

## 3. COMPUTER AIDED INSPECTION SYSTEM (CAIS)

A block diagram outlining the Laser imaging device an pattern processing is shown in Figure (4).

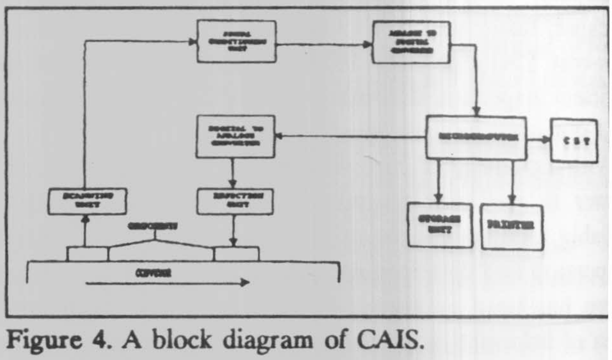

**Figure 4.** A block diagram of CAIS.

The developed CAIS consists of:

1- Specially designed mechanical handling mechani with a rate of bullets/second.
2- Sensing source of Helium-Neon laser tube providing output power of 5 mv at a wavelength of 632.8 nm.
3- Scanning device of a photo-detector having responsitivity of 0.35 mv and responde time of 1 μ
4- Data transmission unit of an analog input range of v, a resolution of 12 bit and a digitized sampling r of 13000 sample/sec.
5- 8088 cpu at 10 MHz. data processor.
6- Mechanical rejection mechanism and stop-mach feed back signal.

- Customized software including modules for scanning, analyzing, comparing data and precision making. A forecasting module has been introduced to the decision making process. The forecasting module helps in filtering random variations. Also, it can help in improving the process performance by projecting fault occurrence.

The product moves past the scanner head on a V-shape conveyor to guarantee the proper location. The belt speed is 3.5 meters per second (40 units of product per second). The reflected Laser beam from the surface of each product is transmitted into a photo detector (response time is 1 us) and an analogue signature of each unit of product is fed to the analogue to digital converter (14 bit, 20 us conversion time). The digitized full signature of the product is processed and stored.

As a commercial finishing procedure an inexpensive compact closed box encloses both hardware and software needed.

## 4. IMAGE PROCESSING AND RESULTS

To verify the performance of the CAIS preliminary tests are conducted. Figure (5) exhibits a sample image of the bullet case corresponding to the shape of the object.

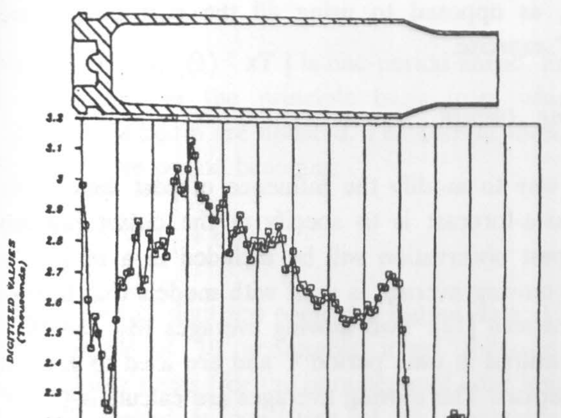


Figure 5. A typical image output.

It is clear that all the component features appears in e signature. The variation in the signature of the bsequent components will be formed for fault detection. gure (6) shows the results obtained from scanning 5 e-of-faults components.

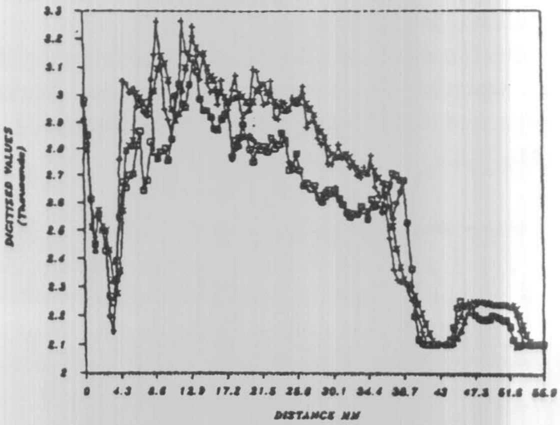

Figure 6. Representative image outpot for five free.

Figure (7) shows the digitized results obtained from measuring the reflected beam from the edge and the recess diameter of 5 components.

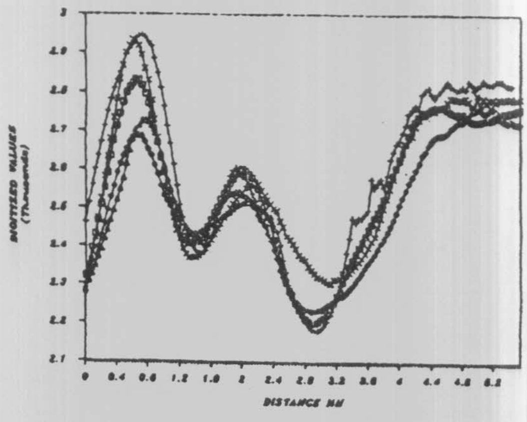

Figure 7. Representative image output for the edge and the recess of good components.

The scattering in the data shown in Figure (6) and (7) is mainly due to variations in surface quality and other relatively less important sources of noise.

To reduce the effect of variability in surface quality the scanning beam is set narrower than the scale of the surface texture and reflectivity changes. Also, all electronic components are shielded and adequate filters are used.

The use of data smoothing techniques established in statistical time series forecasting have reduced significantly the remaining random variations in measurements.

The important dimensional faults in this product are: edge diameter (H), edge length (G), recess diameter (E), recess length (F), main diameter (B), slope length (M), end diameter (C) ... etc. To explain the suggested procedure comprehensively only the first three dimensions were considered in this paper.

To observe the effect of different types of faults on the resulting signature a comparison between healthy components and faulty ones signatures is illustrated in Figure (8).

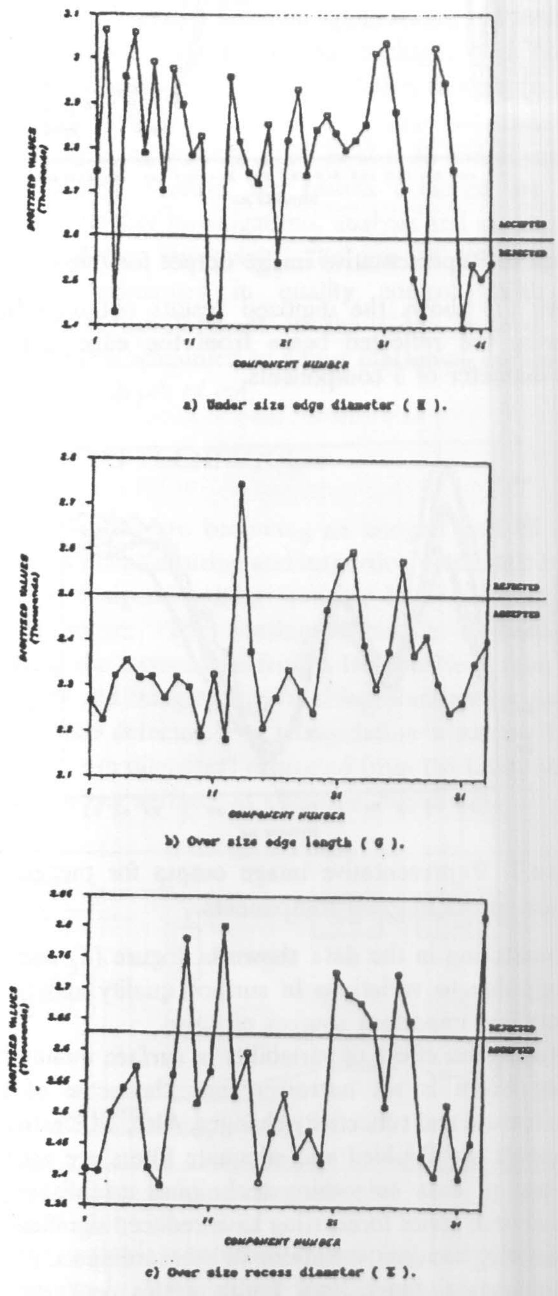


**Figure 8.** A comparison between healthy components and faulty one's.

## 5. STATISTICAL FORECASTING

Statistical time series forecasting is a well establis technique in the business and economic applicatio Forecasting is applicable in the cases where there is a ti lag between the awareness of an impending event or ne and occurrence of that event. This lead time is the ma reason for forecasting. Perspectives on forecasting a probably as diverse as views on any set of scienti methods used by decision makers. In this research tw forecasting smoothing techniques are used to reduce th effect of random variations in the measurements. Tre analysis and measuring the accuracy of the forecasting ar offering a successful feed back signal for process an eventually quality control.

If a time series is generated by a constant proce subject to a random error (noise), then the mean is useful statistic and can be used as a forecast for the nex period(s). however, if the time series involves a trend, the the simple average is no longer able to capture the data pattern. Once a forecasting model has been selected, we fit the model to the known data and obtain the fitted values. For known observations this allows calculation of fitted errors. The smoothing methods are mostly recursive in nature-moving through the known data period by period, as opposed to using all the past data in one "fitting" exercise.

*Moving Average*

One way to modify the influence of past data on the mean-as-a-forecast is to specify at the outset just how many past observation will be included in a mean. The double-moving average is used with models that follow a trend pattern [12]. Two moving averages $M_T$ and $M_T^{(2)}$ are measured at time period T and are used to generate the forecasts. The moving averages are calculating from:

$$M_T = \frac{X_T + X_{T-1} + \dots + X_{T-N+1}}{N}$$

$$M_T^{(2)} = \frac{M_T + M_{T-1} + \dots + M_{T-N+1}}{N}$$

The estimates of b and $a_T$ become

$$\hat{b} = \frac{2}{N-1}[M_T - M_T^{(2)}]$$

$$\hat{a} = 2M_T - M_T^{(2)}$$

These are now applied to yield the forecast relation for the τth future time period, i.e.,

$$\hat{X}_T(\tau) = \hat{a}_T + \hat{b}_\tau$$

*Double Smoothing Method*

Double smoothing is applied with items follow trend pattern. A smoothing parameter "a" is chosen and is used to assign weights to the data entries of the past. A higher weight is assigned to the more current entries. A distinctive advantage of double smoothing over double moving-average is that far fewer data are required to maintain the system. At a current time period (T), the data needed by the forecaster are $x_T$, $a_{T-1}$ and $b_{T-1}$. Here, $a_{T-1}$ and $b_{T-1}$ are estimates of a and b, respectively, as of $t = T - 1$.

With these data, the coefficients are updated by the following two relations:

$$\hat{a}_T = X_T + (1-\alpha)^2 e_T$$

$$\hat{b}_T = \hat{b}_{T-1}(1) + \alpha^2 e_T$$

where $e_T = [\, x_{T-1}(1) - xT \,]$ is one-period-ahead. Forecast error is used as the principle basis from which the coefficients a and b are updated. The current forecast for the τth future period becomes:

$$\hat{X}_{T-1}(1) = \hat{a}_T + \hat{b}_T \tau$$

Two series of digitized computer output data: The first is consisting of 18 acceptable items followed by 7 unacceptable items (for the parameter of edge length G); and the second is consisting of 21 acceptable items followed by 5 unacceptable items (for the parameter of edge diameter H) are used to show the use of data smoothing and trend forecasting. The results of the computer runs are summarized in Figures (9) (a and b), (10) (a and b) which gives the results obtained using double moving average (five data points) and exponential smoothing (Smoothing parameter $\alpha = 0.2$). The two figures show that the effect of scattering in the smoothed data is minimized remarkably.

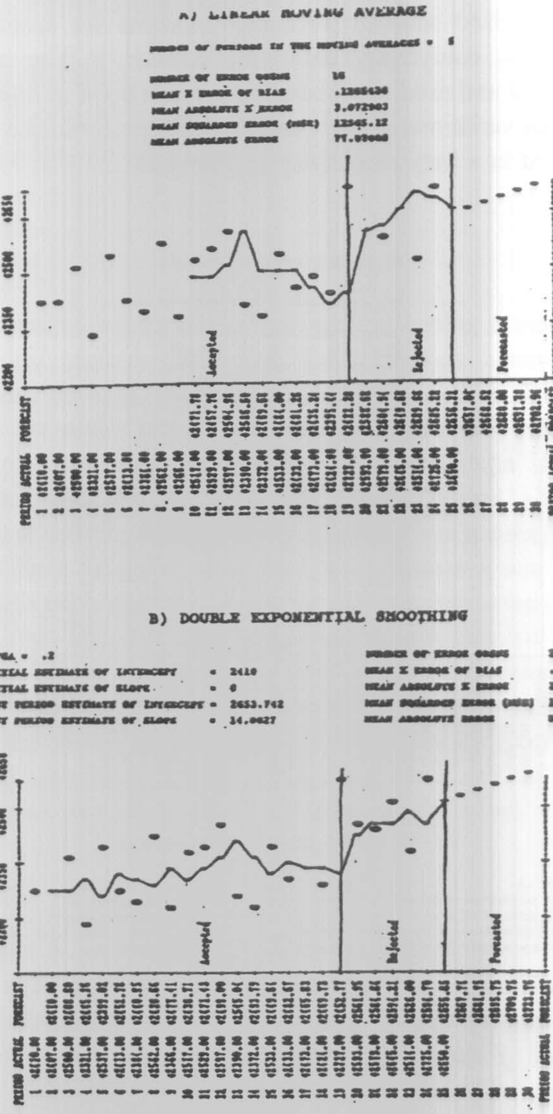


Figure 9. Real time and forecasted output for 18 acceptable and 7 oversize edge length parameter.

## 6. CONCLUSION

Laser gauging and inspection is an idea whose time has come. Recent advances in both technology and hardware have rendered feasible a wide range of new applications that have a direct bearing on improved quality and reduced costs.

A Computer Automatic Inspection System (CAIS) has been developed and tested to replace the old fashioned mechanical system based on limit gauges (go/no go).

The CAIS showed superior performance for detecting and forecasting the trend of faults occurrence.

Customized software including modules for scanning, analyzing, comparing, data and decision making were prepared and used. A forecasting module helps in filtering random variations. Also it enhanced its performance and resulted in a better satisfying performance.

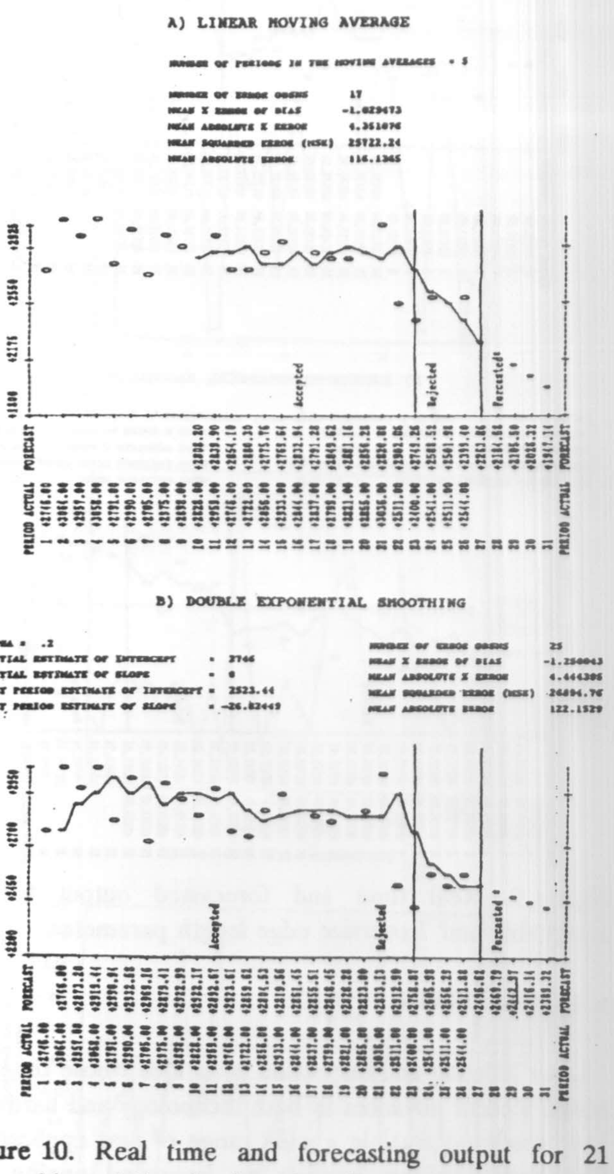


**Figure 10.** Real time and forecasting output for 21 acceptable and 5 undersize edge diameter parameter.

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