Journal of the KSQC
Vol. 18, No. 2, Nov. 1990

1990년 11월 韓國品質管理學會誌 제18권 제2호

The Allocation of Inspection Efforts Using a Knowledge Based System

Kyong-sik Kang*
Christodoulos Stylianides**
Seung-houn La***

ABSTRACT

The location of inspection stations is a significant component of production systems. In this paper, a prototype expert system is designed for deciding the optimal location of inspection stations. The production system is defined as a single channel of n serial operation stations. The potential inspection station can be located after any of the operation stations. Non-conforming units are generated from a compound binomial distribution with known parameters at any given operation station.

Traditionally Dynamic programming, Zero-one integer programming, or Non-linear programming techniques are used to solve this problem. However a problem with these techniques is that the computation time becomes prohibitively large when t be number of potential inspection stations are fifteen or more. An expert system has the potential to solve this problem using a rule-based system to determine the near optimal location of inspection stations.

This prototype expert system is divided into a static database, a dynamic database and a knowledge base. Based on defined production systems, the sophisticated rules are generated by the simulator as a part of the knowledge base. A generate-and-test inference mechanism is utilized to search the solution space by applying appropriate symbolic and quantitative rules based on

* Department of Industrial Engineering and Systems Myong-Ji University, Seoul, Korea

** Department of Industrial Engineering and Management North Dakota State University, Fargo, North Dakota

***Department of Industrial and Manufacturing Engineering Oregon State University, Corvallis, Oregon

input data. The goal of the system is to determine the location of inspection stations while minimizing total cost.

Introduction

One of the most significant economic factors in a quality assurance program is the optimal location of inspection stations. The simplest approach is to inspect 100% all final product, but this is very costly. The high cost is due to the expense of inspecting every unit produced and from removing non-conforming units at the final stage of production. If non-conforming units can be found through inspection at earlier stages of production, unnecessary processing costs can be reduced. Therefore, it is desirable to determine the location of inspection stations which minimized total cost.

Several models for the optimal location of quality inspection stations have been developed for serial production systems. Lindsay and Bishop (1964) developed two models : model 1 minimizes total inspection and scrap costs subject to an Average Outgoing Quality Level (AOQL) and model 2 minimizes these cost but also includes a penalty cost for remaining product after the end of processing. Both models assume the fraction defective leaving an operation station is constant, all rejected items are scrapped, inspection errors do not exist, and 100% inspection of production run rather than sampling the multistage process at some constant rate. They used Dynamic programming and concluded that the extreme point (0% or 100% inspection) is optimal if the constraint on the final product quality level is inactive.

In 1967 Pruzan and Jackson developed two models. First, the number of non-conforming units are discarded at each inspection station and thus is not available to the latter stations in the system. The actual number of units entering each operation station is not known but the location of the last inspection station is known, The second model assumes that both incoming units and the location of the last inspection station are known. They consider a fixed inspection cost for each inspection station in the system and a variable inspection cost for each unit inspected. The cost of improper processing and acceptance of undetected non-conforming units are added. An adoptive model is developed in which the optimal policy at a location depends on the previous inspection history.

Brown developed a model in order to determine the number of units to be inspected at each inspection station while minimizing the expected sum of squared deviations from a Bernoulli parameter. The parameter was estimated from actual values subject to a constraint on the total number of units inspected in the serial system. The system consisted of a single inspection station following each operation station. In 1969 White assumed that rejected units are repaired immediately and return to production flow and that non-repairable rejected units are scrapped with a possible salvage value. The fraction of non-conforming units are assumed to follow a

Bernoulli process with known parameters.

Garey (1972) developed a model that decided the optimal test point for the sequential manufacturing process. Using dynamic programming, he derived an algorithm which utilizes the test and operation costs, along with the operation failure probability, to determine a set of testing points which will result in the minimum expected manufacturing cost. In this model, final inspection was not applied, since it was only increasing the total expected cost.

In 1984 a number of heuristic decision rules were proposed to aid in the location of quality inspection stations within a production line. Peters and williams investigated the relationship between various cost and process characteristics and designated operative conditions.

Yum and McDowell in 1981 investigated the optimal allocation of inspection effort in non-serial production system, through the use of dynamic programming technique. In 1987 they extended their work to serial production systems adding rework, replacement, repair, and scrapping to the model and formulating the problem as a zero-one mixed integer program.

Definition of Problem Domain

The first step for developing the expert system is to define the problem domain. In this study, the problem domain is to decide the proper location of inspection stations using 5 serial operation stations and 5 potential inspection stations after each of the five operation stations.

Prototype Model Formulation

The production system is defined as a single stage of 5 sequential operation stations [Figure 1]. The potential inspection station could be established after any of the operation stations. Incoming material is assumed to enter the first operation station of the production line at the rate of 100 units per unit time. As the units move through the manufacturing operation stations they may incur defects. The fraction of non-conforming units within the unit time P_j generated

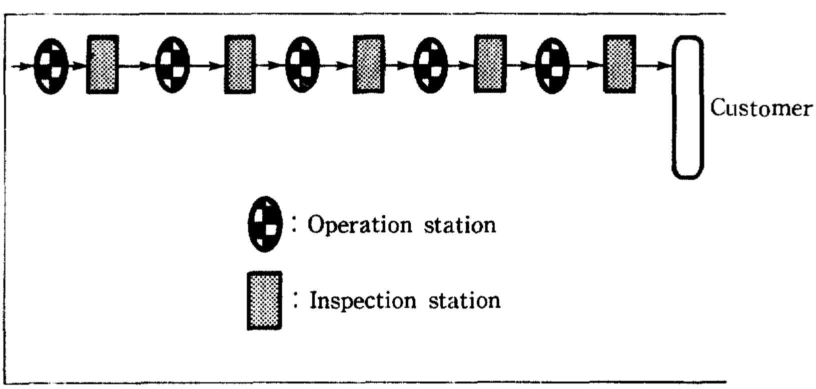


Figure 1.

at j^{th} operation station is viewed as an independent compound binomial process with known parameters. There are no non-conforming units in the incoming system, so inspection does not need to be performed on the incoming unit.

BIG_j represents the number of conforming units coming from the j activity at inspection station j, given that the unit was last inspected at station i. The variable inspection cost per unit (VI_{ij}) is the variable cost per unit inspected at inspection station j given that the unit was last inspected at inspection station i where $i=1,2,3,4,5$ and $j=i+1$ $i<j$. The variable cost of inspection will depend on the type of non-conforming and expected number of non-conforming units. In other words, the inspection cost depends upon the location of inspection given the last inspection station.

$$IC_{(ij)} = FI_{(ij)} + B_{(j)} * VI_{(ij)}$$

Where $B_{(j)} = BIG_j + BIB_j$.

Cost of Repair

Rejected units can be divided into repairable and non-repairable units. The repairable units will be repaired and returned immediately to the production flow. The non-repairable units will be scrapped. The repairing cost will occur only when the inspection takes place at any inspection station.

$$RC_{(ij)} = Cr_j * \{(BIG_j * \alpha_j) + (BIB_j * (1-\beta_j))\} * RP_j/R_j$$

Were $Cr_{(j)}$ is the cost of repairing a unit.

Cost of scrapping :

The fraction of rejected units which are non-repairable will be scrapped at the inspection station where inspection occurs.

$$SC_{(ij)} = Sc_{(ij)} * \{(BIG_j * \alpha_j) + (BIB_j * (1-\beta_j))\} * S_j/R_j$$

Where $Sc_{(ij)}$ is the cost of scrapping a unit found to be non-repairable at station j given that the unit was last inspected at station i.

Unnecessary processing cost :

$$UP_{(ij)} = (AIB_i * Mc_{(j)}) + \sum_{k=i}^{j-i} (BIB_k * Mc_k + 1)$$

Where $Mc(_j)$ is the cost of processing at the j^{th} operation station.

External failure cost :

This is the cost when non-conforming units reach the customer. If the final products are inspected, external failure cost per unit will be $AIB_n * C_t$ where C_t is the cost that a non-conforming unit incurs to leave the system. If not inspected, external failure cost per unit will be represented by $BIB_n * C_t$.

Knowledge Acquistion

Hayes-Roth explained the four ways of knowledge acquisition as follows ; 1. Interview with human. 2. An intelligent program. 3. An induction program. 4. Text understand program.

In most cases interviewing a human expert is used to get knowledge about the problem domain, in this case, the text understand program. In order to accomplish the complex quantitative analysis and interaction of factors in the operation and inspection procedure, a high level of knowledge of the system's dynamic behavior is required. Because of this reason simulation techniques is used.

Input data Matrix and Output

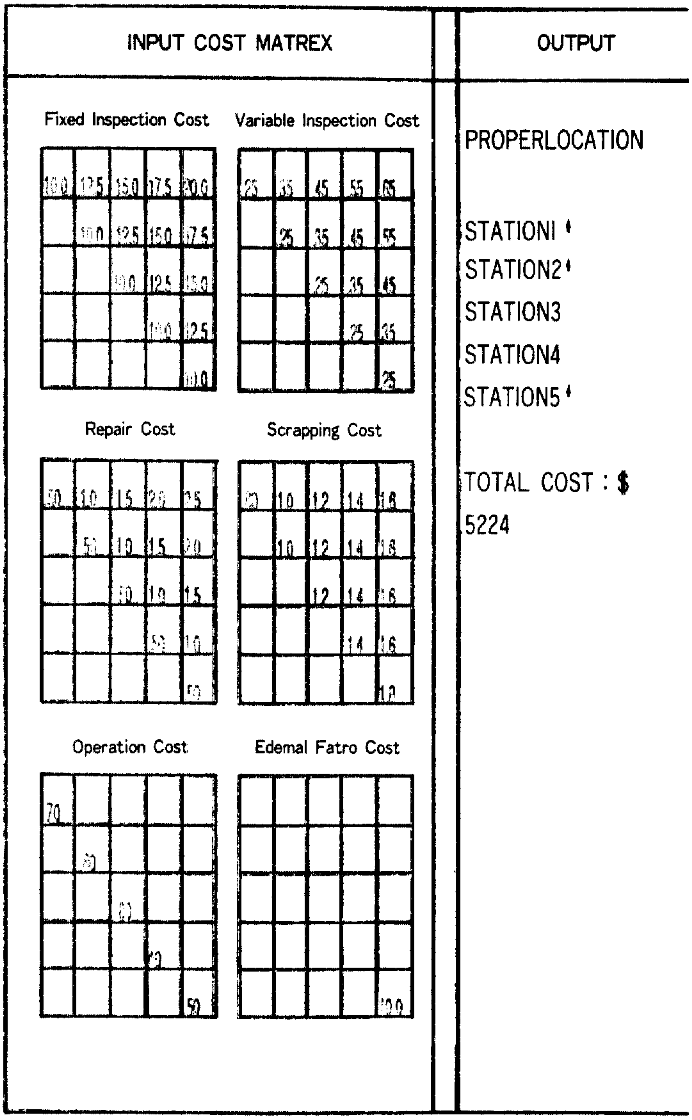
As shown in Figure 3, a formatted set of cost matrix has been represented into a system.

The user only needs to input meaningful data and user specified constraints about the system. The cost matrix is user friendly ; first, it is easy to input data, second it is easy to correct the input data if the user puts in the wrong data, and finally, it is easy to see the data set the user has input. The output is very simple to read and it is very easy to match to the input data.

Conclusion

A rule-based expert system for deciding the proper location of inspection stations in a production system is developed in this study. The conclusions are :

1. Some of the decision rules are heavily dependent on the input data. Therefore the rules are sensitive to input data.
2. It takes a lot of time generating the rules.
3. Since the expert system is only a prototype, its knowledge base is not complete and needs to be updated.
4. The optimal location of inspection stations is not always, guarantied but at least can be expected to be near optimum.



REFERENCE

1. Ballou, Donald P. & Pazer, Harold L. (1982), "*The impact of inspector fallibility on the inspection policy in serial production system*", Management Science Vol. 28, No. 4.
2. Chakravarty, Amiya. (March 1987),

"*Strategic allocation of inspection effort in a serial, multi-product production system*", IIE Transaction.

3. Eppen, Gary D. and Gerald Hurst, Jr. (1974), "*Optimal location of inspection stations in a multistage production process*", Management Science Vol. 20, No. 8.
4. Evans, James R. & Lindsay, William M., "*Expert systems for statistical quality control*", Institute of Industrial Engineering World Productivity Forum & 1987 International Industrial Engineering Conference Proceedings.
5. Flowers, Dale A. & Cole, John R. (1985 September), "*An application of computer simulation to quality control in manufacturing*", IIE Transactions.
6. Hayes-Roth, F., Waterman, D.A. & Lenat, D.B. (1983), "*Building Expert Systems*", Addison-Wesley.
7. Kim, joohee (1988), "*An expert system for FMS scheduling : Knowledge acquisition & development*", Ph.D Thesis Oregon State University.
8. Garey, M. R. (1972), "*Optimal test point selection for sequential manufacturing process*", The Bell System Technical Journal Vol. 51, No.1.
9. Lindsay, Glenn F. (1967), "*A dynamic programming procedure for locating inspection stations*", Proceedings of the 18th Annual Institute Conference and Convention of the American Institute of Industrial Engineers.
10. Lindsay, Glenn F. & Bishop, Albert B. (1964), "*Allocation of screening inspection effort- a dynamic programming approach*", Management Science Vol. 10, No.2.
11. Papadakis, Emmanuel P. (1985), "*The Deming inspection criterion for choosing zero of 100 percent inspection*", Journal of Quality Technology Vol. 17, No.3.
12. Payne, Terry L., "*Optimally locating inspection points to reduce unit cost*", 1986 Fall Industrial Engineering Conference Proceedings.
13. Peters, Michael H. & Williams, W., "*Location of quality inspection stations : an experimental assessment of five normative heuristics*", Decision Sciences Vol. 15, p 389-408.
14. Tzvi Raz (1986), "*A survey of models for allocating inspection effort in multistage production systems*", Journal of Quality Technology Vol. 18, No.4.
15. Watts, Douglas S. & Eldin, Hamed Kamal (1987), "*The role of the industrial engineer in developing expert systems*", Computers and Industrial Engineering Vol. 13, Nos 1-4, p 15-20.
16. White, Leon S. (1966), "*The analysis of a simple class of multistage inspection plans*", Management Science Vol.12, No.9.
17. White, Leon S. (1969), "*Shortest route models for the allocation of inspection effort on a production line*", Management Science Vol. 15, No.5.
18. Yum, Bong Jin & McDowell, Edward D. (1987), "*Optimal inspection policies in a serial production system including scrap, rework and repair : An MILP approach*", Int. J. Prod. Res. Vol. 25, No.10.