STATISTICAL CONTROL

by

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STATISTICAL CONTROL

Theme of Meeting - A Half Century's Progress.

Invitation - "Summarize the development in statistical quality control during the half century and the direction of future work as I see it."

Introduction - Almost everyone thinks of "statistical control" in connection with the control of quality of manufactured product. Naturally so, the phrase "statistical control" was born in that area: it grew up there: applications in that area alone have provided annual savings for many corporations running into the millions.

Some of us have tried to hammer home the idea that these applications of statistical control are not only of interest to the manufacturer who uses them but also to you and me and everyone else as users of manufactured product. Likewise the savings in man power and in scarce materials in World War II reacted to the advantage of all of us. ~~In fact, there is a sense~~ in which everyone of us engages in manufacturing from the cradle to the grave. Each of us manufactures the sounds and/or other gestures by which we try - and only partly succeed - in communicating one with another. Each of us in turn acts as a consumer of sounds and gestures produced by others. The problems of control of our manufactured sounds and/or other gestures are in many ways identical with those of the manufacturer in the industrial area.

There is a sense, however,

Even so, most of you as mathematical statisticians have felt no urge to give more than a passing thought to statistical control as such. Few have paused to consider the wide variety of other areas in which statistical control may pay even greater dividends.

To date statistical control has been almost exclusively used to improve the efficiency of output of the inanimate production process or machine. It is conceivably much more important to apply the techniques ~~of statistical control~~ to the output of the human machine and particularly of the human machine as an "idea" factory.

For fear that some one may have already jumped to the conclusion that I am talking about statistical control as though it were a fully developed science and art of control, let me hasten to say that the main reason for my accepting your invitation was the opportunity of laying before you some of the many unsolved problems. One aspect of control is particularly full of knotty unsolved problems: I refer to establishment of the goal of control based upon the wants and preferences of a specified group of users. The statistician has already made great contributions to the sampling and polling problems in consumer research. But there are many instances in the planning of industrial research looking several years into the future where we need information about human preferences and wants that cannot be obtained by the sampling methods of market research. I shall touch upon some of the statistical problems in this area.

THE ACT OF CONTROL

The urge to control our environment to suit ourselves is as old as the human race. In fact, this urge largely differentiates man from other animals. However, the act or method of control has shown a marked development down through the ages - first instinctively guided by trial and error, later supplemented by appeal to the supernatural, then gradually modified in accord with the developing climate of scientific ideas. Our object here is to trace in bold outline some of the modifications brought about in the act of control through the introduction and use of statistical concepts.

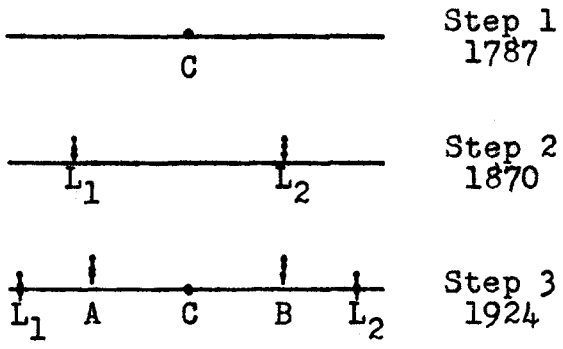
1. Act of Control - three steps

Slide #23040

1.1 Three fundamental steps.
1.2 Introduction of statistics in each step.
1.3 Practical approach has been 3,2,1 and limited to goals that can be specified on engineering grounds.

2. Historical steps

Slide 30586



2.1. Slowness of progress

2.2. L_1 and L_2 originally set on engineering grouns and only worry was to stay within

2.2.1 Cost
2.2.2 Assurance.

2.3. Central value C
Control limits A and B.

2.4. Reduction of tolerance limits

S. S. Wilks - 1941

Slide 25438

3. Problem of Control in Simplest Case

3.1 Repetitive operation under same essential conditions.

3.2 Fundamental concern of science is to attain valid predictability.

3.3 Operation of statistical control to attain predictability

$$X_1 \cdots X_n \mid X_{n+1}, \cdots$$

3.4 Specification under controlled conditions

3.4.1 S.S.Wilks tolerance limits
3.4.2 $f(x)$
3.4.3 Other statistics

All of this is limited to single measurable variable.

How shall we approach case of k correlated variables?

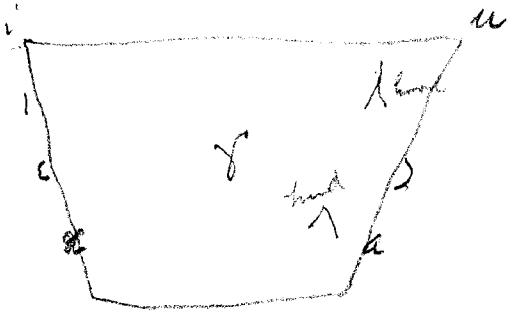
4. IBES of steady state vowels

Slide 35098

4.1 What k characteristics?

4.2 How frame specification in terms of these k? - Some nice statistical problems here.

heed	hawd
hid	hood
head	who'd
had	hud
hod	heard



5. IBES of steady state vowels: F_1 and F_2

Slide 37703

What can be done with F_1 and F_2 from viewpoint of specification?

6. IBES of steady state vowels: vowel loop.

S 3 5 B 24

The producer's problem of controlling his product, in this case his vowels.

6.1 Kinds of feedback

6.1.1 kinesthetic
aural
visual
reaction of others

6.1.2

6.2 End points - kinesthetic

heed heard who'd

6.3 Others more complicated

7. Limited area in which progress has been made.

Slide 30569

7.1 Nonhuman factors that can be controlled.
7.2 Stochastically independent variables.
7.3 The over-all problem of control is of operational research character.
7.4 Polling of consumer wants

7.4.1 Volumes have been written on selecting samples of human beings
7.4.2 The great unknown: How to measure.

8. The need for a broader picture.

Slide 36307.

THE FOUR ACTS OF MAN

8.1 The act of abstraction

8.1.1 much progress on basis of concept of stochastic independent random variable.

8.1.2 Problem of specifying k stochastically dependent variables unsolved.

8.1.3 How can we handle psychological measurements?

8.1.3.1 Theory of games and economic behavior probably important in studying rational preferences where measurements form stationary time processes.

Theory of Communication

9. The act of measurement - Birge

Slide 30669

9.1 Fallacy of assuming randomness.
9.2 Need for going inside control chart.

10. Act of measurement - Birge control chart.

Slide 28087

10.1 Trends
cycles
random component
→ discontinuities

10.2 Set of empirical rules.

P(λ)
Runs
Eta
Autocorrelation
accuracy-precision chart

As in the case of the control chart, theory tells us how many times we would look for trouble when trouble does not exist.

11. 40 repetitive measurements on contacts

Slide 25408

11. Forty repetitive measurements on relay contacts

Slide 25408

11.1 P( ).

11.2 Runs.

A. Effect of impurities in solid state.
B. Break through of surface film.
C. Change of raw material (nonhomogeneity).
D. Change of environment of human being or machine.

12. Output of Machines - Physical

Slide 38230

13. Output of Machines - Human

Slide 38229

STUDY OF VALUATION

Preferences

1. Repetition of vowels Slide 35095

   1.1 Why nonrandom?
   1.2 To what extent predictable?
   1.3 How dependent on feedback of different senses.

2. Perceived lengths of line

   Slide 38520

   Example of simplest type of measurement.

   2.1 Lack of stability

   Trends
   Cycles
   Discontinuities
   Random component jumps from experiment to experiment

   2.2 Difficulty of knowing when conditions are essentially the same.

   2.3 Why?

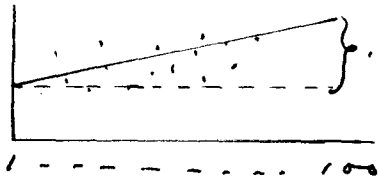
   Beam of mind - attention.
   Intersensory effects.
   Are there nonrational effects.

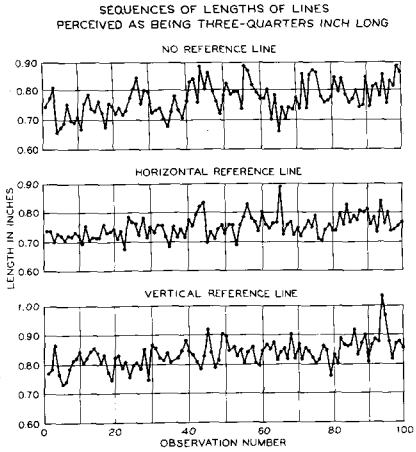
Original observations

		Slope
No reference line	r = .44	.00074"
Hor. " "	r = .44	.00044"
Vert. " "	r = .52	.00073"

Deviations around line of regression

		η
No reference line	$\sigma^2 = 15.65$	1.47
Hor. " "	$\sigma^2 = 7.13$	1.92
Vert. " "	$\sigma^2 = 10.12$	1.61





η: 5% = 1.7 1% = 1.54 .1% = 1.4

The basic contribution of statistics to the science of control is an improved scientific method in which each of the three steps, hypothesis, experiment, and test of hypothesis, is modified to take account of the fact that valid inference can never be more than probable. The use of this method in analyzing the way men and equipment act together in an organization to determine what changes, if any, need to be made in order that the organization may come closer to attaining its objective, has already proved an effective means in many industries for conserving natural resources and human effort in the mass production of goods of standard quality.

To date, however, emphasis has been placed on production and inspection under presumably the same essential conditions. Already there is a healthy growth of interest in applying the principles of statistical design of experiment in many industrial as well as academic and government laboratories. The fundamental control problem of specification is only now beginning to receive the attention of the mathematical statistician and that in connection with the specification of the IBES of speech.

To date, control statisticians have focussed their attention primarily on the machines of MAN. I firmly believe that even greater advances will come when the same techniques are applied to the study of the MAN behind the machine.

To date the progress in applying statistical control has been largely confined to those areas where the goal can be expressed in terms of tolerance limits fixed primarily by engineering considerations and on factors that only indirectly if at all modify the user's preferences. A real challenge to the statistician of tomorrow lies in the study of the human preferences that in the end must shape the goal of production to satisfy human wants expressed in perceivable characteristics of the things produced. To a marked extent preferences depend on perceived magnitudes and yet perceptions even in the simplest cases seem to have an inherent instability that taxes our power of measurement.

A whole field of fundamental research lies before us in developing ways and means of studying the preference systems of individuals and of groups under carefully controlled conditions. The design of experiments in this area takes us beyond the present theory of statistical design: the statistical models applicable here are likely to be far more involved than those with which some of us have played in the past.

Perhaps we shall have much to learn from the strategy of poker and other games in trying to arrive at a rational theory of preference, if such be possible. But the development of such a theory to guide research and development engineers of the future in the development of new things to increase the satisfaction of human wants is an open challenge to the statistician and his scientific colleagues.