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discussion

H. E. Riordan[1]

Professor Porter's communication in the Forum of the December, 1973, issue of the JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT, AND CONTROL raises a question which was indirectly answered by David M. Boyd in the same issue.

Professor Porter also illustrated (unwittingly, I suppose) one of the reasons for the lack of communication between the fields of Cybernetics and Control Engineering.

Control engineers do indeed use disturbance information as well as error information in regulation systems. By "variety" I suppose Professor Porter refers to signals based on other physical phenomena than the controlled variable. If he did mean this, why didn't he say so instead of introducing the jargon term "variety," thereby perpetuating the lack of communications between cyberneticists and control engineers?

David Boyd describes a system in which flow is measured and controlled in order to ease a temperature control problem. Flow is in effect a disturbance on the temperature.

Whether flow is controlled or, alternatively, measured and used to modify the set point of the temperature controller is a question of convenience and economics not a lack of knowledge of cybernetics.

The primary reason for the extensive use of error regulation is its simplicity and economy. The sensing and use of other information is frequently not possible because the phenomenon is physically inaccessible for measurement, or because the required additional equipment is not economically justifiable.

As a final point, I find "Ashby's law of requisite variety" not only obscure, but, as interpreted by Professor Porter, of questionable validity. In practice, error control systems having foreward gains as high as 10^6 produce error signals in the steady state which are of the order of thermal noise at the controller summing point and still vanishingly small under disturbance conditions. Yet these systems perform quite effectively in cancelling error produced by disturbances within the range of magnitudes and frequencies encountered in the application. Such systems, of course, use various forms of temperature and drift compensation in addition to the error feedback, all designed and used successfully without knowledge of "Ashby's law."

Harold L. Wade[2]

Professor B. Porter's recent contribution to the Forum [1][3] deplored the lack of "crosstalk" between cyberneticians and control engineers. He specifically referred to the control based upon the factors giving rise to an error, rather than upon the error itself. A name for his principal, "the law of requisite variety" is attributed to the cybernetician Ashby.

May I suggest that there may also be a lack of vertical communication between theoreticians and practitioners in the field of control. The technique of feedforward control [2] has gained considerable acceptance in the process industries (chemical, petroleum, paper, etc.) for the past fifteen years or so. It is perhaps the only "advanced" control technique which has gained this wide acceptance in actual practice.

However, the technique has been in use for a much longer time. For example, it was used in the early 1930's for boiler drum level regulation. The concept itself is even much older, having been suggested by the French mathematician Poncelet as early as 1826 [3].

Except for Russian investigators, who use the term "principle of invariance," control theoreticians seem generally to have ignored the technique. For example, in the ten years of publication of *IEEE Transactions on Automatic Control*, only one paper has appeared which, from its title, deals specifically with feedforward control (law of requisite variety, principle of invariance, principle of Poncelet, etc.) [4]. A few others have made mention of the technique.

Possibly the reason for this oversight by the control theoreticians is the fact that once a feedforward control approach is adopted, many of the technically interesting and challenging problems associated with feedback control are eliminated. Only to the control practitioner does the idea of feedforward control appear to be exciting.

I agree with Prof. Porter's encouragement for interdisciplinary cross-talk, but we need not let a sophisticated name in another discipline blind us to the fact that the same concept may already exist in our own house.

References

1 Porter, B., "Cybernetics and Control Engineering," JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT, AND CONTROL, TRANS. ASME, Forum, Series G, Vol. 95, No. 4, 1973, p. 349.
2 Shinskey, F. G., *Process-Control Systems*, McGraw-Hill, 1967.
3 Beneš, J., "Two Commemorative Notes," *IEEE Trans. Automatic Control*, Vol. AC-13, No. 1, 1968, pp. 132–133.
4 Preminger, J., and Rootenberg, J., "Some Considerations Relating to Control Systems Employing the Invariance Principle," *IEEE Trans. Automatic Control*, Vol. AC-9, No. 2, 1964, pp. 209–215.

Author's Closure

I wish to make the following brief comments in response to certain of Mr. Riordan's and Mr. Wade's remarks concerning my communication:

(i) the term "variety" has been in regular technical use for about 20 years;
(ii) the essential feature of Ashby's analysis of error-controlled systems is that it is concerned not with simplicity or economy but with bounds of *achievability;*

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[3]Numbers in brackets designate References at end of discussion.

(iii) the "law of requisite variety" has not only been very carefully enunciated by Ashby, but also very clearly illustrated in numerous examples which involve nothing more obscure than elementary arithmetic (see, for example, Chapter 11 of "An Introduction to Cybernetics");

(iv) the law of requisite variety is *not* a name for a principle of control but a law governing the behavior of generalized transducers;

(v) the "lack of vertical communication between theoreticians and practitioners in the field of control" was anathema to Ashby whose principal concern as a doctor was the very practical problem of mental health.