ON COMMUNICATION PROCESSES INVOLVING
LEARNING AND RANDOM DURATION

Richard Bellman and Robert Kalaba

P-1194A

8 October 1957

The RAND Corporation
1700 MAIN ST. • SANTA MONICA • CALIFORNIA
ABSTRACT

Previously we have shown that the fundamental problem of determining the utility of a communication channel in conveying information may be viewed as a problem within the framework of multi-stage decision processes of stochastic type, and as such may be treated by the theory of dynamic programming. Furthermore, the relations between utility and capacity, in Shannon's sense, have been indicated.

Following a brief resume of the foregoing, we show how to treatment of communication problems involving the use of a channel whose properties are not completely known, and those involving processes of random duration, are shown. These are special cases of still more general problems in prediction theory.

Our aim is to show how quite general processes can be treated in a uniform fashion by the functional equation technique of dynamic programming, are discussed.
SUMMARY

ON COMMUNICATION PROCESSES INVOLVING LEARNING AND RANDOM DURATION

by

Richard Bellman and Robert Kalaba

In two earlier papers, [2], [3], we have shown how several general classes of stochastic communication problems may be viewed as multi-stage decision processes of stochastic type, [1]. Our purpose here is to extend these considerations to more general and realistic communication situations involving (1) channels whose properties are only partially known; (2) communication processes of random length; (3) allocation of signal detection equipment.

Our discussion revolves around the determination of the 'utility' of a communication channel, where, naturally, the utility depends upon the use to which the channel is to be put. We conceive of a three-element communication system consisting of a source of signals, a communication channel, and an observer, and assume that the observer uses the received signals (in an optimal fashion) to aid in achieving some objective, in the course of a multi-stage process. The utility of the channel can then be measured by comparing the observer's performance against the performance of a hypothetical reference observer provided with an error-free channel, or against one provided with no channel at all.

The situations covered are quite broad in scope. Not only do our considerations apply to strictly technological communication problems, but also to general problems of experimental physics, in which nature
is the source, the experimenters are the channel, and the scientific
corps is the observer. Also describable in this way are problems of
forecasting (weather or economic conditions), etc.

We have shown previously how a variety of problems arising from
this general framework can be formulated as problems involving functional
equations of a novel type which can be solved analytically in some cases
and in other cases by the use of computing machines. In particular,
generalizing and extending results of Kelly, \cite{1}, we have indicated
the connection between channel utility and channel capacity in the
sense of Shannon.

In the present work, we consider the important case in which the
channel has fixed, but not completely known, characteristics. In the
course of the process, the observer not only makes decisions on the
basis of knowledge possessed, in an effort to attain his goal, but also
attempts to deduce the characteristics of the system from the events
that have occurred \cite{2}, for an interesting exposition of learning
processes). Depending on how the term 'not completely known' is
interpreted, we obtain a hierarchy of processes which can be treated
by the functional equation technique or dynamic programming.

Next we consider processes, which in addition to possessing the
previous features possess the complication of having random duration.
Various radar detection processes are of this type.

The foregoing problems are in turn special cases of still more
general problems arising in prediction theory. Here we encounter the
additional difficulties of utilizing various types of channels, with
different reliability characteristics and different costs. Finally,
extensions of these processes lead to problems involving limited storage of information, and delays in both processing information and evaluating the results of previous decisions.

Our aim throughout is to illustrate how quite general processes of the types described above can be treated in a uniform fashion by means of the theory of dynamic programming.
REFERENCES


