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Information Entropy As a Basis for Media Access Allocation

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Abstract—A key tenet of information theory, Shannon's mathematical equation for the information entropy of a discrete communication channel, is applied by analogy to illustrate how access to political communication channels such as cable television could be allocated. Application of this equation provides a basis for maximizing the information entropy of political communication. However, such applications must overcome a number of theoretical and practical limitations to be politically viable.

INTRODUCTION

THE LARGELY unrealized potential application of general systems research to the political process has been recognized for decades by researchers such as Wiener [27, 28], Bertalanffy [5], Deutsch [8], Easton [9], Ericson [10], Miller [17] and Wood, Jr [34]. The purpose here is to illustrate how selected concepts from engineering systems, specifically information theory and the mathematical theory of communication (as developed by Shannon [21]), can be applied to allocate the access of political candidates to communication media such as cable television.

This illustrative application is addressed in part to the relatively recent and growing political opportunities and problems presented by the 'Information Era' (sometimes also known as the 'Communications', 'Computer', or 'Microchip' Era or Age; see [11, 30, 33]). During the present 'Information Era', the dominant technologies are information processing and amplifying technologies such as the computer, broadcast and cable television, electronic mail, electronic bulletin board, and the like. Cable television exemplifies the diversity of media available for political communication. However, media diversity also presents problems in terms of: the potential for information overload (too many channels, too much information); the allocation of access to the most heavily used channels; and, in general, the balancing of diversity and centrality in the political process necessary to maintain a democratic and stable society.

The central hypothesis is that a key tenet of the communication theory that works for the design and implementation of physical engineering systems can also be applied to political systems in order to maximize the information entropy of political communication. As used here, information entropy is a measure of the diversity of information (or ideas) in a physical (or political) communication system. Information entropy is defined as a measure of the average number of bits of information in messages on a communication system that convey information not already known to the receiver or, in other words, the level of diversity of information (see [21, 22]). In mathematical terms, the information entropy of a discrete noiseless communication channel can be defined as

*The views expressed are those of the author and not necessarily those of the OTA, Technology Assessment Board, or U.S. Congress. The article is based on independent research of the author and not on work conducted for the OTA.

$$H = -[P_1 \log(P_1) + \ldots P_k \log(P_k) + \ldots P_n \log(P_n)], \quad (1)$$

where H is information entropy, log means logarithm to the base 10, and P_k is the probability of occurence of message k over the communication channel.

A review of the theory and application of information entropy has been recently published [3] and will not be repeated here (also see [2, 31] and, generally [6, 7, 19, 24]). Suffice it to say that information entropy has been applied in such diverse fields as economics [13, 23], sociology [1, 12], and organizational structure [14]. This article illustrates its application to the technical level of political communication, that is, the efficient transmission of bits of information or symbols or ideas, as contrasted with the semantic level—the meaning of the information—or the effective level—the impact of the information communicated on the behavior of the recipient (see [22]).

ALLOCATING CABLE TELEVISION ACCESS

The following examples illustrate the application of information entropy to the allocation of access to political communication channels. The channels could range from physical bulletin boards and 'oped' newspaper space to broadcast and cable television time. Cable television has been selected for these examples because cable TV is a medium that generally has the channel capacity for public access. These examples assume that a local cable television station operator has designated one channel for public access, including discussion of political issues and candidates. The question facing the cable system operator would be how to allocate time to candidates for a hypothetical public office.

Illustration one

One possibility is to allocate cable television access to maximize the information entropy of the communication channel. In other words, time would be allocated so that the probability distribution of the different political messages conveyed would maximize the information entropy. The approach illustrated here is to weight the allocation of access time by multiplying the total available time by the information entropy of each candidate's message divided by the total information of all messages. Expressed mathematically, the equation is

$$T_i = T_t(D_i/\S D_i) = T_t[P_i \log(P_i)/\S P_i \log(P_i)], \quad (2)$$

where T_i is the cable access time allocated to candidate i, T_t is the total time available for allocation, D_i is the information entropy of the message of candidate i, P_i is the probability of that message, log stands for logarithm to the base 10, and § stands for sum. P_i can be determined in several different ways, such as by the percentage vote of the candidate's party in the last election or, if an independent candidate, by the candidate's support as measured by polling results or the number of nominating petition signatures collected.

Figure 1 illustrates the results for seven hypothetical candidates—two major party candidates, one third party candidate, one minor party candidate, and three independents—with a total of 10 hr of cable television access time to be allocated. The message probabilities (P_i) are based on the results of hypothetical voter preference polls, conducted, for example, by professional public opinion pollsters hired by the cable television station or perhaps by the local chapter of a nonpartisan civic group (such as the League of Women Voters). These polling percentages are illustrative and purely arbitrary. The weighting factors are $P_i \log(P_i)$ or D_i and the weighted probabilities are $D_i/\S D_i$. The hours allocated are calculated using eqn (2).

Hypothetical candidate	Message probability P_i	$-\log(P_i)$	Weighting factor $P_i \log(P_i) = D_i$	Weighted probability $D_i/\S D_i$	Hours allocated T_i
A—major party	0.45	0.347	0.156	0.269	2.69
B—major party	0.325	0.488	0.159	0.275	2.75
C—third party	0.10	1.000	0.100	0.172	1.72
D—minor party	0.08	1.097	0.088	0.151	1.51
E—independent	0.03	1.523	0.046	0.079	0.79
F—independent	0.01	2.000	0.020	0.034	0.34
G—independent	0.005	2.301	0.012	0.020	0.20
Totals	1.000		0.581 $\S D_i$	1.000	10.00 T_t

Fig. 1. Illustrative use of weighted probability to allocate cable television access. T_i is the cable access time allocated to candidate i. T_t is the total time available for allocation. D_i is the weighted probability of the message of candidate i. P_i is the probability of that message, log stands for the logarithm to the base 10, and § stands for sum. In this example, P_i is based on the results of hypothetical voter preference polls. T_i is calculated using eqn (2) in the text.

The resulting allocation of cable access time illustrates the use of information entropy for weighting the allocation. The two candidates with the largest support receive somewhat less than the allocation that would be based strictly on their level of support in the polls, but still more than the other candidates. The candidates with lower support received a somewhat greater than proportional allocation. This is because maximizing information entropy in this illustration translates into maximizing the diversity of the messages being communicated by the candidates.

Thus, for example as shown in Fig. 1, independent candidate G would be allocated 0.05 hr (or 3 min) if based solely on the level of support (as indicated in voter preference polls) but would receive 0.2 hr (or 12 min) based on eqn (2) in order to maximize information diversity and information entropy. On the other hand, major party candidate A would be allocated 4.5 hr based on the level of support in the polls, but would receive 2.69 hr based on eqn (2).

Illustration two

Communication channel access could also be allocated by some combination of direct proportional measure and weighted probability measure (see [32]). For example, one-half of the total access time available could be allocated on a major minor third party proportional basis, determined by each party's percentage vote in the last election, to assure adequate exposure for candidates of the organized political entities. The other half of the time could be allocated on a weighted probability basis, determined by voter preference polls, to guarantee at least some exposure for independent candidates with some minimal level of support. Expressed mathematically, the equation is:

$$T_i = (a)T_t(V_i)+(1-a)T_t(D_i/\S D_i). \qquad (3)$$

where T_i is the cable access time allocated to candidate i, T_t is the total time available for allocation. V_i is the percentage vote of candidate i or his party in the last election, (a) is the fraction of time (in this example 0.5) to be allocated on a proportional basis. $(1-a)$ is the fraction of time to be allocated on an information-entropic basis, D_i is the information entropy of the message of candidate i (as defined in eqn (2)), and § stands for sum.

Figure 2 illustrates the results for the same seven hypothetical candidates with the same total of 10 hr of cable television access time to be allocated. The time is split evenly with 5 hr allocated on the basis of hypothetical percentage votes in the last election (V_i) and 5 hr allocated on the basis of hypothetical voter preference polls (message probability P_i). The results show how allocation on a party proportional basis favors the established and majority political interests while allocation on a weighted probability basis favors minority and independent political interests. The effect of the weighted probability allocation is to partially offset the advantage accruing to major party candidates from the proportional allocation.

Thus, as shown in Fig. 2, independent candidate G would be allocated no time if based solely on the percentage vote from the last election (assuming a new candidate not affiliated with an organized political party) but would receive 0.1 hr (or 6 min) based on eqn (3). This is one-half the time allocated to candidate G in the previous example, since only one-half of the total allocation in the current example is based on weighted probability. On the other hand, major party candidate A would be allocated a total of 3.85 hr, 2.50 hr based on the major party A's 50% vote in the last election plus 1.35 hr based on candidate A's 45% support level in voter preference polls.

A practical reason for not allocating all access time on a weighted probability basis is that the majority party would likely feel unduly penalized for high levels of support. For example, in Fig. 1

Hypothetical candidate	Proportional allocation % Vote	Hr	Weighted probability allocation P_i	D_i	Hr	Total combined allocation Hr
A major party	0.50	2.50	0.45	0.269	1.35	3.85
B major party	0.30	1.50	0.325	0.275	1.38	2.88
C third party	0.15	0.75	0.10	0.172	0.86	1.61
D minor party	0.05	0.25	0.08	0.151	0.75	1.00
E independent	0	0	0.03	0.079	0.39	0.39
F independent	0	0	0.01	0.034	0.17	0.17
G independent	0	0	0.005	0.020	0.10	0.10
Totals	1.00	5.00	1.000	1.000	5.00	10.00

Fig. 2. Illustrative combined use of direct proportion and weighted probability to allocate cable television time. Percentage vote is based on hypothetical percentage votes (expressed here as a fraction) received by the candidate or his party in the last election. P_i is based on the results of hypothetical voter preference polls. Values of P_i and D_i are taken from Fig. 1. Hours allocated are calculated using eqn (3) in the text.

major party candidate A is allocated about 50% more time than third party candidate C (2.69 hr for candidate A compared to 1.72 hr for candidate C), even though candidate A's voter preference support level is more than four times higher than that of candidate C. This would be a significant concession by major party candidate A but perhaps still politically acceptable. However, if major party candidate A's support level increased to about 70% from 45% and minor party candidate C's remained at 10%, the two party candidates would be allocated approximately the same cable access time according to eqn (2). And if candidate A's support level increased to about 87% and candidate C's remained at 10%, candidate A would be allocated half as much cable access time as candidate C. These latter two scenarios likely would be politically unacceptable and highlight the need to balance this out with some degree of proportional allocation along the lines of eqn (3).

DISCUSSION

The use of information entropy as an approximate measure for allocation of access to political communication channels has a theoretical basis in information theory. Shannon's mathematical equation for the discrete noiseless communication channel (eqn (1)) provides a means to measure the information entropy of a political communication channel (in terms of diversity of messages). In general, increasing the diversity of information in a political communication system at least theoretically will increase the information entropy.

The cable television illustrations show how information entropy could be applied. Further research and experimentation are needed, of course. The alternatives for calculating message probabilities (P_i) in eqn (2) and (3) and the split between proportional and weighted probability allocation (in eqn (3)) need careful scrutiny and refinement by political scientists, as do the likely political implications of applying information entropy measures.

One political issue that would need resolution is how and by whom the decision to use various allocation schemes would be made. Perhaps the major political parties and cable television industry (and other media) and/or various nonpartisan civic groups could reach an agreement that was generally acceptable. However, any particular allocation scheme (and especially the breakdown between proportional and weighted probability time) represents a value judgement as to what is an equitable and efficient balance between established majority political expression and independent and minority expression. In the United States, if a voluntary agreement proved difficult to achieve, the Federal Elections Commission and/or Federal Communications Commission could be tasked by the U.S. Congress to take the lead.

A second issue would be establishing eligibility criteria. For example, cable television (and other media) access time could be provided to candidates who: (1) represent a political party whose candidate placed first or second in the previous election; (2) represent a political party receiving a specified minimum percentage (e.g. 5%) of the total vote in the previous election; (3) receive a designated minimum level of support (e.g. 1%) in voter opinion polls; or (4) gather a specified number of voter signatures (e.g. 0.5% of registered voters) as evidence of an acceptable minimum level of support (see [4, 26]).

A third issue would be the conditions of use, especially with respect to the format for discussion. For example, candidates might be encouraged to emphasize rational discussion of the issues and their own experience, and to avoid deception and exaggeration (see [16]). Some portion of the total time allocated could be required to be used in a debate format with opposing candidates or in a discussion format with community and news media representatives. This issue clearly deals with the semantic and effective levels of communication (as defined by Shannon and Weaver [22]) and could extend to general consideration of the quality as well as the quantity of communication.

In general, the concept of information entropy could be used as one means for ensuring that the entire spectrum of political candidates, parties, and viewpoints receive balanced access to cable (and perhaps eventually broadcast) television. 'Information entropy time' might be a way to implement previously proposed concepts such as 'voters' time' and 'representative time' (see [18, 25] and, generally [20, 32]). The concept also could be used to measure the degree of diversity in political communication of various countries, perhaps as an additional input for use by the U.S. and other countries in the development of foreign policy strategies and by international organizations that monitor human rights such as freedoms of political speech and assembly.

In the broadest sense, it is hoped that the kinds of applications of information theory presented here would help strengthen democratic institutions around the world and that entropy-like properties of political systems could be used to help steer a course toward a democratic and peaceful world future (also see [12, 15, 28, 29]).

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