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Shot Length Distributions in Educational TV Programs
Keiji Fujita

Abstract
Thirty-two TV programs were drawn from the University of the Air lecture series. For each program the distribution of shot lengths was determined, and the mean and the standard deviation were calculated. The average shot length ranged from 14 to 67 seconds with most samples clustering about 20 seconds. The correlation coefficient between the mean and the standard deviation was 0.966, indicating the larger the mean the flatter the distribution. A compound exponential model with two parameters (McGill, 1963) was applied to fit the distributions. Agreement between the observed and theoretical distributions were fairly good with no significant difference at the 5% level in all programs except two. The reciprocals of the first parameter were linearly correlated both with the means and standard deviations with correlation coefficients of 0.977 and 0.909, respectively. The reciprocals of the second parameter, however, were not so closely related to those statistics. A practical application of this analysis to the structural classification of TV programs is discussed.

Keywords
TV program analysis, shot length distribution, visual and verbal presentations, taxonomy of TV programs.

Educational TV programs are now being produced in overwhelming numbers, and there is a growing need for taxonomic studies of the programs so that each program can be properly identified in terms of its structural and functional characteristics. No science has made progress without systematically classifying the subject of its study. A number of evaluative studies have been conducted dealing with various effects of TV programs on viewers. But, there have been few attempts to analyze the structure of TV programs per se. In order to accommodate a variety of educational TV products in a taxonomic system, they should first be analyzed in terms of their structure, content and function.

Since TV programs are now available in the form of videocassettes, they can be treated as a new type of book. As a book consists of many paragraphs, so a TV program is composed of many shots. Shots play as important a role as paragraphs of
a book in shaping a TV program. The sequence of shots and the shot length distribution reflect a number of important structural features of the program. Programs consisting of many short shots tend to be visually active, rich and abundant, whereas those comprising relatively longer shots tend to be visually monotonous, but often verbally active and eloquent. A long shot may comprise a variety of scenes continously changing and moving when it is taken by zooming, panning, following or dollying with the camera. In general, long shots occur less frequently so that most shot length distributions are positively skewed, forming a reversed J shape curve.

This study aims to describe the structural features of educational TV programs in terms of their shot length distributions, and thereby attempts to find some useful indices for the classification of educational TV programs.

Method

A total of thirty-two TV programs were drawn from the University of the Air lecture series. Programs included lectures on science, foreign languages, education, health, philosophy, law and culture. Each program lasts forty-five minutes. The programs were analyzed by an automatic TV editing controller RM-E 50. A shot is defined here as the interval between two consecutive cuts or between a cut and the beginning or end of the program. Every shot was recorded and the shot length was measured in seconds. The content in each shot was also described. For each program the frequency distribution of shot lengths was determined, and the mean and the standard deviation were calculated.

The derivation of our model and its application is entirely based on the work of McGill (1963). Fujita and Naruse (1971) explored his model and applied it to the distributions of response times in classroom question-and-answer activities. In their following study, Fujita and Naruse (1977) investigated test item response times. Response time distributions for correct, incorrect, confident and unconfident groups of students were then statistically analyzed using McGill’s model. Although the context of the previous studies is different from the present study, we can also make use of this model to describe the shot length distribution. Instead of latencies considered in the previous studies, we are considering the actual time required to present certain visual images.

A Theoretical Model

Considering that a sequence of shots corresponds to the partitioning of a line into many segments, one may easily be led to think of an exponential distribution. Suppose
a straight line $l$ is randomly divided into $n$ segments. The lengths of the segments will follow an exponential distribution as $n$ becomes larger. In our model, the total length of the line corresponds to 45 minutes and this length of time is then divided by the number of shots. Now we can consider that a shot consists of two independent time variables $t_1$ and $t_2$, each of which follows an exponential distribution. In this two-stage process, it will be assumed that the first time component deals with the visual presentation of specific objects or overall scene of the shot, and the second time component relates to the auditory information accompanying the shot, although which comes first is unimportant. We shall discuss this point later. The length or duration of a shot, $t$ is the sum of the two variables, $t_1$ and $t_2$.

$$t = t_1 + t_2$$

(1)

Let their density functions be as follows.

$$p(t_1) = a e^{-at_1}, \ p(t_2) = \beta e^{-bt_2}$$

(2)

Using the moment generating function, we can derive the density function for $t$.

Namely, $p(t) = \frac{\alpha \beta}{\beta - \alpha} (e^{-at} - e^{-bt})$

(3)

The mean of shots is the sum of the means of the two components $t_1$ and $t_2$, or the sum of the reciprocals of the two parameters, $\alpha$ and $\beta$.

$$E(t) = E(t_1) + E(t_2) = \frac{1}{\alpha} + \frac{1}{\beta}$$

(4)

Since $p(t) > 0$, it is evident from (3) that $\beta$ should be greater than $\alpha$ and consequently $E(t_1) > E(t_2)$.

Similarly the variance of $t$ is the sum of the variances of $t_1$ and $t_2$, or the sum of the squared reciprocals of the two parameters, and the square root of it is the standard deviation.

$$V(t) = V(t_1) + V(t_2) = \frac{1}{\alpha^2} + \frac{1}{\beta^2}, \ \sigma(t) = \sqrt{\frac{1}{\alpha^2} + \frac{1}{\beta^2}}$$

(5)

By integrating (3) with respect to $t$ we have the distribution function $P(t)$

$$P(t) = 1 - \frac{1}{\beta - \alpha} (\beta e^{-at} - \alpha e^{-bt})$$

(6)

In order to estimate the parameters, we take logarithms of $1-P(t)$ so that we have a linear approximation.

$$\log[1-P(t)] = -at - \log\left(1 - \frac{\alpha}{\beta}\right) + \log\left[1 - \frac{\alpha}{\beta} e^{-(\beta - \alpha)t}\right]$$

(7)

As $t$ increases, the exponential quantity vanishes rapidly and produces a linear approximation for large $t$.

It is also interesting to note that as $\alpha$ approaches $\beta$, Eq. (3) becomes the density function of the gamma distribution.
\[ f(t) = \alpha t e^{-\alpha t} \]  

(8)

And as \( \beta \) tends to infinity, Eq. (3) represents an exponential distribution with its parameter, \( \alpha \).

\[ f(t) = \alpha e^{-\alpha t} \]  

(9)

It can therefore be said that the compound exponential distribution of this model is intermediate between a gamma distribution and an exponential distribution. In fact, when the shot length distribution is reversed J shaped, an exponential distribution can be applied, and when \( \alpha \) comes close to \( \beta \), we can apply a gamma distribution.

In order to estimate the parameters that best fit the distribution of shot lengths, the range in which the least squares method is applied was determined by visual inspection of the computer display. The observed values of \( 1 - P(t) \) were plotted against \( t \), and a straight line best fitting the dots of the earlier part of \( P(t) \) was obtained by the method of least squares, and thereby the irregular dots of extremely large value in the latter part of \( P(t) \) were deliberately ignored.

**Results**

The theoretical distribution discussed above was applied to the thirty-two shot length distributions and the agreements between the observed and the theoretical were fairly good in most cases. The Kolmogorov-Smirnov one-sample test was used as a test of goodness of fit. According to the test there were no significant differences at the 5% level of significance in all cases except two. Fig. 1 shows four examples of shot length distributions superimposed on the theoretical distributions. The two cases which do not agree with the theoretical curve are distributed irregularly with small numbers of shots. When \( \beta \)'s are large as compared with \( \alpha \)'s, an exponential curve can also be used. In fact, an exponential curve fitted better in one case than the compound exponential curve.

One of the interesting statistical findings is the relationship between the means and the standard deviations of the length of shots. As shown in Fig. 2, there is a linear relationship between the two statistics. The correlation coefficient between the two statistics is 0.966. This high positive correlation can be expected, because in the distribution of shots the larger average tends to have the flatter distribution. The theoretical relationship between the mean and the standard deviation as indicated by Eqs. (4) and (5) also implies that the two statistics will be highly correlated. The average shot length ranges from 14 to 67 seconds with most samples clustering about 20 seconds.

In order to clarify the characteristics of the parameters, their relationship to the mean and the standard deviation of shot lengths was examined. Fig. 3 indicates that
Program 2
n = 103
\( \alpha = 0.077 \)
\( \beta = 0.383 \)

Program 8
n = 172
\( \alpha = 0.102 \)
\( \beta = 2.645 \)

Program 16
n = 127
\( \alpha = 0.074 \)
\( \beta = 0.526 \)

Program 24
n = 124
\( \alpha = 0.076 \)
\( \beta = 0.444 \)

Fig. 1 Shot length distributions superimposed on the theoretical distributions: Histograms (observed), Polygons (theoretical) and n (no. shots)
there is a linear relationship between the mean and the reciprocal of $\alpha$. The correlation coefficient is 0.977, which is very high. Considering that the reciprocal of $\alpha$ equals the mean of $t_i$, the first time component, it is understandable that the average shot length tends to be a linear function of the reciprocal of its first component. A similar relationship can also be seen between $\alpha$ and standard deviation, as indicated in Fig. 4.
The mean of the first component $t_i$ is linearly correlated with the standard deviation, with a correlation coefficient of 0.909. We can say therefore that the first parameter, $\alpha$, seems to have a strong influence on the mean and standard deviation of the shot length distribution.
The second parameter $\beta$, however, seems to be not so closely related to the mean and standard deviation of shot lengths. Although Figs. 5 and 6 show similar tendencies with regard to mean and standard deviation, the degree of relationship seems to be loose, as indicated in their low correlation coefficients. The reciprocals of $\beta$ tend to have a linear relationship with the mean and the standard deviation, but the $\beta$ seems to have less influence upon those statistics.

The relationship between the two parameters is shown in Fig. 7, indicating a weak positive correlation with a correlation coefficient of 0.424. A closer look at the
clustering of dots suggests that there seems to be no linear relationship between them and that the $\beta$ tends to stay constant regardless of $\alpha$ and raises suddenly when the distribution shifts to the left end, becoming a reversed J shaped curve.

The way $\alpha$ and $\beta$ relate to the content of the program is also very interesting. Programs whose $\alpha$s and $\beta$s are relatively large tend to be picture-dominated, namely, abundant in pictorial presentation, active and changeable in the variety of scenes. Consequently, there are many short shots in the programs. Whereas, programs with relatively short $\alpha$s and $\beta$s are mostly a lecture-dominated type with long shots. The televised scenes usually stay on without abrupt changes. Hence with some exceptions there seems to be a possibility of qualifying programs in terms of the parameters of their shot length distribution.

Discussion

In this study we have shown that TV programs can be analyzed in terms of their shot length distributions, which follow the theoretical distribution derived from the McGill model of a two component exponential process. We thereby succeeded in describing most of the shot length distributions of the University of Air lecture series by using the theoretical model. It is of great interest for us to find that TV shots are so set up as to follow a compound exponential distribution. Although those who are producing TV programs are not consciously aware of shot sequences and their distribution, they eventually produce programs whose shot lengths are distributed in close approximation with the theoretical curve. There seems a subtle relationship between the content and the container of visual images.

When one tries to introduce a variety of pictures, a great deal of movement or change, one tends to increase the number of cuts, consequently producing a number of short shots. On the other hand, long shots are produced when it takes time to follow the visual image presented and there is a long narration going with a definite picture, as in the case of a "talking head". Within a given time, when shots become longer, the number of shots of a program decreases and the average shot length becomes longer while the standard deviation increases to make the distribution flat.

One problem with this theoretical model is that it has difficulty in describing long shots. Since they are small in number, appearing at the right hand end of the distribution, they must often be ignored in the estimation of the parameters in order to have a best fit to most of the remaining data. In fact, long shot sometimes exceeds five minutes while most shots last less than 20 seconds.

If there are a few extremely long shots, they tend to boost the mean and standard deviation to the extent that the expected mean and standard deviation differ greatly
from the observed ones.

However, as shown in Fig 1, most of the frequency distributions of shot lengths are closely fitted by the theoretical distributions. It is possible to describe most programs in terms of the $\alpha$ and $\beta$ of the shot length distributions, which also substantiate the mean and standard deviation of the distribution. Content-wise, it is also feasible to explore the possible effects of visual image structures of the program as reflected in the two parameters. It is still difficult to distinguish the functional difference between $\alpha$ and $\beta$, but it is evident that the $\alpha$ has a stronger influence upon the mean and standard deviation of the shot length. A comparison of programs with large $\alpha$s and those with small $\alpha$s shows a salient structural difference characteristic of each program, although which is better was not a matter of concern in this study. A further study should be carried out to examine how $\alpha$ and $\beta$ are actually related to the audiovisual content of various kinds of TV programs.

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